Petter, Lauren

From: Augspurger, Tom <tom_augspurger@fws.gov>
Sent: Tuesday, August 11, 2015 11:32 AM
To: Petter, Lauren
Subject: Re: Follow up on Lower Cape Fear Swamp reclassification

Hello,

Thank you for the copy of this feedback Lauren, and for your attention to the technical and policy aspects of the State's request. Your response includes issues that were of concern to FWS in our comments, so we appreciate your follow-up.

I hope you have a good week,

Tom

Tom Augspurger, PhD
Acting Field Supervisor
Ecologist / Environmental Contaminants Specialist
U.S. Fish and Wildlife Service
551-F Pylon Drive
Raleigh NC 27606
919-856-4520 x21
tom_augspurger@fws.gov

On Fri, Aug 7, 2015 at 10:18 AM, Petter, Lauren <Petter.Lauren@epa.gov> wrote:

Hey Elizabeth,

I appreciate your responses to date regarding clarifications on the Lower Cape Fear Reclassification revisions. However, in an effort to work out any possible issues in advance of the rulemaking going final, this email is in response to the recent discussions on the Sw classification to highlight some remaining concerns. Here is a summary:

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  - Given that, there is now a need to document why the amount of 0.1 mg/L was chosen as we did not previously address this point in our comment letter.

- In addition to the need to provide documentation on why the amount of 0.1 mg/L was chosen, the EPA is concerned that the provision may allow a different DO criteria expectation for a single programmatic purpose, NPDES permitting. The EPA expects that criteria should apply for all purposes.

- When other states have adopted a 0.1 mg/L type provision, it has been a provision that applies to all implementing programs and has been provided as an amount of change from background condition. And even then the background condition has to be specifically defined before the provision can be used to deviate from the natural condition.

  - As explained in your 7/29/15 email "[t]he model will first be run with all existing discharges at full permitted capacity...then [with] the addition of the proposed new or expanding discharge...If at any time there is a difference between these two model runs greater than 0.1 mg/L, the discharge will not be allowed." Given the starting point for consideration is full permitted capacity for existing dischargers, this does not appear to equate to a natural condition. Also, how will the language in .0227(b)(2)(C), which appears to allow each new or expanding discharge to lower DO by up to 0.1 mg/L, be implemented in a manner that will protect the DO criterion? Are the requirements of .0227(b)(2)(A) and (B) sufficient to protect all waters?

  - While the language in .0227(b)(2)(C) does not reference natural conditions or natural background, the Sw classification and DO criterion that is associated with Sw classification both reference natural condition/characteristics. Therefore, adoption of the Sw classification would need to be supported by natural condition type documentation as indicated in our March 2, 2015 comment letter. (Note: This would be needed to support both DO and pH levels.)

- Although the EPA's March 2, 2015 comment letter indicated certain comments should be addressed in order to support the EPA's review, the State isn't bound to wait until that point to coordinate with EPA, and in matters of discussing natural background and in this case, an atypical reclassification effort, sooner may be more advantageous to the state. That being said, we feel the questions and comments we are providing further indicate the need for a more holistic approach to address the DO conditions in this particular reach, such as a site specific criterion. Classifying this segment as Sw may not be scientifically justifiable in this instance, recognizing we haven't seen the total documentation yet. Adopting a lower, but still protective DO criterion accomplishes the same endpoint of not utilizing the default SC DO criterion but in a different manner.

I can be reached today at if you would like to discuss. I will be back in the office at the number below on Monday.

Lauren

Petter, Lauren

From: Augspurger, Tom <tom_augspurger@fws.gov>
Sent: Wednesday, May 04, 2016 9:12 AM
To: Petter, Lauren
Subject: Re: Catch up on Lower Cape Fear SW Reclass
Attachments: 20160212_Letter_Augspurger to Kountis_LCFR Reclassification.pdf

Good morning,

It's nice to hear from you. I hope all is well with you and your new little one.

Thanks for the offer to catch-up. Is 1pm tomorrow still available? I have the afternoon open if another time tomorrow is a better fit.

I've attached our most recent reclass letter as an FYI.

Take care,

Tom

Tom Augspurger
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Thanks,

Lauren

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

February 12, 2016

Elizabeth Kountis
DEQ/DWR Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611

Dear Ms. Kountis:

The U.S. Fish and Wildlife Service (Service) provides the following comments on the proposed water quality management plan and reclassification for a part of the Cape Fear River (Brunswick and New Hanover Counties) from Class SC to Class SC Swamp (Sw), announced in the December 18, 2015 *Comment Period for Revisions to 15A NCAC 2B .0227 Water Quality Management Plans*. The NC Environmental Management Commission (EMC) is seeking feedback on proposed revisions to 15A NCAC 2B .0227 in response to comments received on earlier versions of the proposal. As written, the Service does not support the proposed reclassification and management plan because there are no provisions to reduce upstream point and nonpoint sources of oxygen consuming waste that impair this section of the river. The management plan will not improve water quality. The revision also has technical limitations that may have the unintended affect of allowing further water quality degradation.

The Service is the principal Federal agency responsible for conserving, protecting and enhancing fish, wildlife and plants and their habitats for the continuing benefit of the American people. Among our priorities is the health and restoration of diadromous fish stocks in the area, including Striped Bass (*Morone saxatilis*), American Shad (*Alosa sapidissima*), Hickory Shad (*Alosa mediocris*), Blueback Herring (*Alosa aestivalis*), Alewife (*Alosa pseudoharengus*), Shortnose Sturgeon (*Acipenser brevirostrum*), Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*), and American Eel (*Anguilla rostrata*). All diadromous species have complex life cycles entailing use of freshwater and marine habitats, so the proposed reclassification of the lower Cape Fear River is of interest to us and partners working on fish restoration. In that regard, our partners in diadromous species conservation and restoration include the Atlantic States Marine Fisheries Commission (ASMFC), and the South Atlantic Fishery Management Council (SAFMC), on both of which our staff (Dr. Wilson Laney) serve as the Service's Southeast Region representative.

The Service has engaged in the proposed reclassification since April 15, 2014. On April 23, 2014, we emailed references documenting 1) fish of special management importance in the lower Cape Fear River, with emphasis on the lifestages present in late spring, summer and early fall when dissolved oxygen (DO) would be lowest; 2) references demonstrating adverse effects to fish early lifestages at DO concentrations less than the 5 mg/L standard; and 3) concern that a Sw classification, allowing lower DO if caused by natural conditions, might make it more difficult to determine use support related to DO in the future without a clearly defined lower bound on DO. We offered technical suggestions and additional concerns in a letter of March 3, 2015 and

followed-up in a meeting with Division of Water Resources (DWR) about those on April 22, 2015. The April 23, 2014 emails (3) and March 3, 2015 letter are incorporated by reference.

Our review of the revision and *Report of Proceedings on the Proposed Reclassification* (posted with September 10, 2015 materials on the EMC's website) indicate unresolved concerns:

1) There is no connection of the reclassification to any water quality restoration work. The *Report of Proceedings on the Proposed Reclassification* states "The proposal does not include language about correcting or reducing pollution as it is not designed to be a water quality restoration plan." We see that the management plan only addresses point sources of pollution in the reclassified reach despite the supporting model's clear indication that reduction in upstream nonpoint and point sources would bring the system far closer to compliance with existing standards. Basinwide approaches to nutrient reduction would be more appropriate to address water quality problems in the lower river than the reclassification alone.

We appreciate the technical foundation of monitoring and three-dimensional modeling that inform the relative contribution of various sources of oxygen consuming waste, and we do not disagree with the conclusion that the point sources in the modeled reach have little impact on the DO in that reach. However, the proposed rule and management plan do not embrace other conclusions from the same model indicating that upstream source reduction will improve DO -- reducing excursions below the 5mg/L standard. In other words, upstream water quality improvements could positively influence DO in the lower Cape Fear River. With the uncertainty in the few measures of sediment oxygen demand (SOD) in the model and potential that SOD may diminish following upstream nutrient load reductions, there is the potential to achieve the standards much more frequently with restoration. Without a component to improve lower Cape Fear River DO concentrations through watershed-wide waste load modeling, land use planning, and permitting, the management plan falls short.

2) In addition to no pathway to improved water quality, the reclassification and management plan as proposed may allow DO to decrease further with a loss of well established Clean Water Act tools and regulatory controls, further degrading habitat for all aquatic species. We previously recommended that the management plan discuss how DO use-support determinations will be made if there is no lower bound on the frequency and magnitude of DO concentrations. We have expressed concern that there will be an inability to explain how natural conditions will be differentiated from additional impacts associated with development – an inability to identify and remedy further DO degradation. The *Report of Proceedings on the Proposed Reclassification* agreed that this concern was valid and noted the need to develop a use-support attainment tool for swamp waters. However, no plans, schedules or commitments were made to develop the use-support attainment tool for swamp waters. Without that, the rule change may produce an unintended consequence of further degrading water quality.

Although we believe the reclassification needs to be accompanied by basinwide water quality restoration, we would be much more comfortable with the action if the associated management plan included a new numeric DO standard. We note that the modeling expertise partners have provided can be used to estimate a DO concentration of about 4.2 to 4.5 mg/L that is met 80-90% of the time under current conditions. While our preference is for restoration work to achieve the existing standard or a combination of restoration and reclassification, an empirically-derived lower bound DO concentration would better characterize the existing condition and provide a numeric standard by which water quality can be best evaluated and managed to protect aquatic animal health.

As noted previously, there are no federally-listed threatened or endangered species under Service jurisdiction in the affected reach. Shortnose Sturgeon and Atlantic Sturgeon are under the jurisdiction of NOAA Fisheries' Protected Species Division and may be affected by the action, so we encourage your continued coordination with them.

In its current form, the reclassification and associated management plan secure no improvements in water quality and weaken the foundation to protect existing conditions. We encourage the DWR and EMC to embrace the same water quality model's forecast for improvements from watershed-scale nutrient reductions in a corresponding basinwide water quality restoration plan. If you would like additional details on any of our recommendations, please contact me at 919-856-4520 x.21.

Sincerely,

Tom Augspurger

Tom Augspurger
Ecologist

cc: Lauren Petter – USEPA
Lisa Gordon – USEPA
Wilson Laney – USFWS
Mike Wicker – USFWS
Fritz Rhode – NOAA Fisheries
Pace Wilber – NOAA Fisheries
Roger Pugliese – Senior Fishery Biologist, SAFMC, Charleston, SC
Lisa Havel – Habitat Coordinator, ASMFC, Arlington, VA
Patrick Campfield – Science Director, ASMFC, Arlington, VA

Petter, Lauren

From: Augspurger, Tom <tom_augspurger@fws.gov>
Sent: Friday, May 05, 2017 2:20 PM
To: Petter, Lauren
Subject: Re: FW: Cape Fear status

Thanks Lauren,

We have not heard anything more about it lately from DWR or the reclassification proponents.

Have a good weekend, and thanks for the update,

Tom

Tom Augspurger
U.S. Fish and Wildlife Service
551-F Pylon Drive
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919-856-4520 x21 (phone)
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FYI

Lauren Petter, Environmental Scientist

Water Quality Standards Section

Water Protection Division

Phone: (404) 562-9272

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Cc: Manning, Jeff <jeff.manning@ncdenr.gov>
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Elizabeth Kountis

Senior Environmental Specialist

Division of Water Resources

North Carolina Department of Environmental Quality

919 807-6418 office

elizabeth.kountis@ncdenr.gov

512 North Salisbury Street

1611 Mail Service Center

Raleigh, NC 27699

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Attachments: 20160212_Letter_Augspurger to Kountis_LCFR Reclassification.pdf

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February 12, 2016

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1611 Mail Service Center
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Sincerely,

Tom Augspurger

Tom Augspurger
Ecologist

cc: Lauren Petter – USEPA
Lisa Gordon – USEPA
Wilson Laney – USFWS
Mike Wicker – USFWS
Fritz Rhode – NOAA Fisheries
Pace Wilber – NOAA Fisheries
Roger Pugliese – Senior Fishery Biologist, SAFMC, Charleston, SC
Lisa Havel – Habitat Coordinator, ASMFC, Arlington, VA
Patrick Campfield – Science Director, ASMFC, Arlington, VA

Petter, Lauren

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Subject: Re: FW: Cape Fear status

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Tom Augspurger
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FYI

Lauren Petter, Environmental Scientist

Water Quality Standards Section

Water Protection Division

Phone: (404) 562-9272

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Cc: Manning, Jeff <jeff.manning@ncdenr.gov>
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Elizabeth Kountis

Senior Environmental Specialist

Division of Water Resources

North Carolina Department of Environmental Quality

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512 North Salisbury Street

1611 Mail Service Center

Raleigh, NC 27699

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From: Petter, Lauren [mailto:Petter.Lauren@epa.gov]
Sent: Thursday, May 04, 2017 8:44 AM
To: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Subject: Cape Fear status

Hey Elizabeth,

I hope you are doing well! I just wanted to follow up and see if you heard any updates on the Lower Cape Fear reclassification from last week.

Thanks,

Lauren

Lauren Petter, Environmental Scientist

Water Quality Standards Section

Water Protection Division

Phone: (404) 562-9272

Petter, Lauren

From: Andrew Herndon - NOAA Federal <andrew.herndon@noaa.gov>
Sent: Friday, November 03, 2017 12:15 PM
To: pat.shaw-allen@noaa.gov
Cc: Petter, Lauren
Subject: Re: quick question on sturgeon contact

Hey Lauren,

Pat's right. I'm the contact. What's up? What can I do?

On Fri, Nov 3, 2017 at 10:55 AM, Pat Shaw-Allen - NOAA Federal <pat.shaw-allen@noaa.gov> wrote:
Andy Herndon is the biologist you seek. I copied him on this message and added his contact info below

Happy Friday to all!

Andrew Herndon
Phone: (727) 824-5367
E-mail: Andrew.Herndon@noaa.gov

Patricia Shaw-Allen, Ph.D.
Ecotoxicologist
NOAA Fisheries
U.S. Department of Commerce
Office: (301)427-8473
Mobile: (603)545-7827
pat.shaw-allen@noaa.gov
www.nmfs.noaa.gov

On Fri, Nov 3, 2017 at 8:49 AM, Petter, Lauren <Petter.Lauren@epa.gov> wrote:

Hey Pat,

Hope you are having a nice week!

Who is the sturgeon contact at NMFS? If it matters, the area I'm working on is the Lower Cape Fear River in North Carolina (Brunswick and New Hanover counties).

Thanks and happy Friday!

Lauren

Petter, Lauren

From:	Petter, Lauren
Sent:	Thursday, November 09, 2017 1:05 PM
To:	Andrew Herndon - NOAA Federal
Cc:	pat.shaw-allen@noaa.gov; Fonzi, Gina; Tyler, Kip
Subject:	overview on Lower Cape Fear River (LCFR) swamp classification

Hey Andy and Pat,

I have put together a brief background/content summary on the LCFR Swamp topic below. Additionally, I'm trying to balance updating you both, without making you read every piece of paper I've collected on this. I'll start with this update and then send an email with comment letters from EPA and FWS. There is also a letter from Southern Environmental Law Center (SELC) that seems to include some additional references based on NOAA input, and the letter also happens to outline the evolution of the process, from their perspective, that may be of interest to read since it talks about sturgeon and other species. My next email will include the SELC letter also.

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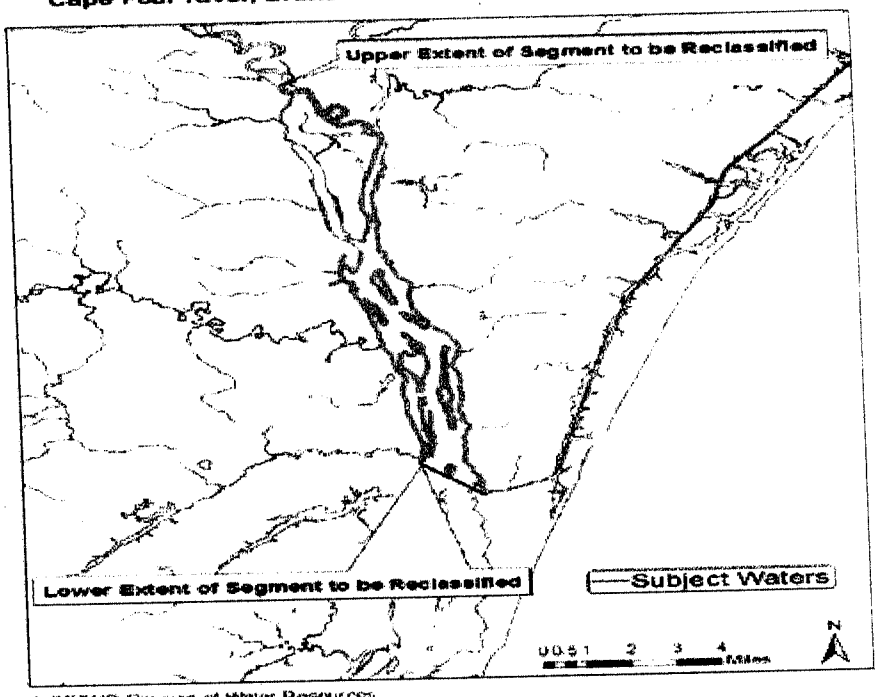
Proposed Swamp Reclassification and Water Quality Management Plan
Cape Fear River, Brunswick and New Hanover Counties, NC



NCDENR-Division of Water Resources
Water Planning Section
November 24, 2014

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Lauren Petter, Environmental Scientist
Water Quality Standards Section
Water Protection Division
Phone: (404) 562-9272

Petter, Lauren

From: Pat Shaw-Allen - NOAA Federal <pat.shaw-allen@noaa.gov>
Sent: Wednesday, November 08, 2017 1:13 PM
To: Petter, Lauren
Cc: Andrew Herndon - NOAA Federal; Fonzi, Gina
Subject: Re: quick question on sturgeon contact

Yes, please continue to keep us in the loop. If you need any of the papers referenced in the opinions, let us know.

Patricia Shaw-Allen, Ph.D.
Ecotoxicologist
NOAA Fisheries
U.S. Department of Commerce
Office: (301)427-8473
Mobile: (603)545-7827
pat.shaw-allen@noaa.gov
www.nmfs.noaa.gov

On Wed, Nov 8, 2017 at 1:00 PM, Petter, Lauren <Petter.Lauren@epa.gov> wrote:

Thanks Pat and Andy!

Andy – I am preparing for a "likely" upcoming water quality standards (WQS) submittal from North Carolina which will subsequently result in a CWA 303(c) review of the WQS change and related ESA consultation. I say "likely" because the state has adopted the change and it sounds like the transmittal for it is ready, but I am uncertain when it will be sent to EPA for review. For your information, there was a mixture of support and opposition to the change during the public process.

The change itself involved adding the Swamp (Sw) classification to a portion of the lower Cape Fear River. Based on previous work on this topic, I understand that Tom Augspurger (FWS) has worked with Dr. Wilson Laney (also FWS) and included Fritz Rhode and Pace Wilber (both NOAA) in communications with the state. Very generally, the effect of this change allows DO to be lower than 5 mg/L due to natural conditions and allows pH to be as low as 4.3 due to natural conditions. Having worked on Florida DO revisions with NMFS previously, I know that DO is of particular interest for sturgeon.

Of course there are plenty more details I can provide, but the main purpose of this email is ensure I am communicating with the most appropriate people from NMFS as I move forward in my review of this revision. Our regional office has worked with both HQ and the St. Pete office so I wanted to clarify the current status of things since it has been a couple years since I have worked on this specific change in North Carolina and it looks like there is now potential for movement on it. For now, unless you or Pat feels otherwise, I can keep you both in the loop.

Lastly, I am working on a summary of the material for my management and would be happy to share with both you and Pat if you like.

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From: Andrew Herndon - NOAA Federal [mailto:andrew.herndon@noaa.gov]
Sent: Friday, November 03, 2017 12:15 PM
To: pat.shaw-allen@noaa.gov
Cc: Petter, Lauren <Petter.Lauren@epa.gov>
Subject: Re: quick question on sturgeon contact

Hey Lauren,

Pat's right. I'm the contact. What's up? What can I do?

On Fri, Nov 3, 2017 at 10:55 AM, Pat Shaw-Allen - NOAA Federal <pat.shaw-allen@noaa.gov> wrote:

Andy Herndon is the biologist you seek. I copied him on this message and added his contact info below

Happy Friday to all!

Andrew Herndon
Phone: (727) 824-5367
E-mail: Andrew.Herndon@noaa.gov

Patricia Shaw-Allen, Ph.D.
Ecotoxicologist
NOAA Fisheries

U.S. Department of Commerce
Office: (301)427-8473
Mobile: (603)545-7827

pat.shaw-allen@noaa.gov
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From: Andrew Herndon - NOAA Federal <andrew.herndon@noaa.gov>
Sent: Wednesday, November 08, 2017 1:21 PM
To: Petter, Lauren
Cc: pat.shaw-allen@noaa.gov; Fonzi, Gina
Subject: Re: quick question on sturgeon contact

Hey Lauren,

Thanks for reaching out. I am the person here to be in contact with regarding sturgeon. I can't speak for Pat, but I certainly would appreciate staying in the loop as this moves forward and as you develop those documents.

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On Fri, Nov 3, 2017 at 8:49 AM, Petter, Lauren <Petter.Lauren@epa.gov> wrote:

Hey Pat,

Hope you are having a nice week!

Who is the sturgeon contact at NMFS? If it matters, the area I'm working on is the Lower Cape Fear River in North Carolina (Brunswick and New Hanover counties).

Petter, Lauren

From: Andrew Herndon - NOAA Federal <andrew.herndon@noaa.gov>
Sent: Wednesday, January 10, 2018 8:03 AM
To: Petter, Lauren
Cc: pat.shaw-allen@noaa.gov; Fonzi, Gina; Tyler, Kip
Subject: Re: overview on Lower Cape Fear River (LCFR) swamp classification

Hi Lauren,

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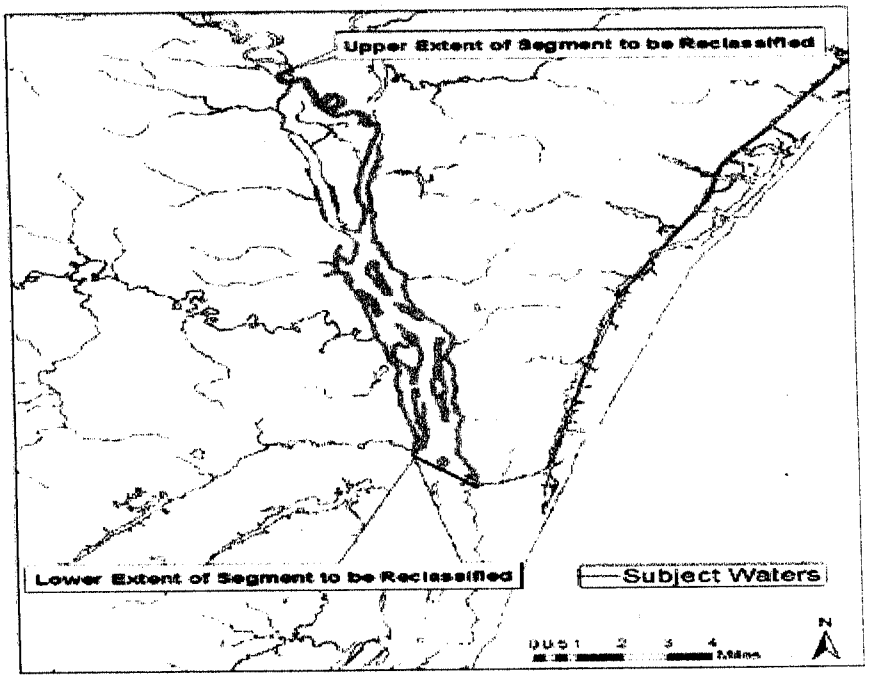

NC DENR-Division of Water Resources
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To: Andrew Herndon - NOAA Federal
Cc: pat.shaw-allen@noaa.gov; Fonzi, Gina; Tyler, Kip
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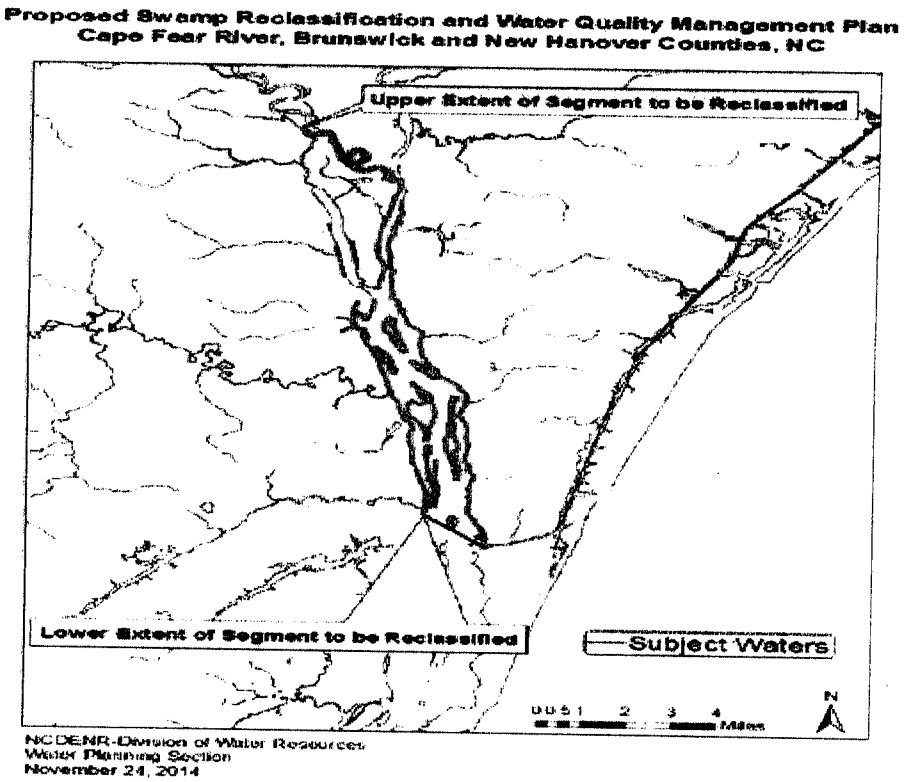

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Water Quality Standards Section

Water Protection Division

Phone: (404) 562-9272

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From: Andrew Herndon - NOAA Federal <andrew.herndon@noaa.gov>
Sent: Wednesday, January 10, 2018 11:25 AM
To: Petter, Lauren
Cc: pat.shaw-allen@noaa.gov; Fonzi, Gina; Tyler, Kip
Subject: Re: overview on Lower Cape Fear River (LCFR) swamp classification

Hi Lauren,

Thanks for the update.

I believe my initial thought was this seems like a bad idea for sturgeon and sturgeon habitat. If I recall correctly, many of the comments I reviewed from FWS (?) and others accurately summarized many of my concerns. While I acknowledge I may be missing part of the context (some of which may be significant) this does appear to be an attempt to avoid additional attempts to improve water quality by simply reclassifying this reach of the river.

Something that may be worth noting is that this area of the Cape Fear River was designated as Atlantic sturgeon critical habitat in August. This designation includes water quality as a parameter that must be considered when evaluating the potential impacts of any federal project that may affect the habitat. Even a classification change from Sc to Sw would not lift that requirement for federal projects. Obviously, a classification change may still be significant for non-federal projects.

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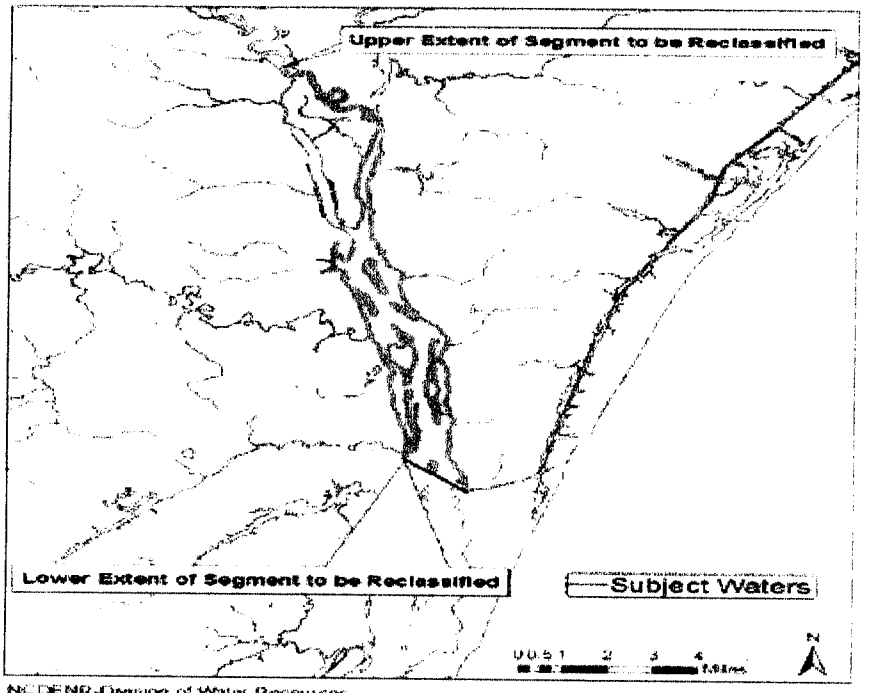

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From: Andrew Herndon - NOAA Federal <andrew.herndon@noaa.gov>
Sent: Wednesday, January 17, 2018 4:02 PM
To: Petter, Lauren
Subject: Re: overview on Lower Cape Fear River (LCFR) swamp classification

OK. Thanks.

On Wed, Jan 17, 2018 at 3:54 PM, Petter, Lauren <Petter.Lauren@epa.gov> wrote:

FYI We have a briefing scheduled with our Director next Wednesday, 1/24 and will follow up with NMFS after that.

Lauren

Lauren Petter, Environmental Scientist

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Thanks for checking in. We still have not seen a formal submittal of this package from the state. We just had a second call with the state seeking additional information and our next steps will include talking with our Division Director. Once we hear back from her, we were planning to schedule a call with you and Pat to discuss our current thinking and any thoughts NMFS has on the provisions the state has adopted. If you already had any concerns that would be good to know to relay to our Director, but otherwise we can just plan to talk once we have management direction on a preferred path forward.

Lauren Petter, Environmental Scientist

Water Quality Standards Section

Water Protection Division

Phone: (404) 562-9272

From: Andrew Herndon - NOAA Federal [mailto:andrew.herndon@noaa.gov]
Sent: Wednesday, January 10, 2018 8:03 AM
To: Petter, Lauren <Petter.Lauren@epa.gov>
Cc: pat.shaw-allen@noaa.gov; Fonzi, Gina <Fonzi.Gina@epa.gov>; Tyler, Kip <Tyler.Kip@epa.gov>
Subject: Re: overview on Lower Cape Fear River (LCFR) swamp classification

Hi Lauren,

Happy New Year.

I just realized I review this information some time ago, but can't remember if I ever got back to you, or if we ever set up any follow up actions.

Where does all this stand?

Thanks,

Andy

On Thu, Nov 9, 2017 at 1:04 PM, Petter, Lauren <Petter.Lauren@epa.gov> wrote:

Hey Andy and Pat,

I have put together a brief background/content summary on the LCFR Swamp topic below. Additionally, I'm trying to balance updating you both, without making you read every piece of paper I've collected on this. I'll start with this update and then send an email with comment letters from EPA and FWS. There is also a letter from Southern Environmental Law Center (SELC) that seems to include some additional references based on NOAA input, and the

letter also happens to outline the evolution of the process, from their perspective, that may be of interest to read since it talks about sturgeon and other species. My next email will include the SELC letter also.

With all that being said, in regards to timing...I just gave my management and attorney an initial briefing on these revisions this morning. They will be mulling over the content themselves and we will touch base again after they form some initial thoughts. On your end, I was hoping you might also take a little time to go over the materials I share and then let me know when you are ready for a touch base conference call with me to talk generally on this topic. How does that sound? Of course if you have any questions in the interim, don't hesitate to call. My number is at the bottom of this email.

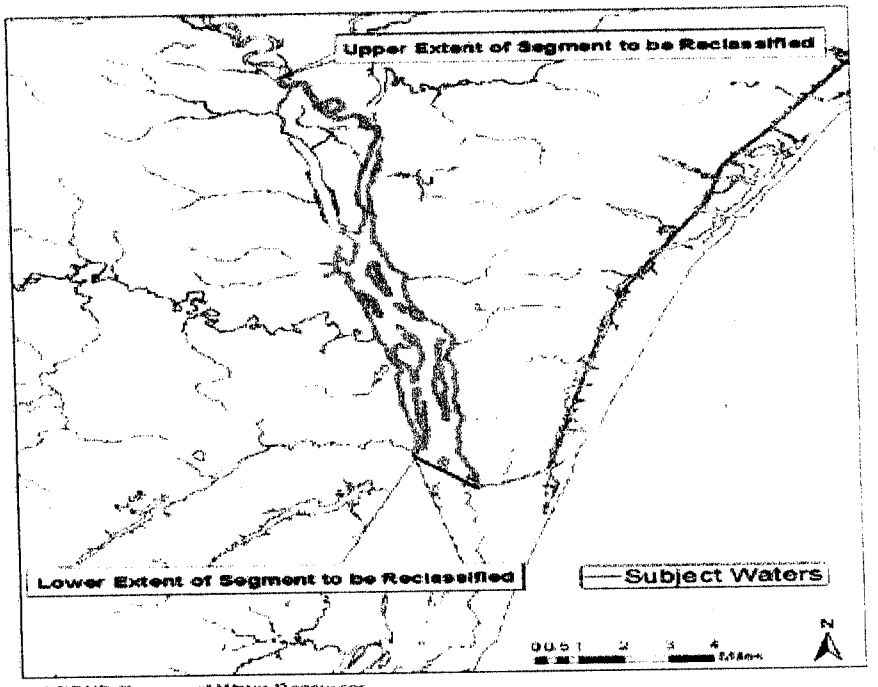
Thanks in advance,

Lauren

Overview:

North Carolina has adopted the supplemental classification, Sw, for a segment of the Lower Cape Fear River which previously was classified as only Class C salt water (SC). The upstream segment is Class C fresh water and Sw, and the immediate downstream segment is SC. The majority of the named tributaries to the subject segment include the Sw classification.

Proposed Swamp Reclassification and Water Quality Management Plan
Cape Fear River, Brunswick and New Hanover Counties, NC



NC DENR-Division of Water Resources
Water Planning Section
November 24, 2014

Definitions and Relevant Class SC Criteria:

(62) Swamp waters mean those waters which are classified by the Environmental Management Commission and which are topographically located so as to generally have very low velocities and other characteristics which are different from adjacent streams draining steeper topography. They are designated by "Sw" following the water classification.

(5) Dissolved oxygen: not less than 5.0 mg/l, except that swamp waters, poorly flushed tidally influenced

streams or embayments, or estuarine bottom waters may have lower values if caused by natural conditions;

(12) pH: shall be normal for the waters in the area, which range between 6.8 and 8.5, except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions

Actual Regulatory Changes That North Carolina Adopted:

New/Revised Language at 15A NCAC 02B .0227(b)

(2) A part of the Cape Fear River (Cape Fear River Basin) comprised of a section of 18-(71) from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut shall be protected by the Class SC Sw standards as well as the following site-specific action: All new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges shall be required to provide treatment for oxygen consuming wastes as described in Parts (A) through (C) of this Subparagraph.

(A) Effluent limitations shall be as follows: BOD5 = 5 mg/l, NH3-N = 1 mg/l and DO = 6 mg/l, or utilize site-specific best available technology on a case-by-case basis for industrial discharges in accordance with Rule .0406 (e) of this Subchapter.

(B) Seasonal effluent limits for oxygen consuming wastes will be considered in accordance with Rule .0404 of this Subchapter.

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New Language at 15A NCAC 02B .0311

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Lauren Petter, Environmental Scientist

Water Quality Standards Section

Water Protection Division

Phone: (404) 562-9272

Petter, Lauren

From: Petter, Lauren
Sent: Wednesday, January 31, 2018 11:37 AM
To: Andrew Herndon - NOAA Federal
Cc: Tyler, Kip; Fonzi, Gina; Petter, Lauren
Subject: RE: overview on Lower Cape Fear River (LCFR) swamp classification

FYI We briefed our Director last week and she will be contacting her counterpart at the state. So, now we are awaiting to hear what comes out of the exchange. Once we know more, I will relay a more substantive update.

Thanks,
Lauren

Lauren Petter, Environmental Scientist
Water Quality Standards Section
Water Protection Division
Phone: (404) 562-9272

From: Andrew Herndon - NOAA Federal [mailto:andrew.herndon@noaa.gov]
Sent: Wednesday, January 17, 2018 4:02 PM
To: Petter, Lauren <Petter.Lauren@epa.gov>
Subject: Re: overview on Lower Cape Fear River (LCFR) swamp classification

OK. Thanks.

On Wed, Jan 17, 2018 at 3:54 PM, Petter, Lauren <Petter.Lauren@epa.gov> wrote:

FYI We have a briefing scheduled with our Director next Wednesday, 1/24 and will follow up with NMFS after that.

Lauren

Lauren Petter, Environmental Scientist

Water Quality Standards Section

Water Protection Division

Phone: (404) 562-9272

From: Petter, Lauren
Sent: Wednesday, January 10, 2018 9:12 AM
To: 'Andrew Herndon - NOAA Federal' <andrew.herndon@noaa.gov>

Cc: pat.shaw-allen@noaa.gov; Fonzi, Gina <Fonzi.Gina@epa.gov>; Tyler, Kip <Tyler.Kip@epa.gov>
Subject: RE: overview on Lower Cape Fear River (LCFR) swamp classification

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Lauren Petter, Environmental Scientist

Water Quality Standards Section

Water Protection Division

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To: Petter, Lauren <Petter.Lauren@epa.gov>
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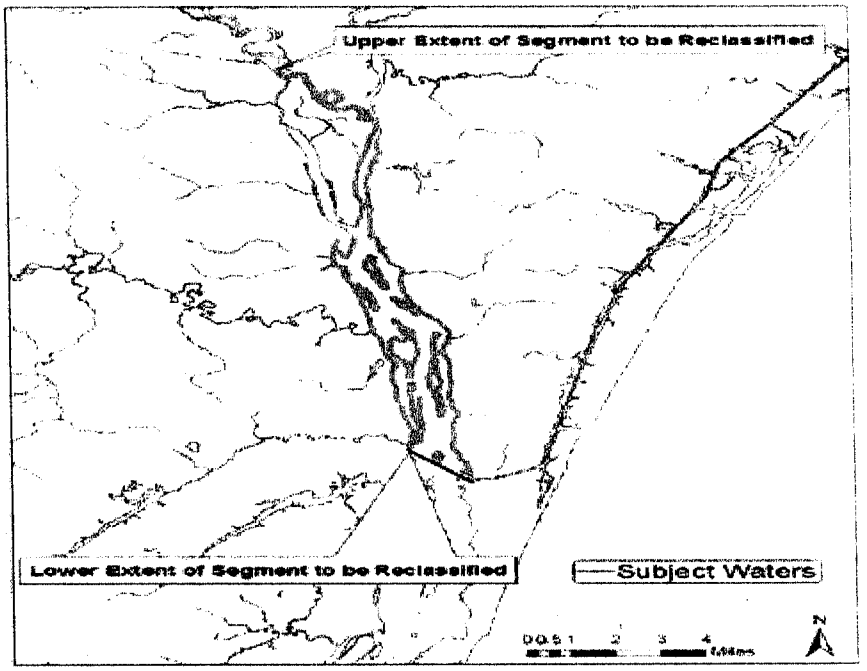
Proposed Swamp Reclassification and Water Quality Management Plan
Cape Fear River, Brunswick and New Hanover Counties, NC



NCDENR-Division of Water Resources
Water Planning Section
November 24, 2014

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Lauren Petter, Environmental Scientist

Water Quality Standards Section

Water Protection Division

Phone: (404) 562-9272

Petter, Lauren

From: Google Calendar <calendar-notification@google.com> on behalf of pat.shaw-allen@noaa.gov
Sent: Monday, April 30, 2018 11:37 AM
To: Petter, Lauren; Fonzi, Gina; pat.shaw-allen@noaa.gov; Godfrey, Annie; Tyler, Kip; andrew.herndon@noaa.gov; Gordon, Lisa Perras; Wetherington, Michele
Subject: EPA R4 & NMFS - Chat about NC Swamp and Triennial

Link to SERO GIS resources

http://sero.nmfs.noaa.gov/maps_gis_data/index.html

EPA R4 & NMFS - Chat about NC Swamp and Triennial

Booked 15A for those in the office.

Call in information:

Phone # & ID

Information Redacted pursuant to 5 U
Section 552 (b)(6), Personal Privacy

Conference phone number:

Conference ID:

Agenda:

* Swamp topic

* Triennial Review topic

When Mon Apr 30, 2018 11am – 12pm Eastern Time

Where R4-15T98-Water-Branch-Conf-Rm/Sam-Nunn-Federal-Building-ATL (map)

Who
- Petter, Lauren - organizer
- pat.shaw-allen@noaa.gov - creator
- Godfrey, Annie
- Fonzi, Gina
- Andrew Herndon - NOAA Federal
- Wetherington, Michele
- Gordon, Lisa Perras
- Tyler, Kip

Phone # & ID

Information Redacted pursuant to 5 U.S
Section 552 (b)(6), Personal Privacy

Petter, Lauren

From: Andrew Herndon - NOAA Federal <andrew.herndon@noaa.gov>
Sent: Monday, April 30, 2018 11:43 AM
To: pat.shaw-allen@noaa.gov
Cc: Petter, Lauren; Fonzi, Gina; Godfrey, Annie; Tyler, Kip; Gordon, Lisa Perras; Wetherington, Michele
Subject: Re: EPA R4 & NMFS - Chat about NC Swamp and Triennial

Thanks Pat.

Just a little more specifically, if you click the "Protected Resources" tab and then the "Critical Habitat" link you'll find the Atlantic sturgeon information, along with other species like smalltooth sawfish.

On Mon, Apr 30, 2018 at 11:36 AM, <pat.shaw-allen@noaa.gov> wrote:

Link to SERO GIS resources

http://sero.nmfs.noaa.gov/maps_gis_data/index.html

EPA R4 & NMFS - Chat about NC Swamp and Triennial

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- Tyler, Kip

Phone # & I.D.

Information Redacted pursuant to 5 U.S.C.
Section 552 (b)(6), Personal Privacy

--

Petter, Lauren

From: Petter, Lauren
Sent: Monday, July 23, 2018 8:57 AM
To: 'Pat Shaw-Allen - NOAA Federal'
Subject: RE: Trying to find the spreadsheet

I'm waiting on a call from my Division Director related to the swamp reclassification in NC. If she hasn't called a little after 9 I will call you, but may have to call you back if she calls during our call.

Lauren Petter, Environmental Scientist
Water Quality Standards Section
Water Protection Division
Phone: (404) 562-9272

From: Pat Shaw-Allen - NOAA Federal [mailto:pat.shaw-allen@noaa.gov]
Sent: Thursday, July 19, 2018 3:38 PM
To: Petter, Lauren
Subject: Re: Trying to find the spreadsheet

Conversations while on travel can be stressful, I think this could wait until Monday morning. This will also give you a chance to look into FW silver. I leave for my trip mid-day and should be available between 8 and noon.

Patricia Shaw-Allen, Ph.D.
Ecotoxicologist
NOAA Fisheries
U.S. Department of Commerce
Office: (301)427-8473
Mobile: (603)545-7827
pat.shaw-allen@noaa.gov
www.nmfs.noaa.gov

NOAA FISHERIES

On Wed, Jul 18, 2018 at 5:29 PM, Petter, Lauren <Petter.Lauren@epa.gov> wrote:

Hey Pat,

The attached file with your name in the title is likely the one you are seeking, but let me know if that's not. I included another file that you prepared since I saw in my NC folder while I was looking just in case that was something you wanted too.

What do you mean have I seen the BiOp from Oregon? It is in my files so I would have reviewed it in order to prepare the materials we sent. I haven't looked at it since so don't quiz me though. ☺

As far as silver, I'd have to read back what I said in the BE so unless it is covered in the ecotox information in the BE or my summary table of each metal (where the papers we looked at were discussed), I think it is likely I didn't use any other information.

I still owe you a call on the WER topic. I am on travel tomorrow and probably free to chat at 4-5 (at 770-841-0423). Otherwise I'm back in Monday and we could chat more then.

Lauren Petter, Environmental Scientist

Water Quality Standards Section

Water Protection Division

Phone: (404) 562-9272

From: Pat Shaw-Allen - NOAA Federal [mailto:pat.shaw-allen@noaa.gov]
Sent: Wednesday, July 18, 2018 4:08 PM
To: Petter, Lauren <Petter.Lauren@epa.gov>
Subject: Trying to find the spreadsheet

Hello Lauren

I hope you can help me out with this. I had a blue screen of death event way back when I was working on the FL NNC. I am not not able to find the May 2015 spreadsheet summary of the prior BiOps I sent you. Do you happen a copy handy that you can send me? Also, did you ever see the actual BiOp for Oregon?

Also, the NC triennial BE does not indicate whether or not there were supplemental papers for silver in fresh water (SIlver was one of those earlier WQGs, might be lots of new data).

Thanks

Pat

Petter, Lauren

From: Pat Shaw-Allen - NOAA Federal <pat.shaw-allen@noaa.gov>
Sent: Monday, July 23 2018 8:59 AM
To: Petter, Lauren
Subject: Re: Trying to find the spreadsheet

I think it is ok to wait until Friday, if that is easier. I know how the first days back from travel can be! The NC item has waited pretty long, a week more is not going to change anything.

Patricia Shaw-Allen, Ph.D.
Ecotoxicologist
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Thanks

Petter, Lauren

From: Petter, Lauren
Sent: Wednesday, August 01, 2018 8:52 AM
To: Andrew Herndon - NOAA Federal; Pat Shaw-Allen - NOAA Federal
Cc: Augspurger, Tom; Fonzi, Gina
Subject: EPA action taken on Lower Cape Fear River Swamp reclassification
Attachments: EPA July 24 2018 Disapproval Ltr and Decision Doc for LCFR.pdf

Andy and Pat (and Tom FYI),

Attached is the EPA's disapproval of the swamp reclassification and a portion of the management strategy that was adopted by North Carolina and submitted to the EPA for its review in April 2018. Given that the action was to disapprove (and for some provisions were not considered to be subject to the Agency's Clean Water Act 303(c) review), there is no further consultation coordination required for this action. Thank you for your support as we worked on our review of the State's recent action! If you have any follow up questions, just let me know.

Lastly, as you will see in the letter, we have offered to work with the state on any future path forwards they may take. We will be sure to coordinate with the Services when any such future activity begins.

Thanks,
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Water Quality Standards Section
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Phone: (404) 562-9272

Petter, Lauren

From: Andrew Herndon - NOAA Federal <andrew.herndon@noaa.gov>
Sent: Wednesday, August 01, 2018 9:07 AM
To: Petter, Lauren
Cc: pat.shaw-allen@noaa.gov; tom_augspurger@fws.gov; Fonzi, Gina
Subject: Re: EPA action taken on Lower Cape Fear River Swamp reclassification

Thanks for the update Lauren!

On Wed, Aug 1, 2018 at 8:52 AM, Petter, Lauren <Petter.Lauren@epa.gov> wrote:

Andy and Pat (and Tom FYI),

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Andy Herndon
Atlantic and Shortnose Sturgeon Recovery Coordinator
Protected Resources Division
NOAA Fisheries - SERO
727-824-5367

Protect **Sturgeon** - **C**onserve Water, **P**rotect Habitat, **R**eport Sightings

Petter, Lauren

From: Augspurger, Tom <tom_augspurger@fws.gov>
Sent: Monday, August 06, 2018 2:26 PM
To: Petter, Lauren
Subject: Re: [EXTERNAL] FW: EPA to NC: Lower Cape Fear River Swamp Supplemental Classification Denied

Good afternoon Lauren,

Thanks for the press release on the path forward and for the copy of the letter last week. The EPA letter is well reasoned with regard to both the practical and procedural aspects of doing reclassifications. You did a good job synthesizing all the technical input with the NCAC on water quality classifications and standards. As you know from our letters and emails, FWS was concerned that it needed a lot more work.

Thanks for your attention to this and the time staff spent on it,

Kind regards,

Tom

Tom Augspurger
Deputy Field Supervisor

U.S. Fish and Wildlife Service
551-F Pylon Drive
Raleigh NC 27606
919-856-4520 x21 (phone)
tom_augspurger@fws.gov

NOTE: This email correspondence and any attachments to and from this sender is subject to the Freedom of Information Act (FOIA) and may be disclosed to third parties.

On Mon, Aug 6, 2018 at 1:05 PM, Petter, Lauren <Petter.Lauren@epa.gov> wrote:

FYI...A copy of the state's press release on our action.

Lauren Petter, Environmental Scientist

Water Quality Standards Section

Water Protection Division

Phone: (404) 562-9272

From: Munger, Bridget
Sent: Monday, August 06, 2018 10:52 AM
To: Manning, Jeff <jeff.manning@ncdenr.gov>
Subject: EPA to NC: Lower Cape Fear River Swamp Supplemental Classification Denied

CAUTION: External email. Do not click links or open attachments unless verified. Send all suspicious email as an attachment to

Roy Cooper, Governor

Michael S. Regan, Secretary

:lease: IMMEDIATE
ıte: July 31, 2018

Contact: Megan Thorpe
Phone: 919-707-8670

EPA to NC: Lower Cape Fear River Swamp Supplemental Classification Denied

ALEIGH – The N.C. Department of Environmental Quality was notified by the Environmental Protection Agency (EPA) of their denial of th ower Cape Fear River (LCFR) supplemental classification as swamp waters. The original effort to push to reclassify the river was driven by ıe previous administration, approved by the EMC in 2015, and eventually submitted to the EPA earlier this year.

'he EPA cited technical details that were absent from the request sent by the state to the EPA, including failure to meet the state's definition swamp water." The existing primary classification as class c salt water will remain in place for all Clean Water Act purposes.

pecifically, this applies to a section of the LCFR that runs from Toomers Creek approximately 15 miles south to Snow's Cut.

)ue to environmental concerns such as the presence of endangered species in the salt waters of the LCFR and ongoing PFAS regulatory issu)EQ intends to advise the EMC at the next regular session that the EPA's disapproval letter should be the final action on this issue.

Petter, Lauren

From: Petter, Lauren
Sent: Monday, August 06, 2018 1:05 PM
To: Pat Shaw-Allen - NOAA Federal; Andrew Herndon - NOAA Federal
Cc: Augspurger, Tom
Subject: FW: EPA to NC: Lower Cape Fear River Swamp Supplemental Classification Denied

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EPA to NC: Lower Cape Fear River Swamp Supplemental Classification Denied

ALEIGH – The N.C. Department of Environmental Quality was notified by the Environmental Protection Agency (EPA) of their denial of th› ›wer Cape Fear River (LCFR) supplemental classification as swamp waters. The original effort to push to reclassify the river was driven by ɛ previous administration, approved by the EMC in 2015, and eventually submitted to the EPA earlier this year.

ıe EPA cited technical details that were absent from the request sent by the state to the EPA, including failure to meet the state's definition wamp water." The existing primary classification as class c salt water will remain in place for all Clean Water Act purposes.

›ecifically, this applies to a section of the LCFR that runs from Toomers Creek approximately 15 miles south to Snow's Cut.

› environmental concerns such as the presence of endangered species in the salt waters of the LCFR and ongoing PFAS regulatory issue: intends to advise the EMC at the next regular session that the EPA's disapproval letter should be the final action on this issue.

e full letter from the EPA, including the scientific and legal citations supporting their decision, click here:
//files.nc.gov/ncdeq/Water%20Quality/EMC/07.24.18%20Lower%20Cape%20Fear%20River%20EPA%20Letter.pdf

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North Carolina Department of Environmental Quality, 217 W. Jones St., Raleigh, NC 27699 United States

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: I live here and this is my home.

Dear Ms. Elizabeth Kountis,

I was born in Southeastern North Carolina and still as an adult I call this place my home. I am shocked and appalled by the decline in our concern for the land on which we all depend and hopefully our children will be able to depend.

I understand no one can have everything they want all of the time, compromise is necessary but some things simply cannot be compromised.

Classifying the water in lower Cape fear River as swap water would be temporary solution to a permanent problem. This decision will effect the popluations of people who sail paddle and fish in this area. Surely we can't think that simply changing the name will change the consequences that will surely come. I implore you to do the right thing. Act responsibly in your position, clean up our river.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U
Section 552 (b)(6), Personal Priva

NCDENR

North Carolina Department of Environment and Natural Resources

Pat McCrory
Governor

Donald R. van der Vaart
Secretary

MEMORANDUM:

TO: Elizabeth Kountis, Division of Water Resources, Planning Section

FROM: Shane Staples, DCM Fisheries Resource Specialist

SUBJECT: Proposed Cape Fear Water Quality Resignation from SC to SW

DATE: 3/3/15

A North Carolina Division of Coastal Management (DCM) Fisheries Resource Specialist has reviewed the proposed swamp reclassification of the Cape Fear River from the mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut where the Intracoastal Waterway meets the river. This reach of the Cape Fear River is currently classified SC and is experiencing impairments in the form of high levels of fecal coliforms and at times low dissolved oxygen levels that can be detrimental to fish and shellfish in the river. Much of the area is closed to shell fishing due to pollution that can be attributed to the highly developed watershed. The Cape Fear River is used by nearly all species of estuarine fish and shellfish found in North Carolina including the federally endangered shortnose sturgeon and Atlantic sturgeon.

Reducing water quality standards in this reach of the river could have negative effects on fish and shell fish that use the Cape Fear River. As well as being known habitat for both federally endangered sturgeon species it is also classified as a Primary Nursery Area (PNA) by the North Carolina Division of Marine Fisheries. Water bodies classified as PNA's are habitats that are essential to larval and juvenile fish and shellfish survival and recruitment. The number and diversity of juvenile fish collected in NDMF sampling in this section of the Cape Fear show this area to be highly productive; reductions in the water quality standards for this area could impair its function as a nursery area. Fish kills caused by low dissolved oxygen levels are a normal summer occurrence in NC estuaries due to already impaired conditions, reducing the dissolved oxygen standard could exacerbate this problem. Additionally, even though many of the shellfish harvest closures in the area are due to pollutant runoff the proposed change in water quality standards could possibly lead to expanded closures in the Cape Fear.

Contact Shane Staples at (252) 948-3950 or shane.staples@ncdenr.gov with further questions or concerns.

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Comments on the Proposed Reclassification
of the Lower Cape Fear River and Estuary to a Class Sc (Sw) Swamp

Prepared for Waterkeeper Alliance by JoAnn M. Burkholder, Ph.D., March 3, 2015

I. Overview

Since 1998, the lower Cape Fear River Estuary (LCFRE) segment from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut has been on North Carolina's 303(d) list of officially "impaired" (degraded) waters due to low dissolved oxygen (DO). In 2006, the state added impairment for pH, copper and turbidity to the 303(d) list for this segment. Throughout the past several decades, a subset of regulated point sources (i.e., with wastes mainly discharged to surface waters through one or more pipes) have been the state's focus for water quality improvement. In 2014, the North Carolina Division of Water Resources within the Department of Environment and Natural Resources (NCDENR-DWR) received a request from a group including various point source dischargers to reclassify the LCFRE from Class Sc to Class Sc-Swamp (Sw) (May 2014). The rationale given for the request included two points - first, that a recent modeling effort (Bowen et al. 2009) had assessed the 20 largest point sources in the lower Cape Fear River basin and concluded that the sources have little influence on water-column DO concentrations in the LCFRE; and second, the group asserted that significant reductions in pollutant loading from other sources which they call "background" loads would not achieve attainment for certain periods of the summer. The request specifically stated,

> ...modeling results indicate that [the 20 assessed] point-source discharges have a relatively minor impact on DO levels, and that even significant reductions in background (both natural and nonpoint source) loads would not result in attainment of the current standard for considerable periods of time during the summer. - May (2014)

Based on this request and information, NCDENR-DWR recently proposed to reclassify the LCFRE to a swamp (Sw) based on the misleading claim that, since the LCFRE cannot meet its present DO standard (≥ 5 mg/L) by controlling the 20 identified point sources alone as assessed in Bowen et al.'s (2009) model, a TMDL (total maximum daily load) to achieve the DO standard would be inappropriate. The proposed reclassification of the LCFRE to a swamp is not consistent with sound science or the law for three reasons:

1. The available evidence shows that the major sources of oxygen-demanding materials in the LCFRE are due to pollution from human activities which are subject to regulation and can be controlled. The major sources of oxygen-demanding materials are **not** natural wetland drainage or other natural background sources. Natural wetland drainage appears to add only a fraction of the massive contribution of oxygen-demanding materials, high levels of toxic copper, high turbidity, and many other pollutants that are being contributed by pollution from point sources, other regulated sources and nonpoint sources (see Sections IIID-E of these Comments).

2. Under the Clean Water Act, the required TMDL for the LCFRE must address ***all*** pollution sources, including point sources, other regulated sources, and nonpoint sources, in the watershed (see Section IIID of these Comments). In its proposed action, NCDENR-DWR has *not* considered ~22 NPDES-permitted point sources in the lower Cape Fear basin, or *any* of the ~153 NPDES-permitted point sources in the upper and middle Cape Fear River basin, which contribute to the impaired (degraded) water quality of the LCFRE which is at the receiving, lower end of the basin. NCDENR-DWR *also* failed to consider the impact of the nearly 1,000 industrial-scale swine Animal Feeding Operations as well as an unknown number of industrial-scale poultry Animal Feeding Operations, many of which are Concentrated (Confined) Animal Feeding Operations (CAFOs) and, thus, point sources under the Clean Water Act. These sources were also omitted from specific analysis in the Bowen et al. (2009) model, although many of the industrial facilities are located in the lower basin (see Section IIIE of these Comments). As a scientist, I first approached their inclusion in these Comments by checking the formal definition of CAFOs in the Clean Water Act (Section 502(14)). *CAFOs are formally defined there as point sources.* They are supposed to be regulated using National Pollution Elimination Discharge System (NPDES) permits, as other industrial point sources are regulated. There are about five million swine in the Cape Fear basin. Each swine produces, on average, about four times more sewage than one person (see Section IIIE). Therefore, the swine CAFO point sources, which are predominantly in the lower Cape Fear basin, contribute roughly the same amount of sewage to that relatively small area, *per year*, as 15 million people. Moreover, swine wastes are much richer in oxygen-demanding materials than human sewage. Industrialized poultry production, also massive in the Cape Fear River basin, contributes to oxygen-demanding materials and other water quality degradation of the LCFRE as well (see Section IIIE). Overall, ~175 NPDES-permitted point sources in the Cape Fear River watershed, and nearly 1,000 swine CAFO point sources as well as an unknown number of poultry CAFOs, were not identified and appropriately evaluated by Bowen et al. (2009) and NCDENR-DWR. These sources are not simply "background" as misleadingly characterized in the materials underlying the NCDENR-DWQ Proposal to reclassify the LCFRE and in the Proposal itself. Collectively, and often individually, these facilities are **extreme**, chronic pollution sources of oxygen-demanding materials to the LCFRE. They can be, and should be, addressed through state regulatory programs, the Clean Water Act and a TMDL for the LCFRE.

3. *Significant reductions in the erroneously termed "background" loads* **would** *achieve attainment of the present DO standard in the LCFRE segment.* As explained above, what was misleadingly and inaccurately called "background" in the lower Cape Fear basin includes the point source pollution from ~175 NPDES-permitted point sources in the Cape Fear River watershed, and from nearly 1,000 swine CAFOs and an unknown number of poultry CAFOs. All of these pollution sources were not among the 20 considered by Bowen et al. (2009) as the main point source contribution to the LCFRE. These sources were, at least, tacitly included in Bowen et al.'s (2009) model within a category called "tributary inputs." The model predicts that a reduction of 30% of the "tributary inputs" would result in median DO levels in the LCFRE that exceed 5 mg/L -- that is, higher than the state standard -- and that a

70% reduction in the "tributary inputs" and the internal oxygen demand (below) largely resulting from these inputs would bring the LCFRE into compliance 99% of the time.

If the proposed reclassification occurs, NCDENR-DWR will accomplish a contrived, highly artificial "official change" of a major, strongly flowing estuary of national importance to a "swamp" with no scientific basis. Rather than providing cleanup and protection of the impaired segment -- which has been officially designated as impaired and in need of improved protection for nearly two decades -- this action would allow much more pollution to occur there, in violation of the Clean Water Act. Consequently, NCDENR-DWR's proposed reclassification would jeopardize the designated uses of the LCFRE. The LCFRE should *not* be reclassified as a swamp.

The scientific facts briefly mentioned above, which accurately describe the status of the LCFRE and the pollution affecting it, are explained in detail in the following comments, supported by peer-reviewed science literature and findings from federal agencies such as the U.S. Department of Agriculture (USDA) and the U.S. Environmental Protection Agency (USEPA).

II. The Mighty Cape Fear River

The Cape Fear River basin, completely contained within North Carolina, is the largest watershed in the state, covering ~16.5% (~9,324 square miles) of total land area. It also contains the largest number of stream miles (6,204) in North Carolina (Lin et al. 2006, Bowen et al. 2009 and references therein). The 26 counties within or overlapping the watershed are expected to grow from 3 million to about 5 million people over the next 20 years.[1] There presently are about 1.7 hogs per person in the Cape Fear basin, and industrialized swine production as well as turkey production in the lower basin are among the most concentrated in the world (Mallin et al. 2003).

The LCFRE is "extremely important... because of its function as a nursery for juvenile fish, crabs, and shrimp . . . The river is also an important natural resource that supports many uses including industry, transportation, recreation, drinking water, and aesthetic enjoyment" (Bowen et al. 2009). On a popular tourism website[2] are quotes such as the following about the LCFRE (emphasis added):

- Hard to review a river! It's *wild, powerful,* beautiful in all seasons....
- Amazing to walk down on the observation area and look at *how fast the river moves through this area.* You can understand how and why it got its name.
- *Cape Fear river current is very swift and strong.*

Thus, casual observers can discern that this segment of the LCFRE is highly river-influenced with strong flow. Bowen et al. (2009, p. 2-4) wrote, "[f]rom a hydrodynamic perspective,

[1] (NDENR) http://www.eenorthcarolina.org/images/River%20Basin%20Images/final_web_capefear.pdf.

[2] (http://www.tripadvisor.com/ShowUserReviews-g49673-d107702-r242913110-Cape_Fear_River-Wilmington_North_Carolina.html#REVIEWS

the Cape Fear has approximately a two-meter [~6-foot] tide range and strong tidal currents (> 0.5 meter per second) in the navigational channel of the open estuary and in the narrower tidal river channels of the three major tributaries (the mainstem freshwater river, and the Northeast Cape Fear and Black Rivers)." The LCFRE system is, in fact, documented in the science literature as strongly flowing down to its confluence with the Atlantic Ocean (e.g. Ensign et al. 2004, Lin et al. 2006, Becker et al. 2010). The strong flow minimizes stagnant areas and helps to add oxygen from the overlying air (Wetzel 2001).

It has been erroneously suggested in the NCDENR-DWQ Proposal and supporting materials that this strongly flowing, high-volume river is so strongly influenced by oxygen-demanding materials from natural drainage of freshwater wetlands and saltmarshes that the LCFRE is "swamp-like" with respect to DO conditions. Slowly flowing blackwater streams with instream wetlands in the Coastal Plain of the southeastern U.S. *can* receive high inputs of DO-demanding materials from the wetlands, and DO can range from 4-6 mg/L (Mallin 2000, Todd et al. 2009, and references therein). However, *such characteristics of slow flow and in-stream wetlands do not characterize most of the LCFRE system.* One area of the estuary north of Wilmington which receives major influx of swine wastes from CAFOs, near the junction of the Cape Fear, Black, and Northeast Cape Fear Rivers, has been described as prone to low DO levels during summer-early fall, but the low DO levels there have been related to *high anthropogenic pollution* along with inputs of natural organic materials (Mallin et al. 2003). Water quality in that area, as throughout the segment, would be greatly improved by reducing the high anthropogenic pollution coming into the segment from the many regulated pollutions sources in the Cape Fear watershed that were inappropriately excluded from consideration or lumped in with background sources in the NCDENR-DWR Proposal and supporting materials.

III. Sources of Water Quality Impairment

A. Historic Background, Assessments, and Erroneous Assertions

Historically, the LCFRE system was considered non-eutrophic because of its rapid flushing (Ensign et al. 2004). In the upper and middle Cape Fear River during 1955-1980, Crawford (1985) noted that DO concentrations at Lock 1 averaged 8.2-8.4 mg/L depending on the data source, and that on only two occasions from 1975 to 1980, DO samples were above 4 mg/L but less than 5 mg/L. Similarly, NCDENR (1999) described the upper portions of the estuary in the 1990s as rarely having sustained low DO levels that caused problems (assumed to refer to problems for aquatic life). The present-day LCFRE, however, is impaired due to major pollution from the upper, middle, and lower watershed (Cahoon et al. 1999, Mallin 2000, Mallin et al. 2003). As a result of declining water quality due to many pollution sources, for the past ~15 years the Cape Fear Estuary has been characterized as moderately eutrophic (= moderately nutrient-polluted; Bricker et al. 1999).

As described by NCDENR (2005),

> The [Cape Fear] watershed (about 9,149 square miles) is the most heavily industrialized in North Carolina with 244 permitted wastewater discharges and (as of 2000) over 1.83 million people residing in the basin....

> Approximately 24% of the land use in the watershed is devoted to agriculture and livestock production.

Historically, post-European settlement, the lower Cape Fear River and Estuary received mostly raw (untreated) or partially treated wastes from the Riegel Paper Corporation (in Wilmington; became Federal Paperboard Company, and then International Paper from 1996 to the present) and the various, relatively small human population centers that developed along it (State Stream Sanitation Committee 1957, CH2MHill 2014a - Technical Memo 1 in May 2014, used to support the request for reclassification of the LCFRE segment). CH2MHill (2014a) described the previous situation as "significant impacts from untreated and poorly treated wastewater under low to moderate flow conditions in the river" prior to improvements in waste treatment. In the mid-1950s on one date (August 30, 1955), low DO (1.3-2 mg/L) and low pH (5-6) were measured in the Northeast Cape Fear and Black Rivers, the two main tributaries to the Cape Fear Estuary other than the mainstem Cape Fear River as mentioned. On two dates (July 23-24, 1956) during moderate flows from these two tributaries and high flow from the mainstem Cape Fear River, DO and pH in the lower river were 2.8-4.9 mg/L and 6.8-7.2, respectively. The interpretation from this sparse information (three dates, ~60 years ago) was that "*under some situations*, swamp drainage conditions *could* significantly influence DO and pH conditions in the river. . .." (emphasis added) (State Stream Sanitation Committee 1957, CH2MHill 2014a).

From there, however, a major "leap" occurred in CH2MHill's (2014a) writing (p.D-15 in May 2014): Riparian wetlands -- that is, natural wetland drainage -- were described, without any other supporting data, as the "significant contributors to the tremendous loads of oxygen-demanding materials." CH2MHill (2014a, p.D-15) secondarily acknowledged that inputs of biochemical oxygen demand (BOD) have also been contributed by raw and partially treated sewage, and from swine wastes, although CH2MHill mistakenly stated that swine wastes only contribute pollution to the LCFRE when cess pits breach. As corrective information, swine wastes *routinely* contaminate the LCFRE (see Section IIIE of these Comments), and researchers have evaluated swine CAFO wastes as a major source of BOD in the LCFRE (e.g. Mallin et al. 1997, 2006; Mallin 2000). Yet, the remainder of CH2MHill's (2014a) writing implicated natural drainage from wetlands as the major contributor of oxygen-demanding materials to the LCFRE. In the 1950s, the Cape Fear basin had less industrialization and fewer point sources (including no CAFOs), but the present reality is far different. As explained above, the Cape Fear River basin is *now* described as the largest, most industrialized watershed in North Carolina (Mallin et al. 2003, NCDENR 2005).

TetraTech (2014 - Technical Memo 2 in May 2014, used to support the request for reclassification) considered BOD loads from three specific point sources, which they erroneously described as contributing about 90% of all point source loads to the LCFRE. In reality, these three point sources contribute only a small fraction of the total point source loads - see Section IIID-E of these Comments. Based on data from the previous 20 years, TetraTech reported a significant downward trend (~23% decrease over time) in oxygen-demanding pollutant loads from the three selected point sources, without a corresponding decrease in water-column DO. The lack of a corresponding decrease in average DO should have been expected, considering that TetraTech *did not* assess ~1,194 other regulated sources in the Cape Fear watershed that are contributing oxygen-demanding materials and other pollution to the LCFRE. Over the same 20-year period in the Cape Fear River basin,

the human population increased by ~0.66 million and swine production increased by ~5 million animals per year (compiled from U.S. Census Bureau data, Burkholder et al. 1997, and Cahoon et al. 1999). Yet, TetraTech (2014) implicated wetlands as the major contributor to oxygen-demanding materials in the the LCFRE. TetraTech stated that the information from its recent analysis supported its previous assessments of the LCFRE (TetraTech 2001, 2003), and erroneously maintained that its assessment supported reclassification of the LCFRE segment to a swamp.

CH2MHill (2014b - Technical Memo 4 in May 2014, used to support the request for reclassification) described an analysis of surface water quality conditions in summer (which was defined as April-October) at main inflows to the Cape Fear River Estuary including the Middle Cape Fear River, the Black River, and the Northeast Cape Fear River. Importantly, *the Northeast Cape Fear River and the Black River stations were* ***erroneously*** *described as characteristic of "water quality as water leaves areas currently classified as swamps."* These segments are classified as swamps, but their present water quality reflects massive pollution, not natural wetland inputs (see Section IIID, p.18 below). During the early to mid-1990s, the relatively small areas of the Northeast Cape Fear and Black River watersheds sustained an influx of more than 800 swine CAFOs with more than 3 million swine produced per year (NCDENR 2005; and *Figures 1 and 2*). They contribute roughly the same amount of wastes as 12 million people, and the wastes are poorly regulated (see Section IIID).

Bowen et al. (2009) tacitly included pollution from swine feeding operations in "tributary inputs" although they were not specifically mentioned. CH2MHill (2014b) and TetraTech (2014) not only failed to mention them (and in CH2MHill 2014a, there was only one, partly inaccurate mention of swine operations as described above), but also omitted them from consideration. All of the other point source contributions from the upper and middle watershed were not considered as well. The omission of CAFO wastes and most other point sources in the watershed from consideration in assessments of oxygen demand in the LCFRE is irrational rather than science-based. The extreme error of omission in those reports is compounded by an equally extreme error of co-mission - repeatedly attributing to natural wetland drainage the massive oxygen-demanding pollution known to be contributed by other sources including CAFOs (e.g. Dewi et al. 1994, Burkholder et al. 2007 and references therein; see Section IIID below). Similarly, NCDENR was described by May (2014, p.D-3) as having stated, erroneously, that "changes in the classification of the LCFRE might be appropriate to recognize the influence of natural drainage from riverine and saltwater marsh systems in the watershed on DO concentration."

There is no basis in fact - no data - supporting major attribution to natural freshwater wetlands and saltmarshes of what CH2MHill (2014a) described as "tremendous" loads of oxygen-demanding materials in the LCFRE, while "overlooking" the massive pollution from ~98% of the point and other regulated sources in the watershed.

B. Processes Influencing DO Conditions, and Available Information for the LCFRE

Several major processes influence water-column DO concentration in rivers (*Figure 3*). Oxygen demand from two general sources controls water-column DO: *external* (incoming)

materials from land-based sources, upstream waters and the overlying airshed, usually referred to as the BOD in the water column, and the "*internal*" oxygen demand from biota respiration and river bottom sediments, usually called the sediment oxygen demand (SOD).

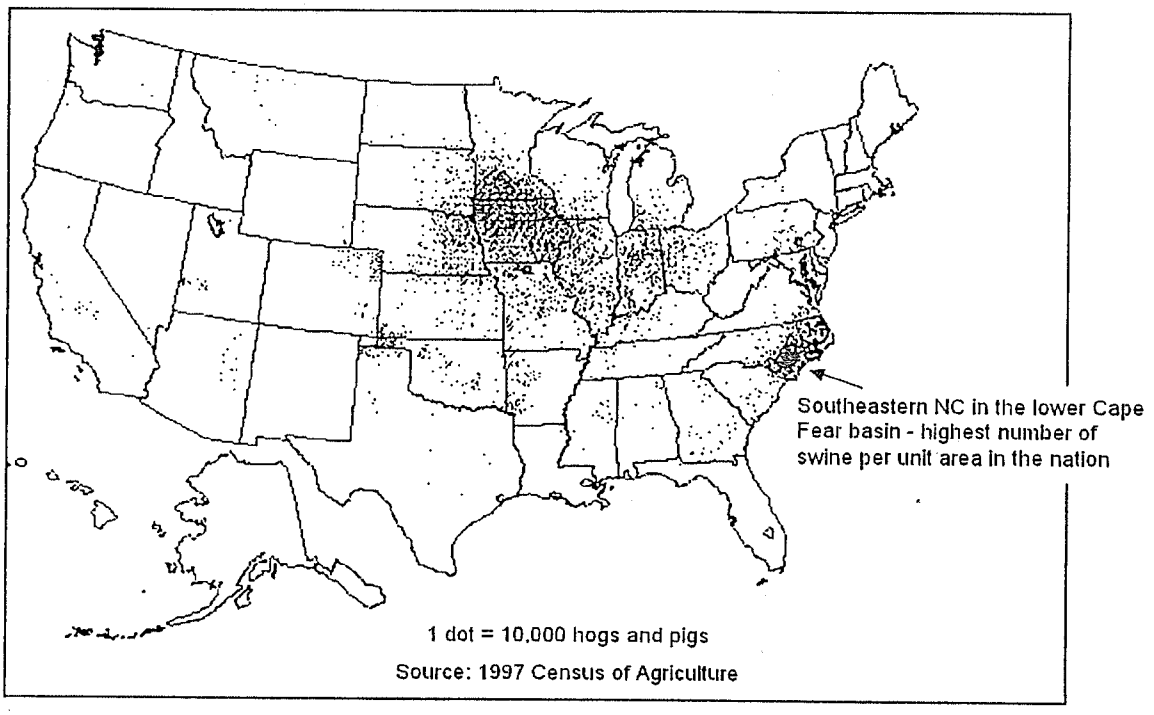

Figure 1. Map showing the number swine in southeastern North Carolina, with most CAFOs in the lower Cape Fear River basin area (source: http://scorecard.goodguide.com/env-releases/aw/nc-riverbasin.tcl?image_id=030300&huc6=030300). This map, produced by the USDA based on 1997, data, is supported by a more recent map, available at http://www.agcensus.usda.gov/Publications/2012/Online_Resources/Ag_Atlas_Maps/Economics/Market_Value_of_Agricultural_Products_Sold/12-M030.php, which shows the value of hogs and pigs sold in 2012 as the percent of the total market value. The highest concentration of swine per unit surface area across the nation is in the lower Cape Fear River basin.

BOD (units, milligrams per liter, mg/L) is the sum of carbonaceous and nitrogenous oxygen demands; it is a measure of the molecular oxygen used in the water column during a specific incubation period, usually 5 days, for the biochemical degradation of organic material (carbona-ceous demand) and the oxygen used to oxidize inorganic material (nitrogenous demand), as well as the amount of oxygen used to reduce forms of nitrogen (Eaton et al.1995, MacPherson 2003).

SOD (units, grams of molecular oxygen per square meter per day, g O_2 /m^2/day) is defined as the rate of DO removal from the water column due to the decomposition of organic matter in the bottom sediments (Hatcher 1986). It consists of biological sediment oxygen demand (usually at the sediment surface, dominated by bacteria that consume organic materials) and chemical sediment oxygen demand (usually ~2 inches down in the sediment, where anaerobic

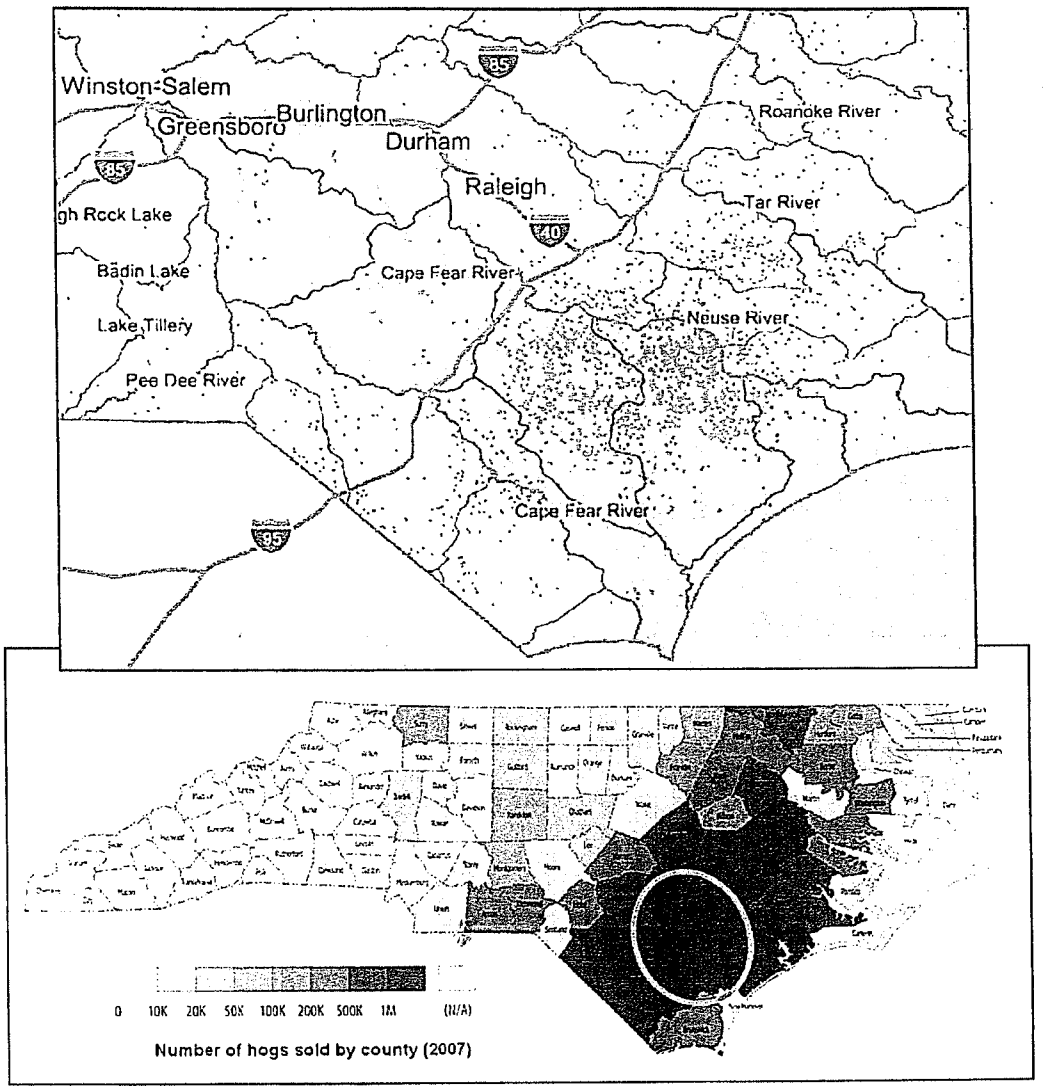

Figure 2. Upper panel - map showing the locations of swine CAFOs in North Carolina, indicating the preponderance of CAFOs in the lower Cape Fear River basin (source: http://scorecard.goodguide.com/env-releases/aw/nc-riverbasin.tcl?image_id=030300&huc6=030300, last accessed in February 2015). Lower panel: Map showing the numbers of hogs sold in North Carolina counties during 2007 (K ≡ thousands, M ≡ millions; U.S. Census data), modified from Learn NC, a program of the University of North Carolina School of Education (available at http://www.learnnc.org/lp/editions/nchist-recent/6257, last accessed in August 2014). The darker area "down east" on the Coastal Plain of the state has, as mentioned, the highest concentration of swine per unit area in the nation (National Hog Farmer 2014.).

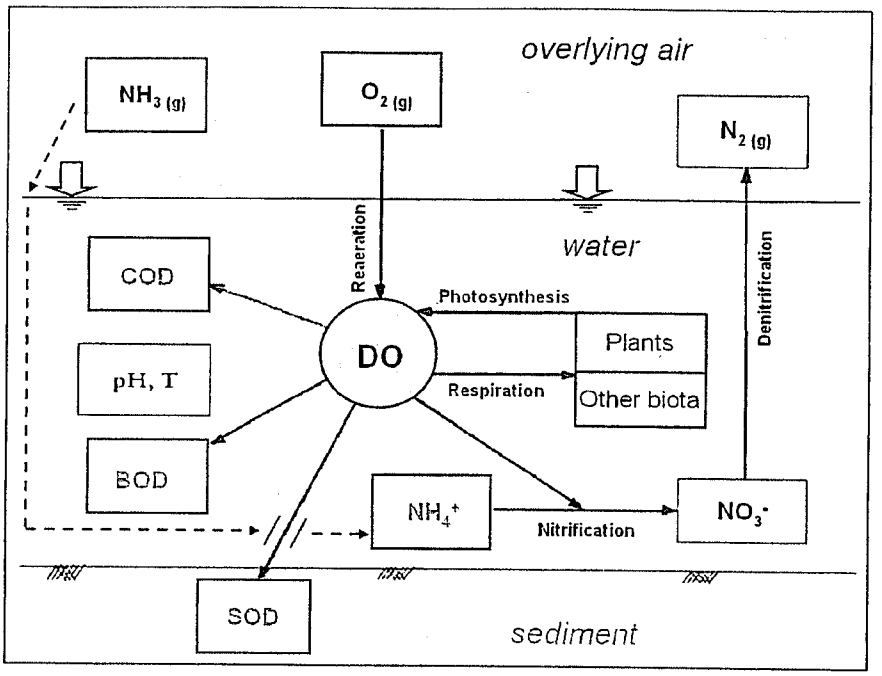

Figure 3. A schematic of the major processes influencing the water-column ("water") DO concentration in rivers: O_2 = the oxygen gas diffusing into the water from the atmosphere; N_2 - the nitrogen gas diffusing out of the water into the atmosphere; COD - the immediate chemical oxygen demand; T - temperature; NH_4^+ - ammonium; NO_3^- - nitrate. Arrows directed toward DO indicate DO sources; arrows directed away from DO indicate DO users (consumers or "sinks"). Parameters in red are oxygen-demanding. Other environmental conditions that can affect DO are represented by pH and temperature (T). The dashed-line arrow indicates that ammonia from the overlying airshed, largely contributed in southeastern North Carolina by swine CAFOs (Walker et al. 2000, Aneja et al. 2003), is mostly ionized to ammonium in neutral to alkaline waters and becomes a source of nitrogenous oxygen demand in forming nitrate. Modified from Cox (2003).

anaerobic bacteria degrade organic matter in a process that produces reduced ions that react with oxygen when they diffuse upward to an oxidized area (Walker and Snodgrass 1986).

The organic materials contributing to SOD can come from outside the system (such as leaf litter or settling of organic particles from human or animal wastes), or from within the system (such as decomposing algae). SOD is positively related to the amount of organic carbon content (i.e., bioavailable organic materials) in the sediment (MacPherson 2003 and references therein). Basically, the rate at which the sediment community consumes oxygen indicates whether the sediment area is degraded by too much organic matter (Massachusetts Water Resources Authority 2002). Once organic material reaches the bottom sediments of the river segment, SOD is influenced by two different processes: the rate at which oxygen diffuses into the sediments and is consumed there, and the rate at which reduced organic substances move into the water column and are then oxidized (Bowie et al. 1985, Todd et al. 2009).

Thus, SOD is the combination of the respiration of bottom-dwelling organisms in the sediment from decomposition of organic matter, and chemical oxidation of reduced substances in the sediment (Todd et al. 2009, and references therein). SOD can create oxygen deficits by reducing the amount of available oxygen in the overlying water (Seiki et al. 1994), and it can be a significant percentage of the total oxygen consumed in a given river or estuary (Caldwell and Doyle 1995). SOD rates serve as proxies for the effects of pollution on the biological activity of the bottom (benthic) community; for example, a nutrient-polluted system generally has an increased demand for oxygen (Natural Research Council 2000). Extreme levels of SOD (~20 $g/m^2/day$) can occur from oxygen consumption by animal wastes or sewage materials that settled out to the bottom (Davis 1950). Reduction in the amount of incoming organic materials from such pollution can lower the SOD as the system recovers (see Massachusetts Water Resources Authority 2002).

The sophisticated three-dimensional, Environmental Fluid Dynamics Code model used by Bowen et al. (2009) requires extensive information for the many factors needed to construct (parameterize) it for a specific river segment (Hamrick 1992; Bowen et al. 2009 - see p.v, Table 1, and Figure 2 in that document). Adequate measurements from the LCFRE for many of these factors were/are not available, and they vary considerably from river to river (Hamrick 1992, Todd et al. 2009, and references therein). The required missing or sparse (inadequate) information includes oxygen fluxes between the water column and the bottom sediment of the river. The information was instead "prescribed" (estimated, or taken from general literature not specific to the LCFRE) (Bowen et al. 2009, p.2-1). Bowen et al.'s (2009) model development revealed that, as in many if not most lower rivers along coastlands, SOD has an especially significant impact on DO concentrations. *SOD varies by as much as three orders of magnitude (1,000-fold) from river to river*, with rates ranging from ~0.1 to 18 grams of oxygen [demand] per square meter per day ($g/m^2/day$) (Rolley and Owens 1967, Chapra 1997, Todd et al. 2009). Importantly,

> The effect of SOD on the oxygen budget of an entire river system should not be underestimated, as it can be a critical sink of DO (Wu 1990). Indeed, in some rivers SOD can account for over half of the total oxygen demand and can play a primary role in the water quality....[Yet] this parameter is often assumed (or estimated) in water quality models (Hatcher 1986, Matlock et al. 2003). Errors in this measurement could lead to inaccurate models for the stream environment, at great biological and financial cost. - Todd et al. (2009)

Only sparse, dated SOD information was available for the LCFRE, taken more than a decade ago by the former NCDENR – DWQ (Division of Water Quality) at five locations on only five dates during summer/fall of one year, 2003 (Bowen et al. 2009, pp. 2-14, 2-15). At a given location, SOD is known to vary substantially by season and from year to year (Hatcher 1986, MacPherson 2003 and references therein). Lacking sufficient data and, thus, finding these sparse data to be a poor fit for the model overall, Bowen et al. (2009) "selected" SOD values until they found one that best fit their model for predicting water-column DO data, which had been constructed using available water-column DO measurements. In other words, Bowen et al. knew what the water-column DO had been because it had been measured during the period of focus, so they tried different SOD values until the model generally "fit" the water-column DO data. The SOD value (adjusted in an attempt to allow

for seasonal changes) was applied to most of the LCFRE; a second, nearly four-fold higher value for SOD was applied to the Northeast Cape Fear River which is heavily influenced by swine CAFOs (see p.18 below). Bowen et al.'s (2009) approach to estimate SOD technically requires that all rates except SOD have been accurately determined based on data for the specific system (Cox 2003). In reality, some of the data needed to accurately estimate the major rates of processes shown in *Figure 3* of these Comments (photosynthesis, respiration, nitrification, denitrification, reaeration) are lacking at representative points along the LCFRE system. Such data should include at least monthly measurements from April through October during dry, average-precipitation, and wet years (Hatcher 1986 and references therein).

C. The Model Predicted 90% Control of LCFRE DO Levels by the "Tributary Inputs," and Compliance with the DO Standard by Reducing Those Inputs

Despite the above-described weaknesses, Bowen et al.'s (2009) model *did* predict - as would be expected from knowledge of pollution sources in the LCFRE basin - that the 20 point sources they considered had only a small effect on the water-column DO concentrations. In contrast, "tributary inputs," loosely defined as excluding the 20 point sources, were evaluated as the major controlling influence on DO. Importantly, when Bowen et al. artificially forced SOD to remain constant over time despite imposing reductions of 30%, 50%, or 70% in BOD loads from the "tribuary inputs," the model predicted that the BOD decreases alone would increase median DO concentrations to well above the present DO standard of 5 mg/L. In addition, if BOD from tributary inputs and SOD were both reduced by 30%, the model predicted that summer DO violations would decrease from 45% to 22%, down to only 7% with a 50% reduction, and down to 1% with a 70% reduction. Such a scenario of decreasing BOD and SOD is realistic, as SOD is known to decrease over time with decreasing water-column BOD inputs, and related decreases in the bioavailabilty of organic matter that settles out to the sediments (Hatcher 1986, MacPherson 2003 and references therein).

Bowen et al. (2009) did not attempt to address the predominant sources in the "tributary inputs." They aptly noted (pp. vii-viii) that their model indicated the importance of benthic fluxes of oxygen. They also aptly recommended additional work to assess SOD and also, importantly, to separately consider the effects of wetland (natural) versus "riverine" (pollution carried by the river and tributaries) loadings to DO conditions in the estuary. The subsequent work in support of this proposal did not conduct these evaluations.

D. Point Source Pollution from NPDES-Permitted Facilities Upstream from the LCFRE

Given the above predictions from Bowen et al.'s (2009) model, control of "tributary inputs" *would* allow the LCFRE to attain the present DO standard. Therefore, a TMDL for the LCFRE segment is entirely appropriate. Moreover, as stated, the available scientific information indicates that human-related pollution - not natural wetland drainage - is the major source of oxygen-demanding materials to this segment (see pp. 18-19 below).

The U.S. EPA states that:[3]

[3] http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/overviewoftmdl.cfm#tmdlrequired

the objective of a TMDL is to determine the loading capacity of a given water body and to allocate that load among different pollutant sources so that the appropriate control actions can be taken and water quality standards achieved....**All contributing sources of the pollutants** (point and nonpoint sources) are identified, and they are allocated a portion of the allowable load...." (emphasis added).

Thus, a TMDL for the LCFRE should consider the entire watershed above that segment as potentially contributing to pollution in that segment. According to NC DENR[4], the upper-middle Cape Fear basin has 38 major point sources (discharging ≥ 1 mgd; *Figure 4*) and ~115 minor point sources (< 1 mgd) with NPDES permits. The lower Cape Fear basin contains 10 major point sources and 33 minor point sources with NPDES permits. Thus, the river sustains loading from 195 NPDES-permitted point sources including nearly 50 major NPDES-permitted point sources and nearly 150 minor NPDES-permitted point sources. Consider the following example of a major point source that was not among the 20 specifically assessed by Bowen et al. (2009):

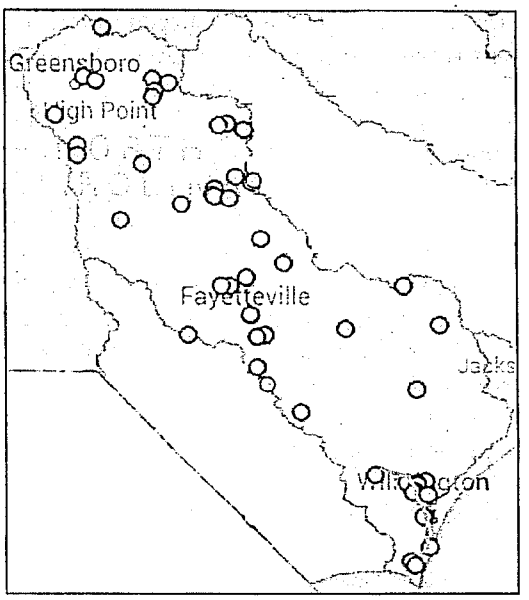

Figure 4. Map showing the locations of major point sources with NPDES permits from NC DENR in the Cape Fear River basin (red dot, Smithfield Packing Company; red line - approximate location of the LCFRE segment proposed for reclassification). Modified from NC DENR (see websites given in footnote 4).

The Smithfield Packing Company at Tar Heel in the mid-Cape Fear River basin, ~60 miles upstream from the LCFRE (location indicated by the red dot in *Figure 4*), is permitted to discharge up to 3 mgd of effluent containing up to 250 pounds of BOD_5 per day during April - October as a monthly average, and up to 500 pounds of BOD_5 as a daily maximum (NC DENR permit #NC0078344). During November-March, the plant is permitted to discharge double those amounts (i.e., 500 pounds per day, monthly average; 1,000 pounds per day, daily maximum, equivalent to 45 mg of biochemical oxygen-demanding materials/L). Rivers are considered to be stressed with too much BOD_5 if concentrations exceed 3 mg/L (Mallin et al. 2006). The plant is also permitted to discharge 30 pounds of ammonia-N/day as a monthly average during April-October, and 60 pounds of ammonia-N per day (7.5 mg/L) as a daily maximum. In November-March, these numbers, as pounds per day, can double. As explained, ammonia is oxygen-demanding, highly toxic to sensitive aquatic life, and a form of inorganic nitrogen that, at concentrations of only 0.1-0.2 mg/L, can stimulate noxious and toxic algal outbreaks (Bricker et al. 1999 and references therein, Mallin 2000). Other inorganic nitrogen forms, nitrate+nitrite, in discharges from the plant can be up to ~120 mg/L as a monthly average, and up to ~185 mg/L as a daily maximum. As stated,

[4] 2014 - http://portal.ncdenr.org/web/wq/npdes-major-facility-map, and http://portal.ncdenr.org/web/wq/npdes-minor-facility-map.

only 0.1-0.2 mg/L of inorganic nitrogen is needed to stimulate noxious and toxic algal outbreaks. Thus, extremely high oxygen-demanding materials and inorganic nitrogen nutrient forms are permitted for discharge by this major point source.

Overall, nearly 150 NPDES-permitted point sources in the Cape Fear River watershed are upstream from or adjacent to the LCFRE. Some pollutants from these point sources, such as the highly soluble nitrogen species, nitrate, are highly soluble; nitrate, for example, is known to travel distances of hundreds of miles downstream from upper to lower watersheds in North Carolina and elsewhere (Mallin et al. 1993, Houser and Richardson 2010, Houser et al. 2010). That is why, for example, various pollutants from the upper Mississippi River drainage are known to contribute to the "dead zone" of little or no oxygen all the way down in southern Louisiana, near the river's confluence with the Gulf of Mexico (Goolsby and Battaglin 2001, Jacobson et al. 2011). Nutrient pollution contributes to oxygen-demanding materials by stimulating algal blooms that die and are then decomposed by bacteria which use oxygen for that process (Burkholder and Glibert 2013, and references therein). Based on the fact that nitrate, much less soluble pollutants such as phosphorus, and oxygen-demanding organic carbon materials can travel much longer distances than 60 miles (above references, Minshall et al. 1983, Meyer and Edwards 1990), the excessive nitrate in the Smithfield Packing Company discharge should be expected to contribute to oxygen-demanding materials in the LCFRE ecosystem. The same is true of other upstream point sources, other regulated sources and nonpoint sources.

E. Point Source Pollution from Animal Production in the Lower Cape Fear Basin

In addition to the ~150 NPDES-permitted point sources that should be considered by NCDENR in developing a TMDL to improve DO in the LCFRE, there are nearly 1,000 swine CAFO point sources in the lower Cape Fear basin (and an unknown number of poultry CAFOs, based on Mallin 2014). The available scientific information shows that swine CAFO point sources are the major source of water quality impairment in the lower Cape Fear basin.

Major degradation of the natural resources in the lower Cape Fear basin due to swine CAFO point sources -- encompassing degradation to the airshed, soils, groundwaters, and surface waters -- has been well-documented and is briefly summarized below. It merits mention that, throughout these Comments, the focus when considering CAFOs is on swine production because relatively little information about poultry production is available to scientists or other members of the general public (e.g. see Rothenberger et al. 2009a). North Carolina is second in poultry production among the states, but nearly all of the operations have fewer animals than are defined by the state legislature as a poultry CAFO, and most information is allowed to the general public only for poultry CAFOs. Thus, most information given below for industrialized animal production in the Cape Fear basin is substantially underestimated because it focuses only on swine.

The available information *does* show that poultry production is a major source of pollution in the Cape Fear watershed (Cahoon et al. 1999). According to the North Carolina Department of Agriculture (http://www.ncagr.gov/stats/coest/Index.htm), in 2012 the lower Cape Fear basin (Brunswick, Pender, Duplin, Sampson, and Cumberland Counties, and estimates for parts of Bladen and Onslow Counties) contained about 5 million swine,

21.5 million poultry, 123 million chickens, and 72,000 cattle. The facilities which produce these animals are *not* required to have streamside buffers, or to control of ammonia or hydrogen sulfide emissions etc. They *are* required to have what can only be described as grossly inadequate waste management because it clearly does not prevent major impacts to public trust natural resources (below). Cahoon et al. (1999) provided the following estimates for the Cape Fear River basin (recall that most swine production occurs in the lower basin):

- Swine: more than 7 million tons of fresh manure per year added to the lower basin;
- Poultry: 2.18 million tons of fresh manure per year;
- Cattle: 2.08 million tons of fresh manure per year;
- Total from this animal production: 82,700 tons of nitrogen (N) and 25,950 tons of phosphorus (P) (Cahoon et al. 1999), the two nutrients that are known to cause major noxious algal outbreaks (Burkholder and Glibert 2013).

Cahoon et al. (1999) concluded that:

> The eutrophication threat to these river basins [which included the Cape Fear River basin]... with expanding animal populations from the potential large nutrient loadings associated with intensive livestock operations is substantial.

Many contaminants are present in swine CAFO wastes and runoff, including extremely high levels of nutrients N and P, more than 100 microbes known to cause human disease, pharmaceutical chemicals that harm beneficial aquatic life, toxic heavy metals (especially copper and zinc), and pesticides such as toxic dithiocarbamates from sprayfield applications (Barker and Zublena 1995; Burkholder et al. 1997, 2007 and references therein, Iowa State University and The University of Iowa Study Group 2002, Extension Toxicology Network 2003). These contaminants can enter the surrounding environment through pathways such as leakage from poorly constructed cesspits, or during major precipitation events that cause cess pit overflow and runoff from recent sprayfield application, or atmospheric deposition followed by wet or dry fallout (Burkholder et al. 2007 and references therein). The magnitude and direction of transport depends on factors such as soil properties, contaminant properties, hydraulic loading characteristics, and crop management practices. Over-application of swine wastes to sprayfields can result in contaminants leaching through permeable soils into vulnerable aquifers (see Section IIIE - Groundwater Degradation from Swine CAFO Point Sources, below).

Contamination of surrounding public-trust surface waters such as the LCFRE in southeastern North Carolina is a common, routine problem *at recommended application rates* as well (e.g. Barker and Zublena 1995; Westerman et al. 1995; Zublena et al. 1995; Stone et al. 1995, 1998; Walker et al. 2000; Aneja et al. 2001, 2003). Improper disposal of animal carcasses and abandoned swine CAFO facilities also contribute to water quality problems. Siting of CAFOs in areas prone to flooding or where there is a shallow water table, such as in the lower Cape Fear basin, increases the potential for contamination of public trust natural resources as well.

Swine CAFO point sources in the lower Cape Fear basin - Swine CAFOs in southeastern North Carolina mostly were installed from the late 1980s through 1995. These CAFOs store

animal wastes in large cess pits (which the industry calls "lagoons") (*Figure 5*). After the solids mostly settle out, the liquid wastes are applied to relatively small sprayfields. The soils in the area are mainly sandy and shallow; the water table is only about three feet from the land surface (Burkholder et al. 1997 and references therein). The shallow, sandy soils simply cannot absorb the massive amounts of waste applied to them by the CAFOs, time after time per season, year after year (see example in *Figure 4*). Waste that is applied to the fields mostly percolates into the shallow groundwater and then moves to receiving streams and rivers (e.g. Evans et al. 1984). Most cess pits for these swine CAFOs were installed in North Carolina prior to 1993, when linings of clay or other materials were not required (Burkholder 1997 and references therein).

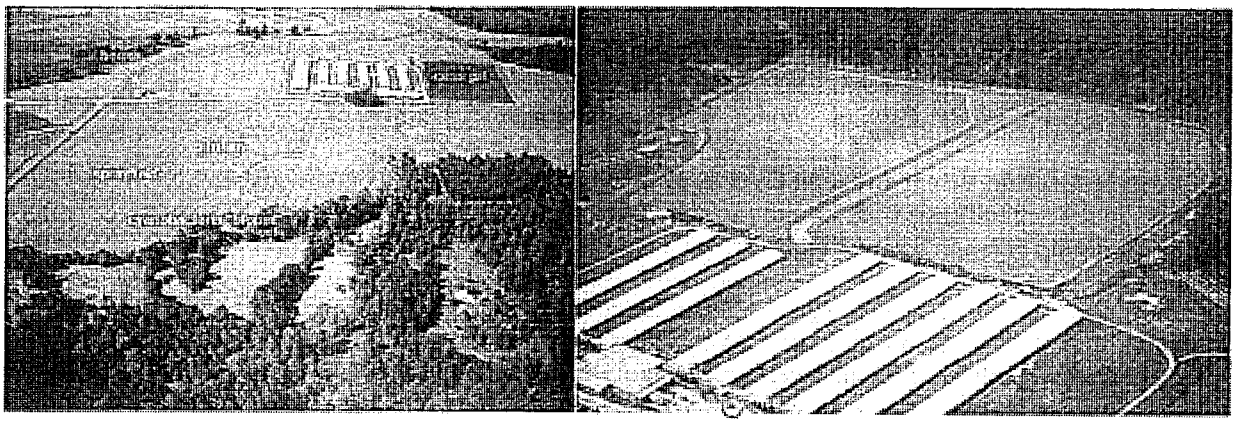

Figure 5. Left: A swine CAFO in the lower Cape Fear River basin, showing (from top to bottom) a house (noted for scale), the buildings that contain about 5,000 animals, the adjacent cess pit, the sprayfield, a stream that has been transformed to a gully conveying wastes from the field into a wetland, and a dense bloom of cyanobacteria (blue-green algae), potentially toxic to humans, that was fueled by the high nutrients in the CAFO wastes (see Burkholder et al. 1997, 2007 for supporting information). Thus, clearly the wastes were moving off-site to contaminate adjacent natural resources. This relatively small field with a shallow layer of soil above the water table, and the cess pit, are "supposed to" adequately treat the liquid wastes, year after year, from 5,000 swine per year, equivalent to the amount of wastes produced by 20,000 people (1 swine produces the equivalent amount of wastes, roughly, of 4 people; see below). Photo: M. Mallin. Right: Two swine CAFO cess pits (the car is circled for scale). The pinkish color is due to anaerobic sulfur bacteria and is suggestive of very high levels of hydrogen sulfide gas, which is toxic to humans (Burkholder et al. 1997, and references therein). Photo: R. Dove, Waterkeeper Alliance.

The general situation was described as follows:

> [CAFO] technology, originally designed for application in upland areas with adequate soil depth above the water table, was embraced in counties where 60-80% of the area put into production was originally low-lying wetlands adjacent to rivers and estuaries. The operations were exempt from land zoning laws and mandatory inspection programs. Waste lagoons were not required to have leakage-reducing liners; some were constructed below the water table less than 20 m [50 feet] from neighboring homes and wells . . . The NC Division of Water

> Quality, charged with water resources management, lacked the personnel and resources necessary to adequately monitor surface or groundwater quality. More fundamentally, the North Carolina Department of Agriculture legally refused to provide the Division of Water Quality with basic data such as the location and number of existing and planned animal operations . . . After considerable effort the North Carolina Environmental Management Commission . . . passed rules in 1993 for design of animal waste lagoons and effluent treatment. These rules mandated use of clay or other suitable liners in future construction of lagoons associated with [CAFOs with] 250 or more swine. They included a grandfather clause to exempt existing operations from having to alter their lagoon design . . ..(Burkholder et al. (1997; references included therein).

The information presented below for airshed, soil and groundwater contamination is included because pollution of those natural resources by swine CAFOs can substantially contribute to surface water contamination, which is the main subject of these Comments regarding the state's classification of the LCFRE segment.

Airshed degradation from swine CAFO point sources

Swine CAFOs emit copious air pollutants known to adversely impact human health and, indirectly, surface waters. For example, ammonia and hydrogen sulfide are emitted at levels toxic to humans (U.S. EPA 1998; also Aneja et al. 2001, Liu et al. 2014). Within a 60-mile radius from where it is emitted, the volatilized ammonia tends to return to the land and surface waters with rain (Aneja et al. 2003), where it can adversely affect river ecosystems (below; e.g. Rothenberger et al. 2009b).

Swine CAFO production in the lower Cape Fear basin has caused a significant increase in air pollutants such as ammonia (Aneja et al. 2003, Wing et al. 2012 and references therein). Surface waters and groundwater are also being adversely impacted; Burkholder et al. (2006) documented a significant increase in ammonia concentrations within the lower Cape Fear River where swine CAFOs are highly concentrated. Cahoon et al. (1999) wrote,

> Aerial deposition of nitrogen, principally ammonia-nitrogen, is recognized as a contributing threat to coastal water quality . . . Some studies estimate that up to 90% of the manure nitrogen produced by swine volatilizes and is deposited downwind [to the land and surface waters] (NC DENR Division of Air Quality 1997).

Sampson County (946 square miles), in the Cape Fear River basin, had 1.8 million swine as of 1998. The National Atmospheric Deposition Program has monitored atmospheric ammonia there since 1978. Mallin (2000) noted that during the 1988-1998 decade, there was a concurrent rise in atmospheric ammonia and the swine population; and that from linear regression analysis, 72% of the variability in airborne ammonia could be explained by changes in the county swine population alone. Upwind in the North Carolina Piedmont, counties with low swine populations showed no ammonia increase during the same period.

Soil degradation from swine CAFO point sources

Swine feed contains metals such as copper act as micronutrients in low concentrations, but

as toxic substances at higher levels. The metals persist in the extremely high amounts of swine wastes (Cahoon et al. 1999; see p.10 of these Comments), which are then applied to fields. Sensitive crops often cannot withdraw the metal in the soil, and leave it behind to accumulate. Research done in eastern North Carolina has explained how waste application contributes to metals pollution in field and, importantly, also has shown that as long ago as the mid-1990s, several counties in the lower Cape Fear River basin could no longer be used to grow metal-sensitive crops and would not need to fertilize with nitrogen or phosphorus for decades (Barker and Zublena 1995, Zublena et al. 1995). Runoff from the contaminated soil during/following precipitation events adds some of these toxic pollutants to adjacent surface waters.

Groundwater degradation from swine CAFO point sources

Areas around the cess pits of swine CAFOs in eastern North Carolina have been shown to receive leakage high in contaminant levels. Wells and subsurface seepage near the cess pits can be contaminated with extremely high levels of nitrate and ammonia (e.g. Huffman and Westerman 1995, Westerman et al. 1995, Ham and DeSutter 2000). The high nitrate levels are a result of the high ammonia levels because the ammonia is oxidized to nitrate as it moves away from the waste sources (see Burkholder et al. 1997, 2007, and references therein). High concentrations of nitrate are hazardous to human health, especially for babies and small children (who can be afflicted with methemoglobinemia or 'blue-baby syndrome'), because nitrate competes with oxygen for hemoglobin in the human bloodstream (Smith 2009, Knobeloch et al. 2010).

Many North Carolinians in the Coastal Plain area rely upon groundwater as their drinking water source (North Carolina Groundwater Association, http://www.ncgwa.org). North Carolina's drinking water standard for nitrate is less than 10 milligrams per liter (mg/L).[5] The available data suggest that many unlined swine effluent cess pits in eastern North Carolina cause nitrate pollution to nearby wells at levels that violate the 10 mg/L drinking water standard (e.g. Huffman 2004, Huffman and Westerman 1995, Westerman et al. 1995). Working in Sampson County within the Cape Fear River basin, Westerman et al.'s (1995, p.1749) study illustrates high contamination from unlined cess pit leakage:

> Two swine manure, anaerobic lagoons located in sandy, coastal plain soil were investigated. Both continued to have significant seepage after 3.5 to 5 years of receiving waste. Monitoring wells indicated *broad seepage plumes* [emphasis added], and much variation in concentrations of several parameters with well location, time, and depth of well . . . In some cases, ammonia and chloride concentrations in well samples were as high or higher than the lagoon liquid.

The last sentence of the above quote is especially of concern - that nearby monitoring wells had ammonia concentrations even higher than the lagoon liquid swine waste. Such

[5] (NC DENR Classifications and Water Quality Standards Applicable to Surface Waters of North Carolina, NC Admin. Code Section 15A NCAC 2B .0200, Environmental Management Commission, Raleigh, NC; http://portal.ncdenr.org/c/document_library/get_file?uuid=ad77b198-aa3d-4874-9723-54ce730b3a8d&groupId=38364).

information points to a major threat to shallow drinking water wells located only short distances, as little as 50 feet, from a swine lagoon cess pit.

Based on the available science literature, substantial groundwater contamination also is contributed by lined cess pits if not properly operated, as described by Westerman et al. (1985, p.1750):

> Ritter and Chirnside (1987) . . . reported high concentrations of NH_3-N and NO_3-N in groundwater monitoring wells near a clay-lined anaerobic lagoon for a hog-finishing unit. Some of the high NH_3-N concentrations were possibly due to lagoon overflow, which occurred several times. They suggested that the lagoon management of completely emptying the lagoon twice a year led to drying and cracking of the clay liner, resulting in seepage. They concluded that if clay-lined lagoons are not operated properly, they will have a serious impact on groundwater quality in loamy sand or sandy loam soils.

Ritter and Chirnside (1990) also reported extreme *average* ammonia-N concentrations, up to 1,000 mg/L, and extreme average nitrate-N up to 50 mg/L, in some wells near a clay-lined swine waste cess pit on the Delmarva Peninsula.

Swine CAFOs (both the land application practices and cess pit leakage) additionally pose a significant threat to well water via contamination by other harmful substances and pathogenic microbes (e.g. Stone et al. 1998, Krapac et al. 2002). Moreover, much lower concentrations of nitrate and ammonia can cause disease and death of beneficial aquatic life in receiving surface waters (see below). During summer low flow conditions on the North Carolina Coastal Plain, at least half of stream and river flow can be contributed by groundwater (Garrett et al. 2012 and references therein). Thus, groundwater contamination by swine CAFOs can contribute significantly to surface water contamination. Cahoon et al. (1999, p.414) wrote,

> An important water quality problem in North Carolina deriving from animal waste inputs is nitrogen loading to surface and groundwaters. Nitrogen frequently limits phytoplankton production in North Carolina's coastal waters, so increased nitrogen loads have stimulated noxious and toxic algal blooms and helped cause fish kills.

Surface water degradation from swine CAFOs

The wastes applied to sprayfields, emitted to the overlying airshed during the spraying activity, or leached into groundwater can make their way into surface waters as explained above. In addition, when the sprayfield soils are saturated with contaminants or with water during moderate to high precipitation periods, or due to over-application, the additional applied wastes rapidly move overland, through tile drains, and through the many ditches in the area to nearby surface waters. Thus, working in eastern North Carolina, Westerman et al. (1985) found high levels of nitrate (3-6 mg/L) in surface runoff from swine CAFO sprayfields that received swine waste effluent ***at recommended rates*** - that is, as a result of routine, accepted practices. For comparison, ~0.1 mg/L of nitrate (and ~0.08

mg/L of phosphorus - below) can cause noxious algal blooms (Mallin 2000, Wetzel 2001, and references therein). Working in Duplin County within the Cape Fear River basin, Stone et al. (1995) measured 6-8 mg of total inorganic nitrogen/L (= nitrate + nitrite + ammonia or ammonium) and 0.7-1.3 mg of phosphorus/L, another important nutrient that can fuel noxious and toxic algal outbreaks (Burkholder 2009), in a stream adjacent to swine effluent sprayfields:

> Mean nitrate-N concentrations of water leaving the [two] watershed outlet[s] were two- and four-times higher than background concentrations . . . Daily mean nitrate-N concentrations [at a tributary adjacent to a swine CAFO] sometimes exceeded 10 mg/L and frequently exceeded 6 mg/L. Over-applied swine lagoon effluent and undersized, overloaded lagoons were likely contributors . . . Mean ammonium-N concentrations . . . were approximately two- and four-times higher than background concentrations. Ammonium-N concentrations [at one watershed outlet] exceeded limits considered harmful to humans (0.5 mg/L) and fish (2.5 mg/L) (U.S. EPA 1973). During the first month of the sampling period, daily ammonium-N concentrations ranged from 6 to 12 mg/L . . . These high concentrations indicated that a significant discharge of animal waste products into the waterway had occurred . . . while storm flows are contributing to the total flux of nitrate-N, the majority of the nitrate-N flux is coming directly from the base flow [in other words, the high contamination occurred with and without precipitation/runoff]. - Stone et al. (1995)

Evans et al. (1984) reported 7-30 mg nitrate/L in subsurface flow draining a sprayfield for swine wastes that were applied at recommended rates:

> The potential for nutrient transport was much greater for subsurface drainage [than for surface drainage] . . . Nitrogen application at the recommended rate resulted in phosphorus application at nearly three times the recommended rate. Although this soil fixes [adsorbs] phosphorus, there was evidence of phosphorus movement in subsurface runoff by the fifth year of waste application at a higher rate. Continued phosphorus application even at the low [recommended] rate would eventually result in movement of P in subsurface runoff as the soil's assimilatory capacity for phosphorus would eventually be exceeded. - Evans et al. (1984)

These reports all describe *excessive* levels of inorganic nitrogen and phosphorus in comparison to what is needed to fuel a noxious or harmful algal outbreak. Evans et al. (1984) highlighted another problem -- that recommended rates of nitrogen application resulted in major excesses of phosphorus that, within a relatively short time, would saturate the soil and contaminate receiving adjacent surface- and ground-waters.

As mentioned, the extremely high nitrate in surface waters and groundwater near swine CAFOs comes from the high ammonia in swine wastes that combines with oxygen. Much lower nitrate levels (0.25-0.28 mg/L) than found in the above-described studies can cause disease and death of beneficial aquatic life (Camargo et al. 2005, Camargo and Alonso 2006). Nitrate can interfere with steroid hormone synthesis, adversely affect sperm

motility and viability, depress fecundity, and can be toxic to embryos (Edwards et al. 2004). It can also decrease immune response, act as an endocrine disruptor, and induce harmful hematological and biochemical changes in beneficial aquatic life (Guillette and Edwards 2005).

Although much of the ammonia which contaminates surface waters from swine CAFOs is oxidized to nitrate, before that occurs the ammonia can cause high toxicity to beneficial aquatic life, or can stimulate noxious algal outbreaks. Ammonia is a preferred form of nitrogen for many algal species including various harmful algae that can cause serious human illness (compiled from Bollos and Berge, Twomy et al. 2005, Herndon and Cochlan 2006, Burkholder 2009). Burkholder et al. (1997) reported ammonia concentrations as high as ~40 mg/L in a stream contaminated by a swine cess pit rupture. Such concentrations can be highly toxic to aquatic life (Camargo et al. 2005, Camargo and Alonso 2006), and would also be expected to stimulate noxious/harmful algal growth as the concentration became more dilute downstream (as was observed by Burkholder et al. 1997 and Mallin et al. 1997).

Swine CAFOs can cause other major surface water impacts from suspended solids loads and turbidity. The water near swine CAFOs is often dark and murky, and inhibits beneficial plant growth (Burkholder et al. 1997, Mallin 2000, and references therein). Swine wastes are acidic (pH ~6.5 - Zu et al. 2001 and references therein) and can impart acidity to receiving surface waters, although the lower mainstem Cape Fear River is well buffered due to the ocean's influence. Toxic levels of metals such as copper occur in runoff from swine effluent sprayfields because copper and other "trace elements" are added to swine feed to promote growth and control disease (Payne et al. 1988). These toxic substances can accumulate in sediments, water, and biota, to levels that are toxic to plants and lead to reproductive impairment, poor body condition, and immune system suppression in beneficial animals (Stubbs and Cathey 1999). Copper from swine and other livestock operations can be added to surface waters via overland discharge and groundwater leachate (U.S. EPA 2013).

Many impacts on surface waters from swine CAFOs are only beginning to be examined. Surface waters in Duplin County, also within the Cape Fear River basin, were recently assessed for fecal indicator bacteria (fecal coliforms, *Escherichia coli*, and *Enterococcus*) and candidate swine-specific microbial source-tracking bacteria over an annual period, both upstream and downstream from swine CAFO sprayfields. The authors noted, importantly, that the proximal "upstream" locations were potentially influenced by numerous upstream swine CAFO sprayfields, and also by poultry CAFO dry litter land application sites. The highest fecal indicator bacteria concentrations were found immediately downstream from swine CAFO sprayfields in spring and summer. The findings were summarized as follows:

> Testing of 187 samples showed high fecal indicator bacteria concentrations at both up- and downstream sites . . . Overall, 40%, 23%, and 61% of samples exceeded state [criteria] and federal recreational water quality guidelines for fecal coliforms, E. coli, and Enterococcus, respectively. Two swine indicator bacteria were 2.30 to 2.47 times as prevalent proximal down- than proximal upstream of swine CAFOs . . . *Results suggest diffuse and overall poor sanitary*

quality of surface waters where swine CAFO density is high [emphasis added].
- Heaney et al. (2015)

The water column of receiving rivers is not the only area affected by CAFO contamination. Burkholder et al. (1997) tracked surface water impacts from a swine cess pit rupture upstream from the New River Estuary near of the Cape Fear River basin. Fecal coliform bacteria densities were in the millions of colony-forming units [CFU] per 100 mL, whereas the state standard for safe human contact of the water is 200 CFU/100 mL. The state does not monitor contamination of bottom sediments by CAFO wastes. After 14 days, water-column fecal coliforms along the surface of the bottom sediments mostly yielded 10,000 CFU/100 mL, one to two orders of magnitude higher than elsewhere in the system. Even after 60 days, fecal bacterial densities in the surficial sediments of the affected area were at 1,000-10,000 CFU/100 mL. The data showed that bottom sediments contaminated by CAFO wastes can function as a repository source of fecal coliform bacteria and, likely, for co-occurring harmful microbes, for weeks to more than a month after a waste spill. The organic materials from the wastes that settled out would have been expected to greatly increase the SOD as well.

Surface waters presently classified as C (Sw) waters in areas draining swine and poultry CAFOs in the lower Cape Fear basin are extremely degraded

There is presently ongoing, persistent, extreme degradation of surface waters in the lower Cape Fear basin due to allowed practices of swine and poultry production. A recent description of a Class C (Sw) stream illustrates this reality:

Stocking Head Creek (8-digit Hydrologic Unit Code 003030007), a second-order tributary of the Northeast Cape Fear River, is presently classified by DWR as Class C (Sw) waters. This small stream (length 13.7 miles) drains 7.6 square miles of area containing 40 swine CAFOs and an estimated 11 poultry CAFOs, with total capacity for more than 94,000 swine and more than 1.3 million broiler chickens; it also includes some unconfined cattle (Mallin et al. 2014). Seven sites along the stream were sampled on 5 dates each in a 30-day period in summer and in fall of 2013. The data indicate a situation of persistent, extreme water quality degradation regardless of weather conditions; the excessive pollutant levels were similar whether the stream was sampled in dry or wet (rainy) periods.

The water quality conditions documented in Stocking Head Creek consistently were hazardous to human health at most stations. Geometric means for fecal coliform bacteria were in the thousands (as colony-forming units per 100 milliliters, CFU/100 mL) at 5 of the 7 sites. The state standard for safe human contact is less than 200 CFU of fecal coliform bacteria/100 mL (geometric mean, based on at least 5 consecutive samples during any 30-day period); and surface waters are supposed to have fewer than 400 CFU of fecal coliform baceria/100 mL in at least 80% of samples examined during the 30-day period. At 5 of the 7 sites on Stocking Head Creek, fecal coliform bacteria exceeded 400 CFU/100 mL on all, or nearly all, sampling dates.

Nutrient levels also demonstrated extreme water quality degradation. Some samples had more than 10 mg of nitrate/L. By comparison, the U.S. EPA (2000) recommends that nitrate should be 0.04 mg/L or less in streams within level III nutrient sub-ecoregion #63,

which includes southeastern North Carolina. The maximum ammonium concentration was 38 mg/L near swine waste sprayfields. BOD (5-day) exceeded 10 mg/L in 11 of 70 stream samples, with a maximum at 88 mg/L. Average total phosphorus (TP) per site ranged from 0.15 to 2.83 mg/L. By comparison, the U.S. EPA (2000) recommends that stream TP concentrations should be less than 0.052 mg/L for streams in this area.

Based on more than 30 years of experience as a water quality specialist, I assess these conditions, ongoing and persistent in this representative stream in the Northeast Cape Fear River basin upstream from the LCFRE segment, as comparable to the filthy conditions that occur just downstream from raw sewage discharge.

Swine CAFO wastes versus the 20 point source wastes and wetlands in the lower Cape Fear basin

Swine wastes are very rich in organic, oxygen-demanding materials in comparison to human wastes. Treated and raw domestic sewage contains ~20-60 mg BOD/L and ~300-400 mg BOD/L, respectively; swine waste slurries contain ~20,000-30,000 mg BOD/L (Webb and Archer 1994; also see Spellman and Whiting 2007). Surface waters contaminated with these wastes rapidly become oxygen-depleted, causing fish to suffocate to death (Burkholder et al. 1997, U.S. EPA 1998, Mallin 2000).

The contribution of oxygen-demanding materials from nearly 1,000 swine CAFO sources, mostly in the lower Cape Fear basin, clearly overwhelms the contribution from the 20 point sources considered by DWR. As stated, about 5 million swine are produced annually in the lower Cape Fear basin in CAFOs (Cahoon et al. 1999). It has been estimated that each animal contributes roughly the equivalent amount of waste -- much richer in oxygen-demanding materials -- of four people (derived from U.S. EPA 2004; see *Table 1* below). The population of the City of Wilmington as of 2014 was ~112,000 people. Overall in the lower Cape Fear basin, the 5 million swine produced per year in CAFOs produce ~179 times more wastes than the largest human population center, Wilmington. Moreover, pound for pound the swine wastes, conservatively estimated, contain about 10 times more oxygen-demanding materials than treated human wastes. Thus, in the lower Cape Fear basin, swine CAFO point sources are estimated to produce three orders of magnitude (~1,790 times) more oxygen-demanding materials than treated human wastes.

These Comments have several times referred to the Northeast Cape Fear River and Black River as having sustained major impacts from swine CAFOs. According to NCDENR (2005), the small sub-watersheds drained by the Northeast Cape Fear River and the Black River, alone, have 896 CAFOS that contain ~3,764,121 animals, roughly the same amount of sewage as more than 15 million people. Stocking Head Creek illustrates the surface water quality of streams draining such areas.

Based on the available information, *the massive contribution of organic-rich, oxygen-demanding materials from swine CAFOs also overwhelms the potential contribution from natural wetlands in the LCFRE.* The sparse available SOD data for the LCFRE (give in Bowen et al. 2009, p.3-20) ranged from 0.1900 to 0.6951 grams of oxygen demand per square meter per day ($g/m^2/day$). The highest values measured were near swine CAFOs, 0.5189 to

Table 1. Manure production per 1,000 pounds (lb) live weight on an annual basis. According to this information from the U.S. EPA (2004, Table 3.3), one 250-lb pig produces 7,250 lb of manure per year (19.86 lb/day), whereas one 150-lb human produces 183 lb of manure/yr (0.5 lb/day). A swine CAFO with 1,000 animals thus would produce about the same amount of waste as a city of 39,617 people. As the U.S. EPA (2004) wrote,

> The important difference lies in the fact that human waste is treated before discharge into the environment, but animal waste is either not treated at all or minimally treated....

It has been argued that swine wastes are about 10-fold more liquid than human wastes; if that dilution factor is taken into account, 1 animal would produce about the same amount of waste of 3.96 people, rounded to a ratio of 1:4.

Manure production per 1000 pounds live weight, on an annual basis.

Animal Species	Manure produced lbs./yr	Typical Handling System
Swine	29,000	Liquid
Poultry		
Broilers	28,000	Solid
Layers	22,000	Liquid
Turkeys	16,000	Solid
Beef	21,000	Solid
Dairy	30,000	Liquid
Humans	1,223[1]	Liquid

[1] Based on 150 lb avg. wt. per person producing 0.5 lb of fecal material per day

0.6951 g/m²/day; even areas near urban Wilmington had lower SOD (0.4440 to 0.4679 g/m²/day). Bowen et al. (p.4-42) used an estimated SOD of ~0.4 g/m²/day except for an area heavily influenced by swine CAFOs, the Northeast Cape Fear River sub-basin, where they used an estimated SOD of 1.5 g/m²/day. This information suggests that the swine CAFO-rich Northeast Cape Fear River alone, contributes excessive SOD in comparison to the rest of the LCFRE, expected since that small sub-watershed contains 502 swine CAFOs with 2,021,000 animals, or the equivalent amount of more than 8 million people's wastes per year (NCDENR 2005).

III. Summary and Recommendations

These Comments have explained the following main points regarding DWR's proposed reclassification of a segment of the LCFRE, from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut, from Class Sc waters to Class Sc (Sw) (= swamp):

- ✓ NCDENR-DWR has proposed to reclassify the lower reaches of one of the most powerful rivers in the nation, a portion of the LCFRE, as a swamp because the agency's efforts to control the relatively small amount of pollution from 20 point sources will not allow that segment to meet present standard for DO (or for pH, turbidity, and toxic copper). This was based on a recent modeling effort (Bowen et al. 2009) which predicted that

the 20 arbitrarily selected point sources have little effect on DO levels in the LCFRE segment. In addition, the segment was described as inappropriate for development of a TMDL, based on two erroneous claims -- that natural wetland drainage is the major contributor of oxygen-demanding materials to the LCFRE segment, and that significant reductions in "background" sources of oxygen-demanding materials would not allow the LCFRE segment to meet the present DO standard.

- ✓ According to the U.S. EPA, assessment of whether a TMDL is needed to improve DO in the LCFRE segment is supposed to consider all point and nonpoint sources in the watershed. In focusing on only 20 point sources, DWR omitted consideration of massive pollution that could be reduced in the so-called "background" loads, including 175 NPDES-permitted, upstream and adjacent point sources in the Cape Fear River basin, and nearly 1,000 swine CAFOs (as well as an unknown number of poultry CAFOs) which are formally defined by the Clean Water Act as point sources. The ~5 million swine produced in the lower Cape Fear River basin contribute the equivalent of ~20 million people's wastes per year, and the massive wastes are much richer in oxygen-demanding materials than human wastes.

- ✓ The available evidence shows that pollution from human activities, not natural drainage from wetlands, is the major source of oxygen-demanding materials to the LCFRE segment, and that the massive pollution also contributes low pH, toxic copper, high turbidity, fecal bacteria, and many other contaminants to the LCFRE segment.

- ✓ The recent modeling effort by Bowen et al. (2009) tacitly included the many other NPDES-permitted point sources and swine/poultry CAFOs within a modeling category called "tributary inputs." The model predicted that a reduction of only 30% of the "tributary inputs" would result in median DO levels higher than the state standard; and that a 70% reduction in the "tributary inputs" would bring the LCFRE into compliance 99% of the time. Thus, reducing the massive pollution from other sources **would** enable the LCFRE segment to attain compliance with its present DO standard.

To protect the health of many North Carolinians of all ages who depend upon this river and estuary to meet its present designated uses, and to protect the LCFRE surface water segment of focus as well as other public trust natural resources in the lower Cape Fear basin, the LCFRE segment should not be reclassified as a Class Sc Swamp (Sw). Instead, DWR should be directed toward efforts to meaningfully reduce the massive pollution from swine CAFOs and NPDES-permitted point sources in the lower Cape Fear Basin (and from poultry production as well, which are a major pollution source with much less available information), which would make it possible for the LCFRE to meet the presently pplicable DO standard, and would also enable the LCFRE to improve in water quality with respect to pH, copper levels, and turbidity.

References

Aneja, V.P., P.A. Roelle, G.C. Murray, J. Southerland, J.W. Erisman, D. Fowler, W.A.H. Asman, and N. Patni. 2001. Atmospheric nitrogen compounds II: emissions, transport, transformation, deposition and assessment. *Atmospheric Environment* 35: 1903-1911.

Aneja, V.P., D.R. Nelson, P.A. Roelle, and J.T. Walker. 2003. Agricultural ammonia emissions and ammonium concentrations associated with aerosols and precipitation in the southeast United States. *Journal of Geophysical Research* 108: ACH12-1 - 12-11.

Barker, J.C. and J.P. Zublena. 1995. *Livestock Manure Nutrient Assessment in North Carolina.* Final Report. North Carolina Agricultural Extension Service, NC State University, Raleigh, NC.

Becker, M.L., R.A. Luettich Jr., and M.A. Mallin. 2010. Hydrodynamic behavior of the Cape Fear River and estuarine system: A synthesis and observational investigation of discharge-salinity intrusion relationships. *Estuarine, Coastal and Shelf Science* 88: 407-418.

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin and J. Williams. 2009. *Development and Use of a Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the lower Cape Fear Estuary, North Carolina.* Department of Civil Engineering, University of North Carolina Charlotte.

Bowie, G.L., W.B. Mills, D.B. Porcella, C.L. Campbell, J.R. Pagenkopf, G.L. Rupp, K.M. Johnson, P.W.H. Chan, S.A. Gherini, and C.E. Chamberlin. 1985. *Rates, Constants, and Kinetic Formulations in Surface Water Quality Modeling*, 2nd edition. Report #EPA/600/3-85/040. U.S. Environmental Protection Agency, ORD, Athens, GA.

Bricker, S. B., C. G. Clement, D. E. Pirhalla, S. P. Orland, and D. G. G. Farrow. 1999. *National Estuarine Eutrophication Assessment: A Summary of Conditions.* National Oceanic and Atmospheric Administration, Silver Spring, MD.

Burkholder, J.M. 2009. Harmful algal blooms, pp. 264-285. In: *Encyclopedia of Inland Waters, Volume 1*, by Likens GE (ed.) Elsevier, Oxford, UK.

Burkholder, J.M. and P.M. Glibert. 2013. Eutrophication and oligotrophication, pp. 347-371. In: *Encyclopedia of Biodiversity*, 2nd edition, Volume 3, by Levin S (ed.). Academic Press, Waltham, MA.

Burkholder, J.M., D.A. Dickey, C. Kinder, R.E. Reed, M.A. Mallin, G. Melia, M.R. McIver, L.B. Cahoon, C. Brownie, N. Deamer, J. Springer, H. Glasgow, D. Toms, and J. Smith (2006) Comprehensive trend analysis of nutrients and related variables in a large eutrophic estuary: A decadal study of anthropogenic and climatic influences. *Limnology and Oceanography* 51: 463-487.

Burkholder, J.M., M.A. Mallin, H.B. Glasgow, L.M. Larsen, M.R. McIver, G.C. Shank, N. Deamer-Melia, D.S. Briley, J. Springer, B.W. Touchette, and E.K. Hannon. 1997. Impacts to a coastal
river and estuary from rupture of a large swine waste holding lagoon. *Journal of Environ-mental Quality* 26: 1451-1466.

Burkholder, J.M., B. Libra, P. Weyer, S. Heathcote, D. Kolpin, P.S. Thorne, and M. Wichman 2007. Impacts of waste from concentrated animal feeding operations on water quality. *Environmental Health Perspectives* 115: 308-312.

Chapra S.C. 1997. *Surface Water-Quality Modeling.* Civil Engineering Series, McGraw-Hill International editions (originally Waveland Press, Inc., Long Grove, IL).

Dewi. I.A., R.F.E. Axford. I. Faycz, M. Marai, and H. Omed (eds.). 1994. *Pollution in Livestock Production Systems.* CAB International, Wallingford, United Kingdom.

Cahoon, L.B., J.A. Mickucki and M.A. Mallin. 1999. Nutrient imports to the Cape Fear and Neuse River basins to support animal production. *Environmental Science and Technology* 33: 410-415.

Caldwell, J. M. and M.C. Doyle. 1995. *Sediment Oxygen Demand in the Lower Willamette River, Oregon, 1994.* United States Geological Survey Water-Resources Investigations Report 95-4196. USGS, Reston, VA.

Camargo, J.A., A. Alonso, and A. Salamanca. 2005, Nitrate toxicity to aquatic animals: A review with new data for freshwater invertebrates, *Chemosphere* 58: 1255-126.

Camargo, J.A. and A. Alonso 2006. Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: A global assessment. *Environment International* 32: 831-849.

CH2MHill. 2014a (February 25). Technical Memo: Task 1 - Summary of Background Information and Previous Studies for the Lower Cape Fear River. Prepared for the Lower Cape Fear River Program. In May (2014).

CH2MHill. 2014b. Technical Memo: Task 3 - Analysis of Water Quality Data at Cape [Fear] River Estuary Model Boundaries. Prepared for the Lower Cape Fear River Program. In May (2014).

Collos, Y. and J.A. Berge. Undated. *Nitrogen Metabolism in Phytoplankton.* Encyclopedia of Life Support Systems - http://www.eolss.net/sample-chapters/c09/E2-27-03-03.pdf.

Cox, B.A. 2003. A review of dissolved oxygen modelling techniques for lowland rivers. *The Science of the Total Environment* 314-316: 303-334.

Crawford, J.K. 1985. *Water Quality of North Carolina Streams - Water-Quality Characteristics for Selected Sites on the Cape Fear River, North Carolina, 1955-80.* United States Geological Survey (USGS) Water-Supply Paper 2185-F. USGS, Alexandria, Virginia.

Davis, W.S. 1950. Brief history of sediment oxygen demand investigations. In: *Sediment Oxygen Demand*, by K.J. Hatcher (editor). Institute of Natural Resources, University of Georgia, Athens, GA.

Eaton, A.D., L.S. Clesceri, and A.E. Greenberg. 1995. *Standard Methods for the Examination of Water and Wastewater*. United Book Press Inc., Baltimore, MD.

Edwards, T.M., L.J. Guillette Jr., K. McCoy, and T. Barbeau. 2004. *Effects of Nitrate/Nitrite on Two Sentinel Species Associated with Florida's Springs*. Final report prepared for the Florida Department of Environmental Protection, Tallahassee, FL.

Ensign, S.H., J.N. Halls, and M.A. Mallin. 2004. Application of digital bathymetry data in an analysis of flushing times of two large estuaries. *Computers & Geosciences* 30: 501-511.

Evans, R.O., P.W. Westerman, and M.R. Overcash. 1984. Subsurface drainage water quality from land application of swine lagoon effluent. *Transactions of the American Society of Agricultural Engineers* 27: 473-480.

Extension Toxicology Network 2003. Exotoxnet - A Pesticide Information Project of the Cooperative Extension Offices of Cornell University, Michigan State University, Oregon State University, and the University of California at Davis. U.S. Department of Agriculture, Extension Service, and the National Agricultural Pesticide Impact Assessment Program. Available at http://ace.orst.edu/info/extoxnet/.

Garrett, C. G., V.M. Vulava, and M.L. Jones. 2012. Groundwater-surface water interactions in a lowland watershed: source contribution to stream flow. *Hydrological Processes* 26: 3195-3206.

Guillette, L.J. Jr. and T.M. Edwards 2005. Is nitrate an ecologically relevant endocrine disruptor in vertebrates? *Integrative and Comparative Biology* 45: 19-27.

Ham, J.M. and T.M. DeSutter. 2000. Toward site-specific design standards for animal-waste lagoons: protecting groundwater quality. *Journal of Environmental Quality* 29: 1721-1732.

Hamrick, J.M. 1992. *A Three-Dimensional Environmental Fluid Dynamics Computer Code: Theoretical and Computational Aspects*. Special Report 317. Virginia Institute of Marine Science, The College of William and Mary, Gloucester, VA.

Hatcher, K.J. 1986. *Sediment Oxygen Demand: Processes, Modeling, and Measurement*. Institute of Natural Resources, University of Georgia, Athens, GA.

Heaney, C.D., K. Myers, S. Wing, D. Hall, D. Baron, and J.R. Stewart. 2015. Source tracking swine fecal waste in surface water proximal to swine concentrated animal feeding operations. *Science of the Total Environment* 511: 676-683.

Herndon, J. and W.P. Cochlan. 2006. Nitrogen utilization by the raphidophyte *Heterosigma akashiwo*: growth and uptake kinetics in laboratory cultures, *Harmful Algae* 6: 260-270.

Hu, W.F., W. Lo, H. Chua, S.N. Sin, and P.H.F. Yu. 2001. Nutrient release and sediment oxygen demand in a eutrophic land-locked embayment in Hong Kong. *Environment International*
26: 369-375.

Huffman, R.L. 2004. Seepage evaluation of older swine lagoons in North Carolina. *Transactions of the American Society of Agricultural Engineers* 47: 1507-1512.

Huffman, R.L. and P.W. Westerman. 1995. Estimated seepage losses from established swine waste lagoons in the lower coastal plain of North Carolina. *Transactions of the American Society of Agricultural Engineers* 38: 449-453.

Iowa State University and The University of Iowa Study Group. 2002. *Iowa Concentrated Animal Feeding Operation Air Quality Study.* Final Report. Environmental Health Sciences Research Center, Iowa City, IA. February 2002. Website - http://www.public-health.uiowa.edu/ehsrc/CAFOstudy.html.

Jacobson, L.M., M.B. David, and L.E. Drinkwater. 2011. A spatial analysis of phosphorus in the Mississippi river basin. *Journal of Environmental Quality* 40: 931-941.

Knobeloch, L., B. Salna, A. Hogan, J. Postle, and H. Anderson. 2000. Blue babies and nitrate-contaminated well water. *Environmental Health Perspectives* 108: 675-678.

Krapac, I.G., W.S. Dey, W.R. Roy, C.A. Smyth, E. Storment, S.L. Sargent, and J.D. Steele. 2002. Impacts of swine manure pits on groundwater quality. *Environmental Pollution* 120: 475-492.

Lin, J., L. Xie, L.J. Pietrafesa, J. Shen, M.A. Mallin, and M.J. Durako. 2006. Dissolved oxygen stratification in two micro-tidal partially-mixed estuaries. *Estuarine, Coastal and Shelf Science* 70: 423-437

Liu, Z., W. Powers, J. Murphy, and r. Maghirang. 2014. Ammonia and hydrogen sulfide emissions from swine production facilities in North America: a meta-analysis. *Journal of Animal Science* 92: 1656-1665.

MacPherson, T.A. 2003. *Sediment Oxygen Demand and Biochemical Oxygen Demand: Patterns of Oxygen Depletion in Tidal Creek Sites.* M.S. Thesis. Program in Marine Science, University of North Carolina Wilmington, Wilmington, NC.

Mallin, M.A. 2000. Impacts of industrial-scale swine and poultry production on rivers and estuaries. *American Scientist* 88: 26-37.

Mallin, M.A., J.M. Burkholder, G.C. Shank, M.R. McIver, H.B. Glasgow, J. Springer, and B.W. Touchette. 1997b. Comparative effects of poultry and swine waste lagoon spills on the quality of receiving stream waters. *Journal of Environmental Quality* 26: 1622-1631.

Mallin, M.A., V.L. Johnson, S.H. Ensign and T.A. MacPherson. 2006. Factors contributing to hypoxia in rivers, lakes and streams. *Limnology and Oceanography* 51: 690-701.

Mallin, M., M. McIver, and J. Merritt. 2008. *Environmental Assessment of the Lower Cape Fear River System, 2007.* CMSR Report No. 08-03, Center for Marine Science, University of North Carolina Wilmington, Wilmington, North Carolina.

Mallin, M., M. McIver, and J. Merritt. 2013. *Environmental Assessment of the Lower Cape Fear River System, 2012*. CMSR Report No. 13-02. Center for Marine Science Research, University of North Carolina Wilmington, Wilmington, NC.

Mallin, M.A., M.R. McIver, A.R. Robuck, and A.K. Dickens. 2014. *Stocking Head Creek 2013 Water Quality Investigation*. Final Report. Center for Marine Sciences, University of North Carolina Wilmington, Wilmington, NC.

Mallin, M., M. McIver, H. Wells, M. Williams, T. Lankford, and J. Merritt. 2003. *Environmental Assessment of the Lower Cape Fear River System, 2002-2003*. CMSR Report No. 03-03. Center for Marine Science, University of North Carolina Wilmington, Wilmington, NC.

Mallin, M. A., H. W. Paerl, J. Rudek, and P. W. Bates. 1993. Regulation of estuarine primary production by watershed rainfall and river flow. *Marine Ecology Progress Series* 93: 199-203.

Mallin, M.A., M.H. Posey, M.L. Moser, G.C. Shank, M.R. McIver, T.D. Alphin, S.H. Ensign, and J.F. Merritt. 1997a. *Water Quality in the Lower Cape Fear River System, 1996-1997*. Center for Marine Science, University of North Carolina Wilmington, Wilmington, NC.

Massachusetts Water Resources Authority. 2002. *The State of Boston Harbor - Mapping the Harbor's Recovery*. Available at: http://www.mwra.state.ma.us/harbor/enquad/pdf/2002-09.pdf.

Matlock, M.D., K.R. Kasprzak, and G.S. Osborn. 2003. Sediment oxygen demand in the Arroyo Colorado River. *Journal of the American Water Resources Association* 39: 267-275.

May, C. 2014 (5 March). Request for Reclassification of a Portion of the Lower Cape Fear River with the Supplemental Swamp Classification. Letter from Mr. May, Chair of the Lower Cape Fear River Program Advisory Board and Executive Director of the Cape Fear River Council of Governments, to Mr. Tom Reeder, Director of the NC DENR DWR.

Meyer J.L. & Edwards R.T. (1990) Ecosystem metabolism and turnover of organic carbon along a blackwater river continuum. *Ecology* 71: 668–677.

Minshall, G.W., R.C. Petersen, K.W. Cummins, T.L. Bott, J.R. Sedell, C.E. Cushing, C. E., and R.L. Vannote. 1983. Interbiome comparison of stream ecosystem dynamics. *Ecological Monographs* 53: 1-25.

Natural Resource Council. 2000. *Clean Coastal Waters- Understanding and Reducing the Effects of Pollution*. National Academy Press, Washington, DC.

North Carolina Department of Environment and Natural Resources (NC DENR). 1997. *Assess-ment Plan for Atmospheric Nitrogen Compounds: Emissions, Transport, Transformation, and Deposition*. Division of Air Quality, NC DENR, Raleigh, NC

North Carolina Department of Environment and Natural Resources (NC DENR). 2005. *Cape Fear River Basinwide Water Quality Plan*. Division of Water Quality, NC DENR, Raleigh, NC. Available at: http://portal.ncdenr.org/c/document_library/get_file?uuid=2eddbd59-b382-4b58-97ed-c4049bf4e8e4&groupId=38364.

Payne, G.G., D.C. Martens, E.T. Kornegay, and M.D. Lindermann. 1988. Availability and form of copper in three soils following eight annual applications of copper-enriched swine manure. *Journal of Environmental Quality* 17: 740-746.

Ritter, W. F. and A. E. M. Chirnside. 1987. Influence of agricultural practices on nitrates in the water table aquifer. *Biological Wastes* 19: 165-178.

Ritter, W. F., and A. E. M. Chirnside. 1990. Impact of animal waste lagoons on groundwater quality. *Biological Wastes* 34: 39–54.

Rolley, H.JL. and M. Owens. 1967. Oxygen consumption rates and some chemical properties of river muds. *Water Research* 1: 759-766.

Rothenberger, M., J.M. Burkholder, and C. Brownie. 2009a. Long-term effects of changing land use practices on surface water quality in a coastal river and lagoonal estuary. *Environmental Management* 44: 505-523.

Rothenberger, M., J.M. Burkholder, and T. Wentworth. 2009b. Multivariate analysis of phytoplankton and environmental factors in a eutrophic estuary. *Limnology and Oceanography* 54: 2107-2127.

Seiki, T., H. Izawa, E. Date, and H. Sunahara. 1994. Sediment oxygen demand in Hiroshima Bay. *Water Research* 28: 385-393.

Smith, R.P. 2009. The blue baby syndromes. *American Scientist* 97: 94-96.

Spellman, F.R. and N.E. Whiting. 2007. *Environmental Management of Concentrated Animal Feeding Operations (CAFOs)*. CRC Press, Boca Raton, FL.

State Stream Sanitation Committee. 1957. *Cape Fear River Basin Pollution Survey Report 1957 (1954-1956)*. North Carolina State Board of Health, Division of Water Pollution Control, Raleigh, North Carolina.

Stone, K.C., P.G. Hunt, F.J. Humenik, and M.H. Johnson. 1998. Impact of swine waste application on ground and stream water quality in an eastern Coastal Plain watershed. *Transactions of the American Society of Agricultural Engineers* 41: 1665-1670.

Stone, K.C., P.G. Hunt, S.W. Coffey, and T.A. Matheny. 1995. Water quality status of a USDA water quality demonstration project in the Eastern Coastal Plain. *Journal of Soil and Water Conservation* 50: 567-571.

Stubbs, K. and K. Cathey. 1999. CAFOs feed a growing problem. *Endangered Species Bulletin* 24: 14-15.

Tetra Tech. 2001 (May). *3-Dimensional EFDC Water Quality Model of the Lower Cape Fear River and its Estuary.* Prepared for the City of Wilmington and New Hanover County, North Carolina.

Tetra Tech. 2003 (January 6). Technical Memo: Results of Dissolved Oxygen and Pollutant Loading Trend Analyses. Submitted to Hugh Caldwell, Ken Vogt, and Wyatt Blanchard from Trevor Clements and Jason Doll.

Tetra Tech. 2014 (February). *Technical Memo: The Relationship of Adjacent Wetlands and Salt Marsh to Dissolved Oxygen in the Lower Cape Fear River Estuary.* Prepared for the Lower Cape Fear River Program. In May (2014).

Todd, M.J., G. Vellidis, R.R. Lowrance, and C.M. Pringle. 2009. High sediment oxygen demand within an instream swamp in southern Georgia: implications for low dissolved oxygen levels in coastal blackwater streams. *Journal of the American Water Resources Association* 45: 1493-1507.

Twomey, L.J., M.F. Piehler, and H.W. Paerl. 2005, Phytoplankton uptake of ammonium, nitrate and urea in the Neuse River Estuary, NC, USA. *Hydrobiologia* 533: 123-134.

U.S. Environmental Protection Agency (U.S. EPA). 1998. *Environmental Impacts of Animal Feeding Operations.* Office of Water, Standards and Applied Sciences Division, U.S. EPA, Washington, DC.

U.S. Environmental Protection Agency (U.S. EPA). 2004. Risk Management Evaluation for Concentrated Animal Feeding Operations. Report #EPA/600/R-04/042. Office of Research and Development, U.S. EPA, Cincinnati, OH. Available at: http://nepis.epa.gov/Adobe/PDF/901V0100.pdf.

Walker, J., V. Aneja and D. Dickey. 2000. Atmospheric transport and wet deposition of ammonium in North Carolina. *Atmospheric Environment* 34: 3407-3418.

Walker, R.R. and W.J. Snodgrass. 1986. Model for sediment oxygen demand in lakes. *Journal of Environmental Engineering* 112: 25-43.

Westerman, P.W., R.L. Huffman, and J.S. Feng. 1995. Swine-lagoon seepage in sandy soil. *Transactions of the American Society of Agricultural Engineers* 38: 1749-1760.

Westerman. P.W., M.R. Overcash, R.O. Evans. L.D. King, J.C. Burns, and G.A. Cummings. 1985. Swine lagoon effluent applied to coastal bermudagrass: III. Irrigation and rainfall runoff. *Journal of Environmental Quality* 14: 22-25.

Wetzel, R.G. 2001. *Limnology*, 3rd edition. Academic Press, New York, NY

Wing, S., R.A. Horton, and K.M. Rose. 2012. Air pollution from industrial swine operations and blood pressure of neighboring residents. *Environmental Health Perspectives* 121: 92-96.

Wu, R.S.S. 1990. A respirometer for continuous, in situ, measurements of sediment oxygen-demand. *Water Research* 24: 391-394.

Zu, J., A. Luo, and P. Ndegwa. 2001. Raising pH by low-level aeration for soluble phosphorus removal of swine manure. *Transactions of the American Society of Agricultural Engineers* 44: 391-396.

Zublena, J.P., J.C. Barker, and D.A. Crouse. 1995. *Capacity of North Carolina Crops to Use Animal Manures: A Nutrient Balance Approach*. Soil Science Notes, NC Agricultural Extension Service, NCSU, Raleigh, NC.

JoAnn M. Burkholder

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March 3, 2015

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RE: Comments on Proposed reclassification of portions of the Cape Fear River

Dear Ms. Kountis:

On behalf of the Cape Fear River Watch, Cape Fear Riverkeeper and Waterkeeper Alliance, we are submitting the following comments pursuant to the Notice issued by your office for the proposal captioned "Proposed Swamp Reclassification with Water Quality Management Plan for Part of Cape Fear River." This proposed reclassification apparently originated from a request on behalf of persons who had been meeting to discuss the development and implementation of a Total Maximum Daily Load for the Lower Cape Fear River.[1] Based upon review of the materials presented, as well as readily available peer-reviewed literature, this proposal suffers the following deficits: constitutes an unlawful attempt to evade the Clean Water Act's directives to correct water quality problems through implementation of Total Maximum Daily Load requirements and to prevent backsliding on Water Quality Standards once they are set; violates the policy declared by the State's constitution and implementing statutory directives to the North Carolina Environmental Management Commission (Commission) and the North Carolina Department of Environment and Natural Resources (Department) to protect and conserve the waters of the state for the benefit of all its citizens; fails to correct the water pollution created by Animal Operations under the regulatory authority of the Commission and CAFOs as regulated by the Clean Water Act, which together are causing impairments for copper, turbidity, pH and low dissolved oxygen (DO); lacks scientific support; and does not comply with the requirements of the North Carolina Administrative Procedures Act (APA).

[1] The letterhead of the request is the Lower Cape Fear River Program, but the request is signed by Chris May, identified as the Executive Director of the Cape Fear Council of Governments. We raise this issue in order to preserve, in any subsequent appeal, the question as to whether Mr. May was acting with actual authority on behalf of a person with legal power to make the request.

I. The Clean Water Act Requires the State of North Carolina to Implement a Total Maximum Daily Load Allocation in the Cape Fear River

The Lower Cape Fear River (LCFR) presents the classic situation that the Clean Water Act (CWA) provisions on Total Maximum Daily Load (TMDL) were designed to address: chronic violations of water quality standards that NPDES-imposed effluent limitations alone are unable to correct. The modern-day CWA was first passed in 1972 in response to growing concern about the continued degradation of many major rivers under inadequate state regulatory schemes. The CWA's stated objective is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." CWA § 101(a). To achieve this objective, the CWA lays out several goals, including the elimination of the discharge of pollutants into navigable waters. The statute sets up several programs to achieve these goals, including the TMDL process.

A. State Water Quality Standards Must Meet CWA Minimum Requirements and Protect Designated Uses

State water quality standards must be approved by the United States Environmental Protection Agency under § 303 of the Clean Water Act, 33 U.S.C. § 1313. Under the Clean Water Act, water quality standards consist of three elements: (1) one or more existing or designated "uses" of a water body (such as fish and aquatic life, fishing, boating, aesthetic quality, irrigation and water supply), (2) water quality "criteria" indicating the amount of a pollutant that may be present in the water body while still protecting the uses, and (3) a provision restricting degradation of certain types of waters. When met, these standards must be stringent enough to protect the designated uses. States are responsible for enforcing their water quality standards on intrastate waters. See 33 U.S.C. § 1319(a).

B. North Carolina's General Statutes Require More Protection of Uses than the CWA Minimum Requirements

Under the provisions of Article 21 of Chapter 143, the North Carolina General Assembly has set forth guidelines for the Commission to use when enacting water quality standards and specifically sets forth criteria more stringent and more specific than the Clean Water Act. North Carolina's standards must be designed to:

1) protect human health,
2) prevent injury to plant and animal life,
3) prevent damage to public and private property,
4) insure the continued enjoyment of the natural attractions of the State,
5) encourage the expansion of employment opportunities,
6) provide a permanent foundation for healthy industrial development,
7) secure for the people of North Carolina, now and in the future, the beneficial uses of these great natural resources.

See N.C. Gen. Stat. § 143-211(c).

State water quality standards established under § 303 provide an important "supplementary basis . . . so that numerous point sources, despite individual compliance with effluent limitations, may be further regulated to prevent water quality from falling below acceptable levels." EPA v. California ex rel. State Water Res. Control Bd., 426 U.S. 200, 205 n.12 (1976). States therefore may impose more stringent water quality controls. See 33 U.S.C. § 1311(b)(1)(c). The CWA standards are a floor, but states are expected to set standards to protect uses based on the water quality issues in their waters. For example, North Carolina requires that water quality standards ensure "the ability of an aquatic ecosystem to support and maintain a balanced and indigenous community of organisms . . . . " 15A NCAC § 2B.0202(11).

Numerous state water quality issues are implicated within the Cape Fear River basin and the State has adopted a broad array of requirements affecting water quality to protect the public welfare and serve the purposes of the Clean Water Act. For the portions of the Cape Fear River system classified as Class SC waters, state regulations provide specific water quality criteria implicated by these classifications. These include chlorophyll, dissolved oxygen, solids or sludge attributable to wastes, dissolved gases, fecal coliform, pH, oils, temperature, turbidity, toxic substances, pesticides, and metals, among others. See15A NCAC § 02B .0220 The Lower Cape Fear River fails to meet the standards imposed for DO, pH, turbidity, and copper. Consequently, the state is required to identify the sources that contribute to these violations and then take corrective action. "[S]ources of water pollution which preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard." 15A NCAC § 2B.0211(2).

C. CWA Requires North Carolina to Allocate Pollutant Loading From Point Sources, Including CAFOs, and From Nonpoint Sources Under TMDL

The CWA requires states to address both point sources[2] and nonpoint sources in order to protect designated uses. Under the CWA scheme, states must designate uses for waterbodies within the state and then develop water quality standards for those waterbodies to ensure achievement of the designated uses. Effluent limitations must be imposed on every point source discharger, including concentrated animal feeding operations (CAFOs),[3] in an effort to meet the water quality standards and maintain the designated uses. Waterbodies that do not meet their standards are placed on the 303(d) list of impaired waters. For those waterbodies, the states must develop TMDLs for the contaminant(s) causing the violation to return the waters to the standards appropriate for the designated use. To achieve a TMDL, CWA § 303 requires the state to undergo a

[2] CWA § 502(14) defines "point source" as "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged."

[3] As discussed more in Section III, North Carolina also regulates all Animal Operations activities involving Animal Waste, even when these operations have not been designated as CAFOs. We do not endorse the Department's decision to use general permits for Animal Operations in this basin and have previously commented on the inadequacy of those permits to prevent the types of problems seen in the LCFR.

continuing planning process and determine appropriate load allocations for all sources, whether categorized as point or nonpoint. The TMDL must consider point and nonpoint sources contributing to impairment and not merely those adjacent to the impaired stretch. The state must incorporate the TMDL waste load allocations into the NPDES permits for each point source discharger and the load allocation for nonpoint sources are to be implemented through regulatory, non-regulatory and voluntary compliance mechanisms depending on the source.

Since 1998, the LCFR segment from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut has been on North Carolina's 303(d) list of impaired waters due to low dissolved oxygen (DO). In 2006, the state added impairment for pH, copper, and turbidity to the 303(d) list for this segment. The CWA requires the state to develop a TMDL for the impairing pollutants and then incorporate the TMDL into NPDES permits for point sources and controls on nonpoint sources necessary to meet the loading limits in the state plans.[4] For example, TMDLs are to be incorporated into the state's Water Quality Management Plan, which must also include effluent limitations and the regulatory, non-regulatory, and other mechanisms necessary to control nonpoint sources and meet water quality standards. The proposed reclassification would avoid this process and allow the waterbody to violate the 5 mg/L DO standard. In doing so, it fails to further the goals of the CWA and violates its express provisions.

The CWA intends for TMDLs to cover pollution from point and nonpoint sources. The TMDL program sets the total amount of a pollutant that a waterbody can assimilate while still achieving its designated uses. The state must set the TMDL with an eye toward the designated use, and then must manage its contributing point and nonpoint sources to meet the TMDL. The CWA requires states to incorporate the TMDL into NPDES permits for point sources and into the regulatory, non-regulatory and other actions in state plans for nonpoint sources. Thus, the TMDL process should comprehensively consider all sources, which this proposed reclassification fails to do by ignoring CAFOs and nonpoint sources. Further, CAFOs are defined as point sources within the CWA (and in more detail by EPA regulations). So, the statute is clearly and explicitly intended for the TMDL process to cover discharges from CAFOs. The proposed reclassification entirely ignores the discharges from these sources, even though there are millions of hogs, poultry, turkeys, and cattle in the basin that contribute to the violations of applicable water quality standards. The proposed reclassification is thus impermissible.

[4] See, e.g. 33 U.S.C. §§1313(e) and 1319; *Pronsolino v. Nastri, 291 F. 3d. 1123 (9th Cir. 2002)* (Upholding EPA's TMDL for a waterbody impaired solely by nonpoint source pollution); U.S. EPA What is a TMDL? http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/overviewoftmdl.cfm ("Load allocations (LAs) are implemented by nonpoint sources through a wide variety of state, local, and federal programs (which may be regulatory, non-regulatory, or incentive-based, depending on the program), as well as voluntary action by citizens.");

D. The Proposed Reclassification Violates the Anti-Degradation Provisions in Both State and Federal Law

The CWA also includes anti-degradation provisions that prohibit the states from allowing the degradation of navigable waters by lowering the standards to achieve compliance. See 33 U.S.C. § 1313(d)(4). Under the federal antidegradation policy, the states are required to develop and adopt statewide antidegradation policies that ensure that "existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected." 40 C.F.R. § 131.12. North Carolina has incorporated this requirement by reference into its water quality standards, and further adopted the requirement that "[e]xisting uses, as defined by Rule .0202 of this Section, and the water quality to protect such uses shall be protected by properly classifying surface waters and having standards to protect these uses." 15A NCAC 02B § .0201 (a) and (b). Existing uses are defined as: "uses actually attained in the water body, in a significant and not incidental manner, on or after November 28, 1975, whether or not they are included in the water quality standards, which either have been actually available to the public or are uses deemed attainable by the Environmental Management Commission. At a minimum, uses shall be deemed attainable if they can be achieved by the imposition of effluent limits and cost-effective and reasonable best management practices (BMPs) for nonpoint source control." See 15A NCAC 02B § .0202(30). The proposed reclassification violates both the CWA and the state's supplemental antidegradation policy regulations because it will not protect and maintain the existing uses in the LCFR, would weaken water quality standards and would allow for further degradation of water quality.

Additionally, EPA regulations prohibit the removal of a designated use where that use is an existing use, which the EPA regulations define as uses "actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards." 40 C.F.R. § 131.10(h)(1). The EPA regulations deem a use attainable if it "can be achieved by the imposition of effluent limits required [for point sources] under sections 301(b) and 306 of the Act and cost-effective and reasonable best management practices for nonpoint source control." 40 C.F.R. §131.10(d). The EPA regulations also prohibit removing a designated use where "[s]uch uses will be attained by implementing effluent limits required under sections 301(b) and 306 of the Act and by implementing cost-effective and reasonable best management practices for nonpoint source control." 40 C.F.R. § 131.10 (h)(2). As demonstrated by materials submitted by the proponents of this reclassification and the comments of Dr. Burkholder set forth below, the SW classification protects an existing use and the designated uses for the LCFR can be achieved through reasonable pollution controls.

If these prohibitions did not apply, a state could seek to remove a designated use where naturally occurring pollutant concentrations prevent the attainment of the use: "States may remove a designated use which is not an existing use, as defined in § 131.3, or establish sub-categories of a use if the State can demonstrate that attaining the designated use is not feasible because: (1) Naturally occurring pollutant concentrations prevent

the attainment of the use." See 40 C.F.R. § 131.10(g)(1). The supplemental Sw "Swamp" classification is an example of such a sub-category of use for SC waters of the LCFR. NC law builds upon these restrictions with supplemental provisions, allowing revision to the water quality standards if the naturally occurring pollutant concentrations are the result of natural background conditions.

Under NC law, "any person subject to the provisions of G.S. 143-215.1 may petition the Commission for a hearing pursuant to G.S. 143-215.4 for a revision to water quality standards adopted pursuant to G.S. 143-214.1 as such water quality standards may apply to a specific stream segment into which the petitioner discharges or proposes to discharge." See N.C. Gen. Stat. § 143-214.3. This section also sets forth the procedure and burdens of proof needed in making such a request. However, the provision specifies that revisions to water quality standards are permitted only when the proponent meets particular criteria, including proving that "natural background conditions on the stream segment preclude the attainment of the applicable water quality standards." As we set forth in Sections III and IV, the proposed reclassification does not meet that burden.

The Commission must also consider several matters prior to granting a reclassification request, including the following factors: "the use and value of State waters for public water supply, propagation of fish and wildlife, recreation, agriculture, industrial and other purposes, use and value for navigation, and ... an estimate ... of the environmental impact, the economic and social costs necessary to achieve the proposed standards, the economic and social benefits of such achievement and an estimate of the date of such achievement." N.C. Gen. Stat. § 143-214.1(d)(4). Since the CWA and its rules set the minimum requirements, this provision is supplemental to that which is required by the CWA's anti-degradation policy. It does not appear that the proponent has provided any support for the Commission to conduct such an analysis.

Thus, under the state and federal regulations, DWR would have to establish that the use is not an existing use, that the use cannot be attained by implementing effluent limits and nonpoint source controls, and that low DO in the LCFR is being caused by naturally occurring pollutant concentrations that make attainment of the use infeasible. This is a burden that cannot be met as set forth in greater detail below in Section III and IV, as well as attached comments by Dr. Joann Burkholder, Ph.D. In any event, because the SC classification includes uses that are specified in CWA Section 101(a)(2), the state cannot remove a designated use or adopt subcategories of uses that require less stringent criteria without conducting a Use Attainability Analysis. See 40 CFR 131.10(j) and 131.3(g). The state has not done so in this instance and, thus, the Commission may not proceed with the reclassification.

II. North Carolina Law Requires the Environmental Management Commission to Correct Impairments Including Low Dissolved Oxygen in LCFR

North Carolina's Constitution and its General Statutes require the Commission to correct pollution in the Cape Fear River to support fish and other aquatic life. The fisheries resources are public trust assets, as are the waters of the Cape Fear River itself. Now that the Commission has designated uses for the Cape Fear River, studied the causes of its impairment and evaluated measures for correcting the same, the Commission must act to correct the problems identified. Reclassifying the Cape Fear River to swamp waters does not fulfill the duties entrusted to the Commission by North Carolina's laws.

More generally, a reclassification and a codification of rules that allow for worsened water quality clearly violate North Carolina's Constitution, which imposes a duty of water quality protection upon this Commission:

> "It shall be the policy of this State to conserve and protect its lands and waters for the benefit of all its citizenry, and to this end it shall be a proper function of the State of North Carolina and its political subdivisions to acquire and preserve park, recreational, and scenic areas, to control and limit the pollution of our air and water, to control excessive noise, and in every other appropriate way to preserve as a part of the common heritage of this State its forests, wetlands, estuaries, beaches, historical sites, openlands, and places of beauty." N.C. Const. Art. XIV, § 5.

The Commission must remember that the people have enshrined this duty in the Constitution of North Carolina. Limiting and controlling pollution is a duty of the State and all its political subdivisions. This provision imposes a duty on the Commission to carry out its powers to protect the lands and waters for the benefit of all its citizenry.

Forty years ago, our General Assembly advanced this Constitutional mission by enacting the General Statutes which protect these values, including the laws which empower the Department and the Commission, such as Chapters: 113, 113A, 113B, 130A, 130B, 132, 139, 143, 143B, 146, 150B, 156, 159, 159A, 159B, 159C, 159G and 162A. Among this comprehensive system of laws is found Article 21 of Chapter 143, captioned, "Water and Air Resources." Within Article 21, the General Assembly declares its intent for those laws: "to achieve and to maintain for the citizens of the State a total environment of superior quality. **Recognizing that the water and air resources of the State belong to the people, the General Assembly affirms the State's ultimate responsibility for the preservation and development of these resources** in the best interest of all its citizens and declares the prudent utilization of these resources to be essential to the general welfare." N.C. Gen. Stat. § 143-211(a) (emphasis added).

The General Assembly's enactments clearly show their intent to clarify the legal points that (a) water and wildlife resources belong to the people and (b) the State bears responsibility to preserve and develop these resources as a public trust. This trust may

not be devolved to private interests through permits or approvals that give perpetual rights to pollute and degrade the public trust resources of the people. See N.C. Const. art. I, §§ 32 and 34.

Under the provisions of Article 21 of Chapter 143, the North Carolina General Assembly has set forth the guidelines for the Commission to use when enacting these standards and specifically sets forth criteria more stringent and more specific than the Clean Water Act. At the core of EPA-approved state water quality standards under 33 U.S.C. § 1313, states are responsible for enforcing their water quality standards on intrastate waters. See 33 U.S.C. § 1319(a).

In setting water quality standards, the General Assembly directed the following be considered: "Standards of water and air purity shall be designed to protect human health, to prevent injury to plant and animal life, to prevent damage to public and private property, to insure the continued enjoyment of the natural attractions of the State, to encourage the expansion of employment opportunities, **to provide a permanent foundation for healthy industrial development and to secure for the people of North Carolina, now and in the future, the beneficial uses of these great natural resources**." N.C. Gen. Stat. § 143-211(c) (emphasis added). These provisions clearly show the recognition of a duty to protect uses of our state's waters for the benefit of today's users and those in the future. Removing the protections from the Lower Cape Fear River does not meet the purposes of North Carolina's Constitution, Law or Rules.

III. Neither the Low DO Conditions Nor the Animal Wastes That Cause Them are Naturally Occurring

As stated above, the proposed reclassification violates numerous provisions of state and federal laws relating to TMDLs, water quality standards, antidegradation policies, and the requirements for removing and establishing designated uses. These hurdles cannot be overcome. However, assuming for the sake of discussion that they could, under North Carolina and federal law, the Commission would have to determine that natural background conditions on the stream segment preclude the attainment of the use in order to consider the proposal. N.C. Gen. Stat. § 143-214.3; 40 C.F.R. 131.10(g)(1). The burden of proof is on the applicant to prove this to the Commission. Neither the applicant nor the Commission can meet this burden, and in any event, the Commission could not classify the LCFR as "swamp waters" as the river does not meet the regulatory definition which requires low velocities, among other things. See 15A NCAC 02B .0101(e)(2), 15A NCAC 02B .0202(62), 15A NCAC 02B .0301(c), and Comments of Dr. Burkholder.

A. North Carolina's Statutes Regulate Animal Operations, Feedlots and Animal Waste, Even When Not Designated as CAFOs, and Legally Recognize the Water Quality Problems Created by Livestock Manure[5]

North Carolina's General Assembly adopted laws to regulate Animal Operations and Feedlots in response to concerns that growth in the numbers of Animal Operations harmed water quality. As the General Assembly found, "The growth of animal operations in recent years has increased the importance of good animal waste management practices to protect water quality. It is critical that the State balance growth with prudent environmental safeguards." N.C. Gen. Stat. § 143-215.10A.

In addition, the General Assembly found the need to control and limit nutrients leaving the Animal Operations by specifying that Animal Waste be applied with careful attention to the both nitrogen and phosphorus as rate limiting elements for applying Animal Waste to land. See N.C. Gen. Stat. § 143-215.10C. The General Assembly also declared that zinc and copper levels in the soils shall be monitored, and alternative crop sites shall be used when these metals approach excess levels. These legislative requirements reflect specific legislative findings as to the water quality problems caused by excess nitrogen, phosphorus, zinc and copper.

These North Carolina legislative findings of fact are supported by studies from federal agencies. The United States Environmental Protection Agency ("EPA") and United States Department of Agriculture's ("USDA") have identified livestock manure as the largest cause of water quality impairment in the country's rivers, streams, lakes, ponds, and reservoirs, and the fifth leading contributor to impairment of estuaries.[6] They contribute to the impairment of approximately 37% of the nation's surveyed rivers and streams.[7]

North Carolina law defines Animal Waste to include livestock or poultry waste. N.C. Gen. Stat. § 143-215.10B. A feedlot is defined as a lot or building or combination intended for the confined feeding, breeding, raising, or holding of animals. N.C. Gen. Stat. § 143-215.10B. An Animal Operation is defined as a feedlot involving 250 or more swine, 100 or more confined cattle, 75 or more horses, 1,000 or more sheep, or 30,000 or

[5] North Carolina and the federal government provide different definitions for CAFOs, but these specific definitions and thresholds do not change the underlying arguments about the shortcomings of the current proposal. Just because the state has not identified something as a CAFO through its case-by-case assessment does not mean that it is not one.

[6] CLAUDIA COPELAND, CONG. RESEARCH SERV., RL31851, ANIMAL WASTE AND WATER QUALITY: EPA REGULATION OF CONCENTRATED ANIMAL FEEDING OPERATIONS (CAFOS) 4 (2002) (citing U.S. EPA, EPA-841-R-08-001, NATIONAL WATER QUALITY INVENTORY: REPORT TO CONGRESS FOR THE 2004 REPORTING CYCLE 18–19 (2009)).

[7] Stephen Harden, Characterization of Surface-Water Quality Associated with Swine CAFOs in Eastern North Carolina, Proposal submitted to the N.C. DEP'T OF ENV'T AND NATURAL RES., DIV. OF WATER QUALITY 1, 3 (May 9, 2011) (citing the EPA's 2002 National Water Quality Inventory).

more confined poultry with liquid waste handling. N.C. Gen. Stat. § 143-215.10B. Thus, any Feedlot with more than 250 swine is an Animal Operation subject to the Commission's regulatory authority as related to its handling of Animal Waste. The Commission has the regulatory authority and a duty to act to reduce the impact of livestock manure on the LCFR through its regulation of Animal Operations and Animal Waste. This must also be done through a TMDL in order to correct low DO in the Lower Cape Fear River.

B. Prior to 1999, the LCFR Experienced Explosive Growth in Animal Operations

The LCFR was not listed as impaired until large numbers of Animal Operations had been built in the basin. North Carolina in general, and the Cape Fear River basin in particular, experienced dramatic increases in the number and size of Animal Operations from the mid-1980s through the late-1990s. During that time, the swine population in the counties in the basin increased fourfold, turkey production doubled, chickens increased by 50%, and beef cattle by 25%. According to a study by scientists from the University of North Carolina at Wilmington, the Cape Fear River basin houses more than half the hog population in North Carolina.[8] The surplus nutrients are excreted in the livestock manure, which in turn feeds nutrients into the Cape Fear River through its tributaries.

The situation in the basin is so severe that analysts with the USDA's Natural Resources Conservation Service ("NRCS") found that the Cape Fear River basin and surrounding land area was the number one priority watershed in the United States based on its vulnerability to livestock manure nutrient pollution.[9] This finding is consistent with an earlier NRCS review as well.[10]

The proliferation of CAFOs in the Cape Fear River watershed is the best explanation for the low DO levels in the lower portion of the river, and this explanation is supported by the science. Research from the University of North Carolina at Wilmington shows that ammonium levels have increased in the river since the mid-1990s.[11] Ammonium is a form of nitrogen in swine and poultry waste that can be transported via runoff, subsoil movement, and volatilization and deposition.[12] This ammonium can be transported downstream to the section of the LCFR at issue here, where it can cause algal

[8] See "Nitrogen and Phosphorus Imports to the Cape Fear and Neuse River Basins to Support Intensive Livestock Production" by Lawrence B. Cahoon, Jill A. Mikucki, and Michael A. Mallin Environ. Sci. Technol., 1999, 33 (3), pp 410–415.
[9] See "Potential Priority Watersheds for Protection from Manure Nutrients" by Robert Kellogg, available online at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_012227.pdf (Accessed Feb, 17, 2015)
[10] See "Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the United States" by Robert Kellogg et al., available online at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_012133.pdf (Accessed Feb. 17, 2015)
[11] Michael A. Mallin & Lawrence B. Cahoon, *Industrialized Animal Production—A Major Source of Nutrient and Microbial Pollution to Aquatic Ecosystems*, 24 POPULATION & ENVT. 369, 376 (2003) (internal citations omitted).
[12] *Id.*

blooms.[13] These algal blooms eventually die, and feed bacteria, generating a high biological oxygen demand (BOD), which in turn causes low DO.[14]

The single major land use change that could account for this increase in ammonia concentrations (and drop in DO) is the rapid growth of CAFOs during the 1980s and 1990s.[15, 16] This research reinforces the NRCS's finding that this area should be a priority watershed for protecting against nutrients from livestock manure.Trends showed a significant importation of these nutrients to the Cape Fear River basin from feed grown outside the basin.[17] (Early studies by UNC-W's Center for Marine Science also found a correlation between fecal coliform indicators and biological oxygen demand in the River.)[18] The Cape Fear River Basinwide Assessment Report of 1996 went even further, finding in 1995 that nitrogen and phosphorous from livestock manure exceeded the assimilative capacity of cropland by more than 400% in several counties within the watershed.[19] This troubling data caused DENR's analysts to state:

> "It should be noted that these figures do not take into account commercial fertilizer applications in the counties. It is clear based on this information, that animal waste management in a number of counties in the basin is becoming a critical issue, and that the animal carrying capacity of these lands (from a waste disposal standpoint) needs to be closely examined. Alternatives to cropland application need to be considered in these counties such as application on forest land or transportation/distribution of the collectable manure to counties that have capacity and could use this nutrient source in lieu of commercial fertilizers." [20]

Nutrients imported to the basin in the form of grain to feed the swine create a nutrient imbalance that this Commission must address.

Of course, since 1995, the numbers of swine, turkeys, layers and cattle have only increased in the Cape Fear River Basin. Their numbers are not a naturally occurring condition and their manure is not a naturally occurring pollutant. The record shows the DO violations are caused by animal feeding operations and other upstream sources, and not by naturally occurring conditions. Accordingly, the Commission must reject the proposed reclassification, and instead take measures to control pollution from animal

[13] *Id.* at 378, and Figure 2.
[14] *Id.*
[15] *Id.*
[16] We are not suggesting that CAFOs are the only source of the DO problem, but the state has the obligation to control the contributions of CAFOs rather than move forward with the reclassification.
[17] See "Nitrogen and Phosphorus Imports to the Cape Fear and Neuse River Basins to Support Intensive Livestock Production" by Lawrence B. Cahoon, Jill A. Mikucki, and Michael A. Mallin Environ. Sci. Technol., 1999, 33 (3), pp 410–415..
[18] See "Environmental Assessment of the Lower Cape Fear River System: 2002-2003" by Michael Mallin et al. CMS Report 03-03 (2003).
[19] See "Cape Fear River Basinwide Water Quality Plan" by NC DENR (1996). Available online at: http://portal.ncdenr.org/web/wq/ps/bpu/basin/capefear/1996 (Accessed Feb. 17, 2015)
[20] Id. at 3-17 through 3-19 and referenced figure.

waste at animal feeding operations and other upstream sources in order to restore water quality.

IV. The Technical Memoranda Do Not Carry the Burden of Proof on Naturally-Occurring Pollutant or Condition Causing the LCFR Impairments

The proponent for reclassification argues that natural conditions result in levels of DO and pH that excuse the violations of water quality standards and offers four Technical Memoranda ("TM") as factual support for the proposal. These TM are grossly deficient and misleading, and they omit significant information. While water quality in the Cape Fear River is influenced by the conditions found in the swamp and estuarine areas, low DO accompanied by high copper levels can be explained only by the contribution of animal waste and other upstream sources.

A. Experts Have Shown the Correlation Between Animal Operations and Eutrophication in the Lower Cape Fear

Dr. Joann Burkholder directs the Center for Applied Aquatic Ecology at North Carolina State University. An internationally recognized expert in her field, Dr. Burkholder has studied and published articles in peer-reviewed journals on topics directly relevant to assessing the causes of impairment in the LCFR: chronic effects of nutrient over-enrichment and other chemical environmental contaminants on aquatic plants; the impacts of cyanobacteria, dinoflagellates, haptophytes, and raphidophytes on aquatic ecosystems; and influences of long-term changes in watershed land use and pollution sources on surface water quality.

Dr. Burkholder reviewed the proposed reclassification, surveyed past literature and research and provided comments regarding the TM and the merits of the proposal itself. These comments, which constitute expert opinion, show that Animal Waste, Animal Operations and CAFOs are the primary cause of impairments for DO, pH, copper and turbidity. A copy of Dr. Burkholder's review is attached to these Comments and is incorporated by reference.

Dr. Burkholder notes that CAFOs are also point sources, and that they should be treated as such in the modelling, but were not evaluated this way. Even though CAFOs in the LCFR are the most concentrated per unit surface area in the entire nation, they are not addressed in the TM. Further, even though supporting data and research showing their contribution to low DO was readily available from peer-reviewed literature, they were not mentioned, evaluated or considered. The TM did not use the best science available, but rather singled-out the information which supported the proposal. The weight of science contradicts the TM and this Commission should reject the Proposal. The applicants have failed to meet their burden of proof to support a reclassification.

B. Impairment for Copper in the LCFR and the TMDL Trigger for those Impairments Also Point to Animal Waste as the Cause

The TM selectively present information to support the proposed reclassification, but the record of research in the Cape Fear Basin demonstrates that manure nutrients from Animal Waste are both contributing to the DO deficit and are subject to the Commission's control. Copper is recommended to be added to animal feeds to promote growth.[21] Professors working at North Carolina State University studied the composition of Animal Waste using samples and the statistics on statewide inventories of livestock animals.[22] In this study, Dr. Barker and Dr. Zublena totaled all the nutrients found in all of the Animal Waste in all of North Carolina's Animal Operations as they existed in 1993. Their published findings show that more than 290 tons of copper per year were present in the Animal Waste produced by North Carolina's Animal Operations. Subsequent studies showed that nitrogen concentrations had slightly declined between 1995 and 2005, but that copper and zinc values have remained steady, with the highest concentration found in liquid animal waste produced at dairies and swine operations, followed by litters produced at broiler and turkey operations.[23] [24] In 2012, North Carolina reported more than 300 miles of streams as impaired for copper on the CWA 303(d) list. The LCFR is part of those stream miles, from just outside Navassa into the area covered by the proposal. A TMDL is needed to address the impairment caused by excess copper.

Neither swamps nor estuaries contribute copper as a naturally occurring pollutant, whereas the scientific literature shows that copper is supplemented in feed to livestock and that hundreds of tons of it are excreted in Animal Waste produced by Animal Operations. Copper impairment on the Cape Fear River is thus a red flag, a fact that the four TM conveniently omit. Coupled with the impairments for low pH and turbidity, and the TMDL previously identified as needed for the LCFR, all signs point to Animal Waste as a primary cause. (The only exception is mercury impairment). Despite this evidence, the four TM omit any information about the contribution of Animal Waste to impairment; to the extent they insist that DO problems in the LCFR are caused by "natural conditions," they are misusing that term.

[21] See "Swine Feeding Suggestions" by Clemson University Extension, Circular 505 (1995), available online at: http://www.clemson.edu/psapublishing/pages/ADVS/EC509.PDF (last accessed Feb. 26, 2015)
[22] See "Livestock Manure Nutrients in North Carolina" by Dr. J.C. Barker and J.P. Zublena (1996), available online at: http://www.bae.ncsu.edu/programs/extension/evans/assess.html (last accessed Feb. 26, 2015)
[23] See "North Carolina Trends in Animal Waste Nutrient Concentrations" by Casteel, S., B. Cleveland, D. Osmond, and C. Hudak-Wise. 2007. In Proc. Soil Science Society of America Natl. Conf. – New Orleans, LA.
[24] Researchers and policymakers for the European Commission looking at allowable concentrations of copper supplements in livestock feed found that copper had negligible benefits to animal health except for piglets and recommended research to evaluate environmental impacts of copper excreted in livestock manure.See "Opinion of the Scientific Committee for Animal Nutrition on the use of copper in feedingstuffs" by the European Commission's Health and Consumer Protection's Directorate-General (2003) available online at: http://ec.europa.eu/food/fs/sc/scan/out115_en.pdf (last accessed Feb. 26, 2015)

C. A Proper Interpretation of the Bowen Model Supports the Use of TMDL to Reduce Loading to the LCFR from sources in the Cape Fear River, Black River and Northeast Cape Fear, Including Animal Operations

The modeling effort for predicting how decreasing loading of pollution to the LCFR would impact DO levels was conducted by Dr. Jim Bowen at UNC- Charlotte (Bowen Model).[25] The Bowen Model ran several scenarios that incorporated assumptions obscuring the impacts of loadings from Animal Operations, including CAFOs. Pollution from Animal Operations, including CAFOs, was treated as given input to the modelling. The Bowen Model lumped together all upstream sources, both natural and anthropogenic, in waste load figures from the three major rivers upstream of the LCFR. Thus, the pollutant load from all sources discharging pollutants into the Northeast Cape Fear River above the LCFR model segment were lumped together into a single pollutant source. This single pollutant load is a combination of types of sources. In developing the load allocations for a TMDL, each of the upstream rivers should be evaluated further to document the contribution from each type of source, including naturally occurring conditions, whether classified as non-point or point sources. There are several NPDES-permitted facilities, including CAFOs, upstream of the LCFRP.[26] Just because the Bowen Model lumps these loads into input categories labeled by the name of their original subbasin, the supporters of the reclassification lumps together with all other upstream sources as "natural." These permitted facilities are obviously not natural sources and should be addressed by the state through the TMDL process.

In the case of the Northeast Cape Fear River, the Bowen Model labeled the upstream pollutant load under the category upstream river source number 20. Likewise the Cape Fear River and Black River were treated as source numbers 18 and 19, respectively. (See Bowen Model, Table 9, p. 47) Based on this assumption, no attempt was made to identify the sources of loadings to the Northeast Cape Fear River, Cape Fear River or the Black River. The model did not consider how much of the loads from these upstream rivers came from naturally-occurring pollutants and how much came from NPDES-permitted discharges or from Animal Waste. Thus, the Bowen Model cannot be used to support any determination that conditions are the result of naturally-occurring pollutants because it lumped the naturally-occurring and anthropogenic pollutants together in each of the three major rivers that flow into the LCFR.

[25] See: "Development and Use of a Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the Lower Cape Fear River Estuary, North Carolina available online at: http://webpages.uncc.edu/~jdbowen/LCFR/LCFR_DOModelReport_Final.pdf (last accessed Feb. 26, 2015)

[26] For example, the following permits appear as NPDES permitted facilities run in connection with livestock operations upstream of LCFR: Godwin Farms Permit no. NCA282225; Dixie Chops, Inc. Permit No. NCA282143; Timothy Smith Farm Permit No. NCA231656; and Troy Sloan Farm Permit No. NCA231655. In addition, the Smithfield Packing Company holds Permit No. NC0078344 allowing up to 3 million gallons per day of water contaminated with pollutants such as those responsible for causing the types of impairments observed in LCFR. In addition, hundreds of Animal Operations in the basin operate under state level permits for handling animal waste. These sources are not naturally occurring and the Bowen Model does not make them such based on its inputs labelling scheme.

The Bowen Model also treated the estuarine tributaries in the same fashion as the three major rivers. Therefore, the Bowen Model cannot be used to support any determination that conditions there are the result of naturally-occurring pollutants because it lumped the naturally-occurring and anthropogenic pollutants together for these tributaries. A total of 20 wastewater treatment plants (WWTPs) with NPDES permits were also evaluated. The Bowen Model concluded that reducing loadings from these 20 WWTPs would not correct DO impairment, although they did have an effect on the amount of DO impairment. The Bowen Model can be interpreted to say that reduced loadings from these 20 WWTPs will not correct DO in the LCFR, but stretching the Bowen Model to prove that the LCFR are swamp waters is unsupported scientifically and is a misreading of the Bowen Model.

Significantly, the Bowen Model did conclude that reducing the combined loading from the Northeast Cape Fear River, Cape Fear River, the Black River and the estuarine tributaries would produce significant DO improvement. This Scenario was dubbed the "Clean River" Scenario. The Report states:

> "The load reductions of riverine, creek, and wetland inputs were found to have a significant impact on the estimated dissolved oxygen concentrations during the summer months in the impaired region of the Lower Cape Fear River Estuary. At the 10th percentile level, DO concentrations for the three load reduction scenarios increased by 0.2, 0.3, and 0.4 mg/L respectively, from 4.3 mg/l to either 4.5, 4.6, or 4.7 mg/L (Figure 80). Unlike the scenarios described in the previous section in which wastewater loading decreases were investigated, the level of increase in DO concentration was maintained at the higher percentiles when reductions in the river, creek, and wetland loadings were made. In fact, for this "clean river" scenario, the median DO concentration increased to even a greater extent than the 10th percentile value, increasing from 5.6 to 5.85 mg/L for the 30% reduction (an increase of 0.25 mg/L), and from 5.6 to 6.2 mg/L (an increase of 0.6 mg/L) for the 70% reduction scenario (Figure 80)." See Bowen Model at page 142, Scenario 6-3.

The Bowen Model then concluded that cleaning up the riverine and estuarine tributaries was still not enough to meet the DO standard. But that was not the end of the modelling efforts. The Bowen team recognized that lowering the inputs from the Black River, Cape Fear River and Northeast Cape Fear River would reduce accumulation of organic materials in the sediments and thus would also reduce Sediment Oxygen Demand (SOD). In most of the model runs, the Bowen Model had held SOD contribution as constant and as uniform. Dr. Burkholder rightly critiques this assumption as a flaw in the model.

To test whether reducing both loadings from SOD and from the Black River, Cape Fear River and Northeast Cape Fear River would meet DO standards, they ran

another scenario, dubbed a "Clean River Scenario." They found that by reducing the loadings from both SOD and upstream riverine and estuarine sources, 99% of the values achieved compliance with the DO standard. As the Bowen Model report noted:

> "In this scenario we examine what conditions would be necessary to produce summertime DO concentrations above 5.0 mg/L. In addition, one limitation of the analysis done previously is that it ignores possible changes that might occur in the benthos if organic matter loadings were reduced. For instance, it is likely that a reduction of 30% or 50% or 70% in organic matter loading would in the long-term also result in lower sediment oxygen demands. The cumulative effect of decreasing both organic matter loading and sediment oxygen demand are examined in this scenario." See Bowen Model at page 146, Scenario 6-5.

The Bowen Model thus shows that a TMDL would work and the designated uses can be protected. These model runs demonstrated that a reduction in the loadings from the Cape Fear River, the Black River and the Northeast Cape Fear River, and the Estuarine Tributaries would reduce loading to SOD. Taken together, this approach would correct DO and achieve compliance. Under the Clean Rivers scenario, DO would exceed the standard 99% of the time. Dr. Bowen's team writes:

> "The 50% reduction case had an even lower rate of water quality violations, but these were not completely eliminated. With both SOD and oxygen demanding wastes decreased, approximately 7% of summertime DO concentrations in the impaired region are below 5.0 mg/L, as compared to 27% when only the oxygen demanding wastes are decreased (Figure 82). There is also a large increase in the minimum predicted DO concentration for this case. The base case had a minimum predicted DO concentration of approximately 3.2 mg/L, whereas the minimum when SOD and oxygen demanding wastes are reduced by 50% is approximately 4.6 mg/L (Figure 82). A decrease in SOD of 70% and a reduction in river load of 70%, however, does almost completely eliminate dissolved oxygen concentrations below 5.0 mg/L (Figure 82). For this case, only about 1% of the predicted dissolved oxygen concentrations are below the water quality standard value." See Bowen Model at page 142, Scenario 6-5.

The TM erred in their use of the Bowen Model by treating the Cape Fear River, Black River and Northeast Cape Fear River inputs as naturally-occurring conditions. This faulty position fails to acknowledge that each of these rivers receive large loadings from pollutant sources – mainly Animal Operations and CAFOs themselves. Once you unpack the assumptions built into the Bowen Model, you see that it actually supports a TMDL effort to reduce the loading impact from the Cape Fear River, Black River and Northeast Cape Fear River to correct the low DO in the LCFR. Loading from Animal Operations, including CAFOs, in these three tributary rivers clearly have caused an increase in LCFR DO concentrations.

D. The TM Are Incorrect in Ascribing Large Loading of Pollution to the LCFR from Riparian Wetlands

Dr. Burkholder further noted that the data do not support the assertion that inputs from riparian wetlands are "significant contributors to the tremendous loads of oxygen-demanding materials." While the Bowen Model treated loadings from the three major rivers and the estuarine tributaries as if they were discharges from giant WWTPs, the Bowen Model does not attempt to distinguish between the pollutant loading caused by anthropogenic activities and those from naturally-occurring pollutants or conditions. Riparian wetlands often act to reduce the impact of pollutants to surface waters.

Other experts have identified Animal Waste as especially significant for Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) from ammonia, in the Northeast Cape Fear River system (e.g., Mallin et al. 1997). Dr. Burkholder points out that TetraTech focused on the three largest NPDES permitted dischargers and showed that reducing loading from these sources would not correct the problem. Once again, this does not prove natural conditions. Rather, it proves that the problem can be corrected only by reducing the impact of Animal Waste and the loading coming to LCFR from the Cape Fear River, Black River and the North East Cape Fear River as supported by the Bowen Model.

Similarly, the TM authored by CH2M HILL contains a description of surface water quality conditions in summer that omits any discussion of the massive contribution of organic-rich, oxygen-demanding materials from Animal Waste. Dr. Burkholder's research, and that of her cited colleagues, shows that Animal Waste is a cause of the impairments currently found in the LCFR: copper, pH, turbidity and low DO. All available data show that past pollution must be dealt with if the Cape Fear River is to continue to serve its role as a public resource. In order to uphold its duty to the people of this State, the Commission and Department must deny the request.

V. Other Issues Prevent this Commission from Approving the Proposal as Submitted

Other problems with this proposal prevent the Commission from proceeding as proposed and require that the sidetracked TMDL proceed again to a conclusion. Even if a reclassification were an appropriate substitute for a TMDL in this case, two oversights would have to be corrected first: (1) the state failed to perform a Use Attainability Analysis (UAA) which could be approved only if the state can show that the current designated use is in fact unattainable; and (2) the fiscal assessment is grossly inadequate.

Under EPA regulations, the state must conduct a UAA if it is removing a designated use or adopting subcategories that impose less stringent water quality criteria. 40 CFR 131.10(j). The proposed reclassification would create a new subcategory for this waterbody, an action that plainly requires the completion of a UAA to demonstrate that attainment of the designated uses is not feasible. The state has not performed a UAA for

this section of the LCFR, so it has not met its obligations under EPA regulations. If the state elects to continue pursuing this reclassification, it must perform a UAA before submitting a reclassification proposal.

In addition, the state is required to prepare a fiscal note under the NC Administrative Procedures Act (APA). The current fiscal analysis claims that there will be no "quantifiable" impacts, positive or negative, of the proposal. No factual support or analysis is made for this claim. Where the extent and quantification of fiscal impacts is uncertain, the agency is forbidden from just assuming that there are none. "If an agency is not sure whether a proposed rule change would have a substantial economic impact, the agency shall ask the Office of State Budget and Management to determine whether the proposed rule change has a substantial economic impact. Failure to prepare or obtain approval of the fiscal note as required by this subsection shall be a basis for objection to the rule under G.S. 150B-21.9 (a)(4)." N.C. Gen. Stat. § 150B-21.4. The fiscal analysis provided for this proposal is plainly insufficient to meet APA requirements.

Here, we provide a few examples of the substantive inadequacies of the current fiscal analysis. First, there would be costs to the implementing agencies, as they would be required to apply the narrative swamp standards and determine whether violations were caused by natural conditions or dischargers. This would be time-intensive, and therefore costly, for the implementing agencies. Second, this proposal poses clear threats to the environment and ecosystem of the LCFR. These include negative impacts on the fish populations (and the fishing and recreation economies of the area) from the permission of decreased DO concentrations (from the reclassification that will potentially allow more lenient permits based on "natural" conditions and from the codification that will allow new permits to result in a 0.1mg/L drop in DO).

Third, the benefits associated with future planning are created by the codification component of the proposal, and entirely unrelated to the reclassification element of the proposal. Indeed, the reclassification might have the opposite effect because it will be difficult to anticipate how the state will apply the narrative standard for swamp waters. Fourth, there will plainly be economic benefits to dischargers who will have the option of dropping the DO concentration (based on the proposed codification) and the opportunity to argue that the natural conditions now being recognized also should have been considered at the time of their original permit issuance, making them eligible for an exception to the anti-backsliding policies (based on the reclassification). The economic analysis even admits that "[d]ischarges (sic) may in the future be granted additional wasteload allocations." Fifth, there is no discussion of the benefits to CAFOs, Animal Operations and Feedlots. CAFOs and Animal Operations may benefit by avoiding their federal and state obligations under NPDES or under a mandatory state TMDL program.

The Commission is not excused from its duties under the APA when impacts are difficult to quantify. It is simple to understand where the weight of the impacts resides -- doing nothing allows continued harm to the river and allows those who are polluting under the status quo to continue their behaviors. Without quantifying the impacts, it is clear that the reclassification part of the proposal is harming the local communities and

the environment, while it is benefiting the Animal Operations that are the original source of the problem. The reclassification is not economically justifiable and should be abandoned. In addition, the current document combines the fiscal analysis of the reclassification and codification components of the proposal. These should be analyzed separately, as they could be separated by the EMC, legislature, or RRC since neither one is necessary for the other. If the proposals are separated in the future, it will be important to understand if they are independently economically justifiable. The current analysis sheds no light on this issue.

VI. Starting a Conversation or Stopping it Cold

A representative from the LCFRP participated in the oral comment process and mentioned that this proposal was meant to "start the conversation" about problems on the LCFR. The actual proposal will not start a conversation, but end it. Once approved, this proposal will put an end to any discussions of the DO water quality of the LCFR. Once the existing NPDES permit holders are off-the-hook, we should expect new NPDES applicants to demand the same consideration and eliminate the management protections as the next step. In addition, low DO will continue to worsen as nutrient cycling creates a worse situation in the sediments. The current proposal is an illegal end-run around the TMDL process, which is squarely counter to the CWA's objectives and scheme. The end point of the CWA was never to surrender to water quality degradation, but to fight for clean water. Our law requires the Commission to reject this proposal.

Very Truly Yours,

/s/

Ryke Longest, Director
Duke Environmental Law and Policy Clinic

cc: EPA Region IV Administrator

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March 3, 2015

VIA ELECTRONIC MAIL
Elizabeth Kountis
DENR-DWR Planning Section
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Re: Proposed Cape Fear River swamp classification and management plan

Dear Ms. Kountis:

The Southern Environmental Law Center appreciates the opportunity to comment on the proposed classification and management plan on behalf of American Rivers, Cape Fear River Watch, and the North Carolina Conservation Network. Together, these organizations represent thousands of North Carolinians who drink, fish, swim, and paddle the state's rivers, including the Cape Fear; who place a high value on the quality of North Carolina's water resources; and who will be adversely affected by the degradation of water quality in the Cape Fear River.

The comments that follow explain and detail our objections to these proposals. Section I emphasizes changes in the goals of environmental protection that led the State to protect waters for use by aquatic life. Section II addresses the relationship between classifications that identify the uses for which waters must be protected and water quality standards designed to afford the desired protection. Section III focuses on the classification and standards applicable to swamp waters. The remaining sections state specific objections to the proposals under consideration, which we believe would ignore the best usage of the Cape Fear River and further impair use of this water body by aquatic life by, among other things, authorizing persistent lower dissolved pH and dissolved oxygen concentrations that would not be protective of species inhabiting the affected segment of the river.

I. Evolution of Protected Uses of North Carolina's Waters

The content of laws protecting North Carolina's waters has always been tied to the use for which our leaders sought to protect these natural resources. Between the colonial era and the 19th century, state and federal laws were enacted primarily to ensure use of water for drinking, navigation, and hydropower.[1] Although some 19th-century enactments designed to protect

[1] For instance, in 1899 Congress, primarily concerned with threats to the commercial use of interstate waterways, outlawed the "dumping of refuse that would obstruct navigation of navigable waters, except under a federal permit." River and Harbors Act of 1899, ch. 425, 30 Stat. 1121 (1899) (codified at 33 U.S.C. § 401-467). In North Carolina, the "first legislative acts concerning streams of the state were acts of the early colonial assembly to encourage

commerce or public health collaterally benefited aquatic life,[2] the primary legislative focus was on preserving the public's water supply source, and "[l]ittle or no protection was yet afforded other uses of surface waters."[3]

The enactment of pollution controls to protect drinking water continued into the 20th century.[4] Even laws reflecting consideration of the use of waters by aquatic life remained focused on protecting commerce or public health.[5] Between the Great Depression and World War II,[6] the focus on commerce and public health persisted, and relatively few advances in state water-pollution law occurred in that period.

After the war, federal and state governments returned their attention to controlling water pollution,[7] and the law increasingly recognized the need to protect water for reasons other than commerce and public health. In 1951, the North Carolina General Assembly enacted the State Stream Sanitation Act, observing that the "best interest of the people" was served when water resources were protected for a variety of uses, including use by aquatic life.[8] The Act created the State Stream Sanitation Committee (SSSC) and empowered it to "establish methods designed to protect the water requirement for health, recreation, fishing, agriculture, industry, and animal life."[9] This expanded approach to water pollution control was advanced by the federal Clean Water Act (CWA),[10] which sought to develop pollution-control programs to conserve water for

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navigation." David H. Howells, Quest for Clean Streams in North Carolina: An Historical Account of Stream Pollution Control in North Carolina, 258 Water Resources Res. Inst. of the Univ. of N.C. 3 (1990).

[2] *See, e.g.*, Public Laws and Resolutions, N.C. General Assembly 1883, ch. 290 (making it "unlawful for any person to put any poisonous substance or matter for the purpose of catching, killing, or driving of any fish in any of the waters of any creek or river within the state."); Public Laws and Resolutions, N.C. General Assembly 1889, ch. 52 (prohibiting sawmill owners from dumping sawdust "into any river, creek, or stream of water, whereby the channel may be obstructed or damage done to any oyster bed, or the health of any person may be impaired").

[3] Howells, *supra* n.1 at 7.

[4] *See, e.g.*, Public Laws and Resolutions, N.C. General Assembly 1903, ch. 159 (criminalizing the pollution of "any well, spring, drain, branch, brook or creek, or other source of public water supply used for drinking purposes."). Notably, the same law prohibited the discharge of raw sewage and spurred statewide advances in municipal sanitation. Howells, *supra* n.1 at 13.

[5] For instance, the Fisheries Commission Board was created in 1915 with the power to enforce new laws prohibiting the discharge of certain substances harmful to commercial fishing. Howells, *supra* n.1 at 17. Another law followed in 1927 prohibiting discharge of substances poisonous to fish in designated fish-producing waters, but "there were no prosecutions under either the 1915 or 1927 acts." *Id.* at 21-22 (noting that "the antipollution provision was never enforced by the board"). Later, in the 1920s, the State Board of Health began restricting shellfish areas where bacteriological contamination rendered harvested shellfish unsafe for human consumption. *Id.* at 18.

[6] By 1944, the State Board of Health claimed that stream sanitation was "becoming more critical each year." *Id.* at 41.

[7] The U.S. Congress enacted the Water Pollution Control Act of 1948 to provide technical and financial assistance to states for the creation of state water pollution control programs. Water Pollution Control Act, Pub. L. No. 80-845, 62 Stat. 1155 (1948).

[8] Session Laws and Resolutions, N.C. General Assembly 1951 ch. 606.

[9] *Id.*

[10] 33 U.S.C. § 1251(a). The Act sought to develop pollution control programs by giving "due regard" to the improvements necessary to conserve waters "for the protection and propagation of fish and aquatic life and wildlife, recreational purposes, and the withdrawal of such water for public water supply, agricultural, industrial, and other purposes." 33 U.S.C. § 1252(a).

various uses, including "the protection and propagation of fish and aquatic life and wildlife, recreational purposes, and the withdrawal of such water for public water supply, agricultural, industrial, and other purposes."[11]

Both federal and state leaders realized the need to categorize water resources by reference to the uses that they sought to protect by law. Accordingly, the North Carolina General Assembly required the SSSC to identify the "best usage" of the state's water resources, then to adopt associated water quality standards to protect those uses.[12] Regulations adopted to implement the CWA similarly required each state to "specify appropriate water uses to be achieved and protected" before adopting water quality standards.[13]

The early evolution of water pollution control in North Carolina serves as an important reminder that the use for which the law seeks to preserve our waters is the primary driver of the standards imposed on the regulated community. As explained below, one problem with the proposal to reclassify a portion of the Cape Fear River as a swamp is that it materially alters an important use for which the river is currently protected. In Section II, we examine the connection between use classifications and associated quality standards.

II. "Best Usage" and Classification of Water Bodies

Today, each state has a duty to adopt water quality standards under the CWA in order to protect public health or welfare, enhance the quality of water, and otherwise serve the purposes of the CWA.[14] As part of this first step in setting appropriately protective water quality standards, states must assign classifications to surface waters within their borders that identify the uses that each water body must support, and then set criteria necessary to protect the uses.

Accordingly, the uses for which the North Carolina Environmental Management Commission (EMC)[15] intends to protect North Carolina's waters are reflected in its assignment of water body classifications. The classification of a water body dictates the applicable water quality standards, which are in turn designed to protect the "best usage" of the waters with that classification.[16] The law requires the EMC to consider multiple factors before determining the classifications of waters. First, it must consider physical characteristics, including "the size, depth, surface area covered, volume, direction and rate of flow, stream gradient and temperature

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[11] *Id.* § 1252(a). North Carolina's water quality classifications must be consistent with the requirements of the CWA.
[12] Session Laws and Resolutions, N.C. General Assembly 1951 ch. 606.
[13] 40 C.F.R. § 131.10(a).
[14] 40 C.F.R. § 131.2.
[15] Many duties originally assigned to the State Stream Sanitation Committee, including those related to the classification of waters, were conferred on the Board of Water and Air Resources in 1967, 1967 N.C. Sess. Laws 1967-892 (1967), and then on the EMC in 1973, 1973 N.C. Sess. Laws 1973-1262 § 19 (1973).
[16] *See* N.C. Gen. Stat. 143-214.1(a)(1) (directing the EMC to develop "a series of classifications and the standards applicable to each such classification"); 15A N.C. Admin. Code 2B .0201 ("Existing uses . . . and the water quality to protect such uses shall be protected by properly classifying surface waters and having standards sufficient to protect these uses."); *see also* 40 C.F.R. § 131.11(a)(1) ("States must adopt those water quality criteria that protect the designated use. . . . For waters with multiple use designations, the criteria shall support the most sensitive use.")

of water."[17] It must also consider whether the "character of the district bordering said water" evinces suitability for, or established economic interest in, a particular use of the water.[18] Most importantly, the EMC must consider the uses that "have been made, are being made, or may in the future be made" of the water.[19] Ultimately, the EMC must adopt classifications and the associated standards "with primary reference to the best usage to be made of the waters to which such classification will be assigned."[20]

Pursuant to this statutory guidance, the EMC developed eight freshwater classifications, four saltwater classifications, and seven supplemental classifications for potential assignment to waters of the state.[21] Some classifications are based on the type of human use for which waters are protected.[22] Some classifications recognize that use of waters by aquatic life requires different protection in freshwater and saltwater.[23] Other classifications, particularly those designed to protect sources of drinking water, are based on the degree of development in the watershed.[24] And some of the primary classifications, like the two reserved for wetlands (Class WL for freshwater; Class SWL for saltwater) reference specific physical characteristics of the waters. The variety of available water body classifications demonstrates that the EMC realized that different uses require different protections. While these broad classifications are often sufficient to protect the best usage of waters, sometimes a more nuanced approach, involving the application of supplemental classifications, is required.

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[17] N.C. Gen. Stat. § 143-214.1.

[18] *Id.* § 143-214.1(d)(2).

[19] *Id.* § 143-214.1(d)(3) (requiring the EMC to consider "[t]he uses and extent thereof which have been made, are being made, or may in the future be made, of such water for domestic consumption, bathing, fish or wildlife and their culture, industrial consumption, transportation, fire prevention, power generation, scientific or research uses, the disposal of sewage, industrial wastes and other wastes, or any other uses"); *see also* 15A N.C. Admin. Code 2B .0101 (requiring consideration, in addition to the uses listed in G.S. 143-214.1(d), of "all existing uses" of the water body in question).

[20] N.C. Gen. Stat. § 143-214.1(b).

[21] 15A N.C. Admin. Code 2B .0101.

[22] For example, while waters in classes C, B, SC, and SB are all protected for "secondary recreation, fishing, aquatic life including propagation and survival, and wildlife," 15A N.C. Admin. Code 2B .0101(c)(1), (2); 15A N.C. Admin. Code 2B .0101(d)(1), (2), Class B and SB waters are also "protected for primary recreation." *Id.* 2B .0220(c)(1)-(2); *id.* 2B .0220(d)(1)-(2). "Primary recreation" contemplates uses "involving human body contact . . . on a frequent basis," *id.*2B .0202(52), while "secondary recreation" contemplates uses "involving human body contact with water . . . on an infrequent, unorganized, or incidental basis," *id.* 2B .0202(57).

[23] For fresh water, the default classification is Class C. 15A N.C. Admin. Code 2B .0211 ("The water quality standards for all fresh surface waters shall be the basic standards applicable to Class C waters. . . . Additional and more stringent standards applicable to other specific freshwater classifications are specified [elsewhere in] this Section."). For salt water, the default classification is Class SC. 15A N.C. Admin. Code 2B .0220 ("The water quality standards for all tidal salt waters shall be the basic standards applicable to Class SC waters. Additional and more stringent standards applicable to other specific tidal salt water classifications are specified in Rules .0221 and .0222 of this Section.").

[24] See 15A N.C. Admin. Code 2B .0101(c)(3)-(6) (listing different classifications for water supplies in "natural and undeveloped watersheds," "predominantly undeveloped watersheds," "low to moderately developed watersheds," "moderately to highly developed watersheds," and "moderately to highly developed watersheds").

Supplemental classifications are used to focus pollution control narrowly by enhancing protection in accordance with specific features of a water body. Many supplemental classifications are therefore based on the water body's physical, biological, or chemical characteristics. For instance, the "Nutrient Sensitive Waters" or "NSW" classification is reserved for "waters subject to growths of microscopic or macroscopic vegetation requiring limitations on nutrient inputs,"[25] and it requires development of strategies to control eutrophication "so that existing and designated uses of the water body are protected or restored."[26] Likewise, waters classified as trout waters (i.e., those that will "sustain and allow for trout propagation and survival of stocked trout on a year-round basis"[27]) are afforded additional protection against pollutants harmful to those fish.[28] Of particular relevance to the proposal under consideration, "waters which have low velocities and other natural characteristics which are different from adjacent streams" may be assigned a supplemental classification as "swamp waters."[29]

III. "Swamp Waters" Classification

The "swamp waters" classification is intended to protect the unique aquatic community adapted to natural conditions found in swamps. Accordingly, the water quality standards associated with the "swamp waters" classification are designed to protect the use of waters for aquatic life propagation and survival that naturally occur in swamp waters.[30] Specifically, the EMC allows certain swamp waters to have higher acidity (i.e., low pH) and lower dissolved oxygen (DO) concentrations.[31]

This is significant because the use of waters for the survival and propagation of aquatic life (i.e., aspects of the "best usage" of Class SC and Class C waters that are not also classified as swamp waters) usually requires *higher* pH and DO levels. Fish production is generally higher in more alkaline waters (i.e., those with high pH),[32] and low pH can limit development and survival

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[25] *Id.* 2B .0101(e)(3).
[26] 15A N.C. Admin. Code 2B .0223(e).
[27] 15A N.C. Admin. Code 2B .0202(65).
[28] *See, e.g.,* 15A N.C. Admin. Code 2B .0211 (stating different standards for chlorophyll-a, dissolved oxygen, cadmium, temperature, and turbidity for designated trout waters).
[29] *Id.* 2B .0101(e)(2).
[30] In contrast, other supplemental classifications result in application of more stringent water quality standards. *See, e.g.,* 15A N.C. Admin. Code 2B .0211(4) (more stringent freshwater chlorophyll-a standards for nutrient-sensitive waters and trout waters); *id.* 2B.011(6) (more stringent DO standards for trout waters); *id.* 2B .0211(19) (toluene standard applicable only to trout waters); *id.* 2B .0211(21) (more stringent turbidity standard for trout waters); *id.* 2B .0220(3) (more stringent saltwater chlorophyll-a standards for nutrient sensitive waters and trout waters); *id.* 2B .0223 (requiring development of nutrient control strategies in nutrient sensitive waters); *id.* 2B .0224 (stating standards applicable to high-quality waters); *id.* 2B .0225 (stating standards for outstanding resource waters). The State's antidegradation policy is also stricter for waters classified as high-quality waters or outstanding resource waters. *Id.* 2B .0201.
[31] 15A N.C. Admin. Code 2B .0211(6), (14) (permitting lower pH and DO standards for Class C waters with the supplemental "swamp waters" classification); 15A N.C. Admin. Code 2B .0220(5), (12) (permitting lower pH and DO standards for Class SC waters with the supplemental "swamp waters" classification).
[32] Louis A. Helfrich et al, *Liming Acidified Lakes and Ponds*, Virginia Cooperative Extension Pub. 420-254 (2009).

of shellfish by inhibiting shell development.[33] In addition, pH affects the solubility and biological availability of nutrients and heavy metals.[34] Low pH can therefore limit the nutrients available for plant growth and increase the toxicity of metals.

Similarly, DO is critical to the survival of fish and other aquatic life, and lower concentrations are typically detrimental.[35] The EMC recognized this fact when requiring higher DO concentrations in trout waters.[36] In waters with low levels of DO, finfish and mobile macroinvertebrates can experience negative impacts ranging from mortality to impaired reproduction, immune responses, and growth.[37] DO is also critical to the decomposition of organic matter in the water and bottom sediments.

In Class SC waters like the lower Cape Fear River, the normal dissolved oxygen standard is 5.0 mg/L.[38] But the law provides that "swamp waters . . . may have lower values if caused by natural conditions."[39] Similarly, while the pH in Class SC waters should be "normal for waters in the area, which range between 6.8 and 8.5,"[40] Class SC waters with the supplemental "swamp waters" classification "may have a pH as low as 4.3 if it is the result of natural conditions."[41] Indeed, the primary consequence of a supplemental designation as swamp waters is the lowering of pH and DO levels to ensure that the standards protect natural conditions.

Ultimately, the standards for pH and DO in swamp waters reflect the EMC's acknowledgment that certain aquatic species have adapted to conditions in relatively stagnant waters, where natural characteristics and processes have combined to alter the chemical composition of the aquatic environment.[42] However, lowering pH and DO where natural conditions have *not* prepared aquatic life for these stressors can have a negative impact on the usage of waters for the propagation and survival of aquatic life. This is why it is only acceptable

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[33] Saskia de Melker, *Coral Reefs and Shellfish Battle Acidifying Oceans*, PBS Newshour (Dec. 5, 2012) ("As acidity increases, animals like scallops, oysters, and clams have a harder time extracting the calcium carbonate they need to build their essential shells. Shells become thinner, growth slows down, and death rates rise."), *available at* http://www.pbs.org/newshour/updates/climate-change-july-dec12-acidification_12-05/

[34] US Geological Survey Water Science School, *ph – Water properties* (2014), available at http://water.usgs.gov/edu/ph.html.

[35] US EPA, Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras 4 (Nov. 2000) ("Oxygen is essential in aerobic organisms for the electron transport system of mitochondria. Oxygen insufficiency at the mitochondria results in reduction in cellular energy and a subsequent loss of ion balance in cellular and circulatory fluids."), *available at* http://water.epa.gov/scitech/swguidance/standards/upload/2007_03_01_criteria_dissolved_docriteria.pdf.

[36] 15A N.C. Admin. Code 2B .0220(6).

[37] Denise L. Brietburg et al, Hypoxia, Nitrogen, and Fisheries: Integrating Effects Across Local and Global Landscapes, 1 Annual Review of Marine Science 333-35 (2009), *available at* http://moritz.botany.ut.ee/~olli/eutrsem/Breitburg09.pdf.

[38] 15A N.C. Admin. Code 2B .0220(5).

[39] *Id.*

[40] 15A N.C. Admin. Code 2B 2B .0220(12).

[41] *Id.*

[42] US EPA, Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras 5 (Nov. 2000) ("Compensatory adaptations are well developed in marine animals that commonly experience hypoxia.").

for a water body designated as swamp waters to have lower pH and DO when "caused by" or the "result of" natural conditions.[43]

IV. The EMC Must Not Ignore the Defining Characteristics of Swamp Waters

The members of the Lower Cape Fear River Program (Petitioners), a collection of permitted wastewater dischargers, have asked the EMC to reclassify a segment of the Cape Fear River as swamp waters.[44] Although Petitioners argue that pH and DO levels in the Cape Fear River are the result of "natural conditions," they ignore the fact that the river lacks the natural *characteristics* that define swamp waters. The first problem with the proposal to reclassify this segment is that doing so would be directly contrary to the EMC's own definition of "swamp waters."

State regulations provide multiple definitions of "swamp waters," and in each the defining characteristic is low velocity.[45] Although Petitioners claim to support their reclassification request with "a wealth of research and technical assessment studies," data about velocity are conspicuously absent from their petition. The lack of velocity data is particularly notable given that Petitioners have a web of monitoring stations, including multiple stations in the affected segment; apparently none of the stations monitors or records velocity data.[46] Yet this is precisely the kind of "data and information required for determining" whether classification of the segment as "swamp waters" is appropriate.[47]

Given the dearth of data provided by Petitioners, it should be noted that data confirm that the Cape Fear River, in fact, has a high velocity. Studies by U.S. Army Corps of Engineers confirm that velocity in the lower Cape Fear River regularly exceeds 2 ft/s.[48] The National

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[43] 15A N.C. Admin. Code 2B .0211(6), (14); 15A N.C. Admin. Code 2B .0220(5), (12).

[44] Specifically, Petitioners seek reclassification of a portion of the river consisting of section 19-(71) from upstream of the mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut.

[45] 15A N.C. Admin. Code 02B .0101(e)(2) ("Swamp waters (Sw): waters which have low velocities and other natural characteristics which are different from adjacent streams"); 15A N.C. Admin. Code 02B .0202(62) ("Swamp waters mean those waters which are classified by the Environmental Management Commission and which are topographically located so as to generally have very low velocities and other characteristics which are different from adjacent streams draining steeper topography."); 15A N.C. Admin. Code 02B .0301(c) (defining swamp waters as "Waters which have low velocities and other natural characteristics which are different from adjacent streams").

[46] To its credit, the coalition has collected a wealth of data about other parameters, including temperature, pH, dissolved oxygen, conductivity, fecal coliform, enterococcus, turbidity, suspended residue, chlorophyll-a, NH3-N, TKN-N, NO2-NO3, Phosphorus, Cadmium, Chromium, Copper, Nickel, Lead, Zinc, Aluminum, Iron, Manganese, Mercury, Arsenic, and Hardness. http://lcfrp.uncw.edu/riverdatabase/queryAll.php?type=parameter.

[47] *See* 15A N.C. Admin. Code 2B .0101(b) (stating that the EMC may only make a classification determination after "appropriate studies of the identified waters to obtain the data and information required for determining the proper classification of the waters or segments of water are completed").

[48] Robert T. McAdory, Jr., *Cape Fear-Northest Cape Fear River, North Carolina, Numerical Model Study* (August 2000), *available at* http://acwc.sdp.sirsi.net/client/search/asset/1000633. Also, data collected by the US Geological Survey (USGS) at Lock & Dam 1 upstream of the affected segment shows that since 1982, the monthly mean discharge has ranged from 9,740 ft3/s in March to 2,940 ft3/s in August. *See* USGS, *Monitoring Station 02105769 on the Cape Fear River at Lock #1 near Kelly, NC* (2015),

Oceanic and Atmospheric Administration predicts that velocities at a monitoring station in the segment of the Cape Fear River proposed for reclassification will reach as high as 2.4 knots (4.1 ft/s) in 2015.[49] For comparison, the average velocity of the Mississippi River is near 1.2 miles per hour (1.8 ft/s) at the headwaters and 3 miles per hour (4.4 ft/s) near New Orleans.[50] Relatively high flow rates have also been documented in studies comparing the Cape Fear River estuary to others in the Southeast.[51] Indeed, the flushing effect of the high-velocity flow of the Cape Fear River has been credited with limiting the prevalence of harmful algal blooms,[52] influencing the migration patterns of local aquatic life,[53] and affecting the location of saltwater intrusion in the estuary.[54]

It would be contrary to the plain language of the law to apply to the fast-moving main stem of the Cape Fear River a "swamp water" classification reserved for waters with "low velocities" or "very low velocities." The EMC should not ignore the definition of the classification—which, critically, includes the velocity—in order to permit lower standards for DO and pH in a high-velocity segment of the river.[55] Notably, in addition to explicit consideration of velocity, the definition of "swamp waters" contemplates waters with "natural characteristics which are different from adjacent streams."[56] Yet Petitioners' argument rests on the alleged *similarity* of natural characteristics in adjacent streams.[57] The EMC should apply its

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http://waterdata.usgs.gov/nwis/monthly/?search_site_no=02105769&agency_cd=USGS&referred_module=sw&format=sites_selection_links.

[49] National Oceanic and Atmospheric Association, *Tides and Currents—2015 Tidal Current Predictions* (2015), http://tidesandcurrents.noaa.gov/get_predc.shtml?year=2015&stn=5133+Charleston Harbor&secstn=Wilmington&sbfh=%2B3&sbfm=52&fldh=%2B4&fldm=07&sbeh=%2B2&sbem=48&ebbh=%2B3&ebbm=07&fldr=0.8&ebbr=0.7&fldavgd=337&ebbavgd=153&footnote=

[50] U.S. National Park Service, Mississippi River Facts (2015), http://www.nps.gov/miss/riverfacts.htm

[51] Richard Dame et al, *Estuaries of the South Atlantic Coast of North America: Their Geographical Signatures*, 23 Estuaries 798 t.1 (2000). Of particular relevance, the data showed higher velocity flows in the Cape Fear estuary than in either the Pamlico or Neuse River estuaries. *Id.*

[52] Michael Mallin et al, *North and South Carolina Coasts*, 41 Marine Pollution Bulletin 56, 58 (2000) ("Well-flushed sounds or unconstrained rivers (such as the Cape Fear system) maintain much lower phytoplankton biomass and productivity."); *id.* at 60 (Well-flushed systems like euhaline sounds, and open rivers like the Cape Fear rarely host algal blooms)

[53] Michael P. Weinstein et al, *Retention of Three Taxa of Postlarval Fishes in an Intensively Flushed Tidal Estuary, Cape Fear River, North Carolina*, 78 Fishery Bulletin 419 (1980) (noting that "[t]idal velocities in the Cape Fear are high" and observing behavioral responses that enable fish to "avoid being flushed seaward"), *available at* http://fishbull.noaa.gov/78-2/weinstein.pdf.

[54] May Ling Becker, *Hydrodynamic Behavior of the Cape Fear River and Estuarine System: A Synthesis and Observational Investigation of Discharge-Salinity Intrusion Relationships*, 88 Estuarine, Coastal and Shelf Science 407 (May 2010).

[55] N.C. Gen. Stat. § 143-214.1.

[56] 15A N.C. Admin. Code 02B .0101(e)(2); 15A N.C. Admin. Code 02B .0301(c); see also 15A N.C. Admin. Code 02B .0202(62) (noting that swamp waters have, other than characteristically low velocity, "other characteristics which are different from adjacent streams draining steeper topography.").

[57] Petitioners contend that changing the classification of the river would "recognize the influence" of "riverine wetland and salt marsh systems that are ubiquitous" in the region and "be consistent with the classifications of [the] immediate upstream segment of the Cape Fear River and the tributaries which all currently carry the supplemental Sw classification." Chris May, Request for Reclassification of a Portion of the Lower Cape Fear River with the Supplemental Swamp Classification (March 5, 2014).

own definition of "swamp waters" and reject the proposal to misapply that supplemental classification to the lower Cape Fear River.

V. The EMC Must Not Prioritize Wastewater Discharge over Best Usage

In addition to ignoring the definition of "swamp waters" adopted by the EMC, Petitioners ignore the very purpose of classification: to protect the best usage of the water body. Petitioners make no argument that reclassification would protect the "best usage" of the segment in question. Nor do they challenge the State's oft-repeated observation that low pH and DO levels have impaired existing use of the river by aquatic life in the segment.[58] Indeed, Petitioners make no attempt to argue that classifying the river as "swamp waters" would adequately protect use of the river by aquatic life.[59]

Instead, Petitioners focus on *their* use of the river. Petitioners want the EMC to relax water quality standards so they can discharge wastewater into the river without implementing additional pollution controls necessary to protect aquatic life.[60] In other words, rather than trying to meet current standards designed to protect the best usage of the waters, Petitioners want the standards changed to accommodate their preferred usage. Since federal law explicitly prohibits the State from adopting "waste assimilation" as a designated use of the Cape Fear River,[61] Petitioners are asking the EMC to reclassify the river in a way that would allow their continued use of the river for precisely that purpose to the detriment of other designated uses.

To be clear, no one is arguing that Petitioners must stop discharging wastewater into the river. The water quality standards in place were drafted in contemplation of the effect of "the discharge of sewage, industrial wastes or other wastes including those from nonpoint sources and other sources of water pollution."[62] However, reclassification for the purpose of masking the impact of such water pollution on aquatic life is unacceptable.[63] If Petitioners want permission from the EMC to discharge effluent with pH and DO concentrations below those appropriate for class SC waters, they should seek a variance through the permitting process.[64] But the EMC must

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[58] *See, e.g.*, NC DENR, *North Carolina 303(d) List-2006* 19 (June 19, 2007) (noting impairment of use by aquatic life); NC DENR, *2014 Category 5 Water Quality Assessments-303(d) List* 3 (Dec. 19, 2014) (same).

[59] *But see* 40 C.F.R. § 131.10(a)(1) ("Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.").

[60] Current impairment of use of the river by aquatic life requires the development and implementation of a TMDL, which would include waste load allocations applicable to Petitioners.

[61] 40 C.F.R. § 131.10 ("In no case shall a State adopt waste transport or waste assimilation as a designated use for any waters of the United States.").

[62] 15A N.C. Admin. Code 2B .0205.

[63] *See* N.C. Gen. Stat. § 143-214.1(b) (directing the EMC to adopt classifications "with primary reference to the best usage to be made of the waters to which such classification will be assigned").

[64] N.C. Gen. Stat. § 143-215.3(e); 15A NCAC 2B.0226 ("Variances from applicable standards, revisions to water quality standards or site-specific water quality standards may be granted by the Commission on a case-by-case basis pursuant to G.S. 143-215.3(e), 143-214.3 or 143-214.1."). That way, their exemption, if granted from existing water quality standards could at least be reviewed as part of the triennial review of water quality standards required under federal law. *See* 15A N.C. Admin. Code 2B .0226.

not pretend that the "best usage" of the river is achieved through attainment of uncharacteristically and unnaturally low pH and DO standards that are associated with swamp waters.

Petitioners do not deny that their discharges contribute to the current impairment of the "best usage" of the river by aquatic life. This impairment was first recognized in 1998, when DENR observed that low DO concentrations meant the river was only providing "partial support" for designated use and opined that Petitioners may be to blame.[65] Even the materials offered in support of their petition establish that Petitioners' discharge contributes to the low pH and DO conditions observed in the river, although Petitioners maintain that their impact is "minor."[66]

Petitioners cite studies which they believe demonstrate that even with significant reductions in pollutant loads, dissolved oxygen in the lower Cape Fear River would occasionally fall below the current standard during summer months.[67] Petitioners apparently assume that aquatic life cannot be adequately protected if, following implementation of additional pollution controls, occasional seasonal drops in pH and DO are observed.[68] Consequently, they want the EMC to assign to the river a classification that would avoid the need to implement those additional pollution controls. Yet, when classifying the lower Cape Fear River as Class SC waters, the EMC recognized that "natural waters may on occasion, or temporarily, have characteristics outside of the normal range established by the standards" and "water quality standards will not be considered violated when values outside the normal range are caused by natural conditions."[69] In other words, the current SC classification is designed to protect use of the river for aquatic life propagation and survival *despite* occasional periods of low DO and pH in the summer months caused by natural conditions.[70] Since use of the river for aquatic life propagation and survival is possible with reasonable pollution control, the EMC should reject the proposal to lower water quality standards through reclassification and instead attempt to actually control pollution that is impairing existing use of the river by aquatic life.[71]

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[65] NC DENR, North Carolina's 1998 303(d) List T-6 (May 15, 1998) (Noting that of the 7,500 acres providing only "partial support" of designated uses, 5,000 were impaired by DO and listing wastewater treatment plants as a source of the impairment.), *available at* http://portal.ncdenr.org/c/document_library/get_file?uuid=2284d944-2134-4c57-a2d9-499c58076d4a&groupId=38364

[66] Letter from Chris May, Chair, Lower Cape Fear River Program Advisory Board, to Tom Reeder, Director, DENR-Division of Water Resources D-4 (March 5, 2014).

[67] *Id.* at D-5.

[68] Notably, oxygen solubility decreases with increasing water temperatures, so lower DO in warmer summer months is unremarkable.

[69] 15A N.C. Admin. Code. 2B .0205.

[70] Even if summertime exceedances of WQS could merit reclassification, there may exist reasonable alternatives to lowering the standards for the entire year. See 40 C.F.R. § 131.10(f) ("States may adopt seasonal uses as an alternative to reclassifying a water body or segment thereof to uses requiring less stringent water quality criteria. If seasonal uses are adopted, water quality criteria should be adjusted to reflect the seasonal uses, however, such criteria shall not preclude the attainment and maintenance of a more protective use in another season.").

[71] 40 C.F.R. § 131.10(d) (stating that "uses are deemed attainable if they can be achieved by the imposition of effluent limits . . . and cost-effective and reasonable best management practices for nonpoint source control").

By lowering pH and DO standards through reclassification, the EMC would instead further limit use of the river by aquatic life, the very use that has long been impaired by pH and DO levels, by allowing persistent, rather than occasional, conditions of low pH and DO. Essentially, reclassification would serve to authorize increased water pollution by existing point and nonpoint sources. The EMC must not apply a classification that would effectively remove an existing use.[72]

In sum, the proposal under consideration would see the EMC abandon efforts to protect the best usage of the Cape Fear River by aquatic life and instead substantially lower the applicable water quality standards for pH and DO to appease polluters who would otherwise be required to limit their pollution of North Carolina's waters. Rather than bless the degradation of water quality and wildlife habitat in the river, the EMC should reject the proposal to reclassify the Cape Fear River as swamp waters.

VI. The EMC Should Protect Use of the Cape Fear by Aquatic Life

The use of the lower Cape Fear River for the survival and propagation of aquatic life is too important to ignore or restrict through reclassification. Petitioners note that the segment in question was once classified as swamp waters, but fail to mention that the State explicitly admitted that this was the result of inadequate consideration of the best usage of the waters by aquatic life.[73] In 1981, the EMC observed that "a low pH is detrimental to shellfish propagation" and that "it is incompatible to have a classification of SA-Sw" in the lower Cape Fear River.[74] Accordingly, the EMC removed the swamp waters classification from the segment Petitioners now seek to have reclassified, as it was immediately upstream of waters classified for commercial production of shellfish and removal of the swamp waters designation was necessary to prevent impairment of the best usage of those downstream waters.[75]

In other words, swamp water classification was removed from this segment to protect aquatic life; the EMC should not repeat the mistake of ignoring effects on aquatic life by again classifying the river as swamp waters. As noted above, higher pH and DO concentrations are required to protect aquatic species unaccustomed to life in stagnant swamp waters. Low pH is

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[72] 40 C.F.R. § 131.10(h)(1) (prohibiting removal of an existing use unless a use requiring more stringent criteria is added). As previously discussed, swamp water classification involves less stringent criteria than are otherwise applicable to SC waters. At minimum, the State should conduct a use attainability analysis before applying a supplemental classification which requires less stringent criteria. 40 C.F.R.§ 131.10(j)(2).

[73] N.C. Dep't of Natural Resources and Community Development, Report of Proceedings Concerning the Proposed Reclassification of South Creek in the Tar-Pamlico River Basin and the Removal of the Swamp Water Designation from Waters in the Neuse River Basin and Cape Fear River Basin ii (1981) ("As a low pH is detrimental to shellfish propagation, it is incompatible to have a classification of SA-Sw. When the original classification of all river basins was done, this fact was recognized in all basins except the Neuse and Cape Fear.").

[74] *Id.*

[75] The segment Petitioners now seek to reclassify was immediately upstream of waters classified for commercial production of shellfish and removal of the swamp water designation was necessary prevent impairment of the best usage of those downstream waters. 40 C.F.R. § 131.10(d) ("In designating uses of a water body and the appropriate criteria for those uses, the State shall take into consideration the water quality standards of downstream waters and shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters."); 15A N.C. Admin. Code. 2B .0203.

particularly dangerous for shellfish, as noted when the EMC classified the segment as Class SC. Moreover, the portion of the river proposed for reclassification plays a critical role in the early life cycles of aquatic life and is home to endangered species.

In late winter, migratory fish including striped bass, Atlantic sturgeon, and American shad migrate from the ocean and lower Cape Fear estuary to spawn upstream in the main stem of the Cape Fear River.[76] Although adult fish return to the ocean or lower estuary after spawning, juveniles remain in nursery habitats through the summer before migrating seaward in late fall.[77] The segment proposed for reclassification includes habitat designated as primary nursery areas by the Division of Marine Fisheries (DMF).[78] Primary nursery areas (PNAs) are those "in the estuarine system where initial post-larval development takes place" and "populations are uniformly early juveniles."[79] The affected segment is also designated as an anadromous fish spawning area (AFSA) by DMF and the Wildlife Resources Commission.[80] This means "evidence of spawning anadromous fish has been documented in [DMF] sampling records through direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae."[81]

Although swamp water classification is not entirely inconsistent with labeling waters as a PNA or AFSA, care must be exercised to avoid inappropriate swamp water classification that would impact finfish at early stages of development. Low dissolved oxygen levels can be particularly problematic in spawning and nursery areas because hypoxia "causes substantial mortality of developing embryos."[82] For this reason, EPA recommends more stringent dissolved oxygen criteria for the early life stages of both coldwater and warmwater fish.[83]

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[76] Cape Fear River Partnership, Cape Fear River Basin Action Plan for Migratory Fish 18 (April 2013), *available at* http://www.habitat.noaa.gov/protection/capefear/pdf/CapeFearActionPlan.pdf

[77] *Id.*

[78] 15A N.C. Admin. Code 3R .0103.

[79] 15A N.C. Admin. Code 3I .0101; *see also* 15A N.C. Admin. Code 2B .0202 ("Primary Nursery Areas (PNAs) are tidal saltwaters which provide essential habitat for the early development of commercially important fish and shellfish and are so designated by the Marine Fisheries Commission.").

[80] 15A N.C. Admin. Code 3R .0115(25); see also Division of Marine Fisheries, Anadromous Fish Spawning Areas (AFSA): Cape Fear River Area, Map 7, *available at* http://portal.ncdenr.org/c/document_library/get_file?uuid=f810ae29-ea4d-4801-a04f-850ff2bc4467&groupId=38337

[81] Anadromous fish spawning areas are those "where evidence of spawning anadromous fish has been documented in Division sampling records through direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae." 15A N.C. Admin. Code 3I .0101(4)(b).

[82] Denise L. Brietburg et al, Hypoxia, Nitrogen, and Fisheries: Integrating Effects Across Local and Global Landscapes, 1 Annual Review of Marine Science 333 (2009)("Developing embryos are particularly sensitive because they lack the ability to behaviorally respond to low oxygen and because oxygen must diffuse across the chorion that encases the embryo."), *available at* http://moritz.botany.ut.ee/~olli/eutrsem/Breitburg09.pdf.

[83] US EPA, *Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*, app. I (Nov. 2000), *available at* http://water.epa.gov/scitech/swguidance/standards/upload/2007_03_01_criteria_dissolved_docriteria.pdf.

In addition to playing a role in the life cycles of multiple fish species, the lower Cape Fear River is home to two endangered species of sturgeon, suggesting a need for more stringent environmental protection.[84] "Maintenance and recovery of the water quality conditions required to sustain and recover federally-listed threatened and endangered aquatic animal species contributes to the support and maintenance of a balanced and indigenous community of aquatic organisms and thereby protects the biological integrity of the waters."[85] As such, the EMC should refrain from classification that could instead prove harmful to endangered aquatic life.

First, the lower Cape Fear is home to the Atlantic sturgeon, a species that NOAA's National Marine Fisheries Service first listed as endangered in 2012. Although the harvest of Atlantic sturgeon has been banned since 1991, the Atlantic States Marine Fisheries Commission (ASMFC) has stated that fishery management measures alone will not sustain stocks of Atlantic sturgeon without sufficient quality and quantity of habitat. As such, it bears emphasis that the estuarine waters of the lower Cape Fear river are precisely the type where juvenile Atlantic sturgeon "for months to years before emigrating to open ocean."[86] Moreover, ASMFC studies demonstrate that DO concentration is a "key habitat parameter[] for the structuring of juvenile Atlantic sturgeon habitat."[87] The EMC should not lower water quality standards in the Cape Fear and thereby further threaten the survival of this species.

The Lower Cape Fear also hosts a population of shortnose sturgeon, a species recognized by the federal government as endangered in 1967 and subject to a fishing moratorium since 1991. Juvenile shortnose sturgeon tend to locate in estuarine waters such as those in the segment proposed for reclassification. Consequently, "protection of essential habitats, especially nursery/summer habitats, from human caused dissolved-oxygen reductions and other impacts is critical."[88] The EMC should not relax such protection and subject this already endangered species to additional environmental stressors.

Instead, the EMC should hold the line in the fight against degrading water quality in the lower Cape Fear River. Petitioners would have the State simply quit trying to protect this resource for use by aquatic life that requires "normal" pH levels above 6.8 and/or DO levels of above 5.0 mg/L. Petitioners essentially claim that because their best efforts will not achieve universal year-round attainment of desired pH and DO levels and eliminate all naturally caused occasional exceedances of current standards, those standards should be replaced with standards designed to allow persistent low DO and pH levels to protect use of different aquatic environments. The EMC should not accept Petitioner's invitation to view the perfect as the

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[84] *See* Mary L. Moser & Steve W. Ross, *Habitat Use and Movements of Shortnose and Atlantic Sturgeon in the Lower Cape Fear River, North Carolina*, 124 Transactions of the American Fisheries Society 225 (1995).
[85] 15A N.C. Admin. Code 2B .0110.
[86] Atlantic Marine Fisheries Commission, *Habitat Addendum IV to Amendment I to the Fishery Management Plan for Atlantic Sturgeon* 2(Sept. 2012), *available at* http://www.asmfc.org/uploads/file/sturgeonHabitatAddendumIV_Sept2012.pdf
[87] *Id.* at 3.
[88] Mark R. Collins et al, *Primary Factors Affecting Sturgeon Populations in the Southeastern United States: Fishing Mortality and Degradation of Essential Habitats*, 66 Bulletin of Marine Science 917, 917 (2000), *available at*

enemy of the good. Instead, we urge the EMC to continue to manage the lower Cape Fear River so as to provide for the best usage of the water body.

VII. Management Plan

The management plan suggested by Petitioners is not designed to achieve best usage of the river and should also therefore be rejected by the EMC. Water quality management plans are supposed to be developed "to attain, maintain or enhance water quality."[89] Yet, the proposed management plan is only being put forth in recognition of the fact that classifying the lower Cape Fear River as swamp waters would lower water quality standards. As explained above, the best way for the EMC to attain, maintain or enhance water quality is to leave in place existing water quality standards and strive to attain them. Instead, the EMC is considering a management plan that starts from the premise that target goals for pH and DO in the river should be lowered.

There are a number of problems with the management plan beyond the fact that it represents a refusal to manage the river to achieve its currently defined "best usage." To begin, the plan would only apply to "new individual NPDES wastewater discharges and expansions of existing NPDES wastewater dischargers." As such, no currently permitted operations would be impacted (i.e., the effluent limits expressed in Petitioner's current NPDES permits would not be amended). In other words, just as Petitioners seek to minimize their responsibility for existing impairment of aquatic life use in the river, they also seek to minimize their responsibility for improving conditions in the river. Moreover, while Petitioners point to studies claiming that point sources contribute less than 10% of the waste load in the River, they propose a management plan that would do little to actually limit point source loading. First, due to its limitation to "individual" NPDES permittees, the management plan would not even apply to point sources operating under a general NDPES permit. The plan further limits its applicability to point sources with a provision noting that the State can impose "seasonal effluent limits for oxygen-consuming waste" on a "case-by-case basis in accordance with 15A NCAC 2B .0404." And even after substantial limitation, the management plan would not apply to point source loading in the tributaries that Petitioners claim are feeding low pH and DO waters into the segment they seek to protect through this management plan. In sum, the proposal would have the EMC adopt a management plan that applied only to a subset of point sources, only in the event of new or expanded operations, only if the permittee was not granted an exemption, and only in the area of the river where Petitioners insist point source waste loading is not resulting in impairment.[90]

Still, the greatest flaw of this management plant is that it makes no attempt to address the contribution of nonpoint sources to water pollution in the river, which are largely to blame for conditions in these tributaries. Most of the Concentrated Animal Feeding Operations (CAFOs) in the Cape Fear River basin, which produces 50% of North Carolina's swine and large numbers

[89] *See* 15A NCAC 02B .0227.

[90] *See* Letter from Chris May, Chair, Lower Cape Fear River Program Advisory Board, to Tom Reeder, Director, DENR-Division of Water Resources D-18 (March 5, 2014) (claiming that the lower Cape Fear River estuary lacks "sensitivity to changes in point source loads").

of poultry, are in watersheds drained by blackwater streams.[91] Petitioners ignore scientific analysis showing that poorly regulated waste management practices of CAFOs mean that "large amounts of nitrogen and phosphorus enter the environment through runoff, percolation into groundwater, and volatilization of ammonia,"[92] all of which can exacerbate DO and pH levels. Indeed, Petitioners ignore data published on their own website showing a statistically significant increase in ammonium in the Northeast Cape Fear River (one of the tributaries Petitioners blame for impairment of the Cape Fear River) suggesting water quality degradation by animal farming operations.[93] "Hypoxia is regulated primarily by controlling nutrients (largely nitrogen) and other oxygen-demanding wastes."[94] Yet, the proposed management plan would neither attempt to limit nonpoint source loading of nutrients and oxygen-demanding waste in the segment Petitioners seek to reclassify nor address considerable loading in upstream tributaries that Petitioner's blame for currently impaired use of the river.

Lastly, the management plan does little to ensure its own effectiveness. The proposed language states that any new or expanded discharge "shall not cause the dissolved oxygen of the receiving water to drop more than 0.1 mg/L below the modeled in-stream dissolved oxygen at total permitted capacity." Again, the plan fails to require monitoring or reduction of the effects of pollutant loading by *existing* point sources or nonpoint sources. And, despite current impairment caused by low pH in the river, the plan would not monitor the effect on pH of additional pollutant loading. The plan also fails to explain how the State will identify the cause of potential future decreases of DO concentration; this is particularly problematic given that Petitioner's reclassification request highlights the difficulty of pinpointing the cause of decreases in DO concentration. Nor is there any explanation of how frequently waters will be monitored under the plan or how the prohibition against causing DO decreases will be enforced, if at all. Finally the plan makes no mention of biological monitoring to ensure that use of the river for aquatic life survival and propagation is actually improving.

Indeed, by disregarding its effect on aquatic life, the management plan bears strong resemblance to the associated reclassification proposal. The EMC should not grant Petitioner's request for permission to further impair use of the Cape Fear River by aquatic life, but should instead continue efforts to develop an appropriate Total Maximum Daily Load (TMDL) and strive to achieve currently applicable water quality standards.

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[91] Michael A. Mallin & Lawrence B. Cahoon, *Industrialized Animal Production—A Major Source of Nutrient and Microbial Pollution to Aquatic Ecosystems*, 24 Population and Environment 369, 369 (2003).
[92] *Id.* at 379.
[93] *Id.* at 376 (citing data "published by the Lower Cape Fear River Program (available at the website http://www.uncwil.edu/cmsr/aquaticecology/labrotory/lcfrp)
[94] US EPA, *Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*, at v (Nov. 2000), *available at* http://water.epa.gov/scitech/swguidance/standards/upload/2007_03_01_criteria_dissolved_docriteria.pdf.

VIII. Conclusion

For more than 30 years, the EMC has concluded that the best usage of the lower Cape Fear by aquatic life is protected by the water quality standards for pH and DO associated with Class SC waters and that swamp waters classification was not appropriate for that segment. More recently, the EMC has recognized that usage of the lower Cape Fear River by aquatic life is impaired by low pH and DO concentrations. The State should not abandon efforts to return these waters to the conditions that support their best usage. Rather than grant its imprimatur to increasing water pollution, the EMC should continue to strive to "maintain, protect, and enhance water quality within North Carolina.[95] Accordingly, we urge the EMC to reject the proposal to adopt the proposed classification and management plan.

Thank you for the opportunity to comment on this important matter.

Sincerely,

Will Hendrick

cc (by email):
Lauren Pedder, USEPA- Region 4
Peter Raabe, American Rivers
Grady McCallie, North Carolina Conservation Network
Kemp Burdette, Cape Fear RIVERKEEPER®
Julie Youngman, Southern Environmental Law Center

[95] N.C. Gen. Stat. § 143-215.2(b).

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Clean Water - Lower Cape Fear River

Dear Ms. Elizabeth Kountis,

Under the federal Clean Water Act, the state should write a cleanup plan to reduce upstream pollution enough for the river to heal. Redefining the water quality standards in the Lower Cape Fear by calling it a 'swamp water' is not the solution to the problem. While it is true that some swamp water can have low dissolved oxygen, the Lower Cape Fear is a flowing river, not a static swamp.

Please reject the proposed reclassification of the Lower Cape Fear.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Cape Fear River

Dear Ms. Elizabeth Kountis,

Are you going to let "Big Money" ruin our river?
Under the federal Clean Water Act, the state should write a cleanup plan to reduce upstream pollution enough for the river to heal. Redefining the water quality standards in the Lower Cape Fear by calling it a 'swamp water' is not the solution to the problem. While it is true that some swamp water can have low dissolved oxygen, the Lower Cape Fear is a flowing river, not a static swamp.

Please reject the proposed reclassification of the Lower Cape Fear.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Protect our water

Dear Ms. Elizabeth Kountis,

Under the federal Clean Water Act, the state should write a cleanup plan to reduce upstream pollution enough for the river to heal. Redefining the water quality standards in the Lower Cape Fear by calling it a 'swamp water' is not the solution to the problem. While it is true that some swamp water can have low dissolved oxygen, the Lower Cape Fear is a flowing river, not a static swamp.

Please reject the proposed reclassification of the Lower Cape Fear.
Try to remember that you are tasked with protecting our environment.
Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Protect the water in the lower Cape Fear

Dear Ms. Elizabeth Kountis,

DENR, redeem yourselves! After the mess you made with the Duke coal ash leaks, your reputation as an agency that might give a damn about clean water has been seriously damaged. Now you want to solve another grave water pollution problem by redefining the description of the water rather than requiring that the pollution be cleaned up. If you do the right thing now, you may regain some public trust.
Under the federal Clean Water Act, the state should write a cleanup plan to reduce upstream pollution enough for the river to heal. Redefining the water quality standards in the Lower Cape Fear by calling it a 'swamp water' is not the solution to the problem. While it is true that some swamp water can have low dissolved oxygen, the Lower Cape Fear is a flowing river, not a static swamp.

Please reject the proposed reclassification of the Lower Cape Fear.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Guarding our Resources

Dear Ms. Elizabeth Kountis,

Under the federal Clean Water Act, the state should write a cleanup plan to reduce upstream pollution enough for the river to heal. Redefining the water quality standards in the Lower Cape Fear by calling it a 'swamp water' is not the solution to the problem. While it is true that some swamp water can have low dissolved oxygen, the Lower Cape Fear is a flowing river, not a static swamp. Having kayaked this river with my sons and grandsons I can speak first hand on this subject!

Please reject the proposed reclassification of the Lower Cape Fear.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.
Section 552 (b)(6), Personal Privac

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: nc matters

Dear Ms. Elizabeth Kountis,

The state should write a cleanup plan to reduce upstream pollution enough for the river to heal. Redefining the water quality standards in the Lower Cape Fear by calling it a 'swamp water' is not the solution to the problem.

Please reject the proposed reclassification of the Lower Cape Fear.

Thank you.

Sincerely,

Name Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Cape Fear River

Dear Ms. Elizabeth Kountis,

Under the federal Clean Water Act, the state should write a cleanup plan to reduce upstream pollution enough for the river to heal. Redefining the water quality standards in the Lower Cape Fear by calling it a 'swamp water' is not the solution to the problem. While it is true that some swamp water can have low dissolved oxygen, the Lower Cape Fear is a flowing river, not a static swamp. I, like many other enjoy kayaking the river. It is an obvious river based on using the current to plan your trip. We see many types of birds and wildlife. We also see many others who use the river for many types of recreation. This is a river, not a swamp. It is your responsibility to clean it and enforce laws. Please do so for us and for future generations.

Please reject the proposed reclassification of the Lower Cape Fear.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Clean up water safety now.

Dear Ms. Elizabeth Kountis,

Water is essential and needs to be protected and preserved, not reclassified.

Under the federal Clean Water Act, the state should write a cleanup plan to reduce upstream pollution enough for the river to heal. Redefining the water quality standards in the Lower Cape Fear by calling it a 'swamp water' is not the solution to the problem. While it is true that some swamp water can have low dissolved oxygen, the Lower Cape Fear is a flowing river, not a static swamp.

Please reject the proposed reclassification of the Lower Cape Fear.

Thank you.

Sincerely,

Dan & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Cape Fear River

Dear Ms. Elizabeth Kountis,

Dear Ms. Elizabeth Kountis,

I was sad to hear that yet again, we are trying to sweep away the acts of a big corporation at the cost of ruining the state that you and I love most.

Under the federal Clean Water Act, the state should write a cleanup plan to reduce upstream pollution enough for the river to heal. Redefining the water quality standards in the Lower Cape Fear by calling it a 'swamp water' is not the solution to the problem. While it is true that some swamp water can have low dissolved oxygen, the Lower Cape Fear is a flowing river, not a static swamp.

The Cape Fear River is not just a body of water. As a resident of Leland and Wilmington for many years, The Cape Fear River is seen as a boating, fishing, tourist attraction. It is one of the main attractions to our beautiful area of our state.

You are not cleaning it up due to funds and laziness. Do you care about our state or not? Just because factory farming puts money in pockets does not make it right. It does not make factory farming something that people want. Did you ever stop to think what the people want? That is who you ultimately are supposed to represent. We do not want factory farms, even if they are Smithfield, the Southern Ham. We would rather our Cape Fear River where we have fished with our grandparents and boated and have pictures for generations and will hope to bring more tourism for generations. Not some toxic, smelling, bad for our health factory farm, (which by the way is going to be shut down in a matter of time anyway if you open your eyes and look around it's not what your citizens want). Your citizens want natural food from farms, with no hormones, no factory farms, no phosphorous, no nitrogen, no pollution. Did you know that the majority of pollution is caused by factory farming.

Think of being a hero instead of the usual political schmuck that just buries everything under the rug. Stop taking easy ways out. Did you not get into politics to make a difference? Didn't you want to do something for your state? For your people? Here is your chance. Stand up and say NO I will not throw this under the rug, The Cape Fear River is a huge part of North Carolina and the history of it and we are not just going to let it be a swamp to save money and save a factory farm's butt. We are going to make them clean it up, by fining them and show the citizens of North Carolina that we value them and where they live as much as they do! Thank you for doing the right thing which although is never easy is always worth it in the end!

With Gratitude

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Thank you.

Sincerely,

Nancy Addison

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Clean up the Cape Fear

Dear Ms. Elizabeth Kountis,

I am very concerned about the proposed reclassification and management plan for the Lower Cape Fear River. When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Lower Cape Fear River Pollution

Dear Ms. Elizabeth Kountis,

I am very concerned about the proposed reclassification and management plan for the Lower Cape Fear River. When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

As concerned as I am with the Lower Cape Fear, I am concerned you'll rewrite the rules to affect the Neuse and the Trent as well.

BTW, are you a Republican appointee?

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Pollution in The Cape Fear River

Dear Ms. Elizabeth Kountis,

I am alarmed about the proposed reclassification and management plan for the Lower Cape Fear River. When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

PLEASE reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Thank you.

Sincerely,

Name & Address
Information Redacted pursuant to 5 U.S.C.
Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Please Act Now to Clean up the Lower Cape Fear River

Dear Ms. Elizabeth Kountis,

As a PhD marine scientist, I am very concerned about the proposed reclassification and management plan for the Lower Cape Fear River. When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Our nation's leaders and political system are being bought by industry, please stand strong and do what is right by rejecting the proposed reclassification, and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Thank you.

Sincerely,

Nancy Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Cape Fear River

Dear Ms. Elizabeth Kountis,

As an avid boater I am very concerned about the proposed reclassification and management plan for the Lower Cape Fear River. When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Thank you.

Sincerely,

Name & Address
Information Redacted pursuant to 5 U.S.C
Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: lower cape fear river

Dear Ms. Elizabeth Kountis,

I am very concerned about the proposed reclassification and management plan for the Lower Cape Fear River. When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

The animal farms, particularly pig farms have been a concern ever since I attended FTI in the 70's and ECU to get my environmental science degrees, the fact that this problem is still being discussed expresses a failure on the part of DENR. Don't cover this failure with a reclassification.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Thank you.

Sincerely,

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Protection for the Cape Fear River

Dear Ms. Elizabeth Kountis,

My family and I often go to the Cape Fear river and beaches in Beaufort and the surrounding area. It is obvious there are problems with pollution in the area that still require attention and actions to reduce that pollution. It is concerning to see large fish kills, crabs dying, and seafood/ shellfish warnings in such a beautiful and unique ecosystem. This last summer my husband and I organized a group camping trip with 4 of our 5 kids, their spouses and our grandbabies, our teenaged daughter with several teenaged friends of hers (some were boys who had never been camping). While we all marvel at the beauty of the area, it was quite distressing to all of us when we went down to the shore of the river late at night and witnessed the hundreds of little fish, big fish and crabs coming to the shore, gasping and dying. We tried to guide fish back out onto the water but they would just turn back to shore and beach themselves. Every morning the beach was littered with dead fish and
crabs.
This was a distressing thing to witness for all of us but also made us aware, and prodded us to search out information on the cause. My husband and I frequent the area of Beafort and surrounding area all up and down the coastline. It is very concerning to see shellfish warnings, large numbers of dead fish and crabs of all kinds in so many of the inlets and areas where the river and tributaries reach the sea. I've looked at the data maps and restriction maps and it is obvious there is much work to do toward cleaning up and protecting the Cape Fear River. We want to protect this beautiful place and be able to take our grandchildren there to net shrimp, gather clams and fish for their dinner. The actions of all activities up river become glaringly obvious in the Lower Cape River areas. I, my husband and our family are very concerned about the proposed reclassification and management plan for the Lower Cape Fear River. When a river is polluted, the Clean Water Act requires the s tate to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Do Not Reclassify the Lower Cape Fear River

Dear Ms. Elizabeth Kountis,

I am very concerned about the proposed reclassification and management plan for the Lower Cape Fear River. When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Citizens like myself use the Lower Cape Fear River for recreation and food, from fishing. We need to protect the river, not ignore the problems it is facing.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Cape Fear River Pollution

Dear Ms. Elizabeth Kountis,

I am very concerned about the proposed reclassification and management plan for the Lower Cape Fear River. When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Ignoring or masking the causes of pollution is never wise and invariably costs more longer-term. Please step up and assure the correct measures are taken.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: My children drink and bathe in our water

Dear Ms. Elizabeth Kountis,

Why would a smart answer to be to adjust the standards to allow more pollution rather than take measures to prevent and reduce said pollution?

I am very concerned about the proposed reclassification and management plan for the Lower Cape Fear River. When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Thank you.

Sincerely,

Name Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Dirty Cape Fear River

Dear Ms. Elizabeth Kountis,

anyone who lives around here knows that the river is terribly polluted and has been for years. we don't take our children to Carolina Beach because of this. You can see the brown colored water spreading into the Sound and ocean. Why do you continue to ignore this awful mess?

I am very concerned about the proposed reclassification and management plan for the Lower Cape Fear River. When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Cape Fear River Polution

Dear Ms. Elizabeth Kountis,

I am very concerned about the proposed reclassification and management plan for the Lower Cape Fear River. When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear. I live on the Northeast Cape Fear River and am very concerned regarding the continuing degradation of the river by farming and logging operations. Now is the time to tighten regulations before we lose this vital resource.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Reclassifying Lower Cape Fear River

Dear Ms. Elizabeth Kountis,

I am very concerned about the proposed reclassification and management plan for the Lower Cape Fear River. When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

As a concerned citizen who lives close to the Lower Cape Fear, I would like for upstream polluters to be held responsible for cleaning up their act. The river and the immense natural world it supports belongs to all of us, not just the pork producers.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Care for our water quality

Dear Ms. Elizabeth Kountis,

Water quality is hugely important to our state. Please take every step possible to protect it.

I am very concerned about the proposed reclassification and management plan for the Lower Cape Fear River. When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Fix the problem, don't hide it

Dear Ms. Elizabeth Kountis,

The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

The Lower Cape Fear has too much nutrient pollution, and it needs to be controlled, not swept under the rug. Please reject this unacceptable proposal and work towards real solutions that reduce the nitrogen and phosphorus pollution from animal farms upstream.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Cape Fear River

Dear Ms. Elizabeth Kountis,

The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

The Lower Cape Fear has too much nutrient pollution, and it needs to be controlled, not swept under the rug. Please reject this unacceptable proposal and work towards real solutions that reduce the nitrogen and phosphorus pollution from animal farms upstream.

Alternatively we can simply wait for the next hurricane to flush the water supply as often happens in the Florida Everglades.

Thank you.

Sincerely,

Nancy Madness

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Clean Up the Animal Farm Waste

Dear Ms. Elizabeth Kountis,

The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream. Don't prostitute North Carolina's beauty and nature for corporate agendas. My children have to live here and their children.

The Lower Cape Fear has too much nutrient pollution, and it needs to be controlled, not swept under the rug. Please reject this unacceptable proposal and work towards real solutions that reduce the nitrogen and phosphorus pollution from animal farms upstream.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Don't

Dear Ms. Elizabeth Kountis,

You probably already know that our local economy DEPENDS on the quality of the water in our river, and the river runs directly into our marine fisheries. Water quality is an economic issue of importance to the entire state of NC!

The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

The Lower Cape Fear has too much nutrient pollution, and it needs to be controlled, not swept under the rug. Please reject this unacceptable proposal and work towards real solutions that reduce the nitrogen and phosphorus pollution from animal farms upstream.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: citizen protection

Dear Ms. Elizabeth Kountis,

The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

Fishing in these waters is a pleasurable pastime for the local residents and we need to be protected by our government. Individually there is little we can do - which is why we rely on agencies such as yours. The Lower Cape Fear has too much nutrient pollution, and it needs to be controlled, not swept under the rug. Please reject this unacceptable proposal and work towards real solutions that reduce the nitrogen and phosphorus pollution from animal farms upstream.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C.
Section 552 (b)(6), Personal Privac

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Cape Fear River

Dear Ms. Elizabeth Kountis,

Don't make it easy on polluters!!

The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

The Lower Cape Fear has too much nutrient pollution, and it needs to be controlled, not swept under the rug. Please reject this unacceptable proposal and work towards real solutions that reduce the nitrogen and phosphorus pollution from animal farms upstream.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Cape Fear River

Dear Ms. Elizabeth Kountis,

This is the height of absurdity. Government officials should be embarrassed by the proposed reclassification. This proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

The Lower Cape Fear has too much nutrient pollution, and it needs to be controlled, not swept under the rug. Please reject this unacceptable proposal and work towards real solutions that reduce the nitrogen and phosphorus pollution from animal farms upstream.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent: Tuesday, February 24, 2015 12:50 PM
To: Kountis, Elizabeth
Subject: Cape Fear River classification

Dear Ms. Elizabeth Kountis,

I have lived my entire life on rivers--the Maumee,the Ohio, the Hidson and now the Cape Fear.The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

The Lower Cape Fear has too much nutrient pollution, and it needs to be controlled, not swept under the rug. Please reject this unacceptable proposal and work towards real solutions that reduce the nitrogen and phosphorus pollution from animal farms upstream.

Thank you.

Sincerely,

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Cape Fear River

Dear Ms. Elizabeth Kountis,

The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river, it has a very strong currant. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

The Lower Cape Fear has too much nutrient pollution, and it needs to be controlled, not swept under the rug. Please reject this unacceptable proposal and work towards real solutions that reduce the nitrogen and phosphorus pollution from animal farms upstream.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U
Section 552 (b)(6), Personal Priva

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Cape Fear River

Dear Ms. Elizabeth Kountis,

I live in Wilmington, and see the river every day. Besides it's natural beauty, the river as a clean water source for New Hanover County is essential to our citizens. The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

The Lower Cape Fear has too much nutrient pollution, and it needs to be controlled, not swept under the rug. Please reject this unacceptable proposal and work towards real solutions that reduce the nitrogen and phosphorus pollution from animal farms upstream.

Thank you.

Sincerely,

Nin's Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: CLEAN UP THIS RIVER, IT IS NOT A SWAMP

Dear Ms. Elizabeth Kountis,

The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

I own a house in a community on this river I was astounded to hear that people are afraid to let their dogs swim in it. This is a travesty and a public health risk to humans as well as dogs. You must do something to clean up the river. IT IS NOT A SWAMP!

The Lower Cape Fear has too much nutrient pollution, and it needs to be controlled, not swept under the rug. Please reject this unacceptable proposal and work towards real solutions that reduce the nitrogen and phosphorus pollution from animal farms upstream.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Pollution on the lower Cape Fear River

Dear Ms. Elizabeth Kountis,

The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. I can personally attest to this fact because I've canoed on the river and work at PPD where I've had the opportunity to watch the Cape Fear River, up close and personal.

It is really cool to watch when the tide is coming in and the downstream flow meets it and they form what looks like a small rapid. I've watched huge tree trunks moving rapidly down the river and get caught under docks.

The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

If the lower Cape Fear was a swamp then I wouldn't have to work so hard going upstream and be so grateful when going downstream.

The Lower Cape Fear has too much nutrient pollution, and it needs to be controlled, not swept under the rug. Please help find ways to control these unnecessary nutrients and reject this unacceptable proposal and work towards real solutions that reduce the nitrogen and phosphorus pollution from animal farms upstream.

Thank you.

Sincerely,

Nancy Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: NO to reclassifying LCF River.

Dear Ms. Elizabeth Kountis,

NC water quality is under attack, and evidently up for sale. Unless we gain control over runoff and dumping and drainage, we willbe ruining the most vital of all our resources at a continuation of the current rate, and damaging the oyster beds, too.

The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

The Lower Cape Fear has too much nutrient pollution, and it needs to be controlled, not swept under the rug. Please reject this unacceptable proposal and work towards real solutions that reduce the nitrogen and phosphorus pollution from animal farms upstream.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: clean Water

Dear Ms. Elizabeth Kountis,

The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Pollution of Cape Fear River

Dear Ms. Elizabeth Kountis,

Whoever is polluting the River is changing the make up of the food chain in Nature. It will take sometime but the problems from the pollution will compound beyond what can be imagined now. There is no way to fore tell the total ramifications.

It all starts small and ends when the last Dr says to a patient I really don't know what has caused this terminal illnesses.

We must take control of our responsibility and it is obvious to everyone the sooner the better.

The only thing that stops you from doing the right thing and stopping the pollution is the influence of money and unfortunately the marine life in the river halve zero dollars and the polluters have the money.

It can not be right to destroy this Ecosystem but it can be justified by the dollar. Please do the right thing and save our river you may never know the life you save may be related to you.

The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Cape Fear Water Quality

Dear Ms. Elizabeth Kountis,

The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. I fish regularily in the river. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Thank you.

Sincerely,

Name Address

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy.

Kountis, Elizabeth

From:
Sent:
To: Kountis, Elizabeth
Subject: Environment

Dear Ms. Elizabeth Kountis,

The Lower Cape Fear is surrounded by swamps, but it is not swamp water; it is a flowing river. The proposal to reclassify the river as swamp water is a transparent attempt to avoid acknowledging the serious man-made pollution problems the river has, caused by heavy loads of nitrogen and phosphorus from animal agriculture upstream.

When a river is polluted, the Clean Water Act requires the state to develop a cleanup plan involving all sources of pollution upstream. That's both legally and practically necessary here.

Please reject the proposed reclassification and instead pursue meaningful reductions in the upstream pollution that is causing the very low dissolved oxygen conditions in the Lower Cape Fear.

Please also encourage the planting of riparian tree lines and other natural pollution barriers to reduce run-off and encourage native wildlife.

Thank you.

Sincerely,

Name & Address

Information Redacted pursuant to 5 U
Section 552 (b)(6), Personal Privacy

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

JUL 24 2018

Ms. Linda Culpepper
Interim Director
Division of Water Resources
North Carolina Department of Environmental Quality
1611 Mail Service Center
Raleigh, North Carolina 27699-1611

Dear Ms. Culpepper:

The United States Environmental Protection Agency has completed its review of the State of North Carolina's reclassification of the Lower Cape Fear River (LCFR). In accordance with section 303(c) of the Clean Water Act (CWA) EPA is disapproving these revisions because the documentation provided does not meet the State's existing definition of swamp waters[1] and does not address the technical concerns expressed in the Agency's formal comments to the State in 2015.[2] The Agency's decision on these revisions is detailed in the enclosed *Decision Document of the United States Environmental Protection Agency Determination Under Section 303(c) of the Clean Water Act Review of North Carolina's Reclassification for Lower Cape Fear River.*

The revisions were approved for adoption by the North Carolina Environmental Management Commission on September 10, 2015 and May 12, 2016. The reclassification was then submitted to the Agency for review by letter, dated April 9, 2018, and received on April 19, 2018. The reclassification added the Swamp supplemental classification to a 15-mile segment of the Lower Cape Fear River and included a management strategy.

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[1] The State defines "swamp waters" as "...those waters which are classified by the Environmental Management Commission and which are topographically located so as to generally have very low velocities and other characteristics which are different from adjacent streams draining steeper topography." The State did not provide documentation indicating that the velocities and other characteristics associated with the swamp classification apply to the LCFR. Nor did North Carolina submit velocity information showing that the LCFR segment is different from adjacent streams, or provide alternative dissolved oxygen or pH values that could demonstrate protection of the organisms living in the river, including endangered sturgeon. There is no support in the record for a structured scientific assessment of the waterbody conditions affecting the attainment of the use. Therefore, the requirements of the CWA and 40 CFR Part 131 have not been met.

[2] The EPA's comment letter dated March 2, 2015, suggested that the State provide additional documentation on the waterbody conditions that define swamp waters, such as velocity, to support North Carolina's determination that the swamp classification is appropriate for this segment of the LCFR.

A certification letter from the Senior Deputy Attorney General, dated March 28, 2018, was included in the submission from North Carolina and concludes that the revision was duly adopted pursuant to State law and is valid and enforceable in the State of North Carolina. In accordance with 40 CFR section 131.21(c), new and revised state and tribal water quality standards are not effective for CWA purposes until approved by the EPA. Since the revision added a designated use for this waterbody which was not supported by the record, the revisions were determined to be inconsistent with the goals of section 101(a) of the CWA and the implementing regulations at 40 CFR part 131.

In general, the EPA is supportive of states developing and utilizing site-specific criteria to support designated uses, and will approve site-specific criteria for specific designated uses if found to be protective of such designated uses. If the State would like to pursue the development of a use attainability analysis or site-specific criteria, the Region 4 EPA staff welcomes the opportunity to work closely with the State to ensure consistency with the current regulations and develop a path forward.

If you have any questions, please feel free to contact me at (404) 562-8357, or have your staff contact Ms. Lauren Petter at (404) 562-9272.

Sincerely,

Onis "Trey" Glenn, III
Regional Administrator

Enclosure

cc: Ms. Julie A Grzyb, NC DWR NPDES
Mr. Jeff Manning, NC DWR WQS

Executive Summary of Regulatory Decision

On April 19, 2018, the North Carolina Department of Environmental Quality transmitted several revisions to the state's water quality standards including a supplemental Swamp classification to a portion of the Lower Cape Fear River (LCFR), and a companion water quality management strategy. As described more fully below, the Environmental Protection Agency (EPA) has reviewed and is disapproving three specific revisions pursuant to section 303(c) of the Clean Water Act (CWA).

Two of the three provisions identify the subject segment of the LCFR as having a Swamp classification, which results in a modification to the state's designated use for this segment. For its review, the EPA considered the available information that North Carolina provided to support the designated use revision. Based on the documentation provided by the state, the record was insufficient in two ways. First, it did not provide adequate justification that the segment meets the state's definition of "swamp waters." Second, as part of the 2015 regulatory revisions to Part 131, the regulations clarify that a structured scientific assessment is required and since the state did not provide such an assessment, the Swamp designated use change is not appropriate. Therefore, the Agency concludes that the requirements at 40 CFR § 131.10 and section 303(c)(2)(A) have not been met and the revisions to include a Swamp classification for the LCFR are disapproved. Because the EPA's disapproval removes a supplemental classification, no further action is required by the EPA, since the default tidal salt water designation remains in place.

The third provision, which is part of the companion water quality management strategy, provides for a deviation from the dissolved oxygen criterion when certain conditions are met. The state did not provide the necessary documentation to show that the provision protects the designated uses and therefore, the requirements at 40 CFR § 131.11 and section 303(c)(2)(A) have not been met and the provision is disapproved. As with the other provisions, the EPA's disapproval removes a supplemental component to the previously existing regulatory requirements so no further action is required by the EPA.

The remainder of this document outlines the full detail of the EPA's review of the revisions received on April 19, 2018.

Decision Document of the United States Environmental Protection Agency Determination Under Section 303(c) of the Clean Water Act Review of North Carolina's Reclassification for Lower Cape Fear River

Introduction

Section 303 of the Clean Water Act (CWA) requires states to establish water quality standards (WQS) and to submit any new or revised WQS to the EPA for approval or disapproval. In a letter dated April 9, 2018, from Linda Culpepper, Interim Director for the Division of Water Resources for the North Carolina Department of Environmental Quality (NCDEQ), to Trey Glenn, Regional Administrator of the EPA's Region 4 Office, NCDEQ submitted new and revised WQS for review by the EPA pursuant to section 303(c) of the CWA. In a March 28, 2018, letter, North Carolina's Senior Deputy Attorney General certified that the WQS revisions were duly adopted pursuant to North Carolina law. These materials were received by the EPA on April 19, 2018.

North Carolina's April 9, 2018, letter transmitted several revisions of the state's regulatory text to incorporate the addition of a supplemental Swamp (Sw) classification to the already existing classifications associated with a 15-mile long section of the Lower Cape Fear River (LCFR), as well as provide details on a companion water quality management strategy. As described more fully below, where the EPA has determined that the amendments to 15A NCAC 02B are themselves, new or revised WQS,[1] the EPA has reviewed and is disapproving those WQS pursuant to section 303(c) of the CWA.

Clean Water Act Requirements

In addition to the requirements of section 303 of the CWA, 33 U.S.C. § 1313, that states establish WQS and submit any new or revised standards to the EPA for review and approval or disapproval, the EPA's implementing regulations require states to specify appropriate water uses to be achieved and protected and to adopt water quality criteria that protect the designated use. See 40 CFR §§ 131.10(a) and 131.11(a). Such criteria must be based on a sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use. Id. For waters with multiple use designations, the criteria shall support the most sensitive use. Id. In addition, the EPA's regulations require that in establishing criteria, a state shall consider WQS of downstream waters and shall ensure that its WQS provide for the attainment and maintenance of WQS of downstream waters. See 40 CFR § 131.10(b).

A state's submission of water quality criteria must include (1) the methods used and analyses conducted to support WQS revisions, (2) water quality criteria sufficient to protect the designated uses and (3) a certification by the State Attorney General or other appropriate legal authority within the state that the WQS were duly adopted pursuant to state law. See 40 CFR § 131.6.

As defined in 40 CFR 131.3(g), a use attainability analysis (UAA) is a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in §131.10(g). States may designate a use, or remove a use that is *not* an existing use, if the state conducts a UAA as specified in 40 CFR 131.10(j) that demonstrates attaining the use is not feasible because of one of the factors in §131.10(g). A state must conduct a UAA as described in §131.3(g) and §131.10(g) whenever the state wishes to designate a sub-category of such a

[1] The EPA has provided FAQs on "What is a New or Revised Water Quality Standard Under CWA 303(c)(3)?" at http://water.epa.gov/scitech/swguidance/standards/cwa303faq.cfm. The link provides detailed information of such analysis.

use that requires criteria less stringent than previously applicable. See 40 CFR 131.10(j)(2). A state is not required to conduct a UAA whenever the state designates a sub-category of a use specified in section 101(a)(2) of the Act that requires criteria at least as stringent as previously applicable. See 40 CFR 131.10(k)(2).

State Regulatory Process and the Revisions

The revisions addressed in this document were discussed in a public hearing on February 5, 2015, and approved for adoption by the North Carolina Environmental Management Commission on September 10, 2015 and May 12, 2016. The first adoption date relates to the addition of 15A NCAC 02B .0311(t) and 15A NCAC 02B .0227, which were public noticed on January 2, 2015, and associated with the hearing on February 5, 2015. The second adoption date relates to the revisions to 15A NCAC 02B .0227, which were requested by the Rule Review Committee counsel, and were subsequently public noticed on December 15, 2015. No hearing was requested for the 15A NCAC 02B .0227 revisions, although a 60-day comment period was provided. In general, the revisions incorporate the supplemental Sw classification to the existing SC (salt water Class C) classification for the segment described below. The language specifically adopted in 15A NCAC 02B .0311(t) states:

> (t) The Schedule of Classifications and Water Quality Standards for the Catawba River was amended effective ~~[November 1, 2015]~~ August 1, 2016 with the reclassification of a section of 18-(71) from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut from Class SC to Class SC Sw. A site-specific management strategy is outlined in 15A NCAC 02B .0227.

The above revision became effective on August 1, 2016, and is further described below.

As noted in 15A NCAC 02B .0311(t), there is a management strategy that corresponds to this section. The language specifically adopted in 15A NCAC 02B .0227(2) states:

> (2) A part of the Cape Fear River (Cape Fear River Basin) comprised of a section of Index No.18-(71) from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut shall be protected by the Class SC Sw standards as well as the following site-specific action: All new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges shall be required to provide treatment for oxygen consuming wastes as described in Parts (A) through *(C)* of this Subparagraph.
>
> (A) Effluent limitations shall be as follows: *BODs* = 5 mg/l, NH3-N = 1 mg/1 and DO= 6 mg/l, or utilize site-specific best available technology on a case-by-case basis for industrial ~~discharges.~~ discharges in accordance with Rule .0406 (e) of this Subchapter.
>
> (B) Seasonal effluent limits for oxygen consuming wastes ~~[will]~~ shall be considered ~~on a case by case basis~~ in accordance with Rule .0404 of this Subchapter.
>
> (C) Any new or expanded permitted pollutant discharge of oxygen consuming waste shall not cause the dissolved oxygen of the receiving water to drop more than 0.1 mg/1 below the modeled in-stream dissolved oxygen at total permitted capacity for all discharges.

The original revision became effective November 1, 2015, with the final language, indicated with the tracked changes shown above, becoming effective on July 1, 2016.

Background

In North Carolina, all tidal salt waters are at least covered by the designated use of Class SC. Class SC waters are protected for aquatic life propagation and maintenance of biological integrity (including fishing and fish), wildlife, secondary recreation and any other usages except for primary recreation or shellfishing. The SC classification is also considered a primary classification. In this instance, the state has added the Sw label as a supplemental classification to the primary classification. The term "swamp waters," which is already part of North Carolina's regulations, is defined as "...those waters which are classified by the Environmental Management Commission and which are topographically located so as to generally have very low velocities and other characteristics which are different from adjacent streams draining steeper topography." They are designated by "Sw" following the water classification.

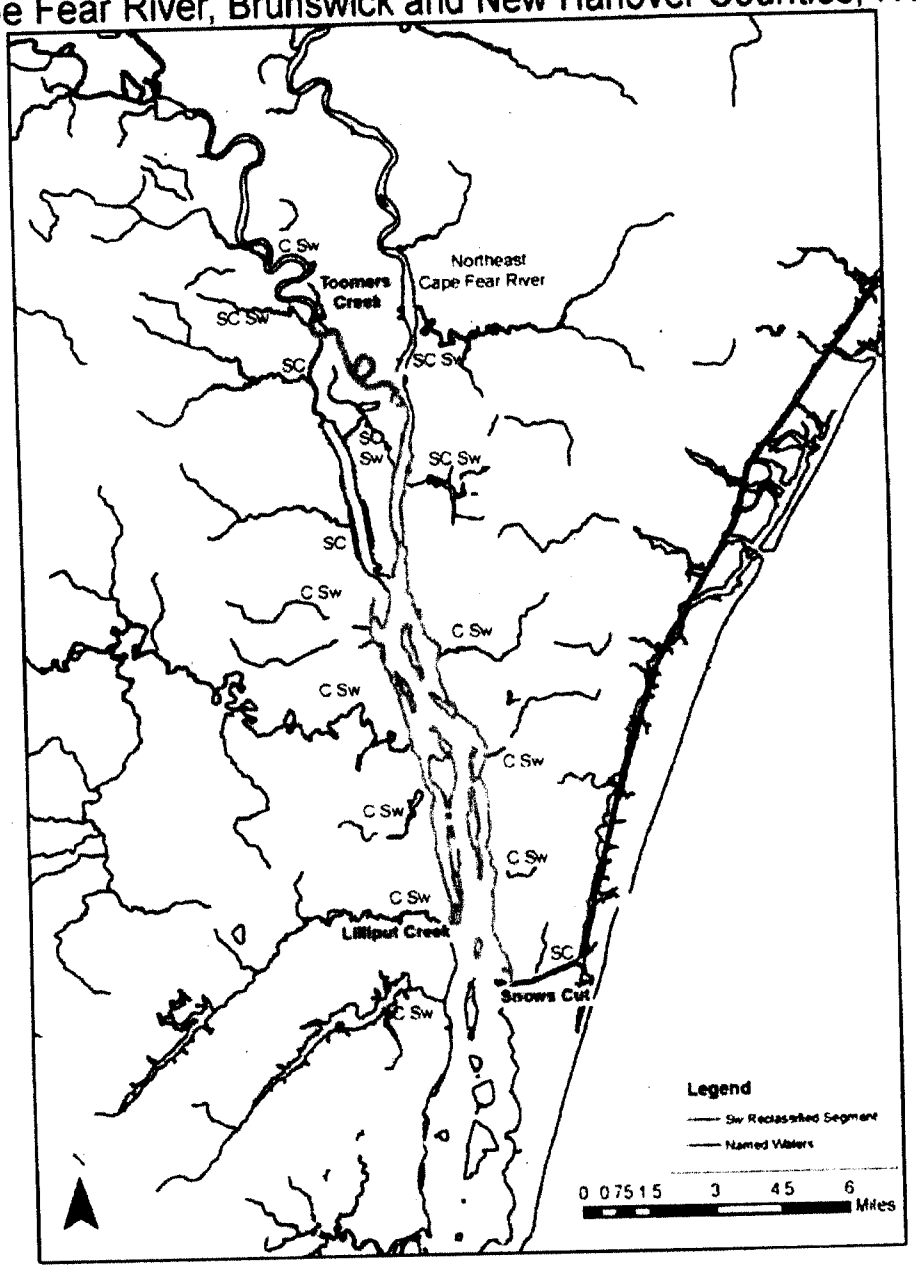
Revising the designated use of the LCFR to add the Sw supplemental classification to the existing SC primary classification allows lower dissolved oxygen and pH criteria than allowed under the SC classification, where lower dissolved oxygen or pH concentrations are caused by natural conditions. In this rulemaking, the state did not simultaneously establish the natural conditions in the river. However, the ability to have lower concentration limits than the previously applicable numeric criteria for pH and dissolved oxygen also results in a potential for lowering of the ambient water quality condition. This ability to have lower criteria is the component that ties the EPA's review to 131.10(j)(2). The following table summarizes the differences associated with the applicable pH and dissolved oxygen criteria before and after the revisions.

Classification	pH	Dissolved Oxygen (DO)
Class SC	6.8 – 8.5	5.0 mg/l
Class SC Sw	6.8 – 8.5, but as low as 4.3 if result of natural conditions	5.0 mg/l, but lower than 5.0 mg/l if caused by natural conditions

In addition to the additional criteria that can be applied to this segment, the state has adopted a water quality management plan to accompany the revisions to the designated uses for this waterbody. As part of the documentation in Enclosure 1, North Carolina indicates that a "water quality management plan is a strategy tailored to protect existing uses or quality of waters in specific waters" and 15A NCAC 02B .0227 specifically provides that: "In implementing the water quality standards to protect the existing uses...of the waters of the state or the water quality which supports those uses, the Commission shall develop water quality management plans on a priority basis to attain, maintain or enhance water quality throughout the state."

In the submission materials, the state provided the following map, which highlights the location associated with the revision, and for additional information, shows which adjacent segments have previously been designated as swamp waters.

Cape Fear River, Brunswick and New Hanover Counties, NC



EPA's Analysis of the Revisions

Before proceeding to the discussion of individual provisions, the EPA's review includes an analysis of whether or not a provision is a new or revised water quality standard. The Agency, using the decision criteria referenced in footnote 1, has determined that some of the provisions adopted by the state are not subject to the EPA's review under section 303(c). In those instances, the discussion will be brief and indicate that was the EPA's conclusion. When a provision is determined to be a new or revised water quality standard, there will be additional discussion regarding the provisions' consistency with statutory and regulatory requirements.

15A NCAC 02B .0311(t)

(t) The Schedule of Classifications and Water Quality Standards for the Catawba River was amended effective ~~[November 1, 2015]~~ August 1, 2016 with the reclassification of a section of 18-(71) from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut from Class SC to Class SC Sw. A site-specific management strategy is outlined in 15A NCAC 02B .0227.

The revision at 15A NCAC 02B .0311(t) includes two sentences. The first sentence is the primary regulatory location where the state added a Sw supplemental classification to the specified segment of the LCFR and is further discussed below. The EPA determined that the second sentence is not a new or revised WQS and therefore is not subject to review under section 303(c) of the CWA.

Since North Carolina's Sw supplemental classification is considered a designated use change, the requirements at 40 CFR § 131.10(a) ("each state must specify appropriate water uses to be achieved and protected") and section 303(c)(2)(A) ("such standards shall be established taking into consideration their use and value for...propagation of fish and wildlife...") were considered for this provision. Pursuant to 40 CFR § 131.6(b), a state's WQS submission must include "methods used and analyses conducted to support water quality standards revisions." In addition, 40 CFR 131.10(j)(2) requires a state to conduct a UAA as described in §131.3(g) and §131.10(g) whenever the state wishes to designate a sub-category of such a use that requires criteria less stringent than previously applicable. The following summarizes the EPA's review of the first sentence of 15A NCAC 02B .0311(t) relative to these regulatory and statutory requirements.

For its review of the first sentence, the EPA considered the available information that North Carolina provided to support the designated use revision. A significant consideration was whether the record supported the designated use change, the sub-category of swamp waters, as defined by the state. Based on the documentation provided by the state, the record does not provide adequate justification that this segment meets the state's definition of "swamp waters." The state did not provide documentation indicating that the velocities and other characteristics associated with the Sw classification apply to the LCFR. Nor did North Carolina submit any velocity information showing that the LCFR segment is different from adjacent streams. The EPA's comment letter dated March 2, 2015, suggested that the state provide this additional documentation to support North Carolina's determination that the Sw classification is appropriate for this segment of the LCFR.

A Southern Environmental Law Center comment letter, dated February 12, 2016, included a quote from a representative of the National Oceanographic and Atmospheric Administration indicating DO levels below 5.0 mg/L and pH of 4.3 "would be problematic for sturgeons of either species" in the river because "[f]undamentally, sturgeons are adapted for life in big, well-flowing rivers..." This statement, which speaks to both the presence of sturgeon and their habitat requirements, serves to further highlight that identifying this segment as swamp waters is inconsistent with both the common interpretation of swamp and the state's own definition of swamp waters. Additionally, while the state has indicated that the surrounding tributaries are also designated as swamp waters and therefore influencing the water quality in the 15-mile segment affected by this revision, the state has not sufficiently demonstrated that this riverine stretch of the LCFR exhibits the same swamp water characteristics of these smaller tributaries. Therefore, for the reasons described above the EPA concludes that North Carolina has not demonstrated that the subject water is "topographically located so as to generally have very low velocities and other characteristics which are different from adjacent streams draining steeper topography."

Further, the Agency considered whether the state met the requirements of 40 CFR § 131.10. As part of the 2015 regulatory revisions to Part 131, the regulations clarify that a UAA is required when a state redesignates a use to one with criteria less stringent than the previously applicable use. Since the criteria for pH and DO can be lowered in the case of natural conditions, the addition of the Sw water designated use does not require criteria at least as stringent as the previously applicable SC use. Given the lack of support in the record for a structured scientific assessment of the §131.10(g) factors affecting the attainment of the use, the Sw designated use change is not appropriate.

Based on the EPA's analysis, the Agency concludes that the requirements at 40 CFR § 131.10 and section 303(c)(2)(A) have not been met and the revision to include a Sw classification for the LCFR is disapproved. Because the EPA's disapproval removes a supplemental classification, no further action is required by the EPA, since the default Class SC designation remains in place. Therefore, North Carolina should continue to utilize the criteria associated with the Class SC designated use for all CWA purposes.

In general, the EPA is supportive of states developing and utilizing site-specific criteria to support designated uses, and will approve site-specific criteria for specific designated uses if the criteria are found to protect such designated uses. If the state would like to pursue the development of a UAA or site-specific criteria, the Region 4 EPA staff would be happy to work closely with the state to ensure consistency with the current regulations and a path forward.

15A NCAC 02B .0227(b)(2)

> (2) A part of the Cape Fear River (Cape Fear River Basin) comprised of a section of Index No.18-(71) from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut shall be protected by the Class SC Sw standards as well as the following site-specific action: All new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges shall be required to provide treatment for oxygen consuming wastes as described in Parts (A) through *(C)* of this Subparagraph.

The revision at 15A NCAC 02B .0227(b)(2) includes two sentences. The first sentence is the secondary regulatory location where the state added a Sw supplemental classification to the specified segment of the LCFR and is further discussed below. The EPA determined that the second sentence is not a new or revised WQS and therefore is not subject to review under section 303(c) of the CWA.

For the same reasons described in the analysis of the first sentence of 15A NCAC 02B .0311(t), the first sentence of 15A NCAC 02B .0227(b)(2) is disapproved and no further action is required by the EPA, since the default Class SC remains in place. Therefore, North Carolina should continue to utilize the criteria associated with the Class SC designated use for all CWA purposes.

15A NCAC 02B .0227(b)(2)(A)

> (A) Effluent limitations shall be as follows: *BODs* = 5 mg/l, NH3-N = 1 mg/l and DO= 6 mg/l, or utilize site-specific best available technology on a case-by-case basis for industrial ~~discharges.~~ discharges in accordance with Rule .0406 (e) of this Subchapter.

The EPA determined that the sentence at 15A NCAC 02B .0227(b)(2)(A) is not a new or revised WQS and therefore is not subject to review under section 303(c) of the CWA.

15A NCAC 02B .0227(b)(2)(B)

> (B) Seasonal effluent limits for oxygen consuming wastes ~~[will]~~ shall be considered ~~on a case by case basis~~ in accordance with Rule .0404 of this Subchapter.

The EPA determined that the sentence at 15A NCAC 02B .0227(b)(2)(B) is not a new or revised WQS and therefore is not subject to review under section 303(c) of the CWA.

15A NCAC 02B .0227(b)(2)(C)

> (C) Any new or expanded permitted pollutant discharge of oxygen consuming waste shall not cause the dissolved oxygen of the receiving water to drop more than 0.1 mg/1 below the modeled in-stream dissolved oxygen at total permitted capacity for all discharges.

The revision at 15A NCAC 02B .0227(b)(2)(C) allows a lowering of 0.1 mg/l from the specified condition of "the modeled in-stream dissolved oxygen at total permitting capacity for all discharges." Since this revision impacts the allowable DO concentration in the waterbody, it is a new or revised water quality standard subject to the EPA's review.

Several other states in Region 4 have adopted provisions which allow a very limited ("0.1mg/L") lowering of ambient DO concentration from a natural background condition. These provisions have typically been adopted by states because of the variable nature of DO and require a demonstration of a natural dissolved oxygen concentration before allowing the deviation of 0.1 mg/L to occur. In this instance, the provision allows DO to deviate from a condition associated with the total permitted capacity for all discharges. The technical documents used by the EPA[2] to support 0.1 mg/L lowering provisions in other states is very specific to natural conditions, not to total permitted capacity. The EPA's comment letter to North Carolina, dated March 2, 2015, suggested that the state provide additional documentation to support this provision. Pages 12-13 of North Carolina's Report of Proceedings Document provides the following response to comments from the state related to this provision:

> Point Sources
> i. The petition seems to indicate that point sources will have waste load allocations developed for them.
> ii. The management plan should include the means by which the 0.1 mg/L cap on lowered DO will be determined. Important details to establish and get reviewed by stakeholders include the model to be used, input parameters, season to be modeled, location of compliance, and whether compliance is to be based on instantaneous versus average conditions.
> iii. How will prohibition against causing DO decreases be enforced it at all?
> iv. Replace "Any" with "All" (at the start of the last sentence of the proposed management plan) so that the cumulative impact of all additional permitted oxygen consuming waste is a diminishment of less than 0.1mg/L.
> v. Shouldn't allow any discharges to drop the DO levels; require whatever necessary to prevent that. 10 discharges could drop it 1 mg/l.

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[2] U.S. Environmental Protection Agency's Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003. (April 1986).

Section 4, Precision and Bias, of the Membrane Electrode Method in *Standard Methods for the Examination of Water and Wasterwater*

vi. Need to set limits on industrial facilities' discharges as with non-industrial discharges.

• **Response:** The language within the following response is not proposed to be incorporated into the rule, but to provide information on how the dissolved oxygen impact from new or expanding discharges will most likely be assessed by the Division.

The model to be used will be the most currently available three dimensional water quality model, which at this time, is the Lower Cape Fear dissolved oxygen model, http://portal.ncdenr.org/c/document_library/get_file?uuid=a84477db-4d83-4cc0-a9b9-f7da7a6a51f9&groupId=38364. The model was finalized on October 2009 by the Division of Water Quality (now known as the Division of Water Resources). The model is calibrated to 2004 observed data and meteorological conditions. Model inputs are described in the report. The most critical season when dissolved oxygen is expected to be impacted is April-October, and this season will be the focus for model comparison.

The model will first be run with all existing discharges at full permitted capacity. This run will establish a baseline model for comparison. The baseline model will then be run with the addition of the proposed new or expanding discharge. Results from the two model runs will then be evaluated to determine the impact of a new or expanding discharge, and the entire area that is impacted by the discharge will be evaluated. If at any time there is a difference between these two model runs greater than 0.1 mg/L, the discharge will not be allowed. So, this approach will basically be a time-series comparison based on model output, and prohibition against causing DO decreases will be enforced via permit requirements stated in the proposed water quality management plan.

When modeling is conducted for a new or expanded discharge (as described directly above), the term "total permitted capacity" as stated in the proposed water quality management plan is to include all existing discharges as operating at their full permit limits plus the new or expanded discharge operating at its full permit limits. Rather than making the suggested language replacement as noted in the above fourth comment regarding point sources, DWR proposes to provide clarity to this issue by adding the following phrase to the end of the last sentence of the management plan: "for all discharges." Thus, the final sentence of the management plan would read as follows: "Any new or expanded permitted pollutant discharge of oxygen consuming waste shall not cause the DO of the receiving water to drop more than 0.1 mg/l below the modeled in-stream DO at total permitted capacity for all discharges."

The provision adopted by North Carolina raises both technical and legal concerns. Technically, the state also has not documented how allowing a deviation of 0.1 mg/L from the condition described in the provision (modeled in-stream DO at total permitted capacity for all discharges) protects the designated uses. Independent of that, the provision does not appear to be consistent with past provisions adopted in other Region 4 states, which allow deviations of DO up to 0.1mg/L from natural background conditions as recommended in EPA guidance. Legally, as written, the provision allows a different DO criterion expectation for National Pollutant Discharge Elimination System (NPDES) facilities which are new or expanding. Criteria must apply for all purposes under the CWA, and cannot be implemented for only some purposes under the CWA, such as NPDES permitting. Because of these concerns, the Agency concludes that the requirements of 40 CFR § 131.11 and section 303(c)(2)(A) have not been met.

Therefore, the EPA is disapproving this sentence and North Carolina should continue to utilize the criteria associated with the Class SC designated use for all CWA purposes.

Should North Carolina revise the designated use for this segment of the LCFR in the future, two possible options are available for North Carolina to address the EPA's disapproval of these revised WQS. The options include either developing a scientific record that supports the deviation of 0.1 mg/L from the total permitted capacity for all discharges or making the provision more akin to the natural conditions deviation language of other states. If the latter option is chosen for a future revision by the state, it is the EPA's recommendation that the state define in regulation what the natural condition of the LCFR is, at the same rulemaking time, in order to facilitate the use of such a provision.

Endangered Species Act

Section 7(a)(2) of the Endangered Species Act requires federal agencies, in consultation with the Fish and Wildlife Service or the National Marine Fisheries Service, to ensure that their actions are not likely to jeopardize the continued existence of federally listed species or result in the destruction or adverse modification of designated critical habitat of such species. However, the EPA Region 4 office concluded that there is no action to consult on since the revisions are either being disapproved or are not new or revised WQS.

Conclusion

Based on the reasons outlined above, it is our conclusion that the requirements of the CWA and 40 CFR part 131 have not been met for the revised use classification and the accompanying water quality management strategy revisions, which were subject to our review, and are therefore disapproved.

JUL 24 2018

Date

Onis "Trey" Glenn, III
Regional Administrator

Water Resources
Environmental Quality

Region 4 - RA's Office
APR 19 2018
Received

ROY COOPER
Governor
MICHAEL S. REGAN
Secretary
LINDA CULPEPPER
Interim Director

April 9, 2018

Mr. Trey Glenn, Regional Administrator
Environmental Protection Agency, Region 4
61 Forsyth Street SW
Atlanta, GA 30303

SUBJECT: Request for Approval of Modifications to North Carolina's Surface Water Quality Classifications

Dear Mr. Glenn:

In accordance with the provisions of Section 303 of the Clean Water Act, I am submitting North Carolina's formal request for review and approval of select revisions to the Surface Water Quality Standards and Stream Classifications rules that became effective in 2017. These revisions pertain to the reclassification of a segment of the Cape Fear River, and are part of the state's Triennial Review of Classifications and Standards.

The reclassification from Class SC to Class SC Sw was based on scientific information provided by the requestor as well as information available to North Carolina's Division of Water Resources staff. This information included documents such as:

- "The Relationship of Adjacent Wetlands and Salt Marsh to Dissolved Oxygen in the Lower Cape Fear River Estuary" (Tetra Tech, 2014)
- "Analysis of Water Quality Data at Cape River Estuary Model Boundaries" and "Summary of Background Information and Previous Studies for the Lower Cape Fear River" (CH_2MHill, 2014)
- "Development and Use of a Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the Lower Cape Fear River Estuary, North Carolina" (Bowen, et al., 2009)
- "The Potential Impacts of Climate Change on Coastal North Carolina" (University of North Carolina Wilmington, 2008)

Standards applicable to Class SC waters, which include the subject waters, provide a base of protection to all North Carolina's tidal salt waters. The supplemental Sw classification recognizes natural conditions, most notably for pH and DO. Thus, additional ambient DO & pH standards apply in the subject waters under natural conditions. This proposal recognizes the inputs and effects of the majority of waters that drain into subject waters, which are also classified as Sw.

To aid the review, a water quality management plan is included for the subject waters that proceeded through rulemaking with the reclassification. The water quality management plan is consistent with and helps to implement the permitting strategy in place for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters. The management plan contains effluent limits that new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges within

the river segment must meet regarding oxygen consuming wastes as of the effective date of the rule. These limits are more stringent than the standards regarding oxygen consuming wastes for Class SC or Class Sw waters, and are very similar to the limits for one of the state's most restrictive supplemental classifications, High Quality Waters.

Discharge Effluent Limit	Before Reclassification	After Reclassification[1]
BOD_5	≥1 MGD = 5 mg/l < 1 MGD = 5 mg/l	5 mg/l
Ammonia Nitrogen	≥ 1 MGD = 1 mg/l < 1 MGD = 2 mg/l	1 mg/l
DO	5 mg/l	6 mg/l
In-stream delta DO	< 0.5 mg/l [2]	< 0.1 mg/l [3]

1. For industrial discharges, site-specific best available technology on a case-by-case basis would be utilized to determine the limits for BOD5, Ammonia and DO according to 15A NCAC 02B .0406(e).
2. HQW rules require more stringent limits if in-stream DO drops more than 0.5 mg/l.
3. The in-stream DO is not to drop more than 0.1 mg/l below the modeled in-stream DO at total permitted capacity for all discharges.

A complete listing of the enclosures submitted as part of this package is enclosed, including a map that indicates all of the upstream waters that are already supplementally classified with the Sw classification. A letter of opinion from our Attorney General certifying that the revised rule was adopted following public hearing and that the revisions are valid and enforceable in the State of North Carolina is included as Enclosure 4.

We believe the reclassification included in this package meets the requirements of the Clean Water Act. If there are any questions during the review, please feel free to contact Elizabeth Kountis at (919) 807-6418.

Sincerely,

Linda Culpepper
Interim Director, Division of Water Resources

TR:EK

Enclosures

cc: Annie Godfrey (EPA)
Tom Fransen (DWR)

List of Enclosures

Enclosure #	Title of Enclosure	Page
Enclosure 1.	*Summary of North Carolina Surface Water Quality Reclassification Effective June 30, 2017 (includes "Table 1. Surface Water Reclassification That Became Effective on June 30, 2017")*	*1*
Enclosure 2.	*Schedule of Classification as Amended on June 30, 2017*	*5*
Enclosure 3.	*Records of Rule-Making for Reclassification*	*7*
Enclosure 4.	*Attorney General's Certification*	*18*

Enclosure 1.
Summary of North Carolina Surface Water Quality Reclassification Effective on June 30, 2017

Summary of North Carolina Surface Water Quality Reclassification Effective June 30, 2017

On June 30, 2017, one surface water reclassification became effective (see Table 1).

Table 1. Surface Water Reclassification That Became Effective on June 30, 2017

Waterbody	River Basin	County	Class Change From	Class Change To	Public Hearing	EMC Final Action	Effective Date
Cape Fear River	Cape Fear	New Hanover, Brunswick	SC	SC Sw (with a water quality management plan)	02/05/15	09/10/15 (and 05/12/16)	June 30, 2017

The chemical, physical, and biological properties; character of the watershed and bordering areas; economic effects; and past, present, and future uses of the watershed were considered when determining the appropriate class for this reclassification.

The most common and basic classification for tidal salt water is Class SC. Class SC waters are protected for aquatic life propagation and maintenance of biological integrity (including fishing and fish), wildlife, secondary recreation and any other usages except for primary recreation or shellfishing. All tidal salt waters of the state are at least protected for Class SC uses.

The SC classification is a primary classification whereas the Sw classification is a supplemental classification that can accompany a primary classification. Sw waters are waters that are topographically located so as to generally have natural characteristics such as low velocity, dissolved oxygen, or pH, which are different from streams draining steeper topography.

A water quality management plan is a strategy tailored to protect existing uses or quality of waters in specific waters. "In implementing the water quality standards to protect the existing uses...of the waters of the state or the water quality which supports those uses, the Commission shall develop water quality management plans on a priority basis to attain, maintain or enhance water quality throughout the state" (15A NCAC 02B .0227).

The reclassification submitted for approval involves a portion of the lower Cape Fear River reclassified from SC to SC Sw. The main segment of the Cape Fear River directly above the reclassified river segment is classified C Sw, and the largest tributary to the subject waters, which is located immediately upstream of the subject waters, is the Northeast Cape Fear River and is classified SC Sw. The majority of the named waters flowing into the subject waters already carry the Sw designation, and this proposal recognizes the inputs and effects of all Sw waters that drain into subject waters. The highly flushed portion of the lower segment of the Cape Fear Rives is not included in this reclassification (see attached map).

Standards applicable to Class SC waters, which include the subject waters, provide a base of protection to all North Carolina's tidal salt waters. The supplemental Sw classification

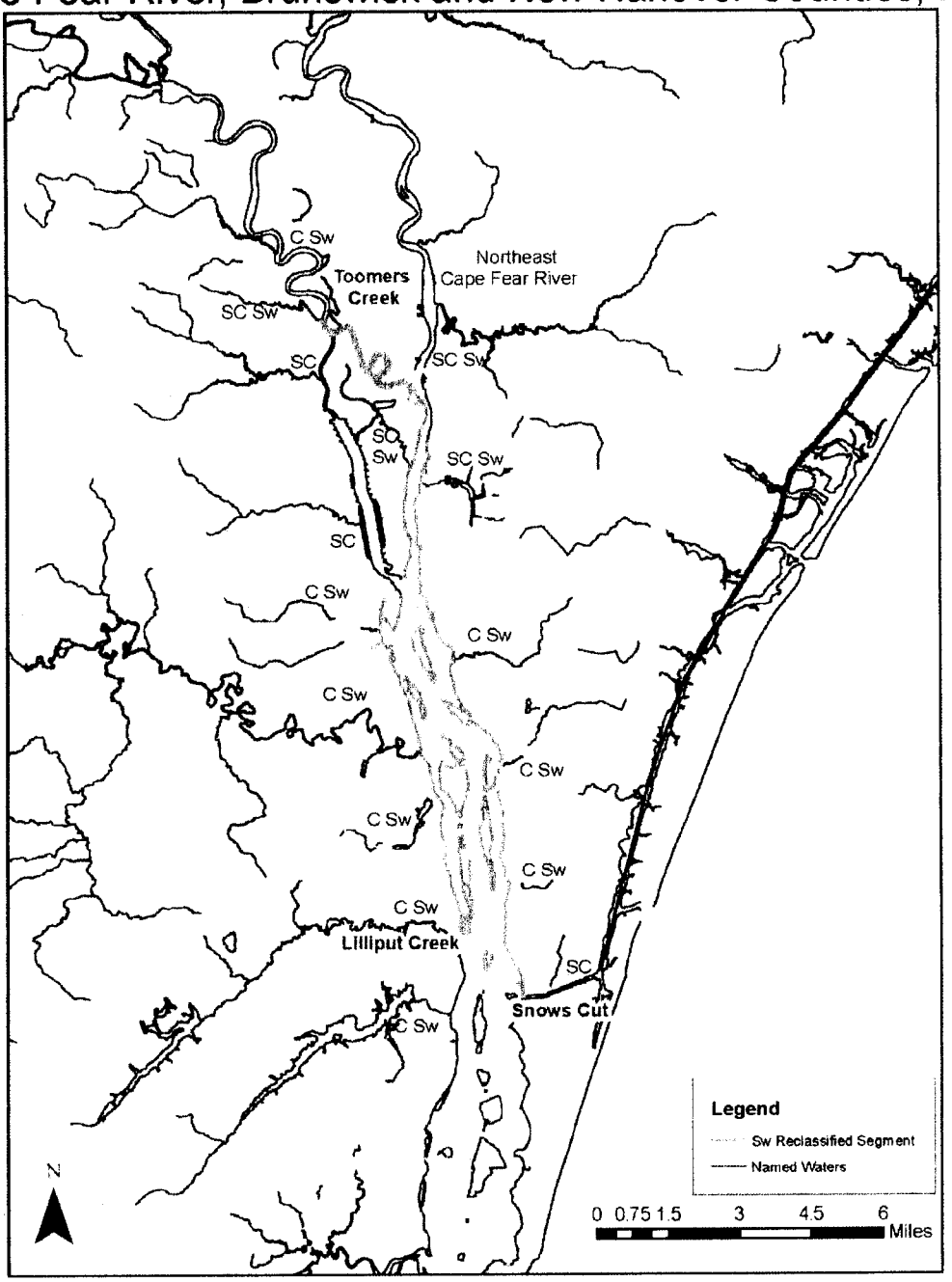
recognizes natural conditions, most notably for pH and DO. Thus, additional ambient DO & pH standards apply in the subject waters under natural conditions.

For your information, a water quality management plan is included for the subject waters that proceeded through rulemaking with the Sw reclassification. The water quality management plan is consistent with and helps to implement the current permitting strategy already in place for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters, which is designed to address water quality and existing uses of these waters. The management plan contains effluent limits that new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges within the river segment must meet regarding oxygen consuming wastes. These limits are more stringent than the standards regarding oxygen consuming wastes for Class SC or Class Sw waters.

The reclassification in conjunction with the management plan aid existing and future communities and the above-mentioned NPDES facilities in this area in preparing for the future. The management plan informs these communities and facilities about what to expect in terms of permitting, thus providing a path forward for future planning purposes.

A "Report of Proceedings" as well as an addendum to that document for the above-mentioned reclassification can be accessed at http://deq.nc.gov/about/divisions/water-resources/planning/classification-standards/current-reclassification-proposals.

Swamp Reclassification and Water Quality Management Plan
Cape Fear River, Brunswick and New Hanover Counties, NC



Enclosure 2.
Schedule of Classifications
as Amended on June 30, 2017

Reference Material to Regulation 15A 2B .0311 Cape Fear River Basin, entitled CLASSIFICATIONS AND WATER QUALITY STANDARDS ASSIGNED TO THE WATERS OF THE CAPE FEAR RIVER BASIN, has been amended 6-30-2017 as follows:

Name of Stream	***Description***	***Class***	***Stream Index #***
Cape Fear River	From upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut	SC Sw	18-(85.5)

Enclosure 3.
Records of Rule-Making for Reclassification

file
5/19/16

SUBMISSION FOR PERMANENT RULE

1. Rule-Making Agency: Environmental Management Commission (EMC)

2. Rule citation & name (name not required for repeal):
15A NCAC 02B .0227 Water Quality Management Plans

3. Action:
☐ ADOPTION ☒ AMENDMENT ☐ REPEAL ☐ READOPTION

4. Rule exempt from RRC review?
☐ Yes. Cite authority:
☒ No

5. Rule automatically subject to legislative review?
☐ Yes. Cite authority:
☒ No

FILED
2016 MAY 19 AM 9:45
OFFICE OF ADMIN HEARINGS

6. Notice for Proposed Rule:

☒ **Notice Required**
Notice of Text published on: December 15, 2015
Link to Agency notice: http://portal.ncdenr.org/web/wq/rules
Hearing on: No hearing held
Adoption by Agency on: May 12, 2016
☐ **Notice not required under G.S.:**
Adoption by Agency on:

7. Rule establishes or increases a fee? (See G.S. 12-3.1)

☐ **Yes**
Agency submitted request for consultation on:
Consultation not required. Cite authority:

☒ **No**

8. Fiscal impact (check all that apply):

☐ **State funds affected**
☐ **Environmental permitting of DOT affected and analysis submitted to Board of Transportation**
☐ **Local funds affected**
☐ **Substantial economic impact (≥$1,000,000)**
☐ **Approved by OSBM**
☒ **No fiscal note required**

9. REASON FOR ACTION

9A. What prompted this action? Check all that apply:

☒ **Agency**
☐ **Court order / cite:**
☐ **Federal statute / cite:**
☐ **Federal regulation / cite:**
☐ **Legislation enacted by the General Assembly**
Cite Session Law:
☐ **Petition for rule-making**
☐ **Other:**

9B. Explain:
At the September 2015 EMC meeting, the EMC approved rule amendments reflecting the reclassification of a portion of the Cape Fear River in New Hanover and Brunswick Counties to Class SC Sw with a water quality management plan. The rulemaking involved proposed amendments to 15A NCAC 2B .0227 and .0311 that had been publicly noticed in early 2015 and adopted in conjunction with each other. Then the Division of Water Resources (DWR) submitted the rule amendments to the RRC, and RRC counsel requested technical changes to 2B .0227 but not 2B .0311. DWR responded to the requested technical changes with a revised version of 2B .0227 that EMC approved at its November 2015 meeting to go out to public notice unaccompanied by 2B .0311. A 60-day public notice period was held from December 15, 2015 – February 15, 2016, and EMC adopted revisions to 2B .0227 on May 12, 2016.

10. Rule-making Coordinator: Jennifer Everett
Address: 1601 Mail Service Center
Raleigh, NC 27699-1601
Phone: (919)707-8614
E-Mail:
jennifer.everett@ncdenr.gov
Agency Contact, if any: Elizabeth Kountis
Phone: (919)807-6418
E-Mail: elizabeth.kountis@ncdenr.gov

11. Signature of Agency Head* or Rule-making Coordinator:

J. L. Everett

***If this function has been delegated (reassigned) pursuant to G.S. 143B-10(a), submit a copy of the delegation with this form.**

Typed Name: Jennifer Everett
Title: Rule-making Coordinator

RRC AND OAH USE ONLY

Action taken:

☐ RRC extended period of review:
☐ RRC determined substantial changes:
☐ Withdrawn by agency
☐ Subject to Legislative Review
☐ Other:

file
6/2/16

FILED

15A NCAC 02B .0227 has been amended with changes as published in 30:12 NCR 1277-1278 as follows:

2016 JUN -2 PM 12: 35

15A NCAC 02B .0227 WATER QUALITY MANAGEMENT PLANS

OFFICE OF ADMIN HEARINGS

(a) In implementing the water quality standards to protect the ~~existing uses~~ "existing uses" [as defined by Rule .0202 of this Section] of the waters of the state or the water quality ~~which~~ that supports those uses, the Commission shall develop water quality management plans on a priority basis to attain, maintain or enhance water quality throughout the state. Additional specific actions deemed necessary by the Commission to protect the water quality or the existing uses of the waters of the state shall be specified in Paragraph (b) of this Rule. These actions may include anything within the powers of the Commission. The Commission may also consider local actions ~~which~~ that have been taken to protect a waterbody in determining the appropriate protection options to be incorporated into the water quality management plan.

(b) All waters determined by the Commission to be protected by a water quality management plan are listed with specific actions either in Rules .0601 - .0608 of this Subchapter that address the Goose Creek watershed (Yadkin Pee-Dee River Basin) or as follows:

(1) The Lockwoods Folly River Area (Lumber River Basin), which includes all waters of the lower Lockwoods Folly River in an area extending north from the Intracoastal Waterway to a line extending from Genoes Point to Mullet Creek, shall be protected by the specific actions described in Parts (A) through ~~(E)~~ (D) of this Subparagraph.

(A) New development activities within 575' of the mean high water line ~~which~~ that require a Sedimentation Erosion Control Plan or a CAMA major development permit ~~must~~ shall comply with the low density option of the coastal ~~Stormwater~~ stormwater ~~Runoff Disposal Rules~~ requirements [~~as specified in 15A NCAC 2H .1005(2)(a)~~]. as specified in 15A NCAC 2H ~~.1005(2)(a)~~ .1005(3)(a).

(B) New or expanded NPDES permits shall be issued only for non-domestic, non-industrial process type discharges ~~(such as non-industrial process cooling or seafood processing discharges).~~ such as non-industrial process cooling or seafood processing discharges. A public hearing ~~is~~ shall be mandatory for any proposed (new or expanded) NPDES permit to this protected area.

~~(C) New non-discharge permits shall be required to meet reduced loading rates and increased buffer zones, to be determined on a case by case basis.~~

~~(D)~~(C) New or expanded marinas ~~must~~ shall be located in upland basin areas.

~~(E)~~(D) No dredge or fill activities shall be allowed ~~where significant shellfish or submerged aquatic vegetation bed resources occur,~~ if those activities would result in a reduction of the beds of ~~submerged~~ "submerged aquatic vegetation [~~habitat~~] habitat" or [~~a reduction of shellfish~~] "shellfish producing habitat" [~~habitat as which~~] that are defined in [~~15A NCAC 03I .0101(b)(20)(A) and (B),~~] 15A NCAC 03I .0101, except for maintenance dredging, such as that required to maintain access to existing channels and facilities located within the protected area or maintenance dredging for activities such as agriculture.

(2) A part of the Cape Fear River (Cape Fear River Basin) comprised of a section of Index No.18-(71) from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut shall be protected by the Class SC Sw standards as well as the following site-specific action: All new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges shall be required to provide treatment for oxygen consuming wastes as described in Parts (A) through (C) of this Subparagraph.

(A) Effluent limitations shall be as follows: BOD_5 = 5 mg/l, NH_3-N = 1 mg/l and DO = 6 mg/l, or utilize site-specific best available technology on a case-by-case basis for industrial ~~discharges~~.discharges in accordance with Rule .0406 (e) of this Subchapter.

(B) Seasonal effluent limits for oxygen consuming wastes [~~will~~] shall be considered ~~on a case-by-case basis~~ in accordance with Rule .0404 of this Subchapter.

(C) Any new or expanded permitted pollutant discharge of oxygen consuming waste shall not cause the dissolved oxygen of the receiving water to drop more than 0.1 mg/l below the modeled in-stream dissolved oxygen at total permitted capacity for all discharges.

History Note: *Authority G.S. 143-214.1; 143-215.8A;*
Eff. October 1, 1995;
Amended Eff. ~~November 1, 2015;~~ July 1, 2016; January 1, 1996.

file
6/14/16

SUBMISSION FOR PERMANENT RULE

1. Rule-Making Agency: Environmental Management Commission

2. Rule citation & name (name not required for repeal): 15A NCAC 02B .0311 Cape Fear River Basin

3. Action:
☐ ADOPTION ☒ AMENDMENT ☐ REPEAL

FILED
2016 JUN 14 AM 11:49
OFFICE OF ADMIN HEARINGS

4. Rule exempt from RRC review?
☐ Yes. Cite authority:
☒ No

5. Rule automatically subject to legislative review?
☐ Yes. Cite authority:
☒ No

6. Notice for Proposed Rule:

☒ Notice Required
Notice of Text published on: January 2, 2015
Link to Agency notice: http://portal.ncdenr.org/web/wq/rules
Hearing on: February 5, 2015
Adoption by agency on: September 10, 2015
☐ Notice not required under G.S.:
Adoption by agency on:

7. Rule establishes or increases a fee? (See G.S. 12-3.1)

☐ Yes
Agency submitted request for consultation on:
Consultation not required. Cite authority:

☒ No

8. Fiscal impact (check all that apply):

☐ State funds affected
☐ Environmental permitting of DOT affected and analysis submitted to Board of Transportation
☐ Local funds affected
☐ Substantial economic impact (≥$1,000,000)
☐ Approved by OSBM
☒ No fiscal note required

9. REASON FOR ACTION

9A. What prompted this action? Check all that apply:

☒ Agency
☐ Court order / cite:
☐ Federal statute / cite:
☐ Federal regulation / cite:
☐ Legislation enacted by the General Assembly
Cite Session Law:
☐ Petition for rule-making
☐ Other:

9B. Explain: Lower Cape Fear River Program staff requested that a section of the Cape Fear River in Brunswick and New Hanover Counties be reclassified. The subject waters are proposed to be reclassified from Class SC to Class SC Sw with a water quality management plan (WQMP). The proposed Sw reclassification would allow, if caused by natural conditions, the pH of the subject waters to reach as low as 4.3 (compared to the currently required 6.8-8.5 range) and the dissolved oxygen to be lower than the currently required 5 mg/l. The proposed WQMP would help implement the current permiting strategy for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters. The overall proposal provides a path forward for these discharges & local communities for future planning purposes.

10. Rule-making Coordinator: Jennifer Everett
Address: 1601 Mail Service Center
Raleigh, NC 27699-1601
Phone: (919)707-8614
E-Mail: jennifer.everett@ncdenr.gov

Agency Contact, if any: Elizabeth Kountis
Phone: (919)807-6418
E-Mail: elizabeth.kountis@ncdenr.gov

11. Signature of Agency Head* or Rule-making Coordinator:

J L Everett

*If this function has been delegated (reassigned) pursuant to G.S. 143B-10(a), submit a copy of the delegation with this form.

Typed Name: Jennifer Everett
Title: Rule-making Coordinator

RRC AND OAH USE ONLY

Action taken:

☐ RRC Extended period of review:
☐ RRC determined substantial changes:
☐ Withdrawn by agency
☐ Subject to Legislative Review
☐ Other:

15A NCAC 02B .0311 has been amended <u>with changes</u> as published in 29:13 NCR 1606-1609 as follows:

15A NCAC 02B .0311 CAPE FEAR RIVER BASIN

(a) Effective February 1, 1976, the adopted classifications assigned to the waters within the Cape Fear River Basin are set forth in the Cape Fear River Basin Schedule of Classifications and Water Quality Standards, which may be inspected at the following places:

(1) the Internet at http://portal.ncdenr.org/web/wq/ps/csu/rules; and

(2) the North Carolina Department of Environment and Natural Resources:

(A) Winston-Salem Regional Office
585 Waughtown Street
Winston-Salem, North Carolina

(B) Fayetteville Regional Office
225 Green Street
Systel Building Suite 714
Fayetteville, North Carolina

(C) Raleigh Regional Office
3800 Barrett Drive
Raleigh, North Carolina

(D) Washington Regional Office
943 Washington Square Mall
Washington, North Carolina

(E) Wilmington Regional Office
127 Cardinal Drive Extension
Wilmington, North Carolina

(F) Division of Water Quality
Central Office
512 North Salisbury Street
Raleigh, North Carolina.

(b) The Cape Fear River Basin Schedule of Classification and Water Quality Standards was amended effective:

(1) March 1, 1977;

(2) December 13, 1979;

(3) December 14, 1980;

(4) August 9, 1981;

(5) April 1, 1982;

(6) December 1, 1983;

(7) January 1, 1985;

(8) August 1, 1985;

(9) December 1, 1985;

(10) February 1, 1986;

(11) July 1, 1987;

(12) October 1, 1987;

(13) March 1, 1988;

(14) August 1, 1990.

(c) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective June 1, 1988 as follows:

(1) Cane Creek [Index No. 16-21-(1)] from source to a point 0.5 mile north of N.C. Hwy. 54 (Cane Reservoir Dam) including the Cane Creek Reservoir and all tributaries has been reclassified from Class WS-III to WS-I.

(2) Morgan Creek [Index No. 16-41-1-(1)] to the University Lake dam including University Lake and all tributaries has been reclassified from Class WS-III to WS-I.

(d) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective July 1, 1988 by the reclassification of Crane Creek (Crains Creek) [Index No. 18-23-16-(1)] from source to mouth of Beaver Creek including all tributaries from C to WS-III.

(e) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective January 1, 1990 as follows:

(1) Intracoastal Waterway (Index No. 18-87) from southern edge of White Oak River Basin to western end of Permuda Island (a line from Morris Landing to Atlantic Ocean), from the eastern mouth of Old Topsail Creek to the southwestern shore of Howe Creek and from the southwest mouth of Shinn Creek to channel marker No. 153 including all tributaries except the King Creek Restricted Area, Hardison Creek, Old Topsail Creek, Mill Creek, Futch Creek and Pages Creek were reclassified from Class SA to Class SA ORW.

(2) Topsail Sound and Middle Sound ORW Area which includes all waters between the Barrier Islands and the Intracoastal Waterway located between a line running from the western most shore of Mason Inlet to the southwestern shore of Howe Creek and a line running from the western shore of New Topsail Inlet to the eastern mouth of Old Topsail Creek was reclassified from Class SA to Class SA ORW.

(3) Masonboro Sound ORW Area which includes all waters between the Barrier Islands and the mainland from a line running from the southwest mouth of Shinn Creek at the Intracoastal Waterway to the southern shore of Masonboro Inlet and a line running from the Intracoastal Waterway Channel marker No. 153 to the southside of the Carolina Beach Inlet was reclassified from Class SA to Class SA ORW.

(f) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective January 1, 1990 as follows: Big Alamance Creek [Index No. 16-19-(1)] from source to Lake Mackintosh Dam including all tributaries has been reclassified from Class WS-III NSW to Class WS-II NSW.

(g) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 3, 1992 with the reclassification of all water supply waters (waters with a primary classification of WS-I, WS-II or WS-III). These waters were reclassified to WS-I, WS-II, WS-III, WS-IV or WS-V as defined in the revised water supply protection rules, (15A NCAC 02B .0100, .0200 and .0300) which became effective on August 3, 1992. In some cases, streams with primary classifications other than WS were reclassified to a WS classification due to their proximity and linkage to water supply waters. In other cases, waters were reclassified from a WS classification to an alternate appropriate primary classification after being identified as downstream of a water supply intake or identified as not being used for water supply purposes.

(h) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective June 1, 1994 as follows:

(1) The Black River from its source to the Cape Fear River [Index Nos. 18-68-(0.5), 18-68-(3.5) and 18-65-(11.5)] was reclassified from Classes C Sw and C Sw HQW to Class C Sw ORW.

(2) The South River from Big Swamp to the Black River [Index Nos. 18-68-12-(0.5) and 18-68-12(11.5)] was reclassified from Classes C Sw and C Sw HQW to Class C Sw ORW.

(3) Six Runs Creek from Quewhiffle Swamp to the Black River [Index No. 18-68-2] was reclassified from Class C Sw to Class C Sw ORW.

(i) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective September 1, 1994 with the reclassification of the Deep River [Index No. 17-(36.5)] from the Town of Gulf-Goldston water supply intake to US highway 421 including associated tributaries from Class C to Classes C, WS-IV and WS-IV CA.

(j) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 1, 1998 with the revision to the primary classification for portions of the Deep River [Index No. 17-(28.5)] from Class WS-IV to Class WS-V, Deep River [Index No. 17-(41.5)] from Class WS-IV to Class C, and the Cape Fear River [Index 18-(10.5)] from Class WS-IV to Class WS-V.

(k) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective April 1, 1999 with the reclassification of Buckhorn Creek (Harris Lake)[Index No. 18-7-(3)] from the backwaters of Harris Lake to the Dam at Harris Lake from Class C to Class WS-V.

(l) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective April 1, 1999 with the reclassification of the Deep River [Index No. 17-(4)] from the dam at Oakdale-Cotton Mills, Inc. to the dam at Randleman Reservoir (located 1.6 mile upstream of U.S. Hwy 220 Business), and including tributaries from Class C and Class B to Class WS-IV and Class WS-IV & B. Streams within the Randleman Reservoir Critical Area have been reclassified to WS-IV CA. The Critical Area for a WS-IV reservoir is defined as 0.5 mile and draining to the normal pool elevation of the reservoir. All waters within the Randleman Reservoir Water Supply Watershed are within a designated Critical Water Supply Watershed and are subject to a special management strategy specified in 15A NCAC 02B .0248.

(m) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 1, 2002 as follows:

(1) Mill Creek [Index Nos. 18-23-11-(1), 18-23-11-(2), 18-23-11-3, 18-23-11-(5)] from its source to the Little River, including all tributaries was reclassified from Class WS-III NSW and Class WS-III B NSW to Class WS-III NSW HQW@ and Class WS-III B NSW HQW@.

(2) McDeed's Creek [Index Nos. 18-23-11-4, 18-23-11-4-1] from its source to Mill Creek, including all tributaries was reclassified from Class WS III NSW and Class WS-III B NSW to Class WS-III NSW HQW@ and Class WS-III B NSW HQW@.

The "@" symbol as used in this Paragraph means that if the governing municipality has deemed that a development is covered under a "5/70 provision" as described in Rule 15A NCAC 02B .0215(3)(b)(i)(E) (Fresh Surface Water Quality Standards for Class WS-III Waters), then that development is not subject to the stormwater requirements as described in rule 15A NCAC 02H .1006 (Stormwater Requirements: High Quality Waters).

(n) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective November 1, 2004 as follows:

(1) the portion of Rocky River [Index Number 17-43-(1)] from a point 0.3 mile upstream of Town of Siler City upper reservoir dam to a point 0.3 mile downstream of Lacy Creek from WS-III to WS-III CA.

(2) the portion of Rocky River [Index Number 17-43-(8)] from dam at lower water supply reservoir for Town of Siler City to a point 65 feet below dam (site of proposed dam) from C to WS-III CA.

(3) the portion of Mud Lick Creek (Index No. 17-43-6) from a point 0.4 mile upstream of Chatham County SR 1355 to Town of Siler City lower water supply reservoir from WS-III to WS-III CA.

(4) the portion of Lacy Creek (17-43-7) from a point 0.6 mile downstream of Chatham County SR 1362 to Town of Siler City lower water supply reservoir from WS-III to WS-III CA.

(o) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective November 1, 2007 with the reclassifications listed below, and the North Carolina Division of Water Quality maintains a Geographic Information Systems data layer of these UWLs.

(1) Military Ocean Terminal Sunny Point Pools, all on the eastern shore of the Cape Fear River [Index No. 18-(71)] were reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(2) Salters Lake Bay near Salters Lake [Index No. 18-44-4] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(3) Jones Lake Bay near Jones Lake [Index No. 18-46-7-1] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(4) Weymouth Woods Sandhill Seep near Mill Creek [18-23-11-(1)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(5) Fly Trap Savanna near Cape Fear River [Index No. 18-(71)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(6) Lily Pond near Cape Fear River [Index No. 18-(71)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(7) Grassy Pond near Cape Fear River [Index No. 18-(71)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(8) The Neck Savanna near Sandy Run Swamp [Index No. 18-74-33-2] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(9) Bower's Bog near Mill Creek [Index No. 18-23-11-(1)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(10) Bushy Lake near Turnbull Creek [Index No. 18-46] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(p) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective January 1, 2009 as follows:

(1) the portion of Cape Fear River [Index No. 18-(26)] (including tributaries) from Smithfield Packing Company's intake, located approximately 2 miles upstream of County Road 1316, to a point 0.5 miles upstream of Smithfield Packing Company's intake from Class C to Class WS-IV CA.

(2) the portion of Cape Fear River [Index No.18-(26)] (including tributaries) from a point 0.5 miles upstream of Smithfield Packing Company's intake to a point 1 mile upstream of Grays Creek from Class C to Class WS-IV.

(q) The schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 11, 2009 with the reclassification of all Class C NSW waters and all Class B NSW waters upstream of the dam at B. Everett Jordan Reservoir from Class C NSW and Class B NSW to Class WS-V NSW and Class WS-V & B NSW, respectively. All waters within the B. Everett Jordan Reservoir Watershed are within a designated Critical Water Supply Watershed and are subject to a special management strategy specified in 15A NCAC 02B .0262 through .0273.

(r) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective September 1, 2009 with the reclassification of a portion of the Haw River [Index No. 16-(28.5)] from the Town of Pittsboro water supply intake, which is located approximately 0.15 mile west of U.S. 15/501, to a point 0.5 mile upstream of the Town of Pittsboro water supply intake from Class WS-IV to Class WS-IV CA.

(s) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective March 1, 2012 with the reclassification of the portion of the Haw River [Index No. 16-(1)] from the City of Greensboro's intake, located approximately 650 feet upstream of Guilford County 2712, to a point 0.5 miles upstream of the intake from Class WS-V NSW to Class WS-IV CA NSW, and the portion of the Haw River [Index No. 16-(1)] from a point 0.5 miles upstream of the intake to a point 0.6 miles downstream of U.S. Route 29 from Class WS-V NSW to Class WS-IV NSW.

(t) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective [~~November 1, 2015~~] August 1, 2016 with the reclassification of a section of 18-(71) from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut from Class SC to Class SC Sw. A site-specific management strategy is outlined in 15A NCAC 02B .0227.

History Note: *Authority G.S. 143-214.1; 143-215.1; 143-215.3(a)(1);*
Eff. February 1, 1976;
Amended Eff. August 1, 2016; March 1, 2012; September 1, 2009; August 11, 2009; January 1, 2009; November 1, 2007; November 1, 2004; August 1, 2002; April 1, 1999; August 1, 1998; September 1, 1994; June 1, 1994; August 3, 1992; August 1, 1990.

Enclosure 4.
Attorney General's Certification

JOSH STEIN
ATTORNEY GENERAL

Reply To:
Daniel S. Hirschman
Environmental Division
Phone: (919) 716-6600
dhirschman@ncdoj.gov

March 28, 2018

Ms. Anne Heard, Acting Regional Administrator
Environmental Protection Agency, Region IV
61 Forsyth Street SW
Atlanta, GA 30303

SUBJECT: Certification of Adoption of Modifications to North Carolina's Surface Water Quality Classifications

Dear Ms. Heard:

Under the provisions of Article 21, Chapter 143 of the North Carolina General Statutes as amended, the North Carolina Environmental Management Commission is directed and empowered to adopt and assign "best use" classifications to all the surface waters of the State and to adopt water quality standards applicable to each classification.

The North Carolina Environmental Management Commission, after notice duly given, has adopted modifications to surface water classifications. The modifications to surface water classifications are shown in the enclosed *"Table 1. Surface Water Reclassification That Became Effective on June 30, 2017."*

By delegation from the Attorney General of North Carolina, I advise you that it is my opinion that the revised stream classifications listed in the enclosure have been duly adopted and promulgated in accordance with the Laws of the State of North Carolina and the Rules of the Environmental Management Commission, and that these revisions are valid and enforceable in the State of North Carolina as of the effective dates provided in the enclosure.

Very truly yours,

Daniel S. Hirschman
Senior Deputy Attorney General

SOUTHERN ENVIRONMENTAL LAW CENTER

Telephone 919-967-1450 601 WEST ROSEMARY STREET, SUITE 220 CHAPEL HILL, NC 27516-2356 Facsimile 919-929-9421

February 12, 2016

VIA ELECTRONIC MAIL
Elizabeth Kountis
DENR-DWR Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611
elizabeth.kountis@ncdenr.gov

Re: Cape Fear River Estuary Water Quality Management Plan

Dear Ms. Kountis:

The Southern Environmental Law Center appreciates the opportunity to comment on the proposed water quality management plan[1] for the Lower Cape Fear River ("LCFR")[2] on behalf of Cape Fear River Watch, Waterkeeper Alliance, and the North Carolina Conservation Network. Together, these organizations represent thousands of North Carolinians who drink, fish, swim, and paddle the state's rivers, including the Cape Fear; who place a high value on the quality of North Carolina's water resources; and who will be adversely affected by the degradation of water quality in the Cape Fear River. As such, these comments are intended to express concern regarding the agency's proposed management strategy for the LCFR.

As described in Section I, the strategy represents an abrupt and questionable departure from years of collaborative efforts to ensure that use of the river by aquatic life would be supported. In Section II, we document the myriad ways in which the water quality management plan under consideration appears intentionally designed to have minimal impact and therefore

[1] Although the agency specifically solicited comments regarding the proposed changes to the water quality management plan for the Lockwoods Folly River Area, those changes are not the only amendments to 15A N.C. Admin. Code 02B .0227 contemplated in the proposed rule published in the North Carolina Register on December 15, 2015. We therefore appreciate your consideration of our comments and their inclusion in the rulemaking record. See N.C. Gen. Stat. § 150B-21.2(f) ("An agency must accept comments on the text of a proposed rule that is published in the North Carolina Register and . . . consider fully any written and oral comments received"); *id.* § 150B-21.2(i) ("An agency must keep a record of a rule-making proceeding. The record must include all written comments received . . . .").

[2] As used herein, "LCFR" refers to the portion of the Cape Fear River from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut.

afford minimal protection to aquatic life. And, in Section III we emphasize the importance of preserving the designated use of the LCFR for aquatic life, which we believe should include efforts to protect endangered species that rely on the river.

I. Retreat Rather than Recovery: TMDL Avoidance in the LCFR

Every two years, the State must assess whether the designated uses[3] of a water body are supported by existing water quality.[4] Where existing pollution control requirements are insufficiently stringent to implement any water quality standard applicable to a water body, the State must take responsive action.[5] First, the water body must be included on the 303(d) list of impaired waters. Then, in order of established priority, the State must establish a total maximum daily load (TMDL) of the pollutant(s) impairing the designated use of listed waters; the TMDL should be calculated to limit pollutant loading to the degree necessary to attain applicable water quality standards.[6] Put more simply, after documenting unacceptable water quality, the State must take action to improve water quality to the degree necessary to support the water body's designated uses.

In Class SC waters like the LCFR, the normal dissolved oxygen standard is 5.0 mg/L.[7] In 1998, the State first observed that the designated uses of the Cape Fear estuary were impaired by low dissolved oxygen (DO) concentrations.[8] At the time, responsive measures were already

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[3] The classification of a water body dictates the applicable water quality standards necessary to protect the "best usage" of the waters with that classification. *See* N.C. Gen. Stat. 143-214.1(a)(1) (directing the EMC to develop "a series of classifications and the standards applicable to each such classification"); 15A N.C. Admin. Code 02B .0201 ("Existing uses . . . and the water quality to protect such uses shall be protected by properly classifying surface waters and having standards sufficient to protect these uses."); *see also* 40 C.F.R. § 131.11(a)(1) ("States must adopt those water quality criteria that protect the designated use. . . . For waters with multiple use designations, the criteria shall support the most sensitive use.").

[4] *See* 33 U.S.C. § 1315(b).

[5] 33 U.S.C. § 1313(d)(1)(A); 40 C.F.R. § 130.7(b). Conversely, where existing control strategies for point and nonpoint source pollution will achieve water quality standards, the law does not mandate such action.

[6] 33 U.S.C. § 1313(d)(1)(C); see also 40 C.F.R. § 130.7(c)(1) ("TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical [water quality standard] with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality.").

[7] 15A N.C. Admin. Code 02B .0220(5).

[8] N.C. Dep't of Env't and Natural Res. (NC DENR), *North Carolina's 1998 303(d) List* T-6 (May 15, 1998) (noting that of the 7,500 acres providing only "partial support" of designated uses, 5,000 were impaired by DO and listing wastewater treatment plants as a source of the impairment.),

under consideration; the State opined that "[p]roper technical conditions exist to develop a TMDL for this water body/pollutant" and that TMDL development was the "[u]sual approach" for responding to DO impairment.[9] A TMDL for Biological Oxygen Demand (BOD) had already been drafted in 1996 that "proposed using a phased approach to reducing BOD loading to the lower Cape Fear and highlighted several options that primarily reduce point source discharges to the river."[10] However, that TMDL was never approved or implemented.

By 2000, the DO impairment had been elevated to a high priority for the agency, which, by then, was meeting with the "regulated community . . . on a regular basis to discuss the modeling approach and investigate funding sources for the TMDL addressing low dissolved oxygen."[11] In 2002, the agency again listed the Cape Fear estuary as a high-priority water body for which a TMDL was required due to low dissolved oxygen.[12] When no TMDL was developed, the water body was again included on the list of impaired waters in 2004.[13]

In 2006, the LCFR was again listed as impaired due to low DO.[14] The State indicated that it expected to submit a TMDL to address this impairment "by the beginning of calendar year 2008."[15] Notably, by this time, the use of the LCFR had also become impaired by low pH.[16] However, the State remained focused on addressing what was nearly a decade-old DO impairment.

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http://portal.ncdenr.org/c/document_library/get_file?uuid=2284d944-2134-4c57-a2d9-499c58076d4a&groupId=38364.

[9] *Id.*

[10] *Id.* at 13 (noting the drafting of a BOD TMDL of 80,000 lbs/day BOD_u for the lower Cape Fear River below Lock and Dam #1).

[11] NC DENR, *North Carolina's 2000 303(d) List* 6 (Oct. 2, 2000), http://portal.ncdenr.org/c/document_library/get_file?uuid=20e877f9-81c3-4536-9622-e605646fcde4&groupId=38364.

[12] NC DENR, *North Carolina 2002 Impaired Waters List* 4 (Feb. 13, 2003), *http://portal.ncdenr.org/c/document_library/get_file?uuid=7cfe0f8a-bde3-4523-9e3e-cdc44e323123&groupId=38364*.

[13] NC DENR, *North Carolina 2002 303(d) Impaired Waters List-2004* 2 (Apr. 26, 2004), *available at http://portal.ncdenr.org/c/document_library/get_file?uuid=1504027b-a8d8-4c2d-83d5-0b1ac5cec792&groupId=38364.*

[14] For the 2006 listing, the State first assigned the "assessment units" currently used to define the LCFRE as the portion of the river from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut.

[15] NC DENR, North Carolina Water Quality Assessment and Impaired Waters List (2006 Integrated 305(b) and 303(d) Report) 54 (May 17, 2007).

[16] NC DENR, *North Carolina 303(d) List- 2006* 19 (June 19, 2007), http://portal.ncdenr.org/c/document_library/get_file?uuid=2648fa39-0975-4b27-8181-b0927ec2a43d&groupId=38364.

In October 2008, DENR staff considered five "Options for Addressing Dissolved Oxygen in the Lower Cape Fear River."[17] One of the options considered was "reclassification" but agency staff observed "[r]eclassifying the water does not appear to be an option at this time because no current NC classification 'fits' better than the water's existing SC designation. For example, Swamp waters have low velocities. The Cape Fear estuary is tidal and well mixed, not low-velocity."[18] Staff noted that "[a] TMDL with a target of 5.0 mg DO/l is doable, but most likely could not be successfully implemented." Ultimately, staff concluded that "[a] site-specific standard might be appropriate in this case" and noted "[i]f the dischargers in the watershed request a site-specific standard, DWR would support and oversee their development of the scientific rationale to derive it."[19] At that point, rather than seek to *attain* existing water quality standards, the agency and regulated community began considering strategies to *change* the water quality standards.

The DO impairment persisted and water quality in the LCFR worsened while the agency continued to study the problem.[20] Although claiming that TMDL development was a high priority in 2008,[21] 2010,[22] and 2012,[23] the agency continued to evaluate how to avoid implementing a TMDL. In November 2012, DWQ met with stakeholders to consider a technical assessment of natural and anthropogenic sources of dissolved oxygen deficit in the Lower Cape Fear Estuary.[24] It was suggested that Kathy Stecker, a DENR staff member, lead the combined effort. Ms. Stecker indicated that "determining a rationale for site specific criteria was likely the

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[17] E-mail from Kathy Stecker, NC DENR, to Elizabeth Kountis, NC DENR (May 16, 2014) (noting the options were prepared for a discussion with Coleen Sullins, then-Director of the Division of Water Quality).

[18] *Id.* Other rejected options included conducting a use attainability analysis or authorizing a temporary variance from water quality standards. *Id.*

[19] *Id.*

[20] By 2008, the LCFR was impaired by violations of standards for DO, pH, nickel, copper, and turbidity. NC DENR), *2008 North Carolina Integrated Report Categories 4 and 5 (Impaired Waters List)* 14 (March 10, 2010), http://portal.ncdenr.org/c/document_library/get_file?uuid=9f453bf9-2053-4329-b943-6614bd4c709a&groupId=38364.

[21] *Id.*

[22] NC DENR, *NC 2010 Integrated Report Categories 4 and 5 Impaired Waters* 16 (Aug. 31, 2010), http://portal.ncdenr.org/c/document_library/get_file?uuid=8ff0bb29-62c2-4b33-810c-2eee5afa75e9&groupId=38364. By 2010, the use of the LCFR was no longer impaired by violations of the water quality standard for nickel.

[23] NC DENR, *2012 North Carolina 303(d) Lists- Category 5* 20 (Aug. 10, 2012), http://portal.ncdenr.org/c/document_library/get_file?uuid=9d45b3b4-d066-4619-82e6-ea8ea0e01930&groupId=38364.

[24] CH2M Hill, Meeting Summary, Technical Assessment of Natural and Anthropogenic Sources of Dissolved Oxygen Deficit in the Lower Cape Fear Estuary (Nov. 7, 2012).

most feasible approach" and would be beneficial because it would "support aquatic life, allow for effective permitting, and provide acceptable limits for dischargers."[25] The agency and regulated community continued to evaluate this approach until early 2014.

In January 2014, the Chairman of the Water Quality Committee of the North Carolina Environmental Management Commission reviewed the list of impaired waters in North Carolina and opined to DWR staff that it "may be worth taking a look" at "streams that are not classified as Swamp Waters but probably should be."[26] He expressed concern that "if you do not have the classification correct then you could call a stream impaired when it is really not and could require much more [wastewater] treatment for a discharger than may be necessary."[27] In response, Ms. Stecker noted that reclassification was not necessary to account for naturally low DO and pH.[28] According to Ms. Stecker, the agency accounted for naturally low DO or pH in other ways when preparing the 303(d) list; she observed:

> Our solution doesn't involve rulemaking. The standards include an "out" for natural conditions, and we have developed a protocol that EPA concurs with. . . . We have successfully de-listed waters with naturally low DO and/or pH, and we've found others that really are impaired and developed TMDLs for those. . . . [I]f we suspect naturally low DO or pH, we don't put it on the list, but in Category 3. Those that we're working on in Category 5 have been there for a long time.[29]

Surmising that the WQC Chairman was primarily concerned with protecting dischargers, another DWQ staff member responded,

> The natural waters determination doesn't always get the dischargers off the hook. For instance, in the lower Cape Fear it gets tricky because modeling shows that

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[25] Id.
[26] E-mail from Steve Tedder, NC EMC, to Dianne Reid, NC DENR (Jan. 28, 2014).
[27] *Id.*; 15A N.C. Admin. Code 02B .0220(5), (12) (permitting lower pH and DO standards for Class SC waters with the supplemental "swamp waters" classification).
[28] E-mail from Kathy Stecker, NC DENR, to Dianne Reid, NC DENR (Jan. 28, 2014) (responding to Tedder's suggestion); *see also* 15A N.C. Admin. Code 02B .0205 (stating that "natural waters may on occasion, or temporarily, have characteristics outside of the normal range established by the standards" and "water quality standards will not be considered violated when values outside the normal range are caused by natural conditions).
[29] *Id.*

> even if we treat it like swamp water, the combined discharges still lower the DO too much and need to be further reduced.[30]

It is unclear whether the WQC Chairman nonetheless suggested the reclassification approach to the members of the Lower Cape Fear River Program (i.e., the members of the regulated community with which the agency had been working for years to address the DO impairment in the LCFR). However, before the next meeting of the WQC, that group submitted a request for reclassification of the LCFR as "swamp waters."[31]

In response, the agency ultimately proposed reclassification of the LCFR as "swamp waters." In tandem with this reclassification, the agency proposed the water quality management plan under consideration. In the following sections, we address concerns regarding this management plan.

II. Intentional Ineffectiveness: Crafting a Plan to Minimize Required Action

Perhaps the most obvious problem with the proposed management plan is its intentionally limited effect. Ordinarily, water quality management plans are adopted "to attain, maintain or enhance water quality" and should include "specific actions deemed necessary . . . to protect the water quality or the existing uses."[32] Yet the agency concedes that the management plan for the LCFR is *not intended to improve water quality*.[33] Nor is it truly intended to *maintain* water quality: it starts from the premise, derived from the reclassification, that it is acceptable for standards for pH and DO in the river to be lowered. Instead, the plan was crafted to have the minimum impact on the regulated community, and hence the least benefit to water quality. So successful was the agency in this regard that it concedes the management plan will have no effect whatsoever on the status quo. [34]

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[30] E-mail from Dianne Reid, NC DENR, to Steve Tedder, NC EMC (Jan. 28, 2014).
[31] Chris May, Request for Reclassification of a Portion of the Lower Cape Fear River with the Supplemental Swamp Classification (Mar. 5, 2014).
[32] 15A N.C. Admin. Code 02B .0227(a).
[33] "The proposal does not include language about correcting or reducing pollution as it is not designed to be a water quality restoration plan." NC DENR, *Report of Proceedings on the Proposed Reclassification of a Cape Fear River Segment, in Brunswick and New Hanover Counties (Broad River Basin) From SC to SC Sw with a Water Quality Management Plan* 10 (Feb. 5, 2015), http://portal.ncdenr.org/c/document_library/get_file?uuid=866ee647-ef8a-4912-8d36-06f26e6b1356&groupId=61581.
[34] *Id.* at 11 ("No changes to the current monitoring strategy as well as the current permitting and compliance strategies for the subject waters will occur due to this proposal.").

First, the plan makes no attempt to regulate nonpoint source pollution. Most notably, the plan does not address the contribution of pollutants from the Concentrated Animal Feeding Operations (CAFOs) in the Cape Fear River basin, which produce 50 percent of North Carolina's swine and large numbers of poultry.[35] The State should not disregard scientific analysis showing that, when waste management practices at CAFOs are poorly regulated, "large amounts of nitrogen and phosphorus enter the environment through runoff, percolation into groundwater, and volatilization of ammonia,"[36] and can exacerbate low DO (and pH) levels. Indeed, according to the EPA, hypoxia (i.e., low DO) "is regulated primarily by controlling nutrients (largely nitrogen) and other oxygen-demanding wastes."[37] North Carolina implicitly agreed with this observation by proposing a management plan focused exclusively on controlling BOD, DO, and ammonia from point sources. Yet, the proposed management plan imposes no limit on nonpoint source loading of nutrients or oxygen-demanding waste in the LCFR; nor does it address nutrient loading in upstream tributaries.

It is particularly ironic that the plan addresses only to point sources, and disregards nonpoint sources, since the supposed justification for reclassification of the river was that *point sources were not the cause* of observed violations of water quality standards.[38] Moreover, the agency intentionally excluded some point sources from the requirements proposed under the plan. Most obviously, the plan does not require any pollution reduction from existing facilities.[39] Initially, agency staff opined that "whatever goes into place for DO and pH may likely affect all discharges, whether new, expanding, renewals, etc."[40] However, the plan was revised to exclude existing facilities when research revealed the inability of existing facilities to comply with the

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[35] Michael A. Mallin & Lawrence B. Cahoon, Industrialized Animal Production—A Major Source of Nutrient and Microbial Pollution to Aquatic Ecosystems, 24 Population and Environment 369, 369 (2003).
[36] *Id.* at 379.
[37] U.S. EPA, *Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*, at v (Nov. 2000), http://water.epa.gov/scitech/swguidance/standards/upload/2007_03_01_criteria_dissolved_docriteria.pdf.
[38] Chris May, Request for Reclassification of a Portion of the Lower Cape Fear River with the Supplemental Swamp Classification (Mar. 5, 2014).
[39] E-mail from Tom Belnick NC DENR, to Elizabeth Kountis, NC DENR (April 16, 2014) ("I don't anticipate any changes to current NPDES permit limits."); e-mail from Ken Pickle, NC DENR, to Elizabeth Kountis, NC DENR (Apr. 17, 2014) ("I don't think any of our permittees (stormwater permittees, or wastewater dischargers under a permit administered by the Stormwater Permitting Program of DEMLR) would be impacted by the re-classification.").
[40] E-mail from Elizabeth Kountis, NC DENR, to Jim Gregson, NC DENR (May 19, 2014).

first draft of the plan.[41] Also, before proposing a plan applicable to only new or expanding facilities, the agency confirmed that there were no pending applications for new or expanded facilities[42] and that the existing facilities anticipating expansion already had permission to expand.[43]

The scope of the management plan was further curtailed when concern was expressed that the plan might apply to facilities authorized to discharge under general permits. Although early drafts proposed to manage *all* new or existing NPDES discharges, the plan was modified to reference only "individual" permits. Yet, even after drastically limiting its applicability, the agency was not finished reducing the plan's impact of the plan on the status quo.

The agency concedes that, because the LCFR is designated as a Primary Nursery Area, it is entitled to additional protection due to its important role in supporting aquatic life.[44] However, although the agency claims the management plan sets limits "similar to the limits for High Quality Waters,"[45] in truth the plan affords less protection.

Ordinarily, new or expanded wastewater discharges into high-quality waters must comply with the following limitations designed to control the discharge of oxygen-consuming waste:

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[41] *See* e-mail from Jim Gregson, NC DENR, to Elizabeth Kountis, NC DENR (May 21, 2014) ("Of the eight existing facilities, the three domestic plants currently have BOD or CBOD limits of 30 and 25, respectively. . . . None of the three Domestic plants would likely be able to meet a BOD limit of 5 mg/L without significant upgrades including filters. Two of the three domestic plants currently do not have Ammonia limits. The one that does (NC0065480) has a monthly ave. limit of 20 mg/l and a daily max. of 35. . . . I don't think any of the three domestic plants could currently meet an Ammonia limit of 1 mg/l."); *see also* e-mail from Bill Kreutzberger, CH2M, to Jeff Manning, NC DENR (June 5, 2014) ("The problem with the statement is that the current cumulative permitted discharge[s] case a decline of 0.2 to 0.3 mg/L below natural conditions. So the reference needs to be that the increase in loading from *new or expanding dischargers* can cause no more than a 0.1 mg/L decline in DO." (emphasis added)).

[42] "I understand that there are no proposed discharge permits for new facilities or expansion of existing facilities that your office is currently working on for this segment." E-mail from Elizabeth Kountis, NC DENR, to Jim Gregson, NC DENR (May 19, 2014); *see also* e-mail from Elizabeth Kountis, NC DENR, to Tom Belnick, NC DENR (July 10, 2014).

[43] "Currently there are 4 NPDES-permitted dischargers that discharge oxygen-consuming waste to the proposed SW reclass segment. Of these facilities, 3 have already received phased permit limits for future expansions." E-mail from Tom Belnick, NC DENR, to Jeff Manning, NC DENR (June 16, 2014).

[44] NC DENR, Report of Proceedings on the Proposed Reclassification of a Cape Fear River Segment, in Brunswick and New Hanover Counties (Broad River Basin) From SC to SC Sw with a Water Quality Management Plan a 3; see also 15A N.C. Admin. Code 02B .0101(e)(5).

[45] NC DENR, Report of Proceedings on the Proposed Reclassification of a Cape Fear River Segment, in Brunswick and New Hanover Counties (Broad River Basin) From SC to SC Sw with a Water Quality Management Plan a 3.

> Effluent limitations shall be as follows: BOD5= 5 mg/l, NH3-N = 2 mg/l and DO = 6 mg/l. More stringent limitations shall be set, if necessary, to ensure that the cumulative pollutant discharge of oxygen-consuming wastes shall not cause the DO of the receiving water to drop more than 0.5 mg/l below background levels, and in no case below the standard.[46]

However, the management plan for the LCFR was designed to impose less stringent limits on oxygen-consuming waste. First, because industrial dischargers may not be able to meet the normal BOD and NH3-N limits for HQW waters, an additional provision was added to exempt them from such limits.[47] Even more concerning is the plan's failure to consider background levels and/or the actual water quality standards applicable to the river.

Here, the evolution of the relevant language bears emphasis. As initially drafted, the water quality management plan for the LCFR was designed to prevent a drop in DO "below the standard." Then the language was amended to prohibit a drop below the "natural conditions." A subsequent draft prohibited a drop below the "modeled natural conditions." And, finally, the proposed language eschews any reference to the standards or natural conditions and instead uses "modeled in-stream dissolved oxygen at total permitted capacity for all discharges" as the baseline against which to measure the effect of a proposed permit.[48]

In other words, instead of considering actual standards and real data, the agency proposes to evaluate the impact of permitted activity based solely on modeling; this approach will have concerning effects on both permitting decisions and future assessments of use impairments. This novel approach appears to be a result of the agency's continued inability (despite a decade of trying) to determine the natural background levels of DO in the segment.[49] Indeed, e-mails

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[46] 15A N.C. Admin. Code 02B .0224(b)(i).

[47] E-mail from Tom Belnick, NC DENR, to Elizabeth Kountis, NC DENR (Aug. 3, 2015) ("The site-specific BAT language for industrials goes back to at least the 2000 Cape Fear River Basin Plan, where it was recognized that industries might not be able to achieve BOD= 5 mg/l and NH3-N = 2 mg/l.").

[48] Notably, the plan does not require consideration of the lower pH that could result from these discharges.

[49] The reluctance to rely on data to identify a change in DO of 0.1 mg/L might also result from the margin of error currently allowed for reporting DO results in laboratory tests. DO results must be reported to the nearest 0.1 mg/L with an accuracy of +/- 0.5 mg/L. North Carolina Wastewater/Groundwater Laboratory Certification Approved Procedure for the Analysis of Dissolved Oxygen (DO) (Apr. 2013).

exchanged within the agency noted the agency's inability to identify background conditions[50] and stated "using the model would be a totally different thing."[51]

Even worse, the agency fails to clarify in the management plan any quality assurance requirements for the modeling in question. Language was specifically omitted from early drafts that would have required modeling results to be "demonstrated," that would have required a person to "obtain Division of Water Resources review and approval of any monitoring study plan and description of the modeling framework to be used prior to commencement of such a study," and that would have required the study plan and modeling framework to "meet any Division requirements for data quality and model support or design in place at that time."

Understandably, the EPA expressed reservations about the approach contemplated in the proposed water quality plan. One federal regulator noted:

> When other states have adopted a 0.1 mg/L type provision, it has been a provision that applies to all implementing programs and has been provided as an amount of change from background condition. And even then the background condition has to be specifically defined before the provision can be used to deviate from the natural condition.[52]

Still, for all the aforementioned problems with the contents of the plan, perhaps the most destructive is the failure to include specific protections for the use of the river by aquatic life. Again, early drafts considered such provisions, and the agency apparently considered establishing a threshold for DO below which the river would not be allowed to fall. Indeed, some drafts even included different DO thresholds designed to protect specific species, including striped bass and endangered sturgeon. Ultimately, however, none of these laudable attempts to protect the designated uses of the river was included in the final management plan.

In other words, after years of observing that low DO impaired the use of the LCFR by aquatic life, the agency now proposes to reclassify the river as swamp waters, removing any floor for DO, and refrain from establishing a new minimum DO standard through the associated

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[50] E-mail from Cam McNutt, NC DENR, to Jeff Manning, NC DENR (June 4, 2014) ("We do not know what natural conditions DO level is so no assessment decision is made.").
[51] E-mail from Cam McNutt, NC DENR, to Jeff Manning, NC DENR (June 5, 2014) ("In the past we have not assess[ed] DO in Sw waters. Using the model would be a totally different thing.").
[52] E-mail from Lauren Petter, US EPA, to Elizabeth Kountis, NC DENR (Aug. 7, 2015).

management plan.[53] In the following section, we address the impropriety of ignoring protection of aquatic life in the LCFR.

III. Prioritizing Refuse over Use: Sacrificing Aquatic Life Protection to Satisfy Dischargers

The water quality standards associated with the "swamp waters" classification are designed to protect the use of waters for the propagation and survival of aquatic species that naturally occur in swamp waters.[54] Specifically, the EMC allows certain swamp waters to have higher acidity (i.e., low pH) and lower dissolved oxygen (DO) concentrations.[55] Class SC waters with the supplemental "swamp waters" classification "may have a pH as low as 4.3 if it is the result of natural conditions."[56] Though the agency has publicly disavowed plans to lower DO or pH standards, internal communications reveal that this is the anticipated effect,[57] or even primary motivation,[58] of the proposed action. A water quality management plan presupposing

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[53] This issue was a particular concern of the US Fish and Wildlife Service. *See* letter from Tom Augspurger, USFWS, to Elizabeth Kountis, NC DENR (March 3, 2015) (expressing "concern that a Sw classification, allowing lower DO if caused by natural conditions, might make it more difficult to determine use support related to DO in the future without some mechanism to define a new lower bound on DO indicative of background conditions").

[54] In contrast, other supplemental classifications result in application of more stringent water quality standards. *See, e.g.*, 15A N.C. Admin. Code 02B .0211(4) (more stringent freshwater chlorophyll-a standards for nutrient-sensitive waters and trout waters); *id.* 02B.011(6) (more stringent DO standards for trout waters); *id.* 02B .0211(19) (toluene standard applicable only to trout waters); *id.* 02B .0211(21) (more stringent turbidity standard for trout waters); *id.* 02B .0220(3) (more stringent saltwater chlorophyll-a standards for nutrient sensitive waters and trout waters); *id.* 02B .0223 (requiring development of nutrient control strategies in nutrient sensitive waters); *id.* 02B .0224 (stating standards applicable to high-quality waters); *id.* 02B .0225 (stating standards for outstanding resource waters). The State's anti-degradation policy is also stricter for waters classified as high-quality waters or outstanding resource waters. *Id.* 02B .0201.

[55] 15A N.C. Admin. Code 02B .0211(6), (14) (permitting lower pH and DO standards for Class C waters with the supplemental "swamp waters" classification); 15A N.C. Admin. Code 02B .0220(5), (12) (permitting lower pH and DO standards for Class SC waters with the supplemental "swamp waters" classification).

[56] *Id.*

[57] *See e.g.*, e-mail from Elizabeth Kountis, NC DENR, to Jim Gregson, NC DENR (May 19, 2014) ("Please note that this reclassification will most likely result in something less strict than what is currently required for DO and pH, so those facilities having a difficult time reaching 5 mg/l and the acceptable pH levels now may get some relief."); e-mail from Elizabeth Kountis, NC DENR, to Tom Belnick, NC DENR (Apr. 17, 2014) ("My understanding is that a Sw reclass . . . would remove the DO and pH impairments for 18-(71)a.").

[58] E-mail from Elizabeth Kountis, NC DENR, to Jeff Manning, NC DENR (May 9, 2014) ("Kathy mentioned that an impairment couldn't be lifted via use of .0227 only, that there would need to be

reclassification of the LCFR as swamp waters should include measures to ensure that the permissive lowering of DO and pH standards will not impair use of the water for aquatic life propagation and survival.

Mindful of the potential for lowering DO limits, a number of scientists expressed concern about the effects that the agency's proposed reclassification and associated water quality management plan for the LCFR would have on aquatic life. DEQ's own Division of Marine Fisheries objected to the proposed action because of anticipated impacts on fish species.[59] A rather blunt assessment was offered by the National Oceanic and Atmospheric Association (NOAA): "Reclassifying the lower Cape Fear is a bad idea."[60]

For the most part, the concern centered around effects that the proposal would have on anadromous species. In late winter, species including striped bass, Atlantic sturgeon, and American shad migrate from the ocean and lower Cape Fear estuary to spawn upstream in the main stem of the Cape Fear River.[61] Although adult fish return to the ocean or lower estuary after spawning, juveniles remain in nursery habitats through the summer before migrating seaward in late fall.[62] As previously noted, the LCFR includes habitat designated as primary nursery areas by the Division of Marine Fisheries (DMF).[63] Primary nursery areas (PNAs) are those "in the estuarine system where initial post-larval development takes place" and "populations are uniformly early juveniles."[64] The affected segment is also designated as an anadromous fish spawning area (AFSA) by DMF and the Wildlife Resources Commission.[65] This means "evidence of spawning anadromous fish has been documented in [DMF] sampling

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something tagged onto a water's current classification and/or a change in the classificaiton [sic] in order to have it delisted (that tag could reference .0227 perhaps).")

[59] E-mail from Anne Deaton, NC DENR, to Elizabeth Kountis, NC DENR (July 8, 2014) ("DMF does not support the reclassification due to the concentration of not only sturgeon in the river, but use by a diversity of other anadromous and estuarine fish species.").

[60] E-mail from Fritz Rohde, NOAA, to Stephania Bolden, NOAA (May 20, 2014) (asking recipient for "reports that document impacts of low DO and low pH on sturgeon").

[61] Cape Fear River Partnership, Cape Fear River Basin Action Plan for Migratory Fish 18 (April 2013), *available at* http://www.habitat.noaa.gov/protection/capefear/pdf/CapeFearActionPlan.pdf.

[62] Id.

[63] 15A N.C. Admin. Code 03R .0103.

[64] 15A N.C. Admin. Code 031 .0101; *see also* 15A N.C. Admin. Code 02B .0202 ("Primary Nursery Areas (PNAs) are tidal saltwaters which provide essential habitat for the early development of commercially important fish and shellfish and are so designated by the Marine Fisheries Commission.").

[65] 15A N.C. Admin. Code 03R .0115(25); see also Division of Marine Fisheries, Anadromous Fish Spawning Areas (AFSA): Cape Fear River Area, Map 7, http://portal.ncdenr.org/c/document_library/get_file?uuid=f810ae29-ea4d-4801-a04f-850ff2bc4467&groupId=38337.

records through direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae."[66]

Low dissolved oxygen levels can be particularly harmful in spawning and nursery areas because hypoxia "causes substantial mortality of developing embryos."[67] For this reason, EPA recommends more stringent dissolved oxygen criteria for the early life stages of both coldwater and warmwater fish.[68] Multiple scientists commenting on the proposed management strategy for the LCFR expressed concern about its impact on fish in early life stages.[69]

In addition to playing a role in the life cycles of multiple fish species, the lower Cape Fear River is home to two endangered species of sturgeon, suggesting a need for more stringent environmental protection.[70] "Maintenance and recovery of the water quality conditions required to sustain and recover federally-listed threatened and endangered aquatic animal species

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[66] Anadromous fish spawning areas are those "where evidence of spawning anadromous fish has been documented in Division sampling records through direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae." 15A N.C. Admin. Code 031 .0101(4)(b).

[67] Denise L. Brietburg et al, Hypoxia, Nitrogen, and Fisheries: Integrating Effects Across Local and Global Landscapes, 1 Annual Review of Marine Science 333 (2009) ("Developing embryos are particularly sensitive because they lack the ability to behaviorally respond to low oxygen and because oxygen must diffuse across the chorion that encases the embryo."), http://moritz.botany.ut.ee/~olli/eutrsem/Breitburg09.pdf.

[68] US EPA, *Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*, app. I (Nov. 2000), http://water.epa.gov/scitech/swguidance/standards/upload/2007_03_01_criteria_dissolved_docriteria.pdf.

[69] E-mail from Tom Augspurger, US FWS, to Elizabeth Kountis, NC DENR (April 23, 2014) ("[P]ublished information on desirable levels of dissolved oxygen for good striped bass production indicate survival of striped bass eggs and larvae are reduced at dissolved oxygen levels from 4 to 5 mg/L (Bain and Bain 1982) and that optimal ranges for larvae and juveniles are >6 to 12 mg/L (Hill et al. 1989; Nicholson et al. 1990)."); *id.* ("DO concentrations higher than the standard of 5 mg/L are desirable for spawning areas. The national dissolved oxygen criteria for sensitive life-stages in non-salmonid waters is a daily minimum of 5 mg/L and a weekly average of 6 mg/L. . . . At concentrations below these, larval mortality, altered growth, and behavioral changes have been reported in both field and lab studies."); e-mail from Brian Kreiser, Univ. of Southern Miss., to Gary Kreiser, NC DENR (May 22, 2014) ("I don't know where potential spawning grounds might be relative to the area they want to classify as a swamp, but that would be an important consideration. The early life stages are probably not going to be as hypoxia tolerant as adults or won't be able to behaviorally avoid those areas.").

[70] *See* Mary L. Moser & Steve W. Ross, Habitat Use and Movements of Shortnose and Atlantic Sturgeon in the Lower Cape Fear River, North Carolina, 124 Transactions of the American Fisheries Society 225 (1995).

contributes to the support and maintenance of a balanced and indigenous community of aquatic organisms and thereby protects the biological integrity of the waters."[71]

First, the lower Cape Fear is home to the Atlantic sturgeon, a species that NOAA's National Marine Fisheries Service first listed as endangered in 2012. Although the harvest of Atlantic sturgeon has been banned since 1991, the Atlantic States Marine Fisheries Commission (ASMFC) has stated that fishery management measures alone will not sustain stocks of Atlantic sturgeon without sufficient quality and quantity of habitat. As such, it bears emphasis that the estuarine waters of the lower Cape Fear river are precisely the type where juvenile Atlantic sturgeon "for months to years before emigrating to open ocean."[72] Moreover, ASMFC studies demonstrate that DO concentration is a "key habitat parameter[] for the structuring of juvenile Atlantic sturgeon habitat."[73]

The Lower Cape Fear also hosts a population of shortnose sturgeon, a species recognized by the federal government as endangered in 1967 and subject to a fishing moratorium since 1991. Juvenile shortnose sturgeon tend to locate in estuarine waters such as those in the LCFR. Consequently, "protection of essential habitats, especially nursery/summer habitats, from human caused dissolved-oxygen reductions and other impacts is critical."[74]

A number of scientists urged the agency not to subject endangered sturgeon species to additional environmental stress by allowing lower dissolved oxygen in the LCFR. One sturgeon specialist noted, "given their benthic nature, DO requirements, and tendency for the Cape Fear to have lower DO events I would imagine they are already often experiencing DO close (or low enough) to killing them."[75] A NOAA scientist observed that, "In habitats with DO less than 4.7 mg/L, young of year Atlantic sturgeon experience a loss in growth."[76] Another noted that "DO

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[71] 15A N.C. Admin. Code 02B .0110.

[72] Atlantic Marine Fisheries Commission, *Habitat Addendum IV to Amendment I to the Fishery Management Plan for Atlantic Sturgeon* 2 (Sept. 2012), http://www.asmfc.org/uploads/file/sturgeonHabitatAddendumIV_Sept2012.pdf.

[73] *Id.* at 3.

[74] Mark R. Collins et al, Primary Factors Affecting Sturgeon Populations in the Southeastern United States: Fishing Mortality and Degradation of Essential Habitats, 66 Bulletin of Marine Science 917, 917 (2000), available at

[75] E-mail from Joseph Facendola, NC DMF, to Bennett Wynne, NC WRC (June 2, 2014) (e-mail forwarded by Chip Collier, NC DMF to Adriene Weaver, NC DENR on June 4, 2014); *see also id.* (opining that "reduced WQ standards in the lower cape fear will have negative impacts on the sizes of sturgeon that we have movement data for, and I suspect that it could have a greater impact on YOY that we have no data for (and are far less mobile).").

[76] E-mail from Fritz Rohde, NOAA, to Elizabeth Kountis, NC DENR (May 13, 2014) (citing Secor and Niklitshcek 2001))."

levels below 5.0 mg/L and ph of 4.3 would be problematic for sturgeons of either species" in the river because "[f]undamentally, sturgeons are adapted for life in big, well-flowing rivers with good oxygenation 6-9 mg/L and ph with[in] 0.5 units of neutral."[77]

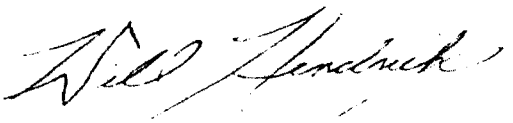
To protect aquatic life, the agency should fight against degrading water quality in the LCFR instead of capitulating at the behest of the regulated community. While polluters want the State to quit trying to protect the LCFR for use by aquatic life that requires "normal" pH levels above 6.8 and/or DO levels of above 5.0 mg/L, the agency should strive to manage the LCFR so as to provide for the best usage of the water body.

IV. Conclusion

For more than 30 years, the State has determined that the best usage of the lower Cape Fear by aquatic life is protected by the water quality standards for pH and DO associated with Class SC waters. For more than 15 years, the State has recognized that usage of the lower Cape Fear River by aquatic life is impaired by low DO concentrations. The State should not abandon efforts to return these waters to the conditions that support their best usage. Rather than adopt a water quality management plan that is designed to avoid necessary efforts to improve water quality, the State should continue to strive to "maintain, protect, and enhance water quality within North Carolina.[78] Accordingly, we urge the agency to reject the proposed management plan.

Thank you for the opportunity to comment on this important matter.

Sincerely,



Will Hendrick
Associate Attorney
Southern Environmental Law Center

cc (by e-mail):

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[77] E-mail from Kenneth Sulak, USGS, to Fritz Rohde, NOAA (May 20, 2014). This e-mail was forwarded to NC DENR on May 20, 2014. See e-mail from Fritz Rohde, NOAA, to Elizabeth Kountis, NC DENR (May 20, 2014).
[78] N.C. Gen. Stat. § 143-215.2(b).

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Region 4 - RA's Office

MAY 01 2018

Received

April 26, 2018

Mr. Trey Glenn, Regional Administrator
U.S. Environmental Protection Agency, Region 4
61 Forsyth Street, SW
Atlanta, GA 30303-3104

Re: North Carolina's April 9, 2018 Request for Approval of Modifications to the Water-Quality Classification for the Lower Cape Fear River

Dear Mr. Glenn:

Recently, we learned that the North Carolina Department of Environmental Quality has asked the U.S. Environmental Protection Agency to approve a revised water-quality standard reclassifying the Lower Cape Fear River as a "swamp water."[1] The reclassification defies both federal law and observable facts. On behalf of Cape Fear River Watch and Waterkeeper Alliance, we accordingly urge the EPA to deny the Department's request.

For nearly two decades, the Lower Cape Fear River—a fifteen-mile stretch of tidal salt water flowing southward past Wilmington—has been stuck on North Carolina's 303(d) list.[2] At the time of its original listing, in 1998, the waterway was

[1] North Carolina Department of Environmental Quality, Request for Approval of Modifications to North Carolina's Surface Water Quality Classifications (Apr. 9, 2018) ("Request for Approval").

[2] *See* North Carolina Department of Environment and Natural Resources, Report of Proceedings on the Proposed Reclassification of a Cape Fear River Segment (2015) ("Report of Proceedings"), at 1, *available at* https://ncdenr.s3.amazonaws.com/s3fs-public/Environmental%20Management%20Commission/EMC%20Meetings/2015/September/Report_of_Proceedings_for_Cape_Fear_River_Proposal%20%281%29.pdf (last visited Apr. 26, 2018); 2014 North Carolina 303(d) List (Dec. 19, 2014) ("2014 303(d) List"), at 2-4, *available at* https://ncdenr.s3.amazonaws.com/s3fs-public/Water%20Quality/Planning/TMDL/303d/2014/2014_303dlist.pdf (last visited Apr. 26, 2018).

primarily burdened by low levels of dissolved oxygen—a problem the Department of Environmental Quality attributed, in part, to nonpoint "ag" and "urban runoff" pollution.[3] In the intervening years, however, the river has acquired additional problems, including arsenic, copper, nickel, and acidity.[4]

The appearance of the Lower Cape Fear River on North Carolina's 303(d) list, as you know, required the preparation of a "total maximum daily load."[5] Indeed, the need for a TMDL was long acknowledged by state regulators and members of industry. Within two years of the listing, the Department of Environmental Quality and the regulated community were "meeting on a regular basis to discuss the modeling approach and investigate funding sources for ... [a] TMDL addressing low dissolved oxygen" in the Lower Cape Fear.[6] Work on the TMDL reportedly continued for more than a decade, with little apparent progress. And then someone had an idea.

On March 5, 2014, the Lower Cape Fear River Program wrote the Department of Environmental Quality to ask that the "portions of the Lower Cape Fear River Estuary ... that [we]re ... classified as Class SC Waters be reclassified to include the supplemental Swamp (Sw) classification."[7] According to the Program—a self-described "coalition of citizens groups, industry, business, local, regional, and state government, and the university community"—a "swamp" designation "would recognize the influence of natural drainage from riverine wetland and salt marsh systems that are ubiquitous throughout the Lower Cape Fear River, Northeast Cape Fear River and Black River watersheds on water quality conditions in the river."[8] It would shift the blame, in other words, from the region's polluters to the river's "natural conditions"—

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[3] 1998 North Carolina 303(d) List (May 15, 1998), at T-6 (noting that 5,000 of the estuary's 7,500 acres were impaired as a result of low dissolved-oxygen levels, and that 5,561 of the estuary's acres were burdened by nonpoint pollution, including "ag" and "urban runoff"), *available at* https://files.nc.gov/ncdeq/Water%20Quality/Planning/TMDL/303d/1998%20303d%20list.pdf (last visited Apr. 26, 2018).

[4] 2014 303(d) List at 2-4.

[5] *See* 33 U.S.C. § 1313(d)(1)(C).

[6] 2000 North Carolina 303(d) List (Oct. 2, 2000), at 6, *available at* https://ncdenr.s3.amazonaws.com/s3fs-public/Water%20Quality/Planning/TMDL/303d/2000%20303d%20list.pdf (last visited Apr. 26, 2018).

[7] Report of Proceedings at a-2 (reclassification request).

[8] *Id.* at a-2–a-3.

which would purportedly allow the state's long-promised TMDL to be officially abandoned.[9]

The superficial attraction of declaring the Lower Cape Fear a "swamp" stemmed from a number of provisions within North Carolina's water-quality standards. Under state regulations, the "Class SC" designation establishes a "minimum" level of protection for tidal "saltwaters" along the coast.[10] All "SC" waters must be made "suitable for aquatic life propagation and maintenance of biological integrity, wildlife, and secondary recreation."[11] With respect to dissolved oxygen, these uses are generally translated into a numeric limit of "not less than 5.0 mg/l[.]"[12] In "swamp waters, poorly flushed tidally influenced streams or embayments, ... [and] estuarine bottom waters[,]" however, "lower values" are allowed if they are "caused by natural conditions[.]"[13] The "SC" standard for acidity is similarly reduced in "swamp waters."[14] While pH generally must "be normal for the waters in the area, which range between 6.8 and 8.5, ... swamp waters may have a pH as low as 4.3 if it is the result of natural conditions[.]"[15]

The Lower Cape Fear River Program premised its reclassification request on these "swamp waters" standards, arguing that the estuary's low dissolved-oxygen levels somehow prove that it's a "swamp."[16] In the words of the Program's petition:

> It ... [was] clear from the data collection, modeling and technical analyses [that had been undertaken by the

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[9] *See* 15A NCAC 02B .0220(5) (establishing a "natural conditions" standard for dissolved oxygen in tidal "swamp waters").

[10] 15A NCAC 02B .0101(d)(1).

[11] 15A NCAC 02B .0220(2); *see also id.* 02B .0101(d)(1) (noting that Class SC waters are "protected for secondary recreation, fishing, aquatic life including propagation and survival, and wildlife"); *id.* 02B .0220(1) (providing that "[b]est ... usages" for Class SC waters "include aquatic life propagation and maintenance of biological integrity (including fishing, fish and functioning Primary Nursery Areas (PNAs)), wildlife, and secondary recreation").

[12] 15A NCAC 02B .0220(5).

[13] *Id.*

[14] 15A NCAC 02B .0220(12).

[15] *Id.*

[16] *See* Report of Proceedings at a-7 (reclassification request).

> coalition] that the DO standard of 5 mg/L for the ... [Lower Cape Fear was] not appropriate since it is not achieved a significant portion of the time as a result of natural drainage from riverine wetlands and salt marshes.[17]

"From a regulatory standpoint," the petition argued, "a straightforward way to deal with this issue is to reclassify the area with the supplemental Sw classification."[18]

In electing to grant the Lower Cape Fear River Program's reclassification request, North Carolina officials acted arbitrarily and unlawfully. Most notably, while the Department of Environmental Quality has assured you that "[t]he reclassification ... was based on scientific information provided by the requestor[,]"[19] this "information" failed to demonstrate that the river's dissolved-oxygen problem is actually "a result of natural drainage[.]"[20] As the Lower Cape Fear River Program's lead researcher noted in his comments on the reclassification, which are attached to this letter, "[l]ivestock manures as waste inputs were *not even mentioned* in ... [the Program's] model!"[21] Given that "[l]ivestock wastes are clearly the largest source of BOD-forcing pollutants in the Cape Fear Basin[,]" it was arbitrary for the model—and the State of North Carolina—to ignore them.[22]

Remarkably, the state's reclassification decision also ignored the very definition of "swamp waters."[23] Under North Carolina law, "[s]wamp waters" are those with "*low velocities* and other natural characteristics which are different from adjacent streams."[24] In granting the Lower Cape Fear River Program's reclassification request, however,

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[17] *Id.*

[18] *Id.*

[19] Request for Approval at 1.

[20] Report of Proceedings at a-7 (reclassification request).

[21] Report of Proceedings at a-105 (comments of Dr. Michael Mallin, a research professor at the University of North Carolina Wilmington) (emphasis in original) (Attachment 1).

[22] *Id.* at a-106.

[23] *See* Report of Proceedings (reclassification request).

[24] 15A NCAC 02B .0101(e)(2) (emphasis added); *see also id.* 02B .0202(62) (stating that "[s]wamp waters mean those waters which are classified by the Environmental Management Commission and which are topographically located so as to generally have very low velocities and other characteristics which are different from adjacent streams draining steeper topography").

state officials made no mention of water velocities in the river.[25] This omission does not seem to have been inadvertent. As Dr. JoAnn Burkholder noted in a lengthy comment letter, which is also attached, the "Mighty Cape Fear" is a "strongly flowing, high-volume river"[26]—one in which the U.S.S. North Carolina, a battleship, is currently "[m]oored in quiet dignity and majesty ... across ... from downtown Wilmington[.]"[27]

Only three years ago, the EPA confirmed the importance of evaluating a waterbody's "flow regime, channel gradient, and ... geomorphology" in a guidance document addressing "natural conditions" criteria.[28] In the words of the agency, "[a]n examination of natural geomorphic factors, such as lack of re-aeration due to the low channel gradient, as well as naturally high biological oxygen demand ... from decomposition of riparian vegetation, should be documented to demonstrate that [a waterbody's] low DO is not due to eutrophication or other human-caused impacts."[29] In reclassifying the Lower Cape Fear River as a "swamp water," North Carolina officials failed to undertake this critical analysis.

All told, North Carolina's reclassification of the Lower Cape Fear was nothing more than an attempt to avoid addressing the river's significant water-quality problems. Because such an action cannot be squared with the fundamental purpose of the Clean Water Act—"restor[ing] and maintain[ing] the chemical, physical, and biological integrity of the Nation's waters"—it should be rejected by the EPA.[30]

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[25] *See* Report of Proceedings.

[26] *Id.* at a-112–a-113 (comments of Dr. Burkholder, a professor at North Carolina State University) (Attachment 2).

[27] Welcome to the Battleship North Carolina, http://www.battleshipnc.com/ (last visited Apr. 26, 2018).

[28] *See* Framework for Defining and Documenting Natural Conditions for Development of Site-Specific Natural Background Aquatic Life Criteria for Temperature, Dissolved Oxygen, and pH: Interim Document (Feb. 2015), at 12, *available at* https://www.epa.gov/sites/production/files/2015-02/documents/natural-conditions-framework-2015.pdf (last visited Apr. 26, 2018).

[29] *Id.*

[30] 33 U.S.C. § 1251(a); *see also* 40 C.F.R. § 131.6(a) (requiring the EPA to ensure that state use designations are "consistent with the provisions of sections 101(a)(2) and 303(c)(2) of the [Clean Water] Act").

History Note: *Authority G.S. 143-214.1; 143-215.1; 143-215.3(a)(1);*
Eff. February 1, 1976;
Amended Eff. August 1, 2016; March 1, 2012; September 1, 2009; August 11, 2009; January 1, 2009; November 1, 2007; November 1, 2004; August 1, 2002; April 1, 1999; August 1, 1998; September 1, 1994; June 1, 1994; August 3, 1992; August 1, 1990.

North Carolina's reclassification of the Lower Cape Fear River is also at odds with the "antidegradation" requirements of state and federal law.[31] As the EPA has emphasized in its regulations, the Clean Water Act requires that "[e]xisting instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected."[32] North Carolina's antidegradation policy accordingly provides that "[e]xisting uses ... and the water quality to protect such uses shall be protected by properly classifying surface waters and having standards sufficient to protect these uses."[33] In arbitrarily declaring that the Lower Cape Fear is a "swamp water" with no need for dissolved-oxygen protections, state officials defied these requirements.

The ecological significance of North Carolina's effort to ignore the water-quality problems on the Lower Cape Fear River was recently confirmed by the National Marine Fisheries Service. On August 17, 2017, the agency issued a final rule designating critical habitat for the endangered "Carolina" population of the Atlantic sturgeon.[34] The designation includes all of the Cape Fear waters that North Carolina has deemed a swamp.[35] It also confirms the importance of sustaining "oxygen values that support" sturgeon "[s]pawning[,] ... survival[,] ... growth, development, and recruitment"—values that are substantially higher than those currently found in the Lower Cape Fear River.[36]

As a result of the recent critical-habitat designation, the EPA must consult with the National Marine Fisheries Service before taking action on North Carolina's

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[31] *See* 15A NCAC 02B .0201 (North Carolina's antidegradation policy); 40 C.F.R. § 131.12(a) (establishing the minimum requirements for state antidegradation policies); *id.* § 131.6(d) (requiring the EPA to ensure that state water-quality standards include "[a]n antidegradation policy consistent with § 131.12").

[32] 40 C.F.R. § 131.12(a)(1).

[33] 15A NCAC 02B .0201(b).

[34] 82 Fed. Reg. 39,160 (Aug. 17, 2017) (Attachment 3).

[35] *See id.* at 39,258.

[36] *Id.* at 39,240 (codified at 50 C.F.R. § 226.225(b)(4)); *see also id.* (noting that "6.0 mg/L dissolved oxygen or greater likely supports juvenile rearing habitat, whereas dissolved oxygen less than 5.0 mg/L for longer than 30 days is less likely to support rearing when water temperature is greater than 25 °C").

request.[37] And as a result of the reclassification's impermissible impacts on water quality in the Lower Cape Fear River, the state's request should be denied.

If you have any questions, do not hesitate to contact us. Thank you for your attention to this matter.

Sincerely,

Mary Maclean Asbill
Senior Attorney

Brooks Rainey Pearson
Staff Attorney

[37] *See* 16 U.S.C. § 1536(a)(2); *see also, e.g.*, National Marine Fisheries Service, Biological Opinion on EPA Approval of Water Quality Standards Under Section 303 of the Clean Water Act (July 29, 2016) (evaluating the impact of Florida's revised water-quality standards on listed species), *available at* https://repository.library.noaa.gov/view/noaa/14795 (last visited Apr. 26, 2018).

Memo to: NC Division of Water Resources, and NC Environmental Management Commission

From: Dr. Michael A. Mallin, Research Professor, Center for Marine Sciences, University of North Carolina Wilmington, Wilmington, NC, 28409

Date: February 9, 2015

Subject: Comment on the proposed reclassification of the lower Cape Fear River and Estuary to Class Sc-Swamp (Sw) classification.

1) I am very supportive of the statement in the reclassification proposal that states that any further municipal point sources will require the highest level of treatment in North Carolina. I would ask for more specifics regarding industrial discharges – at the least setting some limits on biochemical oxygen demanding agents such as biochemical oxygen demand (BOD), ammonia, total nitrogen (TN) and total phosphorus (TP).

2) An important statement that needs to be clarified is found in the narrative standards where it states that DO should not be less than 5.0 mg/L except that "swamp waters, poorly flushed tidally influenced streams or embayments, or estuarine bottom waters may have lower values if caused by natural conditions" . The issue that requires clarification is who decides, and by what criteria, if such a deviation is caused by "natural" conditions.

3) The proposed CFR reclassification does not adequately address non-point contributions of BOD or nutrients (which lead to BOD increases). If focus on non-point sources potentially contributing to oxygen depletion is continued to be addressed by on-going water quality programs; based on the summer blue-green algal blooms that occurred annually from 2009-2012, this approach has been inadequate and will continue to be inadequate.

4) In the lower Cape Fear River and Estuary, peer-reviewed research published in *Limnology and Oceanography* has demonstrated that BOD is driven by a number of biological and chemical factors (Mallin et al. 2004; Tables 4, 5 and 6) see the following:

- Chlorophyll *a* (the principal measure of algal bloom strength) has been positively correlated with BOD5 in the mainstem river at Lock and Dam #1 ($r = 0.55$, $p = 0.0001$), Browns Creek ($r = 0.45$, $p = 0.007$), Hammond Creek ($r = 0.45$, $p = 0.004$), Great Coharie Creek ($r = 0.51$, $p = 0.001$), Colly Creek ($r = 0.64$, $p = 0.0001$), Barnards Creek ($r = 0.37$, $p = 0.040$), Motts Creek ($r = 0.42$, $p = 0.020$), and Smith Creek ($r = 0.57$, $p = 0.0009$). I note that Browns, Hammond, Barnards and Smith Creeks drain directly into the mainstem river or estuary, while Colly and Great Coharie creeks drain into the lower Black River, a major 5th order tributary of the 6th order Cape Fear River.
- TN has been positively correlated with either BOD5 or BOD20 or both in the 5th-order Northeast Cape Fear River ($r = 0.30$, $p = 0.02$), the Black River ($r = 0.45$, $p = 0.0003$), Hammond Creek ($r = 0.47$, $p = 0.0003$), Six Runs Creek ($r = 0.54$, $p = 0.0005$), Great

Coharie Creek ($r = 0.44$, $p = 0.006$), Little Coharie Creek ($r = 0.52$, $p = p = 0.0008$), and Colly Creek ($r = 0.54$, $p = 0.0005$).

- TP has been positively correlated with either BOD5, BOD20 or both in the Northeast Cape Fear River ($r = 0.34$, $p = 0.008$) the Black River ($r = 0.33$, $p = 0.010$), Browns Creek ($r = 0.40$, $p = 0.012$), Hammond Creek ($r = 0.42$, $p = 0.009$), Six Runs Creek ($r = 0.49$, $p = 0.002$), Great Coharie Creek ($r = 0.66$, $p = 0.0001$), and Colly Creek ($r = 0.39$, $p = 0.015$).
- Chlorophyll *a* represents algal blooms, which upon death and decomposition become highly labile sources of BOD. Nutrients drive BOD in two ways: directly and indirectly. A peer-reviewed article in *Ecological Applications* by Mallin et al. (2004) showed that for streams in the Black and Northeast Cape Fear River basins, inputs of dissolved phosphorus directly stimulate BOD5 and BOD20, as well as natural bacteria abundance (the direct driver of BOD). The data also showed that inputs of dissolved nitrogen (nitrate ammonium, and urea) significantly stimulate algal growth, which in turn significantly stimulates BOD. Thus, the correlation between nutrient loading and BOD is not surprising.

5) The proposed reclassification is based on the Bowen (2009) model predicting DO concentrations in the lower Cape Fear River Estuary

- The Bowen model concludes that further reduction of current point sources would have little effect on DO concentrations – I will accept the model's conclusions on that matter.
- But, Bowen's model shows that reducing nutrient, carbon and BOD loads from the incoming rivers, creeks and wetlands by 30% and 70% would <u>increase</u> median DO from 5.6 mg/L to 5.85 and 6.2 mg/L, respectively – and this assumes sediment oxygen demand (SOD) stays the same regardless of reductions! See Bowen (2009) pages 6-4, 6-8, and 6-22 in particular for more on this topic.
- Assuming that such BOD load reduction would similarly reduce SOD, than the model says summer DO violations would decrease from 45% to 22% violations (30% reduction case), down to 7% (with 50% reduction) and down to only 1% violations (70% reduction case).
- I further note that SOD cannot simply be considered "natural" only. A year-long study of several tidal creeks in New Hanover County was published in the peer-reviewed journal *Hydrobiologia* (MacPherson et al. 2007). Results demonstrated that chlorophyll *a* concentrations were positively correlated with SOD ($r = 0.35$, $p < 0.05$), as well as BOD5 ($r = 0.50$, $p < 0.05$).

6) I note that Bowen does not discuss non-point source pollution sources specifically.

7) Yet, non-point runoff plays a major role in the middle to lower basin of the mainstem Cape Fear River, from crop agriculture, urban runoff and some livestock production. In the lower Cape Fear system I note that livestock waste pollution and crop agriculture are the predominant non-point nutrient and BOD sources in the Black and Northeast Cape Fear River basins.

8) Livestock manures as waste inputs were *not even mentioned* in Bowen's model! However, 2012 livestock counts for Brunswick, Pender, Duplin, Sampson, Cumberland

and parts of Bladen and Onslow Counties (Cape Fear lower watershed) are as follows (information for counties that are partially within the basin, Bladen and Onslow, are estimates):

- Hogs: approximately 5,000,000
- Turkeys: approximately 21,500,000
- Broiler chickens: > 122,000,000
- Other chickens: > 870,000
- Cattle: approximately 72,000

(from NCDA website September 2014)

Livestock wastes are clearly the largest source of BOD-forcing pollutants in the Cape Fear Basin – and remain virtually unregulated (i.e. no required streamside buffers, no required control of ammonia off gassing, etc.).

9) Industrialized swine farms (CAFOs) are a source of large-scale chronic nitrogen and phosphorus loading to nearby soils and receiving water bodies, nutrients which have been directly correlated to BOD in the blackwater streams and rivers of the Cape Fear Basin (Mallin et al. 2006). An peer-reviewed analysis by Cahoon et al. (1999) published in *Environmental Science and Technology* found that vast quantities of nitrogen and phosphorus feed are imported into the watershed annually to feed swine, poultry, and cattle in production facilities (CAFOs), which in turn annually load large quantities of nutrients as waste into the watershed. This analysis found that for the Cape Fear River basin alone, CAFOs produce 82,700 tons of nitrogen and 25,950 tons of phosphorus annually into this watershed. Thus, N and P enter the state as animal feed from elsewhere, but much of it leaves the livestock as manure (or carcasses) and enters soils or waters of the Coastal Plain.

10) Finally, swine waste lagoons, as well as lagoons servicing egg-laying poultry CAFOs, produce copious amounts of ammonia to the atmosphere; NC Division of Air Quality estimates a swine ammonia emission factor of 9.21 kg/hog-year. 9.21 x 5,000,000 head of swine = 46,050,000 kg or 46,050 metric tons of ammonia released to the airshed of the Cape Fear River basin (and coastal ocean) <u>per year</u>, much of which comes to earth within 60 miles of the source (Walker et al. 2000; Costanza et al. 2008). Ammonia is well-known in the environmental engineering literature to exert an oxygen demand (nitrogenous BOD) on waters – that is why it is regulated in wastewater discharges (Clark et al. 1977). Efforts need to be made to control this major source of oxygen-demanding wastes to the Cape Fear system as well.

11) Clearly, non-point sources of BOD, nitrogen, and phosphorus entering the waters of the lower Cape Fear River system are very large and lead to reduced dissolved oxygen levels.

I conclude that the proposed reclassification, as it stands, will be inadequate to produce or maintain proper dissolved oxygen concentrations in the lower Cape Fear River and Estuary due to the lack of attention to non-point sources of nutrients and BOD. The source of much of this pollution is industrial livestock production, along with unknown inputs from traditional agriculture, and some urban runoff in the Fayetteville and Wilmington areas. **Any**

proposed reclassification of the lower Cape Fear River and Estuary must include strong language specifically aimed at reducing such non-point sources of pollution.

Literature Cited

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin and J. Williams. 2009. Development and use of a three-dimensional water quality model to predict dissolved oxygen concentrations in the lower Cape Fear Estuary, North Carolina. Department of Civil Engineering, University of North Carolina Charlotte.

Cahoon, L.B., J.A. Mickucki and M.A. Mallin. 1999. Nutrient imports to the Cape Fear and Neuse River basins to support animal production. *Environmental Science and Technology* 33:410-415.

Clark, J.W., W. Viessman, Jr. and M.J. Hammer. 1977. Water Supply and Pollution Control, 3rd Edition. IEP-A Dun-Donnelley Publisher, New York.

Costanza, J.K., S.E. Marcinko, A.E. Goewert and C.E. Mitchell. 2008. Potential geographic distribution of atmospheric nitrogen deposition from intensive livestock production in North Carolina, USA. *Science of the Total Environment* 398:76-86.

MacPherson, T.A., M.A. Mallin and L.B. Cahoon. 2007. Biochemical and sediment oxygen demand: patterns of oxygen depletion in tidal creeks. *Hydrobiologia* 586: 235-248.

Mallin, M.A., M.R. McIver, S.H. Ensign and L.B. Cahoon. 2004. Photosynthetic and heterotrophic impacts of nutrient loading to blackwater streams. *Ecological Applications* 14:823-838.

Mallin, M.A., V.L. Johnson, S.H. Ensign and T.A. MacPherson. 2006. Factors contributing to hypoxia in rivers, lakes and streams. *Limnology and Oceanography* 51:690-701.

Walker, J., V. Aneja and D. Dickey. 2000. Atmospheric transport and wet deposition of ammonium in North Carolina. *Atmospheric Environment* 34:3407-3418.

Comments on the Proposed Reclassification
of the Lower Cape Fear River and Estuary to a Class Sc (Sw) Swamp

Prepared for Waterkeeper Alliance by JoAnn M. Burkholder, Ph.D., March 3, 2015

I. Overview

Since 1998, the lower Cape Fear River Estuary (LCFRE) segment from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut has been on North Carolina's 303(d) list of officially "impaired" (degraded) waters due to low dissolved oxygen (DO). In 2006, the state added impairment for pH, copper and turbidity to the 303(d) list for this segment. Throughout the past several decades, a subset of regulated point sources (i.e., with wastes mainly discharged to surface waters through one or more pipes) have been the state's focus for water quality improvement. In 2014, the North Carolina Division of Water Resources within the Department of Environment and Natural Resources (NCDENR-DWR) received a request from a group including various point source dischargers to reclassify the LCFRE from Class Sc to Class Sc-Swamp (Sw) (May 2014). The rationale given for the request included two points - first, that a recent modeling effort (Bowen et al. 2009) had assessed the 20 largest point sources in the lower Cape Fear River basin and concluded that the sources have little influence on water-column DO concentrations in the LCFRE; and second, the group asserted that significant reductions in pollutant loading from other sources which they call "background" loads would not achieve attainment for certain periods of the summer. The request specifically stated,

> ...modeling results indicate that [the 20 assessed] point-source discharges have a relatively minor impact on DO levels, and that even significant reductions in background (both natural and nonpoint source) loads would not result in attainment of the current standard for considerable periods of time during the summer. - May (2014)

Based on this request and information, NCDENR-DWR recently proposed to reclassify the LCFRE to a swamp (Sw) based on the misleading claim that, since the LCFRE cannot meet its present DO standard (≥ 5 mg/L) by controlling the 20 identified point sources alone as assessed in Bowen et al.'s (2009) model, a TMDL (total maximum daily load) to achieve the DO standard would be inappropriate. The proposed reclassification of the LCFRE to a swamp is not consistent with sound science or the law for three reasons:

1. The available evidence shows that the major sources of oxygen-demanding materials in the LCFRE are due to pollution from human activities which are subject to regulation and can be controlled. The major sources of oxygen-demanding materials are **not** natural wetland drainage or other natural background sources. Natural wetland drainage appears to add only a fraction of the massive contribution of oxygen-demanding materials, high levels of toxic copper, high turbidity, and many other pollutants that are being contributed by pollution from point sources, other regulated sources and nonpoint sources (see Sections IIID-E of these Comments).

2. Under the Clean Water Act, the required TMDL for the LCFRE must address ***all*** pollution sources, including point sources, other regulated sources, and nonpoint sources, in the watershed (see Section IIID of these Comments). In its proposed action, NCDENR-DWR has *not* considered ~22 NPDES-permitted point sources in the lower Cape Fear basin, or *any* of the ~153 NPDES-permitted point sources in the upper and middle Cape Fear River basin, which contribute to the impaired (degraded) water quality of the LCFRE which is at the receiving, lower end of the basin. NCDENR-DWR *also* failed to consider the impact of the nearly 1,000 industrial-scale swine Animal Feeding Operations as well as an unknown number of industrial-scale poultry Animal Feeding Operations, many of which are Concentrated (Confined) Animal Feeding Operations (CAFOs) and, thus, point sources under the Clean Water Act. These sources were also omitted from specific analysis in the Bowen et al. (2009) model, although many of the industrial facilities are located in the lower basin (see Section IIIE of these Comments). As a scientist, I first approached their inclusion in these Comments by checking the formal definition of CAFOs in the Clean Water Act (Section 502(14)). *CAFOs are formally defined there as point sources.* They are supposed to be regulated using National Pollution Elimination Discharge System (NPDES) permits, as other industrial point sources are regulated. There are about five million swine in the Cape Fear basin. Each swine produces, on average, about four times more sewage than one person (see Section IIIE). Therefore, the swine CAFO point sources, which are predominantly in the lower Cape Fear basin, contribute roughly the same amount of sewage to that relatively small area, *per year*, as 15 million people. Moreover, swine wastes are much richer in oxygen-demanding materials than human sewage. Industrialized poultry production, also massive in the Cape Fear River basin, contributes to oxygen-demanding materials and other water quality degradation of the LCFRE as well (see Section IIIE). Overall, ~175 NPDES-permitted point sources in the Cape Fear River watershed, and nearly 1,000 swine CAFO point sources as well as an unknown number of poultry CAFOs, were not identified and appropriately evaluated by Bowen et al. (2009) and NCDENR-DWR. These sources are not simply "background" as misleadingly characterized in the materials underlying the NCDENR-DWQ Proposal to reclassify the LCFRE and in the Proposal itself. Collectively, and often individually, these facilities are **extreme**, chronic pollution sources of oxygen-demanding materials to the LCFRE. They can be, and should be, addressed through state regulatory programs, the Clean Water Act and a TMDL for the LCFRE.

3. *Significant reductions in the erroneously termed "background" loads* **would** *achieve attainment of the present DO standard in the LCFRE segment.* As explained above, what was misleadingly and inaccurately called "background" in the lower Cape Fear basin includes the point source pollution from ~175 NPDES-permitted point sources in the Cape Fear River watershed, and from nearly 1,000 swine CAFOs and an unknown number of poultry CAFOs. All of these pollution sources were not among the 20 considered by Bowen et al. (2009) as the main point source contribution to the LCFRE. These sources were, at least, tacitly included in Bowen et al.'s (2009) model within a category called "tributary inputs." The model predicts that a reduction of 30% of the "tributary inputs" would result in median DO levels in the LCFRE that exceed 5 mg/L -- that is, higher than the state standard -- and that a

70% reduction in the "tributary inputs" and the internal oxygen demand (below) largely resulting from these inputs would bring the LCFRE into compliance 99% of the time.

If the proposed reclassification occurs, NCDENR-DWR will accomplish a contrived, highly artificial "official change" of a major, strongly flowing estuary of national importance to a "swamp" with no scientific basis. Rather than providing cleanup and protection of the impaired segment -- which has been officially designated as impaired and in need of improved protection for nearly two decades -- this action would allow much more pollution to occur there, in violation of the Clean Water Act. Consequently, NCDENR-DWR's proposed reclassification would jeopardize the designated uses of the LCFRE. The LCFRE should *not* be reclassified as a swamp.

The scientific facts briefly mentioned above, which accurately describe the status of the LCFRE and the pollution affecting it, are explained in detail in the following comments, supported by peer-reviewed science literature and findings from federal agencies such as the U.S. Department of Agriculture (USDA) and the U.S. Environmental Protection Agency (USEPA).

II. The Mighty Cape Fear River

The Cape Fear River basin, completely contained within North Carolina, is the largest watershed in the state, covering ~16.5% (~9,324 square miles) of total land area. It also contains the largest number of stream miles (6,204) in North Carolina (Lin et al. 2006, Bowen et al. 2009 and references therein). The 26 counties within or overlapping the watershed are expected to grow from 3 million to about 5 million people over the next 20 years.[1] There presently are about 1.7 hogs per person in the Cape Fear basin, and industrialized swine production as well as turkey production in the lower basin are among the most concentrated in the world (Mallin et al. 2003).

The LCFRE is "extremely important... because of its function as a nursery for juvenile fish, crabs, and shrimp . . . The river is also an important natural resource that supports many uses including industry, transportation, recreation, drinking water, and aesthetic enjoyment" (Bowen et al. 2009). On a popular tourism website[2] are quotes such as the following about the LCFRE (emphasis added):

- Hard to review a river! It's *wild, powerful,* beautiful in all seasons....
- Amazing to walk down on the observation area and look at *how fast the river moves through this area.* You can understand how and why it got its name.
- *Cape Fear river current is very swift and strong.*

Thus, casual observers can discern that this segment of the LCFRE is highly river-influenced with strong flow. Bowen et al. (2009, p. 2-4) wrote, "[f]rom a hydrodynamic perspective,

[1] (NDENR) http://www.eenorthcarolina.org/images/River%20Basin%20Images/final_web_capefear.pdf.

[2] (http://www.tripadvisor.com/ShowUserReviews-g49673-d107702-r242913110-Cape_Fear_River-Wilmington_North_Carolina.html#REVIEWS

the Cape Fear has approximately a two-meter [~6-foot] tide range and strong tidal currents (> 0.5 meter per second) in the navigational channel of the open estuary and in the narrower tidal river channels of the three major tributaries (the mainstem freshwater river, and the Northeast Cape Fear and Black Rivers)." The LCFRE system is, in fact, documented in the science literature as strongly flowing down to its confluence with the Atlantic Ocean (e.g. Ensign et al. 2004, Lin et al. 2006, Becker et al. 2010). The strong flow minimizes stagnant areas and helps to add oxygen from the overlying air (Wetzel 2001).

It has been erroneously suggested in the NCDENR-DWQ Proposal and supporting materials that this strongly flowing, high-volume river is so strongly influenced by oxygen-demanding materials from natural drainage of freshwater wetlands and saltmarshes that the LCFRE is "swamp-like" with respect to DO conditions. Slowly flowing blackwater streams with instream wetlands in the Coastal Plain of the southeastern U.S. *can* receive high inputs of DO-demanding materials from the wetlands, and DO can range from 4-6 mg/L (Mallin 2000, Todd et al. 2009, and references therein). However, *such characteristics of slow flow and in-stream wetlands do not characterize most of the LCFRE system.* One area of the estuary north of Wilmington which receives major influx of swine wastes from CAFOs, near the junction of the Cape Fear, Black, and Northeast Cape Fear Rivers, has been described as prone to low DO levels during summer-early fall, but the low DO levels there have been related to *high anthropogenic pollution* along with inputs of natural organic materials (Mallin et al. 2003). Water quality in that area, as throughout the segment, would be greatly improved by reducing the high anthropogenic pollution coming into the segment from the many regulated pollutions sources in the Cape Fear watershed that were inappropriately excluded from consideration or lumped in with background sources in the NCDENR-DWR Proposal and supporting materials.

III. Sources of Water Quality Impairment

A. Historic Background, Assessments, and Erroneous Assertions

Historically, the LCFRE system was considered non-eutrophic because of its rapid flushing (Ensign et al. 2004). In the upper and middle Cape Fear River during 1955-1980, Crawford (1985) noted that DO concentrations at Lock 1 averaged 8.2-8.4 mg/L depending on the data source, and that on only two occasions from 1975 to 1980, DO samples were above 4 mg/L but less than 5 mg/L. Similarly, NCDENR (1999) described the upper portions of the estuary in the 1990s as rarely having sustained low DO levels that caused problems (assumed to refer to problems for aquatic life). The present-day LCFRE, however, is impaired due to major pollution from the upper, middle, and lower watershed (Cahoon et al. 1999, Mallin 2000, Mallin et al. 2003). As a result of declining water quality due to many pollution sources, for the past ~15 years the Cape Fear Estuary has been characterized as moderately eutrophic (= moderately nutrient-polluted; Bricker et al. 1999).

As described by NCDENR (2005),

> The [Cape Fear] watershed (about 9,149 square miles) is the most heavily industrialized in North Carolina with 244 permitted wastewater discharges and (as of 2000) over 1.83 million people residing in the basin....

> Approximately 24% of the land use in the watershed is devoted to agriculture and livestock production.

Historically, post-European settlement, the lower Cape Fear River and Estuary received mostly raw (untreated) or partially treated wastes from the Riegel Paper Corporation (in Wilmington; became Federal Paperboard Company, and then International Paper from 1996 to the present) and the various, relatively small human population centers that developed along it (State Stream Sanitation Committee 1957, CH2MHill 2014a - Technical Memo 1 in May 2014, used to support the request for reclassification of the LCFRE segment). CH2MHill (2014a) described the previous situation as "significant impacts from untreated and poorly treated wastewater under low to moderate flow conditions in the river" prior to improvements in waste treatment. In the mid-1950s on one date (August 30, 1955), low DO (1.3-2 mg/L) and low pH (5-6) were measured in the Northeast Cape Fear and Black Rivers, the two main tributaries to the Cape Fear Estuary other than the mainstem Cape Fear River as mentioned. On two dates (July 23-24, 1956) during moderate flows from these two tributaries and high flow from the mainstem Cape Fear River, DO and pH in the lower river were 2.8-4.9 mg/L and 6.8-7.2, respectively. The interpretation from this sparse information (three dates, ~60 years ago) was that "*under some situations*, swamp drainage conditions *could* significantly influence DO and pH conditions in the river. . .." (emphasis added) (State Stream Sanitation Committee 1957, CH2MHill 2014a).

From there, however, a major "leap" occurred in CH2MHill's (2014a) writing (p.D-15 in May 2014): Riparian wetlands -- that is, natural wetland drainage -- were described, without any other supporting data, as the "significant contributors to the tremendous loads of oxygen-demanding materials." CH2MHill (2014a, p.D-15) secondarily acknowledged that inputs of biochemical oxygen demand (BOD) have also been contributed by raw and partially treated sewage, and from swine wastes, although CH2MHill mistakenly stated that swine wastes only contribute pollution to the LCFRE when cess pits breach. As corrective information, swine wastes *routinely* contaminate the LCFRE (see Section IIIE of these Comments), and researchers have evaluated swine CAFO wastes as a major source of BOD in the LCFRE (e.g. Mallin et al. 1997, 2006; Mallin 2000). Yet, the remainder of CH2MHill's (2014a) writing implicated natural drainage from wetlands as the major contributor of oxygen-demanding materials to the LCFRE. In the 1950s, the Cape Fear basin had less industrialization and fewer point sources (including no CAFOs), but the present reality is far different. As explained above, the Cape Fear River basin is *now* described as the largest, most industrialized watershed in North Carolina (Mallin et al. 2003, NCDENR 2005).

TetraTech (2014 - Technical Memo 2 in May 2014, used to support the request for reclassification) considered BOD loads from three specific point sources, which they erroneously described as contributing about 90% of all point source loads to the LCFRE. In reality, these three point sources contribute only a small fraction of the total point source loads - see Section IIID-E of these Comments. Based on data from the previous 20 years, TetraTech reported a significant downward trend (~23% decrease over time) in oxygen-demanding pollutant loads from the three selected point sources, without a corresponding decrease in water-column DO. The lack of a corresponding decrease in average DO should have been expected, considering that TetraTech *did not* assess ~1,194 other regulated sources in the Cape Fear watershed that are contributing oxygen-demanding materials and other pollution to the LCFRE. Over the same 20-year period in the Cape Fear River basin,

the human population increased by ~0.66 million and swine production increased by ~5 million animals per year (compiled from U.S. Census Bureau data, Burkholder et al. 1997, and Cahoon et al. 1999). Yet, TetraTech (2014) implicated wetlands as the major contributor to oxygen-demanding materials in the the LCFRE. TetraTech stated that the information from its recent analysis supported its previous assessments of the LCFRE (TetraTech 2001, 2003), and erroneously maintained that its assessment supported reclassification of the LCFRE segment to a swamp.

CH2MHill (2014b - Technical Memo 4 in May 2014, used to support the request for reclassification) described an analysis of surface water quality conditions in summer (which was defined as April-October) at main inflows to the Cape Fear River Estuary including the Middle Cape Fear River, the Black River, and the Northeast Cape Fear River. Importantly, *the Northeast Cape Fear River and the Black River stations were* ***erroneously*** *described as characteristic of "water quality as water leaves areas currently classified as swamps."* These segments are classified as swamps, but their present water quality reflects massive pollution, not natural wetland inputs (see Section IIID, p.18 below). During the early to mid-1990s, the relatively small areas of the Northeast Cape Fear and Black River watersheds sustained an influx of more than 800 swine CAFOs with more than 3 million swine produced per year (NCDENR 2005; and *Figures 1 and 2*). They contribute roughly the same amount of wastes as 12 million people, and the wastes are poorly regulated (see Section IIID).

Bowen et al. (2009) tacitly included pollution from swine feeding operations in "tributary inputs" although they were not specifically mentioned. CH2MHill (2014b) and TetraTech (2014) not only failed to mention them (and in CH2MHill 2014a, there was only one, partly inaccurate mention of swine operations as described above), but also omitted them from consideration. All of the other point source contributions from the upper and middle watershed were not considered as well. The omission of CAFO wastes and most other point sources in the watershed from consideration in assessments of oxygen demand in the LCFRE is irrational rather than science-based. The extreme error of omission in those reports is compounded by an equally extreme error of co-mission - repeatedly attributing to natural wetland drainage the massive oxygen-demanding pollution known to be contributed by other sources including CAFOs (e.g. Dewi et al. 1994, Burkholder et al. 2007 and references therein; see Section IIID below). Similarly, NCDENR was described by May (2014, p.D-3) as having stated, erroneously, that "changes in the classification of the LCFRE might be appropriate to recognize the influence of natural drainage from riverine and saltwater marsh systems in the watershed on DO concentration."

There is no basis in fact - no data - supporting major attribution to natural freshwater wetlands and saltmarshes of what CH2MHill (2014a) described as "tremendous" loads of oxygen-demanding materials in the LCFRE, while "overlooking" the massive pollution from ~98% of the point and other regulated sources in the watershed.

B. Processes Influencing DO Conditions, and Available Information for the LCFRE

Several major processes influence water-column DO concentration in rivers (*Figure 3*). Oxygen demand from two general sources controls water-column DO: *external* (incoming)

materials from land-based sources, upstream waters and the overlying airshed, usually referred to as the BOD in the water column, and the "*internal*" oxygen demand from biota respiration and river bottom sediments, usually called the sediment oxygen demand (SOD).

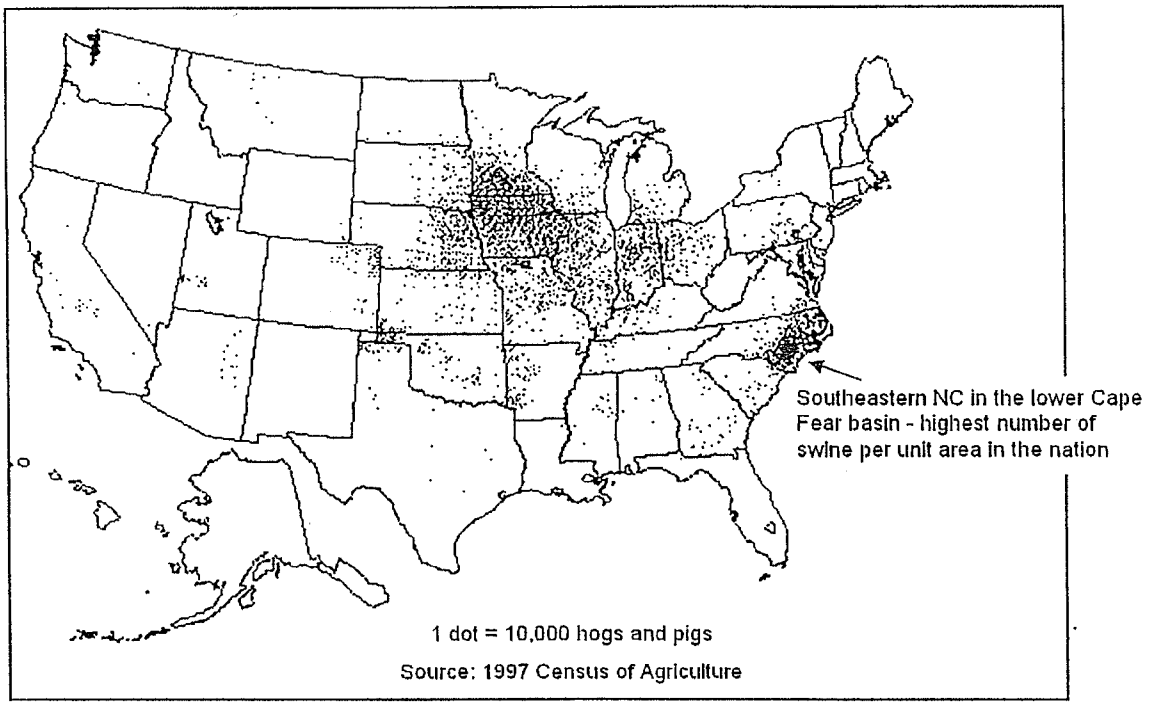

Figure 1. Map showing the number swine in southeastern North Carolina, with most CAFOs in the lower Cape Fear River basin area (source: http://scorecard.goodguide.com/env-releases/aw/nc-riverbasin.tcl?image_id=030300&huc6=030300). This map, produced by the USDA based on 1997, data, is supported by a more recent map, available at http://www.agcensus.usda.gov/Publications/2012/Online_Resources/Ag_Atlas_Maps/Economics/Market_Value_of_Agricultural_Products_Sold/12-M030.php, which shows the value of hogs and pigs sold in 2012 as the percent of the total market value. The highest concentration of swine per unit surface area across the nation is in the lower Cape Fear River basin.

BOD (units, milligrams per liter, mg/L) is the sum of carbonaceous and nitrogenous oxygen demands; it is a measure of the molecular oxygen used in the water column during a specific incubation period, usually 5 days, for the biochemical degradation of organic material (carbona-ceous demand) and the oxygen used to oxidize inorganic material (nitrogenous demand), as well as the amount of oxygen used to reduce forms of nitrogen (Eaton et al.1995, MacPherson 2003).

SOD (units, grams of molecular oxygen per square meter per day, g O_2 /m^2/day) is defined as the rate of DO removal from the water column due to the decomposition of organic matter in the bottom sediments (Hatcher 1986). It consists of biological sediment oxygen demand (usually at the sediment surface, dominated by bacteria that consume organic materials) and chemical sediment oxygen demand (usually ~2 inches down in the sediment, where anaerobic

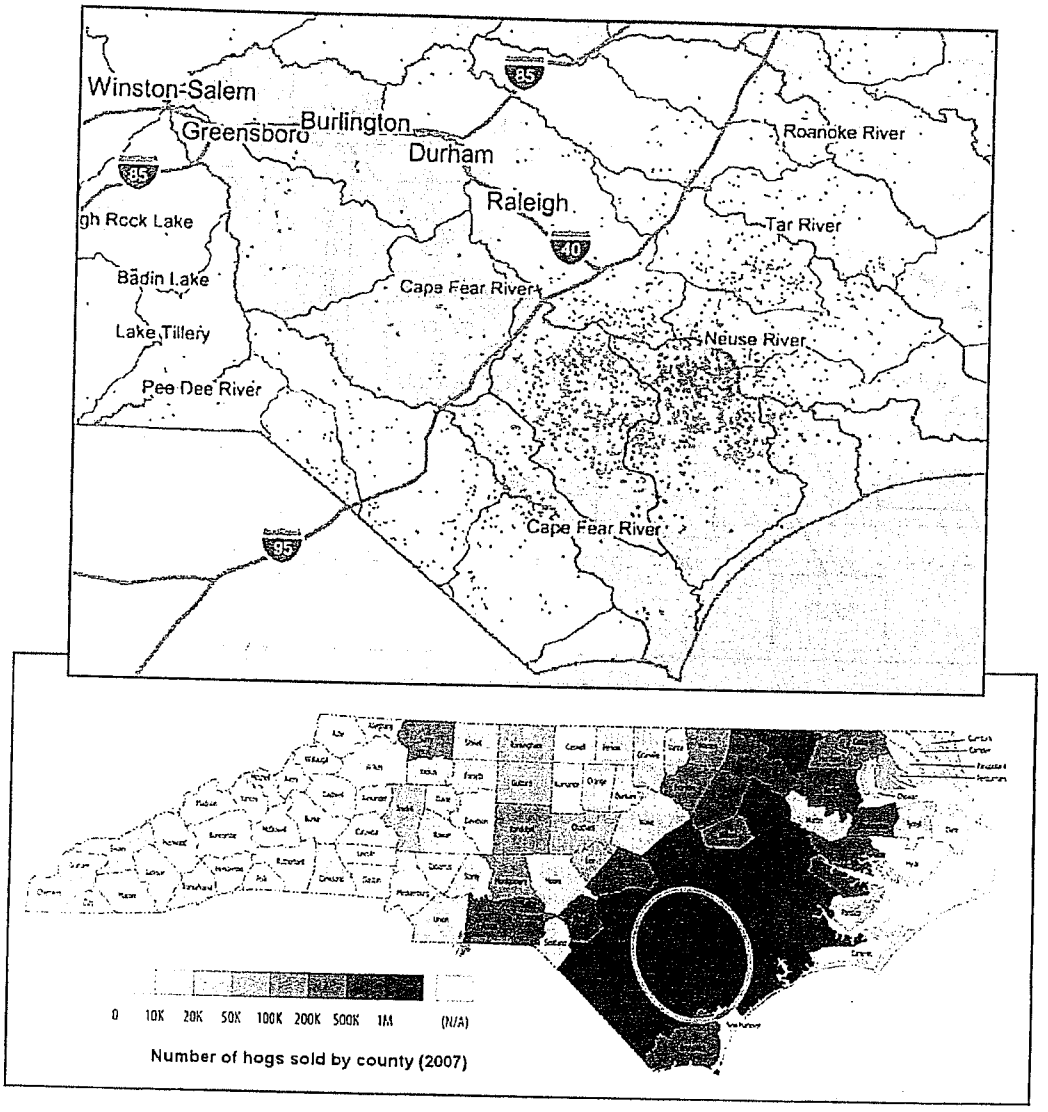

Figure 2. Upper panel - map showing the locations of swine CAFOs in North Carolina, indicating the preponderance of CAFOs in the lower Cape Fear River basin (source: http://scorecard.goodguide.com/env-releases/aw/nc-riverbasin.tcl?image_id=030300&huc6=030300, last accessed in February 2015). Lower panel: Map showing the numbers of hogs sold in North Carolina counties during 2007 (K ≡ thousands, M ≡ millions; U.S. Census data), modified from Learn NC, a program of the University of North Carolina School of Education (available at http://www.learnnc.org/lp/editions/nchist-recent/6257, last accessed in August 2014). The darker area "down east" on the Coastal Plain of the state has, as mentioned, the highest concentration of swine per unit area in the nation (National Hog Farmer 2014.).

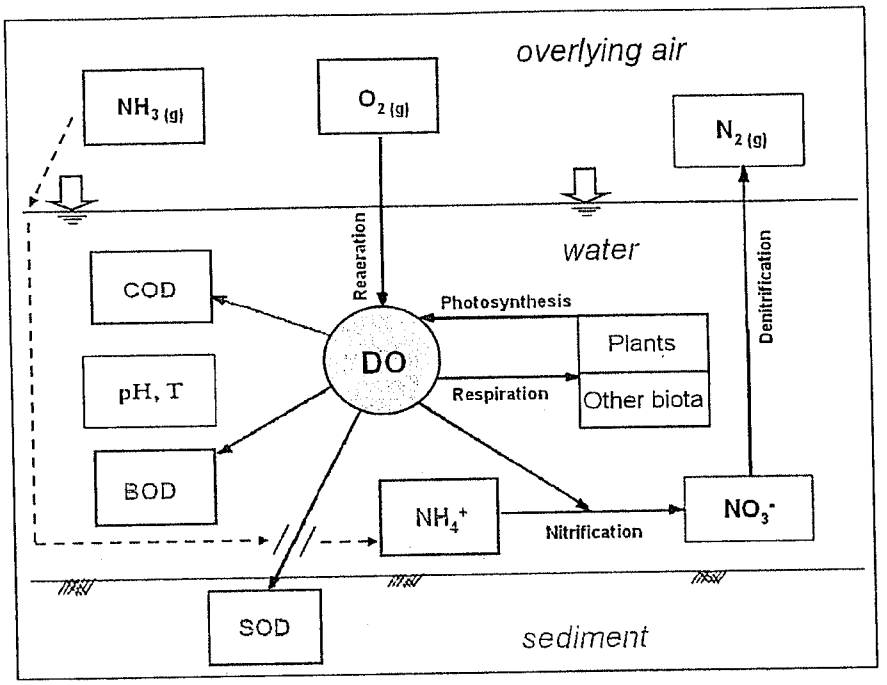

Figure 3. A schematic of the major processes influencing the water-column ("water") DO concentration in rivers: O_2 = the oxygen gas diffusing into the water from the atmosphere; N_2 - the nitrogen gas diffusing out of the water into the atmosphere; COD - the immediate chemical oxygen demand; T - temperature; NH_4^+ - ammonium; NO_3^- - nitrate. Arrows directed toward DO indicate DO sources; arrows directed away from DO indicate DO users (consumers or "sinks"). Parameters in red are oxygen-demanding. Other environmental conditions that can affect DO are represented by pH and temperature (T). The dashed-line arrow indicates that ammonia from the overlying airshed, largely contributed in southeastern North Carolina by swine CAFOs (Walker et al. 2000, Aneja et al. 2003), is mostly ionized to ammonium in neutral to alkaline waters and becomes a source of nitrogenous oxygen demand in forming nitrate. Modified from Cox (2003).

anaerobic bacteria degrade organic matter in a process that produces reduced ions that react with oxygen when they diffuse upward to an oxidized area (Walker and Snodgrass 1986).

The organic materials contributing to SOD can come from outside the system (such as leaf litter or settling of organic particles from human or animal wastes), or from within the system (such as decomposing algae). SOD is positively related to the amount of organic carbon content (i.e., bioavailable organic materials) in the sediment (MacPherson 2003 and references therein). Basically, the rate at which the sediment community consumes oxygen indicates whether the sediment area is degraded by too much organic matter (Massachusetts Water Resources Authority 2002). Once organic material reaches the bottom sediments of the river segment, SOD is influenced by two different processes: the rate at which oxygen diffuses into the sediments and is consumed there, and the rate at which reduced organic substances move into the water column and are then oxidized (Bowie et al. 1985, Todd et al. 2009).

Thus, SOD is the combination of the respiration of bottom-dwelling organisms in the sediment from decomposition of organic matter, and chemical oxidation of reduced substances in the sediment (Todd et al. 2009, and references therein). SOD can create oxygen deficits by reducing the amount of available oxygen in the overlying water (Seiki et al. 1994), and it can be a significant percentage of the total oxygen consumed in a given river or estuary (Caldwell and Doyle 1995). SOD rates serve as proxies for the effects of pollution on the biological activity of the bottom (benthic) community; for example, a nutrient-polluted system generally has an increased demand for oxygen (Natural Research Council 2000). Extreme levels of SOD (~20 $g/m^2/day$) can occur from oxygen consumption by animal wastes or sewage materials that settled out to the bottom (Davis 1950). Reduction in the amount of incoming organic materials from such pollution can lower the SOD as the system recovers (see Massachusetts Water Resources Authority 2002).

The sophisticated three-dimensional, Environmental Fluid Dynamics Code model used by Bowen et al. (2009) requires extensive information for the many factors needed to construct (parameterize) it for a specific river segment (Hamrick 1992; Bowen et al. 2009 - see p.v, Table 1, and Figure 2 in that document). Adequate measurements from the LCFRE for many of these factors were/are not available, and they vary considerably from river to river (Hamrick 1992, Todd et al. 2009, and references therein). The required missing or sparse (inadequate) information includes oxygen fluxes between the water column and the bottom sediment of the river. The information was instead "prescribed" (estimated, or taken from general literature not specific to the LCFRE) (Bowen et al. 2009, p.2-1). Bowen et al.'s (2009) model development revealed that, as in many if not most lower rivers along coastlands, SOD has an especially significant impact on DO concentrations. *SOD varies by as much as three orders of magnitude (1,000-fold) from river to river*, with rates ranging from ~0.1 to 18 grams of oxygen [demand] per square meter per day ($g/m^2/day$) (Rolley and Owens 1967, Chapra 1997, Todd et al. 2009). Importantly,

> The effect of SOD on the oxygen budget of an entire river system should not be underestimated, as it can be a critical sink of DO (Wu 1990). Indeed, in some rivers SOD can account for over half of the total oxygen demand and can play a primary role in the water quality....[Yet] this parameter is often assumed (or estimated) in water quality models (Hatcher 1986, Matlock et al. 2003). Errors in this measurement could lead to inaccurate models for the stream environment, at great biological and financial cost. - Todd et al. (2009)

Only sparse, dated SOD information was available for the LCFRE, taken more than a decade ago by the former NCDENR – DWQ (Division of Water Quality) at five locations on only five dates during summer/fall of one year, 2003 (Bowen et al. 2009, pp. 2-14, 2-15). At a given location, SOD is known to vary substantially by season and from year to year (Hatcher 1986, MacPherson 2003 and references therein). Lacking sufficient data and, thus, finding these sparse data to be a poor fit for the model overall, Bowen et al. (2009) "selected" SOD values until they found one that best fit their model for predicting water-column DO data, which had been constructed using available water-column DO measurements. In other words, Bowen et al. knew what the water-column DO had been because it had been measured during the period of focus, so they tried different SOD values until the model generally "fit" the water-column DO data. The SOD value (adjusted in an attempt to allow

for seasonal changes) was applied to most of the LCFRE; a second, nearly four-fold higher value for SOD was applied to the Northeast Cape Fear River which is heavily influenced by swine CAFOs (see p.18 below). Bowen et al.'s (2009) approach to estimate SOD technically requires that all rates except SOD have been accurately determined based on data for the specific system (Cox 2003). In reality, some of the data needed to accurately estimate the major rates of processes shown in *Figure 3* of these Comments (photosynthesis, respiration, nitrification, denitrification, reaeration) are lacking at representative points along the LCFRE system. Such data should include at least monthly measurements from April through October during dry, average-precipitation, and wet years (Hatcher 1986 and references therein).

C. The Model Predicted 90% Control of LCFRE DO Levels by the "Tributary Inputs," and Compliance with the DO Standard by Reducing Those Inputs

Despite the above-described weaknesses, Bowen et al.'s (2009) model *did* predict - as would be expected from knowledge of pollution sources in the LCFRE basin - that the 20 point sources they considered had only a small effect on the water-column DO concentrations. In contrast, "tributary inputs," loosely defined as excluding the 20 point sources, were evaluated as the major controlling influence on DO. Importantly, when Bowen et al. artificially forced SOD to remain constant over time despite imposing reductions of 30%, 50%, or 70% in BOD loads from the "tribuary inputs," the model predicted that the BOD decreases alone would increase median DO concentrations to well above the present DO standard of 5 mg/L. In addition, if BOD from tributary inputs and SOD were both reduced by 30%, the model predicted that summer DO violations would decrease from 45% to 22%, down to only 7% with a 50% reduction, and down to 1% with a 70% reduction. Such a scenario of decreasing BOD and SOD is realistic, as SOD is known to decrease over time with decreasing water-column BOD inputs, and related decreases in the bioavailabilty of organic matter that settles out to the sediments (Hatcher 1986, MacPherson 2003 and references therein).

Bowen et al. (2009) did not attempt to address the predominant sources in the "tributary inputs." They aptly noted (pp. vii-viii) that their model indicated the importance of benthic fluxes of oxygen. They also aptly recommended additional work to assess SOD and also, importantly, to separately consider the effects of wetland (natural) versus "riverine" (pollution carried by the river and tributaries) loadings to DO conditions in the estuary. The subsequent work in support of this proposal did not conduct these evaluations.

D. Point Source Pollution from NPDES-Permitted Facilities Upstream from the LCFRE

Given the above predictions from Bowen et al.'s (2009) model, control of "tributary inputs" *would* allow the LCFRE to attain the present DO standard. Therefore, a TMDL for the LCFRE segment is entirely appropriate. Moreover, as stated, the available scientific information indicates that human-related pollution - not natural wetland drainage - is the major source of oxygen-demanding materials to this segment (see pp. 18-19 below).

The U.S. EPA states that:[3]

[3] http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/overviewoftmdl.cfm#tmdlrequired

the objective of a TMDL is to determine the loading capacity of a given water body and to allocate that load among different pollutant sources so that the appropriate control actions can be taken and water quality standards achieved....**All contributing sources of the pollutants** (point and nonpoint sources) are identified, and they are allocated a portion of the allowable load...." (emphasis added).

Thus, a TMDL for the LCFRE should consider the entire watershed above that segment as potentially contributing to pollution in that segment. According to NC DENR[4], the upper-middle Cape Fear basin has 38 major point sources (discharging ≥ 1 mgd; *Figure 4*) and ~115 minor point sources (< 1 mgd) with NPDES permits. The lower Cape Fear basin contains 10 major point sources and 33 minor point sources with NPDES permits. Thus, the river sustains loading from 195 NPDES-permitted point sources including nearly 50 major NPDES-permitted point sources and nearly 150 minor NPDES-permitted point sources. Consider the following example of a major point source that was not among the 20 specifically assessed by Bowen et al. (2009):

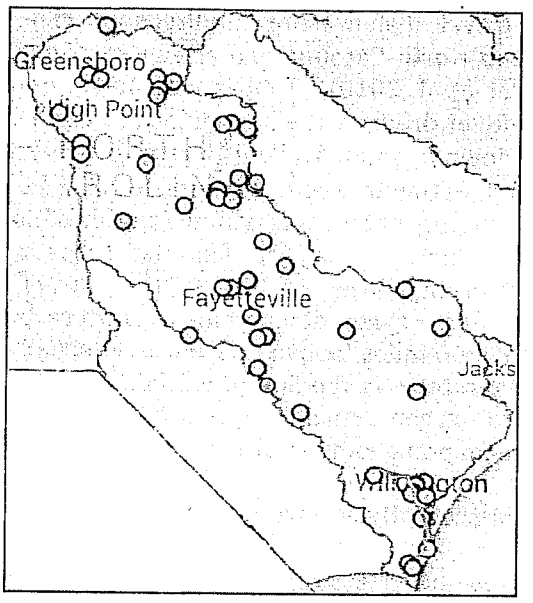

Figure 4. Map showing the locations of major point sources with NPDES permits from NC DENR in the Cape Fear River basin (red dot, Smithfield Packing Company; red line - approximate location of the LCFRE segment proposed for reclassification). Modified from NC DENR (see websites given in footnote 4).

The Smithfield Packing Company at Tar Heel in the mid-Cape Fear River basin, ~60 miles upstream from the LCFRE (location indicated by the red dot in *Figure 4*), is permitted to discharge up to 3 mgd of effluent containing up to 250 pounds of BOD_5 per day during April - October as a monthly average, and up to 500 pounds of BOD_5 as a daily maximum (NC DENR permit #NC0078344). During November-March, the plant is permitted to discharge double those amounts (i.e., 500 pounds per day, monthly average; 1,000 pounds per day, daily maximum, equivalent to 45 mg of biochemical oxygen-demanding materials/L). Rivers are considered to be stressed with too much BOD_5 if concentrations exceed 3 mg/L (Mallin et al. 2006). The plant is also permitted to discharge 30 pounds of ammonia-N/day as a monthly average during April-October, and 60 pounds of ammonia-N per day (7.5 mg/L) as a daily maximum. In November-March, these numbers, as pounds per day, can double. As explained, ammonia is oxygen-demanding, highly toxic to sensitive aquatic life, and a form of inorganic nitrogen that, at concentrations of only 0.1-0.2 mg/L, can stimulate noxious and toxic algal outbreaks (Bricker et al. 1999 and references therein, Mallin 2000). Other inorganic nitrogen forms, nitrate+nitrite, in discharges from the plant can be up to ~120 mg/L as a monthly average, and up to ~185 mg/L as a daily maximum. As stated,

[4] 2014 - http://portal.ncdenr.org/web/wq/npdes-major-facility-map, and http://portal.ncdenr.org/web/wq/npdes-minor-facility-map.

only 0.1-0.2 mg/L of inorganic nitrogen is needed to stimulate noxious and toxic algal outbreaks. Thus, extremely high oxygen-demanding materials and inorganic nitrogen nutrient forms are permitted for discharge by this major point source.

Overall, nearly 150 NPDES-permitted point sources in the Cape Fear River watershed are upstream from or adjacent to the LCFRE. Some pollutants from these point sources, such as the highly soluble nitrogen species, nitrate, are highly soluble; nitrate, for example, is known to travel distances of hundreds of miles downstream from upper to lower watersheds in North Carolina and elsewhere (Mallin et al. 1993, Houser and Richardson 2010, Houser et al. 2010). That is why, for example, various pollutants from the upper Mississippi River drainage are known to contribute to the "dead zone" of little or no oxygen all the way down in southern Louisiana, near the river's confluence with the Gulf of Mexico (Goolsby and Battaglin 2001, Jacobson et al. 2011). Nutrient pollution contributes to oxygen-demanding materials by stimulating algal blooms that die and are then decomposed by bacteria which use oxygen for that process (Burkholder and Glibert 2013, and references therein). Based on the fact that nitrate, much less soluble pollutants such as phosphorus, and oxygen-demanding organic carbon materials can travel much longer distances than 60 miles (above references, Minshall et al. 1983, Meyer and Edwards 1990), the excessive nitrate in the Smithfield Packing Company discharge should be expected to contribute to oxygen-demanding materials in the LCFRE ecosystem. The same is true of other upstream point sources, other regulated sources and nonpoint sources.

E. Point Source Pollution from Animal Production in the Lower Cape Fear Basin

In addition to the ~150 NPDES-permitted point sources that should be considered by NCDENR in developing a TMDL to improve DO in the LCFRE, there are nearly 1,000 swine CAFO point sources in the lower Cape Fear basin (and an unknown number of poultry CAFOs, based on Mallin 2014). The available scientific information shows that swine CAFO point sources are the major source of water quality impairment in the lower Cape Fear basin.

Major degradation of the natural resources in the lower Cape Fear basin due to swine CAFO point sources -- encompassing degradation to the airshed, soils, groundwaters, and surface waters -- has been well-documented and is briefly summarized below. It merits mention that, throughout these Comments, the focus when considering CAFOs is on swine production because relatively little information about poultry production is available to scientists or other members of the general public (e.g. see Rothenberger et al. 2009a). North Carolina is second in poultry production among the states, but nearly all of the operations have fewer animals than are defined by the state legislature as a poultry CAFO, and most information is allowed to the general public only for poultry CAFOs. Thus, most information given below for industrialized animal production in the Cape Fear basin is substantially underestimated because it focuses only on swine.

The available information *does* show that poultry production is a major source of pollution in the Cape Fear watershed (Cahoon et al. 1999). According to the North Carolina Department of Agriculture (http://www.ncagr.gov/stats/coest/Index.htm), in 2012 the lower Cape Fear basin (Brunswick, Pender, Duplin, Sampson, and Cumberland Counties, and estimates for parts of Bladen and Onslow Counties) contained about 5 million swine,

21.5 million poultry, 123 million chickens, and 72,000 cattle. The facilities which produce these animals are *not* required to have streamside buffers, or to control of ammonia or hydrogen sulfide emissions etc. They *are* required to have what can only be described as grossly inadequate waste management because it clearly does not prevent major impacts to public trust natural resources (below). Cahoon et al. (1999) provided the following estimates for the Cape Fear River basin (recall that most swine production occurs in the lower basin):

- Swine: more than 7 million tons of fresh manure per year added to the lower basin;
- Poultry: 2.18 million tons of fresh manure per year;
- Cattle: 2.08 million tons of fresh manure per year;
- Total from this animal production: 82,700 tons of nitrogen (N) and 25,950 tons of phosphorus (P) (Cahoon et al. 1999), the two nutrients that are known to cause major noxious algal outbreaks (Burkholder and Glibert 2013).

Cahoon et al. (1999) concluded that:

> The eutrophication threat to these river basins [which included the Cape Fear River basin]... with expanding animal populations from the potential large nutrient loadings associated with intensive livestock operations is substantial.

Many contaminants are present in swine CAFO wastes and runoff, including extremely high levels of nutrients N and P, more than 100 microbes known to cause human disease, pharmaceutical chemicals that harm beneficial aquatic life, toxic heavy metals (especially copper and zinc), and pesticides such as toxic dithiocarbamates from sprayfield applications (Barker and Zublena 1995; Burkholder et al. 1997, 2007 and references therein, Iowa State University and The University of Iowa Study Group 2002, Extension Toxicology Network 2003). These contaminants can enter the surrounding environment through pathways such as leakage from poorly constructed cesspits, or during major precipitation events that cause cess pit overflow and runoff from recent sprayfield application, or atmospheric deposition followed by wet or dry fallout (Burkholder et al. 2007 and references therein). The magnitude and direction of transport depends on factors such as soil properties, contaminant properties, hydraulic loading characteristics, and crop management practices. Over-application of swine wastes to sprayfields can result in contaminants leaching through permeable soils into vulnerable aquifers (see Section IIIE - Groundwater Degradation from Swine CAFO Point Sources, below).

Contamination of surrounding public-trust surface waters such as the LCFRE in southeastern North Carolina is a common, routine problem *at recommended application rates* as well (e.g. Barker and Zublena 1995; Westerman et al. 1995; Zublena et al. 1995; Stone et al. 1995, 1998; Walker et al. 2000; Aneja et al. 2001, 2003). Improper disposal of animal carcasses and abandoned swine CAFO facilities also contribute to water quality problems. Siting of CAFOs in areas prone to flooding or where there is a shallow water table, such as in the lower Cape Fear basin, increases the potential for contamination of public trust natural resources as well.

Swine CAFO point sources in the lower Cape Fear basin - Swine CAFOs in southeastern North Carolina mostly were installed from the late 1980s through 1995. These CAFOs store

animal wastes in large cess pits (which the industry calls "lagoons") (*Figure 5*). After the solids mostly settle out, the liquid wastes are applied to relatively small sprayfields. The soils in the area are mainly sandy and shallow; the water table is only about three feet from the land surface (Burkholder et al. 1997 and references therein). The shallow, sandy soils simply cannot absorb the massive amounts of waste applied to them by the CAFOs, time after time per season, year after year (see example in *Figure 4*). Waste that is applied to the fields mostly percolates into the shallow groundwater and then moves to receiving streams and rivers (e.g. Evans et al. 1984). Most cess pits for these swine CAFOs were installed in North Carolina prior to 1993, when linings of clay or other materials were not required (Burkholder 1997 and references therein).

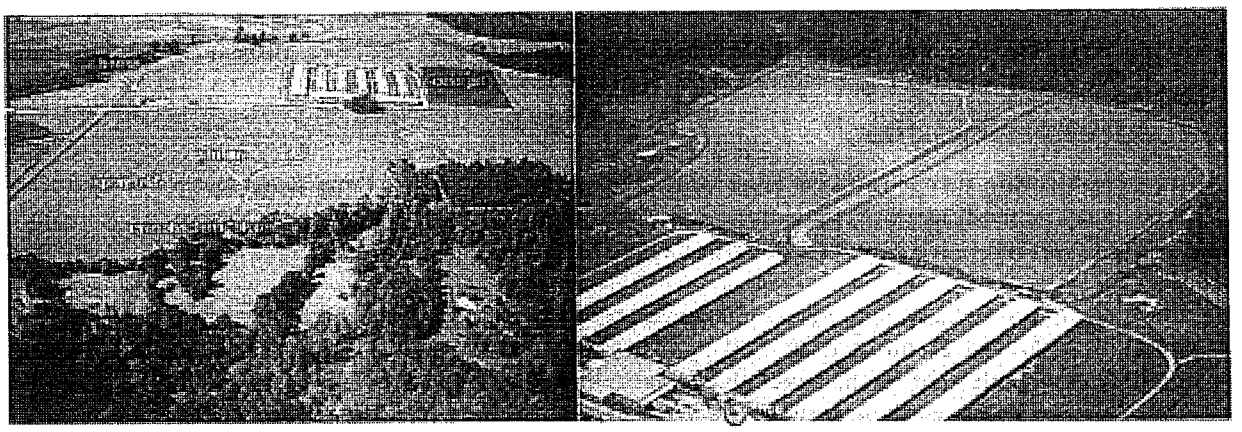

Figure 5. Left: A swine CAFO in the lower Cape Fear River basin, showing (from top to bottom) a house (noted for scale), the buildings that contain about 5,000 animals, the adjacent cess pit, the sprayfield, a stream that has been transformed to a gully conveying wastes from the field into a wetland, and a dense bloom of cyanobacteria (blue-green algae), potentially toxic to humans, that was fueled by the high nutrients in the CAFO wastes (see Burkholder et al. 1997, 2007 for supporting information). Thus, clearly the wastes were moving off-site to contaminate adjacent natural resources. This relatively small field with a shallow layer of soil above the water table, and the cess pit, are "supposed to" adequately treat the liquid wastes, year after year, from 5,000 swine per year, equivalent to the amount of wastes produced by 20,000 people (1 swine produces the equivalent amount of wastes, roughly, of 4 people; see below). Photo: M. Mallin. Right: Two swine CAFO cess pits (the car is circled for scale). The pinkish color is due to anaerobic sulfur bacteria and is suggestive of very high levels of hydrogen sulfide gas, which is toxic to humans (Burkholder et al. 1997, and references therein). Photo: R. Dove, Waterkeeper Alliance.

The general situation was described as follows:

> [CAFO] technology, originally designed for application in upland areas with adequate soil depth above the water table, was embraced in counties where 60-80% of the area put into production was originally low-lying wetlands adjacent to rivers and estuaries. The operations were exempt from land zoning laws and mandatory inspection programs. Waste lagoons were not required to have leakage-reducing liners; some were constructed below the water table less than 20 m [50 feet] from neighboring homes and wells . . . The NC Division of Water

> Quality, charged with water resources management, lacked the personnel and resources necessary to adequately monitor surface or groundwater quality. More fundamentally, the North Carolina Department of Agriculture legally refused to provide the Division of Water Quality with basic data such as the location and number of existing and planned animal operations . . . After considerable effort the North Carolina Environmental Management Commission . . . passed rules in 1993 for design of animal waste lagoons and effluent treatment. These rules mandated use of clay or other suitable liners in future construction of lagoons associated with [CAFOs with] 250 or more swine. They included a grandfather clause to exempt existing operations from having to alter their lagoon design . . ..(Burkholder et al. (1997; references included therein).

The information presented below for airshed, soil and groundwater contamination is included because pollution of those natural resources by swine CAFOs can substantially contribute to surface water contamination, which is the main subject of these Comments regarding the state's classification of the LCFRE segment.

Airshed degradation from swine CAFO point sources

Swine CAFOs emit copious air pollutants known to adversely impact human health and, indirectly, surface waters. For example, ammonia and hydrogen sulfide are emitted at levels toxic to humans (U.S. EPA 1998; also Aneja et al. 2001, Liu et al. 2014). Within a 60-mile radius from where it is emitted, the volatilized ammonia tends to return to the land and surface waters with rain (Aneja et al. 2003), where it can adversely affect river ecosystems (below; e.g. Rothenberger et al. 2009b).

Swine CAFO production in the lower Cape Fear basin has caused a significant increase in air pollutants such as ammonia (Aneja et al. 2003, Wing et al. 2012 and references therein). Surface waters and groundwater are also being adversely impacted; Burkholder et al. (2006) documented a significant increase in ammonia concentrations within the lower Cape Fear River where swine CAFOs are highly concentrated. Cahoon et al. (1999) wrote,

> Aerial deposition of nitrogen, principally ammonia-nitrogen, is recognized as a contributing threat to coastal water quality . . . Some studies estimate that up to 90% of the manure nitrogen produced by swine volatilizes and is deposited downwind [to the land and surface waters] (NC DENR Division of Air Quality 1997).

Sampson County (946 square miles), in the Cape Fear River basin, had 1.8 million swine as of 1998. The National Atmospheric Deposition Program has monitored atmospheric ammonia there since 1978. Mallin (2000) noted that during the 1988-1998 decade, there was a concurrent rise in atmospheric ammonia and the swine population; and that from linear regression analysis, 72% of the variability in airborne ammonia could be explained by changes in the county swine population alone. Upwind in the North Carolina Piedmont, counties with low swine populations showed no ammonia increase during the same period.

Soil degradation from swine CAFO point sources

Swine feed contains metals such as copper act as micronutrients in low concentrations, but

as toxic substances at higher levels. The metals persist in the extremely high amounts of swine wastes (Cahoon et al. 1999; see p.10 of these Comments), which are then applied to fields. Sensitive crops often cannot withdraw the metal in the soil, and leave it behind to accumulate. Research done in eastern North Carolina has explained how waste application contributes to metals pollution in field and, importantly, also has shown that as long ago as the mid-1990s, several counties in the lower Cape Fear River basin could no longer be used to grow metal-sensitive crops and would not need to fertilize with nitrogen or phosphorus for decades (Barker and Zublena 1995, Zublena et al. 1995). Runoff from the contaminated soil during/following precipitation events adds some of these toxic pollutants to adjacent surface waters.

Groundwater degradation from swine CAFO point sources

Areas around the cess pits of swine CAFOs in eastern North Carolina have been shown to receive leakage high in contaminant levels. Wells and subsurface seepage near the cess pits can be contaminated with extremely high levels of nitrate and ammonia (e.g. Huffman and Westerman 1995, Westerman et al. 1995, Ham and DeSutter 2000). The high nitrate levels are a result of the high ammonia levels because the ammonia is oxidized to nitrate as it moves away from the waste sources (see Burkholder et al. 1997, 2007, and references therein). High concentrations of nitrate are hazardous to human health, especially for babies and small children (who can be afflicted with methemoglobinemia or 'blue-baby syndrome'), because nitrate competes with oxygen for hemoglobin in the human bloodstream (Smith 2009, Knobeloch et al. 2010).

Many North Carolinians in the Coastal Plain area rely upon groundwater as their drinking water source (North Carolina Groundwater Association, http://www.ncgwa.org). North Carolina's drinking water standard for nitrate is less than 10 milligrams per liter (mg/L).[5] The available data suggest that many unlined swine effluent cess pits in eastern North Carolina cause nitrate pollution to nearby wells at levels that violate the 10 mg/L drinking water standard (e.g. Huffman 2004, Huffman and Westerman 1995, Westerman et al. 1995). Working in Sampson County within the Cape Fear River basin, Westerman et al.'s (1995, p.1749) study illustrates high contamination from unlined cess pit leakage:

> Two swine manure, anaerobic lagoons located in sandy, coastal plain soil were investigated. Both continued to have significant seepage after 3.5 to 5 years of receiving waste. Monitoring wells indicated *broad seepage plumes* [emphasis added], and much variation in concentrations of several parameters with well location, time, and depth of well . . . In some cases, ammonia and chloride concentrations in well samples were as high or higher than the lagoon liquid.

The last sentence of the above quote is especially of concern - that nearby monitoring wells had ammonia concentrations even higher than the lagoon liquid swine waste. Such

[5] (NC DENR Classifications and Water Quality Standards Applicable to Surface Waters of North Carolina, NC Admin. Code Section 15A NCAC 2B .0200, Environmental Management Commission, Raleigh, NC; http://portal.ncdenr.org/c/document_library/get_file?uuid=ad77b198-aa3d-4874-9723-54ce730b3a8d&groupId=38364).

information points to a major threat to shallow drinking water wells located only short distances, as little as 50 feet, from a swine lagoon cess pit.

Based on the available science literature, substantial groundwater contamination also is contributed by lined cess pits if not properly operated, as described by Westerman et al. (1985, p.1750):

> Ritter and Chirnside (1987) . . . reported high concentrations of NH_3-N and NO_3-N in groundwater monitoring wells near a clay-lined anaerobic lagoon for a hog-finishing unit. Some of the high NH_3-N concentrations were possibly due to lagoon overflow, which occurred several times. They suggested that the lagoon management of completely emptying the lagoon twice a year led to drying and cracking of the clay liner, resulting in seepage. They concluded that if clay-lined lagoons are not operated properly, they will have a serious impact on groundwater quality in loamy sand or sandy loam soils.

Ritter and Chirnside (1990) also reported extreme *average* ammonia-N concentrations, up to 1,000 mg/L, and extreme average nitrate-N up to 50 mg/L, in some wells near a clay-lined swine waste cess pit on the Delmarva Peninsula.

Swine CAFOs (both the land application practices and cess pit leakage) additionally pose a significant threat to well water via contamination by other harmful substances and pathogenic microbes (e.g. Stone et al. 1998, Krapac et al. 2002). Moreover, much lower concentrations of nitrate and ammonia can cause disease and death of beneficial aquatic life in receiving surface waters (see below). During summer low flow conditions on the North Carolina Coastal Plain, at least half of stream and river flow can be contributed by groundwater (Garrett et al. 2012 and references therein). Thus, groundwater contamination by swine CAFOs can contribute significantly to surface water contamination. Cahoon et al. (1999, p.414) wrote,

> An important water quality problem in North Carolina deriving from animal waste inputs is nitrogen loading to surface and groundwaters. Nitrogen frequently limits phytoplankton production in North Carolina's coastal waters, so increased nitrogen loads have stimulated noxious and toxic algal blooms and helped cause fish kills.

Surface water degradation from swine CAFOs

The wastes applied to sprayfields, emitted to the overlying airshed during the spraying activity, or leached into groundwater can make their way into surface waters as explained above. In addition, when the sprayfield soils are saturated with contaminants or with water during moderate to high precipitation periods, or due to over-application, the additional applied wastes rapidly move overland, through tile drains, and through the many ditches in the area to nearby surface waters. Thus, working in eastern North Carolina, Westerman et al. (1985) found high levels of nitrate (3-6 mg/L) in surface runoff from swine CAFO sprayfields that received swine waste effluent ***at recommended rates*** - that is, as a result of routine, accepted practices. For comparison, ~0.1 mg/L of nitrate (and ~0.08

mg/L of phosphorus - below) can cause noxious algal blooms (Mallin 2000, Wetzel 2001, and references therein). Working in Duplin County within the Cape Fear River basin, Stone et al. (1995) measured 6-8 mg of total inorganic nitrogen/L (= nitrate + nitrite + ammonia or ammonium) and 0.7-1.3 mg of phosphorus/L, another important nutrient that can fuel noxious and toxic algal outbreaks (Burkholder 2009), in a stream adjacent to swine effluent sprayfields:

> Mean nitrate-N concentrations of water leaving the [two] watershed outlet[s] were two- and four-times higher than background concentrations . . . Daily mean nitrate-N concentrations [at a tributary adjacent to a swine CAFO] sometimes exceeded 10 mg/L and frequently exceeded 6 mg/L. Over-applied swine lagoon effluent and undersized, overloaded lagoons were likely contributors . . . Mean ammonium-N concentrations . . . were approximately two- and four-times higher than background concentrations. Ammonium-N concentrations [at one watershed outlet] exceeded limits considered harmful to humans (0.5 mg/L) and fish (2.5 mg/L) (U.S. EPA 1973). During the first month of the sampling period, daily ammonium-N concentrations ranged from 6 to 12 mg/L . . . These high concentrations indicated that a significant discharge of animal waste products into the waterway had occurred . . . while storm flows are contributing to the total flux of nitrate-N, the majority of the nitrate-N flux is coming directly from the base flow [in other words, the high contamination occurred with and without precipitation/runoff]. - Stone et al. (1995)

Evans et al. (1984) reported 7-30 mg nitrate/L in subsurface flow draining a sprayfield for swine wastes that were applied at recommended rates:

> The potential for nutrient transport was much greater for subsurface drainage [than for surface drainage] . . . Nitrogen application at the recommended rate resulted in phosphorus application at nearly three times the recommended rate. Although this soil fixes [adsorbs] phosphorus, there was evidence of phosphorus movement in subsurface runoff by the fifth year of waste application at a higher rate. Continued phosphorus application even at the low [recommended] rate would eventually result in movement of P in subsurface runoff as the soil's assimilatory capacity for phosphorus would eventually be exceeded. - Evans et al. (1984)

These reports all describe *excessive* levels of inorganic nitrogen and phosphorus in comparison to what is needed to fuel a noxious or harmful algal outbreak. Evans et al. (1984) highlighted another problem -- that recommended rates of nitrogen application resulted in major excesses of phosphorus that, within a relatively short time, would saturate the soil and contaminate receiving adjacent surface- and ground-waters.

As mentioned, the extremely high nitrate in surface waters and groundwater near swine CAFOs comes from the high ammonia in swine wastes that combines with oxygen. Much lower nitrate levels (0.25-0.28 mg/L) than found in the above-described studies can cause disease and death of beneficial aquatic life (Camargo et al. 2005, Camargo and Alonso 2006). Nitrate can interfere with steroid hormone synthesis, adversely affect sperm

motility and viability, depress fecundity, and can be toxic to embryos (Edwards et al. 2004). It can also decrease immune response, act as an endocrine disruptor, and induce harmful hematological and biochemical changes in beneficial aquatic life (Guillette and Edwards 2005).

Although much of the ammonia which contaminates surface waters from swine CAFOs is oxidized to nitrate, before that occurs the ammonia can cause high toxicity to beneficial aquatic life, or can stimulate noxious algal outbreaks. Ammonia is a preferred form of nitrogen for many algal species including various harmful algae that can cause serious human illness (compiled from Bollos and Berge, Twomy et al. 2005, Herndon and Cochlan 2006, Burkholder 2009). Burkholder et al. (1997) reported ammonia concentrations as high as ~40 mg/L in a stream contaminated by a swine cess pit rupture. Such concentrations can be highly toxic to aquatic life (Camargo et al. 2005, Camargo and Alonso 2006), and would also be expected to stimulate noxious/harmful algal growth as the concentration became more dilute downstream (as was observed by Burkholder et al. 1997 and Mallin et al. 1997).

Swine CAFOs can cause other major surface water impacts from suspended solids loads and turbidity. The water near swine CAFOs is often dark and murky, and inhibits beneficial plant growth (Burkholder et al. 1997, Mallin 2000, and references therein). Swine wastes are acidic (pH ~6.5 - Zu et al. 2001 and references therein) and can impart acidity to receiving surface waters, although the lower mainstem Cape Fear River is well buffered due to the ocean's influence. Toxic levels of metals such as copper occur in runoff from swine effluent sprayfields because copper and other "trace elements" are added to swine feed to promote growth and control disease (Payne et al. 1988). These toxic substances can accumulate in sediments, water, and biota, to levels that are toxic to plants and lead to reproductive impairment, poor body condition, and immune system suppression in beneficial animals (Stubbs and Cathey 1999). Copper from swine and other livestock operations can be added to surface waters via overland discharge and groundwater leachate (U.S. EPA 2013).

Many impacts on surface waters from swine CAFOs are only beginning to be examined. Surface waters in Duplin County, also within the Cape Fear River basin, were recently assessed for fecal indicator bacteria (fecal coliforms, *Escherichia coli*, and *Enterococcus*) and candidate swine-specific microbial source-tracking bacteria over an annual period, both upstream and downstream from swine CAFO sprayfields. The authors noted, importantly, that the proximal "upstream" locations were potentially influenced by numerous upstream swine CAFO sprayfields, and also by poultry CAFO dry litter land application sites. The highest fecal indicator bacteria concentrations were found immediately downstream from swine CAFO sprayfields in spring and summer. The findings were summarized as follows:

> Testing of 187 samples showed high fecal indicator bacteria concentrations at both up- and downstream sites . . . Overall, 40%, 23%, and 61% of samples exceeded state [criteria] and federal recreational water quality guidelines for fecal coliforms, E. coli, and Enterococcus, respectively. Two swine indicator bacteria were 2.30 to 2.47 times as prevalent proximal down- than proximal upstream of swine CAFOs . . . *Results suggest diffuse and overall poor sanitary*

quality of surface waters where swine CAFO density is high [emphasis added].
- Heaney et al. (2015)

The water column of receiving rivers is not the only area affected by CAFO contamination. Burkholder et al. (1997) tracked surface water impacts from a swine cess pit rupture upstream from the New River Estuary near of the Cape Fear River basin. Fecal coliform bacteria densities were in the millions of colony-forming units [CFU] per 100 mL, whereas the state standard for safe human contact of the water is 200 CFU/100 mL. The state does not monitor contamination of bottom sediments by CAFO wastes. After 14 days, water-column fecal coliforms along the surface of the bottom sediments mostly yielded 10,000 CFU/100 mL, one to two orders of magnitude higher than elsewhere in the system. Even after 60 days, fecal bacterial densities in the surficial sediments of the affected area were at 1,000-10,000 CFU/100 mL. The data showed that bottom sediments contaminated by CAFO wastes can function as a repository source of fecal coliform bacteria and, likely, for co-occurring harmful microbes, for weeks to more than a month after a waste spill. The organic materials from the wastes that settled out would have been expected to greatly increase the SOD as well.

Surface waters presently classified as C (Sw) waters in areas draining swine and poultry CAFOs in the lower Cape Fear basin are extremely degraded

There is presently ongoing, persistent, extreme degradation of surface waters in the lower Cape Fear basin due to allowed practices of swine and poultry production. A recent description of a Class C (Sw) stream illustrates this reality:

Stocking Head Creek (8-digit Hydrologic Unit Code 003030007), a second-order tributary of the Northeast Cape Fear River, is presently classified by DWR as Class C (Sw) waters. This small stream (length 13.7 miles) drains 7.6 square miles of area containing 40 swine CAFOs and an estimated 11 poultry CAFOs, with total capacity for more than 94,000 swine and more than 1.3 million broiler chickens; it also includes some unconfined cattle (Mallin et al. 2014). Seven sites along the stream were sampled on 5 dates each in a 30-day period in summer and in fall of 2013. The data indicate a situation of persistent, extreme water quality degradation regardless of weather conditions; the excessive pollutant levels were similar whether the stream was sampled in dry or wet (rainy) periods.

The water quality conditions documented in Stocking Head Creek consistently were hazardous to human health at most stations. Geometric means for fecal coliform bacteria were in the thousands (as colony-forming units per 100 milliliters, CFU/100 mL) at 5 of the 7 sites. The state standard for safe human contact is less than 200 CFU of fecal coliform bacteria/100 mL (geometric mean, based on at least 5 consecutive samples during any 30-day period); and surface waters are supposed to have fewer than 400 CFU of fecal coliform baceria/100 mL in at least 80% of samples examined during the 30-day period. At 5 of the 7 sites on Stocking Head Creek, fecal coliform bacteria exceeded 400 CFU/100 mL on all, or nearly all, sampling dates.

Nutrient levels also demonstrated extreme water quality degradation. Some samples had more than 10 mg of nitrate/L. By comparison, the U.S. EPA (2000) recommends that nitrate should be 0.04 mg/L or less in streams within level III nutrient sub-ecoregion #63,

which includes southeastern North Carolina. The maximum ammonium concentration was 38 mg/L near swine waste sprayfields. BOD (5-day) exceeded 10 mg/L in 11 of 70 stream samples, with a maximum at 88 mg/L. Average total phosphorus (TP) per site ranged from 0.15 to 2.83 mg/L. By comparison, the U.S. EPA (2000) recommends that stream TP concentrations should be less than 0.052 mg/L for streams in this area.

Based on more than 30 years of experience as a water quality specialist, I assess these conditions, ongoing and persistent in this representative stream in the Northeast Cape Fear River basin upstream from the LCFRE segment, as comparable to the filthy conditions that occur just downstream from raw sewage discharge.

Swine CAFO wastes versus the 20 point source wastes and wetlands in the lower Cape Fear basin

Swine wastes are very rich in organic, oxygen-demanding materials in comparison to human wastes. Treated and raw domestic sewage contains ~20-60 mg BOD/L and ~300-400 mg BOD/L, respectively; swine waste slurries contain ~20,000-30,000 mg BOD/L (Webb and Archer 1994; also see Spellman and Whiting 2007). Surface waters contaminated with these wastes rapidly become oxygen-depleted, causing fish to suffocate to death (Burkholder et al. 1997, U.S. EPA 1998, Mallin 2000).

The contribution of oxygen-demanding materials from nearly 1,000 swine CAFO sources, mostly in the lower Cape Fear basin, clearly overwhelms the contribution from the 20 point sources considered by DWR. As stated, about 5 million swine are produced annually in the lower Cape Fear basin in CAFOs (Cahoon et al. 1999). It has been estimated that each animal contributes roughly the equivalent amount of waste -- much richer in oxygen-demanding materials -- of four people (derived from U.S. EPA 2004; see *Table 1* below). The population of the City of Wilmington as of 2014 was ~112,000 people. Overall in the lower Cape Fear basin, the 5 million swine produced per year in CAFOs produce ~179 times more wastes than the largest human population center, Wilmington. Moreover, pound for pound the swine wastes, conservatively estimated, contain about 10 times more oxygen-demanding materials than treated human wastes. Thus, in the lower Cape Fear basin, swine CAFO point sources are estimated to produce three orders of magnitude (~1,790 times) more oxygen-demanding materials than treated human wastes.

These Comments have several times referred to the Northeast Cape Fear River and Black River as having sustained major impacts from swine CAFOs. According to NCDENR (2005), the small sub-watersheds drained by the Northeast Cape Fear River and the Black River, alone, have 896 CAFOS that contain ~3,764,121 animals, roughly the same amount of sewage as more than 15 million people. Stocking Head Creek illustrates the surface water quality of streams draining such areas.

Based on the available information, *the massive contribution of organic-rich, oxygen-demanding materials from swine CAFOs also overwhelms the potential contribution from natural wetlands in the LCFRE.* The sparse available SOD data for the LCFRE (give in Bowen et al. 2009, p.3-20) ranged from 0.1900 to 0.6951 grams of oxygen demand per square meter per day ($g/m^2/day$). The highest values measured were near swine CAFOs, 0.5189 to

Table 1. Manure production per 1,000 pounds (lb) live weight on an annual basis. According to this information from the U.S. EPA (2004, Table 3.3), one 250-lb pig produces 7,250 lb of manure per year (19.86 lb/day), whereas one 150-lb human produces 183 lb of manure/yr (0.5 lb/day). A swine CAFO with 1,000 animals thus would produce about the same amount of waste as a city of 39,617 people. As the U.S. EPA (2004) wrote,

> The important difference lies in the fact that human waste is treated before discharge into the environment, but animal waste is either not treated at all or minimally treated....

It has been argued that swine wastes are about 10-fold more liquid than human wastes; if that dilution factor is taken into account, 1 animal would produce about the same amount of waste of 3.96 people, rounded to a ratio of 1:4.

Manure production per 1000 pounds live weight, on an annual basis.

Animal Species	Manure produced lbs./yr	Typical Handling System
Swine	29,000	Liquid
Poultry		
Broilers	28,000	Solid
Layers	22,000	Liquid
Turkeys	16,000	Solid
Beef	21,000	Solid
Dairy	30,000	Liquid
Humans	1,223[1]	Liquid

[1] Based on 150 lb avg. wt. per person producing 0.5 lb of fecal material per day

0.6951 g/m²/day; even areas near urban Wilmington had lower SOD (0.4440 to 0.4679 g/m²/day). Bowen et al. (p.4-42) used an estimated SOD of ~0.4 g/m²/day except for an area heavily influenced by swine CAFOs, the Northeast Cape Fear River sub-basin, where they used an estimated SOD of 1.5 g/m²/day. This information suggests that the swine CAFO-rich Northeast Cape Fear River alone, contributes excessive SOD in comparison to the rest of the LCFRE, expected since that small sub-watershed contains 502 swine CAFOs with 2,021,000 animals, or the equivalent amount of more than 8 million people's wastes per year (NCDENR 2005).

III. Summary and Recommendations

These Comments have explained the following main points regarding DWR's proposed reclassification of a segment of the LCFRE, from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut, from Class Sc waters to Class Sc (Sw) (= swamp):

- ✓ NCDENR-DWR has proposed to reclassify the lower reaches of one of the most powerful rivers in the nation, a portion of the LCFRE, as a swamp because the agency's efforts to control the relatively small amount of pollution from 20 point sources will not allow that segment to meet present standard for DO (or for pH, turbidity, and toxic copper). This was based on a recent modeling effort (Bowen et al. 2009) which predicted that

the 20 arbitrarily selected point sources have little effect on DO levels in the LCFRE segment. In addition, the segment was described as inappropriate for development of a TMDL, based on two erroneous claims -- that natural wetland drainage is the major contributor of oxygen-demanding materials to the LCFRE segment, and that significant reductions in "background" sources of oxygen-demanding materials would not allow the LCFRE segment to meet the present DO standard.

- ✓ According to the U.S. EPA, assessment of whether a TMDL is needed to improve DO in the LCFRE segment is supposed to consider all point and nonpoint sources in the watershed. In focusing on only 20 point sources, DWR omitted consideration of massive pollution that could be reduced in the so-called "background" loads, including 175 NPDES-permitted, upstream and adjacent point sources in the Cape Fear River basin, and nearly 1,000 swine CAFOs (as well as an unknown number of poultry CAFOs) which are formally defined by the Clean Water Act as point sources. The ~5 million swine produced in the lower Cape Fear River basin contribute the equivalent of ~20 million people's wastes per year, and the massive wastes are much richer in oxygen-demanding materials than human wastes.

- ✓ The available evidence shows that pollution from human activities, not natural drainage from wetlands, is the major source of oxygen-demanding materials to the LCFRE segment, and that the massive pollution also contributes low pH, toxic copper, high turbidity, fecal bacteria, and many other contaminants to the LCFRE segment.

- ✓ The recent modeling effort by Bowen et al. (2009) tacitly included the many other NPDES-permitted point sources and swine/poultry CAFOs within a modeling category called "tributary inputs." The model predicted that a reduction of only 30% of the "tributary inputs" would result in median DO levels higher than the state standard; and that a 70% reduction in the "tributary inputs" would bring the LCFRE into compliance 99% of the time. Thus, reducing the massive pollution from other sources **would** enable the LCFRE segment to attain compliance with its present DO standard.

To protect the health of many North Carolinians of all ages who depend upon this river and estuary to meet its present designated uses, and to protect the LCFRE surface water segment of focus as well as other public trust natural resources in the lower Cape Fear basin, the LCFRE segment should not be reclassified as a Class Sc Swamp (Sw). Instead, DWR should be directed toward efforts to meaningfully reduce the massive pollution from swine CAFOs and NPDES-permitted point sources in the lower Cape Fear Basin (and from poultry production as well, which are a major pollution source with much less available information), which would make it possible for the LCFRE to meet the presently pplicable DO standard, and would also enable the LCFRE to improve in water quality with respect to pH, copper levels, and turbidity.

References

Aneja, V.P., P.A. Roelle, G.C. Murray, J. Southerland, J.W. Erisman, D. Fowler, W.A.H. Asman, and N. Patni. 2001. Atmospheric nitrogen compounds II: emissions, transport, transformation, deposition and assessment. *Atmospheric Environment* 35: 1903-1911.

Aneja, V.P., D.R. Nelson, P.A. Roelle, and J.T. Walker. 2003. Agricultural ammonia emissions and ammonium concentrations associated with aerosols and precipitation in the southeast United States. *Journal of Geophysical Research* 108: ACH12-1 - 12-11.

Barker, J.C. and J.P. Zublena. 1995. *Livestock Manure Nutrient Assessment in North Carolina.* Final Report. North Carolina Agricultural Extension Service, NC State University, Raleigh, NC.

Becker, M.L., R.A. Luettich Jr., and M.A. Mallin. 2010. Hydrodynamic behavior of the Cape Fear River and estuarine system: A synthesis and observational investigation of discharge-salinity intrusion relationships. *Estuarine, Coastal and Shelf Science* 88: 407-418.

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin and J. Williams. 2009. *Development and Use of a Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the lower Cape Fear Estuary, North Carolina.* Department of Civil Engineering, University of North Carolina Charlotte.

Bowie, G.L., W.B. Mills, D.B. Porcella, C.L. Campbell, J.R. Pagenkopf, G.L. Rupp, K.M. Johnson, P.W.H. Chan, S.A. Gherini, and C.E. Chamberlin. 1985. *Rates, Constants, and Kinetic Formulations in Surface Water Quality Modeling*, 2nd edition. Report #EPA/600/3-85/040. U.S. Environmental Protection Agency, ORD, Athens, GA.

Bricker, S. B., C. G. Clement, D. E. Pirhalla, S. P. Orland, and D. G. G. Farrow. 1999. *National Estuarine Eutrophication Assessment: A Summary of Conditions.* National Oceanic and Atmospheric Administration, Silver Spring, MD.

Burkholder, J.M. 2009. Harmful algal blooms, pp. 264-285. In: *Encyclopedia of Inland Waters, Volume 1*, by Likens GE (ed.) Elsevier, Oxford, UK.

Burkholder, J.M. and P.M. Glibert. 2013. Eutrophication and oligotrophication, pp. 347-371. In: *Encyclopedia of Biodiversity*, 2nd edition, Volume 3, by Levin S (ed.). Academic Press, Waltham, MA.

Burkholder, J.M., D.A. Dickey, C. Kinder, R.E. Reed, M.A. Mallin, G. Melia, M.R. McIver, L.B. Cahoon, C. Brownie, N. Deamer, J. Springer, H. Glasgow, D. Toms, and J. Smith (2006) Comprehensive trend analysis of nutrients and related variables in a large eutrophic estuary: A decadal study of anthropogenic and climatic influences. *Limnology and Oceanography* 51: 463-487.

Burkholder, J.M., M.A. Mallin, H.B. Glasgow, L.M. Larsen, M.R. McIver, G.C. Shank, N. Deamer-Melia, D.S. Briley, J. Springer, B.W. Touchette, and E.K. Hannon. 1997. Impacts to a coastal
river and estuary from rupture of a large swine waste holding lagoon. *Journal of Environ-mental Quality* 26: 1451-1466.

Burkholder, J.M., B. Libra, P. Weyer, S. Heathcote, D. Kolpin, P.S. Thorne, and M. Wichman 2007. Impacts of waste from concentrated animal feeding operations on water quality. *Environmental Health Perspectives* 115: 308-312.

Chapra S.C. 1997. *Surface Water-Quality Modeling.* Civil Engineering Series, McGraw-Hill International editions (originally Waveland Press, Inc., Long Grove, IL).

Dewi. I.A., R.F.E. Axford. I. Faycz, M. Marai, and H. Omed (eds.). 1994. *Pollution in Livestock Production Systems.* CAB International, Wallingford, United Kingdom.

Cahoon, L.B., J.A. Mickucki and M.A. Mallin. 1999. Nutrient imports to the Cape Fear and Neuse River basins to support animal production. *Environmental Science and Technology* 33: 410-415.

Caldwell, J. M. and M.C. Doyle. 1995. *Sediment Oxygen Demand in the Lower Willamette River, Oregon, 1994.* United States Geological Survey Water-Resources Investigations Report 95-4196. USGS, Reston, VA.

Camargo, J.A., A. Alonso, and A. Salamanca. 2005, Nitrate toxicity to aquatic animals: A review with new data for freshwater invertebrates, *Chemosphere* 58: 1255-126.

Camargo, J.A. and A. Alonso 2006. Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: A global assessment. *Environment International* 32: 831-849.

CH2MHill. 2014a (February 25). Technical Memo: Task 1 - Summary of Background Information and Previous Studies for the Lower Cape Fear River. Prepared for the Lower Cape Fear River Program. In May (2014).

CH2MHill. 2014b. Technical Memo: Task 3 - Analysis of Water Quality Data at Cape [Fear] River Estuary Model Boundaries. Prepared for the Lower Cape Fear River Program. In May (2014).

Collos, Y. and J.A. Berge. Undated. *Nitrogen Metabolism in Phytoplankton.* Encyclopedia of Life Support Systems - http://www.eolss.net/sample-chapters/c09/E2-27-03-03.pdf.

Cox, B.A. 2003. A review of dissolved oxygen modelling techniques for lowland rivers. *The Science of the Total Environment* 314-316: 303-334.

Crawford, J.K. 1985. *Water Quality of North Carolina Streams - Water-Quality Characteristics for Selected Sites on the Cape Fear River, North Carolina, 1955-80.* United States Geological Survey (USGS) Water-Supply Paper 2185-F. USGS, Alexandria, Virginia.

Davis, W.S. 1950. Brief history of sediment oxygen demand investigations. In: *Sediment Oxygen Demand*, by K.J. Hatcher (editor). Institute of Natural Resources, University of Georgia, Athens, GA.

Eaton, A.D., L.S. Clesceri, and A.E. Greenberg. 1995. *Standard Methods for the Examination of Water and Wastewater.* United Book Press Inc., Baltimore, MD.

Edwards, T.M., L.J. Guillette Jr., K. McCoy, and T. Barbeau. 2004. *Effects of Nitrate/Nitrite on Two Sentinel Species Associated with Florida's Springs.* Final report prepared for the Florida Department of Environmental Protection, Tallahassee, FL.

Ensign, S.H., J.N. Halls, and M.A. Mallin. 2004. Application of digital bathymetry data in an analysis of flushing times of two large estuaries. *Computers & Geosciences* 30: 501-511.

Evans, R.O., P.W. Westerman, and M.R. Overcash. 1984. Subsurface drainage water quality from land application of swine lagoon effluent. *Transactions of the American Society of Agricultural Engineers* 27: 473-480.

Extension Toxicology Network 2003. Exotoxnet - A Pesticide Information Project of the Cooperative Extension Offices of Cornell University, Michigan State University, Oregon State University, and the University of California at Davis. U.S. Department of Agriculture, Extension Service, and the National Agricultural Pesticide Impact Assessment Program. Available at http://ace.orst.edu/info/extoxnet/.

Garrett, C. G., V.M. Vulava, and M.L. Jones. 2012. Groundwater-surface water interactions in a lowland watershed: source contribution to stream flow. *Hydrological Processes* 26: 3195-3206.

Guillette, L.J. Jr. and T.M. Edwards 2005. Is nitrate an ecologically relevant endocrine disruptor in vertebrates? *Integrative and Comparative Biology* 45: 19-27.

Ham, J.M. and T.M. DeSutter. 2000. Toward site-specific design standards for animal-waste lagoons: protecting groundwater quality. *Journal of Environmental Quality* 29: 1721-1732.

Hamrick, J.M. 1992. *A Three-Dimensional Environmental Fluid Dynamics Computer Code: Theoretical and Computational Aspects.* Special Report 317. Virginia Institute of Marine Science, The College of William and Mary, Gloucester, VA.

Hatcher, K.J. 1986. *Sediment Oxygen Demand: Processes, Modeling, and Measurement.* Institute of Natural Resources, University of Georgia, Athens, GA.

Heaney, C.D., K. Myers, S. Wing, D. Hall, D. Baron, and J.R. Stewart. 2015. Source tracking swine fecal waste in surface water proximal to swine concentrated animal feeding operations. *Science of the Total Environment* 511: 676-683.

Herndon, J. and W.P. Cochlan. 2006. Nitrogen utilization by the raphidophyte *Heterosigma akashiwo*: growth and uptake kinetics in laboratory cultures, *Harmful Algae* 6: 260-270.

Hu, W.F., W. Lo, H. Chua, S.N. Sin, and P.H.F. Yu. 2001. Nutrient release and sediment oxygen demand in a eutrophic land-locked embayment in Hong Kong. *Environment International*
26: 369-375.

Huffman, R.L. 2004. Seepage evaluation of older swine lagoons in North Carolina. *Transactions of the American Society of Agricultural Engineers* 47: 1507-1512.

Huffman, R.L. and P.W. Westerman. 1995. Estimated seepage losses from established swine waste lagoons in the lower coastal plain of North Carolina. *Transactions of the American Society of Agricultural Engineers* 38: 449-453.

Iowa State University and The University of Iowa Study Group. 2002. *Iowa Concentrated Animal Feeding Operation Air Quality Study.* Final Report. Environmental Health Sciences Research Center, Iowa City, IA. February 2002. Website - http://www.public-health.uiowa.edu/ehsrc/CAFOstudy.html.

Jacobson, L.M., M.B. David, and L.E. Drinkwater. 2011. A spatial analysis of phosphorus in the Mississippi river basin. *Journal of Environmental Quality* 40: 931-941.

Knobeloch, L., B. Salna, A. Hogan, J. Postle, and H. Anderson. 2000. Blue babies and nitrate-contaminated well water. *Environmental Health Perspectives* 108: 675-678.

Krapac, I.G., W.S. Dey, W.R. Roy, C.A. Smyth, E. Storment, S.L. Sargent, and J.D. Steele. 2002. Impacts of swine manure pits on groundwater quality. *Environmental Pollution* 120: 475-492.

Lin, J., L. Xie, L.J. Pietrafesa, J. Shen, M.A. Mallin, and M.J. Durako. 2006. Dissolved oxygen stratification in two micro-tidal partially-mixed estuaries. *Estuarine, Coastal and Shelf Science* 70: 423-437

Liu, Z., W. Powers, J. Murphy, and r. Maghirang. 2014. Ammonia and hydrogen sulfide emissions from swine production facilities in North America: a meta-analysis. *Journal of Animal Science* 92: 1656-1665.

MacPherson, T.A. 2003. *Sediment Oxygen Demand and Biochemical Oxygen Demand: Patterns of Oxygen Depletion in Tidal Creek Sites.* M.S. Thesis. Program in Marine Science, University of North Carolina Wilmington, Wilmington, NC.

Mallin, M.A. 2000. Impacts of industrial-scale swine and poultry production on rivers and estuaries. *American Scientist* 88: 26-37.

Mallin, M.A., J.M. Burkholder, G.C. Shank, M.R. McIver, H.B. Glasgow, J. Springer, and B.W. Touchette. 1997b. Comparative effects of poultry and swine waste lagoon spills on the quality of receiving stream waters. *Journal of Environmental Quality* 26: 1622-1631.

Mallin, M.A., V.L. Johnson, S.H. Ensign and T.A. MacPherson. 2006. Factors contributing to hypoxia in rivers, lakes and streams. *Limnology and Oceanography* 51: 690-701.

Mallin, M., M. McIver, and J. Merritt. 2008. *Environmental Assessment of the Lower Cape Fear River System, 2007.* CMSR Report No. 08-03, Center for Marine Science, University of North Carolina Wilmington, Wilmington, North Carolina.

Mallin, M., M. McIver, and J. Merritt. 2013. *Environmental Assessment of the Lower Cape Fear River System, 2012*. CMSR Report No. 13-02. Center for Marine Science Research, University of North Carolina Wilmington, Wilmington, NC.

Mallin, M.A., M.R. McIver, A.R. Robuck, and A.K. Dickens. 2014. *Stocking Head Creek 2013 Water Quality Investigation*. Final Report. Center for Marine Sciences, University of North Carolina Wilmington, Wilmington, NC.

Mallin, M., M. McIver, H. Wells, M. Williams, T. Lankford, and J. Merritt. 2003. *Environmental Assessment of the Lower Cape Fear River System, 2002-2003*. CMSR Report No. 03-03. Center for Marine Science, University of North Carolina Wilmington, Wilmington, NC.

Mallin, M. A., H. W. Paerl, J. Rudek, and P. W. Bates. 1993. Regulation of estuarine primary production by watershed rainfall and river flow. *Marine Ecology Progress Series* 93: 199-203.

Mallin, M.A., M.H. Posey, M.L. Moser, G.C. Shank, M.R. McIver, T.D. Alphin, S.H. Ensign, and J.F. Merritt. 1997a. *Water Quality in the Lower Cape Fear River System, 1996-1997*. Center for Marine Science, University of North Carolina Wilmington, Wilmington, NC.

Massachusetts Water Resources Authority. 2002. *The State of Boston Harbor - Mapping the Harbor's Recovery*. Available at: http://www.mwra.state.ma.us/harbor/enquad/pdf/2002-09.pdf.

Matlock, M.D., K.R. Kasprzak, and G.S. Osborn. 2003. Sediment oxygen demand in the Arroyo Colorado River. *Journal of the American Water Resources Association* 39: 267-275.

May, C. 2014 (5 March). Request for Reclassification of a Portion of the Lower Cape Fear River with the Supplemental Swamp Classification. Letter from Mr. May, Chair of the Lower Cape Fear River Program Advisory Board and Executive Director of the Cape Fear River Council of Governments, to Mr. Tom Reeder, Director of the NC DENR DWR.

Meyer J.L. & Edwards R.T. (1990) Ecosystem metabolism and turnover of organic carbon along a blackwater river continuum. *Ecology* 71: 668–677.

Minshall, G.W., R.C. Petersen, K.W. Cummins, T.L. Bott, J.R. Sedell, C.E. Cushing, C. E., and R.L. Vannote. 1983. Interbiome comparison of stream ecosystem dynamics. *Ecological Monographs* 53: 1-25.

Natural Resource Council. 2000. *Clean Coastal Waters- Understanding and Reducing the Effects of Pollution*. National Academy Press, Washington, DC.

North Carolina Department of Environment and Natural Resources (NC DENR). 1997. *Assess-ment Plan for Atmospheric Nitrogen Compounds: Emissions, Transport, Transformation, and Deposition*. Division of Air Quality, NC DENR, Raleigh, NC

North Carolina Department of Environment and Natural Resources (NC DENR). 2005. *Cape Fear River Basinwide Water Quality Plan*. Division of Water Quality, NC DENR, Raleigh, NC. Available at: http://portal.ncdenr.org/c/document_library/get_file?uuid=2eddbd59-b382-4b58-97ed-c4049bf4e8e4&groupId=38364.

Payne, G.G., D.C. Martens, E.T. Kornegay, and M.D. Lindermann. 1988. Availability and form of copper in three soils following eight annual applications of copper-enriched swine manure. *Journal of Environmental Quality* 17: 740-746.

Ritter, W. F. and A. E. M. Chirnside. 1987. Influence of agricultural practices on nitrates in the water table aquifer. *Biological Wastes* 19: 165-178.

Ritter, W. F., and A. E. M. Chirnside. 1990. Impact of animal waste lagoons on groundwater quality. *Biological Wastes* 34: 39–54.

Rolley, H.JL. and M. Owens. 1967. Oxygen consumption rates and some chemical properties of river muds. *Water Research* 1: 759-766.

Rothenberger, M., J.M. Burkholder, and C. Brownie. 2009a. Long-term effects of changing land use practices on surface water quality in a coastal river and lagoonal estuary. *Environmental Management* 44: 505-523.

Rothenberger, M., J.M. Burkholder, and T. Wentworth. 2009b. Multivariate analysis of phytoplankton and environmental factors in a eutrophic estuary. *Limnology and Oceanography* 54: 2107-2127.

Seiki, T., H. Izawa, E. Date, and H. Sunahara. 1994. Sediment oxygen demand in Hiroshima Bay. *Water Research* 28: 385-393.

Smith, R.P. 2009. The blue baby syndromes. *American Scientist* 97: 94-96.

Spellman, F.R. and N.E. Whiting. 2007. *Environmental Management of Concentrated Animal Feeding Operations (CAFOs)*. CRC Press, Boca Raton, FL.

State Stream Sanitation Committee. 1957. *Cape Fear River Basin Pollution Survey Report 1957 (1954-1956)*. North Carolina State Board of Health, Division of Water Pollution Control, Raleigh, North Carolina.

Stone, K.C., P.G. Hunt, F.J. Humenik, and M.H. Johnson. 1998. Impact of swine waste application on ground and stream water quality in an eastern Coastal Plain watershed. *Transactions of the American Society of Agricultural Engineers* 41: 1665-1670.

Stone, K.C., P.G. Hunt, S.W. Coffey, and T.A. Matheny. 1995. Water quality status of a USDA water quality demonstration project in the Eastern Coastal Plain. *Journal of Soil and Water Conservation* 50: 567-571.

Stubbs, K. and K. Cathey. 1999. CAFOs feed a growing problem. *Endangered Species Bulletin* 24: 14-15.

Tetra Tech. 2001 (May). *3-Dimensional EFDC Water Quality Model of the Lower Cape Fear River and its Estuary.* Prepared for the City of Wilmington and New Hanover County, North Carolina.

Tetra Tech. 2003 (January 6). Technical Memo: Results of Dissolved Oxygen and Pollutant Loading Trend Analyses. Submitted to Hugh Caldwell, Ken Vogt, and Wyatt Blanchard from Trevor Clements and Jason Doll.

Tetra Tech. 2014 (February). *Technical Memo: The Relationship of Adjacent Wetlands and Salt Marsh to Dissolved Oxygen in the Lower Cape Fear River Estuary*. Prepared for the Lower Cape Fear River Program. In May (2014).

Todd, M.J., G. Vellidis, R.R. Lowrance, and C.M. Pringle. 2009. High sediment oxygen demand within an instream swamp in southern Georgia: implications for low dissolved oxygen levels in coastal blackwater streams. *Journal of the American Water Resources Association* 45: 1493-1507.

Twomey, L.J., M.F. Piehler, and H.W. Paerl. 2005, Phytoplankton uptake of ammonium, nitrate and urea in the Neuse River Estuary, NC, USA. *Hydrobiologia* 533: 123-134.

U.S. Environmental Protection Agency (U.S. EPA). 1998. *Environmental Impacts of Animal Feeding Operations.* Office of Water, Standards and Applied Sciences Division, U.S. EPA, Washington, DC.

U.S. Environmental Protection Agency (U.S. EPA). 2004. Risk Management Evaluation for Concentrated Animal Feeding Operations. Report #EPA/600/R-04/042. Office of Research and Development, U.S. EPA, Cincinnati, OH. Available at: http://nepis.epa.gov/Adobe/PDF/901V0100.pdf.

Walker, J., V. Aneja and D. Dickey. 2000. Atmospheric transport and wet deposition of ammonium in North Carolina. *Atmospheric Environment* 34: 3407-3418.

Walker, R.R. and W.J. Snodgrass. 1986. Model for sediment oxygen demand in lakes. *Journal of Environmental Engineering* 112: 25-43.

Westerman, P.W., R.L. Huffman, and J.S. Feng. 1995. Swine-lagoon seepage in sandy soil. *Transactions of the American Society of Agricultural Engineers* 38: 1749-1760.

Westerman. P.W., M.R. Overcash, R.O. Evans. L.D. King, J.C. Burns, and G.A. Cummings. 1985. Swine lagoon effluent applied to coastal bermudagrass: III. Irrigation and rainfall runoff. *Journal of Environmental Quality* 14: 22-25.

Wetzel, R.G. 2001. *Limnology*, 3rd edition. Academic Press, New York, NY

Wing, S., R.A. Horton, and K.M. Rose. 2012. Air pollution from industrial swine operations and blood pressure of neighboring residents. *Environmental Health Perspectives* 121: 92-96.

Wu, R.S.S. 1990. A respirometer for continuous, in situ, measurements of sediment oxygen-demand. *Water Research* 24: 391-394.

Zu, J., A. Luo, and P. Ndegwa. 2001. Raising pH by low-level aeration for soluble phosphorus removal of swine manure. *Transactions of the American Society of Agricultural Engineers* 44: 391-396.

Zublena, J.P., J.C. Barker, and D.A. Crouse. 1995. *Capacity of North Carolina Crops to Use Animal Manures: A Nutrient Balance Approach*. Soil Science Notes, NC Agricultural Extension Service, NCSU, Raleigh, NC.

JoAnn M. Burkholder

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
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February 12, 2016

Elizabeth Kountis
DEQ/DWR Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611

Dear Ms. Kountis:

The U.S. Fish and Wildlife Service (Service) provides the following comments on the proposed water quality management plan and reclassification for a part of the Cape Fear River (Brunswick and New Hanover Counties) from Class SC to Class SC Swamp (Sw), announced in the December 18, 2015 *Comment Period for Revisions to 15A NCAC 2B .0227 Water Quality Management Plans*. The NC Environmental Management Commission (EMC) is seeking feedback on proposed revisions to 15A NCAC 2B .0227 in response to comments received on earlier versions of the proposal. As written, the Service does not support the proposed reclassification and management plan because there are no provisions to reduce upstream point and nonpoint sources of oxygen consuming waste that impair this section of the river. The management plan will not improve water quality. The revision also has technical limitations that may have the unintended affect of allowing further water quality degradation.

The Service is the principal Federal agency responsible for conserving, protecting and enhancing fish, wildlife and plants and their habitats for the continuing benefit of the American people. Among our priorities is the health and restoration of diadromous fish stocks in the area, including Striped Bass (*Morone saxatilis*), American Shad (*Alosa sapidissima*), Hickory Shad (*Alosa mediocris*), Blueback Herring (*Alosa aestivalis*), Alewife (*Alosa pseudoharengus*), Shortnose Sturgeon (*Acipenser brevirostrum*), Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*), and American Eel (*Anguilla rostrata*). All diadromous species have complex life cycles entailing use of freshwater and marine habitats, so the proposed reclassification of the lower Cape Fear River is of interest to us and partners working on fish restoration. In that regard, our partners in diadromous species conservation and restoration include the Atlantic States Marine Fisheries Commission (ASMFC), and the South Atlantic Fishery Management Council (SAFMC), on both of which our staff (Dr. Wilson Laney) serve as the Service's Southeast Region representative.

The Service has engaged in the proposed reclassification since April 15, 2014. On April 23, 2014, we emailed references documenting 1) fish of special management importance in the lower Cape Fear River, with emphasis on the lifestages present in late spring, summer and early fall when dissolved oxygen (DO) would be lowest; 2) references demonstrating adverse effects to fish early lifestages at DO concentrations less than the 5 mg/L standard; and 3) concern that a Sw classification, allowing lower DO if caused by natural conditions, might make it more difficult to determine use support related to DO in the future without a clearly defined lower bound on DO. We offered technical suggestions and additional concerns in a letter of March 3, 2015 and

followed-up in a meeting with Division of Water Resources (DWR) about those on April 22, 2015. The April 23, 2014 emails (3) and March 3, 2015 letter are incorporated by reference.

Our review of the revision and *Report of Proceedings on the Proposed Reclassification* (posted with September 10, 2015 materials on the EMC's website) indicate unresolved concerns:

1) There is no connection of the reclassification to any water quality restoration work. The *Report of Proceedings on the Proposed Reclassification* states "The proposal does not include language about correcting or reducing pollution as it is not designed to be a water quality restoration plan." We see that the management plan only addresses point sources of pollution in the reclassified reach despite the supporting model's clear indication that reduction in upstream nonpoint and point sources would bring the system far closer to compliance with existing standards. Basinwide approaches to nutrient reduction would be more appropriate to address water quality problems in the lower river than the reclassification alone.

We appreciate the technical foundation of monitoring and three-dimensional modeling that inform the relative contribution of various sources of oxygen consuming waste, and we do not disagree with the conclusion that the point sources in the modeled reach have little impact on the DO in that reach. However, the proposed rule and management plan do not embrace other conclusions from the same model indicating that upstream source reduction will improve DO -- reducing excursions below the 5mg/L standard. In other words, upstream water quality improvements could positively influence DO in the lower Cape Fear River. With the uncertainty in the few measures of sediment oxygen demand (SOD) in the model and potential that SOD may diminish following upstream nutrient load reductions, there is the potential to achieve the standards much more frequently with restoration. Without a component to improve lower Cape Fear River DO concentrations through watershed-wide waste load modeling, land use planning, and permitting, the management plan falls short.

2) In addition to no pathway to improved water quality, the reclassification and management plan as proposed may allow DO to decrease further with a loss of well established Clean Water Act tools and regulatory controls, further degrading habitat for all aquatic species. We previously recommended that the management plan discuss how DO use-support determinations will be made if there is no lower bound on the frequency and magnitude of DO concentrations. We have expressed concern that there will be an inability to explain how natural conditions will be differentiated from additional impacts associated with development – an inability to identify and remedy further DO degradation. The *Report of Proceedings on the Proposed Reclassification* agreed that this concern was valid and noted the need to develop a use-support attainment tool for swamp waters. However, no plans, schedules or commitments were made to develop the use-support attainment tool for swamp waters. Without that, the rule change may produce an unintended consequence of further degrading water quality.

Although we believe the reclassification needs to be accompanied by basinwide water quality restoration, we would be much more comfortable with the action if the associated management plan included a new numeric DO standard. We note that the modeling expertise partners have provided can be used to estimate a DO concentration of about 4.2 to 4.5 mg/L that is met 80-90% of the time under current conditions. While our preference is for restoration work to achieve the existing standard or a combination of restoration and reclassification, an empirically-derived lower bound DO concentration would better characterize the existing condition and provide a numeric standard by which water quality can be best evaluated and managed to protect aquatic animal health.

As noted previously, there are no federally-listed threatened or endangered species under Service jurisdiction in the affected reach. Shortnose Sturgeon and Atlantic Sturgeon are under the jurisdiction of NOAA Fisheries' Protected Species Division and may be affected by the action, so we encourage your continued coordination with them.

In its current form, the reclassification and associated management plan secure no improvements in water quality and weaken the foundation to protect existing conditions. We encourage the DWR and EMC to embrace the same water quality model's forecast for improvements from watershed-scale nutrient reductions in a corresponding basinwide water quality restoration plan. If you would like additional details on any of our recommendations, please contact me at 919-856-4520 x.21.

Sincerely,

Tom Augspurger

Tom Augspurger
Ecologist

cc: Lauren Petter – USEPA
Lisa Gordon – USEPA
Wilson Laney – USFWS
Mike Wicker – USFWS
Fritz Rhode – NOAA Fisheries
Pace Wilber – NOAA Fisheries
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Lisa Havel – Habitat Coordinator, ASMFC, Arlington, VA
Patrick Campfield – Science Director, ASMFC, Arlington, VA

STATE OF NORTH CAROLINA
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

ADDENDUM
TO
REPORT OF PROCEEDINGS
ON THE
PROPOSED RECLASSIFICATION OF A CAPE FEAR RIVER SEGMENT IN BRUNSWICK AND NEW HANOVER COUNTIES (CAPE FEAR RIVER BASIN) FROM CLASS SC TO SC Sw WITH A WATER QUALITY MANAGEMENT PLAN

PUBLIC NOTICE
DECEMBER 15, 2015 – FEBRUARY 15, 2016

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SUMMARY AND RECOMMENDATION

SUMMARY

At the September 2015 Environmental Management Commission (EMC) meeting, the EMC approved rule amendments reflecting the reclassification of a portion of the Cape Fear River in New Hanover and Brunswick Counties to Class SC Sw with a water quality management plan. The rulemaking involved proposed amendments to 15A NCAC 2B .0227 (2B .0227) and 15A NCAC 2B .0311 (2B .0311) that had been publicly noticed in early 2015. Then the Division of Water Resources (DWR) submitted the EMC approved rule amendments to the Rules Review Commission (RRC), and RRC legal staff requested technical changes to 2B .0227. The requested changes addressed 2B .0227 rule language primarily in existence prior to the rule amendments approved at the September 2015 EMC meeting. DWR considered the requested changes for the purposes of clarity only, and DWR responded to the requested technical changes with revisions to 2B .0227 that DWR felt did not alter the intent or purpose of the rule. EMC approved the revisions at its November 2015 meeting to go out to public notice (revised version of 2B .0227 attached as pages a-2 and a-3).

Public Notice and Comments Received

Public notice of the revised version of 2B .0227 was published in the December 15, 2015 and January 4, 2016 editions of the *North Carolina Register* (Volume 30, Issues 12 and 13) along with the EMC approved responses to the technical changes. An announcement of the comment period (announcement attached as pages a-4 and a-5) was sent to the Water Resources Rule-Making Announcements mailing list, the DWR Rules e-mail list, staff (including library staff) of the local governments with jurisdiction over land adjacent to the subject waters, wastewater facilities discharging directly to the subject waters, and to other persons potentially interested in the proposal, including staff of interest groups such as The Nature Conservancy, Cape Fear River Watch, Waterkeeper Alliance, and Cape Fear River Assembly, staff of federal and state agencies, and legislators within North Carolina. The public announcement and request for publication were submitted on December 18, 2015 to five local newspapers, *Coastal Review Online, Brunswick Beacon, Star News, Wilmington Journal,* and *Port City Daily* (newspaper request for publication attached as page a-6). The opportunity to request a public hearing was included in the public notice, but no hearing was requested, and therefore, no hearing was held.

Written comments were accepted from December 15, 2015 through February 15, 2016, and four written letters were received. Two comment letters, one each from the U.S. Fish and Wildlife Service and Southern Environmental Law Center (SELC) (two letters attached as pages a-7 through a-25), raise several of the same issues of concern that were raised during the previous comment period in early 2015, which DWR staff had investigated and responded to in the Report of Proceedings that was featured as an attachment to the September 2015 EMC meeting agenda item regarding the proposed reclassification and water quality management plan; these letters do not provide proposed language changes to 2B .0227. Of the remaining two letters, one letter was received from SELC and the other letter was received N.C. Division of Marine Fisheries (DMF)

(two letters attached as pages a-26 through a-35); these two letters provide proposed language changes to two areas within 2B .0227.

Proposed Language Changes from Comments & DWR Responses

The proposed language changes requested within the comments are as follows:

In regard to the word "significant" in the last sentence of (b)(1):

- "Remove the word "significantly" from the existing language...(or) use language...relative to SAV in Nationwide 19 General Conditions and Regional Conditions relating to all Nationwide Permits in the coastal area...(or) use language...relative in shell bottom and SAV in 15A NCAC 07H .0208..." (NC DMF)
- "...prohibit non-maintenance dredge and fill activities "where shellfish producing habitat or submerged aquatic vegetation habitat as defined in 15A NCAC 03I .0101(4)(g) and (i), occurs or would be reduced as a result of such activity." (SELC)

In regard to the provision for new non-discharge permits in the fifth sentence of (b)(1):

- "(Return) "New non-discharge permits shall be required to meet reduced loading rates and increased..." (and add)..."setbacks beyond those specified in Subchapter 2T of these rules... The adjusted loading rates and setbacks shall be determined by the Director on a case-by-case basis and designed to prevent runoff into surface waters." (SELC)

DWR had removed the word "significantly" from the last sentence of 2B .0227 (b)(1) (revised version of 2B .0227 attached as pages a-2 and a-3), an above-mentioned NC DMF suggested language change. In addition, the proposed language in the SELC comment letter alters the degree of restrictiveness of 2B .0227; as a reminder, the purpose of the DWR revisions made to 2B .0227 is to address requested technical changes, and not to propose any language that would make this rule more or less restrictive.

DWR, as well as SELC in their comment letter, noted that a reference in the published version of the rule needs to be corrected. To remedy this incorrect citation, DWR proposes to remove "(b)(20)(A) and (B)" from the last sentence of 2B .0227 (b)(1). In addition, the Division proposes to further clarify this sentence by adding the word "habitat" after "submerged aquatic vegetation", removing "a reduction of " prior to shellfish producing habitat," and replacing "which are" with "as" (language changes are highlighted in **bold** below).

RECOMMENDATION

After careful consideration of the record in this matter, it is the recommendation of DWR staff that the proposed revisions in 2B .0227 in response to requested technical changes, as proposed herein, be approved by the EMC in their entirety with the above-mentioned citation correction and clarifying language, which are shown below in **bold** (revised version of 2B .0227 with

additional changes (made after published in December 2015) attached as pages a-36 and a-37). In making this recommendation, DWR staff has considered applicable requirements within General Statutes 150B and 143, Rules within 15A NCAC 02B, and the written comments received.

In taking this action, 2B .0227 will show that the EMC has made revisions to this rule to address requested technical changes and EMC has made the following additional edits to 2B .0227 (b)(1)(D) in **bold** (revised version of 2B .0227 with additional changes (made after published in December 2015) attached as pages a-36 and a-37) :

> ~~(E)~~(D) No dredge or fill activities shall be allowed ~~where significant shellfish or submerged aquatic vegetation bed resources occur;~~ if those activities would result in a reduction of the beds of submerged aquatic vegetation **habitat** or shellfish producing habitat **which are** defined in 15A NCAC 03I .0101, except for maintenance dredging, such as that required to maintain access to existing channels and facilities located within the protected area or maintenance dredging for activities such as agriculture.

The proposed effective date for all modifications to 2B .0227 that were approved by the EMC at its September 2015 and May 2016 meetings is July 1, 2016. In addition, given that proposed amendments to 2B .0227 for a water quality management plan for a Cape Fear River segment were approved in conjunction with proposed amendments to 2B .0311 for a reclassification of the same Cape Fear River segment to Class SC Sw, the proposed effective date of the above-mentioned amendments to 2B .0311 is also July 1, 2016.

15A NCAC 02B .0227 is proposed for amendment as follows (text already adopted by Environmental Management Commission and pending RRC approval appears in italics):

15A NCAC 02B .0227 WATER QUALITY MANAGEMENT PLANS

(a) In implementing the water quality standards to protect the existing uses [as defined by Rule .0202 of this Section] of the waters of the state or the water quality which supports those uses, the Commission shall develop water quality management plans on a priority basis to attain, maintain or enhance water quality throughout the state. Additional specific actions deemed necessary by the Commission to protect the water quality or the existing uses of the waters of the state shall be specified in Paragraph (b) of this Rule. These actions may include anything within the powers of the Commission. The Commission may also consider local actions which have been taken to protect a waterbody in determining the appropriate protection options to be incorporated into the water quality management plan.

(b) All waters determined by the Commission to be protected by a water quality management plan are listed with specific actions either in Rules .0601- .0608 of this Subchapter that address the Goose Creek watershed (Yadkin Pee-Dee River Basin) or as follows:

(1) The Lockwoods Folly River Area (Lumber River Basin), which includes all waters of the lower Lockwoods Folly River in an area extending north from the Intracoastal Waterway to a line extending from Genoes Point to Mullet Creek, shall be protected by the specific actions described in *Parts (A) through* ~~*(E)*~~ (D) *of this Subparagraph.*

(A) New development activities within 575' of the mean high water line which require a Sedimentation Erosion Control Plan or a CAMA major development permit must comply with the low density option of the coastal Stormwater Runoff Disposal Rules ~~[as specified in 15A NCAC 2H .1005(2)(a)].~~ as specified in 15A NCAC 2H .1005(2)(a).

(B) New or expanded NPDES permits shall be issued only for non-domestic, non-industrial process type discharges ~~(such as non-industrial process cooling or seafood processing discharges).~~ such as non-industrial process cooling or seafood processing discharges. A public hearing is mandatory for any proposed (new or expanded) NPDES permit to this protected area.

~~*(C)* New non-discharge permits shall be required to meet reduced loading rates and increased buffer zones, to be determined on a case-by-case basis.~~

~~*(D)*~~(C) New or expanded marinas ~~must~~ shall be located in upland basin areas.

~~*(E)*~~(D) No dredge or fill activities shall be allowed ~~where significant shellfish or submerged aquatic vegetation bed resources occur,~~ if those activities would result in a reduction of the beds of submerged aquatic vegetation or a reduction of shellfish producing habitat as defined in 15A NCAC 03I .0101(b)(20)(A) and (B), except for maintenance dredging, such as that required to maintain access to existing channels and facilities located within the protected area or maintenance dredging for activities such as agriculture.

(2) A part of the Cape Fear River (Cape Fear River Basin) comprised of a section of 18-(71) from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut shall be protected by the Class SC Sw standards as well as the following site-specific action: All new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges shall be required to provide treatment for oxygen consuming wastes as described in Parts (A) through (C) of this Subparagraph.

(A) Effluent limitations shall be as follows: BOD_5 = 5 mg/l, NH_3-N = 1 mg/l and DO = 6 mg/l, or utilize *site-specific best available technology on a case-by-case basis for industrial* ~~*discharges*~~.discharges in accordance with Rule .0406 (e) of this Subchapter.

(B) Seasonal effluent limits for oxygen consuming wastes will be considered ~~*on a case-by-case basis*~~ *in accordance with Rule .0404 of this Subchapter.*

(C) Any new or expanded permitted pollutant discharge of oxygen consuming waste shall not cause the dissolved oxygen of the receiving water to drop more than 0.1 mg/l below the modeled in-stream dissolved oxygen at total permitted capacity for all discharges.

History Note: Authority G.S. 143-214.1; 143-215.8A;
Eff. October 1, 1995;
Amended Eff. ~~*November 1, 2015;*~~ *July 1, 2016; January 1, 1996.*

ANNOUNCEMENT FOR PUBLIC COMMENT PERIOD:

REVISED WATER QUALITY MANAGEMENT PLAN FOR PART OF CAPE FEAR RIVER IN NEW HANOVER AND BRUNSWICK COUNTIES

HISTORY

A Notice of Text was previously published in the 29:13 issue of the North Carolina Register for a proposed water quality management plan and Class Sc Sw reclassification for a part of the Cape Fear River, and it included notice of a public hearing, which was held on February 5, 2015, as well as a comment period.

At the September 2015 Environmental Management Commission (EMC) meeting, the EMC considered comments received concerning the rule amendments reflecting the reclassification and water quality management plan, and approved the rule amendments in conjunction with each other. The rulemaking involved proposed amendments to 15A NCAC 2B .0227 for the water quality management plan as well as to 15A NCAC 2B .0311 for the reclassification. Then the Division of Water Resources (DWR) submitted the rule amendments to the Rules Review Commission (RRC), and RRC legal staff requested technical changes to 2B .0227 but not 2B .0311. The requested changes primarily addressed 2B .0227 rule language in existence prior to the rule amendments approved at the September 2015 EMC meeting, and DWR considered the requested changes for the purposes of clarity only. DWR responded to the requested technical changes with a revised version of 2B .0227 that EMC approved at its November 2015 meeting to go out to public notice unaccompanied by 2B .0311.

REVISIONS TO 2B .0227

Revisions made to 2B .0227 in response to the requested technical changes, for which public comment is currently desired, appear underlined or ~~struck-through~~ in the revised rule whereas the September 2015 EMC approved amendments to 2B .0227, for which public comment has already been received, appear in *italics* in the revised rule. The revisions due to the requested technical changes are as follows:

1. First sentence in (b): Addition of "either in Rules .0601 - .0608 of this Subchapter that address the Goose Creek watershed (Yadkin Pee-Dee River Basin)" to address requested clarification of North Carolina waters deemed by the EMC as protected by a "water quality management plan"

2. Only sentence in (b)(1)(A): Removal of brackets around "as specified in 15A NCAC 2H .1005(2)(a)" to address requested grammatical change

3. First sentence in (b)(1)(B): Removal of parentheses around "such as non-industrial process cooling or seafood processing discharges" to address requested grammatical change

4. Only sentence in (b)(1)(C): Removal of entire sentence and "(C)" to address requested clarification of "reduced loading rates" and "increased buffer zones"

   The conditions in this sentence of the rule are difficult to implement as there is no established process or criteria for determining the application rates or setbacks in this rule. In addition, DWR is not considering more restrictive application rates or setbacks for facilities located in any specific basins, or areas in the state, other than what is prescribed in the 2T rules. The 2T rules were adopted in 2006, after the 2B .0227 language regarding the Lockwoods Folly River Area (Lumber River Basin) was adopted, and were intended to provide protection to water resources by means such as setbacks and application rate restrictions. Lastly, as part of the Session Law 2013-413 process, Rule 2L .0107 Compliance Boundary will be reviewed for potential amendments to provide adequate protection to surface waters currently within the compliance boundary for a spray field.

5. Only sentence in (b)(1) new (C): Replacement of "must" with "shall" to address requested grammatical change

6. Only sentence in (b)(1) new (D): Replacement of "where significant shellfish or submerged aquatic vegetation bed resources occur," with "if those activities would result in a reduction of the beds of submerged aquatic vegetation or a reduction of shellfish producing habitat as defined in 15A NCAC 03I .0101(b)(20)(A) and (B)," to address requested deletion or clarification of "significant"

   A technical change was requested for the same existing language in 2B .0225 (c)(2) as part of a triennial review rulemaking about 15 years ago, and given the revision made to address that technical change request became effective in the North Carolina Administrative Code (NCAC), DWR recommended the same revision be made to 2B .0227.

7. Only sentence in (b)(2)(A): Addition of "utilize" and replacement of "discharges" with "discharges in accordance with Rule .0406(e) of this Subchapter" to address requested clarification of the process for a "case-by-case" determination

   DWR added the word "utilize" and a reference to 2B .0406(e) to the proposed rule to clarify the required determination process.

8. Only sentence in (b)(2)(B): Removal of "on a case-by-case basis" to address requested clarification of the process for a "case-by-case" determination

   This part of the proposed rule already references Rule 2B .0404, which states that "the staff shall also provide on a case-by-case basis for seasonal variation in the discharge of oxygen-consuming wastes" and that rule provides the criteria to do so. Because the "case-by-case" language is already provided in the referenced .0404 rule, DWR recommended removal of "on a case-by-case basis" from the proposed rule.

HOT TO SUBMIT COMMENTS

The purpose of this announcement is to provide opportunity for comments on the revisions made to 2B .0227, which were made in response to requested technical changes, to be submitted to DWR. **You may submit written comments, data or other relevant information on the proposed 2B .0227 revised rule by February 15, 2016.**

The EMC is very interested in all comments pertaining to the revisions made to 2B .0227. All persons interested and potentially affected by the revised rule are encouraged to make comments on the proposed revisions. The EMC may not adopt a rule that differs substantially from the text of the proposed rule published in the North Carolina Register unless the EMC publishes the text of the proposed different rule and accepts comments on the new text. The proposed effective date for this proposed rule is July 1, 2016. **Written comments on the proposed revisions to 2B .0227 may be submitted to Elizabeth Kountis of the DEQ/DWR Planning Section at the postal address, e-mail address, or fax number listed below.**

FOR ADDITIONAL INFORMATION

This announcement and the revised 02B .0227 rule as well as a table of the requested technical changes and resulting DWR responses for 2B .0227 are located on the internet via http://portal.ncdenr.org/web/wq/event-calendar (look under "2015-12-15") and http://portal.ncdenr.org/web/wq/rules. Further explanations and details on reclassifications may be obtained by writing or calling:

Elizabeth Kountis, DEQ/DWR Planning Section
1611 Mail Service Center, Raleigh, NC 27699-1611
phone (919) 807-6418, fax (919) 807-6497, e-mail elizabeth.kountis@ncdenr.gov

North Carolina Department of Environmental Quality

Pat McCrory
Governor

Donald R. van der Vaart
Secretary

December 18, 2015

TO: Major Newspapers of NC

FROM: Ms. Elizabeth Kountis
Environmental Senior Specialist
N.C. Department of Environmental Quality
Division of Water Resources

SUBJECT: Publication of "Announcement for Public Comment Period: Revised Water Quality Management Plan for Part of Cape Fear River in New Hanover and Brunswick Counties"

"Announcement for Public Comment Period: Revised Water Quality Management Plan for Part of Cape Fear River in New Hanover and Brunswick Counties" is attached. The legal requirements for notice as required by G.S. 150B-21.2 have been met by publishing this notice in the *NC Register*. Publishing this notice in newspapers is not a statutory requirement and has therefore been cut from the Department's budget as non-essential spending. However, we do recognize that newspapers are one of the most effective methods to convey information to the public, and many newspapers contain a public announcement (or similar) section that does not charge a fee to service its readers with public announcements. Therefore, we are presenting the attached announcement to you for your information to publish at your discretion.

Should you decide to publish this information, it would be greatly appreciated if you would notify us. I can be contacted at any of the following:

By Email: Elizabeth.Kountis@ncdenr.gov
By Fax #: (919) 807-6497
By postal mail:
Ms. Elizabeth Kountis
NCDEQ/DWR-Planning Section
1611 Mail Service Center, Raleigh, NC 27699-1611
By phone: (919) 807-6418

If you should have any questions, please do not hesitate to contact me. Thank you sincerely for your consideration.

Enclosure

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

February 12, 2016

Elizabeth Kountis
DEQ/DWR Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611

Dear Ms. Kountis:

The U.S. Fish and Wildlife Service (Service) provides the following comments on the proposed water quality management plan and reclassification for a part of the Cape Fear River (Brunswick and New Hanover Counties) from Class SC to Class SC Swamp (Sw), announced in the December 18, 2015 *Comment Period for Revisions to 15A NCAC 2B .0227 Water Quality Management Plans*. The NC Environmental Management Commission (EMC) is seeking feedback on proposed revisions to 15A NCAC 2B .0227 in response to comments received on earlier versions of the proposal. As written, the Service does not support the proposed reclassification and management plan because there are no provisions to reduce upstream point and nonpoint sources of oxygen consuming waste that impair this section of the river. The management plan will not improve water quality. The revision also has technical limitations that may have the unintended affect of allowing further water quality degradation.

The Service is the principal Federal agency responsible for conserving, protecting and enhancing fish, wildlife and plants and their habitats for the continuing benefit of the American people. Among our priorities is the health and restoration of diadromous fish stocks in the area, including Striped Bass (*Morone saxatilis*), American Shad (*Alosa sapidissima*), Hickory Shad (*Alosa mediocris*), Blueback Herring (*Alosa aestivalis*), Alewife (*Alosa pseudoharengus*), Shortnose Sturgeon (*Acipenser brevirostrum*), Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*), and American Eel (*Anguilla rostrata*). All diadromous species have complex life cycles entailing use of freshwater and marine habitats, so the proposed reclassification of the lower Cape Fear River is of interest to us and partners working on fish restoration. In that regard, our partners in diadromous species conservation and restoration include the Atlantic States Marine Fisheries Commission (ASMFC), and the South Atlantic Fishery Management Council (SAFMC), on both of which our staff (Dr. Wilson Laney) serve as the Service's Southeast Region representative.

The Service has engaged in the proposed reclassification since April 15, 2014. On April 23, 2014, we emailed references documenting 1) fish of special management importance in the lower Cape Fear River, with emphasis on the lifestages present in late spring, summer and early fall when dissolved oxygen (DO) would be lowest; 2) references demonstrating adverse effects to fish early lifestages at DO concentrations less than the 5 mg/L standard; and 3) concern that a Sw classification, allowing lower DO if caused by natural conditions, might make it more difficult to determine use support related to DO in the future without a clearly defined lower bound on DO. We offered technical suggestions and additional concerns in a letter of March 3, 2015 and

followed-up in a meeting with Division of Water Resources (DWR) about those on April 22, 2015. The April 23, 2014 emails (3) and March 3, 2015 letter are incorporated by reference.

Our review of the revision and *Report of Proceedings on the Proposed Reclassification* (posted with September 10, 2015 materials on the EMC's website) indicate unresolved concerns:

1) There is no connection of the reclassification to any water quality restoration work. The *Report of Proceedings on the Proposed Reclassification* states "The proposal does not include language about correcting or reducing pollution as it is not designed to be a water quality restoration plan." We see that the management plan only addresses point sources of pollution in the reclassified reach despite the supporting model's clear indication that reduction in upstream nonpoint and point sources would bring the system far closer to compliance with existing standards. Basinwide approaches to nutrient reduction would be more appropriate to address water quality problems in the lower river than the reclassification alone.

We appreciate the technical foundation of monitoring and three-dimensional modeling that inform the relative contribution of various sources of oxygen consuming waste, and we do not disagree with the conclusion that the point sources in the modeled reach have little impact on the DO in that reach. However, the proposed rule and management plan do not embrace other conclusions from the same model indicating that upstream source reduction will improve DO -- reducing excursions below the 5mg/L standard. In other words, upstream water quality improvements could positively influence DO in the lower Cape Fear River. With the uncertainty in the few measures of sediment oxygen demand (SOD) in the model and potential that SOD may diminish following upstream nutrient load reductions, there is the potential to achieve the standards much more frequently with restoration. Without a component to improve lower Cape Fear River DO concentrations through watershed-wide waste load modeling, land use planning, and permitting, the management plan falls short.

2) In addition to no pathway to improved water quality, the reclassification and management plan as proposed may allow DO to decrease further with a loss of well established Clean Water Act tools and regulatory controls, further degrading habitat for all aquatic species. We previously recommended that the management plan discuss how DO use-support determinations will be made if there is no lower bound on the frequency and magnitude of DO concentrations. We have expressed concern that there will be an inability to explain how natural conditions will be differentiated from additional impacts associated with development – an inability to identify and remedy further DO degradation. The *Report of Proceedings on the Proposed Reclassification* agreed that this concern was valid and noted the need to develop a use-support attainment tool for swamp waters. However, no plans, schedules or commitments were made to develop the use-support attainment tool for swamp waters. Without that, the rule change may produce an unintended consequence of further degrading water quality.

Although we believe the reclassification needs to be accompanied by basinwide water quality restoration, we would be much more comfortable with the action if the associated management plan included a new numeric DO standard. We note that the modeling expertise partners have provided can be used to estimate a DO concentration of about 4.2 to 4.5 mg/L that is met 80-90% of the time under current conditions. While our preference is for restoration work to achieve the existing standard or a combination of restoration and reclassification, an empirically-derived lower bound DO concentration would better characterize the existing condition and provide a numeric standard by which water quality can be best evaluated and managed to protect aquatic animal health.

As noted previously, there are no federally-listed threatened or endangered species under Service jurisdiction in the affected reach. Shortnose Sturgeon and Atlantic Sturgeon are under the jurisdiction of NOAA Fisheries' Protected Species Division and may be affected by the action, so we encourage your continued coordination with them.

In its current form, the reclassification and associated management plan secure no improvements in water quality and weaken the foundation to protect existing conditions. We encourage the DWR and EMC to embrace the same water quality model's forecast for improvements from watershed-scale nutrient reductions in a corresponding basinwide water quality restoration plan. If you would like additional details on any of our recommendations, please contact me at 919-856-4520 x.21.

Sincerely,

Tom Augspurger

Tom Augspurger
Ecologist

cc: Lauren Petter – USEPA
Lisa Gordon – USEPA
Wilson Laney – USFWS
Mike Wicker – USFWS
Fritz Rhode – NOAA Fisheries
Pace Wilber – NOAA Fisheries
Roger Pugliese – Senior Fishery Biologist, SAFMC, Charleston, SC
Lisa Havel – Habitat Coordinator, ASMFC, Arlington, VA
Patrick Campfield – Science Director, ASMFC, Arlington, VA

SOUTHERN ENVIRONMENTAL LAW CENTER

Telephone 919-967-1450 601 WEST ROSEMARY STREET, SUITE 220 Facsimile 919-929-9421
CHAPEL HILL, NC 27516-2356

February 12, 2016

VIA ELECTRONIC MAIL
Elizabeth Kountis
DENR-DWR Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611
elizabeth.kountis@ncdenr.gov

Re: Cape Fear River Estuary Water Quality Management Plan

Dear Ms. Kountis:

The Southern Environmental Law Center appreciates the opportunity to comment on the proposed water quality management plan[1] for the Lower Cape Fear River ("LCFR")[2] on behalf of Cape Fear River Watch, Waterkeeper Alliance, and the North Carolina Conservation Network. Together, these organizations represent thousands of North Carolinians who drink, fish, swim, and paddle the state's rivers, including the Cape Fear; who place a high value on the quality of North Carolina's water resources; and who will be adversely affected by the degradation of water quality in the Cape Fear River. As such, these comments are intended to express concern regarding the agency's proposed management strategy for the LCFR.

As described in Section I, the strategy represents an abrupt and questionable departure from years of collaborative efforts to ensure that use of the river by aquatic life would be supported. In Section II, we document the myriad ways in which the water quality management plan under consideration appears intentionally designed to have minimal impact and therefore

[1] Although the agency specifically solicited comments regarding the proposed changes to the water quality management plan for the Lockwoods Folly River Area, those changes are not the only amendments to 15A N.C. Admin. Code 02B .0227 contemplated in the proposed rule published in the North Carolina Register on December 15, 2015. We therefore appreciate your consideration of our comments and their inclusion in the rulemaking record. See N.C. Gen. Stat. § 150B-21.2(f) ("An agency must accept comments on the text of a proposed rule that is published in the North Carolina Register and . . . consider fully any written and oral comments received"); *id.* § 150B-21.2(i) ("An agency must keep a record of a rule-making proceeding. The record must include all written comments received . . . .").
[2] As used herein, "LCFR" refers to the portion of the Cape Fear River from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut.

afford minimal protection to aquatic life. And, in Section III we emphasize the importance of preserving the designated use of the LCFR for aquatic life, which we believe should include efforts to protect endangered species that rely on the river.

I. Retreat Rather than Recovery: TMDL Avoidance in the LCFR

Every two years, the State must assess whether the designated uses[3] of a water body are supported by existing water quality.[4] Where existing pollution control requirements are insufficiently stringent to implement any water quality standard applicable to a water body, the State must take responsive action.[5] First, the water body must be included on the 303(d) list of impaired waters. Then, in order of established priority, the State must establish a total maximum daily load (TMDL) of the pollutant(s) impairing the designated use of listed waters; the TMDL should be calculated to limit pollutant loading to the degree necessary to attain applicable water quality standards.[6] Put more simply, after documenting unacceptable water quality, the State must take action to improve water quality to the degree necessary to support the water body's designated uses.

In Class SC waters like the LCFR, the normal dissolved oxygen standard is 5.0 mg/L.[7] In 1998, the State first observed that the designated uses of the Cape Fear estuary were impaired by low dissolved oxygen (DO) concentrations.[8] At the time, responsive measures were already

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[3] The classification of a water body dictates the applicable water quality standards necessary to protect the "best usage" of the waters with that classification. *See* N.C. Gen. Stat. 143-214.1(a)(1) (directing the EMC to develop "a series of classifications and the standards applicable to each such classification"); 15A N.C. Admin. Code 02B .0201 ("Existing uses . . . and the water quality to protect such uses shall be protected by properly classifying surface waters and having standards sufficient to protect these uses."); *see also* 40 C.F.R. § 131.11(a)(1) ("States must adopt those water quality criteria that protect the designated use. . . . For waters with multiple use designations, the criteria shall support the most sensitive use.").

[4] *See* 33 U.S.C. § 1315(b).

[5] 33 U.S.C. § 1313(d)(1)(A); 40 C.F.R. § 130.7(b). Conversely, where existing control strategies for point and nonpoint source pollution will achieve water quality standards, the law does not mandate such action.

[6] 33 U.S.C. § 1313(d)(1)(C); see also 40 C.F.R. § 130.7(c)(1) ("TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical [water quality standard] with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality.").

[7] 15A N.C. Admin. Code 02B .0220(5).

[8] N.C. Dep't of Env't and Natural Res. (NC DENR), *North Carolina's 1998 303(d) List* T-6 (May 15, 1998) (noting that of the 7,500 acres providing only "partial support" of designated uses, 5,000 were impaired by DO and listing wastewater treatment plants as a source of the impairment.),

under consideration; the State opined that "[p]roper technical conditions exist to develop a TMDL for this water body/pollutant" and that TMDL development was the "[u]sual approach" for responding to DO impairment.[9] A TMDL for Biological Oxygen Demand (BOD) had already been drafted in 1996 that "proposed using a phased approach to reducing BOD loading to the lower Cape Fear and highlighted several options that primarily reduce point source discharges to the river."[10] However, that TMDL was never approved or implemented.

By 2000, the DO impairment had been elevated to a high priority for the agency, which, by then, was meeting with the "regulated community . . . on a regular basis to discuss the modeling approach and investigate funding sources for the TMDL addressing low dissolved oxygen."[11] In 2002, the agency again listed the Cape Fear estuary as a high-priority water body for which a TMDL was required due to low dissolved oxygen.[12] When no TMDL was developed, the water body was again included on the list of impaired waters in 2004.[13]

In 2006, the LCFR was again listed as impaired due to low DO.[14] The State indicated that it expected to submit a TMDL to address this impairment "by the beginning of calendar year 2008."[15] Notably, by this time, the use of the LCFR had also become impaired by low pH.[16] However, the State remained focused on addressing what was nearly a decade-old DO impairment.

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http://portal.ncdenr.org/c/document_library/get_file?uuid=2284d944-2134-4c57-a2d9-499c58076d4a&groupId=38364.

[9] *Id.*

[10] *Id.* at 13 (noting the drafting of a BOD TMDL of 80,000 lbs/day BOD_u for the lower Cape Fear River below Lock and Dam #1).

[11] NC DENR, *North Carolina's 2000 303(d) List* 6 (Oct. 2, 2000), http://portal.ncdenr.org/c/document_library/get_file?uuid=20e877f9-81c3-4536-9622-e605646fcde4&groupId=38364.

[12] NC DENR, *North Carolina 2002 Impaired Waters List* 4 (Feb. 13, 2003), *http://portal.ncdenr.org/c/document_library/get_file?uuid=7cfe0f8a-bde3-4523-9e3e-cdc44e323123&groupId=38364.*

[13] NC DENR, *North Carolina 2002 303(d) Impaired Waters List-2004* 2 (Apr. 26, 2004), *available at http://portal.ncdenr.org/c/document_library/get_file?uuid=1504027b-a8d8-4c2d-83d5-0b1ac5cec792&groupId=38364.*

[14] For the 2006 listing, the State first assigned the "assessment units" currently used to define the LCFRE as the portion of the river from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut.

[15] NC DENR, North Carolina Water Quality Assessment and Impaired Waters List (2006 Integrated 305(b) and 303(d) Report) 54 (May 17, 2007).

[16] NC DENR, *North Carolina 303(d) List- 2006* 19 (June 19, 2007), http://portal.ncdenr.org/c/document_library/get_file?uuid=2648fa39-0975-4b27-8181-b0927ec2a43d&groupId=38364.

In October 2008, DENR staff considered five "Options for Addressing Dissolved Oxygen in the Lower Cape Fear River."[17] One of the options considered was "reclassification" but agency staff observed "[r]eclassifying the water does not appear to be an option at this time because no current NC classification 'fits' better than the water's existing SC designation. For example, Swamp waters have low velocities. The Cape Fear estuary is tidal and well mixed, not low-velocity."[18] Staff noted that "[a] TMDL with a target of 5.0 mg DO/l is doable, but most likely could not be successfully implemented." Ultimately, staff concluded that "[a] site-specific standard might be appropriate in this case" and noted "[i]f the dischargers in the watershed request a site-specific standard, DWR would support and oversee their development of the scientific rationale to derive it."[19] At that point, rather than seek to *attain* existing water quality standards, the agency and regulated community began considering strategies to *change* the water quality standards.

The DO impairment persisted and water quality in the LCFR worsened while the agency continued to study the problem.[20] Although claiming that TMDL development was a high priority in 2008,[21] 2010,[22] and 2012,[23] the agency continued to evaluate how to avoid implementing a TMDL. In November 2012, DWQ met with stakeholders to consider a technical assessment of natural and anthropogenic sources of dissolved oxygen deficit in the Lower Cape Fear Estuary.[24] It was suggested that Kathy Stecker, a DENR staff member, lead the combined effort. Ms. Stecker indicated that "determining a rationale for site specific criteria was likely the

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[17] E-mail from Kathy Stecker, NC DENR, to Elizabeth Kountis, NC DENR (May 16, 2014) (noting the options were prepared for a discussion with Coleen Sullins, then-Director of the Division of Water Quality).

[18] *Id.* Other rejected options included conducting a use attainability analysis or authorizing a temporary variance from water quality standards. *Id.*

[19] *Id.*

[20] By 2008, the LCFR was impaired by violations of standards for DO, pH, nickel, copper, and turbidity. NC DENR), *2008 North Carolina Integrated Report Categories 4 and 5 (Impaired Waters List)* 14 (March 10, 2010), http://portal.ncdenr.org/c/document_library/get_file?uuid=9f453bf9-2053-4329-b943-6614bd4e709a&groupId=38364.

[21] *Id.*

[22] NC DENR, *NC 2010 Integrated Report Categories 4 and 5 Impaired Waters* 16 (Aug. 31, 2010), http://portal.ncdenr.org/c/document_library/get_file?uuid=8ff0bb29-62c2-4b33-810c-2eee5afa75e9&groupId=38364. By 2010, the use of the LCFR was no longer impaired by violations of the water quality standard for nickel.

[23] NC DENR, *2012 North Carolina 303(d) Lists- Category 5* 20 (Aug. 10, 2012), http://portal.ncdenr.org/c/document_library/get_file?uuid=9d45b3b4-d066-4619-82e6-ea8ea0e01930&groupId=38364.

[24] CH2M Hill, Meeting Summary, Technical Assessment of Natural and Anthropogenic Sources of Dissolved Oxygen Deficit in the Lower Cape Fear Estuary (Nov. 7, 2012).

most feasible approach" and would be beneficial because it would "support aquatic life, allow for effective permitting, and provide acceptable limits for dischargers."[25] The agency and regulated community continued to evaluate this approach until early 2014.

In January 2014, the Chairman of the Water Quality Committee of the North Carolina Environmental Management Commission reviewed the list of impaired waters in North Carolina and opined to DWR staff that it "may be worth taking a look" at "streams that are not classified as Swamp Waters but probably should be."[26] He expressed concern that "if you do not have the classification correct then you could call a stream impaired when it is really not and could require much more [wastewater] treatment for a discharger than may be necessary."[27] In response, Ms. Stecker noted that reclassification was not necessary to account for naturally low DO and pH.[28] According to Ms. Stecker, the agency accounted for naturally low DO or pH in other ways when preparing the 303(d) list; she observed:

> Our solution doesn't involve rulemaking. The standards include an "out" for natural conditions, and we have developed a protocol that EPA concurs with. . . . We have successfully de-listed waters with naturally low DO and/or pH, and we've found others that really are impaired and developed TMDLs for those. . . . [I]f we suspect naturally low DO or pH, we don't put it on the list, but in Category 3. Those that we're working on in Category 5 have been there for a long time.[29]

Surmising that the WQC Chairman was primarily concerned with protecting dischargers, another DWQ staff member responded,

> The natural waters determination doesn't always get the dischargers off the hook. For instance, in the lower Cape Fear it gets tricky because modeling shows that

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[25] Id.
[26] E-mail from Steve Tedder, NC EMC, to Dianne Reid, NC DENR (Jan. 28, 2014).
[27] *Id.*; 15A N.C. Admin. Code 02B .0220(5), (12) (permitting lower pH and DO standards for Class SC waters with the supplemental "swamp waters" classification).
[28] E-mail from Kathy Stecker, NC DENR, to Dianne Reid, NC DENR (Jan. 28, 2014) (responding to Tedder's suggestion); *see also* 15A N.C. Admin. Code 02B .0205 (stating that "natural waters may on occasion, or temporarily, have characteristics outside of the normal range established by the standards" and "water quality standards will not be considered violated when values outside the normal range are caused by natural conditions).
[29] *Id.*

> even if we treat it like swamp water, the combined discharges still lower the DO too much and need to be further reduced.[30]

It is unclear whether the WQC Chairman nonetheless suggested the reclassification approach to the members of the Lower Cape Fear River Program (i.e., the members of the regulated community with which the agency had been working for years to address the DO impairment in the LCFR). However, before the next meeting of the WQC, that group submitted a request for reclassification of the LCFR as "swamp waters."[31]

In response, the agency ultimately proposed reclassification of the LCFR as "swamp waters." In tandem with this reclassification, the agency proposed the water quality management plan under consideration. In the following sections, we address concerns regarding this management plan.

II. Intentional Ineffectiveness: Crafting a Plan to Minimize Required Action

Perhaps the most obvious problem with the proposed management plan is its intentionally limited effect. Ordinarily, water quality management plans are adopted "to attain, maintain or enhance water quality" and should include "specific actions deemed necessary . . . to protect the water quality or the existing uses."[32] Yet the agency concedes that the management plan for the LCFR is *not intended to improve water quality.*[33] Nor is it truly intended to *maintain* water quality: it starts from the premise, derived from the reclassification, that it is acceptable for standards for pH and DO in the river to be lowered. Instead, the plan was crafted to have the minimum impact on the regulated community, and hence the least benefit to water quality. So successful was the agency in this regard that it concedes the management plan will have no effect whatsoever on the status quo. [34]

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[30] E-mail from Dianne Reid, NC DENR, to Steve Tedder, NC EMC (Jan. 28, 2014).
[31] Chris May, Request for Reclassification of a Portion of the Lower Cape Fear River with the Supplemental Swamp Classification (Mar. 5, 2014).
[32] 15A N.C. Admin. Code 02B .0227(a).
[33] "The proposal does not include language about correcting or reducing pollution as it is not designed to be a water quality restoration plan." NC DENR, *Report of Proceedings on the Proposed Reclassification of a Cape Fear River Segment, in Brunswick and New Hanover Counties (Broad River Basin) From SC to SC Sw with a Water Quality Management Plan* 10 (Feb. 5, 2015), http://portal.ncdenr.org/c/document_library/get_file?uuid=866ee647-ef8a-4912-8d36-06f26e6b1356&groupId=61581.
[34] *Id.* at 11 ("No changes to the current monitoring strategy as well as the current permitting and compliance strategies for the subject waters will occur due to this proposal.").

First, the plan makes no attempt to regulate nonpoint source pollution. Most notably, the plan does not address the contribution of pollutants from the Concentrated Animal Feeding Operations (CAFOs) in the Cape Fear River basin, which produce 50 percent of North Carolina's swine and large numbers of poultry.[35] The State should not disregard scientific analysis showing that, when waste management practices at CAFOs are poorly regulated, "large amounts of nitrogen and phosphorus enter the environment through runoff, percolation into groundwater, and volatilization of ammonia,"[36] and can exacerbate low DO (and pH) levels. Indeed, according to the EPA, hypoxia (i.e., low DO) "is regulated primarily by controlling nutrients (largely nitrogen) and other oxygen-demanding wastes."[37] North Carolina implicitly agreed with this observation by proposing a management plan focused exclusively on controlling BOD, DO, and ammonia from point sources. Yet, the proposed management plan imposes no limit on nonpoint source loading of nutrients or oxygen-demanding waste in the LCFR; nor does it address nutrient loading in upstream tributaries.

It is particularly ironic that the plan addresses only to point sources, and disregards nonpoint sources, since the supposed justification for reclassification of the river was that *point sources were not the cause* of observed violations of water quality standards.[38] Moreover, the agency intentionally excluded some point sources from the requirements proposed under the plan. Most obviously, the plan does not require any pollution reduction from existing facilities.[39] Initially, agency staff opined that "whatever goes into place for DO and pH may likely affect all discharges, whether new, expanding, renewals, etc."[40] However, the plan was revised to exclude existing facilities when research revealed the inability of existing facilities to comply with the

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[35] Michael A. Mallin & Lawrence B. Cahoon, Industrialized Animal Production—A Major Source of Nutrient and Microbial Pollution to Aquatic Ecosystems, 24 Population and Environment 369, 369 (2003).
[36] *Id.* at 379.
[37] U.S. EPA, *Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*, at v (Nov. 2000), http://water.epa.gov/scitech/swguidance/standards/upload/2007_03_01_criteria_dissolved_docriteria.pdf.
[38] Chris May, Request for Reclassification of a Portion of the Lower Cape Fear River with the Supplemental Swamp Classification (Mar. 5, 2014).
[39] E-mail from Tom Belnick NC DENR, to Elizabeth Kountis, NC DENR (April 16, 2014) ("I don't anticipate any changes to current NPDES permit limits."); e-mail from Ken Pickle, NC DENR, to Elizabeth Kountis, NC DENR (Apr. 17, 2014) ("I don't think any of our permittees (stormwater permittees, or wastewater dischargers under a permit administered by the Stormwater Permitting Program of DEMLR) would be impacted by the re-classification.").
[40] E-mail from Elizabeth Kountis, NC DENR, to Jim Gregson, NC DENR (May 19, 2014).

first draft of the plan.[41] Also, before proposing a plan applicable to only new or expanding facilities, the agency confirmed that there were no pending applications for new or expanded facilities[42] and that the existing facilities anticipating expansion already had permission to expand.[43]

The scope of the management plan was further curtailed when concern was expressed that the plan might apply to facilities authorized to discharge under general permits. Although early drafts proposed to manage *all* new or existing NPDES discharges, the plan was modified to reference only "individual" permits. Yet, even after drastically limiting its applicability, the agency was not finished reducing the plan's impact of the plan on the status quo.

The agency concedes that, because the LCFR is designated as a Primary Nursery Area, it is entitled to additional protection due to its important role in supporting aquatic life.[44] However, although the agency claims the management plan sets limits "similar to the limits for High Quality Waters,"[45] in truth the plan affords less protection.

Ordinarily, new or expanded wastewater discharges into high-quality waters must comply with the following limitations designed to control the discharge of oxygen-consuming waste:

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[41] *See* e-mail from Jim Gregson, NC DENR, to Elizabeth Kountis, NC DENR (May 21, 2014) ("Of the eight existing facilities, the three domestic plants currently have BOD or CBOD limits of 30 and 25, respectively. . . . None of the three Domestic plants would likely be able to meet a BOD limit of 5 mg/L without significant upgrades including filters. Two of the three domestic plants currently do not have Ammonia limits. The one that does (NC0065480) has a monthly ave. limit of 20 mg/l and a daily max. of 35. . . . I don't think any of the three domestic plants could currently meet an Ammonia limit of 1 mg/l."); *see also* e-mail from Bill Kreutzberger, CH2M, to Jeff Manning, NC DENR (June 5, 2014) ("The problem with the statement is that the current cumulative permitted discharge[s] case a decline of 0.2 to 0.3 mg/L below natural conditions. So the reference needs to be that the increase in loading from *new or expanding dischargers* can cause no more than a 0.1 mg/L decline in DO." (emphasis added)).

[42] "I understand that there are no proposed discharge permits for new facilities or expansion of existing facilities that your office is currently working on for this segment." E-mail from Elizabeth Kountis, NC DENR, to Jim Gregson, NC DENR (May 19, 2014); *see also* e-mail from Elizabeth Kountis, NC DENR, to Tom Belnick, NC DENR (July 10, 2014).

[43] "Currently there are 4 NPDES-permitted dischargers that discharge oxygen-consuming waste to the proposed SW reclass segment. Of these facilities, 3 have already received phased permit limits for future expansions." E-mail from Tom Belnick, NC DENR, to Jeff Manning, NC DENR (June 16, 2014).

[44] NC DENR, Report of Proceedings on the Proposed Reclassification of a Cape Fear River Segment, in Brunswick and New Hanover Counties (Broad River Basin) From SC to SC Sw with a Water Quality Management Plan a 3; see also 15A N.C. Admin. Code 02B .0101(e)(5).

[45] NC DENR, Report of Proceedings on the Proposed Reclassification of a Cape Fear River Segment, in Brunswick and New Hanover Counties (Broad River Basin) From SC to SC Sw with a Water Quality Management Plan a 3.

> Effluent limitations shall be as follows: BOD5= 5 mg/l, NH3-N = 2 mg/l and DO = 6 mg/l. More stringent limitations shall be set, if necessary, to ensure that the cumulative pollutant discharge of oxygen-consuming wastes shall not cause the DO of the receiving water to drop more than 0.5 mg/l below background levels, and in no case below the standard.[46]

However, the management plan for the LCFR was designed to impose less stringent limits on oxygen-consuming waste. First, because industrial dischargers may not be able to meet the normal BOD and NH3-N limits for HQW waters, an additional provision was added to exempt them from such limits.[47] Even more concerning is the plan's failure to consider background levels and/or the actual water quality standards applicable to the river.

Here, the evolution of the relevant language bears emphasis. As initially drafted, the water quality management plan for the LCFR was designed to prevent a drop in DO "below the standard." Then the language was amended to prohibit a drop below the "natural conditions." A subsequent draft prohibited a drop below the "modeled natural conditions." And, finally, the proposed language eschews any reference to the standards or natural conditions and instead uses "modeled in-stream dissolved oxygen at total permitted capacity for all discharges" as the baseline against which to measure the effect of a proposed permit.[48]

In other words, instead of considering actual standards and real data, the agency proposes to evaluate the impact of permitted activity based solely on modeling; this approach will have concerning effects on both permitting decisions and future assessments of use impairments. This novel approach appears to be a result of the agency's continued inability (despite a decade of trying) to determine the natural background levels of DO in the segment.[49] Indeed, e-mails

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[46] 15A N.C. Admin. Code 02B .0224(b)(i).

[47] E-mail from Tom Belnick, NC DENR, to Elizabeth Kountis, NC DENR (Aug. 3, 2015) ("The site-specific BAT language for industrials goes back to at least the 2000 Cape Fear River Basin Plan, where it was recognized that industries might not be able to achieve BOD= 5 mg/l and NH3-N = 2 mg/l.").

[48] Notably, the plan does not require consideration of the lower pH that could result from these discharges.

[49] The reluctance to rely on data to identify a change in DO of 0.1 mg/L might also result from the margin of error currently allowed for reporting DO results in laboratory tests. DO results must be reported to the nearest 0.1 mg/L with an accuracy of +/- 0.5 mg/L. North Carolina Wastewater/Groundwater Laboratory Certification Approved Procedure for the Analysis of Dissolved Oxygen (DO) (Apr. 2013).

exchanged within the agency noted the agency's inability to identify background conditions[50] and stated "using the model would be a totally different thing."[51]

Even worse, the agency fails to clarify in the management plan any quality assurance requirements for the modeling in question. Language was specifically omitted from early drafts that would have required modeling results to be "demonstrated," that would have required a person to "obtain Division of Water Resources review and approval of any monitoring study plan and description of the modeling framework to be used prior to commencement of such a study," and that would have required the study plan and modeling framework to "meet any Division requirements for data quality and model support or design in place at that time."

Understandably, the EPA expressed reservations about the approach contemplated in the proposed water quality plan. One federal regulator noted:

> When other states have adopted a 0.1 mg/L type provision, it has been a provision that applies to all implementing programs and has been provided as an amount of change from background condition. And even then the background condition has to be specifically defined before the provision can be used to deviate from the natural condition.[52]

Still, for all the aforementioned problems with the contents of the plan, perhaps the most destructive is the failure to include specific protections for the use of the river by aquatic life. Again, early drafts considered such provisions, and the agency apparently considered establishing a threshold for DO below which the river would not be allowed to fall. Indeed, some drafts even included different DO thresholds designed to protect specific species, including striped bass and endangered sturgeon. Ultimately, however, none of these laudable attempts to protect the designated uses of the river was included in the final management plan.

In other words, after years of observing that low DO impaired the use of the LCFR by aquatic life, the agency now proposes to reclassify the river as swamp waters, removing any floor for DO, and refrain from establishing a new minimum DO standard through the associated

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[50] E-mail from Cam McNutt, NC DENR, to Jeff Manning, NC DENR (June 4, 2014) ("We do not know what natural conditions DO level is so no assessment decision is made.").
[51] E-mail from Cam McNutt, NC DENR, to Jeff Manning, NC DENR (June 5, 2014) ("In the past we have not assess[ed] DO in Sw waters. Using the model would be a totally different thing.").
[52] E-mail from Lauren Petter, US EPA, to Elizabeth Kountis, NC DENR (Aug. 7, 2015).

management plan.[53] In the following section, we address the impropriety of ignoring protection of aquatic life in the LCFR.

III. Prioritizing Refuse over Use: Sacrificing Aquatic Life Protection to Satisfy Dischargers

The water quality standards associated with the "swamp waters" classification are designed to protect the use of waters for the propagation and survival of aquatic species that naturally occur in swamp waters.[54] Specifically, the EMC allows certain swamp waters to have higher acidity (i.e., low pH) and lower dissolved oxygen (DO) concentrations.[55] Class SC waters with the supplemental "swamp waters" classification "may have a pH as low as 4.3 if it is the result of natural conditions."[56] Though the agency has publicly disavowed plans to lower DO or pH standards, internal communications reveal that this is the anticipated effect,[57] or even primary motivation,[58] of the proposed action. A water quality management plan presupposing

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[53] This issue was a particular concern of the US Fish and Wildlife Service. *See* letter from Tom Augspurger, USFWS, to Elizabeth Kountis, NC DENR (March 3, 2015) (expressing "concern that a Sw classification, allowing lower DO if caused by natural conditions, might make it more difficult to determine use support related to DO in the future without some mechanism to define a new lower bound on DO indicative of background conditions").

[54] In contrast, other supplemental classifications result in application of more stringent water quality standards. *See, e.g.,* 15A N.C. Admin. Code 02B .0211(4) (more stringent freshwater chlorophyll-a standards for nutrient-sensitive waters and trout waters); *id.* 02B.011(6) (more stringent DO standards for trout waters); *id.* 02B .0211(19) (toluene standard applicable only to trout waters); *id.* 02B .0211(21) (more stringent turbidity standard for trout waters); *id.* 02B .0220(3) (more stringent saltwater chlorophyll-a standards for nutrient sensitive waters and trout waters); *id.* 02B .0223 (requiring development of nutrient control strategies in nutrient sensitive waters); *id.* 02B .0224 (stating standards applicable to high-quality waters); *id.* 02B .0225 (stating standards for outstanding resource waters). The State's anti-degradation policy is also stricter for waters classified as high-quality waters or outstanding resource waters. *Id.* 02B .0201.

[55] 15A N.C. Admin. Code 02B .0211(6), (14) (permitting lower pH and DO standards for Class C waters with the supplemental "swamp waters" classification); 15A N.C. Admin. Code 02B .0220(5), (12) (permitting lower pH and DO standards for Class SC waters with the supplemental "swamp waters" classification).

[56] *Id.*

[57] *See e.g.,* e-mail from Elizabeth Kountis, NC DENR, to Jim Gregson, NC DENR (May 19, 2014) ("Please note that this reclassification will most likely result in something less strict than what is currently required for DO and pH, so those facilities having a difficult time reaching 5 mg/l and the acceptable pH levels now may get some relief."); e-mail from Elizabeth Kountis, NC DENR, to Tom Belnick, NC DENR (Apr. 17, 2014) ("My understanding is that a Sw reclass . . . would remove the DO and pH impairments for 18-(71)a.").

[58] E-mail from Elizabeth Kountis, NC DENR, to Jeff Manning, NC DENR (May 9, 2014) ("Kathy mentioned that an impairment couldn't be lifted via use of .0227 only, that there would need to be

reclassification of the LCFR as swamp waters should include measures to ensure that the permissive lowering of DO and pH standards will not impair use of the water for aquatic life propagation and survival.

Mindful of the potential for lowering DO limits, a number of scientists expressed concern about the effects that the agency's proposed reclassification and associated water quality management plan for the LCFR would have on aquatic life. DEQ's own Division of Marine Fisheries objected to the proposed action because of anticipated impacts on fish species.[59] A rather blunt assessment was offered by the National Oceanic and Atmospheric Association (NOAA): "Reclassifying the lower Cape Fear is a bad idea."[60]

For the most part, the concern centered around effects that the proposal would have on anadromous species. In late winter, species including striped bass, Atlantic sturgeon, and American shad migrate from the ocean and lower Cape Fear estuary to spawn upstream in the main stem of the Cape Fear River.[61] Although adult fish return to the ocean or lower estuary after spawning, juveniles remain in nursery habitats through the summer before migrating seaward in late fall.[62] As previously noted, the LCFR includes habitat designated as primary nursery areas by the Division of Marine Fisheries (DMF).[63] Primary nursery areas (PNAs) are those "in the estuarine system where initial post-larval development takes place" and "populations are uniformly early juveniles."[64] The affected segment is also designated as an anadromous fish spawning area (AFSA) by DMF and the Wildlife Resources Commission.[65] This means "evidence of spawning anadromous fish has been documented in [DMF] sampling

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something tagged onto a water's current classification and/or a change in the classificaiton [sic] in order to have it delisted (that tag could reference .0227 perhaps).")

[59] E-mail from Anne Deaton, NC DENR, to Elizabeth Kountis, NC DENR (July 8, 2014) ("DMF does not support the reclassification due to the concentration of not only sturgeon in the river, but use by a diversity of other anadromous and estuarine fish species.").

[60] E-mail from Fritz Rohde, NOAA, to Stephania Bolden, NOAA (May 20, 2014) (asking recipient for "reports that document impacts of low DO and low pH on sturgeon").

[61] Cape Fear River Partnership, Cape Fear River Basin Action Plan for Migratory Fish 18 (April 2013), *available at* http://www.habitat.noaa.gov/protection/capefear/pdf/CapeFearActionPlan.pdf.

[62] Id.

[63] 15A N.C. Admin. Code 03R .0103.

[64] 15A N.C. Admin. Code 03I .0101; *see also* 15A N.C. Admin. Code 02B .0202 ("Primary Nursery Areas (PNAs) are tidal saltwaters which provide essential habitat for the early development of commercially important fish and shellfish and are so designated by the Marine Fisheries Commission.").

[65] 15A N.C. Admin. Code 03R .0115(25); see also Division of Marine Fisheries, Anadromous Fish Spawning Areas (AFSA): Cape Fear River Area, Map 7, http://portal.ncdenr.org/c/document_library/get_file?uuid=f810ae29-ea4d-4801-a04f-850ff2bc4467&groupId=38337.

records through direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae."[66]

Low dissolved oxygen levels can be particularly harmful in spawning and nursery areas because hypoxia "causes substantial mortality of developing embryos."[67] For this reason, EPA recommends more stringent dissolved oxygen criteria for the early life stages of both coldwater and warmwater fish.[68] Multiple scientists commenting on the proposed management strategy for the LCFR expressed concern about its impact on fish in early life stages.[69]

In addition to playing a role in the life cycles of multiple fish species, the lower Cape Fear River is home to two endangered species of sturgeon, suggesting a need for more stringent environmental protection.[70] "Maintenance and recovery of the water quality conditions required to sustain and recover federally-listed threatened and endangered aquatic animal species

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[66] Anadromous fish spawning areas are those "where evidence of spawning anadromous fish has been documented in Division sampling records through direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae." 15A N.C. Admin. Code 03I .0101(4)(b).
[67] Denise L. Brietburg et al, Hypoxia, Nitrogen, and Fisheries: Integrating Effects Across Local and Global Landscapes, 1 Annual Review of Marine Science 333 (2009) ("Developing embryos are particularly sensitive because they lack the ability to behaviorally respond to low oxygen and because oxygen must diffuse across the chorion that encases the embryo."), http://moritz.botany.ut.ee/~olli/eutrsem/Breitburg09.pdf.
[68] US EPA, *Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*, app. I (Nov. 2000), http://water.epa.gov/scitech/swguidance/standards/upload/2007_03_01_criteria_dissolved_docriteria.pdf.
[69] E-mail from Tom Augspurger, US FWS, to Elizabeth Kountis, NC DENR (April 23, 2014) ("[P]ublished information on desirable levels of dissolved oxygen for good striped bass production indicate survival of striped bass eggs and larvae are reduced at dissolved oxygen levels from 4 to 5 mg/L (Bain and Bain 1982) and that optimal ranges for larvae and juveniles are >6 to 12 mg/L (Hill et al. 1989; Nicholson et al. 1990)."); *id.* ("DO concentrations higher than the standard of 5 mg/L are desirable for spawning areas. The national dissolved oxygen criteria for sensitive life-stages in non-salmonid waters is a daily minimum of 5 mg/L and a weekly average of 6 mg/L. . . . At concentrations below these, larval mortality, altered growth, and behavioral changes have been reported in both field and lab studies."); e-mail from Brian Kreiser, Univ. of Southern Miss., to Gary Kreiser, NC DENR (May 22, 2014) ("I don't know where potential spawning grounds might be relative to the area they want to classify as a swamp, but that would be an important consideration. The early life stages are probably not going to be as hypoxia tolerant as adults or won't be able to behaviorally avoid those areas.").
[70] *See* Mary L. Moser & Steve W. Ross, Habitat Use and Movements of Shortnose and Atlantic Sturgeon in the Lower Cape Fear River, North Carolina, 124 Transactions of the American Fisheries Society 225 (1995).

contributes to the support and maintenance of a balanced and indigenous community of aquatic organisms and thereby protects the biological integrity of the waters."[71]

First, the lower Cape Fear is home to the Atlantic sturgeon, a species that NOAA's National Marine Fisheries Service first listed as endangered in 2012. Although the harvest of Atlantic sturgeon has been banned since 1991, the Atlantic States Marine Fisheries Commission (ASMFC) has stated that fishery management measures alone will not sustain stocks of Atlantic sturgeon without sufficient quality and quantity of habitat. As such, it bears emphasis that the estuarine waters of the lower Cape Fear river are precisely the type where juvenile Atlantic sturgeon "for months to years before emigrating to open ocean."[72] Moreover, ASMFC studies demonstrate that DO concentration is a "key habitat parameter[] for the structuring of juvenile Atlantic sturgeon habitat."[73]

The Lower Cape Fear also hosts a population of shortnose sturgeon, a species recognized by the federal government as endangered in 1967 and subject to a fishing moratorium since 1991. Juvenile shortnose sturgeon tend to locate in estuarine waters such as those in the LCFR. Consequently, "protection of essential habitats, especially nursery/summer habitats, from human caused dissolved-oxygen reductions and other impacts is critical."[74]

A number of scientists urged the agency not to subject endangered sturgeon species to additional environmental stress by allowing lower dissolved oxygen in the LCFR. One sturgeon specialist noted, "given their benthic nature, DO requirements, and tendency for the Cape Fear to have lower DO events I would imagine they are already often experiencing DO close (or low enough) to killing them."[75] A NOAA scientist observed that, "In habitats with DO less than 4.7 mg/L, young of year Atlantic sturgeon experience a loss in growth."[76] Another noted that "DO

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[71] 15A N.C. Admin. Code 02B .0110.
[72] Atlantic Marine Fisheries Commission, *Habitat Addendum IV to Amendment I to the Fishery Management Plan for Atlantic Sturgeon* 2 (Sept. 2012), http://www.asmfc.org/uploads/file/sturgeonHabitatAddendumIV_Sept2012.pdf.
[73] *Id.* at 3.
[74] Mark R. Collins et al, Primary Factors Affecting Sturgeon Populations in the Southeastern United States: Fishing Mortality and Degradation of Essential Habitats, 66 Bulletin of Marine Science 917, 917 (2000), available at
[75] E-mail from Joseph Facendola, NC DMF, to Bennett Wynne, NC WRC (June 2, 2014) (e-mail forwarded by Chip Collier, NC DMF to Adriene Weaver, NC DENR on June 4, 2014); *see also id.* (opining that "reduced WQ standards in the lower cape fear will have negative impacts on the sizes of sturgeon that we have movement data for, and I suspect that it could have a greater impact on YOY that we have no data for (and are far less mobile).").
[76] E-mail from Fritz Rohde, NOAA, to Elizabeth Kountis, NC DENR (May 13, 2014) (citing Secor and Niklitshcek 2001))."

levels below 5.0 mg/L and ph of 4.3 would be problematic for sturgeons of either species" in the river because "[f]undamentally, sturgeons are adapted for life in big, well-flowing rivers with good oxygenation 6-9 mg/L and ph with[in] 0.5 units of neutral."[77]

To protect aquatic life, the agency should fight against degrading water quality in the LCFR instead of capitulating at the behest of the regulated community. While polluters want the State to quit trying to protect the LCFR for use by aquatic life that requires "normal" pH levels above 6.8 and/or DO levels of above 5.0 mg/L, the agency should strive to manage the LCFR so as to provide for the best usage of the water body.

IV. Conclusion

For more than 30 years, the State has determined that the best usage of the lower Cape Fear by aquatic life is protected by the water quality standards for pH and DO associated with Class SC waters. For more than 15 years, the State has recognized that usage of the lower Cape Fear River by aquatic life is impaired by low DO concentrations. The State should not abandon efforts to return these waters to the conditions that support their best usage. Rather than adopt a water quality management plan that is designed to avoid necessary efforts to improve water quality, the State should continue to strive to "maintain, protect, and enhance water quality within North Carolina.[78] Accordingly, we urge the agency to reject the proposed management plan.

Thank you for the opportunity to comment on this important matter.

Sincerely,

Will Hendrick
Associate Attorney
Southern Environmental Law Center

cc (by e-mail):

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[77] E-mail from Kenneth Sulak, USGS, to Fritz Rohde, NOAA (May 20, 2014). This e-mail was forwarded to NC DENR on May 20, 2014. See e-mail from Fritz Rohde, NOAA, to Elizabeth Kountis, NC DENR (May 20, 2014).
[78] N.C. Gen. Stat. § 143-215.2(b).

Frank Yelverton, Cape Fear River Watch
Grady McCallie, North Carolina Conservation Network
Gray Jernigan, Waterkeeper Alliance
Kemp Burdette, Cape Fear River Watch
Lauren Petter, USEPA- Region 4

PAT MCCRORY
Governor

DONALD R. VAN DER VAART
Secretary

LOUIS DANIEL
Director

Marine Fisheries
ENVIRONMENTAL QUALITY

TO: Elizabeth Kountis, Division of Water Resources

FROM: Tere Barrett, Division of Marine Fisheries

SUBJECT: Proposed revisions to 15A NCAC 2B .0227, Water Quality Management Plans

DATE: February 15, 2016

I appreciate the opportunity to review the proposed technical changes to 15A NCAC 02B .0227, on behalf of the Division of Marine Fisheries. After so doing, I have only one comment to offer.

I am concerned with item 6, replacing "where significant shellfish or submerged aquatic vegetation bed resources occur" with "if those activities would result in a reduction of the beds of submerged aquatic vegetation or a reduction of shellfish producing habitat as defined in 15A 33 NCAC 03I .0101(b)(20)(A) and (B)."

In context, this language refers to regulating dredge and fill activities in the Lockwood Folly River Area. Within the described area, shellfish producing habitat is abundant. There is no documentation of submerged aquatic vegetation southwest of the Cape Fear River, although future colonization could occur.

The division feels that the 15A NCAC 02B .0227 (6) is important to protect vital and limited habitat in eastern North Carolina from irreversible damage. However, the proposed language change could, in my opinion, lead to a weakening of the regulation of habitat due to the subjectivity of the language and because habitat impacts from dredging are not always immediate or limited to reduced habitat area - sublethal stress can result in reduced health and viability and a slow decline. I am sympathetic to the problem with the word "significant," however.

Excavation and filling of aquatic habitat has the direct influence of removing the immediate resource, and has short and long term consequences involving sedimentation during construction, alteration of the substrate and the current/water movement within and through the system, changes in use of the system, and changes in the energy regime, among other things.

As you are aware, the Coastal Habitat Protection Plan explores the significance of six coastal habitats, of which submerged aquatic vegetation and shellfish habitats are two. The 2015 CHPP Source document describes the importance of these habitats to the overall system, and their vulnerability to factors of disturbance.

The economic value of ecosystem services provided by shell bottom and SAV habitat is reportedly very large. Costanza et al., estimated the value of ecosystem services of seagrass and algal beds to be $19,000/ha/yr ($7,700/ac/yr). Rates of denitrification by oyster reefs are similar to that of SAV and marsh. The dollar benefit of the nitrogen removal service provided by oyster reefs was estimated to be $3,167/ac/yr in 2014 dollars. The functions of SAV improve water quality in estuaries by removing TSS from the water column, improving water clarity, and adding DO (Biber et al. 2008; Dennison et al. 1993; Virnstein and Morris 1996).

In addition to water quality benefits, both shell bottom and SAV provide critical habitat for numerous economically important fishery species. The SAFMC considers SAV as Essential Fish Habitat (EFH) for brown, white, and pink shrimp, and species in the snapper-grouper complex, while shell bottom is EFH for snapper-grouper species.

State of North Carolina | Environmental Quality | Marine Fisheries
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When sediment settles on oysters and SAV living organisms can be smothered, resulting in mortality or impeded growth (Wilber 2005), while elevated turbidity reduces light necessary for SAV survival (Thayer et al. 1984; Wilber 2005). Even low levels of siltation can affect the growth of oyster beds by reducing larval recruitment. Excessive sedimentation increases survival time of pathogenic bacteria (SAFMC 1998b). Oyster eggs and larvae are most sensitive to suspended sediment loading (Davis and Hidu 1969).

All dredging activities produce some level of turbidity, and it is difficult to anticipate and quantify losses of a resource such as seagrass or oyster beds; hence, the wording necessitates some level of site differentiation and expertise specific to each unique scenario. Additionally, there is the possibility of change in energy levels/currents within the system from dredge activities that can lead to future losses, or change of use that can do the same. All of these require a level of judgement to be imparted on the validity of each project, taking into account adjacent land uses, physical, chemical, and biological characteristics, etc.

In recognizing the need to rid the rule of the word "significant," DMF suggests changing the language to one of the following options:

1) Remove the word "significantly" from the existing language: "No dredge or fill activities shall be allowed where shellfish producing habitat or submerged aquatic vegetation occurs."
2) Use language already in rule by the USACE (see language relative to SAV in Nationwide 19 General Conditions and Regional Conditions relating to all Nationwide Permits in the coastal area)
3) Use language already in rule by the Coastal Resources Commission (see language relative to shell bottom and SAV in 15A NCAC 07H .0208). Alternatively, we recommend:

USACE and CRC wording is pasted below for consideration.

Again, the division appreciates the opportunity to comment.

USACOE NWP 19: General Conditions

Minor Dredging. Dredging ... This NWP <u>does not authorize the dredging or degradation through siltation</u> of coral reefs, <u>sites that support submerged aquatic vegetation (including sites where submerged aquatic vegetation is documented to exist but may not be present in a given year)</u>, anadromous fish spawning areas, or wetlands, or the connection of canals or other artificial waterways to navigable waters of the United States (see 33 CFR 322.5(g)).

<u>Final 2012 Regional Conditions for Nationwide Permits (NWP) in the Wilmington District:</u>

3.8 Preservation of Submerged Aquatic Vegetation:

<u>Adverse impacts to Submerged Aquatic Vegetation (SAV) are not authorized</u> by any NWP within any of the twenty coastal counties defined by North Carolina's Coastal Area Management Act of 1974 (CAMA).

CRC 15A NCAC 07H .0208(b) Specific Use Standards

(1) Navigation channels, canals, and boat basins shall be aligned or located so as <u>to avoid</u> primary nursery areas, <u>shellfish beds, beds of submerged aquatic vegetation</u> as defined by the MFC, or areas of coastal wetlands except as otherwise allowed within this Subchapter. Navigation channels, canals and boat basins shall also comply with the following standards: ...

SOUTHERN ENVIRONMENTAL LAW CENTER

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CHAPEL HILL, NC 27516-2356

February 12, 2016

VIA EMAIL

Ms. Elizabeth Kountis
DEQ-DWR Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611
Elizabeth.kountis@ncdenr.gov

Re: Proposed Amendments to 15A N.C. Admin. Code 02B .0227 – Water Quality Management Plans

Dear Ms. Kountis:

The Southern Environmental Law Center submits these comments on behalf of the North Carolina Coastal Federation ("the Federation") in response to the proposed amendments to the provisions of 15A N.C. Admin. Code 02B .0227 ("the Rule") comprising the water quality management plan for the Lockwoods Folly River watershed.

I. Water Quality Management in the Lockwoods Folly River Basin

The Lockwoods Folly River drains a 153-square-mile watershed in southeast Brunswick County, one of the fastest growing counties in the nation.[1] This surging development has had noticeable effects on water quality in the river; for instance, the percentage of shellfish beds in the river closed to shell fishing tripled between 1980 and 2010.[2] Notably, rapid growth in the area is "expected to continue, increasing the degree of threat to watershed functions from increased nonpoint source pollutant loading and loss of aquatic and terrestrial habitat."[3] It is critical that water quality management strategies be designed to combat this threat.

[1] "Since 1980 the county's population has more than tripled to over 95,000 and another 30,000 or so residents are expected to make this last bastion of undeveloped southeastern NC their home by 2020 . . . ." Mike Giles, *Water Quality Strategy for the Lockwoods Folly River: A Partnership For An Ailing River* (2010), *available at* http://aquaticcommons.org/3903/1/Giles_papers.pdf.

[2] *Id.* (noting an increase from 18% closure in 1980 to 60% closure in 2010). In 2006, the Lockwoods Folly River was listed on the 303(d) list because high concentrations of fecal coliform bacteria impaired designated uses of the river.

[3] N.C. Ecosystem Enhancement Program, *Lockwoods Folly River Local Watershed Plan: Detailed Assessment and Targeting of Management Report* 1.3 (2007) (hereinafter "Watershed Plan"), http://portal.ncdenr.org/c/document_library/get_file?uuid=b1e27660-7128-4198-99f5-3c9c55ffe4eb&groupId=60329.

In recent years, the North Carolina Coastal Federation has partnered with representatives from local, state, and federal governments on a number of efforts designed to improve water quality in the Lockwoods Folly River. The Federation was a founding member of the Lockwoods Folly Watershed Roundtable organized in 2005 to identify and recommend strategies to protect and restore water quality in the river.[4] In cooperation with the Roundtable, the North Carolina Ecosystem Enhancement Program adopted a watershed management plan for the basin in 2007.[5] In 2010, a fecal coliform TMDL was adopted for the basin, thanks in part to years of research sponsored by the Federation.[6]

It bears emphasis that the North Carolina Coastal Federation was also instrumental in the creation of the Lockwoods Folly River watershed water quality management plan. As originally designed, the plan was intended to affect multiple activities impacting water quality, including the density of development, discharge and non-discharge permitting, marina expansion, and dredge and fill operations. It is concerning that proposed revisions to that water quality management plan appear contrary to the efforts that had been undertaken to improve water quality in the basin. Before elaborating on those concerns, however, it is helpful to summarize the rulemaking efforts that resulted in the proposed amendments.

II. Regulation by Afterthought: Background on the Proposed Amendments

On January 2, 2015, the EMC proposed an amendment to the Rule that would, in a new subsection (b)(2), add a water quality management plan for a portion of the lower Cape Fear River.[7] After the conclusion of the public comment period, the hearing officer recommended adoption of the amendment.[8] The amendment was approved unanimously by the EMC, and in no way affected the Lockwoods Folly River watershed water quality management plan.[9]

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[4] The Roundtable included representatives from the Federation, Brunswick County Board of Commissioners, EPA, and the N.C. Ecosystem Enhancement Program.

[5] *Watershed Plan*, supra note 3.

[6] The TMDL was approved by EPA on September 7, 2010. The TMDL document is available at http://ofmpub.epa.gov/waters10/attains_impaired_waters.show_tmdl_document?p_tmdl_doc_blobs_id=73402.

[7] 29 N.C. Register 1604-09 (Jan 2, 2015). The EMC simultaneously proposed to reclassify the same portion of the Lower Cape Fear River as swamp waters. *Id.* On February 5, 2015, a hearing was held to provide an opportunity for the public to comment on the proposed amendment to the Rule.

[8] N.C. DENR, Report of Proceedings on the Proposed Reclassification of a Cape Fear Segment, In Brunswick and New Hanover Counties (Broad River Basin) from SC to SC Sw with a Water Quality Management Plan (2015), http://portal.ncdenr.org/c/document_library/get_file?uuid=866ee647-ef8a-4912-8d36-06f26e6b1356&groupId=61581. The report contained no discussion of changes to the water quality management plan for the Lockwoods Folly River watershed.

[9] The only proposed changes to subjection (b)(1) of the Rule were the replacement of language referencing "Subparagraphs (1) through (5) of this Paragraph" with language referencing the identical rule provisions as "Parts (A) through (E) of this Subparagraph." *Id.* at 1605.

After its adoption by the EMC, the amended rule was submitted to the Rules Review Commission ("RRC") for review.[10] Although the EMC only sought to amend part of the Rule, the RRC was statutorily authorized to review the entire rule for consistency with the RRC's standards.[11] RRC staff conducted a preliminary review and concluded that there were a number of technical changes that should be made to increase the clarity of the Rule.[12] Accordingly, before the rule was presented for RRC review, a member of the RRC staff submitted a "Request for Technical Change" to the EMC on October 9, 2015.[13]

At that point, the RRC raised, for the first time in the rulemaking proceedings, questions about the water quality management plan for the Lockwoods Folly River watershed. Specifically, to ensure that the amended Rule was clear and unambiguous prior to recodification, the RRC staff asked clarifying questions about, and proposed changes to, that management plan. The "Request for Technical Change" included the following questions and suggested edits:

> *In (b)(1)(C), what do you mean by "reduced loading rates" and "increased buffer zones." Is there a rule or statute that provides what the typical loading rates and buffer zones are? Also, how is this determination made? Please include factors that will be used in making this decision. Also, by whom will this determination be made? Please provide additional information.*
>
> ...
>
> *In (b)(1)(E), please delete or define "significant."*[14]

In response to these questions, DWR now proposes substantive amendments to the water quality management plan for the Lockwoods Folly River watershed. In the following sections, we review and recommend revision of those amendments.

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[10] *See* N.C. Gen. Stat. § 150B-21.2(g) ("An agency must submit an adopted rule to the Rules Review Commission within 30 days of the agency's adoption of the rule.").

[11] N.C. Gen. Stat. § 150B-21.8 ("When the [RRC] reviews an amendment to a permanent rule, it may review the entire rule that is being amended.").

[12] *See* N.C. Gen. Stat. § 150B-21.9 (requiring the RRC to determine whether a rule "is clear and unambiguous"); Ultimately, the Commission extended the period for reviewing the rule, having determined it needed "additional information on the rule to be able to decide whether the rule meets the standards of review." *See* N.C. Gen. Stat. § 150B-21.10.

[13] http://portal.ncdenr.org/c/document_library/get_file?uuid=db0c57c2-2cf4-4044-959b-18d105710635&groupId=61581 A request for technical change submitted by RRC staff is distinguishable from a request for technical change by the RRC itself. *See* N.C. Gen. Stat. § 150B-21.10 ("In reviewing . . . an amendment to an existing rule, the Commission may request an agency to make technical changes to the rule and may condition its approval of the rule on the agency's making the requested technical changes.")

[14] The subsections of the Rule that were referenced by the RRC staff – (b)(1)(C) and (b)(1)(E) – state provisions of the water quality management plan for the Lockwoods Folly River watershed.

III. Duplication Rather than Clarification: Limiting Dredge and Fill Activities

First, rather than simply deleting or defining the word "significant" in (b)(1)(E), DWR proposes to alter the nature of limits on dredge and fill activities imposed under the Rule. As currently codified, the Rule prohibits dredge or fill activities, except for maintenance dredging, "where significant shellfish or submerged aquatic vegetation bed resources occur."[15] The proposed amendment would instead prohibit dredge or fill activities, other than maintenance dredging, "if those activities would result in a reduction of the beds of submerged aquatic vegetation or a reduction of shellfish producing habitat as defined in 15A NCAC 03I .0101(b)(20)(A) and (B)."

Rather than clarifying existing language in the Rule, it appears that DWR simply copied language from another rule specifying water quality management strategies and proposed to insert it into the Lockwoods Folly River watershed management plan.[16] Ironically, this only increased confusion, since the copied provision contains outdated cross-references.[17] At minimum, before the EMC is asked to adopt amendments to the Rule, these cross-references, if retained, should be updated.

More importantly, the proposed amendment also injects uncertainty into the Rule by shifting from a management strategy that limits activity based on the *presence* of certain natural resources to one that limits activity based on *prediction* of its impact on those same resources. Ideally, the Rule would be easy for regulators, the regulated community, and the public to understand and apply. It is much easier to document accurately whether/where a specific natural resource exists than it is to predict accurately the impacts to that resource that may be caused by future activity. While the latter exercise relies on educated guesswork, the former can be completed through "marine and estuarine survey sampling" and associated collection of data.[18] Rather than hypothesizing about the extent of damage that, once caused, may be irreparable, the agency should simply protect resources from damage by prohibiting activity that can cause it in locations where such damage is untenable.

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[15] 15A N.C. Admin. Code 02B .0227(b)(5).

[16] *See* 15A N.C. Admin. Code 02B .0225(c)(2) ("No dredge or fill activities shall be allowed if those activities would result in a reduction of the beds of submerged aquatic vegetation or a reduction of shellfish producing habitat as defined in 15A NCAC 03I .0101(b)(20)(A) and (B), except for maintenance dredging, such as that required to maintain access to existing channels and facilities located within the designated areas or maintenance dredging for activities such as agriculture.").

[17] The undersigned confirmed that DWR intended to reference definitions of "shellfish producing habitat" and submerged aquatic vegetation habitat" codified at 15A N.C. Admin. Code 03I .0101(4)(g) and (i) respectively.

[18] *See* 15A N.C. Admin. Code 03I .0101(4) (observing that "shellfish producing habitat" and "submerged aquatic vegetation habitat" is determined through "marine and estuarine survey sampling").

That said, one benefit of referencing the (correct) definitions in 15A N.C. Admin. Code 3I .0101 would be the potential expansion of protection to both existing and historic natural resources. Under the Rule as currently codified, shellfish producing habitat and submerged aquatic vegetation (SAV) habitat is only protected from dredging where those resources now "occur." In contrast, 15A N.C. Admin. Code 03I .0101 defines "shellfish producing habitat" to include "historic and existing" areas used by shellfish to "reproduce and survive."[19] Given the recent rate of closures in the Lockwoods Folly River, it is particularly notable that the rule's definition of "shellfish producing habitat" also explicitly includes "those shellfish producing areas closed to shellfish harvest due to pollution."[20] Similarly, the definition of "submerged aquatic vegetation habitat" in 15A N.C. Admin. Code 03I .0101 includes submerged lands currently vegetated with specified species *and*, in some cases, submerged lands vegetated where those species grew in the last 10 years.[21] We believe the water quality management plan should strive to protect historic and existing aquatic habitat critical to preserving the designated uses of the river. Therefore, we are not wholly opposed to the incorporation of cross-references to the definitions in 15A N.C. Admin. Code 03I .0101.

Similarly, there may be value to *augmenting* the "presence" test with the proposed "prediction" test. After all, the impacts of non-maintenance dredge and fill activities may not be confined to the location where they are conducted.[22] If such activities are not proposed where valuable natural resources are located, but would nonetheless result in a reduction of such resources, they should be prohibited. Based on the foregoing, we recommend amending the Rule to prohibit non-maintenance dredge and fill activities "where shellfish producing habitat or submerged aquatic vegetation habitat, as defined in 15A NCAC 03I .0101(4)(g) and (i), occurs or would be reduced as a result of such activity."

IV. Retreat Rather than Revision: Limiting New Non-discharge Permits

When asked to clarify limitations on dredge and fill activities, DWR proposed new language. In contrast, rather than answering any of the questions posed by RRC staff regarding limitations on new non-discharge permits, DWR proposes to delete that part of the Rule entirely.

The Rule currently states, "New non-discharge permits shall be required to meet reduced loading rates and increased buffer zones, to be determined on a case-by-case basis."[23] The

[19] 15A N.C. Admin. Code 03I .0101(4)(g).
[20] *Id.*
[21] *Id.* at 03I .0101(4)(i)(i), (ii).
[22] For instance, sediment re-suspended as a result of dredging activities may affect habitat downstream.
[23] 15A N.C. Admin. Code 2B .0227(b)(3).

proposed amendment would strip the water quality management plan of any specific limits on the issuance of new non-discharge permits. We strenuously object to the agency's decision to forego water quality protection rather than define its scope.

As previously mentioned, to clarify language regarding dredge and fill activities, DWR referenced existing provisions of 15A N. C. Admin. Code 02B .0225. Notably, that rule contains *identical* language to that proposed to be deleted from 15A N. C. Admin. Code 02B .0227. This provides some evidence of the value of supplementing standard limitations on the issuance of new non-discharge permits where nearby water bodies are in need of additional protection. Notably, the RRC letter did not object to this additional protection; rather, staff reviewing the Rule for clarity simply wanted to identify (1) the baselines from which "reduced" loading rates and "increased" buffer zones were determined; (2) how departure from those baselines would be calculated; and (3) who would conduct the calculations.

The Lockwoods Folly River watershed can certainly benefit through additional protection from nonpoint sources pollution in the permitting process. As observed in the recently adopted TMDL, which was designed to prevent fecal coliform concentrations from impairing designated uses of the river, "the data indicates that the major contributions of fecal coliform loads are nonpoint source runoff."[24] The TMDL also observes that "[t]he availability of fecal coliform for runoff is highly variable between sites and depends upon factors such as soils, vegetated buffer condition, slope, and setbacks."[25] In other words, the greatest threat to water quality in the river is not direct discharge of pollutants, but rather insufficient prevention of pollutant runoff from land. Therefore, reducing the loads of pollutants applied to land and increasing the distance between that application and the nearest water body are activities meriting inclusion in a water quality management strategy specific to the Lockwoods Folly River. Water quality in the Lockwoods Folly should not be put at risk through the rote application the standard limitations placed on non-discharge permits under Subchapter 2T of the Chapter 15A of the North Carolina Administrative Code.

Notably, when the Rule was first codified, a separate rule then-codified at 15A NCAC 2H .0219 stated minimum design requirements for permitted non-discharge facilities and required, for "treatment works and disposal systems," maintenance of "buffer zones" of "at least" specified distances from various types of waters "and greater where necessary to comply with

[24] NC DENR, *Total Maximum Daily Loads of Fecal Coliform for the Shellfish Harvesting Areas in the Lockwoods Folly River, Lumber River Basin, Brunswick County, North Carolina* ix (August 2010), *available at* http://ofmpub.epa.gov/waters10/attains_impaired_waters.show_tmdl_document?p_tmdl_doc_blobs_id=73402
[25] *Id.* at 60.

Section 2H .0400 of this Subchapter or to address particular site or waste characteristics."[26] In other words, the agency recognized the need for additional protection in coastal systems (hence the reference to Section 2H .0400, governing Coastal Waste Treatment Disposal) and also realized that the "buffer zones" might need to be wider to address site- or waste-specific characteristics.

Although the rules administered by the agency have been reorganized and these "buffer zones" are now called "setbacks" (presumably to distinguish from other required riparian buffers),[27] their utility in preserving water quality remains unquestioned and the agency should have flexibility to widen them as needed to protect the Lockwoods Folly River. Notably, over the years, the agency has adjusted setbacks based on the relevant waste characteristics.[28] However, the agency should also be authorized to impose greater setbacks in the Lockwoods Folly River watershed on a site-specific basis. After all, the primary purpose of establishing a water quality management plan is to impose site-specific management controls. By deleting the provision currently ensuring the availability of such site-specific controls, the agency jeopardizes water quality in an area where special action is needed to preserve water quality.

Rather than remove provisions in the Rule governing the issuance of new non-discharge permits in the Lockwoods Folly River watershed, DWR should answer the questions posed by RRC staff. To do so, we recommend amending the provision in question to state as follows: "New non-discharge permits shall be required to meet reduced loading rates and increased setbacks beyond those specified in Subchapter 2T of these rules. The adjusted loading rates and setbacks shall be determined by the Director on a case-by-case basis and designed to prevent runoff into surface waters." This revision will provide the clarity requested by RRC staff without sacrificing important water quality protections in the Rule.

V. Conclusion

Thank you for your consideration of the foregoing comments. The North Carolina Coastal Federation appreciates this opportunity to once again suggest action we believe necessary to protect water quality in the Lockwoods Folly River.

Sincerely,

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[26] 15A N.C. Admin. Code 2H .0219 (1995).
[27] *See, e.g.,* 15A N.C. Admin. Code 2T .0506, .0606, .0706, .0806.
[28] *Id.*

Will Hendrick
Associate Attorney
Southern Environmental Law Center

CC: Mike Giles, N.C. Coastal Federation

DWH/lap

15A NCAC 02B .0227 has been amended with changes as published in 30:12 NCR 1277-1278 as follows (text already adopted by Environmental Management Commission and pending RRC approval appears in italics):

15A NCAC 02B .0227 WATER QUALITY MANAGEMENT PLANS

(a) In implementing the water quality standards to protect the existing uses [as defined by Rule .0202 of this Section] of the waters of the state or the water quality which supports those uses, the Commission shall develop water quality management plans on a priority basis to attain, maintain or enhance water quality throughout the state. Additional specific actions deemed necessary by the Commission to protect the water quality or the existing uses of the waters of the state shall be specified in Paragraph (b) of this Rule. These actions may include anything within the powers of the Commission. The Commission may also consider local actions which have been taken to protect a waterbody in determining the appropriate protection options to be incorporated into the water quality management plan.

(b) All waters determined by the Commission to be protected by a water quality management plan are listed with specific actions either in Rules .0601- .0608 of this Subchapter that address the Goose Creek watershed (Yadkin Pee-Dee River Basin) or as follows:

(1) The Lockwoods Folly River Area (Lumber River Basin), which includes all waters of the lower Lockwoods Folly River in an area extending north from the Intracoastal Waterway to a line extending from Genoes Point to Mullet Creek, shall be protected by the specific actions described in *Parts (A) through* ~~*(E)*~~ (D) *of this Subparagraph.*

(A) New development activities within 575' of the mean high water line which require a Sedimentation Erosion Control Plan or a CAMA major development permit must comply with the low density option of the coastal Stormwater Runoff Disposal Rules ~~[as specified in 15A NCAC 2H .1005(2)(a)].~~ as specified in 15A NCAC 2H .1005(2)(a).

(B) New or expanded NPDES permits shall be issued only for non-domestic, non-industrial process type discharges ~~(such as non-industrial process cooling or seafood processing discharges).~~ such as non-industrial process cooling or seafood processing discharges. A public hearing is mandatory for any proposed (new or expanded) NPDES permit to this protected area.

~~*(C)* New non-discharge permits shall be required to meet reduced loading rates and increased buffer zones, to be determined on a case-by-case basis.~~

~~*(D)*~~(C) New or expanded marinas ~~must~~ shall be located in upland basin areas.

~~*(E)*~~(D) No dredge or fill activities shall be allowed ~~where significant shellfish or submerged aquatic vegetation bed resources occur,~~ if those activities would result in a reduction of the beds of submerged aquatic vegetation habitat or shellfish producing habitat which are defined in 15A NCAC 03I .0101, except for maintenance dredging, such as that required to maintain access to existing channels and facilities located within the protected area or maintenance dredging for activities such as agriculture.

(2) A part of the Cape Fear River (Cape Fear River Basin) comprised of a section of 18-(71) from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut shall be protected

by the Class SC Sw standards as well as the following site-specific action: All new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges shall be required to provide treatment for oxygen consuming wastes as described in Parts (A) through (C) of this Subparagraph.

(A) Effluent limitations shall be as follows: BOD_5 = 5 mg/l, NH_3-N = 1 mg/l and DO = 6 mg/l, or utilize *site-specific best available technology on a case-by-case basis for industrial* ~~*discharges*~~.discharges in accordance with Rule .0406 (e) of this Subchapter.

(B) Seasonal effluent limits for oxygen consuming wastes will be considered ~~*on a case-by-case basis*~~ *in accordance with Rule .0404 of this Subchapter.*

(C) Any new or expanded permitted pollutant discharge of oxygen consuming waste shall not cause the dissolved oxygen of the receiving water to drop more than 0.1 mg/l below the modeled in-stream dissolved oxygen at total permitted capacity for all discharges.

History Note: Authority G.S. 143-214.1; 143-215.8A;
Eff. October 1, 1995;
Amended Eff. ~~*November 1, 2015;*~~ *July 1, 2016; January 1, 1996.*

MEMORANDUM FOR
JULY 9, 2014 WATER QUALITY COMMITTEE (WQC) MEETING

SUBJECT: **Proposed Reclassification of a Segment of the Cape Fear River in New Hanover and Brunswick Counties (Cape Fear River Basin) from Class SC to Class SC Sw with a Water Quality Management Plan**

The Division of Water Resources (DWR) is requesting that the Environmental Management Commission (EMC) grant staff permission to proceed with the proposed reclassification of a portion of the Lower Cape Fear River. The Lower Cape Fear River Program has requested that a segment of the lower Cape Fear River in New Hanover and Brunswick Counties (Cape Fear River Basin) be reclassified from Class SC to Class SC Sw. This reclassification concerns the portion of the Cape Fear River from the upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut, where the Intracoastal Waterway (ICW) meets the river (a map is included in the request as Figure 1).

Wetlands, some developed lands, other open waters, forest lands, shrub/scrub lands and other swamp tributaries exist directly adjacent to the proposed waters. Several tidal saltwater species, including the federally endangered shortnose sturgeon and federally endangered Atlantic sturgeon, live in the subject waters. Within the subject waters, there are 8 existing NPDES wastewater discharges.

According to the reclassification request, "...the DO standard of 5 mg/l for the Lower Cape Fear River Estuary is not appropriate since it is not achieved a significant portion of the time as a result of natural drainage from riverine wetlands and salt marshes;" in addition, the reclassification request states that "From a regulatory standpoint, a straightforward way to deal with this issue is to reclassify the area with the supplemental Sw classification." The proposed Sw reclassification would allow, if caused by natural conditions, the pH of the subject waters to reach as low as 4.3 and the DO to be lower than 5 mg/l , and in turn, may result in the removal of this segment from the state's TMDL list for DO and/or pH; thus, this proposal serves the public interest per Executive Order #70 and complies with G.S. 150B, the Administrative Procedures Act (APA). In addition, the proposed water quality management plan associated with the proposed reclassification codifies the current permitting policy already in existence for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters. The proposed reclassification in partnership with the proposed management plan spells out a path forward for these discharges and enables the community to plan accordingly.

A fiscal analysis for this proposal has been conducted and revealed no quantifiable cost or benefit to the ecosystem, humans, implementing agencies, and new and expanding individual NPDES wastewater discharges. Staff recommends sending this proposal and associated fiscal analysis to the November 2014 EMC meeting to request permission to proceed to public notice. The estimated effective date of the proposed rules is November 1, 2015.

Fact Sheet

Proposed Reclassification of a Portion of the Lower Cape Fear River Estuary from Class SC to Class SC-Swamp (Sw) and Associated Implementation Rule

Purpose

Reclassification – The reclassification to Class SC-Sw will add a swamp narrative to the existing water quality standard recognizing that natural conditions result in levels for some parameters, particularly dissolved oxygen (DO) and pH, which vary from the established water quality standards for Class SC.

Implementation Rule (15A NCAC 2B .0227) – Specifies the highest level of treatment required in North Carolina for oxygen-consuming wastes for new and expanding NPDES discharges.

Background

- In 1998, the Lower Cape Fear River was listed as impaired (on the Clean Water Act 303(d) list) for DO and pH.
- Extensive monitoring and modeling work led to the development of a 3-dimensional hydrodynamic and water quality model of the Cape Fear River from Lock and Dam #1 to the mouth including portions of major tributaries
- Modeling results indicate that the current DO standard of 5 mg/L is not attained about 30 percent of the time during the summer months and that point sources in this segment are a minor contributor to overall dissolved oxygen depletion
- Subsequent modeling and data analyses have indicated that drainage and the wetting and drying of floodplain wetlands and salt marshes are the most significant contributor to the waterbody's not meeting the DO standard

Proposed Changes

- Reclassify the Lower Cape Fear River from Class SC to Class SC-Sw - From a point upstream Toomers Creek to a line across the river from Snows Cut to Lilliput Creek and apply the Swamp supplemental standards to these waters.
- Modify 15A NCAC 2B.0227 Water Quality Management Plans with the following additional language specific to the reclassified section:

  (1) All new NPDES wastewater discharges and expansions of existing NPDES wastewater discharges shall be required to provide the treatment described below:

  (A) Oxygen consuming wastes: Effluent limitations shall be as follows: BOD_5= 5 mg/l, NH_3-N = 1 mg/l and DO = 6 mg/l, or site-specific best available technology on a case-by-case basis for industrial discharges. Seasonal effluent limits for oxygen-consuming wastes will be considered on a case-by-case basis in accordance with 15A NCAC 2B.0404. Any new or expanded permitted pollutant discharge of oxygen-consuming waste shall not cause the dissolved oxygen of the receiving water to drop more than 0.1 mg/l below the modeled in-stream dissolved oxygen at total permitted capacity.

Anticipated Outcomes

- Narrative standard for "Swamp" waters will be added to standards applicable to portion of lower estuary as follows:
  - "DO: not less than 5.0 mg/l, except that swamp waters, poorly flushed tidally influenced streams or embayments, or estuarine bottom waters may have lower values if caused by natural conditions".
  - "pH: shall be normal for the waters in the area, which generally shall range between 6.8 and 8.5 except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions."
- All new and expanding NPDES dischargers must meet the highly protective limits for oxygen consuming wastes
- The impairment status of lower estuary for DO and pH will be re-evaluated
- There will be continued focus on nonpoint sources potentially contributing to oxygen depletion through on-going water quality programs

15A NCAC 02B .0311 CAPE FEAR RIVER BASIN

(a) Effective February 1, 1976, the adopted classifications assigned to the waters within the Cape Fear River Basin are set forth in the Cape Fear River Basin Schedule of Classifications and Water Quality Standards, which may be inspected at the following places:

(1) the Internet at http://portal.ncdenr.org/web/wq/ps/csu/rules; and

(2) the North Carolina Department of Environment and Natural Resources:

(A) Winston-Salem Regional Office
585 Waughtown Street
Winston-Salem, North Carolina

(B) Fayetteville Regional Office
225 Green Street
Systel Building Suite 714
Fayetteville, North Carolina

(C) Raleigh Regional Office
3800 Barrett Drive
Raleigh, North Carolina

(D) Washington Regional Office
943 Washington Square Mall
Washington, North Carolina

(E) Wilmington Regional Office
127 Cardinal Drive Extension
Wilmington, North Carolina

(F) Division of Water Quality
Central Office
512 North Salisbury Street
Raleigh, North Carolina.

(b) The Cape Fear River Basin Schedule of Classification and Water Quality Standards was amended effective:

(1) March 1, 1977;
(2) December 13, 1979;
(3) December 14, 1980;
(4) August 9, 1981;
(5) April 1, 1982;
(6) December 1, 1983;
(7) January 1, 1985;
(8) August 1, 1985;
(9) December 1, 1985;
(10) February 1, 1986;
(11) July 1, 1987;
(12) October 1, 1987;
(13) March 1, 1988;
(14) August 1, 1990.

(c) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective June 1, 1988 as follows:

(1) Cane Creek [Index No. 16-21-(1)] from source to a point 0.5 mile north of N.C. Hwy. 54 (Cane Reservoir Dam) including the Cane Creek Reservoir and all tributaries has been reclassified from Class WS-III to WS-I.

(2) Morgan Creek [Index No. 16-41-1-(1)] to the University Lake dam including University Lake and all tributaries has been reclassified from Class WS-III to WS-I.

(d) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective July 1, 1988 by the reclassification of Crane Creek (Crains Creek) [Index No. 18-23-16-(1)] from source to mouth of Beaver Creek including all tributaries from C to WS-III.

(e) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective January 1, 1990 as follows:

(1) Intracoastal Waterway (Index No. 18-87) from southern edge of White Oak River Basin to western end of Permuda Island (a line from Morris Landing to Atlantic Ocean), from the eastern mouth of Old Topsail Creek to the southwestern shore of Howe Creek and from the southwest

mouth of Shinn Creek to channel marker No. 153 including all tributaries except the King Creek Restricted Area, Hardison Creek, Old Topsail Creek, Mill Creek, Futch Creek and Pages Creek were reclassified from Class SA to Class SA ORW.

(2) Topsail Sound and Middle Sound ORW Area which includes all waters between the Barrier Islands and the Intracoastal Waterway located between a line running from the western most shore of Mason Inlet to the southwestern shore of Howe Creek and a line running from the western shore of New Topsail Inlet to the eastern mouth of Old Topsail Creek was reclassified from Class SA to Class SA ORW.

(3) Masonboro Sound ORW Area which includes all waters between the Barrier Islands and the mainland from a line running from the southwest mouth of Shinn Creek at the Intracoastal Waterway to the southern shore of Masonboro Inlet and a line running from the Intracoastal Waterway Channel marker No. 153 to the southside of the Carolina Beach Inlet was reclassified from Class SA to Class SA ORW.

(f) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective January 1, 1990 as follows: Big Alamance Creek [Index No. 16-19-(1)] from source to Lake Mackintosh Dam including all tributaries has been reclassified from Class WS-III NSW to Class WS-II NSW.

(g) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 3, 1992 with the reclassification of all water supply waters (waters with a primary classification of WS-I, WS-II or WS-III). These waters were reclassified to WS-I, WS-II, WS-III, WS-IV or WS-V as defined in the revised water supply protection rules, (15A NCAC 02B .0100, .0200 and .0300) which became effective on August 3, 1992. In some cases, streams with primary classifications other than WS were reclassified to a WS classification due to their proximity and linkage to water supply waters. In other cases, waters were reclassified from a WS classification to an alternate appropriate primary classification after being identified as downstream of a water supply intake or identified as not being used for water supply purposes.

(h) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective June 1, 1994 as follows:

(1) The Black River from its source to the Cape Fear River [Index Nos. 18-68-(0.5), 18-68-(3.5) and 18-65-(11.5)] was reclassified from Classes C Sw and C Sw HQW to Class C Sw ORW.

(2) The South River from Big Swamp to the Black River [Index Nos. 18-68-12-(0.5) and 18-68-12(11.5)] was reclassified from Classes C Sw and C Sw HQW to Class C Sw ORW.

(3) Six Runs Creek from Quewhiffle Swamp to the Black River [Index No. 18-68-2] was reclassified from Class C Sw to Class C Sw ORW.

(i) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective September 1, 1994 with the reclassification of the Deep River [Index No. 17-(36.5)] from the Town of Gulf-Goldston water supply intake to US highway 421 including associated tributaries from Class C to Classes C, WS-IV and WS-IV CA.

(j) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 1, 1998 with the revision to the primary classification for portions of the Deep River [Index No. 17-(28.5)] from Class WS-IV to Class WS-V, Deep River [Index No. 17-(41.5)] from Class WS-IV to Class C, and the Cape Fear River [Index 18-(10.5)] from Class WS-IV to Class WS-V.

(k) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective April 1, 1999 with the reclassification of Buckhorn Creek (Harris Lake)[Index No. 18-7-(3)] from the backwaters of Harris Lake to the Dam at Harris Lake from Class C to Class WS-V.

(l) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective April 1, 1999 with the reclassification of the Deep River [Index No. 17-(4)] from the dam at Oakdale-Cotton Mills, Inc. to the dam at Randleman Reservoir (located 1.6 mile upstream of U.S. Hwy 220 Business), and including tributaries from Class C and Class B to Class WS-IV and Class WS-IV & B. Streams within the Randleman Reservoir Critical Area have been reclassified to WS-IV CA. The Critical Area for a WS-IV reservoir is defined as 0.5 mile and draining to the normal pool elevation of the reservoir. All waters within the Randleman Reservoir Water Supply Watershed are within a designated Critical Water Supply Watershed and are subject to a special management strategy specified in 15A NCAC 02B .0248.

(m) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 1, 2002 as follows:

(1) Mill Creek [Index Nos. 18-23-11-(1), 18-23-11-(2), 18-23-11-3, 18-23-11-(5)] from its source to the Little River, including all tributaries was reclassified from Class WS-III NSW and Class WS-III B NSW to Class WS-III NSW HQW@ and Class WS-III B NSW HQW@.

(2) McDeed's Creek [Index Nos. 18-23-11-4, 18-23-11-4-1] from its source to Mill Creek, including all tributaries was reclassified from Class WS III NSW and Class WS-III B NSW to Class WS-III NSW HQW@ and Class WS-III B NSW HQW@.

The "@" symbol as used in this Paragraph means that if the governing municipality has deemed that a development is covered under a "5/70 provision" as described in Rule 15A NCAC 02B .0215(3)(b)(i)(E) (Fresh Surface Water Quality Standards for Class WS-III Waters), then that development is not subject to the stormwater requirements as described in rule 15A NCAC 02H .1006 (Stormwater Requirements: High Quality Waters).

(n) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective November 1, 2004 as follows:

(1) the portion of Rocky River [Index Number 17-43-(1)] from a point 0.3 mile upstream of Town of Siler City upper reservoir dam to a point 0.3 mile downstream of Lacy Creek from WS-III to WS-III CA.

(2) the portion of Rocky River [Index Number 17-43-(8)] from dam at lower water supply reservoir for Town of Siler City to a point 65 feet below dam (site of proposed dam) from C to WS-III CA.

(3) the portion of Mud Lick Creek (Index No. 17-43-6) from a point 0.4 mile upstream of Chatham County SR 1355 to Town of Siler City lower water supply reservoir from WS-III to WS-III CA.

(4) the portion of Lacy Creek (17-43-7) from a point 0.6 mile downstream of Chatham County SR 1362 to Town of Siler City lower water supply reservoir from WS-III to WS-III CA.

(o) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective November 1, 2007 with the reclassifications listed below, and the North Carolina Division of Water Quality maintains a Geographic Information Systems data layer of these UWLs.

(1) Military Ocean Terminal Sunny Point Pools, all on the eastern shore of the Cape Fear River [Index No. 18-(71)] were reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(2) Salters Lake Bay near Salters Lake [Index No. 18-44-4] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(3) Jones Lake Bay near Jones Lake [Index No. 18-46-7-1] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(4) Weymouth Woods Sandhill Seep near Mill Creek [18-23-11-(1)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(5) Fly Trap Savanna near Cape Fear River [Index No. 18-(71)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(6) Lily Pond near Cape Fear River [Index No. 18-(71)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(7) Grassy Pond near Cape Fear River [Index No. 18-(71)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(8) The Neck Savanna near Sandy Run Swamp [Index No. 18-74-33-2] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(9) Bower's Bog near Mill Creek [Index No. 18-23-11-(1)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(10) Bushy Lake near Turnbull Creek [Index No. 18-46] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(p) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective January 1, 2009 as follows:

(1) the portion of Cape Fear River [Index No. 18-(26)] (including tributaries) from Smithfield Packing Company's intake, located approximately 2 miles upstream of County Road 1316, to a point 0.5 miles upstream of Smithfield Packing Company's intake from Class C to Class WS-IV CA.

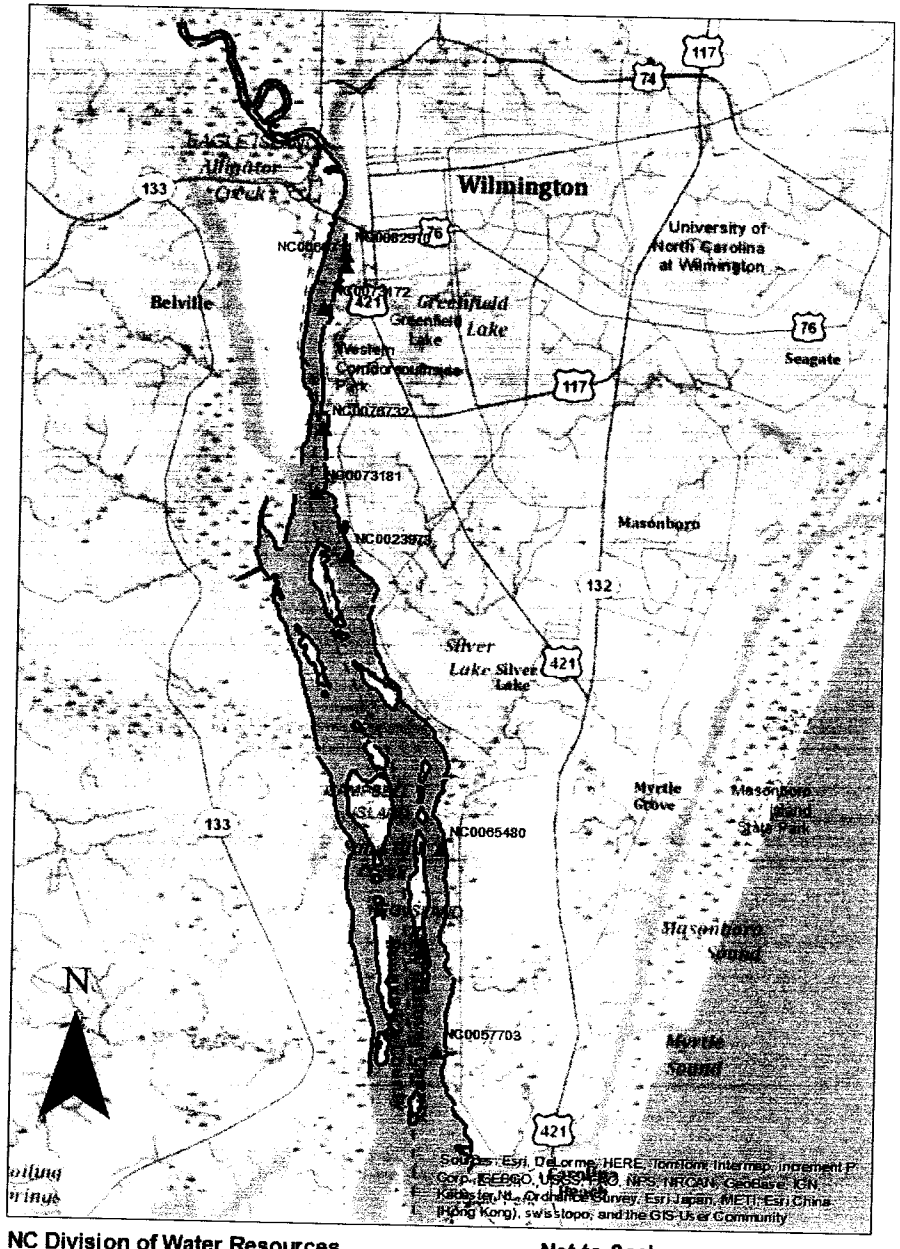
(2) the portion of Cape Fear River [Index No.18-(26)] (including tributaries) from a point 0.5 miles upstream of Smithfield Packing Company's intake to a point 1 mile upstream of Grays Creek from Class C to Class WS-IV.

(q) The schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 11, 2009 with the reclassification of all Class C NSW waters and all Class B NSW waters upstream of the dam at B. Everett Jordan Reservoir from Class C NSW and Class B NSW to Class WS-V NSW and Class WS-V & B NSW, respectively. All waters within the B. Everett Jordan Reservoir Watershed are within a designated Critical Water Supply Watershed and are subject to a special management strategy specified in 15A NCAC 02B .0262 through .0273.

(r) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective September 1, 2009 with the reclassification of a portion of the Haw River [Index No. 16-(28.5)] from the Town of Pittsboro water supply intake, which is located approximately 0.15 mile west of U.S. 15/501, to a point 0.5 mile upstream of the Town of Pittsboro water supply intake from Class WS-IV to Class WS-IV CA.
(s) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective March 1, 2012 with the reclassification of the portion of the Haw River [Index No. 16-(1)] from the City of Greensboro's intake, located approximately 650 feet upstream of Guilford County 2712, to a point 0.5 miles upstream of the intake from Class WS-V NSW to Class WS-IV CA NSW, and the portion of the Haw River [Index No. 16-(1)] from a point 0.5 miles upstream of the intake to a point 0.6 miles downstream of U.S. Route 29 from Class WS-V NSW to Class WS-IV NSW.
(t) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective November 1, 2015 with the reclassification of a section of 18-(71) from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut from Class SC to Class SC Sw. A site-specific management strategy is outlined in 15A NCAC 02B .0227.

History Note: *Authority G.S. 143-214.1; 143-215.1; 143-215.3(a)(1);*
Eff. February 1, 1976;
Amended Eff. November 1, 2015; March 1, 2012; September 1, 2009; August 11, 2009; January 1, 2009; November 1, 2007; November 1, 2004; August 1, 2002; April 1, 1999; August 1, 1998; September 1, 1994; June 1, 1994; August 3, 1992; August 1, 1990.

NPDES Discharges to Proposed Swamp Reclassification Portion of Cape Fear River, 18-(71)



NC Division of Water Resources
July 1, 2014

Not to Scale

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US ARMY CORPS OF ENGINEERS

March 5, 2014

Mr. Tom Reeder
Director, Division of Water Resources
NC Department of Environment and Natural Resources
1611 Mail Service Center
Raleigh, NC 27699-1611

Subject: Request for Reclassification of a Portion of the Lower Cape Fear River with the Supplemental Swamp Classification

Dear Mr. Reeder:

The purpose of this letter is to formally request that the Division of Water Resources (DWR) recommend to the Environmental Management Commission (EMC) that portions of the Lower Cape Fear River Estuary (LCFRE) that are currently classified as Class SC Waters be reclassified to include the supplemental Swamp (Sw) classification. This would recognize the influence of natural drainage from riverine wetland and salt marsh systems that are ubiquitous throughout the Lower Cape Fear River, Northeast Cape Fear River and Black River watersheds on water quality conditions in the river. This would be consistent with the classifications of immediate upstream segment of the Cape Fear River and the tributaries which all currently carry the supplemental Sw classification.

Information typically requested by DWR for reclassification requests is included in Table 1 and a map showing the area being requested for consideration for the Sw supplemental classification is included as Figure 1. An additional map based on the US Geological Survey 7.5 minute topographic maps will be included in the hard copy of this letter and attachments.

Information typically requested by DWR for reclassification requests is included in Table 1 and a map showing the area being requested for consideration for the Sw supplemental classification is included as Figure 1. An additional map based on the US Geological Survey 7.5 minute topographic maps will be included in the hard copy of this letter and attachments.

This letter provides additional background on the Lower Cape Fear River Program (LCFRP) and this specific request and a summary of supporting technical papers that have been prepared.

Background on LCFRP and LCFRE

The Lower Cape Fear River Program is an integrative effort which brings together a coalition of citizens groups, industry, business, local, regional, and state government, and the university community. The Lower Cape Fear River Program (LCFRP) was formed in May, 1994 to develop an understanding of the fundamental scientific processes shaping and controlling the Cape Fear River Estuary and provide a mechanism for information exchange and public education. It is administered in cooperation with the University of North Carolina Wilmington's Center for Marine Science.

Since the group was formed, comprehensive data to assess ecological conditions in the river has been collected. The LCFRP was one of the first coalition monitoring groups established through a memorandum of agreement (MOA) with NC Department of Environment and Natural Resources (DENR) that relieves NPDES permit holders of individual requirements to perform instream monitoring and replaces that with a comprehensive and coordinated monitoring program. Currently, there are 17 NPDES permit holders that are party to the MOA, but many other advisory board members from throughout the lower basin as listed on the border on the first page of this letter. All of the monitoring data is submitted to DENR in accordance with the MOA. The program also has an interactive data base available on the internet where the LCFRP data can be accessed. This site also includes data from the Middle and Upper Cape Fear River Basin coalition groups for a comprehensive tool to review water quality conditions for the entire river basin.

Beginning in 1998, the section of the LCFRE from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut has been listed on the State of North Carolina's 303d List as impaired for DO. In 2006, DENR added pH as impaired for this segment, and in 2008, DENR added copper and turbidity to the listing, as well. The draft 2014 303d List maintains these impairments despite some changes to the listing methodology (DENR, 2014).

Until recently, DENR had been pursuing development of a total maximum daily load (TMDL) to establish what were originally believed to be reduction needs for oxygen-

demanding pollutants, including biochemical oxygen demand (BOD) and ammonia nitrogen (NH_3-N). An extensive effort had gone into developing a three-dimensional hydrodynamic and water quality model (using the Environmental Fluid Dynamics Code, or EFDC, model) between 2000 and 2009. This model provides an excellent tool for evaluating water quality conditions in the LCFRE. Based on the modeling analysis, the DENR determined that developing a TMDL using the existing standard for the Class SC portion of the LCFRE of 5 milligrams per liter (mg/L) (at all times) would not be appropriate because the modeling results indicate that point-source discharges have a relatively minor impact on DO levels, and that even significant reductions in background (both natural and nonpoint source) loads would not result in attainment of the current standard for considerable periods of time during the summer. Recently, DENR indicated that changes to the classification of the LCFRE might be appropriate to recognize the influence of natural drainage from riverine and saltwater marsh systems in the watershed on DO concentrations. A reclassification with the supplemental Sw classification would allow the water quality standards for DO and pH to be interpreted with narrative portion of the standard [from 15A NCAC 2B .0220 (3)]:

> *(b) Dissolved oxygen: not less than 5.0 mg/l, except that swamp waters, poorly flushed tidally influenced streams or embayments, or estuarine bottom waters may have lower values if caused by natural conditions;*
>
> *(g) pH: shall be normal for the waters in the area, which generally shall range between 6.8 and 8.5 except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions;*

It is recognized that with this classification change, DWR will still require the development of implementation procedures for determining allowable waste load allocations for point source discharges.

Supporting Information

There is a wealth of research and technical assessment studies that have been conducted on the LCFRE since the formation of the LCFRP in 1995, as well as during the 40 years prior to that time. In discussing this reclassification request with DWR staff, it was suggested that a summary of information be prepared to support the reclassification request. Four Technical Memoranda (TM) have been prepared in support of this reclassification request and are included as Attachments to this letter. The following is a brief summary of each TM.

TM 1 - Summary of Background Information and Previous Studies for the Lower Cape Fear River

This TM served to review available background information for the LCFRE dating back to original studies in the 1950s where water quality and pollutions sources were assessed and initial recommendations on stream classifications were made. Key studies and assessments up to the present time were also reviewed and a bibliography or studies and research papers was also included. A several of the key points from this TM include:

- Swamp influences were identified even during the early studies and the entire LCFRE and tributaries were recommended and subsequently classified with the supplemental Sw classification

- The supplemental Sw classification was removed from the Class SC portion of the Cape Fear River in 1981 without extensive evaluation for the basis of this change

- LCFRP monitoring in the mid to late 1990s documented the impact of swamp drainage following hurricanes, similar to what was documented during the 1990s

- The EFDC hydrodynamic and water quality model completed in 2009 demonstrated that the point sources had a minor contribution to the DO deficit and that even with 30 to 70 percent reductions in loadings of oxygen demanding materials from tributaries and wetlands/marsh systems (a combination of anthropogenic and natural sources), the DO standard of 5 mg/L could not be achieved between 20 and 30 percent of the time.

TM 2 - Updated Trend Analysis of DO Conditions and Pollutant Loading from Point Sources

This TM was an update of an analysis done in 2003. The previous DO trend analysis found no statistically significant trend for DO for the period of 1984 through 2002 for DO conditions at several stations within or immediately adjacent to the 303(d) listed portion of the LCFRE. The same conclusion was drawn for the period of 1991 through 2002, despite a statistically significant reduction in major point source ultimate biochemical oxygen demand (BODu) load of approximately 25 percent for that period. The updated analysis used monitoring data and information on point source loading from 1994 through 2013. The updated point source analysis focused on International Paper and Cape Fear Public Utilities Authority (CFPUA) Northside and Southside discharges since these facilities comprise over 90 percent of the point source loading to the local watershed. This analysis also showed no significant trend in DO levels in the LCFRE over the 20 year period while the loading of BODu from these three facilities declined by 23 percent over the same time period. This analysis confirms model results indicating that point sources are having a minor impact on DO levels in the LCFRE.

TM 3 - Analysis of Long-term Data near the Limits of the Tidal Influence for the Cape Fear River, Black River, and NE Cape Fear River

This TM presents an analysis of water quality parameters at the sampling stations representative of inflows to the system, with the purpose of examining issues related to a supplemental Sw classification for the estuary. Data was examined for several key parameters, including nutrients, pH, and DO, that are related to the occurrence of low DO in the Cape Fear River. The evaluation of water quality data at the boundary conditions supports the concept that inflows from the swamp areas have a significant impact on water quality in the Cape Fear River. The levels of nutrients, DO, and pH are consistently different between the station at Lock & Dam 1 (L&D1) on the main stem of the Cape Fear River, and in the major blackwater tributaries – the Black River and the NE Cape Fear River. A distinct response from these inflows can be seen in the levels for these parameters in the portion of the Cape Fear River near Navassa, providing additional supporting evidence that water quality in the Cape Fear River is significantly influenced by the conditions found in the swamp areas tributary to the river downstream of L&D1.

TM 4 - An Analysis of Model Results to Assess the Relative Impact of Riparian Wetlands and Salt Marshes versus other Tributary Loadings

This TM used the results of the two modeling efforts with the EFDC model in the 2000s to examine the technical basis for a supplemental Sw classification for the LCFRE. The two modeling studies included the initial EFDC model developments by Tetra Tech on behalf of the City of Wilmington and New Hanover County and the follow up work by the University of North Carolina – Charlotte on behalf of NC DENR. Both modeling efforts demonstrated that the impact from point source loads in the LCFRE contributes to less than 10 percent of the DO deficit in the LCFRE. The 2001 modeling effort demonstrated that an accurate calibration could not be achieved without representing the wetting and drying of adjacent low elevation wetland and salt marsh areas. That modeling estimated that wetland/marsh and sediment oxygen demand (SOD) sources accounted for between 75 and 80 percent of all oxygen demand in the LCFRE. The 2009 modeling effort validated and expanded the influence of adjacent marshland based on more detailed analysis. Further, application of the 2009 model that simulated up to 70 percent of nonpoint source load reduction demonstrated that even with such large pollutant loading reductions, DO concentrations would be expected to be below 5 mg/L approximately 20 percent of the time in the LCFRE during the summer. Therefore, the 2001 and 2009 modeling analyses provide further weight of evidence collectively that flow and oxygen-demanding loads from wetlands/marsh systems SOD are driving low DO during the summer period and suggest that reinstitution of the supplemental Sw designation for the LCFRE should be considered by DENR and the EMC.

Summary

It is clear from the data collection, modeling and technical analyses that the DO standard of 5 mg/L for the LCFRE is not appropriate since it is not achieved a significant portion of the time as a result of natural drainage from riverine wetlands and salt marshes. From a regulatory standpoint, a straightforward way to deal with this issue is to reclassify the area with the supplemental Sw classification. The information summarized in this letter and the attached TMs support this classification action.

Our organization appreciates DENR and the EMC's consideration of this request. We are also willing to provide further information and analysis related to this request as needed.

Sincerely,

Chris May
Chair Lower Cape Fear River Program Advisory Board and
Executive Director, Cape Fear River Council of Governments

Reclassification Request Letter_Final_03062014.docx

c: LCFRP Advisory Board and Technical Committee Members
Bill Kreutzberger/CH2M HILL
Trevor Clements/Tetra Tech

Table 1.
DWR Requested Information in Support of Reclassification Requests

Date of Request	March 6, 2014
Requested by	Lower Cape Fear River Program
River Basin and Counties	Cape Fear River Basin New Hanover and Brunswick Counties
Water bodies requested for Reclassification	Water Body: *Cape Fear River* Description: *From a point upstream Toomers creek to a line across the river from Snows Point (through Snows Marsh) to Federal Point* Index No.: *18-(71)* Current Classification: *SC* Requested Classification: *SC Sw*
Map	See Figure 1 from 7.5 minute USGS GIS Information
Rationale for Request	See text of letter and attached Technical Memoranda
Local Champions for Request	Lower Cape Fear River Program Members

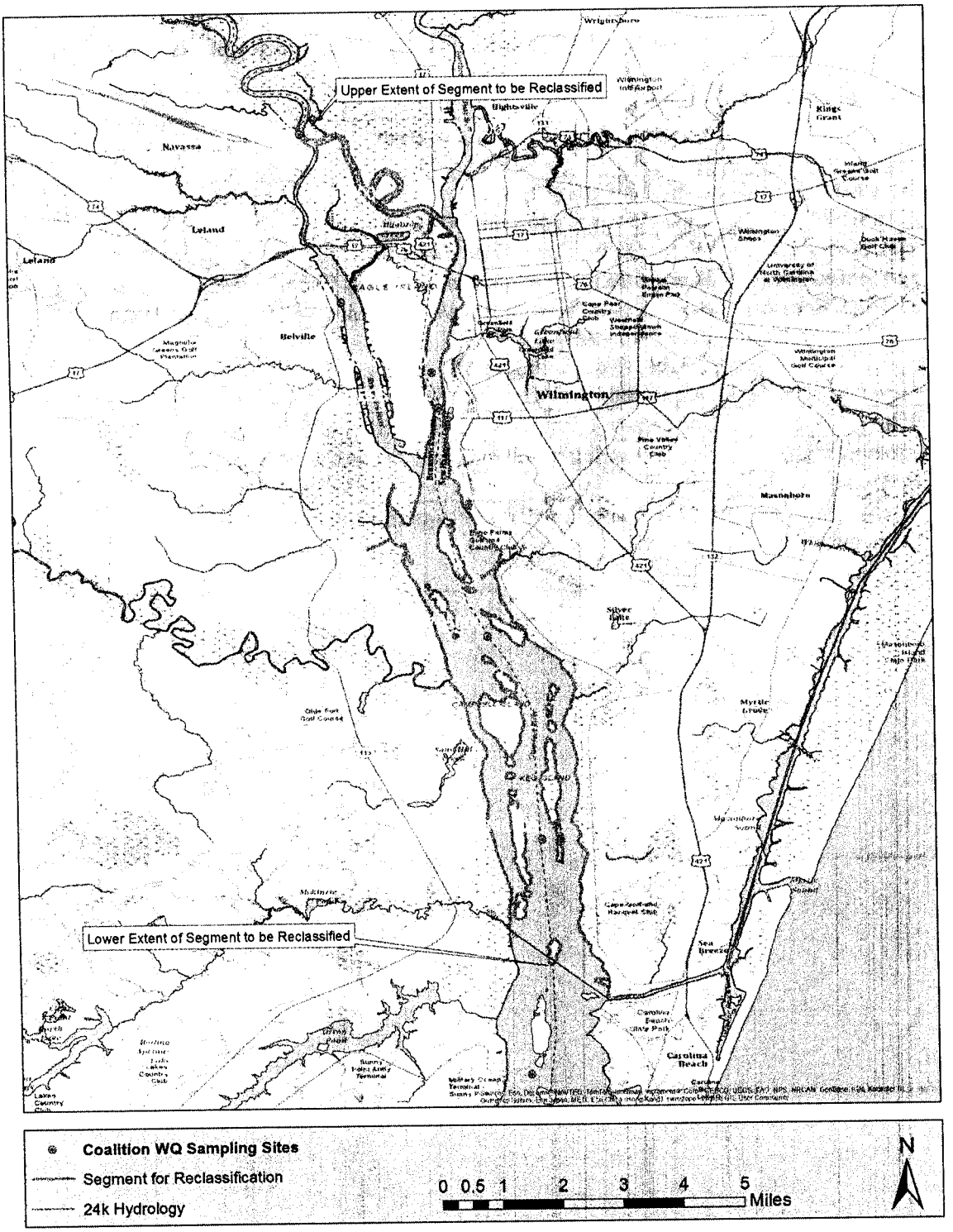

Figure 1.
Requested portion of Lower Cape Fear River Estuary for Consideration for Supplemental Swamp Classification

Attachments

TM 1 - Summary of Background Information and Previous Studies for the Lower Cape Fear River

TM 2 - Updated Trend Analysis of DO Conditions and Pollutant Loading from Point Sources

TM 3 - Analysis of Long-term Data near the Limits of the Tidal Influence for the Cape Fear River, Black River, and NE Cape Fear River

TM 4 - An Analysis of Model Results to Assess the Relative Impact of Riparian Wetlands and Salt Marshes versus other Tributary Loadings

Technical Memo: Task 1 – Summary of Background Information and Previous Studies for the Lower Cape Fear River

Prepared for

Lower Cape Fear River Program

Prepared by

CH2MHILL®

February 25, 2014

1 Introduction

The purpose of this technical memorandum (TM) is to identify available data and studies pertaining to the Lower Cape Fear River Estuary (LCFRE), and highlight key information pertaining to the influence of natural drainage from riverine and saltwater marsh systems in the watershed on dissolved oxygen (DO) conditions. This information is being summarized at a high level, for further consideration as the North Carolina Department of Environment and Natural Resources (DENR) and Environmental Management Commission consider appropriate stream classification and associated water quality criteria for the Cape Fear River.

1.1 BACKGROUND

The Lower Cape Fear River Program (LCFRP) was established in 1995 as a collaborative effort by public, private, and academic interests to collect data and research information on the LCFRE and its coastal watershed. Since the group was formed, comprehensive data to assess environmental conditions in the river has been collected.

Beginning in 1998, the section of the LCFRE from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut has been listed on the State of North Carolina's 303d List as impaired for DO. In 2006, DENR added pH as impaired for this segment, and in 2008, DENR added copper and turbidity to the listing, as well. The draft 2014 303d List maintains these impairments despite some changes to the listing methodology (DENR, 2014).

Until recently, DENR had been pursuing development of a total maximum daily load (TMDL) to establish what were originally believed to be reduction needs for oxygen-demanding pollutants, including biochemical oxygen demand (BOD) and ammonia nitrogen (NH_3-N). However, the DENR has recently determined that, based on the technical information compiled and assessed to date, developing a TMDL using the existing standard for the LCFRE of 5 milligrams per liter (mg/L) (at all times) would not be appropriate because the modeling results indicate that point-source discharges have a relatively minor impact on DO levels, and that even significant reductions in background (both natural and nonpoint source) loads would not result in attainment of the current standard for considerable periods of time during the summer. Recently, DENR indicated that changes to the classification of the LCFRE might be appropriate to recognize the influence of natural drainage from riverine and saltwater marsh systems in the watershed on DO concentrations.

There is a wealth of research and technical assessment studies that have been conducted on the LCFRE since the formation of the LCFRP in 1995, as well as during the 40 years prior to that time. Over the years, many technical studies of the LCFRE have been conducted by the LCFRP, DENR, other agencies and academic researchers, and consultants. As a result, an extensive technical foundation of knowledge on the LCFRE has been created, including information on physical, chemical, and biological features and processes.

1.2 SUMMARY OF AVAILABLE INFORMATION

A comprehensive listing of studies and research related to the LCFR has been included in the Attachment to this TM. In reviewing this information, it was decided to start with the early study of the river used to determine the stream classification and water quality standards and then move forward to the present. The following is a summary of this available information related to understanding the LCFRE, especially as it relates to assessing DO concentrations..

1.2.1 Original North Carolina State Board of Health Studies

Beginning in the mid-1950s and continuing until the early 1960s, the Division of Water Pollution Control of the State Board of Health conducted sanitary surveys of all the river basins in North Carolina, and made recommendations for stream classifications to be included in state water quality standards. The Cape Fear River Basin was sampled in 1955 and 1956, and the study report was published in 1957 (State Stream Sanitation Committee, 1957). This report includes analytical results from stream sampling and documented pollution loads from major sources of pollution.

The setting at the time of this study was that many towns and cities did not have any treatment, and industries varied from having no treatment to primary treatment facilities. There were no major impoundments in the Cape Fear Basin, so the basin experienced extreme ranges in flow conditions, depending on precipitation and hurricane conditions, which were apparent during 1955 when three hurricanes impacted eastern North Carolina.

In the lower river, there were two principal sources of pollution identified, the Riegel Paper Corporation (Riegel) and the City of Wilmington, plus numerous other smaller communities and industrial facilities. The following table summarizes the treatment and loads from the primary facilities.

Table 1. Primary Facility Treatment and Load Summary

Facility	Type of Treatment	Estimated Load (PE)
Riegel	Primary (13% efficient)	330,000
City of Wilmington	None	44,700
Timmie Manufacturing	Lagoon (20% efficient)	1,144
Wilmington Packing	Grease removal (20% efficient)	3,850
Wanet Sausage Co.	Grease removal (20% efficient)	3,200

Note:

PE - population equivalent

These loads cannot be directly transferred to the way oxygen-demanding loads are measured today. However, assuming 0.17 pounds per day (lb/d) of $CBOD_5$ per PE, this translates to about 65,000 lb/d of $CBOD_5$ discharged as highly reactive raw or primary treated waste. No information was presented in the study to estimate the nitrogenous (organic nitrogen and ammonia) oxygen demand load. This is estimated to be about 10 times greater than the current loading of $CBOD_5$ based on comparison with current discharger monitoring data. The water quality data demonstrated impacts on DO conditions in the river. Summertime DO levels from downstream of Riegel to downstream of Wilmington typically ranged from 2 to 3 mg/L, with some values considerably less than that. The highly reactive wastewater resulted in a double DO sag beginning just a few miles below the Riegel discharge to downstream of Wilmington.

Despite the significant impacts from untreated and poorly treated wastewater under low to moderate flow conditions in the river, two different situations influencing DO condition were also described in the report:

1. High flows from the Black and NE Cape Fear Rivers, and moderate flow from the Cape Fear River (data from August 30, 1955):
   - Low DO (1.3 to 2 mg/L) and low pH (5 to 6) coming from NE Cape Fear and Black Rivers
   - Resulting in low DO (1.3 to 2.2 mg/L) and low pH (5.8 to 6) in the typically brackish area below Wilmington
2. High flows from the Cape Fear River, and moderate flows from the NE Cape Fear and Black Rivers (data from July 23-24, 1956):
   - DO (2.8 to 4.9 mg/L and pH 6.8 to 7.2) conditions in lower river were moderate

They concluded that under some situations, swamp drainage conditions could significantly influence DO and pH conditions in the river, and recommended that the freshwater portion of the Lower Cape Fear River (LCFR) be Class C-Swamp (C-Sw) from the Riegel water intake to Toomers Creek, and Class SC-Swamp (SC-Sw) from Toomers Creek to the mouth of the Cape Fear River. These recommendation were adopted in 1962.

1.2.2 Reclassification in 1981

In 1981, a rule-making proceeding was initiated to remove the "Swamp" designation from waters classified as Class SA (for shellfishing). The record includes little basis for the removal of the Swamp designation from

tidal saltwater classes other than statements that the designation is inconsistent with a shellfishing designation. There was little other discussion of the changes and nothing specific to Class SC waters. Based on the lack of objection, the Swamp designation was removed from a substantial portion of all tidal saltwaters in North Carolina in 1981 in conjunction with some other stream/coastal water classification changes (DEM, 1981). This action changed the classification of the Cape Fear River from "upstream of the mouth of Toomers creek to Atlantic Ocean" from Class SC Sw to Class SC. However, the Sw designation was not removed from the Class SC portion of the NE Cape Fear River by this action. As a result of this reclassification, the DO standard of not less than 5 mg/L at all times and pH standard not less than 6.8 became effective for the Class SC portion of the Cape Fear River, with no recognition of the potential influence of natural conditions.

1.2.3 Initial Water Quality Modeling

Despite significant improvement in wastewater treatment throughout the basin since the initial studies in the 1950s, there was a recognition that water quality conditions in the Cape Fear River might limit future industrial and urban growth. In addition, hydrological conditions in the basin had changed with the filling of Jordan Lake in 1981. This lake has a watershed of approximately 1,700 square miles (mi^2), and has authorized purposes of flood damage reduction, water supply, water quality control, fish and wildlife conservation, and outdoor recreation. With this changed hydrology, and significant urban and industrial growth in the Wilmington area, the Division of Environmental Management (DEM) initiated the development of a water quality model using a program called the Georgia Estuary Model (DEM, 1984). The U.S. Environmental Protection Agency (USEPA) and Georgia Environmental Protection Division had been promoting the model as a useful tool for coastal river/estuary systems and were in the process of applying the model to the Lower Savannah River along the Georgia-South Carolina border. Although the report was finalized in 1984, the model was not apparently used for any major permitting decisions for the river.

1.2.4 Federal Paperboard Co. Studies

In 1990, Federal Paperboard Co., the current owner of the facility formerly called the Riegel Paper Corporation, conducted a series of studies in order to resolve a long-time permit dispute. While the facility had greatly expanded treatment with the installation of an aerated stabilization basin (ASB) system, the facility and DEM could not agree on appropriate permit limits for the facility. This included development of a water quality model for the LCFR (Hydroscience, 1990) and extensive biological surveys on the LCFRE, as well as lower portions of the Black River and NE Cape Fear River (CH2M HILL, 1992).

The water quality model was developed as a slack-tide calibrated QUAL 2E model, recognizing that this was a conservative approach for modeling the impacts of the Federal Paperboard Co. discharge, since it did not consider dilution provided by tidal exchange. The DEM developed a similar model of the river, and both models indicated that there was only a small DO sag resulting from the Federal Paperboard Co. discharge under this conservative modeling approach (Kreutzberger and Wakild, 1993).

Biological investigations of the river, including habitat characteristics, benthic macroinvertebrates, and fisheries, indicated that the aquatic life uses of the river were not impaired as a result of wastewater discharges. Habitat characteristics of the Cape Fear River related to basin hydrology and historical dredging were determined to be primary factors affecting variability in biological characteristics in the river (CH2M HILL, 1992; Kreutzberger and Wakild, 1993; Sacco et al., 1993).

Information provided by these studies allowed the National Pollutant Discharge Elimination System (NPDES) permit issues for Federal Paperboard Co. to be resolved with a permit issued and a Special Order by Consent (SOC) to achieve those limits by 1999. International Paper purchased the mill in 1996 and continues to operate this facility today.

1.2.5 1996 Cape Fear River Basinwide Water Quality Management Plan

In the mid-1990s, the DENR began development of basinwide water quality management plans for each of the river basins in the state, with plans to update them every 5 years. They also rearranged permit expiration schedules so that these plans could then guide all of the permitting in each basin. In the 1996 Plan, the LCFRE was not considered impaired, and there was no specific water quality management strategy presented. However, because portions of the estuary were designated as Primary Nursery Areas (PNA) by the Division of Marine Fisheries, this area was subject to High Quality Waters (HQW) requirements according to the plan.

This actually includes significant portions of the currently impaired areas. Based on this requirement, all new and expanding dischargers were required to meet advanced treatment requirements for oxygen-consuming wastes for which the specific limitations have evolved over the years (DENR, 1996).

1.2.6 Lower Cape Fear River Program Studies

As noted in the background, the LCFRP was established in 1995 and has been providing excellent data on ambient conditions in the river, as well as a wide variety of targeted research efforts. The annual and special reports, as well as published research papers, are listed in the attachment. A comprehensive review of the efforts is beyond the scope of this TM. The following provides a brief overview of the consistent findings over the years and a few highlighted observations that seem pertinent to consideration of the appropriate classification for the LCFRE.

In reviewing annual reports over the nearly 20 years of monitoring, the characterization of the LCFRE and tributaries has been fairly consistent. The LCFR has been characterized as experiencing periodically high turbidity with moderate to high levels of inorganic nutrients. The estuary also has two major blackwater tributaries (the Black and Northeast Cape Fear Rivers) that generally exhibit low levels of turbidity, lower levels of inorganic nutrients, and high levels of color. Despite the high levels of nutrients, algal blooms are typically limited in the rivers due to a combination of limited light as a result of turbidity and flushing in the Cape Fear River, or limited light because of the highly colored waters in the tributaries. During periods of low flow, discussed later in this section, chlorophyll a levels increase because water clarity increases and flushing decreases, allowing more time for algal populations to develop. Some major algal blooms have been observed in tributaries where point-source influences have been noted. Blackwater swamps and agricultural areas have been characterized as periodically having high pollutant levels (Mallin et al., 2013).

In addition to the overall summary of conditions, the LCFRP has documented water quality conditions following major hurricanes and during two extreme droughts. The following summarizes some observations during these periods.

The early years of the monitoring effort allowed for extensive documentation of hurricane effects similar to those observed during the initial water quality surveys in 1955. In the summer of 1996, eastern North Carolina experienced the effects of Hurricane Bertha (July 1996) and Hurricane Fran (September 1996). The ongoing LCFRP was able to document the water quality response from Hurricane Fran in particular, where hurricane-induced flooding resulted in significant inputs from riparian wetlands, especially in the NE Cape Fear River. The DO in the NE Cape Fear River fell to about zero for approximately 3 weeks, and there were also documented fish kills. The DO levels in the mainstem of the Cape Fear River were as low as 2 mg/L but recovered faster due to flushing from flows originating from the upper part of the watershed. It is important to note that while inputs from riparian wetlands were significant contributors to the tremendous loads of oxygen-demanding materials, there were also significant inputs of raw and partially treated sewage as a result of power failures, as well as significant inputs of swine waste from breached lagoon storage systems. Therefore, the natural inputs from wetlands could not be separated from anthropogenically derived inputs, which were concluded to be especially significant in the NE Cape Fear River system based on monitoring results for BOD and ammonia (Mallin et al., 1997).

Much of North Carolina and the Cape Fear River basin, in particular, experienced a severe drought in 2001 and 2002 that ended in 2003. The LCFRP documented higher salinity levels and extended low DO conditions in the main river during the summer of 2002. Several tributaries, Angola Creek, the upper portion of the NE Cape Fear River, and the upper South River were noted to have extremely low DO levels. Turbidity levels were lower than the mean conditions for the period of record in the Cape Fear River and the upper estuary, but algal blooms were not documented in the major rivers but were observed in some small streams (Mallin et al., 2003).

Another severe drought occurred during 2007. Observations were similar for the 2001-2002 drought in terms of low DO levels and lower than typical levels of turbidity in the Cape Fear River. While algal blooms were not observed in the Cape Fear River, some severe blooms were observed in many small tributaries where turbidity levels were also significantly lower than the long-term trend (Mallin et al., 2008).

This is just a brief summary of the extensive assessment efforts conducted by the LCFRP. There has also been a wide variety of published papers. The assessment reports and other publications are listed in the Attachment A.

1.2.7 City of Wilmington/New Hanover County Studies

In the period between 2000 and 2001, efforts were made on behalf of the City of Wilmington and New Hanover County to develop an initial application of a three-dimensional hydrodynamic model (the Environmental Fluid Dynamics Code, or EFDC, model), with the intention of meeting several objectives deemed important at the time (Tetra Tech, 2001). This model was an important step in developing an assessment tool for the river. However, DENR and stakeholders determined that more data for development and calibration were required to support development of a model that could be used to determine a TMDL for the impaired portions of the river. This effort is discussed in this section relative to the University of North Carolina (UNC)-Charlotte Water Quality Model.

In addition to the initial EFDC model development, a trend analysis was also conducted of available data to determine whether there was any significant change in DO levels in the impaired portion of the river during a period when significant reductions in point-source loadings of oxygen-consuming wastes occurred (Doll and Clements, 2003). The previous DO trend analysis found no statistically significant trend for DO for the period of 1984 through 2002. The same conclusion was drawn for the period of 1991 through 2002, despite a statistically significant reduction in major point-source ultimate biochemical oxygen demand (BODu) load of approximately 25 percent for that period. This analysis has been updated with recent data and is presented in TM A-2 (Tetra Tech, 2014).

1.2.8 UNC-Charlotte Water Quality Model

As an extension of the effort started by consultants to the City of Wilmington and New Hanover County (Tetra Tech, 2001), DENR contracted with UNC-Charlotte to further develop the hydrodynamic model and water quality model using EFDC (Bowen et al., 2009). The objective of the study was to develop a water quality model of the LCFRE that would be suitable for use in developing a TMDL to address DO impairment. This model generally covers the tidally influenced areas of the Cape Fear River, Black River, and NE Cape Fear River, and extends to the mouth of the Cape Fear River with the Atlantic Ocean. The final report documents the details of the model development and calibration.

Analyses were conducted upon completion of model development, and calibration including the following eight scenarios:

1. Eliminating wastewater point-source loadings
2. Reducing river, creek, and wetland loadings
3. Changing wastewater loadings for various values of sediment oxygen demand
4. Reducing river, creek, and wetland loadings, and sediment oxygen demand
5. Eliminating ammonia inputs from wastewater point sources
6. Increasing wastewater inputs to maximum permitted values
7. Deepening of the navigation channel
8. Changing Brunswick County wastewater loadings

The following are a few highlights of major observations for some scenarios based on a simulation period to include April through October during a relatively low flow year – 2004.

1.2.8.1 Eliminating Wastewater Point-source Loadings

The sensitivity of the system to point sources was performed by running the model under different point-source conditions, including one with all point sources removed. Results from this analysis are shown in Figure 1 for the impaired portion of the Cape Fear River as a cumulative frequency diagram illustrating the percentage of the time the DO was above a certain level. Key findings include:

- During the period of lowest DO (selected as the 10th percentile), turning off all point-source discharges resulted in an increase in the DO from about 4.3 to 4.6 mg/L.

- DO levels were less than the standard of 5 mg/L approximately 32 percent of the time with the point-source discharges, and 27 percent of the time when these loadings were turned off.

1.2.8.2 Reducing River, Creek, and Wetland Loadings

Nonpoint-source reduction scenarios were also run by reducing the loading of oxygen-demanding pollutants for the tributaries and wetland cells by 30, 50, and 70 percent. These results indicate the following:

- During the period of lowest DO (selected as the 10th percentile), the difference between the base case with all calibrated pollutant loading and a 70 percent reduction in tributary/wetland loading resulted in an increase in DO of about 4.3 to 4.7 mg/L.
- DO levels were less than the standard of 5 mg/L approximately 32 percent of the time for the base case, 24 percent of the time with a 30 percent reduction in tributary/wetland loads, 20 percent of the time with a 50 percent reduction in tributary/wetland loads, and 18 percent of the time with a 70 percent reduction of tributary wetland loads.

1.2.8.3 Eliminating Ammonia Inputs from Wastewater Point Sources

The model results indicated that elimination of ammonia from point sources resulted in an approximate 0.1 mg/L increase in DO for periods when the DO was less than 5 mg/L.

Based on the results of the UNC-Charlotte modeling study, DENR determined that it could not move forward with development of a TMDL because it was apparent that point sources contributed a relatively small portion of the observed DO impairment based on the DO standard of 5 mg/L. DENR also concluded that although natural sources appeared to be a significant contributor to the low DO conditions, they could not differentiate what portion of the DO deficit was due to natural sources versus anthropogenic sources.

April through October Simulated Dissolved Oxygen Concentrations in the Impaired Area, Lower Cape Fear River Estuary

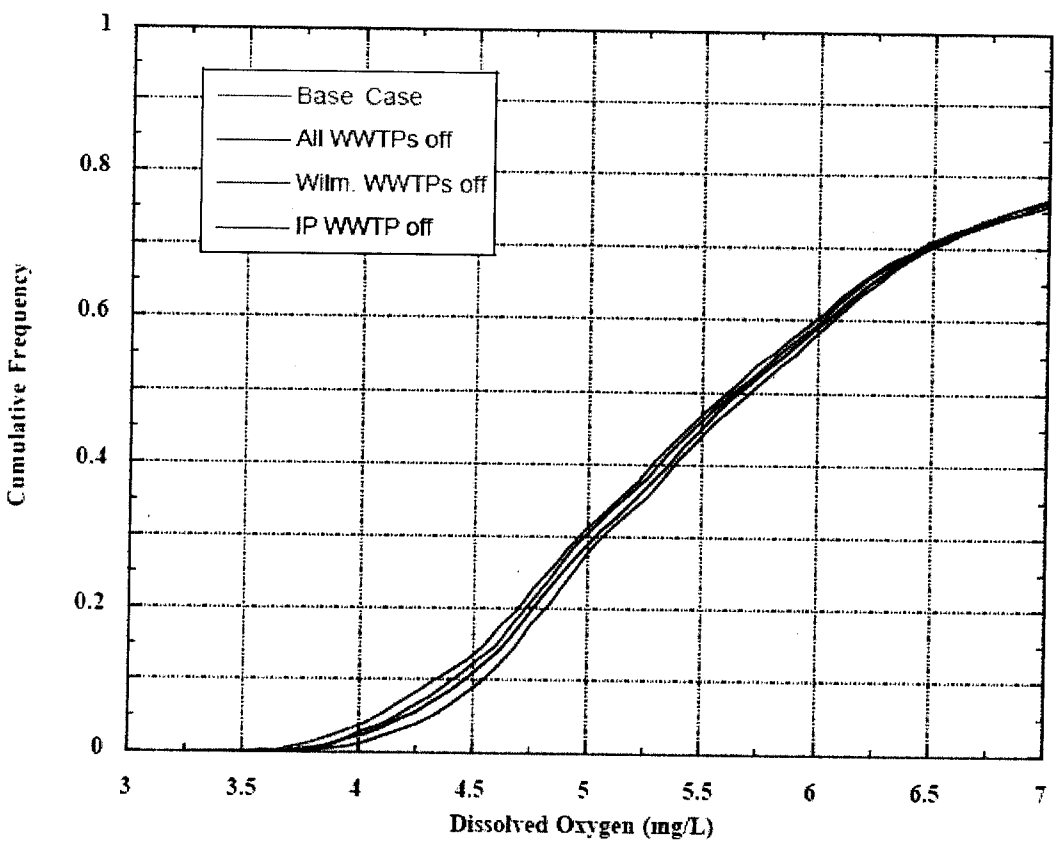

Figure 1. Cumulative frequency of model-predicted DO concentrations (April through October 2004) in the impaired portion of the LCFRE for the base case and three reduction scenarios for WWTP loads (reproduced from Bowen et al., 2009)

The three analyses highlighted above demonstrate the LCFRE lack of sensitivity to changes in point source loads. It should also be pointed out that the modeling also showed a significant impact of further channel dredging on DO conditions in the river.

2 Summary

There is a vast amount of data, research, technical analysis, and modeling for the LCFRE. While discharges from point sources and nonpoint sources appear to have some contribution to the DO deficit, it is also clear that natural drainage from riparian wetlands, salt marshes, and blackwater tributaries are more significant contributors to DO conditions not meeting the assigned standard of 5 mg/L and the pH minimum of 6.8 at all times for Class SC waters (see TM 4 for additional technical details on relative impact of sources on DO deficit) (Tetra Tech, 2014). The supplemental "Swamp" classification appears appropriate for these areas to recognize the natural source contributions to deviations in these parameters.

Other TMs prepared in conjunction with this summary address other aspects of these issues, including:

- TM 2 - Updated trend analysis of DO conditions and pollutant loading from point sources
- TM 3 - Analysis of long-term data near the limits of the tidal influence for the Cape Fear River, Black River, and NE Cape Fear River, which are approximate boundaries in the EFDC model
- TM 4 - An analysis of model results to assess the relative impact of riparian wetlands and salt marshes versus other tributary loadings

3 References

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin, and J. Williams. 2009. *Development and Use of a Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the Lower Cape Fear River Estuary, North Carolina.* Charlotte, North Carolina: Department of Civil and Environmental Engineering, University of North Carolina at Charlotte.

CH2M HILL. 1992. *Biological Assessment in the Cape Fear River Watershed.* Atlanta, Georgia: CH2M HILL.

Department of Environment and Natural Resources (DENR). 1996. *Cape Fear River Basinwide Water Quality Management Plan.* Raleigh, North Carolina.

Department of Environment and Natural Resources (DENR). 2014. *2014 Draft Category 5 Water Quality Assessments-303(d) List.* Raleigh, North Carolina.

Division of Environmental Management (DEM). 1981. *Proceedings of the Reclassification of Tidal Saltwaters.* Raleigh, North Carolina.

Division of Environmental Management (DEM). 1984. *Water Quality Analysis and Model Lower Cape Fear River.* North Carolina Division of Natural Resources (NCDNR) and Community Development. Report No. 84-08.

Doll, J., and T. Clements. 2003. *Results of Dissolved Oxygen and Pollutant Loading Trend Analyses.* Research Triangle Park, North Carolina: Tetra Tech.

Hydroscience. 1990. *Water Quality Model of the Lower Cape Fear River.* Report submitted to Federal Paperboard Company, Riegelwood, North Carolina. June.

Kreutzberger, W., and C. Wakild. 1993. "Water quality and biological investigation of the lower cape fear basin." *Tappi Journal*. Vol. 76(7). July.

Mallin, M.A., M.H. Posey, M.L. Moser, G.C. Shank, M.R. McIver, T.D. Alphin, S.H. Ensign, and J.F. Merritt. 1997. *Water Quality in the Lower Cape Fear River System, 1996-1997*. Wilmington, North Carolina: University of North Carolina – Wilmington, Center for Marine Science Research.

Mallin, M., M. McIver, H. Wells, M. Williams, T. Lankford, and J. Merritt. 2003. *Environmental Assessment of the Lower Cape Fear River System, 2002-2003*. CMSR Report No. 03-03, Center for Marine Science Research. Wilmington, North Carolina: University of North Carolina Wilmington. October.

Mallin, M., M. McIver, and J. Merritt. 2008. *Environmental Assessment of the Lower Cape Fear River System, 2007*. CMSR Report No. 08-03, Center for Marine Science Research. Wilmington, North Carolina: University of North Carolina Wilmington. December.

Mallin, M., M. McIver, and J. Merritt. 2013. *Environmental Assessment of the Lower Cape Fear River System, 2012*. CMSR Report No. 13-02, Center for Marine Science. Wilmington, North Carolina: University of North Carolina Wilmington. October.

Sacco, P., T. Simpson, and W. Kreutzberger. 1993. Adapting the EPA Rapid Bioassessment Protocol for Use Attainability Study in the Cape Fear River. *Proceedings of the 1993 Georgia Water Resources Conference*. Kathryn J. Hatcher, ed. Athens, Georgia: The University of Georgia, Institute of Natural Resources. April 20 and 21.

State Stream Sanitation Committee. 1957. *Cape Fear River Basin Pollution Survey Report 1957 (1954-1956)*. Raleigh, North Carolina: North Carolina State Board of Health, Division of Water Pollution Control.

Tetra Tech. 2001. *3-Dimensional EFDC Water Quality Model of the Lower Cape Fear River and its Estuary*. Prepared for the City of Wilmington and New Hanover County, North Carolina. May.

Tetra Tech. 2014. *Technical Memo: The Relationship of Adjacent Wetlands and Salt Marsh to Dissolved Oxygen in the Lower Cape Fear River Estuary*. Prepared for the Lower Cape Fear River Program. February (Draft).

Attachment A – Bibliography of Studies Pertinent to Water Quality Conditions in the Lower Cape Fear River

Lower Cape Fear River Program Related Reports and Publications

Benedetti, M.M., M.J. Raber, M.S. Smith, and L.A. Leonard. 2006. *Physical Geography*. 27: 258-281.

Burkholder, J. M., Dickey, D. A., Kinder, C. A., Reed, R. E., Mallin, M. A., McIver, M. R., Cahoon, L. B., Melia, G., Brownie, C., Smith, J., Deamer, N., Springer, J., Glasgow, H. B., and D. Toms. 2006. *Limnology and oceanography*. 51:463-487.

Cahoon, L.B., J.A. Mikucki, and M.A. Mallin. 1998. "Nutrient imports to the Cape Fear and Neuse River basins on animal feeds." *Manure Management in Harmony with Environment and Society*. Ames, Iowa: Soil and Water Conservation Service. pp. 228-232.

Cahoon, L.B., J.A. Mickucki, and M.A. Mallin. 1999a *Environmental Science and Technology*. 33:410-415.

Cahoon, L.B., J.A. Mikucki, and M.A. Mallin. 1999b. *Environmental Science and Technology*. 33: 410-415.

Dafner, E.V., M.A. Mallin, J.J. Souza, H. A. Wells, and D.C. Parsons. 2007. *Marine Chemistry*. 103: 289-303.

Dame, R., M. Alber, D. Allen, M. Mallin, C. Montague, A. Lewitus, A. Chalmers, R. Gardner, C. Gilman, B. Kjerfve, J. Pinckney, and N. Smith. 2000. *Estuaries*. 23: 793-819.

Lin, J., L. Xie, L.J. Pietrafesa, J. Shen, M.A. Mallin, M.J. Durako. 2006. *Estuarine Coastal and Shelf Science*. 70: 423-437.

Mallin, M., M. McIver, and J. Merritt. 2013. *Environmental Assessment of the Lower Cape Fear River System, 2012*. CMS Report No. 13-02. Wilmington, North Carolina: Center for Marine Science, University of North Carolina Wilmington. October.

Mallin, M.A. 1994. *Estuaries*. 17: 561-574.

Mallin, M.A. 2000. "Impacts of industrial-scale swine and poultry production on rivers and estuaries." *American Scientist*. 88:26-37.

Mallin, M.A., and C.A. Corbett. 2006. *Estuaries and Coasts*. 29: 1046-1061.

Mallin, M.A., G.C. Shank, M.R. McIver, and J.F. Merritt. 1996. *Water Quality in the Lower Cape Fear Watershed, 1995-1996*. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington.

Mallin, M.A., G.C. Shank, M.R. McIver, L.B. Cahoon, and D.C. Parsons. 1996. Spatial and temporal nutrient patterns in the Lower Cape Fear River system. *Solutions: Proceedings of a technical conference on water quality*. Raleigh, North Carolina: North Carolina State University. March 19-21.

Mallin, M.A., J.M. Burkholder, G.C. Shank, M.R. McIver, and H.B. Glasgow, Jr. 1996. Effects of animal waste spills on receiving waters. *Solutions: Proceeding of a technical conference on water quality*. Raleigh, North Carolina: North Carolina State University. March 19-21.

Mallin, M.A., J.M. Burkholder, M.R. McIver, G.C. Shank, H.B. Glasgow, Jr., B.W. Touchette, and J. Springer. 1997. "Comparative effects of poultry and swine waste lagoon spills on the quality of receiving streamwaters." *Journal of Environmental Quality*. 26:1622-1631.

Mallin, M.A., L.B. Cahoon, D.C. Parsons, and S.H. Ensign. 1998. *Effect of organic and inorganic nutrient loading on photosynthetic and heterotrophic plankton communities in blackwater rivers*. Report No. 315. Raleigh, North Carolina: Water Resources Research Institute of the University of North Carolina.

Mallin, M.A., L.B. Cahoon, M.R. McIver, D.C. Parsons, and G.C. Shank. 1997. *Nutrient limitation and eutrophication potential in the Cape Fear and New River Estuaries*. Report No. 313. Raleigh, North Carolina: Water Resources Research Institute of the University of North Carolina.

Mallin, M.A., L.B. Cahoon, M.R. McIver, D.C. Parsons, and G.C. Shank. 1999. *Estuaries*. 22:985-996.

Mallin, M.A., M.H. Posey, G.C. Shank, M.R. McIver, S.H. Ensign, and T.D. Alphin. 1999. *Ecological Applications*. 9:350-362.

Mallin, M.A., M.H. Posey, M.L. Moser, G.C. Shank, M.R. McIver, T.D. Alphin, S.H. Ensign, and J.F. Merritt. 1997. *Environmental Assessment of the Lower Cape Fear River System, 1996-1997*. CMSR Report No. 97-01. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington.

Mallin, M.A., M.H. Posey, M.L. Moser, G.C. Shank, M.R. McIver, T.D. Alphin, S.H. Ensign, and J.F. Merritt. 1998. *Environmental Assessment of the Lower Cape Fear River System, 1997-1998*. CMSR Report No. 98-02. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington.

Mallin, M.A., M.H. Posey, M.L. Moser, L.A. Leonard, T.D. Alphin, S.H. Ensign, M.R. McIver, G.C. Shank, and J.F. Merritt. 1999. *Environmental Assessment of the Lower Cape Fear River System, 1998-1999*. CMSR Report No. 99-01. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington.

Mallin, M.A., M.H. Posey, M.R. McIver, S.H. Ensign, T.D. Alphin, M.S. Williams, M.L. Moser, and J.F. Merritt. 2000. *Environmental Assessment of the Lower Cape Fear River System, 1999-2000*. CMS Report No. 00-01. Wilmington, North Carolina: Center for Marine Science, University of North Carolina at Wilmington.

Mallin, M.A., M.H. Posey, T.E. Lankford, M.R. McIver, H.A. CoVan, T.D. Alphin, M.S. Williams, and J.F. Merritt. 2002. *Environmental Assessment of the Lower Cape Fear River System, 2001-2002*. CMS Report No. 02-01. Wilmington, North Carolina: Center for Marine Science, University of North Carolina at Wilmington.

Mallin, M.A., M.H. Posey, T.E. Lankford, M.R. McIver, S.H. Ensign, T.D. Alphin, M.S. Williams, M.L. Moser, and J.F. Merritt. 2001. *Environmental Assessment of the Lower Cape Fear River System, 2000-2001*. CMS Report No. 01-01. Wilmington, North Carolina: Center for Marine Science, University of North Carolina at Wilmington.

Mallin, M.A., M.R. McIver, H.A. Wells, M.S. Williams, T.E. Lankford, and J.F. Merritt. 2003. *Environmental Assessment of the Lower Cape Fear River System, 2002-2003*. CMS Report No. 03-01. Wilmington, North Carolina: Center for Marine Science, University of North Carolina at Wilmington.

Mallin, Michael A., Lawrence B. Cahoon, John J. Manock, James F. Merritt, Martin H. Posey, Troy D. Alphin, Douglas C. Parsons, and Tracy L. Wheeler. 1998. *Environmental Quality of Wilmington and New Hanover County Watersheds 1997-1998*. CMSR Report No. 98-03. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington. November.

Mallin, Michael A., Lawrence B. Cahoon, John J. Manock, James F. Merritt, Martin H. Posey, Ronald K. Sizemore, W. David Webster, and Troy D. Alphin. 1998. *A Four Year Environmental Analysis of New Hanover County Tidal Creeks 1993-1997*. CMSR Report No. 98-01. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington.

Mallin, Michael A., Scott H. Ensign, Douglas C. Parsons, and Tracy L. Wheeler. 1999. *Environmental Quality of Wilmington and New Hanover County Watersheds 1998-1999*. CMSR Report No. 99-02. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington. December.

Mallin, Michael, Matthew R. McIver, and James F. Merritt. 2008. *Environmental Assessment of the Lower Cape Fear River System, 2007*. CMSR Report No. 08-03. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington. December.

Mallin, Michael, Matthew R. McIver, and James F. Merritt. 2012. *Environmental Assessment of the Lower Cape Fear River System, 2011*. CMSR Report No. 12-03. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington. September.

Padgett, D.E., M.A. Mallin, and L.B. Cahoon. 2000. "Evaluating the use of ergosterol as a bioindicator for assessing water quality." *Environmental Monitoring and Assessment* 00:1-12.

Xia, M., L. Xie. and L.J. Pietrafesa. 2007. *Estuaries and Coasts*. 30: 698-709.

State and Federal Government Studies

Hackney CT, Posey M, Leonard LL, Alphin T, and Avery GB. 2002. *Monitoring Effects of a Potential Increased Tidal Range in the Cape Fear River Ecosystem Due to Deepening Wilmington Harbor, NC, Year 1: August 1, 2000-July, 2001.* Prepared for the U.S. Army Corps of Engineers, Wilmington District. Contract No. DACW 54-00-R-0008. April.

National Oceanic and Atmospheric Administration (NOAA). 1979. *Circulation and Hydrodynamics of the LCFR, NC. National Ocean Survey*. U.S. Department of Commerce. August.

North Carolina Department of Environment and Natural Resources (DENR). 1995. *Cape Fear River Basinwide Assessment Report*. Raleigh, North Carolina.

North Carolina Department of Environment and Natural Resources. (DENR). 1996. *Cape Fear River Basinwide Water Quality Management Plan*. Raleigh, North Carolina.

North Carolina Department of Environment and Natural Resources (DENR). 2000. *Cape Fear River Basinwide Assessment Report*. Raleigh, North Carolina.

North Carolina Department of Environment and Natural Resources (DENR). 2001. *Cape Fear River Basinwide Water Quality Management Plan*. Raleigh, North Carolina.

North Carolina Department of Environment and Natural Resources (DENR). 2005. *Cape Fear River Basinwide Assessment Report*. Raleigh, North Carolina.

North Carolina Department of Environment and Natural Resources (DENR). 2006. *Cape Fear River Basinwide Water Quality Management Plan*. Raleigh, North Carolina.

North Carolina Department of Environment and Natural Resources, Water Quality (DWQ). 1998. *Basinwide Wetland and Riparian Restoration Plan for the Cape Fear River Basin*. NC Wetlands Restoration Program.

North Carolina Department of Environment and Natural Resources, Water Quality (DWQ). 2001. *Watershed Restoration Plan for the Cape Fear River Basin*. NC Wetlands Restoration Program.

North Carolina Department of Natural Resources and Community Development. 1984. *Water Quality Analysis and Model, Lower Cape Fear River*. Report No 84-08. Division of Environmental Management. June.

North Carolina Department of Natural Resources and Community Development, and U.S. Water Resources Council. 1983a. *Status of Water Resources in the Cape Fear River Basin*. Cape Fear River Basin Study. June.

North Carolina Department of Natural Resources and Community Development, and U.S. Water Resources Council. 1983b. *Wetlands Technical Memorandum 1.1 Cape Fear River Basin*. Cape Fear River Basin Study. September.

North Carolina Department of Natural Resources and Community Development, and U.S. Water Resources Council. 1984. *Summary Report: Cape Fear River Basin Study, 1981-84*.

North Carolina Division of Environmental Management (DEM). 1981. *Proceedings of the Reclassification of Tidal Saltwaters*. Raleigh, North Carolina.

North Carolina Division of Water Pollution Control. 1962. Proceedings of the Classification of the Waters of the Cape Fear River Basin.

State Stream Sanitation Committee. 1957. *Cape Fear River Basin Pollution Survey Report 1957 (1954-1956)*. Raleigh, North Carolina: North Carolina State Board of Health, Division of Water Pollution Control.

Other Studies

Becker, May Ling. 2006. Hydrodynamics Behavior of the Cape fear River Estuarine System, NC. Doctoral dissertation. University of North Carolina at Charlotte.

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin, and J. Williams. 2009. *Development and Use of a Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the Lower Cape Fear River Estuary, North Carolina.* Charlotte, North Carolina: Department of Civil and Environmental Engineering, University of North Carolina at Charlotte.

Carolina Power and Light. 1973-2008.. *Brunswick Nuclear Power Plant Biological Monitoring Report and Other Studies, 1973 to 2008.*

CH2M HILL. 1992. *Biological Assessment in the Cape Fear River Watershed.* Report prepared for Federal Paper Board Co. Atlanta, Georgia: CH2M HILL.

Doll, J., and T. Clements. 2003. *Results of Dissolved Oxygen and Pollutant Loading Trend Analyses.* Research Triangle Park, North Carolina: Tetra Tech.

Henry Von Oesen and Associates, Inc. 1984.*Lower Cape fear River Water Quality Problems, Impacts and Alternatives for Remedial Action.* Prepared for Wilmington Industrial Development, Inc. July..

Hydroscience, 1990. *Water Quality Model of the Lower Cape Fear River.* Report submitted to Federal Paperboard Co., Riegelwood, North Carolina. June.

Kreutzberger, W., and C. Wakild. 1993. "Water quality and biological investigation of the lower cape fear basin." *TAPPI Journal.* Vol. 76(7). July.

Sacco, P., T. Simpson, and W. Kreutzberger. 1993. Adapting the EPA Rapid Bioassessment Protocol for Use Attainability Study in the Cape Fear River. *Proceedings of the 1993 Georgia Water Resources Conference.* Kathryn J. Hatcher, ed. Athens, Georgia: The University of Georgia, Institute of Natural Resources. April 20 and 21.

Tetra Tech, Inc. 2001. *3-Dimensional EFDC Water Quality Model of the Lower Cape Fear River and its Estuary.* Prepared for the City of Wilmington and New Hanover County, North Carolina. May.

Technical Memo: Dissolved Oxygen Trend Analysis for the Lower Cape Fear River Estuary

Prepared for

The Lower Cape Fear River Program

Prepared by

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February 21, 2014

1 Introduction

The Lower Cape Fear River Program (LCFRP) is a large-scale water quality and environmental assessment program covering the Cape Fear River Estuary and a large portion of the lower Cape Fear River watershed. The LCFRP represents a collaboration of academia, government, industry, and the public, which has been coordinating with the North Carolina Department of Environment and Natural Resources (DENR) since 1995. The purpose of this memo is to update a previous (Tetra Tech, 2003) statistical trend analysis performed on dissolved oxygen (DO) data collected in the Lower Cape Fear River Estuary (LCFRE) portion of the basin. The current memo was prepared as part of a joint LCFRP-DENR effort to summarize the existing body of technical evidence for submission to the North Carolina Environmental Management Commission (EMC) requesting reclassification of portions of the LCFRE into a supplemental "Swamp" designation— a designation which had been applied to the LCFRE from the late 1950's until the early 1980's.

The previous DO trend analysis found no statistically significant trend for DO for the period of 1984 through 2002. The same conclusion was drawn for the period of 1991 through 2002, despite a statistically significant reduction in major point source ultimate biochemical oxygen demand (BODu) load of approximately 25 percent for that period. For this updated review, advanced statistical analyses were performed to determine if ambient DO data or major point source BODu loads exhibit significant trends over an extended period of time in the LCFRE (i.e., extending the data reviewed out to 2013). Monitoring data compilation, preparation, and analysis methods and results are summarized below.

2 Monitoring Data

The first step for the extended trend analysis involved obtaining ambient DO data and major point source data relevant for the LCFRE. The following subsections describe what data were compiled and how the data were processed to address outliers and fill gaps in preparation for the statistical tests.

2.1 Dissolved Oxygen

DO data were obtained from STORET (EPA's online data storage and retrieval resource) for five monitoring stations in the Cape Fear Estuary (Table 1 and Figure 1). These stations were chosen for the analysis because they offered the longest available period of monitoring records and because they are each located either directly within or immediately adjacent to the 303(d) listed portion of the Cape Fear Estuary. Note that the names of the last two stations in the table have changed since the first trend analysis memo was produced in 2003, due apparently to renumbering of the channel markers. The station IDs, and thus the locations, are identical.

Table 1. Ambient Monitoring Stations Used in the DO Trend Analysis

Station ID	Station Name	Selected Period of Record
B902000	Cape Fear River downstream Hale Point Landing near Phoenix	January 1992 – April 2013
B905000	Cape Fear River at Navassa	May 1984 – April 2013
B974000	Northeast Cape Fear River at NC 133 at Wilmington	January 1981 – April 2013
B980000	Cape Fear River at Channel Marker 61 at Wilmington	January 1985 – April 2013
B982000	Cape Fear River at Channel Marker 56 near Wilmington	January 1981 – April 2013

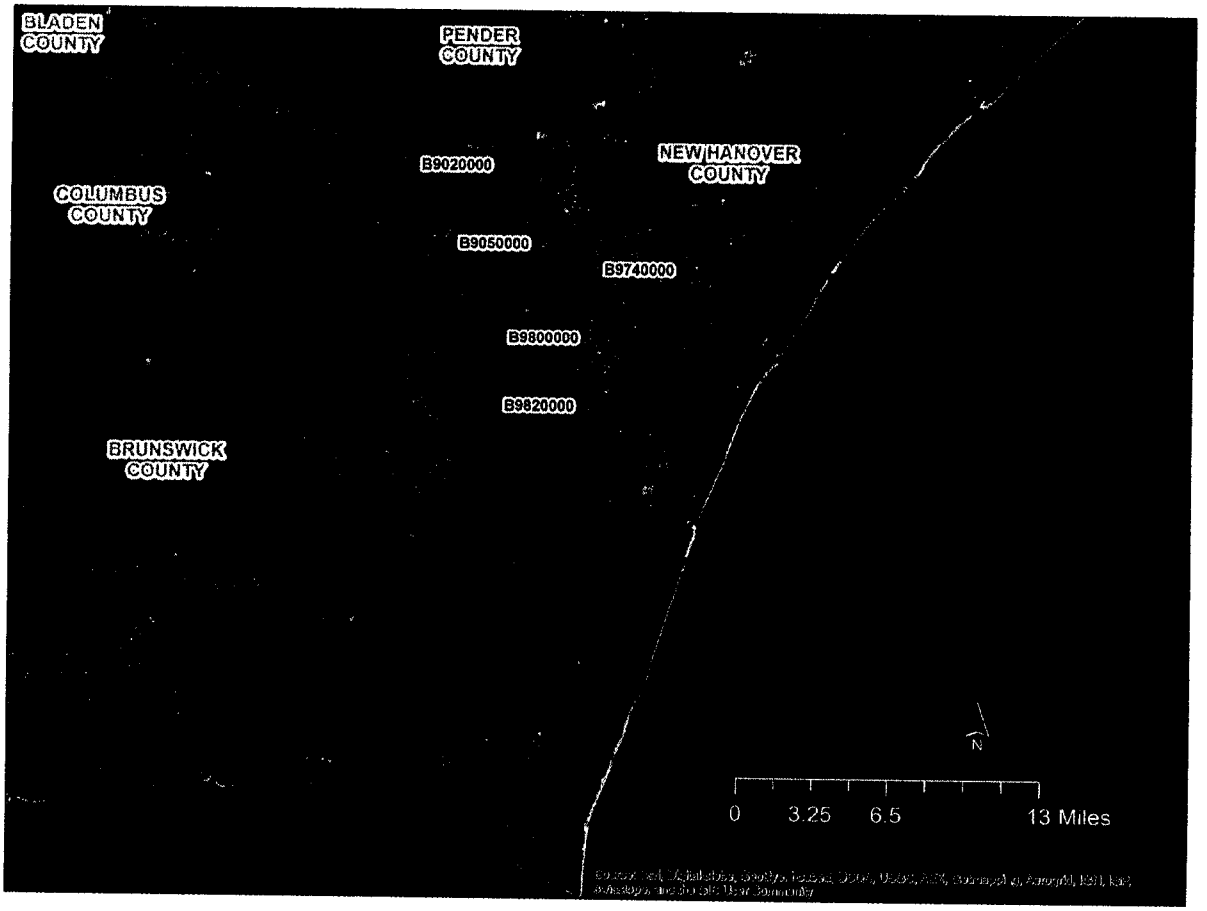

Figure 1. Locations of Ambient Monitoring Stations Used in the DO Trend Analysis

Only DO measurements within one foot the water surface were evaluated, because historical depth stratified monitoring data has consistently indicated strong mixing with little vertical stratification in the estuary. As was done with the previous analysis, one outlier was removed from the dataset; 0.4 mg/l from February 1998 at the Northeast Cape Fear River station. Observations associated with major hurricane events that affected the Cape Fear Estuary were also removed. Following Hurricane Bertha on July 12, 1996 and Hurricane Fran on September 5, 1996, prolonged periods of depressed instream dissolved oxygen levels in the Cape Fear Estuary followed each storm (Mallin et al., 1997). The Mallin report indicated conditions approached anoxia at several monitoring locations after Fran, likely due to significant undocumented "point sources" including pump station and WWTP failures as well as hog lagoon breaches. After each storm, dissolved oxygen levels did not return to normal until about two months following each event. Two other hurricanes were identified that struck in the vicinity of the Cape Fear Estuary – Hurricane Bonnie on August 27, 1998 and Hurricane Floyd on September 16, 1999. Based on the recovery period reported by Mallin et al., observations were removed from each of the datasets for a period of two months following each of the four hurricanes. Figure 2 through Figure 6 show the dissolved oxygen observations for the five stations. The hurricane event observations that were omitted from the analysis are shown in red; the impact of the hurricanes on DO is visible in many cases.

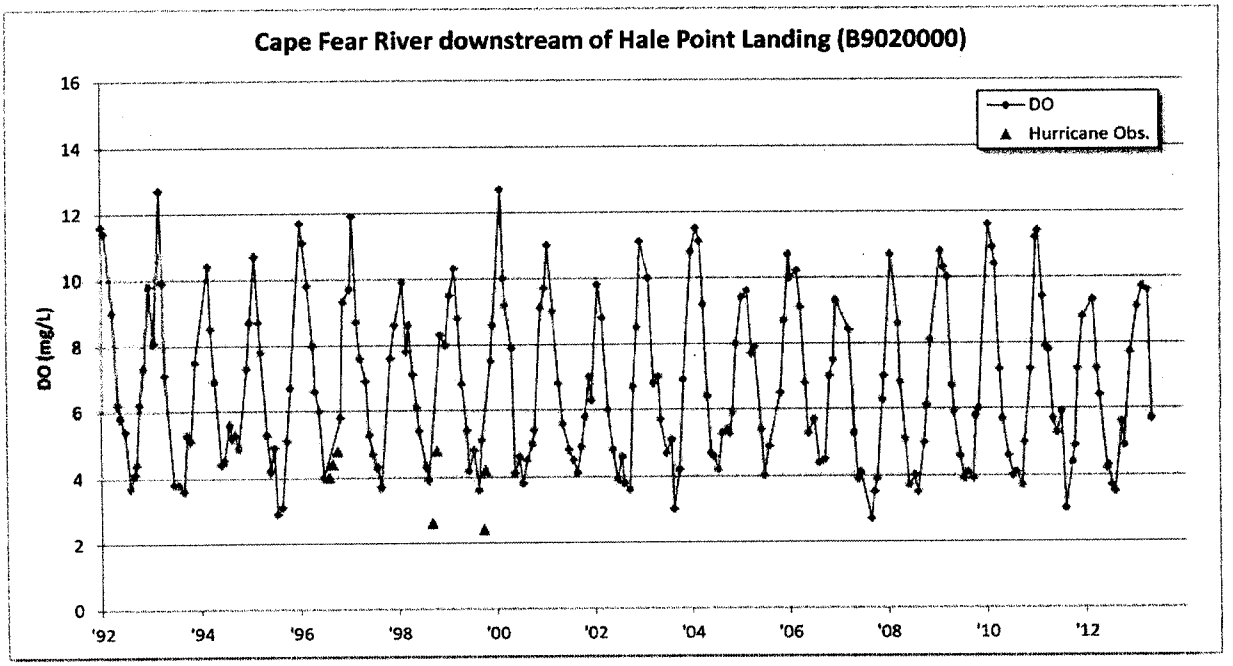

Figure 2. Dissolved Oxygen at B9020000, Cape Fear River Downstream of Hale Point Landing

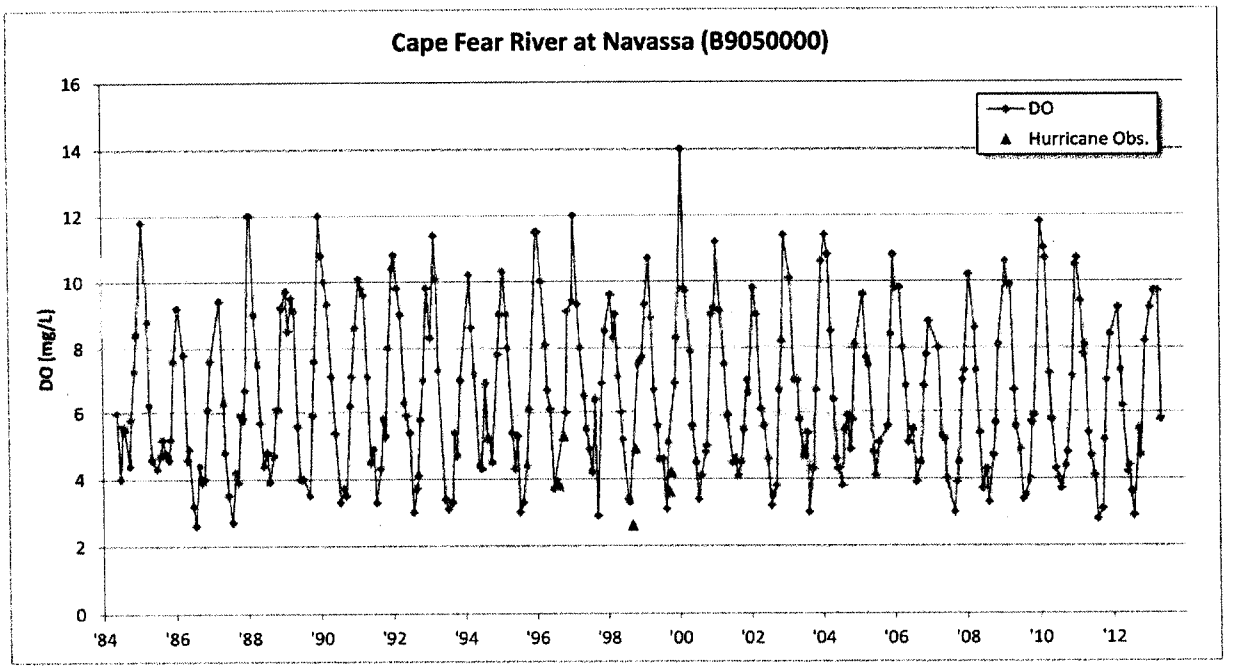

Figure 3. Dissolved Oxygen at B9050000, Cape Fear River at Navassa

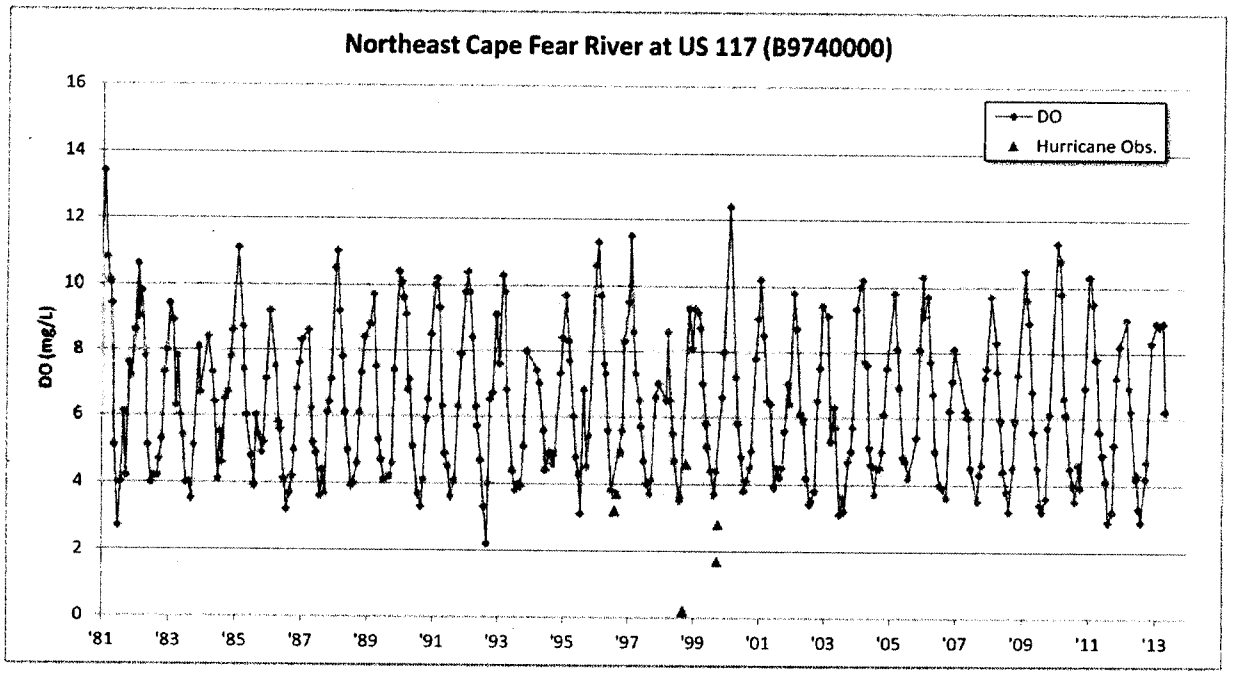

Figure 4. Dissolved Oxygen at B9740000, Northeast Cape Fear River at US 117

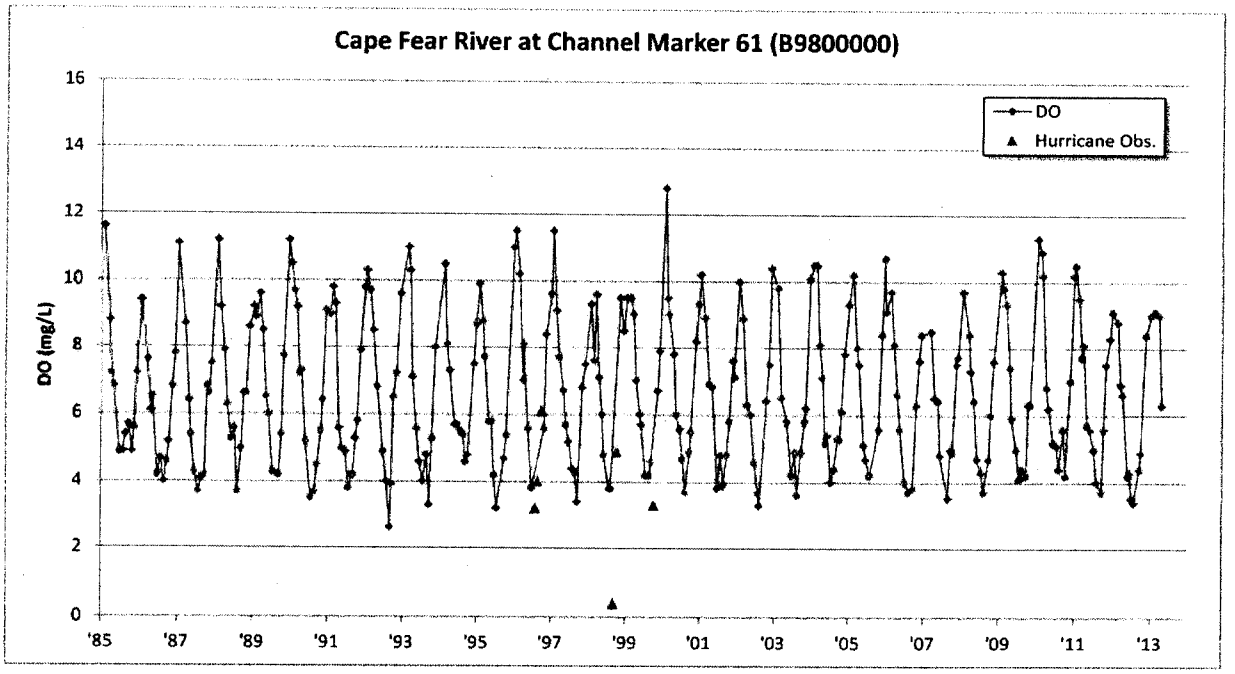

Figure 5. Dissolved Oxygen at B9800000, Cape Fear River at Channel Marker 61

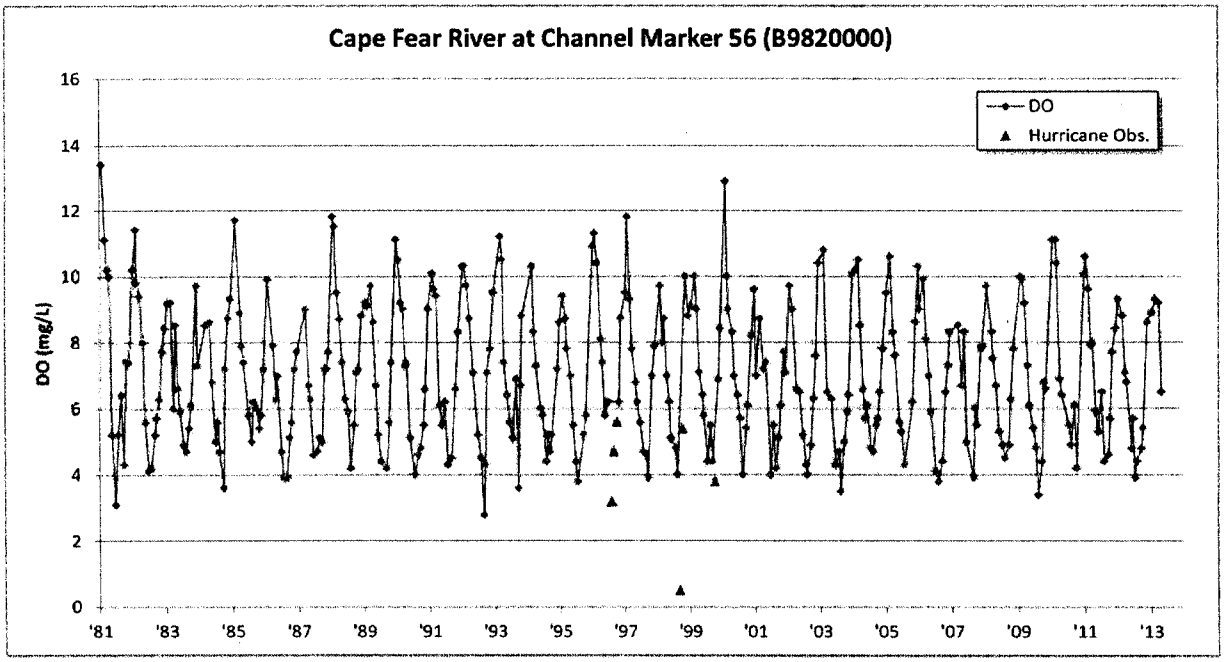

Figure 6. Dissolved Oxygen at B9820000, Cape Fear River at Channel Marker 56

2.2 POINT SOURCE DATA

Data were obtained from DENR for major facilities discharging oxygen demanding waste from January of 1994 through November of 2013. Previous point source pollutant loading assessments by DENR (1999) have shown that, based on actual summer effluent data from 1998 and 1999, 90% of the total point source based oxygen demanding pollutant load to the estuary comes from three facilities – International Paper (NPDES NC0003298), Wilmington Northside WWTP (NPDES NC0003298), and Wilmington Southside WWTPs (NPDES NC0003298). Brief correspondence with the DENR NPDES Permitting Unit indicated that these facilities remain the bulk of total discharge in the LCFRE. For that reason, the analysis is focused on those three point sources.

For each of the facilities, monthly loads of BOD5 and ammonia were estimated using monitoring data. In most cases, BOD5 and ammonia were reported as a daily concentration. Daily load was calculated on days where both daily concentration and daily flow data existed. The one exception was BOD5 from International Paper, which was already reported as a daily load. These daily loads were then averaged on a monthly basis, and multiplied by the number of days in the month to obtain the monthly load. There were a few cases where monthly loads had to be estimated differently:

- Daily discharge data for BOD5 and ammonia were not available from DENR for the Wilmington Southside facility during 1999. As a result, City of Wilmington monthly discharge data were used for this period. The 1999 monthly loads were estimated for the previous 2003 trend analysis memo, and were used in this analysis as well.
- Ammonia data were not reported on a routine basis between January 1994 and January 1997 at International Paper; rather, three monthly values were available during each of the three years spanning 1994 – 1996. Yearly averages were calculated from the available months, and missing values were set equal to the average from the same year; January 1997 was set equal to the average for 1996. A total of 28 values were estimated using these methods.

- Data were not available to estimate BOD5 during November 2001 at International Paper and May 2005 at Wilmington Southside. There was also an apparent reporting error for January 1997 at International Paper, with average BOD5 reported about two orders of magnitude lower than typical values. In each case, values were estimated by taking the average of the value for the previous month and the subsequent month.

Monthly BOD5 loads were converted to CBODu using multipliers inferred from graphs provided in Bowen et al. (2009). A multiplier of 5.65 was used for International Paper based on the combined average from two long term BOD studies. The multiplier for the Wilmington Southside facility long term BOD measurement was estimated as 3.0. The near detection low level of long term BOD measurement for the Wilmington Northside facility prevented estimating a multiplier from the graph with sufficient confidence, so 3.0 was used to be consistent with the Southside value. Monthly ammonia loads were converted to NBODu using a multiplier of 4.5 (the stoichiometric ratio for the amount of DO required for the oxidation of ammonia). The estimated monthly CBODu loads for each of the three facilities are shown in Figure 7 through Figure 9, and monthly NBODu loads are shown in Figure 10 through Figure 12.

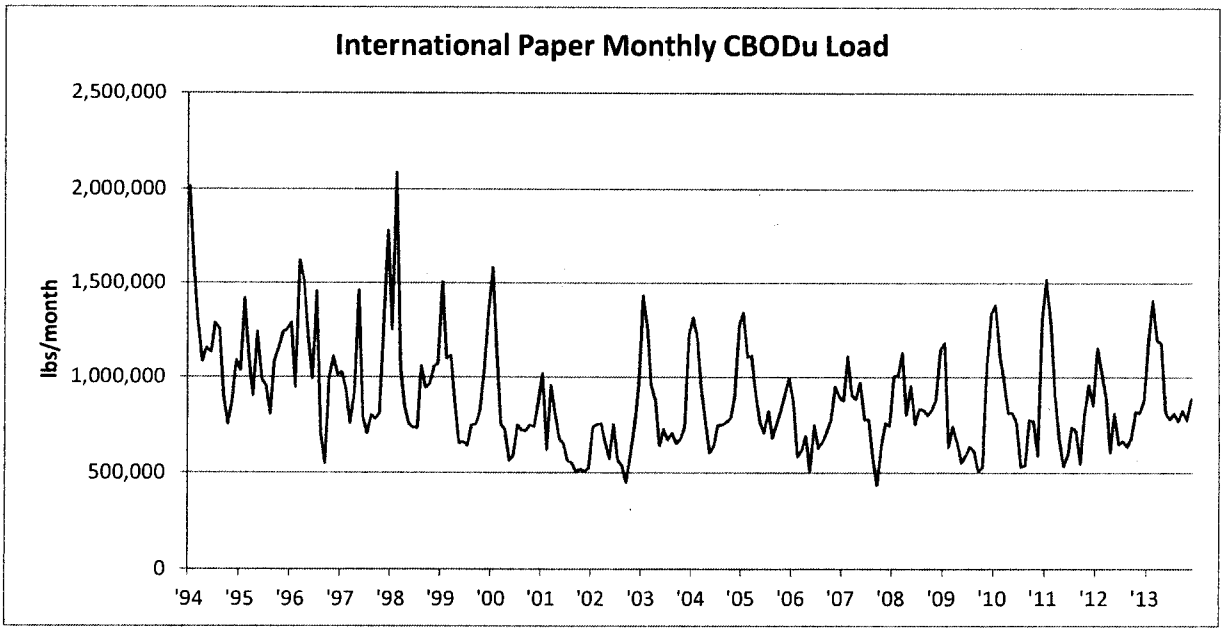

Figure 7. Estimated Monthly CBODu for International Paper

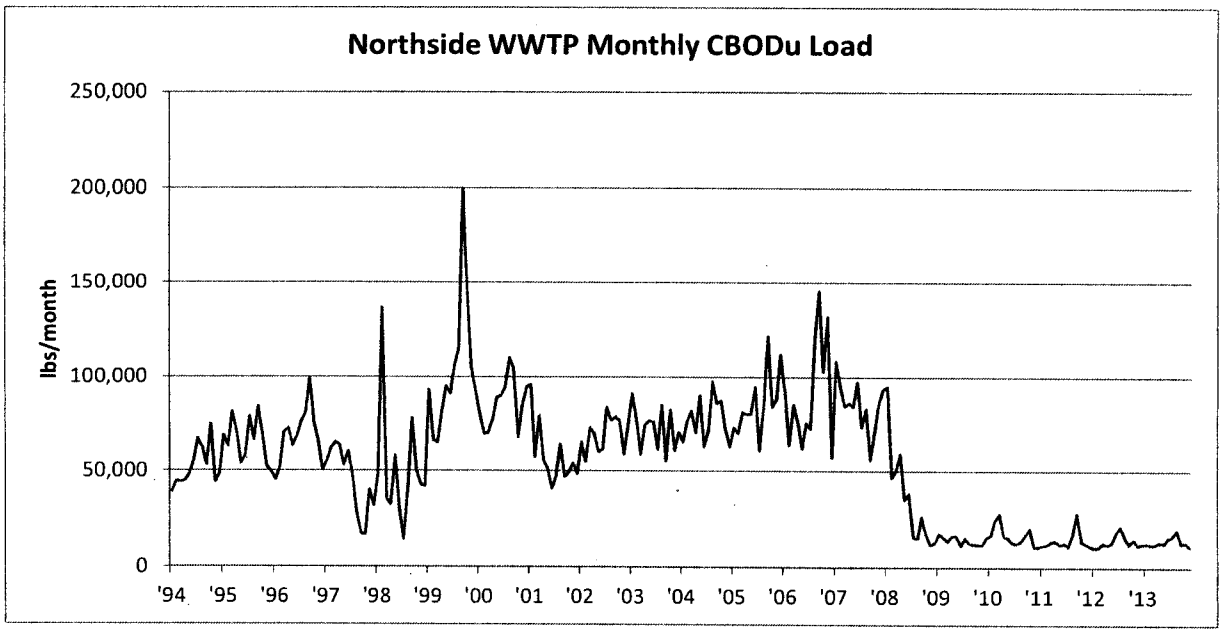

Figure 8. Estimated Monthly CBODu for Northside WWTP

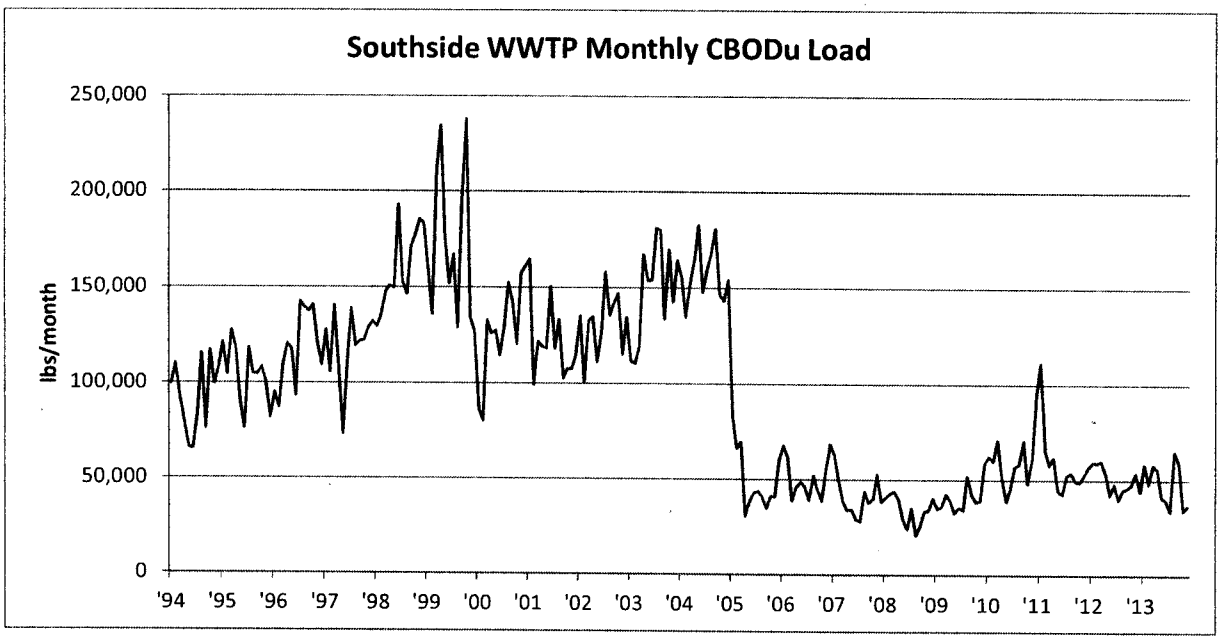

Figure 9. Estimated Monthly CBODu for Southside WWTP

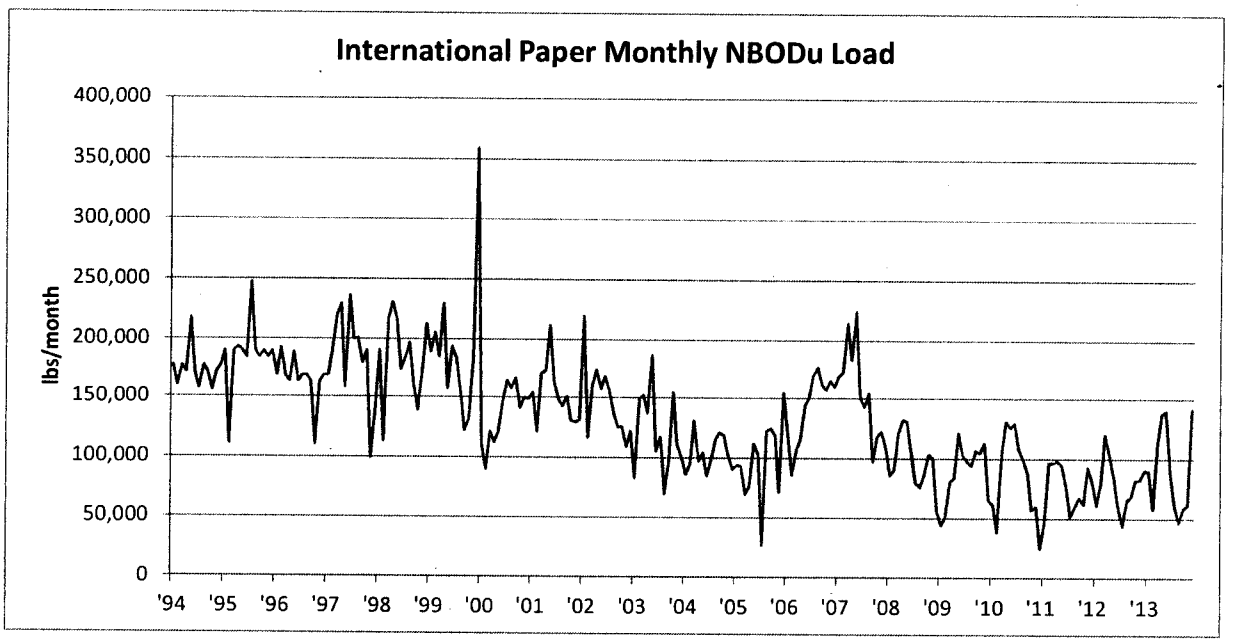

Figure 10. Estimated Monthly NBODu for International Paper

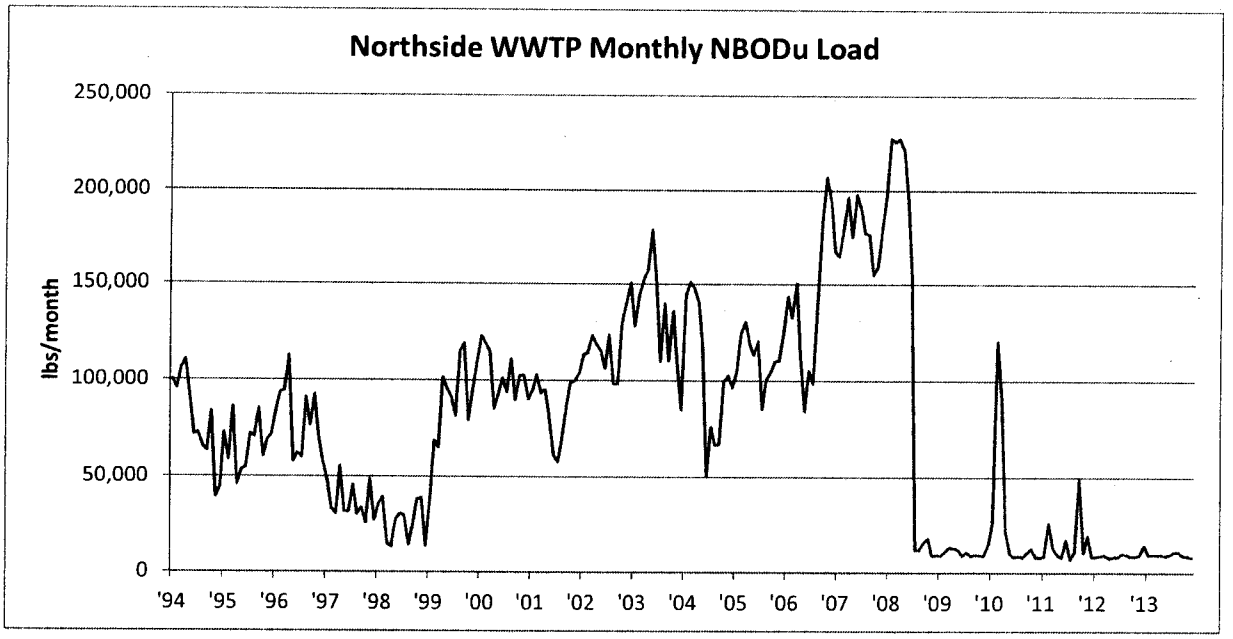

Figure 11. Estimated Monthly NBODu for Northside WWTP

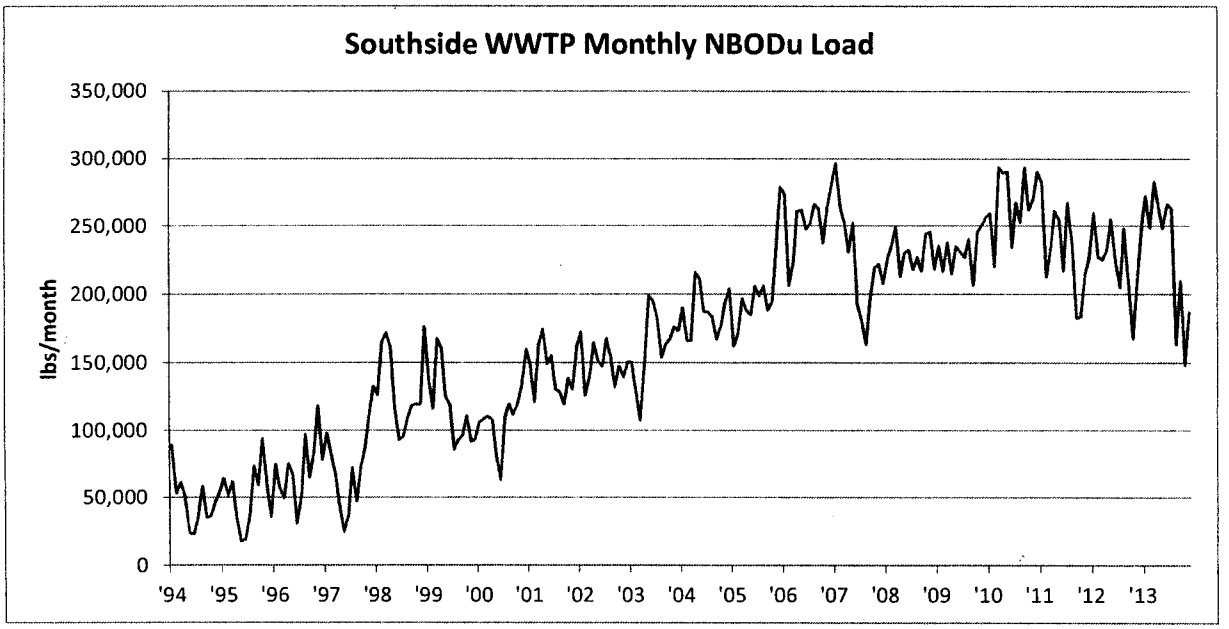

Figure 12. Estimated Monthly NBODu for Southside WWTP

3 Trend Analysis

3.1 Statistical Tests

The USGS Kendall Program (Helsel et al., 2006) was used to perform the statistical trend analysis on the DO and BODu monitoring data. Specifically, the Seasonal Kendall test was selected within the USGS Kendall Program for the trend analysis because seasonality is present in the both the ambient DO and BODu data, and the Seasonal Kendall test accounts for autocorrelation across seasons. Also, the Seasonal Kendall test allows for missing values and does not require complete years of data (i.e., bias in not introduced). Additional background on the statistical methods applied is provided in Attachment A. DO is known to show a seasonal pattern, but seasonality in BOD should be confirmed prior to conducting the test. CBODu and NBODu were summed across the three point sources to develop an overall point source estimated BODu time series. Average monthly BODu was then calculated across the monitoring period of 1994 – 2013. As seen in Figure 13, there is clearly a seasonal pattern in BODu loads to the Cape Fear Estuary.

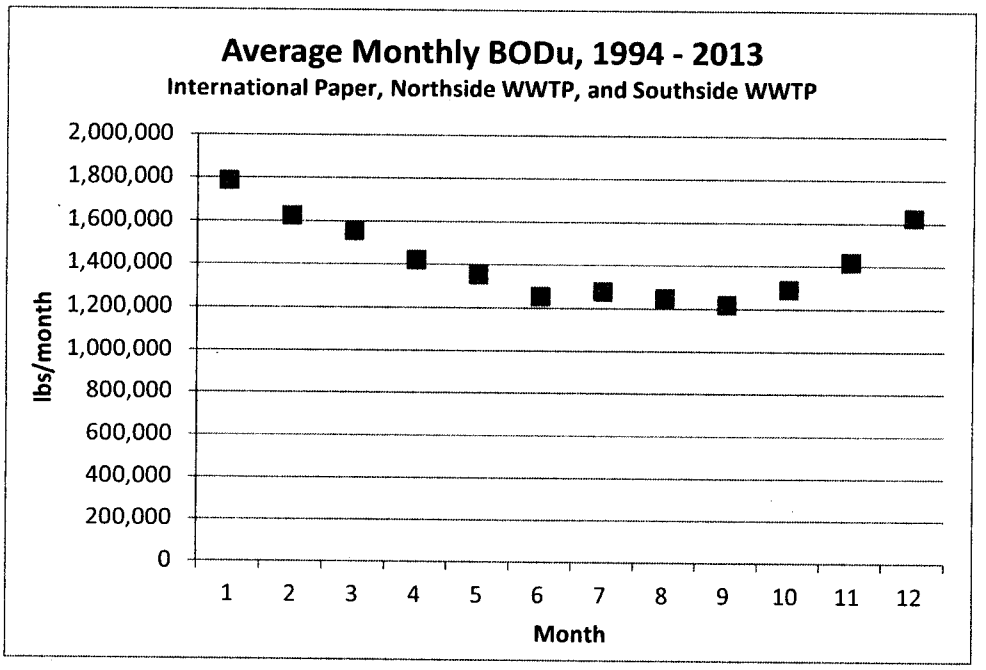

Figure 13. Estimated Average Total Monthly BODu to Cape Fear Estuary, 1999 - 2013

The Seasonal Kendall test was performed on the total BODu time series, using "seasons" defined by months. Monthly seasons are typically used for the Seasonal Kendall test; while seasons of a different duration can be used (e.g., bi-weekly, quarterly), the Seasonal Kendall test was developed using monthly data, and much of the guidance on minimum period of record and adjusting for autocorrelation is focused on using monthly data (Hirsch et al., 1981). In the previous trend analysis, quarterly data were used to reduce seasonal autocorrelation associated with monthly data. However, the USGS Kendall program calculates a modified version of the test statistic that accounts for the autocorrelation, so the data did not require any adjustment for the analyses conducted for this memorandum.

For total BODu, the Seasonal Kendall test indicated a trend of strong statistical significance, with a *p*-value adjusted for autocorrelation of 0.0034; any *p*-value less than 0.05 is considered significant with 95 percent confidence. The trend calculated using Sen's slope estimator (Sen, 1968) was -18,340 lbs/month; in other words an overall annual reduction of 220,080 lbs/yr. A plot of estimated total BODu with the trend superimposed is shown in Figure 14. An additional test was conducted using BODu for a reduced time period (2003 – 2013) to check whether the trend has continued since publication of the previous trend analysis. The adjusted *p*-value was 0.0143, indicating a highly significant trend for the reduced time period, and the magnitude was actually higher at -32,730 lbs/month.

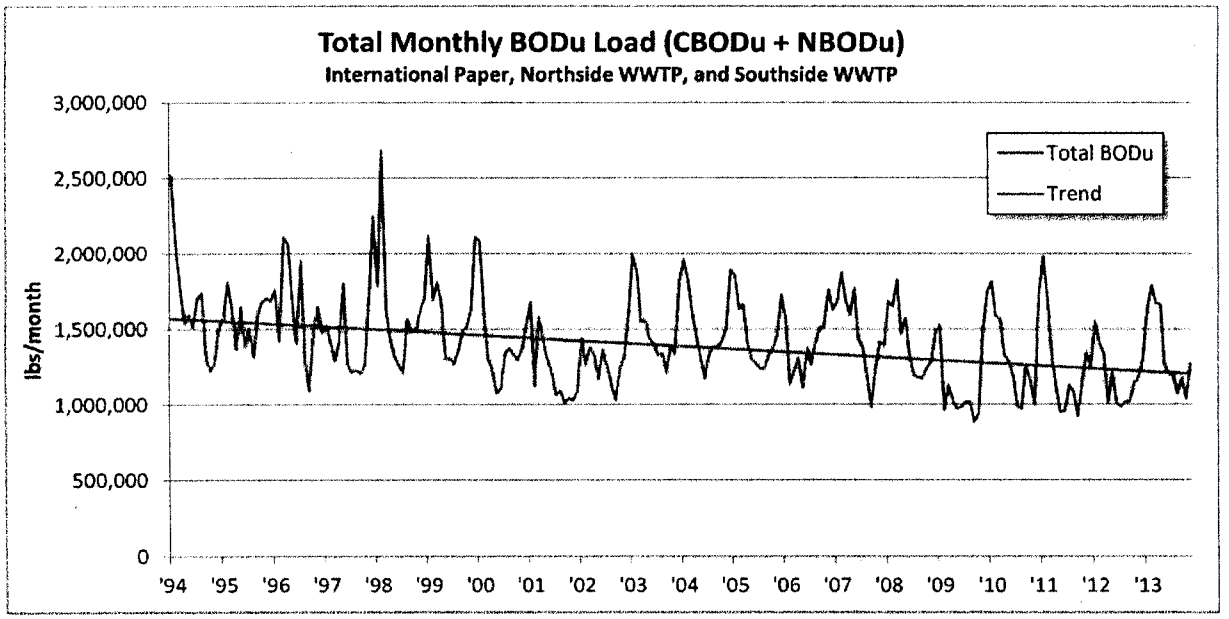

Figure 14. Estimated Total Monthly BODu to Cape Fear Estuary, with Reported Trend

Seasonal Kendall tests were then performed for DO at each of the five stations for the periods of record shown in Table 1. In all cases, the null hypothesis of no trend could not be rejected – in other words, a finding of no trend. The *p*-values adjusted for autocorrelation did not indicate anything close to statistical significance (Table 2). The tests were repeated for reduced time periods of 2003 – 2013 to test for any trend following publication of the previous trend analysis. Again, no trends were found and all the adjusted *p*-values did not show any statistical significance.

Table 2. Results of DO Trend Analysis Showing No Trend of Significance

Station ID	*p*-value, full period of record	*p*-value, 2003 – 2013
B9020000	0.5026	0.9238
B9050000	0.6853	0.4310
B9740000	0.1532	0.9334
B9800000	0.4823	0.9159
B9820000	0.1342	0.8636

3.2 CONCLUSIONS

This memorandum supports the same finding as the previous analysis conducted in 2003. A significant downward trend was detected in the total oxygen demanding pollutant loads from the three facilities that comprise roughly 90 percent of all point source loads to the LCFRE, while no corresponding trend was found in DO monitoring data at five separate LCFRE stations. During the 20 years of point source load monitoring included in this analysis, the total estimated BODu load from the three facilities has declined about 23 percent as indicated by the trend estimate.

References

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin, and J. Williams. 2009. *Development and Use of a Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the Lower Cape Fear River Estuary, North Carolina*. Department of Civil and Environmental Engineering, University of North Carolina at Charlotte.

Helsel, D.R., D.K. Mueller, and J.R. Slack. 2006. *Computer Program for the Kendall Family of Trend Tests*. Scientific Investigations Report 2005-5275. U.S. Geological Survey. Reston, VA.

Hirsch, R.M., J.R. Slack, and R.A Smith. 1982. Techniques of trend analysis for monthly water quality data. *Water Resources Research*. 18:107-121.

Mallin, M.A., M.H. Posey, M.L. Moser, G.C. Shank, M.R. McIver, T.D. Alphin, S.H. Ensign, and J.F. Merritt. 1997. *Water Quality in the Lower Cape Fear River System, 1996-1997*. University of North Carolina – Wilmington, Center for Marine Science Research. 255 pp.

North Carolina DENR. 1999. Point Source Loading Analysis Table prepared by Andy McDaniel for Presentation to Lower Cape Fear River Program Technical Committee. 2 pp.

Sen, P.K. 1968. Estimates of the regression coefficient based on Kendall's tau. *Journal of the American Statistical Association*. 63:1379-1389.

Tetra Tech. 2003. Technical Memorandum: Results of Dissolved Oxygen and Pollutant Loading Trend Analyses. Submitted to Hugh Caldwell, Ken Vogt, and Wyatt Blanchard from Trevor Clements and Jason Doll. January 16, 2003.

Attachment A – Background on Statistical Methods

The Seasonal Kendall test (Hirsch et al., 1982) and Sen's nonparametric slope estimator (Sen, 1968) were used to test for the presence of a statistically significant trend. Background information outlining the technical basis for the selection of these methods is provided below.

The nonparametric Mann-Kendall test for trend (Mann, 1945; Kendall, 1975) forms the basis of a method that is frequently used for trend analyses performed on water quality monitoring data – the Seasonal Kendall Test. The method was developed and popularized by USGS researchers throughout the 1980s (Hirsch et al., 1991), and USGS published computer code supporting its use.

Mann-Kendall is especially useful for detecting trends in environmental variables for several reasons:

- The test is nonparametric, and the data do not need to be normally distributed.
- Missing values are allowed; gaps are simply ignored.
- Data reported at the detection limit can be used without censoring, so long as the values are set lower than the smallest observation.

This is all possible because Mann-Kendall looks only at the relative magnitudes of sequential data, so the type of distribution, gaps, and the assumptions used for non-detects become irrelevant. The test does, however, assume that the data are not serially correlated, an assumption frequently violated by environmental monitoring data. Serial correlation (also called autocorrelation) occurs when data points are not independent from each other. Monitoring data tend to show positive serial correlation, meaning that positive errors (about the mean) in one time period are associated with positive errors in adjacent time periods (and negative errors are associated with adjacent negative errors).

The Seasonal Kendall test is a generalization of the Mann-Kendall test, developed by Hirsch et al. (1982). In its original application, data were divided into 12 "seasons", with each month representing a season. Missing values are allowed (as is the case with the Mann-Kendall test), and complete years of all 12 seasons are not required. The Mann-Kendall test statistic and its variance are calculated separately on each season. The statistics are summed and a Z statistic computed, which is compared to the standard normal tables. The null hypothesis HO is there is no trend, while the alternative hypothesis HA is either an upland or downward trend (a two-tailed test). Serial correlation among values within a season can be addressed by a modification of the test statistic (Hirsch and Slack, 1984). The modification is recommended in cases where there are 10 or more observations per season (i.e., 10 years of data if seasons are defined monthly) due to difficulties accurately determining covariance for fewer data.

A slope can be calculated as well for the Seasonal Kendall test. The slope is based on Sen's nonparametric slope estimator (Sen, 1968). The method estimates a series of slopes between values from the same season. The Seasonal Kendall slope is the median of this series of slopes.

The USGS Kendall Program (Helsel et al., 2006) was developed to address a gap in publically available software for estimating trends using the Seasonal Kendall test and other Kendall tests. In the 1980s USGS popularized Kendall methods, and USGS published computer code supporting its use in popular statistical packages. However, in later years as statistical analysis moved to desktop computing, the code became difficult to execute without purchase of commercial statistical software. As a result, USGS repackaged the code into an executable program which can be used on computers supporting DOS or DOS emulation. The USGS Kendall program is freely available from a USGS website.

Helsel, D.R., D.K. Mueller, and J.R. Slack. 2006. *Computer Program for the Kendall Family of Trend Tests.* Scientific Investigations Report 2005-5275. U.S. Geological Survey. Reston, VA.

Hirsch, R.M., J.R. Slack, and R.A Smith. 1982. Techniques of trend analysis for monthly water quality data. *Water Resources Research*. 18:107-121.

Hirsch, R.M., R.B. Alexander, and R.A. Smith. 1991. Selection of methods for the detection and estimation of trends in water quality. *Water Resources Research*. 27:803–813.

Kendall, M.G. 1975. *Rank Correlation Methods*. 4th ed. Charles Griffin, London.

Mann, H.B. 1945. Non-parametric test against trend. *Econometrica*. 13:245-259.

Sen, P.K. 1968. Estimates of the regression coefficient based on Kendall's tau. *Journal of the American Statistical Association*. 63:1379-1389.

Technical Memo: Task 3 - Analysis of Water Quality Data at Cape River Estuary Model Boundaries

Prepared for

Lower Cape Fear River Program

Prepared by

CH2MHILL®

February 25, 2014

1 Introduction

Since 1998, the section of the Lower Cape Fear River Estuary (LCFRE) from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut has been listed on the State of North Carolina's 303d List as impaired for dissolved oxygen (DO). Since the original listing for DO, many technical studies of the LCFRE have been conducted by the North Carolina Department of Environment and Natural Resources (DENR), the Lower Cape Fear River Program (LCFRP), other agencies and academic researchers, and consultants. As a result, an extensive technical foundation of knowledge on the LCFRE has been created, including information on physical, chemical, and biological features and processes. Monitoring programs have provided insight regarding ambient conditions over many years on water quality, benthos, and fish. Additionally, sophisticated three-dimensional (3D), hydrodynamic modeling tools have been developed for the entire estuary and the portion of the river beginning at Lock and Dam #1 (L&D1) (Tetra Tech, 2001; Bowen et al., 2009).

The modeling results indicate that point-source discharges have little impact on DO levels, and that even significant reductions in background (both natural and nonpoint source) loads would not result in attainment of the current standard at all times. DENR has also agreed with representatives of the LCFRP that a more thorough understanding of natural and anthropogenic sources of oxygen deficit is needed.

This technical memorandum (TM) presents an analysis of water quality parameters at the points representative of inflows to the system, with the purpose of examining issues related to a supplemental DENR "Swamp" classification for the estuary. This TM examines data related to key parameters, including nutrients, pH, and DO, that are related to the occurrence of low DO in the Cape Fear River.

1.1 Data Sources and Processing

The LCFRP has conducted monitoring in coordination with DENR since 1995, and a considerable amount of data is available prior to that. There has also been extensive data collected by the Middle Cape Fear Basin Association (MCFBA) upstream of L&D1 since mid-1998 and the Upper Cape Fear Basin Association (UCFBA) since about 2000. Data for this evaluation were downloaded from the Cape Fear River Basin Monitoring Coalitions Water Quality Data website (accessible at http://www.cormp.org/CFP/CFP_map.php) and the U.S. Environmental Protection Agency's (USEPA's) STOrage and RETrieval (STORET) Data Warehouse (2012accessible at http://www.epa.gov/storet/). The primary stations of interest for this evaluation were:

- B8360000 Cape Fear River at NC 11 near East Arcadia (downstream of L&D1)
- B9670000 Northeast (NE) Cape Fear River near Wrightsboro
- B9000000 Black River at NC 210 at Still Bluff
- B9050000 Cape Fear River at Navassa

These stations (shown in Figure 1) represent the water quality conditions at the main inflows to the system: the Middle Cape Fear River, the Black River, and the NE Cape Fear River, and coincide with the boundary conditions of the 3D hydrodynamic model developed for the system. The station at L&D1 represents water quality in the Cape Fear River as water leaves the Sandhills and enters the coastal area. The NE Cape Fear and Black River stations measure water quality as water leaves areas currently classified as swamps. The Cape Fear monitoring station at Navassa is included in the analysis, as it reflects the changes in water quality as a result of the confluence of the middle Cape Fear River and Black River. While data is available at a number of other stations, such as B980000 (Cape Fear River at Channel Marker 61), they were not used for this analysis. The data would also capture the changes as a result of the inflow of the NE Cape Fear River, but would also more directly reflect the influence of tidal flows.

Figure 1. Location of Stations used for Evaluation of Boundary Conditions

The data were downloaded from the Cape Fear River Basin Monitoring Coalition's Water Quality Data and USEPA's STORET websites in February 2014. Data downloaded included all data available for these sites at that time. Parameters evaluated for this analysis include DO, nitrate-nitrite (NO_2-NO_3), total Kjeldahl nitrogen (TKN), pH, total phosphorus (TP), and ammonia (NH_3). Data were processed to identify measurements collected during the summer period (April through October) to focus on critical DO periods. The dataset was also processed to only evaluate surface grab samples. Depth-stratified monitoring showed little vertical stratification, and inclusion of all data would have skewed results toward deeper locations with more samples per event. Finally, data were averaged on a monthly basis to simplify the comparison and reduce the effects of any outliers.

1.2 RESULTS

The water quality monitoring data was evaluated using basic statistics, as well as time series plots. The statistics provide a long-term evaluation of water quality; whereas, the time series plots allow for identification of key periods and the relative difference in water quality between stations in more detail. Table 1 provides a summary of the basic monthly summer (April through October) statistics for the stations of interest.

Review of the data shows distinct differences in water quality between the Cape Fear River at L&D1 and the major tributaries, the Black River, and NE Cape Fear River. The average summer (April through October) monthly DO level at L&D1 is greater than 7 mg/L; whereas, as the DO levels in the Black River are nearly 2 mg/L lower at 5.19 mg/L and more than 2 mg/L less in the NE Cape Fear River at 4.96 mg/L. This primarily reflects the low DO found in these swamp areas but it is important to note that the DO below L&D 1 maybe somewhat influenced by reaeration from the dam.

The influence of the Black River and the NE Cape Fear River on the Cape Fear River mainstem can also be seen in the summer (April through October) monthly average NO_2-NO_3 and TP values. Concentrations of both of these constituents are higher at L&D1 when compared to the other stations. The addition of the flows from the tributaries significantly reduces the concentrations, as is seen at Navassa.

A number of time series plots were generated to assess changes in these constituents over time and to also provide a method to compare stations in a more detailed fashion. The plots for each constituent and a brief discussion is provided in Figures 2 through 7.

The DO time series (Figure 2) shows that summer (April through October) DO levels at L&D1 are greater than 5 mg/L the majority of the time. Only one event fell below 4 mg/L, which corresponded to Hurricane Fran. Summer (April through October) DO levels in the NE Cape Fear River are significantly lower at all times. The lowest observed DO in the NE Cape Fear River coincides with Hurricane Fran in 1996, Hurricane Bonnie in 1998, and Hurricane Floyd in 1999. While DO levels at L&D1 show some decrease during these events, a more significant effect is seen at the tributary stations and at Navassa. In general, the NE Cape Fear River shows the lowest DO levels, with levels at Navassa being second lowest. This suggests that inflow from the NE Cape Fear River and the swamps it drains has a significant impact on DO levels in the Cape Fear River mainstem. DO in the Black River tends to be more moderate, typically being less than concentrations at L&D1 but not as low as in the NE Cape Fear River. Inflow from the Black River is likely to have an impact but of a lesser magnitude. DO does not appear to show a negative or positive trend if the excursions related to hurricanes in the late 1990s are excluded.

Summer (April through October) nitrate-nitrite levels (Figure 3) are the highest at L&D1, receiving nitrate loading from upstream sources and atmospheric deposition. Nitrate is readily utilized in anoxic systems, such as swamps, as an oxygen source and can often fall below 0.1 mg/L. This is reflected in the low values seen in the Black River and the NE Cape Fear River. The levels at Navassa reflect the inflow from these low nitrate areas, with levels in the Cape Fear River dropping from those seen at L&D1. Nitrate-nitrite concentrations appear to show a slight positive trend in recent years at L&D1 and Navassa.

Table 1. Summary of Monthly Water Quality Statistics for Summer Periods (April through October)

	Cape Fear River at L&D1	Black River at NC 210 at Still Bluff	Cape Fear River at Navassa	NE Cape Fear River near Wrightsboro
DO				
Minimum (mg/L)	3.60	1.20	0.85	0.10
Maximum (mg/L)	10.10	8.00	9.20	8.50
Average (mg/L)	7.14	5.19	5.10	4.96
NO_2+NO_3-N				
Minimum (mg/L)	0.01	0.01	0.00	0.01
Maximum (mg/L)	1.58	0.52	1.14	0.51
Average (mg/L)	0.64	0.14	0.42	0.23
TKN-N				
Minimum (mg/L)	0.10	0.20	0.10	0.10
Maximum (mg/L)	2.00	2.00	1.50	2.10
Average (mg/L)	0.69	0.81	0.72	0.78
pH				
Minimum (mg/L)	5.30	4.80	5.60	5.00
Maximum (mg/L)	7.35	7.80	7.90	7.30
Average (mg/L)	6.61	6.13	6.87	6.63
TP				
Minimum (mg/L)	0.08	0.04	0.04	0.05
Maximum (mg/L)	0.61	0.36	0.31	0.36
Average (mg/L)	0.18	0.10	0.14	0.12
NH_3-N				
Minimum (mg/L)	0.01	0.01	0.01	0.01
Maximum (mg/L)	0.22	0.20	0.20	0.30
Average (mg/L)	0.07	0.05	0.07	0.05

Note:
mg/L - milligram per liter

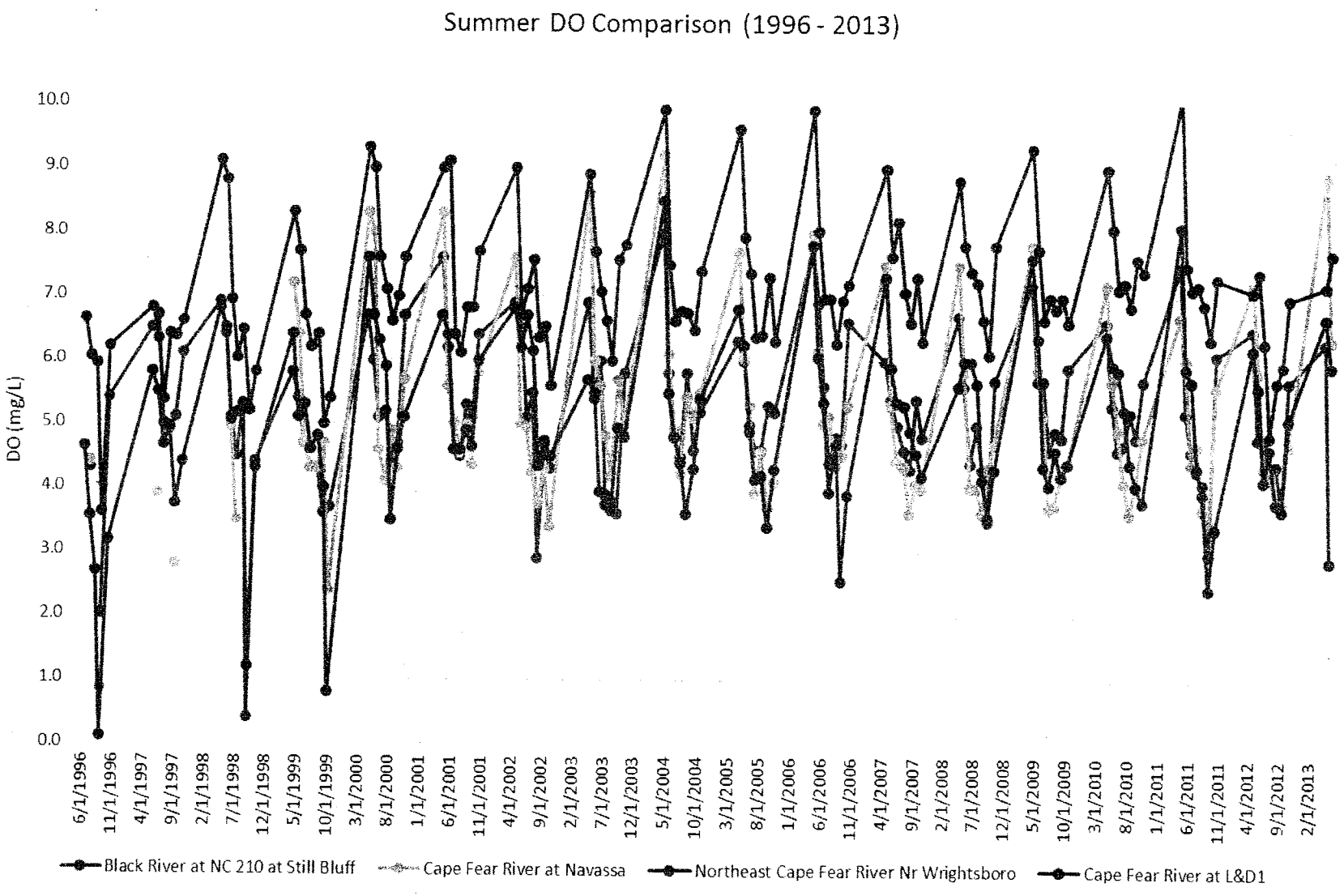

Figure 2. Dissolved Oxygen in the LCFRE (April through October Data Only)

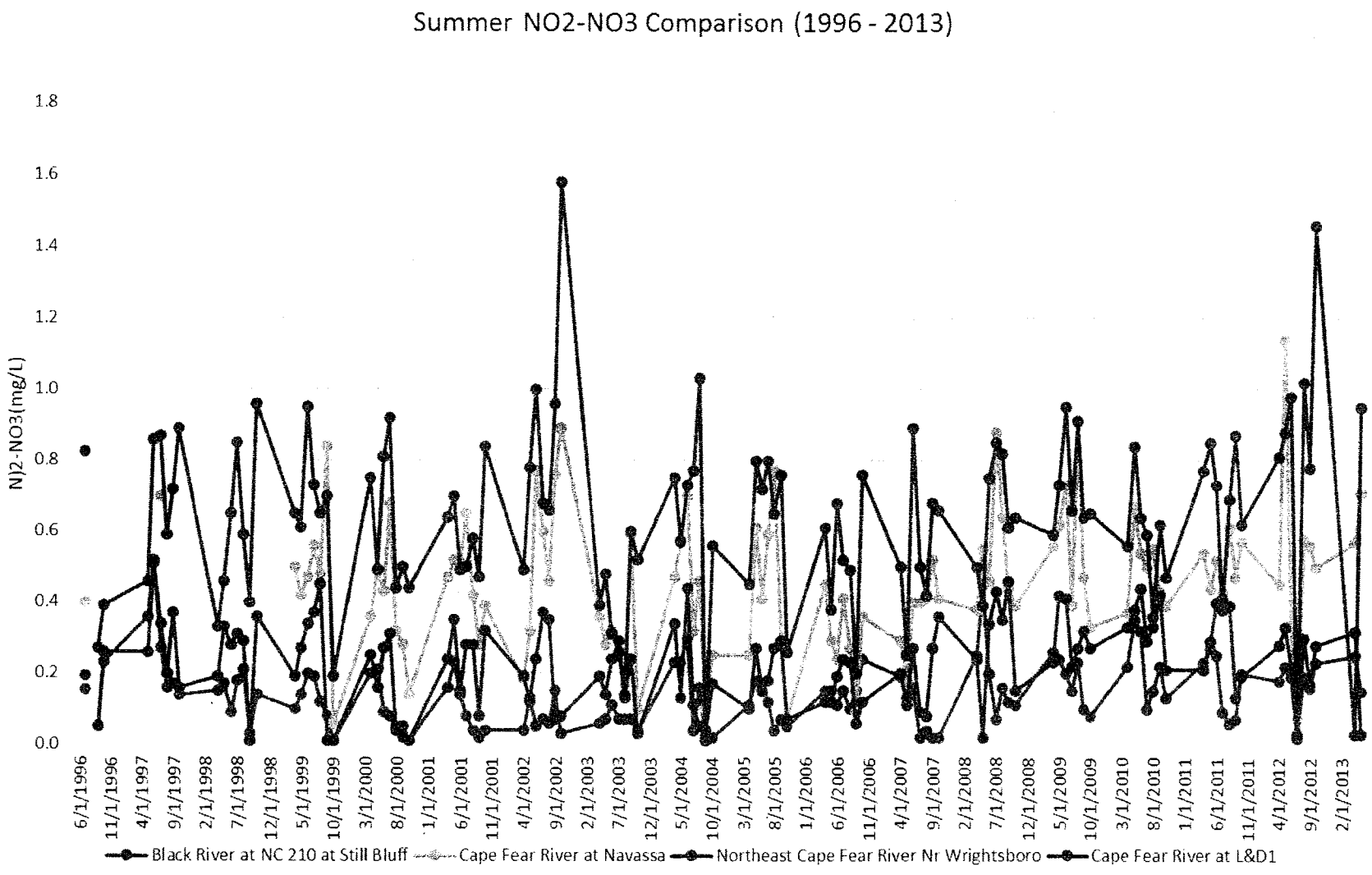

Figure 3. Nitrate-Nitrite in the LCFRE (April through October Data Only)

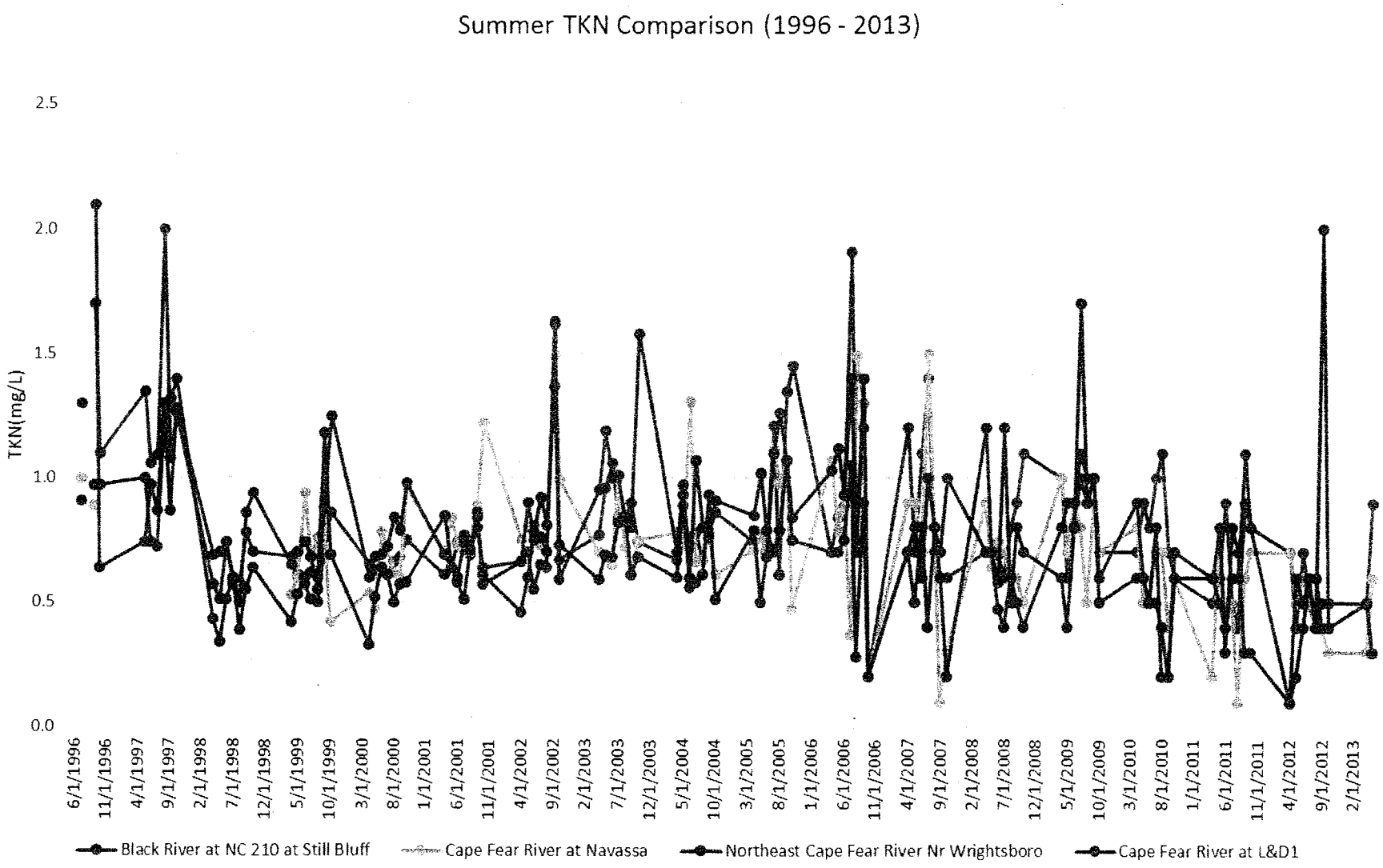

Figure 4. Total Kjeldahl Nitrogen in the LCFRE (April through October Data Only)

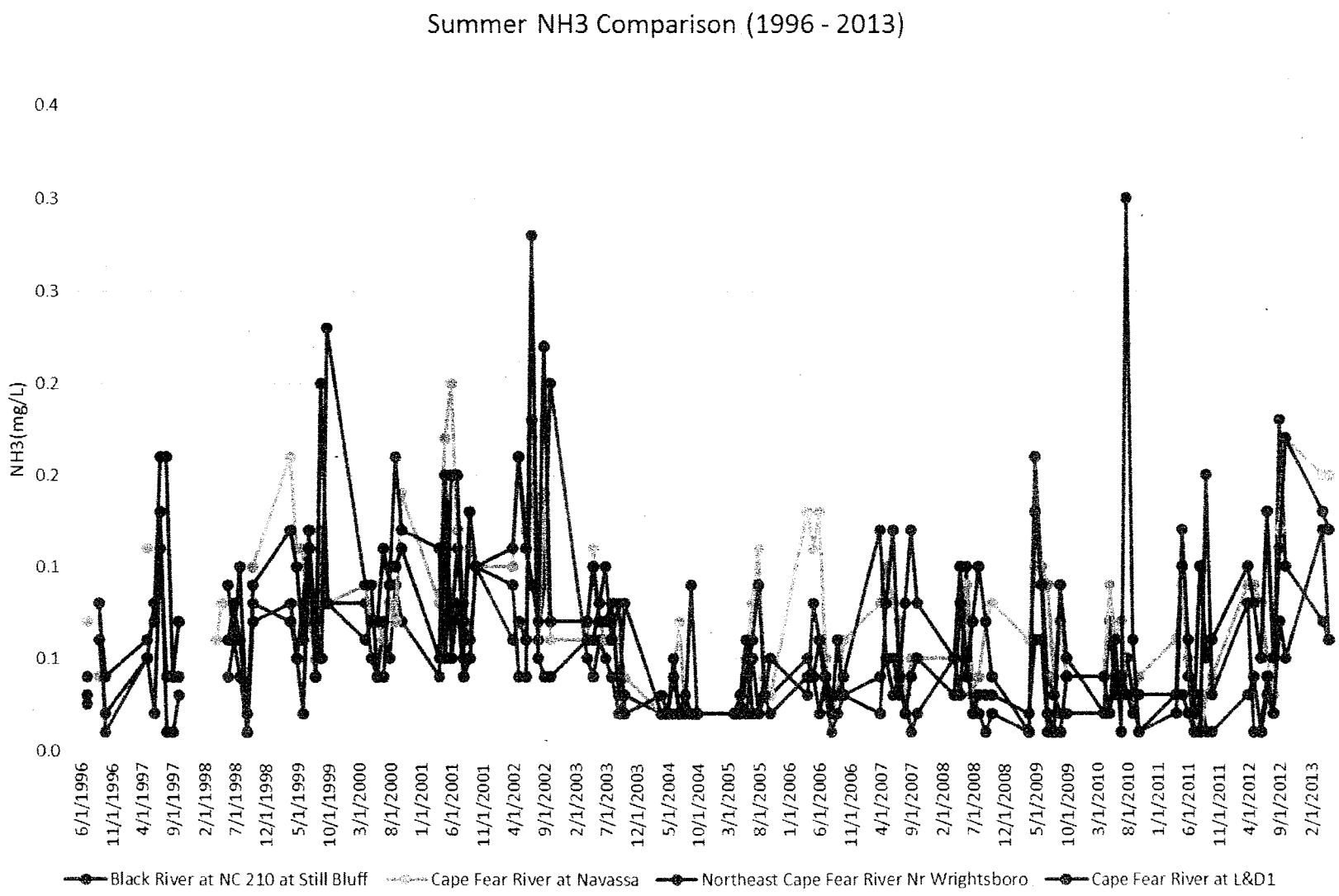

Figure 5. Ammonia in the LCFRE (April through October Data Only)

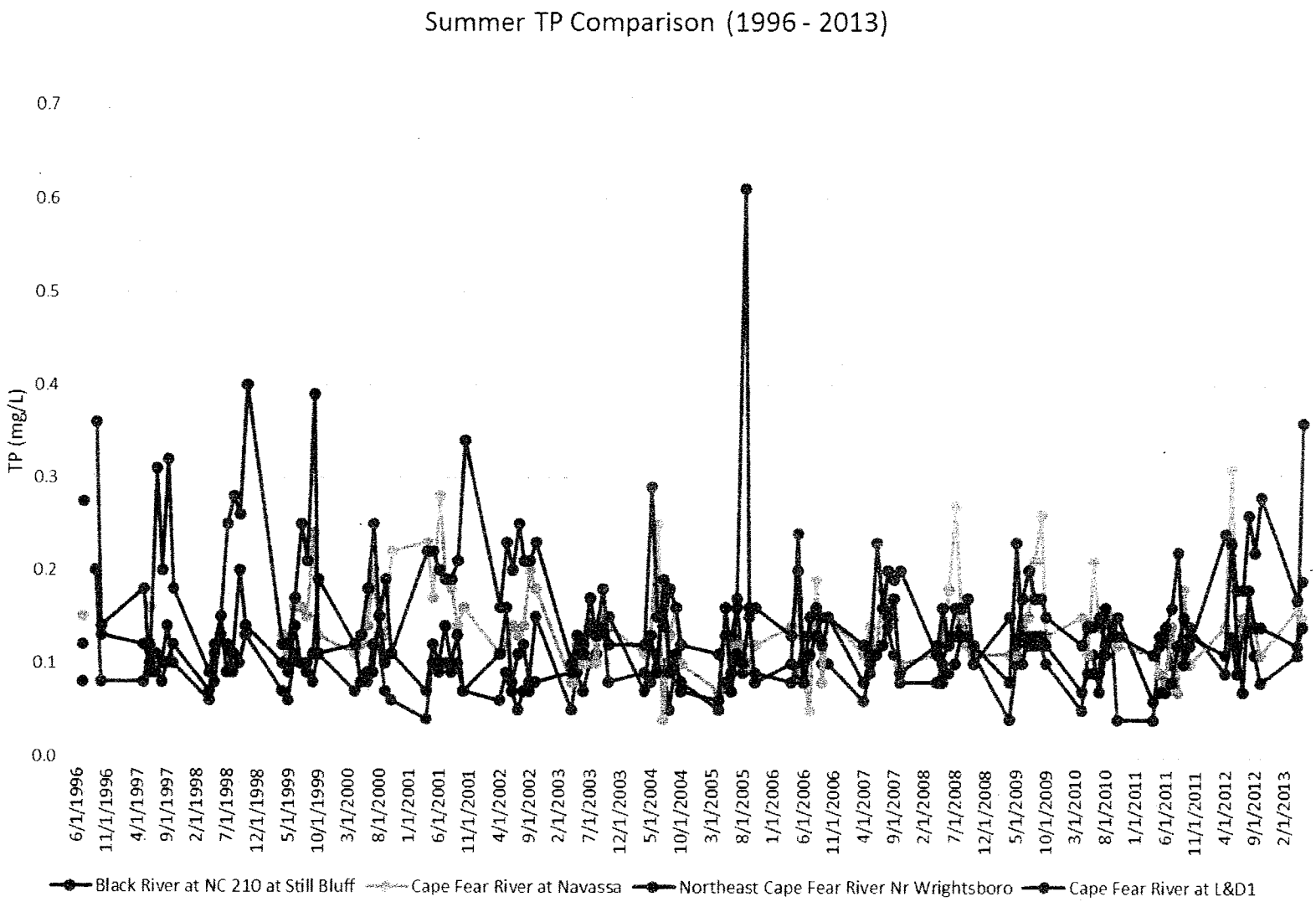

Figure 6. Total Phosphorus in the LCFRE (April through October Data Only)

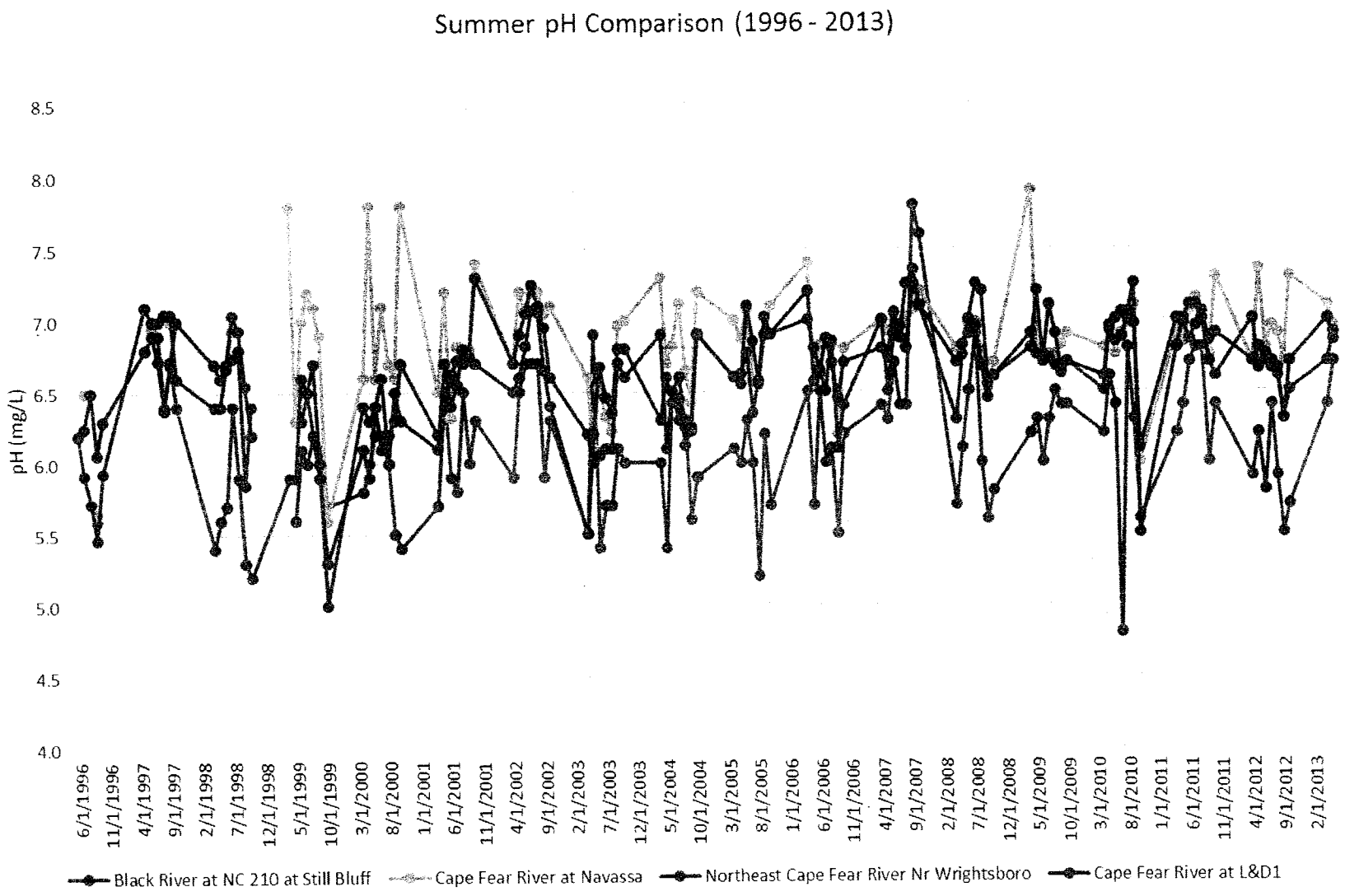

Figure 7. pH in the LCFRE (April through October Data Only)

The highest levels of summer (April through October) TKN (Figure 4) are typically seen in the Black River and reflect the organic load generated by the high biological productivity of the adjacent marsh areas. Levels at L&D1 are consistently the lowest, although a few high values do occur at this station. TKN levels appear to be trending lower in recent years.

Summer (April through October) ammonia levels (Figure 5) at all stations were relatively similar and typically less than 0.1 mg/L. Ammonia is readily utilized for primary production, so ammonia loads are quickly transformed into organic matter. Ammonia levels appear to have dropped since 2002, with a slight increase in 2012.

Summer (April through October) phosphorus levels (Figure 6) at all stations were relatively similar and typically less than 0.2 mg/L. Phosphorus is utilized for primary production but is not the limiting nutrient in estuarine systems. Phosphorus levels in the Cape Fear River appear to have dropped since 2002, with a slight increase in 2012.

The sum er summer (April through October) pH levels (Figure 7) at the boundary stations show an interesting pattern. The lowest levels are consistently seen in the Black River with levels often less than 6 standard units. This is typical for swamp areas where decomposition of organic matter results in the occurrence of high levels of humic acids. Levels in the NE Cape Fear River are higher than in the Black River, suggesting that the vegetation and substrate is different between the two drainages. The highest levels are at Navassa. The pH at L&D1 and NE Cape Fear are fairly similar, with the L&D1 values being approximately 0.5 standard units higher. The Cape Fear River is listed for pH impairment. A review of Figure 7 shows that the low pH excursions may be naturally occurring. Levels in the Black River are typically less than 6.5 standard pH units, and frequently fall below 6.0 standard units. A coinciding drop of pH at Navassa is seen during these periods, supporting the conclusion that low pH in the Cape Fear is driven by an influx of low pH waters from adjacent swamp areas.

2 Conclusions

The evaluation of water quality data at the boundary conditions supports the concept that inflows from the swamp areas have a significant impact on water quality in the Cape Fear River. The levels of nutrients, DO, and pH are consistently different between the station at L&D1, and in the Black River and the NE Cape Fear River. A distinct response from these inflows can be seen in the levels at Navassa for these parameters, supporting the idea that water quality in the Cape Fear River is dominated by the conditions found in the swamp areas below L&D1.

3 Works Cited

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin, and J. Williams. 2009. Development and Use of a *Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the Lower Cape Fear River Estuary, North Carolina.* Department of Civil and Environmental Engineering, University of North Carolina at Charlotte.

Cape Fear River Basin Monitoring Coalition. Water Quality Data website. http://www.cormp.org/CFP/CFP_map.php. Accessed February 3, 2014.

Tetra Tech. 2001. 3-Dimensional EFDC Water Quality Model of the Lower Cape Fear River and its Estuary. Prepared for the City of Wilmington and New Hanover County, North Carolina. May, 2001.

U.S. Environmental Protection Agency (USEPA). 2012. STOrage and RETrieval (STORET) Data Warehouse. April 20. http://www.epa.gov/storet/. Accessed February 3, 2014.

Technical Memo: The Relationship of Adjacent Wetlands and Salt Marsh to Dissolved Oxygen in the Lower Cape Fear River Estuary

Prepared for

The Lower Cape Fear River Program

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February 21, 2014

1 Introduction

The Lower Cape Fear River Program (LCFRP) is a large-scale water quality and environmental assessment program covering the Cape Fear River Estuary and a large portion of the lower Cape Fear River watershed. The LCFRP represents a collaboration of academia, government, industry, and the public, which has been coordinating with the North Carolina Department of Environment and Natural Resources (DENR) since 1995. The purpose of this memo is to summarize previous water quality modeling performed to analyze the impact that adjacent wetlands and salt marsh areas in the Lower Cape Fear River Estuary (LCFRE) portion of the basin have on dissolved oxygen (DO) concentrations in that region. The memo was prepared as part of a joint LCFRP-DENR effort to summarize the existing body of technical evidence for submission to the North Carolina Environmental Management Commission (EMC) requesting reclassification of portions of the LCFRE into a supplemental "Swamp" designation— a designation which had been applied to the LCFRE from the late 1950's until the early 1980's.

Contents of the memo focus on two relatively extensive modeling studies. The first was completed in 2001 by Tetra Tech on behalf of the City of Wilmington and New Hanover County, prior to the formation of the Cape Fear Public Utility Authority (CFPUA). In that study, the physical link between wetlands, salt marshes, the main channel, water movement, and contributions to dissolved oxygen (DO) deficit was established (Tetra Tech, 2001). Follow up work by the University of North Carolina – Charlotte on behalf of NC DENR both confirmed and expanded on the link (Bowen, et. Al., 2009). The results of these modeling studies are summarized here to provide a significant part of the technical basis for reclassifying the portions of the LCFR with the supplemental "Swamp" designation.

2 Preliminary Modeling Effort (2001)

In the period between 2000 and 2001, efforts were made on behalf of the City of Wilmington and New Hanover County to develop an initial application of a three-dimensional hydrodynamic model (the Environmental Fluid Dynamics Code, or EFDC, model) with the intention of meeting several objectives deemed important at the time (Tetra Tech, 2001):

- Simulation of the mixing and transport of the existing and proposed future Wilmington Northside and Wilmington Southside wastewater treatment plant effluents.
- Simulation of the impact of existing and proposed future Northside and Southside facility pollutant loads for oxygen-demanding substances.
- Evaluation of multiple sources and cumulative loads of oxygen-demanding substances to the lower Cape Fear River estuary.
- Analysis of the various processes affecting dissolved oxygen and their relative contribution to ambient dissolved oxygen deficit levels.

EFDC was selected because it is versatile, peer reviewed, accepted and endorsed by the USEPA, available in the public domain, and could be used for 1, 2, or 3-dimensional (3-D) simulation of rivers, lakes, estuaries, coastal regions and wetlands. The 2001 model development was considered a scoping level effort with an end goal of providing model results to guide further, more expansive model development supporting long term water quality management of the LCFRE. Specifically, an important question at the time was whether a 3-D model or 2-D model would be needed for the anticipated Total Maximum Daily Load (TMDL) development planned for the estuary because of its inclusion on the State's 303(d) list of impaired waters for low dissolved oxygen in 1998 with low pH added in 2006.

2.1.1 Preliminary Model Approach

A vast amount of data characterizing the LCFRE system available from numerous agencies and organizations was drawn upon to set up, calibrate, and validate the initial 3-D EFDC model. An overview of the data used in the preliminary model setup and calibration listed by sources and associated types is provided below:

- National Oceanic and Atmospheric Administration – digital bathymetry, land surface elevations, and tide data.
- US EPA– Reach File 1.0 cross-sectional data; Reach File 3.0 river shoreline data.
- National Weather Service – atmospheric data including observations of wind speed, wind direction, barometric pressure, air temperature, rainfall and cloud cover.
- US Army Corps of Engineers – electronic navigational survey data; water level, current, temperature, and salinity data collected during extensive 3 month intensive survey in 1993.
- US Geological Survey – daily river flow data; dye dispersion study.
- LCFRP – ambient water quality data.
- NC DENR – ambient water quality data; NPDES discharge data; Long-term BOD analyses; Sediment Oxygen Demand (SOD) in-situ measurements.

Additionally, two extensive dye studies were conducted in December 1999 (Tetra Tech, 2001). Approximately 1,300 samples were collected for dye, salinity, and temperature throughout the estuary during the two studies. A fixed station was also monitored for water level, salinity, and temperature at 15-minute intervals for 10 days. In addition to providing data to support calibration of the hydrodynamic portion of the model, the dye studies provided a basis for examining near field mixing and far field transport of the existing effluents. During these initial field studies, movement of water into adjacent wetlands and salt marshes during flood portions of the tide, and drainage of these areas during the ebb portion of tides, was observed.

In the course of the subsequent EFDC model calibration, the previously set up model grid was enhanced through the addition of several areas of swamp grid cells to better represent the wetting and drying of floodplain wetlands and their effect on in-stream dissolved oxygen levels (Figure 1). Out of the revised total of 950 cells, 146 (~15%) were "marsh" cells with the remaining 804 modeled as "channel" cells. To evaluate the sensitivity of the model to the presence of the swamp areas, the model was run without the additional grid cells. Although there were not specific model calibration points in swamp only areas, the main model calibration points showed substantial improvement of model performance with the added representation of the marsh cells.

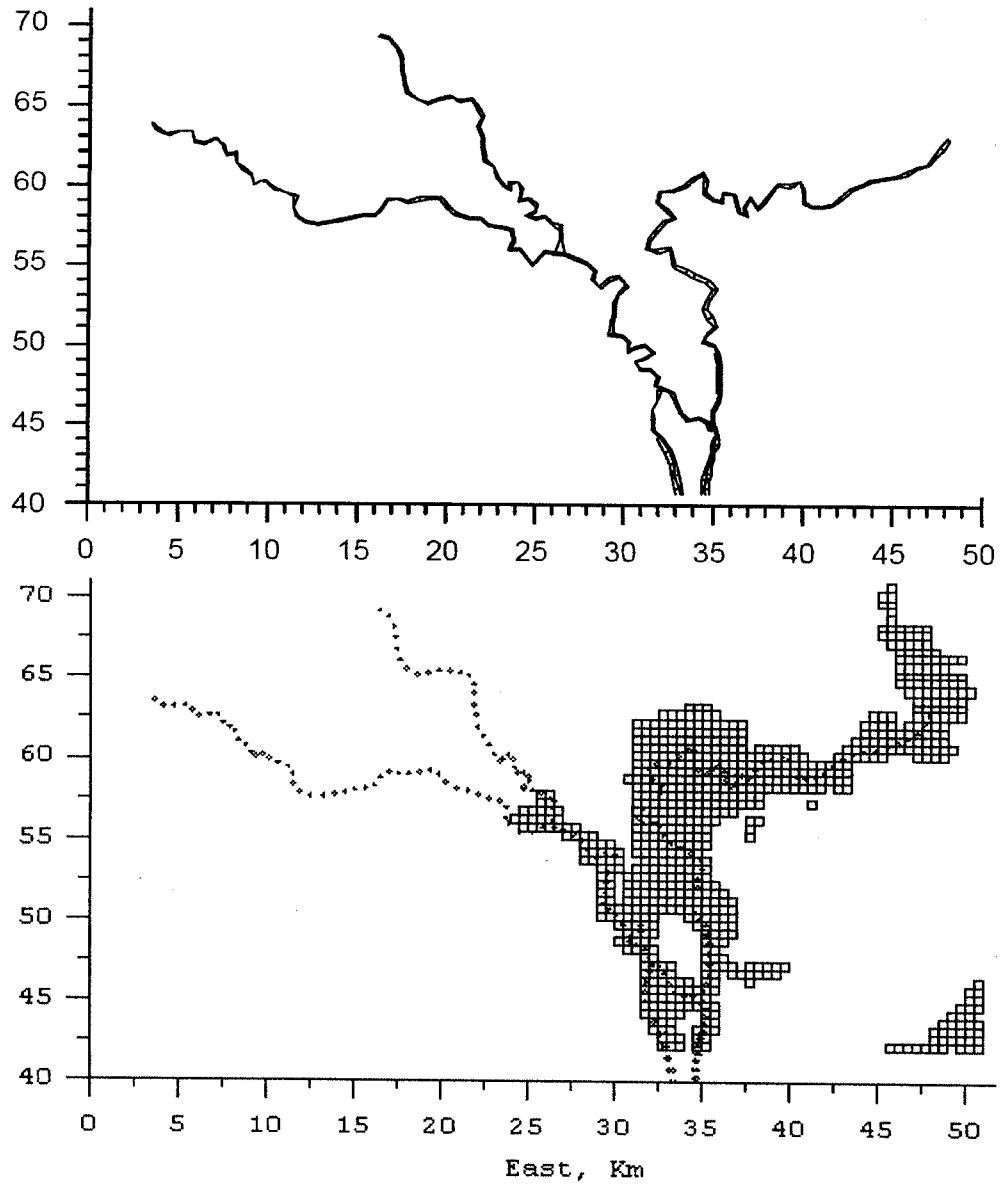

Figure 1. Upper Section of 2001 EFDC Model Grid Without, and With, Swamp Areas Delineated on the Basis of Elevation from the NOAA Coastal Relief Database

2.1.2 Preliminary Model Results

Results of multiple sensitivity analyses performed with the 2001 EFDC model for the LCFRE provided for a type of DO deficit component analysis. Results for July 19, 1998 were graphed in the study, and are shown below in Figure 2. July 19, 1998 was selected because it represented the day of lowest predicted DO for the baseline analysis prior to the effect of Hurricane Bonnie (i.e., a summer critical condition day). Each bar graph displays the model-predicted relative effect of each source of oxygen demand at five separate stations in the LCFRE for the simulated day of July 19. The bar graphs for the Navassa and Northeast Cape Fear River mouth stations (where observed DO concentrations are often the lowest during summer critical periods) show that SOD and swamp oxygen demand are predicted to account for between 73 and 84 percent of the total oxygen demand at those stations. SOD and swamp oxygen demand also comprised the majority of the total oxygen demands at other stations showing the importance of these

sources. Overall, the combined effect of SOD and swamp oxygen demand was predicted to be between 3 and 4 times greater than the combined impact of loading from point source and tributary BOD loads during a summer critical condition day. This was one of the first demonstrations that the low DO occurring in the LCFRE was driven by exchange with the bottom sediment and naturally occurring low DO from adjacent marsh/swamp lands and not from loads from point source discharges and major tributaries including the mainstem above Lock and Dam No. 1.

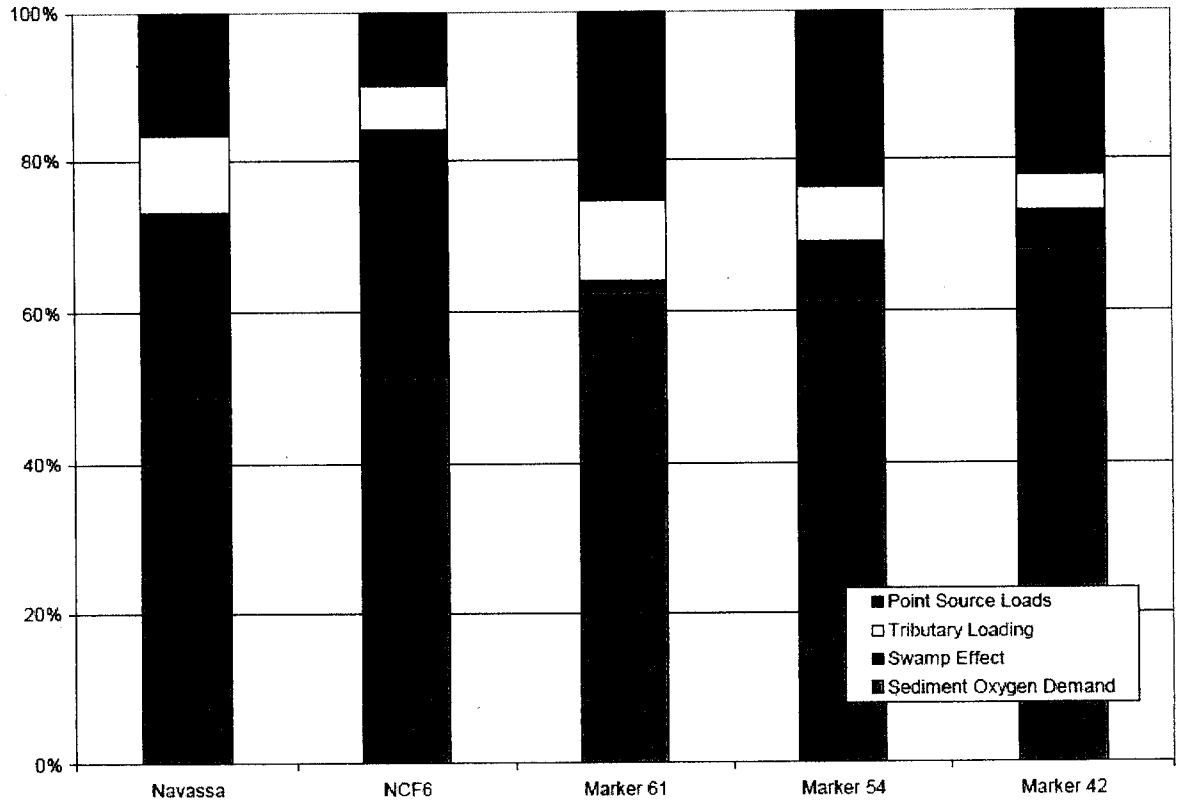

Figure 2. Predicted Relative Impact of Sources of Oxygen Demand in the Estuary (July 19, 1998)

Although the 2001 EFDC modeling demonstrated that a significant portion of the DO deficit near Navassa and down through Channel Marker 61 could be attributed to the combined effects of instream SOD and the oxygen demand from adjacent decaying marsh and swamp vegetation, it was acknowledged that uncertainty remained regarding the precise allocation to the two different oxygen demanding sources because of limited field data on each. The 2001 study recommended that additional study be performed on the LCFRE system to help delineate marsh impacts from instream SOD, which could help further refine the modeling assumptions for these parameters.

3 Subsequent Modeling Effort (2009)

To support the State's regulatory program for dissolved oxygen management in the LCFRE, a detailed monitoring and modeling program was conducted in the mid-2000s culminating with an updated EFDC modeling study (Bowen, et. al., 2009). As with the 2001 modeling effort, existing pertinent data were gathered to support model development, calibration, and validation. Two recommendations from the

earlier 2001 modeling effort—that additional information be gathered on the bathymetry within the estuary, and that additional work be done to quantify the effect of the riparian wetlands within the estuary—were undertaken during the updated hydrodynamic model calibration.

Twenty-one river cross-sections were surveyed by NC DENR and the additional bathymetric information was incorporated into the updated specification of the model grid. Additional grid work was also performed to specify the location and size of "wetland" cells that adjoin the main river channel. The overall strategy in determining wetland surface area was to use the information on the attenuation of the tidal amplitude to determine the distribution and overall area of the fringing marshes while considering the wetland delineations performed by the NC Division of Coastal Management in1999. As a result, the 2009 EFDC model included 100 additional model grid cells, of which 95 were "marsh" cells (Figure 3). This modification brought the number of marsh cells up to 241, approximately 23 percent of the model's total cell count of 1050 (up from 15 percent of 2001 model's total cell count).

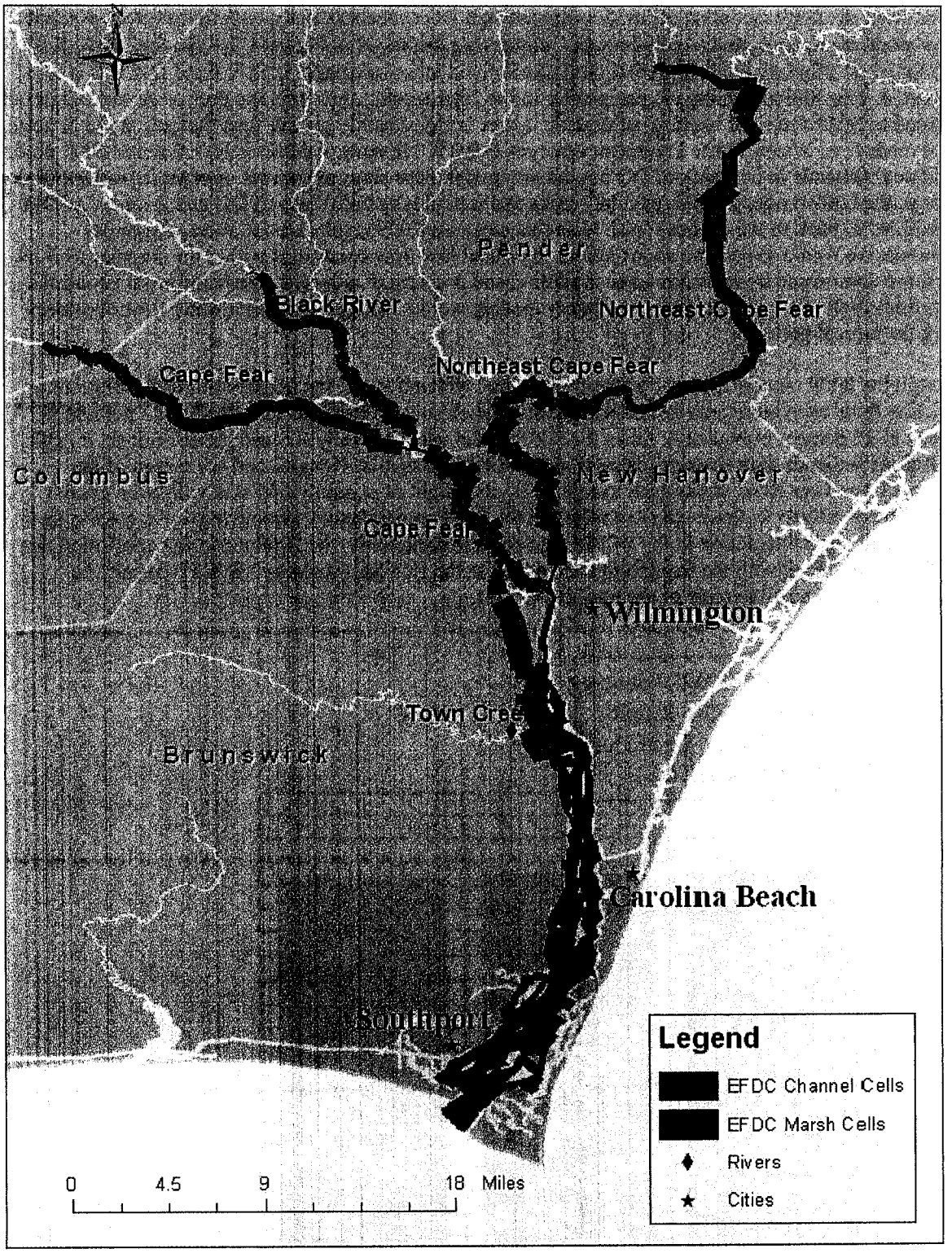

Figure 3. 2009 EFDC Model Grid Showing Location and Size of Marsh Cells; (map image extracted from Bowen, et al., 2009)

Results from the 2009 modeling effort showing average DO concentrations and deficit sources predicted for the model summer period (April through October) are displayed in Figure **4**. Unlike the 2001 effort, the swamp and tributary loading predictions were lumped into one category, "Riv Load Def." as labeled in Figure **4**. The 2009 modeling results, similar to the 2001 results, show that the portion of the DO deficit attributed to SOD and river loadings of organic matter is significantly greater than that attributed to point source loads (i.e., Waste Water Treatment Plant, or WWTP, effluent). Additionally, while the 2001 model considered wetlands to be a sink of DO but did not model these areas as sources of organic matter (OM) loadings, the 2009 model considered tidal creeks and wetlands as both sinks of DO and a source of OM and freshwater back to the channel cells. Note that since the 2009 results are for average summer conditions; we would expect the contributions at critical low flow conditions within the summer to show even more dominance by wetlands since the filling and draining of adjacent marshland would continue due to tidal cycle while the amount of tributary loading would decrease with freshwater flow decreases during the critical period.

Although the 2009 model results combine riverine and wetland loads, the updated model configuration physically links even more area to wetland and salt marsh sources than the 2001 model (23 percent as opposed to 15 percent previously). Since the 2001 model results already showed greater impact on DO deficit from wetlands than riverine loadings at key locations such as Navassa and the mouth of the Northeast Cape Fear River (refer back to Figure 2), one might reasonably infer that with even greater physical attribution to wetlands and salt marsh in the 2009 model that the swamp impact is greater than the river load regarding deficit in the LCFRE hot spots. Additionally, the 2009 modeling confirmed that DO deficit associated with the total point source load in the LCFRE (noted by "WWTP deficit" in Figure **4**) is less than 10 percent of the total DO deficit.

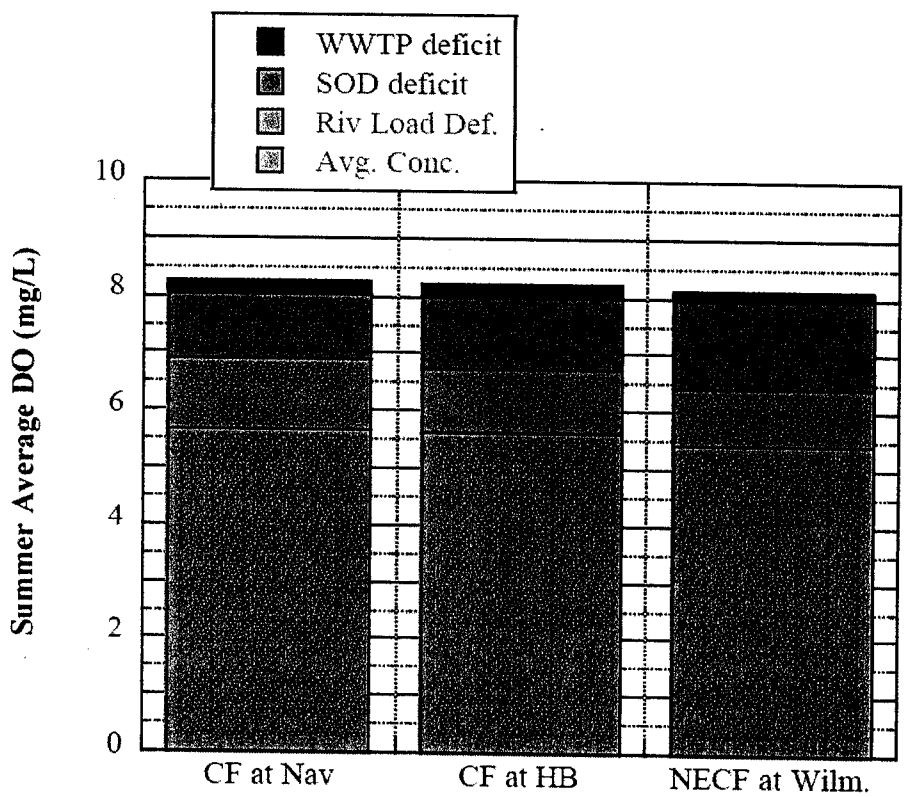

Figure 4. Summer Season (Apr-Oct) Time-Averaged Model Predicted DO Concentrations (image from Bowen, et al., 2009)

Additional scenario testing performed by Bowen et. al. (2009) simulated conditions in the LCFRE with up to 70 percent of the riverine (nonpoint source) oxygen demanding load being removed. The results indicated that even with such a large nonpoint source load reduction, DO concentrations are predicted to be less than the current water quality standard of 5 mg/L roughly 20 percent of the time during summer conditions. The 2009 modeling study therefore added further weight of evidence that other local, naturally occurring sources of oxygen demand (i.e., marshland and SOD) are driving low DO during the summer period.

4 Summary

At the time of the initial 1998 303(d) listing of the LCFRE as impaired due to low dissolved oxygen, NC DENR used a DO standard of 5 mg/L to make its assessment and the reason for impairment was thought to be a combination of point source discharge and nonpoint source pollutant loadings. The setup, calibration, validation, and independent application of two EFDC hydrodynamic water quality models for the LCFRE (Tetra Tech, 2001, and Bowen et.al., 2009) provide a strong scientific basis for isolating primary influences on DO concentrations in the LCFRE. Both modeling efforts demonstrated that the impact from point source loads in the LCFRE contributes to less than 10 percent of the DO deficit in the LCFRE. The 2001 modeling effort demonstrated that an accurate calibration could not be achieved without representing the wetting and drying of adjacent low elevation wetland and salt marsh areas. That modeling estimated that wetland/marsh and SOD sources accounted for between three quarters and four fifths of all oxygen demand in the LCFRE. The 2009 modeling effort validated and expanded the influence of adjacent marshland based on more detailed analysis. Further, application of the 2009 model that simulated up to 70 percent of nonpoint source load reduction demonstrated that even with such large pollutant loading reductions, DO concentrations would be expected to be below 5 mg/L 20 percent of the time in the LCFRE during the summer. Therefore, the 2001 and 2009 modeling analyses provide further weight of evidence collectively that other local, naturally occurring sources of oxygen demand (i.e., marshland and SOD) are driving low DO during the summer period and suggest that reinstitution of the supplemental "Swamp" designation for the LCFRE should be considered by NC DENR and the Environmental Management Commission.

References

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin, and J. Williams. 2009. Development And Use Of A Three-Dimensional Water Quality Model To Predict Dissolved Oxygen Concentrations In The Lower Cape Fear River Estuary, North Carolina. Department of Civil and Environmental Engineering, University of North Carolina at Charlotte. Prepared for NCDENR.

Tetra Tech. 2001. 3-Dimensional EFDC Water Quality Model of the Lower Cape Fear River and its Estuary. Prepared for the City of Wilmington and New Hanover County, North Carolina. May, 2001.

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Region 4 - RA's Office

JUN 20 2018

Received

June 14, 2018

Trey Glenn, Regional Administrator
Region 4 (Southeast Region)
United States Environmental Protection Agency
61 Forsyth Street SW
Atlanta, GA 30303

Dear Mr. Glenn:

As members of the New Hanover County Board of Commissioners, we join with the City of Wilmington in expressing significant concern about the North Carolina Environmental Management Commission's recommendation to re-classify a 15-mile portion of the Lower Cape Fear River and estuary. The re-classification (from 'SC', 'tidal salt water' and Primary Nursery Area to an 'SC-SW', 'swamp water' classification) will lower water quality testing standards for dissolved oxygen concentrations and pH levels in the river, and reduce protection for the river's fish population. Considering that the Cape Fear River is one of North Carolina's greatest natural resources and the primary source for drinking water for multiple counties and municipalities, every effort should be made to protect the diverse aquatic life and quality of the water.

Re-classifying portions of the river or lowering the water quality standards fails to address many of the known causes of the chronically low concentrations of dissolved oxygen and pH levels that have been reported in water quality sampling and testing over the past two decades. Scientific analysis presented to the state has repeatedly indicated that the low levels are caused by both 'point' and 'non-point' sources of pollution.

Currently, state regulators look only at 'point source' pollution (identifiable sources from industry or sewage treatment plants) when establishing water quality classifications in the Cape Fear River. 'Non-point' sources of pollution (the result of poorly regulated waste management practices at industrial livestock production facilities and from traditional agriculture and urban runoff) are not recognized as sources of pollution even though they are a significant source of ammonia, nitrogen, and phosphorus pollution, all of which contribute to the low dissolved oxygen concentrations and pH levels in the Lower Cape Fear River.

Any proposed re-classification of the Lower Cape Fear River and estuary should consider all data and recommendations of scientists that have identified both 'non-point' and 'point' sources of pollution.

We are asking that the Environmental Protection Agency (EPA) delay any action related to a change in designation of the Lower Cape Fear River until local officials, scientists, and citizens have an opportunity to evaluate the proposed changes and provide additional information for consideration.

As members of the New Hanover County Board of Commissioners, we look forward to working with state officials and the EPA on this matter.

Sincerely,

Rob Zapple
County Commissioner

Jonathan Barfield, Jr.
County Commissioner

cc: J. D. Solomon, Chairman, NC Environmental Management Commission

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

50 CFR Part 226

[Docket No. 150818735–7452–02]

RIN 0648–BF28

Endangered and Threatened Species; Designation of Critical Habitat for the Endangered New York Bight, Chesapeake Bay, Carolina and South Atlantic Distinct Population Segments of Atlantic Sturgeon and the Threatened Gulf of Maine Distinct Population Segment of Atlantic Sturgeon

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Final rule.

SUMMARY: We (NMFS) are issuing this final rule to designate critical habitat for the threatened Gulf of Maine distinct population segment (DPS) of Atlantic sturgeon, the endangered New York Bight DPS of Atlantic sturgeon, the endangered Chesapeake Bay DPS of Atlantic sturgeon, the endangered Carolina DPS of Atlantic sturgeon and the endangered South Atlantic DPS of Atlantic sturgeon pursuant to the Endangered Species Act (ESA). Specific occupied areas designated as critical habitat for the Gulf of Maine DPS of Atlantic sturgeon contain approximately 244 kilometers (km; 152 miles) of aquatic habitat in the following rivers of Maine, New Hampshire, and Massachusetts: Penobscot, Kennebec, Androscoggin, Piscataqua, Cocheco, Salmon Falls, and Merrimack. Specific occupied areas designated as critical habitat for the New York Bight DPS of Atlantic sturgeon contain approximately 547 km (340 miles) of aquatic habitat in the following rivers of Connecticut, Massachusetts, New York, New Jersey, Pennsylvania, and Delaware: Connecticut, Housatonic, Hudson, and Delaware. Specific occupied areas designated as critical habitat for the Chesapeake Bay DPS of Atlantic sturgeon contain approximately 773 km (480 miles) of aquatic habitat in the following rivers of Maryland, Virginia, and the District of Columbia: Potomac, Rappahannock, York, Pamunkey, Mattaponi, James, Nanticoke, and the following other water body: Marshyhope Creek. Specific occupied areas designated as critical habitat for the Carolina DPS of Atlantic sturgeon contain approximately 1,939 km (1,205 miles) of aquatic habitat in the following rivers of North Carolina and South Carolina: Roanoke, Tar-Pamlico, Neuse, Cape Fear, Northeast Cape Fear, Waccamaw, Pee Dee, Black, Santee, North Santee, South Santee, and Cooper, and the following other water body: Bull Creek. Specific occupied areas designated as critical habitat for the South Atlantic DPS of Atlantic sturgeon contain approximately 2,883 km (1,791 miles) of aquatic habitat in the following rivers of South Carolina, Georgia, and Florida: Edisto, Combahee-Salkehatchie, Savannah, Ogeechee, Altamaha, Ocmulgee, Oconee, Satilla, and St. Marys Rivers.

DATES: This rule becomes effective September 18, 2017.

ADDRESSES: The final rule, maps, Final Impacts Analysis Reports and Final Regulatory Flexibility Analyses used in preparation of this final rule are available on the NMFS Greater Atlantic Regional Fisheries Office (GARFO) Web site at *http://www.greateratlantic.fisheries.noaa.gov/*, and NMFS Southeast Regional Fisheries Office (SERO) Web site at *http://sero.nmfs.noaa.gov/*, or by contacting Lynn Lankshear, NMFS, GARFO, 55 Great Republic Drive, Gloucester, MA 01930 or Andrew Herndon, NMFS, SERO, 263 13th Avenue South, Saint Petersburg, FL 33701.

FOR FURTHER INFORMATION CONTACT: Lynn Lankshear, NMFS, GARFO at the address above or at 978–282–8473; Andrew Herndon, NMFS, SERO at the address above or at 727–824–5312; or Marta Nammack, NMFS, Office of Protected Resources at 301–427–8469.

SUPPLEMENTARY INFORMATION:

Background

In 2012, we listed five DPSs of Atlantic sturgeon under the ESA: Four were listed as endangered (New York Bight DPS and Chesapeake Bay DPS; 77 FR 5880; February 6, 2012; Carolina DPS and South Atlantic DPS; 77 FR 5914; February 6, 2012) and one as threatened (Gulf of Maine DPS; 77 FR 5880; February 6, 2012). On March 18, 2014, two non-governmental organizations filed a lawsuit alleging we had violated the ESA by failing to issue proposed and final rules designating critical habitat for the Atlantic sturgeon DPSs. Pursuant to a court-ordered settlement agreement, as modified, we agreed to submit proposed rules designating critical habitat for all DPSs of Atlantic sturgeon to the Office of the Federal Register by May 30, 2016. NMFS met that deadline and the two proposed critical habitat rules for the five Atlantic sturgeon DPSs were published on June 3, 2016. The proposed designations can be found at 81 FR 35701 for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon and at 81 FR 36077 for the Carolina and South Atlantic DPSs of Atlantic sturgeon. A subsequent correction notice clarifying the types of manmade structures not included in the proposed designation for the Carolina and South Atlantic DPSs was published on June 28, 2016 (81 FR 41926). On February 11, 2016, NMFS and the USFWS published a final rule, Implementing Changes to the Regulations for Designating Critical Habitat (81 FR 7414) (the Implementation rule). As the Implementation rule discussed, the changes to these regulations were meant to more clearly describe the Services' past and ongoing practices for designating critical habitat. The proposed rules designating critical habitat for Atlantic sturgeon were largely drafted at the time the final Implementation rule was published, and were based on past practices incorporated into that rule. Thus, no substantive changes were made to the Atlantic sturgeon proposed rules as a result of finalizing the Implementation rule.

We solicited comments from the public on all aspects of the proposed rules and held public hearings in Gloucester, Massachusetts; Brunswick, Georgia; Charleston, South Carolina; and Morehead City, North Carolina. The initial regulatory flexibility analysis (IRFA) and the draft Impacts Analysis (DIA) prepared for each proposed rule pursuant to section 4(b)(2) of the ESA were made available for public review and comment along with the proposed rules. Upon request, we re-opened the public comment period of both proposed rules for an additional 15 days, from September 29, 2016, to October 14, 2016 (81 FR 66911; Sept. 29, 2016); the entire public comment period totaled 105 days. After receiving public comment, we decided to complete the critical habitat designations with one final rule. Combining the designations into a single final rule will provide greater clarity to the public about the total extent of the Atlantic sturgeon critical habitat designations, reduce redundancy, and enable the public to better understand the need to designate the affected areas.

Final regulatory flexibility analyses (FRFAs) and final Impacts Analysis reports (IAs) updating the initial analyses and reports, that were published with the proposed rules, have been prepared to accompany this final rule. Combining the regional FRFAs and

IAs into single documents would make it difficult for the public to keep track of which parts of the single documents built upon the underlying data from the individual analyses published with the proposed rules. In addition, at the proposed rule stage, our two NMFS regions used different methodologies to evaluate impacts, relying on consultation databases that are region specific to address the different circumstances applicable to a specific region. Courts have noted the ESA provides the USFWS and NMFS (the Services) with broad discretion and flexibility in determining which particular methodologies or approaches are best for each specific set of circumstances (*See, e.g., Bldg. Indus. Ass'n of the Bay Area et al.* v. *U.S. Dep't. of Commerce et al.,* No. 13–15132, 9th Cir., July 7, 2015 (upholding district court's ruling that the ESA does not require the agency to follow a specific methodology when designating critical habitat under section 4(b)(2)). Accordingly, we maintained the separate sets because combining the two distinct sets of regional analyses would not have gained any efficiencies and would have created overly complicated reports that would be difficult for the public to follow. The final analyses are publicly available (see **ADDRESSES**).

We determined that a key conservation objective for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs is to increase the abundance of each DPS by facilitating increased successful reproduction and recruitment to the marine environment. We know that each of these DPSs is at a low level of abundance and that successful reproduction and recruitment, which are essential to the conservation of the species, occur in a limited number of rivers for each DPS. Based on the best scientific information available for the life history needs of the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs, the physical features essential to the conservation of the species and that may require special management considerations or protection are:

(1) Hard bottom substrate (*e.g.,* rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (*i.e.,* 0.0 to 0.5 parts per thousand (ppt) range) for settlement of fertilized eggs, refuge, growth, and development of early life stages;

(2) Aquatic habitat with a gradual downstream salinity gradient of 0.5 up to as high as 30 ppt and soft substrate (*e.g.,* sand, mud) between the river mouth and spawning sites for juvenile foraging and physiological development;

(3) Water of appropriate depth and absent physical barriers to passage (*e.g.,* locks, dams, thermal plumes, turbidity, sound, reservoirs, gear, etc.) between the river mouth and spawning sites necessary to support:

(i) Unimpeded movement of adults to and from spawning sites;

(ii) Seasonal and physiologically dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary; and

(iii) Staging, resting, or holding of subadults or spawning condition adults.

Water depths in main river channels must also be deep enough (*e.g.,* at least 1.2 m) to ensure continuous flow in the main channel at all times when any sturgeon life stage would be in the river.

(4) Water, between the river mouth and spawning sites, especially in the bottom meter of the water column, with the temperature, salinity, and oxygen values that, combined, support:

(i) Spawning;

(ii) Annual and interannual adult, subadult, larval, and juvenile survival; and

(iii) Larval, juvenile, and subadult growth, development, and recruitment (*e.g.,* 13 °C to 26 °C for spawning habitat and no more than 30 °C for juvenile rearing habitat, and 6 milligrams per liter (mg/L) dissolved oxygen (DO) or greater for juvenile rearing habitat).

We determined that the key conservation objectives for the Carolina and South Atlantic DPSs of Atlantic sturgeon are to increase the abundance of each DPS by facilitating increased survival of all life stages and facilitating adult reproduction and juvenile and subadult recruitment into the adult population. We determined the physical features essential to the conservation of the species and that may require special management considerations or protection, which support the identified conservation objectives, are:

(1) Hard bottom substrate (*e.g.,* rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (*i.e.,* 0.0–0.5 ppt range) for settlement of fertilized eggs and refuge, growth, and development of early life stages;

(2) Transitional salinity zones inclusive of waters with a gradual downstream gradient of 0.5– up to 30 ppt and soft substrate (*e.g.,* sand, mud) between the river mouths and spawning sites for juvenile foraging and physiological development;

(3) Water of appropriate depth and absent physical barriers to passage (*e.g.,* locks, dams, thermal plumes, turbidity, sound, reservoirs, gear, etc.) between the river mouths and spawning sites necessary to support:

(i) Unimpeded movement of adults to and from spawning sites;

(ii) Seasonal and physiologically-dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary; and

(iii) Staging, resting, or holding of subadults or spawning condition adults.

Water depths in main river channels must also be deep enough (at least 1.2 m) to ensure continuous flow in the main channel at all times when any sturgeon life stage would be in the river.

(4) Water quality conditions, especially in the bottom meter of the water column, between the river mouths and spawning sites with temperature and oxygen values that support:

(i) Spawning;

(ii) Annual and inter-annual adult, subadult, larval, and juvenile survival; and

(iii) Larval, juvenile, and subadult growth, development, and recruitment. Appropriate temperature and oxygen values will vary interdependently, and depending on salinity in a particular habitat. For example, 6.0 mg/L DO or greater likely supports juvenile rearing habitat, whereas DO less than 5.0 mg/L for longer than 30 days is less likely to support rearing when water temperature is greater than 25 °C. In temperatures greater than 26 °C, DO greater than 4.3 mg/L is needed to protect survival and growth. Temperatures of 13 to 26 °C likely to support spawning habitat.

Atlantic Sturgeon Natural History and Status

There are two subspecies of Atlantic sturgeon—the Gulf sturgeon (*Acipenser oxyrinchus desotoi*) and the Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). Historically, the Gulf sturgeon occurred from the Mississippi River east to Tampa Bay in Florida. Its present range extends from Lake Pontchartrain and the Pearl River system in Louisiana and Mississippi east to the Suwannee River in Florida. The Gulf sturgeon was listed as threatened under the ESA in 1991. This rule addresses the Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), which is distributed along the eastern coast of North America. Historically, sightings of Atlantic sturgeon have been reported from Hamilton Inlet, Labrador, Canada, south to the St. Johns River, Florida, United States. Reported occurrences south of the St. Johns River, Florida, have been rare but have increased recently with the evolution of acoustic telemetry coupled with increased receiver arrays.

Although there is considerable variability among species, all sturgeon species (Order *Acipenseriformes*) have

some common life history traits. They all: (1) Occur within the Northern Hemisphere; (2) spawn in freshwater over hard bottom substrates; (3) generally do not spawn annually; (4) are benthic foragers; (5) mature relatively late and are relatively long lived; and (6) are relatively sensitive to low DO levels (Dees, 1961; Sulak and Clugston, 1999; Billard and Lecointre, 2001; Secor and Niklitschek, 2002; Pikitch *et al.*, 2005).

Atlantic sturgeon have all of the above traits. They occur along the eastern coast of North America from Hamilton Inlet, Labrador, Canada to Cape Canaveral, Florida, United States (Bigelow and Welsh, 1925; Dees, 1961; Vladykov and Greeley, 1963; NMFS and U.S. Fish and Wildlife Service (USFWS), 2007; T. Savoy, CT DEEP, pers. comm.). Atlantic sturgeon are a long-lived, late-maturing, estuarine-dependent, anadromous species with a maximum lifespan of up to 60 years, although the typical lifespan is probably much shorter (Sulak and Randall, 2002; Balazik *et al.*, 2010). Atlantic sturgeon reach lengths up to 14 ft (4.27 m), and weigh over 800 pounds (363 kilograms (kg)). Many datasets demonstrate clinal variation in vital parameters of Atlantic sturgeon populations, with faster growth and earlier age at maturation in more southern systems. Atlantic sturgeon mature between the ages of 5 and 19 years in South Carolina (Smith *et al.*, 1982), between 11 and 21 years in the Hudson River (Young *et al.*, 1988), and between 22 and 34 years in the St. Lawrence River (Scott and Crossman, 1973). Atlantic sturgeon generally do not spawn every year. Multiple studies have shown that spawning intervals range from 1 to 5 years for males (Smith, 1985; Collins *et al.*, 2000; Caron *et al.*, 2002) and 2 to 5 years for females (Vladykov and Greeley, 1963; Van Eenennaam *et al.*, 1996; Stevenson and Secor, 1999). Fecundity of Atlantic sturgeon has been correlated with age and body size, with egg production ranging from 400,000 to 8 million eggs per year (Smith *et al.*, 1982; Van Eenennaam and Doroshov, 1998; Dadswell, 2006). The average age at which 50 percent of maximum lifetime egg production is achieved is estimated to be 29 years, approximately 3 to 10 times longer than for other bony fish species examined (Boreman, 1997).

Analysis of stomach contents for adults, subadults (*i.e.*, sexually immature Atlantic sturgeon that have emigrated from the natal estuary to the marine environment), and juveniles (*i.e.*, sexually immature Atlantic sturgeon that have not yet emigrated from the natal estuary) confirms that Atlantic sturgeon are benthic foragers (Ryder, 1888; Bigelow and Schroeder, 1953; Johnson *et al.*, 1997; Secor *et al.*, 2000; ASSRT, 2007; Guilbard *et al.*, 2007; Hatin *et al.*, 2007; Savoy, 2007; Dzaugis, 2013; McLean *et al.*, 2013).

An anadromous species, Atlantic sturgeon spawns in freshwater of rivers that flow into a coastal estuary. Spawning adults migrate upriver in the spring, typically during February and March in southern systems, April and May in mid-Atlantic systems, and May and July in Canadian systems (Murawski and Pacheco, 1977; Smith, 1985; Bain, 1997; Smith and Clugston, 1997; Caron *et al.*, 2002). A fall spawning migration has been hypothesized for many years (Rogers and Weber, 1995; Weber and Jennings, 1996; Moser *et al.*, 1998) and was recently verified in the Roanoke River, North Carolina, and the Altamaha River, Georgia (Smith et. al., 2015; Ingram and Peterson 2016). There is also a growing body of evidence that some Atlantic sturgeon river populations have two spawning seasons comprised of different spawning adults (Balazik and Musick, 2015; Farrae *et al.*, 2017). Since the listings, additional evidence of fall as well as spring spawning has been obtained for the Chesapeake Bay DPS of Atlantic sturgeon (Balazik *et al.*, 2012; Hager *et al.*, 2014; Kahn *et al.*, 2014).

Spawning typically occurs in flowing water upriver of the salt front of estuaries and below the fall line of large rivers (Borodin, 1925; Leland, 1968; Scott and Crossman, 1973; Crance, 1987; Bain *et al.*, 2000). The fall line is the boundary between an upland region of continental bedrock and an alluvial coastal plain, sometimes characterized by waterfalls or rapids. Spawning sites are well-oxygenated areas with flowing water ranging in temperature from 13 °C (55 °F) to 26 °C (79 °F), and hard bottom substrate such as cobble, hard clay, and bedrock (Ryder, 1888; Dees, 1961; Vladykov and Greeley, 1963; Scott and Crossman, 1973; Gilbert, 1989; Smith and Clugston, 1997; Bain *et al.*, 2000; Collins *et al.*, 2000; Balazik *et al.*, 2012; Hager *et al.*, 2014). Depth at which fish spawn and water depth leading to spawning sites may be highly variable. Atlantic sturgeon in spawning condition have been tracked and captured at depths up to 27 m (Borodin 1925; Dees 1961; Hatin *et al.*, 2002; Balazik *et al.*, 2012; Hager *et al.*, 2014).

Within minutes of being fertilized, the eggs become sticky and adhere to the substrate for the relatively short and temperature-dependent period of larval development (Ryder, 1888; Vladykov and Greeley, 1963; Murawski and Pacheco, 1977; Smith *et al.*, 1980; Van den Avyle, 1984; Mohler, 2003). Hatching occurs approximately 94 to 140 hours after egg deposition at temperatures of 68.0 to 64.4 °F (20 to 18 °C), respectively. The newly emerged larvae assume a demersal existence (Smith *et al.*, 1980). The yolk sac larval stage is completed in about 8 to 12 days, during which time the larvae move downstream to rearing grounds (Kynard and Horgan, 2002). During the first half of their migration downstream, movement occurs only at night. During the day, larvae use benthic structure (*e.g.*, gravel matrix) as refuge (Kynard and Horgan, 2002). During the latter half of migration, when larvae are more fully developed, movement to rearing grounds occurs during both the day and night.

Larval Atlantic sturgeon (*i.e.*, less than 4 weeks old, with total lengths (TL) less than 30 mm; Van Eenennaam *et al.*, 1996) are assumed to inhabit the same areas where they were spawned and live at or near the bottom (Ryder, 1888; Smith *et al.*, 1980; Bain *et al.*, 2000; Kynard and Horgan, 2002; Greene *et al.*, 2009). The best scientific information available for behavior of larval Atlantic sturgeon is described from hatchery studies. Upon hatching, larvae are nourished by the yolk sac, are mostly pelagic (*e.g.*, exhibit a "swim-up and drift-down" behavior in hatchery tanks; Mohler, 2003), and move away from light (*i.e.*, negative photo-taxis; Kynard and Horgan, 2002; Mohler, 2003). Within days, larvae exhibit more benthic behavior until the yolk sac is absorbed at about 8 to 10 days post-hatching (Kynard and Horgan, 2002; Mohler, 2003). Post-yolk sac larvae occur in the water column but feed at the bottom of the water column (Mohler, 2003; Richardson *et al.*, 2007).

The next phase of development, referred to as the juvenile stage, lasts months to years in brackish waters of the natal estuary (Holland and Yelverton, 1973; Dovel and Berggen, 1983; Waldman *et al.*, 1996; Shirey *et al.*, 1997; Collins *et al.*, 2000; Secor *et al.*, 2000; Dadswell, 2006; Hatin *et al.*, 2007; ASSRT, 2007; Calvo *et al.*, 2010; Schueller and Peterson, 2010). Juvenile rearing habitat is that habitat necessary for juveniles to grow, develop, and emigrate to the marine environment where they begin the subadult life stage, eventually maturing into adults. Juveniles occur in oligohaline waters (salinity of 0.5 to 5 ppt) and mesohaline waters (salinity of 5 to 18 ppt) of the natal estuary during growth and development. They will eventually move into polyhaline waters (salinity of 18–30 ppt), if available in the natal river estuary, before emigrating from the natal river estuary. Larger, presumably older,

juveniles occur across a broader salinity range than smaller, presumably younger, juveniles (Bain, 1997; Shirey *et al.*, 1997; Haley, 1999; Bain *et al.*, 2000; Collins *et al.*, 2000; Secor *et al.*, 2000; Hatin *et al.*, 2007; McCord *et al.*, 2007; Munro *et al.*, 2007; Sweka *et al.*, 2007; Calvo *et al.*, 2010).

The distribution of Atlantic sturgeon juveniles in the natal estuary is a function of physiological development and habitat selection based on water quality factors of temperature, salinity, and DO, which are inter-related environmental variables. In laboratory studies with salinities of 8 to 15 ppt and temperatures of 12 and 20 °C (53.6 and 68 °F), juveniles less than a year old (also known as young-of-year [YOY]) had reduced growth at 40 percent DO saturation, grew best at 70 percent DO saturation, and selected conditions that supported growth (Niklitschek and Secor, 2009 I; Niklitschek and Secor, 2009 II). Similar results were obtained for age-1 juveniles (*i.e.*, greater than 1 year old and less than 2 years old), which have been shown to tolerate salinities of 33 ppt (*e.g.*, a salinity level associated with seawater), but grow faster in lower salinity waters (Niklitschek and Secor, 2009 I; Allen *et al.*, 2014). For the conditions tested, the best growth for both age groups occurred at DO concentrations greater than 6.5 mg/L (*e.g.*, 70 percent DO saturation with salinity of 8 to 15 ppt and temperature of 12 and 20 °C). While specific DO concentrations at temperatures considered stressful for Atlantic sturgeon are not available, instantaneous minimum DO concentrations of 4.3 mg/L protect survival of shortnose sturgeon at temperatures greater than 29 °C (84.2 °F) (EPA, 2003). However, data from Secor and Niklitschek (2001) show that shortnose sturgeon are more tolerant of higher temperatures than Atlantic sturgeon, and the "high temperature" for Atlantic sturgeon is actually considered 26 °C (78.8 °F) (Secor and Gunderson, 1998).

Once suitably developed, Atlantic sturgeon leave the natal estuary and enter marine waters (*i.e.*, waters with salinity greater than 30 ppt); this marks the beginning of the subadult life stage. In the marine environment, subadults mix with adults and subadults from other river systems (Bowen and Avise, 1990; Wirgin *et al.*, 2012; Waldman *et al.*, 2013; O'Leary *et al.*, 2014). Atlantic sturgeon travel long distances in marine waters, aggregate in both oceanic and estuarine areas at certain times of the year, and exhibit seasonal coastal movements in the spring and fall (Vladykov and Greeley, 1963; Oliver *et al.*, 2013).

The exact spawning locations for Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPS Atlantic sturgeon are unknown but inferred based on the location of freshwater, hard substrate, water depth, tracking of adults to upriver locations and the behavior of adults at those locations, historical accounts of where the caviar fishery occurred, capture of YOY and, in limited cases, capture of larvae and eggs. Spawning sites at multiple locations within the tidal-affected river likely help to ensure successful spawning given annual changes in the location of the salt wedge.

Public Comments and Our Responses

We requested comments on the proposed rule to designate critical habitat for the Gulf of Maine, New York Bight, Chesapeake Bay DPSs of Atlantic sturgeon (81 FR 35701; June 3, 2016) and on the proposed rule to designate critical habitat for the Carolina and South Atlantic DPSs of Atlantic sturgeon (81 FR 36077; June 3, 2016) for a 90-day period. Following requests from the public, we re-opened the public comment period for an additional 15 days (81 FR 66911; Sept. 29, 2016), for a total comment period of 105 days. Five public hearings were also held on the following dates and in the following locations:

1. Thursday, July 21, 2016, 3 to 5 p.m., Gloucester, Massachusetts.
2. Thursday, July 21, 2016, 6 to 8 p.m., Gloucester, Massachusetts.
3. Monday, June 20, 2016, 7 to 9 p.m., Brunswick, Georgia.
4. Tuesday, June 21, 2016, 7 to 9 p.m., Charleston, South Carolina.
5. Thursday, June 23, 2016, 7 to 9 p.m., Morehead City, North Carolina.

In addition to the public hearings, during which substantive comments on the proposed designations could be provided by the public, we held a public informational meeting prior to each public hearing in Massachusetts, Georgia, South Carolina, and North Carolina. We also held public informational meetings in Annapolis, Maryland on July 13, 2016, and in Portland, Maine on July 18, 2016. These informational meetings reviewed the purpose of designating critical habitat and answered procedural questions. We did not accept public comment or answer substantive questions about the areas proposed for designation at the informational meetings; rather, we provided information on the public comment process. To further facilitate public participation, the proposed rules were made available on our regional Web pages and comments were accepted during public hearings, and via standard mail, facsimile, and through the Federal eRulemaking portal. In addition to the proposed rules, the correction notice for the proposed rule for the Carolina and South Atlantic DPSs, maps of the proposed critical habitat units, and the DIAs supporting our conclusions under section 4(b)(2) of the ESA were made publicly available.

Twenty-one people attended the public hearings for the proposed rule to designate critical habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon, either in-person or via telephone, and we received 1,577 responses to the request for public comments on the proposed rule and supporting documents through *Regulations.gov* and by mail, including over 1,000 form letters. Approximately 40 people attended the public hearings for the proposed rule to designate critical habitat for the Carolina and South Atlantic DPSs of Atlantic sturgeon, and 354 public comments were received on the proposed rule and supporting documents.

We reviewed all comments received for substantive issues relevant to the proposed critical habitat rules. Some comments resulted in changes between the proposed and final designation. Changes between the proposed designations and final designation are highlighted in the "Summary of Changes From the Proposed Rules" section of this rule. The relevant public comments received, both written and oral, are addressed below. We have responded to the comments received on the proposed rule for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon separately from our responses to the comments received on the proposed rule for the Carolina and South Atlantic DPSs of Atlantic sturgeon because it would be difficult for a commenter to identify his or her individual comment and our response if we merged the comment responses. However, we have assigned comments to major issue categories and, where appropriate, have combined similar comments from multiple members of the public or referenced the response to identical comments received on both proposed rules. We received some comments related to the listing and DPS delineation and comments critical of our final rule Implementing Changes to the Regulations for Designating Critical Habitat (81 FR 7414; February 11, 2016); those comments are not relevant to this

critical habitat designation and are not addressed below.

Comments on the Gulf of Maine, New York Bight, and Chesapeake Bay DPS Proposed Critical Habitat Designations (81 FR 35701; June 3, 2016)

Comments on Geographical Area Occupied

Comment 1: A commenter stated that we have not provided any evidence that Atlantic sturgeon occupied the Susquehanna River at the time the species was listed, or at any time in recent history. They stated that the most recent sighting of Atlantic sturgeon occurred in 1987, nearly 25 years before the species was listed in 2012, and that sighting occurred near the mouth of the Susquehanna River rather than in the Susquehanna River. The commenter noted that Exelon monitored the Susquehanna River for sonic transmitter tagged sturgeons from other river systems (Delaware River, Potomac River) during 2010 and 2011 with fixed station acoustic telemetry receivers, and no tagged Atlantic sturgeon were recorded in the Susquehanna River in either year. In addition, they stated that Atlantic sturgeon have not been caught in the Conowingo Dam fish lift in 44 years of fish lift operations, there have been no reports of anglers catching Atlantic sturgeon or observations of breaching Atlantic sturgeon in the Susquehanna River, and there are no records for Atlantic sturgeon in the Susquehanna River in the USFWS tagging database or the Maryland Department of Natural Resources reward program database.

Our Response: Our regulations at 50 CFR 424.02 define "geographical area occupied by the species" as "An area that may generally be delineated around species' occurrences, as determined by the Secretary (*i.e.*, range). Such areas may include those areas used throughout all or part of the species' life cycle, even if not used on a regular basis (*e.g.*, migratory corridors, seasonal habitats, and habitats used periodically, but not solely, by vagrant individuals)." The range of each DPS is informed by numerous lines of evidence including the life history of Atlantic sturgeon, tagging, tracking, and genetic analyses. Often at the time of designating critical habitat, we do not have detailed information or the same level of detail for every part of the species' range. However, the absence of collection or sighting of Atlantic sturgeon in any part of their range does not equate to absence of Atlantic sturgeon. Atlantic sturgeon can be difficult to detect when present in marine and estuarine waters because they are benthic fish, spending most of their lives well below the water surface, they do not school, they move within the estuary, and subadults and adults spend only part of the year in estuarine waters.

There has been very little effort to detect the presence of Atlantic sturgeon in the Susquehanna River in recent times. Receivers were placed in the Susquehanna River to detect acoustically tagged Atlantic sturgeon in 2010 and 2011 but, at that time, we made it clear that an absence of detections was not confirmation of absence of the species in the river, given the low number of Atlantic sturgeon that were acoustically tagged and the limited number of receivers placed in the river below Conowingo Dam.

Fish behavior rather than fish abundance influences whether a sturgeon enters a fish lift that was designed for a different fish species. Therefore, absence of Atlantic sturgeon in the fish lift also does not equate to absence of Atlantic sturgeon in the river below a dam. Many of the rivers for which we have more abundant documentation of Atlantic sturgeon presence also have dams with fish lifts (*e.g.*, Connecticut, Penobscot, and Saco Rivers), and only one Atlantic sturgeon has been observed and documented in a fish lift (at the Holyoke Dam in the Connecticut River (ASSRT 2007)).

The Maryland Reward Program relied upon reports of Atlantic sturgeon incidentally caught in fishing gear. The Program operated when directed fishing for, and incidental capture of, Atlantic sturgeon was prohibited and when abundance of Atlantic sturgeon was unknown and estimated to be low (thus later necessitating listing under the ESA). The lack of reported captures of Atlantic sturgeon in the Susquehanna can be explained by any number of factors including whether: Fishing was occurring in the Susquehanna when Atlantic sturgeon were present, the gear type fished was conducive to catching Atlantic sturgeon, or the fisherman reported the capture. Similarly, to assess whether the absence of USFWS tagging database records for Atlantic sturgeon captures in the Susquehanna reflects absence of Atlantic sturgeon in the Susquehanna River, a measure of the amount of effort to search for, capture, and tag Atlantic sturgeon in the Susquehanna River must be provided. Based on the best scientific information available, there was no directed effort to search for, capture, and tag Atlantic sturgeon in the Susquehanna River. Therefore, the absence of records in the USFWS tagging database does not inform the presence or absence of Atlantic sturgeon in the river.

The lack of evidence for Atlantic sturgeon presence in the Susquehanna based on the scientific studies or recreational fishing in the river is more likely the result of methods and gear that do not effectively capture sturgeon. Sturgeon tend to sink rather than float when exposed to electroshocking (Moser *et al.*, 2000). Electroshocking conducted to retrieve other fish species often does not result in detection of Atlantic sturgeon because the electric current may only penetrate a few feet from the surface of the water and not reach the bottom where sturgeon are most likely to occur. Although some sturgeon have been detected during electrofishing for other species, electroshocking is not an effective means for detecting sturgeon presence. Gillnet gear is only effective when selective for the size of sturgeon present, and sturgeon can get snagged on recreational hook gear but do not typically take a hook. Therefore, creel surveys of recreational fisheries are unlikely to provide evidence of sturgeon presence, particularly when the recreational fisheries are targeting fish species dissimilar to sturgeons (*e.g.*, in size, feeding characteristics).

Since the listing of the Chesapeake Bay DPS in 2012, increased effort to detect Atlantic sturgeon in the Pamunkey, Nanticoke, and Rappahannock Rivers has led to the discovery of Atlantic sturgeon spawning populations and sturgeon presence that were undetected before the listing. These include a spawning population in the Pamunkey River (Hager *et al.*, 2014; Kahn *et al.*, 2014), a likely spawning population in the Nanticoke River, and detection of Atlantic sturgeon in the Rappahannock River.

Comment 2: An industry trade group stated we inappropriately delineated the "geographical area occupied" by the species as the entire "aquatic habitat (*e.g.*, below the high tide line)" of inland freshwater areas that are currently accessible to the Atlantic sturgeon. These commenters stated that we inappropriately included not just areas where the species has actually been located, but instead we also included wider areas around the species' occurrences and areas that may be used only temporarily or periodically by the species. They stated that "areas identified as occupied include vast areas where there is no evidence the species even occurs, much less occupies." The commenter states that the Services' Consultation Handbook provides that occupied critical habitat is "critical habitat that contains

individuals of the species at the time of the project analysis."

Our Response: Our regulations at 50 CFR 424.02 define the geographical area occupied by the species as an area that may generally be delineated around species' occurrences (*i.e.,* range), and this may include those areas used throughout all or part of the species' life cycle, even if they are not used on a regular basis (*e.g.,* migratory corridors, seasonal habitats, and or habitats used periodically, but not solely by vagrant individuals). This is consistent with past critical habitat designations (*e.g.,* Final Rule Designating Critical Habitat for Threatened Elkhorn and Staghorn Corals (73 FR 72210; November 26, 2008): "We have long interpreted 'geographical area occupied' in the definition of critical habitat to mean the range of the species at the time of listing (45 FR 13011; February 27, 1980)"). The geographical area occupied as specified in this designation meets the regulatory definition, and our application of the term "geographical area occupied" to Atlantic sturgeon is appropriate. As the court in *Arizona Cattle Growers Ass'n* v. *Salazar* (606 F.3d 1160, 1164 (9th Cir. 2010)) held, "[d]etermining whether a species uses an area with sufficient regularity that it is 'occupied' is a highly contextual and fact-dependent inquiry. Cf. *Cape Hatteras Access Pres. Alliance* v. *United States DOI,* 344 F. Supp. 2d 108, 119–20 (D.D.C. 2004). Relevant factors may include how often the area is used, how the species uses the area, the necessity of the area for the species' conservation, species characteristics such as degree of mobility or migration, and any other factors that may bear on the inquiry." In claiming that the 1998 Consultation Handbook provides that occupied critical habitat is that which is occupied by individuals of the species at the time of a project analysis, the commenter did not include the entire discussion about occupied critical habitat. As we explained more fully in our Handbook, "[a] species does not have to occupy critical habitat throughout the year for the habitat to be considered occupied (*e.g.* migratory birds)." The court in *Arizona Cattle Growers* cited this language as appropriately recognizing that "a species need not be present continuously for habitat to be considered "occupied." 606 F.3d at 1165. The court rejected a narrow interpretation of "occupied" based solely on documented "residence" of individual animals, holding that "[w]here data are inconclusive or where habitat is used on a sporadic basis, allowing the FWS to designate as 'occupied' habitat where the species is likely to be found promotes the ESA's conservation goals and comports with the ESA's policy of "institutionalized caution" (*Id.* at 1166–1167), and that "[t]he fact that a member of the species is not present in an area at a given instant does not mean the area is suitable only for future occupancy if the species regularly uses the area" (*Id.* at 1167).

For Atlantic sturgeon, we identified the geographical area occupied based on the species' well-known anadromous life history, including returning to natal rivers to spawn, spawning behaviors, and habitat common to sturgeon species and verified for Atlantic sturgeon, as well as the need to protect spawning and reproductive habitat for population growth and conservation of the species, among other factors. Some portion of each river population returns to its natal river to spawn every year, and if spawning occurs and is successful, young sturgeon use the natal river to forage, develop and mature every year.

Comment 3: A state agency stated there may be habitat features conducive for Atlantic sturgeon reproduction and recruitment in the Piscataqua, Salmon Falls, and Cocheco Rivers, but there was no evidence that Atlantic sturgeon have used New Hampshire estuaries and coastal rivers as spawning and nursery habitat from at least 35 years of surveys, studies, etc. The commenter stated that recent evidence from acoustical tagging (Micah Kieffer, USGS, personal communication, as cited in the comment) leads to the conclusion that sturgeons spend only brief periods in the Piscataqua River/Great Bay system during longer movements between the Merrimack and Kennebec Rivers. A fisherman similarly stated that in all of his fishing trips in the Piscataqua River over the course of 20-plus years, he had never encountered Atlantic sturgeon in the Piscataqua River, and he does not believe that Atlantic sturgeon spawning or juvenile rearing occurs in the Piscataqua, Salmon Falls, and Cocheco Rivers.

Our Response: We disagree with these commenters' assertions that Atlantic sturgeon do not occur in these waterbodies. The Piscataqua River as well as the Cocheco and Salmon Falls Rivers downriver of their respective lowermost dams are part of the geographical area occupied by Atlantic sturgeon. Recent evidence of their presence includes detection of tagged Atlantic sturgeon (M.Kieffer, USGS, pers. comm.). Because the number of tagged Atlantic sturgeon represents only a fraction of the total number of sturgeon, and receivers for detecting tags are not in the rivers throughout the year, the number of Atlantic sturgeon detected in the Piscataqua is very likely less than the total number of Atlantic sturgeon that actually occur in the Piscataqua and as far upriver as the lowermost dams of the Cocheco and Salmon Falls Rivers.

We identified the Piscataqua River and portions of the Salmon Falls and Cocheco Rivers as a potential critical habitat area for the Gulf of Maine DPS because the physical features are present. We considered whether the identified area was essential to the conservation of the Gulf of Maine DPS and concluded that it was, given the capture of a large female Atlantic sturgeon with eggs, at the head-of-tide in the Salmon Falls River in South Berwick, Maine on June 18, 1990, thus demonstrating behavior consistent with spawning was occurring in the system. We also took into consideration the limited number of other rivers with spawning and rearing habitat in the Gulf of Maine DPS, the continuing threats to the DPS, the threats to the features of critical habitat, and the uncertainty for how much spawning and rearing habitat is necessary to recover the Gulf of Maine DPS. Together, this information supports our conclusion that the Piscataqua River, and portions of the Salmon Falls and Cocheco Rivers, are part of the geographical area occupied by the Gulf of Maine DPS and these areas are essential to the conservation of the Gulf of Maine DPS.

We are not surprised that there have been very few incidental captures of Atlantic sturgeon in fisheries or research surveys and studies conducted in the Piscataqua River. We know from other river systems that capture of any of the Atlantic sturgeon life stages can be difficult even when the proper gear for capturing Atlantic sturgeon is used, and used at the time and in the area where Atlantic sturgeon are likely to occur. Atlantic sturgeon populations in a number of rivers were considered extirpated at one point, only later to find that genetically unique populations were present (*e.g.,* the James River and York River systems, the Connecticut River, the Nanticoke River, and Marshyhope Creek).

Comment 4: A representative for a power operation on the Hudson River stated that atypical passage or straying is not enough to constitute critical habitat, and critical habitat shall not include the entire geographical area which can be occupied by the threatened or endangered species.

Our Response: We agree that it is inappropriate to designate the entire area occupied by a DPS as critical

habitat. However, we have not done that for any of the Atlantic sturgeon DPSs. The geographical area occupied by the New York Bight DPS of Atlantic sturgeon is a broad area that includes the Hudson River as far upriver as the Federal Dam near Albany, NY. The New York Bight DPS consists of all Atlantic sturgeon spawned in the watersheds that drain into coastal waters, including Long Island Sound, the New York Bight, and Delaware Bay, from Chatham, Massachusetts to the Delaware-Maryland border on Fenwick Island. The range of the DPS in marine waters extends from Labrador, Canada to Cape Canaveral, Florida, United States. The area of the Hudson River that we are designating as critical habitat is, therefore, a specific area within the much broader geographical area occupied by the DPS.

Comments on Physical or Biological Features (PBFs)

Comment 5: A commenter stated the critical habitat designation for Atlantic sturgeon fails to identify any in-river habitats that are important aggregation areas for Atlantic sturgeon. They also stated that we designated in-river habitats where sturgeon congregate, presumably for resting and energy conservation, for both the southern DPS of green sturgeon, and for Gulf sturgeon, and it is likely that Atlantic sturgeon have a similar habitat requirement.

Our Response: While there are similarities between all sturgeon species, there are also differences. The proposed rule and the Impacts Analysis and Biological Information Source Document summarized the literature describing spawning behavior for male and female Atlantic sturgeon. Briefly, male Atlantic sturgeon in spawning condition have been observed to stage in more saline waters of the coastal estuary before moving upriver once the water temperature reaches approximately 6 °C (43 °F). They may spend weeks moving upstream and downstream of the presumed spawning area(s) before moving back downriver to the lower estuary and residing there until outmigration in the fall (Smith *et al.*, 1982; Dovel and Berggren, 1983; Smith, 1985; Bain, 1997; Bain *et al.*, 2000; Collins *et al.*, 2000; Hatin *et al.*, 2002; Greene *et al.*, 2009; Balazik *et al.*, 2012; Breece *et al.*, 2013). In contrast, spawning females move upriver when temperatures are closer to 12 to 13 °C (54 to 55 °F), return downriver relatively quickly, and may leave the estuary and travel to other coastal estuaries until outmigration to marine waters in the fall (Smith *et al.*, 1982; Dovel and Berggren, 1983; Smith, 1985; Bain, 1997; Bain *et al.*, 2000; Collins *et al.*, 2000; Greene *et al.*, 2009; Balazik *et al.*, 2012; Breece *et al.*, 2013).

The use of telemetry tags for Atlantic sturgeon and more widespread use of receiver arrays has provided new information on Atlantic sturgeon spawning behavior and whether or when staging occurs. In the James River, some males moved straight to the hypothesized spawning ground without any apparent staging period while others occurred downriver in brackish water during the summer before moving upstream in August or early September; still others occurred farther upriver for a period of time before the spawning period (Balazik and Musick, 2015). Given the various movement patterns, it is not clear to what extent staging occurs or, for those fish that do appear to stage, whether it is essential for successful reproduction. Therefore, we have not included specific staging areas as a physical or biological feature of Atlantic sturgeon critical habitat. However, we recognize new research may lead to better identification regarding whether, where, and when Atlantic sturgeon stage. Therefore, the feature addressing access includes open passage between the river mouth and spawning sites to support life history needs associated with reproduction such as staging, resting, or holding of spawning condition adults.

Comment 6: Two commenters provided information on the presence of Atlantic sturgeon in the Hudson River and in Delaware Bay in proximity to sand waves, postulating that sand wave habitat provides the same function as deep holes provide for green and Gulf sturgeon, allowing Atlantic sturgeon to rest and feed during the spawning season. According to the commenters, in the Hudson River, sand waves were found in proximity to the Atlantic sturgeon spawning areas. Side scan sonar showed a high density of spawning size Atlantic sturgeon in sand wave habitat and no sturgeon in sand habitat without waves. A gill net set in proximity to the sand wave habitat had high catch rates of Atlantic sturgeon. Similarly, in the Delaware Bay, telemetry tagged Atlantic sturgeon were detected in high density in a relatively small area (18.8 acres) within, and bordering sand wave habitat. The commenters point out that habitat that provides for rest or cover has been identified as an essential feature for other fish species.

Our Response: The commenters provide new, intriguing information for a possible association between Atlantic sturgeon and sand wave habitat. When designating critical habitat, we do not have to know exactly why the listed species occurs in an area. We do, however, need to identify physical or biological features that support the life history needs of the species. The commenters postulate that the sand waves provide resting and feeding areas for Atlantic sturgeon during spawning and feeding in the lower estuary. However, no information was provided to support this theory and the literature does not point toward evidence of feeding or resting during spawning. On the contrary, available references suggest female Atlantic sturgeon make rapid upriver and downriver movements during spawning and can completely leave the spawning estuary and travel to other estuarine environments, presumably for foraging. Males move upriver and downriver of the spawning area during the spawning season, and then move downriver at the end of the spawning season presumably to rest and forage before leaving the spawning estuary in the fall. At this time, we do not have sufficient information to determine what life history needs sand waves may support.

Sand waves are a common feature of the Hudson River and Delaware Bay as well as other rivers and bays (*e.g.*, see information for the Delaware Bay Benthic Mapping Project at *http://www.dnrec.delaware.gov/coastal/dnerr/documents/benthic4plet.pdf*, and Levin *et al.*, 1992). The mapping images provided by the commenter for the Hudson River depict dynamic wave habitat and approximate spawning area for Atlantic sturgeon. Wave habitat is depicted as occurring in a number of areas. Some of these are in proximity to spawning areas and some are not. Similarly, the information provided by the commenter for Delaware Bay depicts sand wave habitat in proximity to an observed aggregation of Atlantic sturgeon. However, no information is provided for Atlantic sturgeon presence in other areas of the Bay where sand wave habitat also occurs and does not occur. Therefore, the information provided and the other available information (*i.e.*, published literature) do not support the commenter's position that sand waves in the Hudson River and Delaware Bay support the life history needs of the New York Bight DPS, and we have not included sand waves as a physical or biological feature of critical habitat for the New York Bight DPS of Atlantic sturgeon.

Comment 7: A commenter stated that while the proposed designation includes soft-bottom habitats for juvenile foraging and development, it fails to expressly recognize the need to protect soft-bottom areas that serve as

resting and feeding habitats for spawning adults. The commenter called upon us to designate soft-bottom areas of the Hudson River for resting and feeding habitats for spawning adults, particularly the areas with sand waves, as critical habitat.

Our Response: Soft-bottom areas of the Hudson River are part of the Hudson River critical habitat unit based on the best available scientific information that soft bottom substrates and the transitional salinity zone are needed for juvenile rearing. We are not aware of any information that indicates Atlantic sturgeon spawning adults feed or rest in spawning areas, and the commenters did not provide any such information. Available references indicate spawning female Atlantic sturgeon make rapid upriver movements to spawning areas and quickly depart spawning areas while males move upriver and downriver of the spawning area during the spawning season. If new information on the use of soft substrate by spawning adults becomes available, it will be considered by Federal agencies assessing the effects of proposed actions on the Hudson River critical habitat, and by us as the consulting agency in ESA section 7 consultations. More details of our consideration of sand wave habitat as a physical or biological feature is provided in our response to Comment 6. As noted there, the best scientific information available does not currently support sand waves as a physical or biological feature for Atlantic sturgeon critical habitat.

Comment 8: An industry trade group asserted that we must revise our proposed designation to explain how each specific critical habitat unit to be designated contains the PBFs essential to the conservation of the species, suggesting that our approach should be the same as that taken in the designation of critical habitat for the Southern DPS of green sturgeon (74 FR 52300; October 9, 2009). They also suggested our proposed designation is overly broad, improperly used "ephemeral reference points," and is unsupported by facts or science. The commenters suggested we identified and proposed to designate sweeping areas of occupied habitat that undoubtedly capture many areas that do not have, and likely never will have, physical or biological characteristics essential for the conservation of the species, noting that the designations cover manmade areas that they state are not important to the species, such as "manmade features" below the mean high water mark that cannot or would not be accessed by the species (*e.g.,* outfalls, enclosures, quays) and industrialized areas used by ocean-going vessels. One commenter suggested it appeared we had merely designated entire rivers from the confluence of the Atlantic Ocean back to either some major tributary or some large impoundment or impassable boundary upstream. Several commenters suggested that areas should not be designated as critical habitat because environmental conditions in certain stretches of rivers are poor and would not support the PBFs. Similarly, other commenters stated we had failed to limit the mapped areas in our proposed designation to areas where we believe the PBFs occur.

Our Response: We disagree. As we explained in our final rule, Implementing Changes to the Regulations for Designating Critical Habitat (81 FR 7414; February 11, 2016), in each designation we will identify specific areas of critical habitat "at a scale determined by the Secretary to be appropriate." We are not required to make determinations at an infinitely fine scale, and we need not determine that each square inch, square yard, acre, or even square mile independently meets the definition of critical habitat. We have discretion to determine the appropriate scale for the analysis, which is informed by, among other things, the life history of the species, the scales at which data are available, and biological or geophysical boundaries (such as watersheds). Our regulations at 50 CFR 424.02 also indicate that PBFs may be ephemeral or dynamic, and we may designate areas with ephemeral or dynamic PBFs if the other applicable requirements of critical habitat designations are met, and if there are documented occurrences that a particular habitat type is in the area and there is a reasonable expectation of that habitat occurring again (81 FR 7414; February 11, 2016). As we acknowledged in the proposed rule, there are large areas of most rivers where data are still lacking. The available data also represent a snapshot in time, and the exact location of a PBF may change over time (*e.g.,* water depth fluctuates seasonally, as well as annually, and even hard substrate may shift position). Although the PBFs may vary even at the same location, if any of the available data regarding a particular PBF fell within the suitable range (*e.g.,* salinity of 0–0.5 ppt or hard substrate [gravel, cobble, etc.]), we considered that the essential PBF is present in the area. When data were not available for certain rivers or portions of occupied rivers, we used our general knowledge of Atlantic sturgeon spawning and applied river-specific information to determine the location of PBFs essential to spawning. Smaller specific areas within each unit could not be identified because the submerged nature of the essential PBF, the limits of available information on the distribution of the PBFs, the varying distribution of the PBFs from time to time, and limits on mapping methodologies make it infeasible to define the specific areas containing the PBFs more finely than described in this rule. The presence of manmade structures that do not provide the PBFs within a specific area being designated as critical habitat does not render the boundaries of the specific area invalid; we have explained that the PBFs must be in a project area for it to function as critical habitat. While we agree that manmade structures themselves (*e.g.,* an outfall pipe, dock, pier, navigational buoy) cannot and do not contain the PBFs and therefore are not part of the critical habitat designation, the mere presence of such a manmade structure in an area does not mean that the area does not contain one or more PBFs or that these areas are not important to the species. We have clarified the point in regulatory text that manmade features that do not provide the PBFs are not essential to the species and are not included in critical habitat. We believe our designation is consistent with our regulations and based on the best scientific information available for Atlantic sturgeon DPSs.

Comment 9: Two commenters stated we failed to consider in a complete and meaningful way, the role certain aspects of aquatic chemistry play on determining whether a river has suitable spawning habitat. The commenters suggested we should have considered pH and levels of calcium and magnesium ions. They suggest these chemical characteristics can determine whether Atlantic sturgeon will spawn in a particular reach of river, and thus, it is crucial that these features are given special management consideration in future section 7 consultations and, if need be, protected accordingly.

Our Response: The literature on Atlantic sturgeon has not typically reported pH, calcium, and magnesium levels for rivers where Atlantic sturgeon spawn. For example, in their review of essential Atlantic sturgeon spawning habitat in Virginia, Bushnoe *et al.* (2005) reported pH for waters of the James, York, Pamunkey, Mattaponi, and Rappahannock Rivers where they anticipated Atlantic sturgeon spawning could occur. However, with respect to other water parameters, they noted available water quality data for the James River measured calcium carbonate concentration, not calcium

concentration, as an indicator of hardness. Therefore, they could not directly compare the measured calcium carbonate concentrations with reported calcium concentrations measured in other rivers where Atlantic sturgeon spawn. Conductivity was measured in the Rappahannock River, but neither hardness or conductivity measurements were available for the Pamunkey River or Mattaponi River. Recent publications regarding Atlantic sturgeon spawning for the Chesapeake Bay DPS of Atlantic sturgeon (*e.g.*, Balazik *et al.*, 2012; Hager *et al.*, 2014) do not include measures of water pH, calcium, or magnesium in spawning areas.

We considered the information provided by the commenters in the report they provided with their comments and references cited within that report. Unfortunately, the report itself does not provide any new information regarding pH and levels of calcium and magnesium ions. The report mentions a 1976 study that indicated spawning of the European Atlantic sturgeon had been successful in the Rione River of the Russian Caucasus when the pH ranged from 7.4–7.6. The report also states that a pH level of 6.8–7.7 is acceptable to various species of sturgeon (Holcik *et al.*, 1989), but continues to state there is no specific research on pH levels appropriate for Atlantic sturgeon. Beyond this, no further conclusions regarding pH and Atlantic sturgeon were made. The provided report also briefly mentioned calcium and magnesium ions. It states: "Salinity was 0.4 psu, which is on the high side of Ca[lcium] and M[a]g[nesium] ion levels present in rivers where Gulf Sturgeon spawn successfully (Ken Sulak, pers. comm. to B. Kynard, 15 Aug 2016). Specific acceptable levels of salinity for gametes and eggs of Atlantic sturgeon are not known and are not discussed by the Atlantic Sturgeon Status Review Team (ASSRT 2007) or in the preamble to NMFS' proposed designation. However, based on Gulf Sturgeon tolerance and Cherr and Clark (1985), the levels of Ca[lcium] and M[a]g[nesium] ions in the Ocklawaha River should not be a problem for egg fertilization or egg rearing of sturgeons." Beyond this discussion of calcium and magnesium, no further information is provided regarding the relationship of these ions to successful spawning of Atlantic sturgeon. The report provided by the commenters also cited additional literature that may discuss these water quality parameters. However, we attempted to acquire these references and were unable to because they were not readily available to the public. Thus, we determined there was not enough information for us to include the specific water quality parameters mentioned by the commenter as essential PBFs for any DPS of Atlantic sturgeon.

Comment 10: An association of municipal wastewater agencies stated that the preamble of the proposed rule for the Gulf of Maine, New York Bight, and Chesapeake Bay DPS properly explains that "specific oxygen concentration and temperature values are provided as examples and guidance" but the proposed rule omits this key language from the regulatory text. The commenter believes the regulatory text should include this explanation or, alternatively, the examples of the water feature characteristics should be removed from the final rule or be made more specific to the spawning and subsequent stages of development of the Atlantic sturgeon in the specific habitats described in the proposed rule.

Our Response: We do not provide explanations of the regulations in the regulatory text. The use of "*e.g.*" in the regulatory text informs the reader that the DO level and water temperature are provided only as guidance, and these are not the only values for either DO or temperature that are suitable for all Atlantic sturgeon age classes addressed by the PBFs.

Comment 11: A commenter stated the proposed rule for the Carolina and South Atlantic DPSs also frames the features as "optimal" and "suboptimal" and recommended that we "revise Part (a)(4)(iii) of the proposed rule for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs" to frame the features as optimal and suboptimal.

Our Response: Upon reading the comment, we realized that framing the example of dissolved oxygen and temperature values as "optimal" and "suboptimal" can be misinterpreted as establishing specific, exclusive values. Since these values were meant to be examples of the numerous possible combinations of dissolved oxygen, water temperature, and salinity essential to Atlantic sturgeon conservation, we did not revise the language for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon to frame the features as "optimal" and "suboptimal." This is because there is not one single DO level or temperature range that is best for Atlantic sturgeon in terms of habitat avoidance. We did revise the language for the Carolina and South Atlantic DPSs of Atlantic sturgeon by replacing the terms "optimal" and "suboptimal." The new phrases convey that the examples provide context, but do not establish static, exclusive values for the essential physical feature.

The dissolved oxygen levels and water temperature values set forth in the proposed rules for the Atlantic Sturgeon DPSs were examples based on the best available information for conditions in different rivers occupied by Atlantic sturgeon and observed responses of sturgeon to these variables. Water quality factors of temperature, salinity and dissolved oxygen are inter-related environmental variables. Dissolved oxygen concentrations in water can fluctuate given a number of factors including water temperature (*e.g.*, cold water holds more oxygen than warm water) and salinity (*e.g.*, the amount of oxygen that can dissolve in water decreases as salinity increases). This means that, for example, the dissolved oxygen levels that support growth and development will be different at different combinations of water temperature and salinity. Similarly, the dissolved oxygen levels that we would expect Atlantic sturgeon to avoid would also vary depending on the particular water temperature and salinity. As dissolved oxygen tolerance changes with age, the conditions that support growth and development and likewise, the dissolved oxygen levels that would be avoided, change. This combination of factors makes it such that we cannot identify a single set of dissolved oxygen, water temperature and/or salinity conditions as optimal or suboptimal for any of the DPSs.

Like salinity and dissolved oxygen, water temperature fluctuates in the dynamic rivers and estuaries used by Atlantic sturgeon. The scientific literature for Atlantic sturgeon does not always include the water temperature where Atlantic sturgeon are detected or captured. There may also be differences in temperature tolerance of Atlantic sturgeon that originate from different rivers, and differences in temperature tolerance within the same river depending on the life stage. Therefore, while we generally know the ranges of water temperature and dissolved oxygen in which Atlantic sturgeon occur, we cannot identify a single "best" water temperature or dissolved oxygen level for all Atlantic sturgeon, in all rivers, under all circumstances.

We stated in the preamble of the proposed rule for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs that, "Specific areas designated as critical habitat based on the four features are not expected to have water with oxygen concentration of 6 mg/L and the specific water temperatures at all times and within all parts of the

area." We similarly stated for the example in the proposed rule for the Carolina and South Atlantic DPSs of Atlantic sturgeon that, "Appropriate temperature and oxygen values will vary interdependently, and depending on salinity in a particular habitat." Thus, we believe the terms "optimal" and "suboptimal" inadvertently conveyed a different meaning.

Comment 12: A commenter recommended that we revise the guidance for DO concentrations and temperature values provided in the proposed rule to be consistent with existing U.S. Environmental Protection Agency Clean Water Act water quality criteria applicable to the Chesapeake Bay Watershed. The commenter further stated the proposed regulatory language establishing a DO concentration of 6 mg/L and a maximum temperature of 30 °C for juvenile rearing habitat is inconsistent with existing water quality criteria. The commenter also stated that the proposed rule should evaluate and address existing conditions in the waters for the features which will dictate where to designate critical habitat. This framework will provide a necessary reference for both the agency and commenters from which the true implications of the proposed habitat components can be evaluated. For example, the proposed rule provides that temperature between 13 °C to 26 °C is optimal for spawning habitat, but there is no indication of how that temperature range compares to the ambient temperature of the waters themselves. In other words, does the proposed critical habitat meet the habitat component for temperature most of the time, some of the time, etc. Second, the proposed rule must include a natural condition provision to reflect natural instream temperature and DO levels which are outside of the temperature and DO features in the proposed rule. Where ambient temperature and/or DO is outside of these levels, the natural condition must control. Any regulatory requirements must be targeted toward the natural condition and not critical temperature/dissolved oxygen elements that are not naturally present.

Our Response: The water quality features are a physical feature essential to the corresponding Atlantic sturgeon DPSs. As discussed in our response to Comment 11, because DO and temperature vary interpedently based on local environmental conditions, the DO and temperature values provided in the proposed rules are provided as examples only. For example, the earliest life stages are the most sensitive to DO levels. Therefore, earlier life stages (*e.g.,* juveniles) may avoid areas based on one DO level while older life stages (*e.g.,* subadults or adults) may avoid areas based on a different DO level. The example provided in the regulatory text in the proposed rule for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon is just one example. We have not included a framework for each critical habitat area or a natural condition provision. However, we agree that these should be considered when Federal agencies are determining whether a proposed Federal agency action may affect designated critical habitat for the Atlantic sturgeon DPSs, and considered by us when we are consulting on Federal agency actions. See our responses to Comments 83, 84 and 85 for more information on the water quality feature for the Carolina and South Atlantic DPSs of Atlantic sturgeon.

Comments on Special Management Considerations or Protection

Comment 13: A commenter stated the proposal does not specify what "special management considerations or protections" are appropriate or necessary for the conservation of Atlantic sturgeon in all and/or each specific DPS. Given the areal extent of the proposed designation and the potential for consultation on numerous and varied actions (water use, wastewater discharges, dredging, etc.), the final rule needs to be more specific regarding the special management considerations or protections that may be required for all or specific DPSs.

Our Response: Special management considerations or protections are the methods or procedures useful in protecting the PBFs essential to conservation of listed species. We provided information in the proposed rule for why the PBFs essential to the conservation of each DPS may require special management or protection. This provision of a designation does not establish measures that may be recommended or required during section 7 consultation, such as RPMs and terms and conditions. Our impacts analyses and 4(b)(2) report describe the types of measures that might be required to address adverse impacts to the PBFs for federal actions expected to require consultation.

Comment 14: An industry trade group believes we failed to provide any assessment of current management or protections in place and whether those are adequate for the conservation of the Atlantic sturgeon. The commenters claim we must consider whether any of the proposed critical habitat units are presently under special management or protection for Atlantic sturgeon. The commenters acknowledge we have identified a number of initiatives that could protect Atlantic sturgeon but believe we must actually assess these initiatives to determine whether they are sufficient and determine what further management actions may benefit from critical habitat designation. The commenters go on to state we should consider each feature and specific area proposed and assess current management measures in place to make an actual determination as to whether special management may be needed in the reasonably foreseeable future, and if so, what that management would be, and how the critical habitat designation would further that management. The commenters conclude that our discussion of special management considerations is limited to general discussion regarding how barriers, water withdrawals, and dredging can generally affect water flow, quality, and depth and/or alter hard substrate, and that we have made non-specific assertions that special management for the essential PBFs may be required "as a result of global climate change."

Our Response: We disagree. When determining whether PBFs may require special management considerations or protection, we do not base our decisions on whether management is currently in place or whether that management is adequate (81 FR 7414; February 11, 2016). In *Center for Biological Diversity* v. *Norton,* 240 F.Supp. 2d 1090, 1096–1100 (D. AZ, 2003), the court rejected reading the ESA to mean that if adequate management or protections are already in place, then an area cannot meet the definition of critical habitat because special management considerations or protections are not required ("Defendant's construction of 'critical habitat' also adds the term 'additional' to the statute. As Defendant stated in its final rule, '*Additional* special management is not required if adequate management or protection is already in place. . .' There is absolutely nothing in § 1532, or its implementing regulations, to support Defendant's inclusion of 'additional.' As such, Defendant's construction of the 'critical habitat' definition is impermissible and contrary to law.") Additionally, we are not required to determine if a PBF currently requires special management considerations, or to determine what that management would be, and how critical habitat designation would further that management. We are only required to make a determination that a PBF *may* require special management

considerations or protection (81 FR 7414; February 11, 2016). Consequently, we assessed the need for special management considerations for each PBF in the proposed rule and identified numerous actions or natural factors that could adversely impact each PBF, as is required by the ESA ("Because the emphasis in the requirement is on the word 'may,' the evidence shown by the Service supports the reasonable conclusion that *some* special management considerations or protection may be needed in the future to protect the sea ice habitat PCE [primary constituent element]. However, neither the Service nor the ESA have to be the vehicles by which the procedures or actions involved in the considerations or protection are accomplished. The Service has shown that someday, not necessarily at this time, such considerations or protection *may* be required. In other words, the Service has shown that it is within the realm of possibility that such considerations or protection may be needed now or in the future. Furthermore, the Service does not have to identify the source of such considerations or protection, merely that the considerations or protection may be necessary in the future. For example, the evidence in the record showing that sea ice is melting and that it will continue to melt in the future, perhaps at an accelerated rate, is more than enough proof that protection *may* be needed at some point" (*Alaska Oil and Gas Ass'n* v. *Salazar,* 916 F. Supp. 2d 974, 990–992 (D. AK 2013), (Reversed on other grounds and remanded by *Alaska Oil & Gas Ass'n* v. *Jewell,* 815 F.3d 544 (9th Cir. 2016)).

We also disagree with the commenters' characterization that we made non-specific assertions regarding the special management needs of the PBFs that may be necessary as a result of global climate change. The proposed rule specifically identifies the impact from global climate change's impacts to water temperature and DO, as potential threats to the survival and recovery of Atlantic sturgeon in the southeastern United States.

Comment 15: A commenter asked if the objective of the special management considerations or protections is to create optimal habitat, specifically, to create the physical features described in § 226.225(a)(1) of the proposed rule, even if those features do not currently exist.

Our Response: The answer to this question is no. Critical habitat is based on the presence of PBFs essential to the conservation of the listed species and which may require special management or protection. We only designate critical habitat when the PBFs essential to conservation of the listed species may require special management considerations or protections. If we identify PBFs essential to the listed species but those features do not require special management or protection, then we do not designate critical habitat based on those PBFs.

The purpose of designating critical habitat is to prevent the destruction or adverse modification of the habitat as a result of Federal activities. Section 7(a)(1) of the ESA requires Federal agencies to use their authorities in furtherance of the purposes of the ESA (*i.e.,* aid in the conservation of listed species). However, there is not a requirement that Federal agency actions improve or create habitat for ESA-listed species.

Comment 16: Commenters requested that we include language to address known, significant, and growing uses that will adversely impact Atlantic sturgeon habitat in the Hudson River.

Our Response: For critical habitat designations we identify activities that may necessitate special management or protection of the PBFs. We have provided this information for the PBFs identified for the critical habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs. We cannot foresee every activity that would necessitate special management or protection of the PBFs. However, we believe the list of activities provided by us is comprehensive enough to provide adequate notice on which activities may affect critical habitat. The impact of Federal agency actions on the critical habitat features are assessed through ESA section 7 consultation.

Comment 17: One commenter requested that we include "clear guidance for considering the effects of a changing climate on critical habitat designation for species recovery in the final rule." They requested we consider "projected changes to salinity, temperature and DO, including changes in sea level rise." They further requested that we document the extent that climate change was considered when assessing the need for the inclusion of currently unoccupied habitat in the final rule.

Our Response: We acknowledge climate change is likely a factor contributing to the possible need for special management considerations or protection for the PBFs, and we recognize that climate change may affect the availability of some PBFs to sturgeon in some areas. As discussed in the response to comments for our regulations, Implementing Changes to the Regulations for Designating Critical Habitat (81 FR 7414; 7426; February 11, 2016), in those circumstances where the best scientific data available indicate that a species may be shifting habitats or habitat use, we may include specific areas accommodating these changes in a designation, provided we can explain why the areas meet the definition of critical habitat. No information is currently available, and none was provided by the commenter, that indicates any of the Atlantic sturgeon DPSs may be shifting habitats or habitat use in response to the effects of climate change. For example, Breece *et al.* (2016) projected how habitat use by adult Atlantic sturgeon of the Delaware River could shift in response to climate change, but did not provide evidence that Atlantic sturgeon are, or may be, shifting habitats or habitat use in the Delaware River as a result of climate change. We are not aware of other publications that indicate that any DPS of Atlantic sturgeon is shifting habitats or habitat use in response to the effects of climate change.

The commenter did not include any riverine-specific information regarding the areal influence of changes to salinity, temperature and DO, or sea level rise. We are designating as critical habitat the river areas that capture the varying distribution of the PBFs and that are appropriate to encompass the habitat essential for the conservation of the species. The designation includes all habitat required for reproduction and recruitment essential for the recovery of the DPSs, and reflects consideration of in-river changes that may result from climate change (*e.g.,* temperature, salt-water intrusion, etc.). We did consider the presence of the PBFs in each river, and the variability in the salt wedge seasonally and annually that influences where the Atlantic sturgeon life stages occur in the estuary, and we accommodated for these shifts in the critical habitat designation.

We considered whether any designations of unoccupied habitat were essential for the conservation of the Gulf of Maine, New York Bight or Chesapeake Bay DPSs because of the function they are likely to serve as climate changes, and we determined there were no such areas. We will continue to review Atlantic sturgeon habitat needs as new information about potential effects from climate change becomes available. Consistent with NMFS guidance in the context of individual section 7 consultations, we will consider how climate change interacts with a proposed action's effects on the PBFs in assessing an action's impacts on the critical habitat's

ability to support the species' recovery. These analyses will necessarily be case-by-case and dependent on the action, environmental conditions at the time in the affected river (including projected changes from climate change, if relevant), and the status of the species.

Comment 18: An industry trade group indicated we failed to map potential threats to Atlantic sturgeon (*e.g.*, manmade structures, dredging areas). This industry trade group also noted that we did not include an exception from critical habitat for manmade structures in the regulatory language for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs.

Our Response: Threats to the species were identified in both the Listing Rules (77 FR 5880; February 6, 2012 and 77 FR 5914; February 6, 2012) and the Status Review (ASSRT, 2007). There is no requirement to map the existence of threats to the species in a critical habitat designation. Information on activities that may affect critical habitat is properly characterized in the impact analyses. We appreciate the comment noting that we did not include an exception from critical habitat for manmade structures that do not provide the PBFs for northeastern DPSs. This was an oversight, as we did include the exception for the Carolina and South Atlantic DPSs. We have now included and clarified this exception for all five DPSs.

Comments on Designation of Unoccupied Critical Habitat

Comment 19: A commenter asked that the final rules expand on the documentation for upstream and downstream critical habitat boundaries of the critical habitat units and identify unoccupied habitat essential to the conservation of a particular DPS. The commenter noted that many of the upstream critical habitat boundaries are defined by dams or locks, and that presence of a barrier, in and of itself, should not constitute the upstream extent of critical habitat. As one of the objectives of the rule is to "increase the abundance of each DPS by facilitating increased successful reproduction and recruitment to the marine environment," the commenter suggested revisiting consideration of these reaches as essential, but currently unoccupied habitat.

Our Response: Section 3(5)(A) of the ESA allows for consideration and inclusion of unoccupied habitat in a critical habitat designation if such habitat is essential for conservation of the species. The 1998 and 2007 status reviews for Atlantic sturgeon, ASMFC's 2009 review of Atlantic coast diadromous fish habitat, and the 2012 listing rule for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs (77 FR 5880; February 6, 2012) of Atlantic sturgeon reviewed historical and current use of rivers within the range of each DPS. We have considered the life history, status, and conservation needs information in these reviews, the cited literature, and new literature for each DPS (*e.g.*, Wippelhauser and Squiers, 2015 for the Gulf of Maine DPS; Breece *et al.*, 2013 for the New York Bight DPS; Hager *et al.*, 2014 for the Chesapeake Bay DPS). We have concluded that unoccupied habitat is not essential to the recovery of the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs because Atlantic sturgeon reproduction and rearing habitat for each DPS is available downriver of dams or in rivers that are not dammed, and the boundaries of the critical habitat areas take into consideration the seasonal and annual variations in the location of the salt wedge that influences where Atlantic sturgeon life stages occur within the estuary as well as any potential shifts that may occur as a result of climate change. Therefore, we are not designating unoccupied habitat for these DPSs.

We agree that presence of a barrier does not necessarily constitute the upstream extent of critical habitat; however, in the case of the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon, the barriers included to denote the upstream limit of the designation are the same designators as the upstream limit of the area occupied and therefore are appropriate in this case. We recognize that the upstream limits of the area occupied at the time of listing is not necessarily the historical upstream limit (*e.g.*, there is historical reference to the presence of sturgeon below Mohawk Falls which is upstream of the modern-day upstream limit of Atlantic sturgeon in the Hudson River); however, we have determined that currently unoccupied habitat is not essential for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs. Additionally, barriers that occur at a critical habitat boundary provide an easily recognizable landmark for where critical habitat begins or ends. Non-ephemeral reference points (*e.g.*, dams, bridges) can be used in a textual description of the boundaries of critical habitat.

Comments Designating Specific River Units or River Areas

Comment 20: Several environmental organizations stated that we incorrectly claimed that we could not designate estuarine or marine areas as critical habitat due to insufficient data and that the best available scientific information supports identification of PBFs in estuarine and marine environments that are essential to Atlantic sturgeon conservation. These commenters said that a growing body of research has identified critical feeding and seasonal aggregation sites, and that the sites identified to date should be designated as critical habitat. The commenters stated there is a scientific consensus that Atlantic sturgeon use marine waters of particular depths as migration corridors; the commenters asserted that available information supports the contention that all five DPSs use the same narrow migration corridor and known aggregation sites. The commenters stated that water depth, available prey, substrates, temperature, salinity and seascapes are factors correlated with, and that influence, Atlantic sturgeon use of specific estuarine and marine habitats as feeding or seasonal (winter, summer) aggregations, and migratory corridors, and that these features may require special management considerations or protection. The commenters stated that our regulations, Implementing Changes to the Regulations for Designating Critical Habitat, (81 FR 7414; February 11, 2016) support the use of generally-defined PBFs or an ecosystem approach. Finally, the commenters discussed our previous critical habitat designations for green and Gulf sturgeon as valid models for designating estuarine and marine areas as critical habitat for Atlantic sturgeon.

Our Response: We reconsidered the information available, but reached the same conclusion that we cannot identify critical habitat for adults or subadults of any of the five Atlantic sturgeon DPSs in marine or nearshore estuarine waters at this time. We agree that the regulatory definition of PBFs is intentionally broad because we cannot predict what species will be listed in the future, and what features that support the life history needs of those species will be necessary for designating their critical habitats. However, as described in the response to comments for our regulations, Implementing Changes to the Regulations for Designating Critical Habitat (81 FR 7414; February 11, 2016), "we need to clearly articulate in our proposed and final rules designating critical habitat for each species how the essential features relate to the life-history and conservation needs of the species. This type of specificity will be in the individual proposed and final rules designating critical habitat for

each species." Thus, while prior designations for other species may provide important background, critical habitat designations are specific to particular species, their life history traits, habitat and resource uses, and information available for that species.

Some of the literature available for Atlantic sturgeon uses the term "critical habitat" in reference to areas where Atlantic sturgeon occur. However, the literature is not applying the term "critical habitat" as it is defined in the ESA. Similarly, the word "essential" has been used in the literature, but it is not used in the same context as it is in the critical habitat regulations. The Background of our regulations (81 FR 7414; February 11, 2016) explains that "[t]he purpose of critical habitat is to identify the areas that are essential to the species' recovery." The explanation makes clear that critical habitat is the specific area(s) essential to species recovery.

We reviewed the critical habitat designations for the Southern DPS of green sturgeon and for Gulf sturgeon in the event there were similarities in the life history of sturgeon species that could inform the essential PBFs for the Atlantic sturgeon DPSs. Marine waters were designated for Gulf sturgeon and the Southern DPS of green sturgeon based on information that certain marine waters were a migratory/connectivity corridor for subadult and adult sturgeon between estuaries and marine foraging areas. However, unlike the Southern DPS of green sturgeon and Gulf sturgeon, the available information for Atlantic sturgeon foraging in marine waters (Johnson *et al.*, 1997; Dunton, 2014) is inconclusive regarding whether any particular marine waters are essential foraging areas for Atlantic sturgeon, and thus there are no identifiable migratory corridors between specific foraging areas. Furthermore, those sources do not provide the necessary information to allow us to identify what the PBFs associated with potential marine foraging for Atlantic sturgeon might be.

The scientific information available on Atlantic sturgeon forage items does not provide the specificity we need in identifying PBFs that are essential to the DPSs. The available information indicates that Atlantic sturgeon are opportunistic, benthic-cruisers that consume benthic prey over soft (unconsolidated) substrates. Other than being benthic prey, the specific Atlantic sturgeon prey items identified in the literature were common and vary between sites. Therefore, it is not possible to determine if gravel-sand and sand substrate types are essential habitat features for Atlantic sturgeon prey or, because Atlantic sturgeon are opportunistic foragers, the sturgeon happen to be feeding over these substrate types because they are ubiquitous, and we lack information to define prey, substrates or feeding areas more specifically for Atlantic sturgeon.

We cited in the preamble of the proposed rules the literature that identifies Atlantic sturgeon aggregation areas. The term "aggregation" as it is used in the literature for Atlantic sturgeon is not defined by any particular quantitative measure. The number of areas described in the literature as an "Atlantic sturgeon aggregation area" demonstrates the ubiquitous nature of Atlantic sturgeon in the marine range as well as the liberal use of the term for characterizing the presence of Atlantic sturgeon in an area. For example, the commenters referred to literature identifying Atlantic sturgeon feeding areas in the Bay of Fundy and Long Island Sound. Our background information cited to literature describing other Atlantic sturgeon foraging areas, including areas with mud bottom, gravelly-sand substrate, and sand substrate. Stein *et al.* (2004) noted that sturgeon were most often incidentally captured over gravelly-sand and sand substrate and suggested that their presence was associated with foraging. However, Stein *et al.* (2004) also reflected that the gravel-sand and sand substrate types were the dominant substrate types along the coastline, so it was uncertain if Atlantic sturgeon presence was correlated to the substrate type or if Atlantic sturgeon presence was coincidental to the substrate type.

The commenters referred to Laney *et al.* (2007) as demonstrating that "shallow, nearshore waters off North Carolina are an important winter habitat for Atlantic sturgeon." The commenters did not provide information for why these particular shallow, nearshore waters are essential to one or more of the Atlantic sturgeon DPSs compared to all shallow, nearshore waters that are accessible to the DPSs. We need to have information to be able to make the connection between species' presence and presence of one or more PBFs that are essential to the conservation of the species and may require special management or protection. The commenters did not provide, and we could not find, information to distinguish these shallow, nearshore waters from other shallow, nearshore waters, or information that identifies more specific features of these waters. Tagging work by Erickson *et al.* (2011) showed that adult Atlantic sturgeon from the Hudson River move about within the Mid-Atlantic Bight, occurring as far south as Delaware for the late fall to early winter and then as far south as the area off Chesapeake Bay for the latter part of the winter. The data do not suggest movement from the river to a specific overwintering area where the fish reside throughout the winter. The available information for where Atlantic sturgeon occur in the winter also includes evidence of sturgeon in marine waters off estuaries where they were detected in the fall, sturgeon making long migrations along the coast to southern coastal waters, sturgeon possibly overwintering in an estuary, and at least one sturgeon moving in and out of a Gulf of Maine estuary during the winter (Laney *et al.*, 2007; Dunton *et al.*, 2010; Oliver *et al.*, 2013; Dunton *et al.* 2015; Taylor *et al.* 2016; C. Hager, Chesapeake Scientific, pers. comm.; T. Savoy, CT DEEP, pers. comm.; G. Zydlewski, Univ. of Maine, pers. comm.). Because this information is conflicting, we could not determine whether or where overwintering areas are essential to one or more of the Atlantic sturgeon DPSs.

We cannot designate critical habitat based on the presence of the species alone. Therefore, while we acknowledge there is literature that identifies aggregation areas where Atlantic sturgeon are generally found, it does not provide specificity as to the purpose of the aggregations or the features that support those purposes. Therefore, we do not believe it provides the information we need to meet the statutory and regulatory requirements to designate critical habitat.

The commenters stated that the Atlantic sturgeon DPSs use a narrow migratory corridor within marine waters and we should designate this narrow corridor as critical habitat. The commenters' characterization of these waters as a "narrow corridor" is subjective. As we described in the preamble for the proposed rules, Atlantic sturgeon generally occur within the 50 m depth contour. However, the literature is not consistent for the depth contour where Atlantic sturgeon occur in the marine environment. Based on fisheries-dependent data for incidental captures of Atlantic sturgeon, Stein *et al.* (2004) described that "peak sturgeon captures along the coast were approximately bracketed by isobaths ranging from 10 to 50 m" while Dunton *et al.*, (2010), using both fisheries-dependent and fisheries-independent data of incidental Atlantic sturgeon captures, concluded that "Atlantic

sturgeon were largely confined to water depths less than 20 meters." Erickson *et al.* (2011), using location data of tagged Atlantic sturgeon, described the mean range of marine waters where Atlantic sturgeon occurred as 9.9 to 24.4 m depth depending on time of year. Erickson *et al.* also noted differences between fish, with some sturgeon using more shallow waters (5–15 m) and some using deeper waters (35–70 m) compared to the other tagged Atlantic sturgeon. Given these inconsistencies, we could not identify the PBFs that facilitate migration for any of the five DPSs.

The commenters also pointed to the findings of Breece *et al.* (2016) as research that could inform our designation of critical habitat in marine waters, nearshore bays, and sounds. Noting that Atlantic sturgeons' seasonal coastal migrations are difficult to predict, Breece *et al.* (2016) used ocean color and sea surface temperature recorded during the spring to partition waters of the Delaware Bay and ocean waters off Delaware Bay into six "seascapes," and tested the hypothesis that these seascapes are predictors of the occurrence of Atlantic sturgeon during their spring migration in the mid-Atlantic. The commenters stated that Seascape E is a physical feature of marine waters that is essential to the Atlantic sturgeon DPSs (*e.g.,* for migrating between estuaries and marine waters and for where Atlantic sturgeon spend most of their life in marine waters) and asked us to designate marine waters as critical habitat for the Atlantic sturgeon DPSs. We considered and cited the Breece *et al.* (2016) study for the information that it provides for Atlantic sturgeon marine distribution. However, we did not conclude that Seascape E was an essential PBF because: (1) The equipment to detect sturgeon was primarily placed in or occurred within Seascape E, and the information was not provided on the presence of Seascape E in other parts of the marine range; and (2) because a clear correlation between what specific PBF(s) is essential to the conservation of the species could not be determined.

The Breece *et al.* (2016) study was temporally and geographically limited in scope relative to the range of the DPSs. Detection data were collected by fixed receivers and by receivers fixed to a glider for the months of April through June, the period of peak Atlantic sturgeon abundance during spring migration (Breece *et al.,* 2016). More than half of the fixed receivers were located in Delaware Bay. The remaining receivers were placed within approximately 20 km of the shoreline along the coast from approximately 30 km (*i.e.,* off New Jersey) and south (*i.e.,* off Maryland) of the mouth of the Bay. The glider mission covered a greater area; within approximately 25 km of the shoreline along a 120 km stretch of coastline between Bethany Beach, Delaware (south of the mouth of the Bay), and Chincoteague, Virginia. While the geographic area covered is large and the time period is when we would expect many Atlantic sturgeon to occur in the areas, this is a small geographic area, relatively mid-range, of the expansive Atlantic sturgeon DPSs' marine range from Canada to Florida, United States. Breece *et al.* (2016) noted that the variables used to define the seascapes were so dynamic, that the results of the study were presented with respect to an 8-day average of ocean color and sea surface temperature for each seascape. Based on the average, Seascape E was the most prevalent seascape class in the study area, and the equipment to detect the presence of Atlantic sturgeon occurred primarily within Seascape E. Additionally, Breece *et al.* (2016) were unable to determine why Atlantic sturgeon were associated with Seascape E. The authors state: "[f]ull understanding of the processes driving the association of Atlantic Sturgeon to Seascape E is not yet known; however, it appears we can use this global product to estimate spatial occurrence without requiring direct observation of individuals to inform coastal ocean users during spring migration." Therefore, while potentially useful to resource managers for identifying potential areas of high sturgeon abundance in the Mid-Atlantic Bight region, the information still does not help us understand what, if any, PBFs exist in the area that may be essential to the conservation of the species.

Finally, the commenters stated that Atlantic sturgeon aggregation areas in marine and nearshore estuarine waters should be designated as critical habitat because these require special management and protection as a result of vessel strikes of Atlantic sturgeon from ships using the marine corridors, strikes from turbine blades in tidal estuaries, impingement and entrainment in water intakes, fisheries bycatch, and other threats to the fish including dredging, sand mining, pipeline and other construction, wind farm development, and impaired water quality. However, special management considerations or protection in the context of critical habitat designations are the methods or procedures useful in protecting the PBFs essential to the conservation of the listed species. The threats described by the commenters are threats to individual Atlantic sturgeon and not their habitat.

Comment 21: Several additional environmental organizations, including one that established an online form letter submission from which we received over 1,000 form letters, as well as a representative for New York State Department of Environmental Conservation, and academics, also pointed to the publications by Dunton *et al.* (2015) and Breece *et al.* (2016) and stated that we should designate critical habitat for the Atlantic sturgeon DPSs in marine waters, bays, and sounds.

Our Response: Some bays are part of the critical habitat designations. These include Merrymeeting Bay of the Kennebec River critical habitat unit, and Haverstraw Bay of the Hudson River critical habitat unit. Bays that occur between the mouth of the river and the Atlantic Ocean, such as Chesapeake Bay, are not part of the designated critical habitat because we do not have information that these areas contain PBFs that are essential to reproduction and recruitment of the offspring. The available information describes spawning adults as moving into the rivers and either staging in the river for a period of time or immediately moving upriver to spawning areas and, similarly, after spawning, moving downriver and either remaining in the river until outmigration in the fall or leaving immediately to move to other estuarine systems (Savoy and Pacileo, 2003; ASSRT, 2007; Greene *et al.,* 2009; Simpson, 2008; Austin, 2012; Balazik *et al.,* 2012; Breece *et al.,* 2013; Hager *et al.,* 2014; Kahn *et al.,* 2014). Juveniles spend months to years in the natal estuary, moving upriver and downriver with seasonal and annual changes in the salt front to access rearing habitat (*e.g.,* within their preferred salinity range). There is no information that natal juveniles are moving as far downriver as a bay or sound between the river mouth and the ocean, and returning to the natal river without continuing the outmigration to the ocean. Available information from tracking suggests they move downriver through the river estuary, into and through any adjoining bay or sound upon their first outmigration to the ocean. Thus, while soft substrate between the river mouth and spawning sites is essential for successful recruitment, we do not have information that soft substrate in these bays and sounds is essential to recruitment of the offspring to the marine environment. The comments did not provide new information for juvenile use of bays and sounds between the natal river and the ocean.

See also our response to Comment 20, and the biological information for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs in the Impacts Analysis and Biological Information Source Document.

Comment 22: A commenter stated that further spatial delineation of the Delaware River critical habitat areas is essential, given the multiple and vital uses of this waterway, which include but are not limited to: 94 discharges regulated under a Total Maximum Daily Load for polychlorinated biphenyls (PCBs) under the Clean Water Act; multiple water withdrawals serving regional populations; and significant commercial navigation. In addition, given the varying requirements of the different life stages of the Atlantic sturgeon, temporal delineation of critical habitat should also be considered for the final designation.

Our Response: The PBFs that support reproduction and recruitment and that are essential to the conservation of the New York Bight DPS are all of those that we have identified in the proposed critical habitat designation. These may require special management considerations or protection as a result of certain kinds of activities, including activities listed by the commenter. We are, therefore, required to designate these areas as critical habitat for the New York Bight DPS. The boundaries of each critical habitat area, including the Delaware River critical habitat area, encompass no more and no less than the area containing the PBFs essential to the conservation of the DPS and which may require special management considerations or protection.

It appears that the commenter is requesting that we identify the specific areas within the Delaware River where each of the features occurs; however, this goes beyond the scope of what is required in a critical habitat designation. (see *Home Builders Ass'n of Northern California* v. *U.S. Fish and Wildlife Service,* 616 F.3d 983 (9th Cir., 2010)). We have provided references in the rule, and in the Impacts Analysis and Biological Information Source Document that support our determination that the PBFs are present in the area designated and can provide guidance to Federal agencies when they need to request ESA section 7 consultation and consider the effects of their actions on critical habitat.

We do not use temporal designations for critical habitat because the PBFs are either present year round or will be present at some expected time during the year that cannot be predicted with precision (*e.g.,* the location of the salt front moves throughout the year, but given the multitude of factors that influence the exact location, we could not predict with any reasonable certainty the timing of any particular location). The timing of a proposed Federal action and the effects it would have on the critical habitat are considered during ESA section 7 consultation. For example, the effects of an activity that will impact hard substrate in freshwater reaches of the Delaware River may be different during the spawning season than during the winter.

Comment 23: The Navy raised concern that freshwater suitable for Atlantic sturgeon spawning was not available to Atlantic sturgeon in the Piscataqua River system below the lowermost dams of the Salmon Falls and Cocheco Rivers.

Our Response: Freshwater is available below the lowermost dams of the Salmon Falls and Cocheco Rivers. The salinity changes within the river estuary seasonally and daily depending on freshwater flow and tidal changes. See our response to Comment 3 for additional information on the Piscataqua River.

Comment 24: A commenter stated that nearshore shallow water areas of the Potomac River from Key Bridge to at least Marshall Hall should not be considered critical habitat because substrate from at least Marshall Hall to Key Bridge is deeply silty, and near shore salinity is closer to fresh than to 0.5 ppt salinity. The commenter stated that the feature is substrate with salinity greater than 0.5 ppt. Therefore, this area should not be designated critical habitat.

Our Response: We are not required to determine that every segment of the critical habitat contains all of the PBFs essential to conservation of the species, but rather, we demonstrate overall that the designated unit contains the PBFs essential to conservation of the species. We have provided references in the rule, and in the Impacts Analysis and Biological Information Source Document that support our determination that the PBFs are present in the area designated as critical habitat in the Potomac River. Briefly, the Potomac River estuary extends approximately 187 river kilometers (rkm) from the Chain Bridge to the mouth of the river. The river is tidal freshwater from Chain Bridge to Quantico, VA; the mixing zone of transitional salinity occurs from Quantico, VA, to the crossing of the U.S. Highway 301 Bridge, MD, and the remainder of the river estuary, from the U.S. Highway 301 Bridge crossing to the Chesapeake Bay, has a wide channel with gradually sloping, shallow flats near shore (USGS, 1984).

Comment 25: The Virginia Institute of Marine Science provided new information, based on their data collections, that adult Atlantic sturgeon occur upriver of the Route 360 bridges on both the Pamunkey and Mattaponi Rivers.

In 2015, a receiver placed at rkm 144 of the Pamunkey River, 5 km above the Route 360 Bridge, regularly detected 18 acoustically-tagged, adult sturgeon during the summer and early fall. The commenter believes that the occurrence of the adults in freshwater of the Pamunkey River during the spawning period (Hager *et al.,* 2014; Kahn *et al.,* 2014) and the detected movements of the adults support that the geographical area occupied includes the waters at least 5 km upriver of the Route 360 Bridge crossing, and suggests that this part of the Pamunkey River has the essential PBFs of critical habitat based on patches of sand from bank erosion. The commenter recommends that we extend critical habitat above the Route 360 bridge in the Pamunkey River approximately 14 rkm up to Nelson's Bridge Road Route 615 crossing on the Pamunkey.

The commenter also recommended extending the upriver boundary of the Mattaponi critical habitat unit by 10 rkm above the Route 360 bridge to rkm 122. In the summer and early fall of 2015, one tagged adult female Atlantic sturgeon ascended the Mattaponi River and was detected at the uppermost receiver located near the Route 360 bridge crossing. This is during the time and in an area where spawning would be expected to occur. Based on the time series of detections at this receiver, the commenter believes this individual moved past the receiver upstream, then moved back down again.

Our Response: We considered the information provided and agree that the detected presence of at least 18 adult Atlantic sturgeon in the Pamunkey River above the Route 360 Bridge crossing provides evidence that the geographical area occupied by the DPS in the Pamunkey is above the Bridge crossing, and the area is used by adults during the fall spawning period for the Chesapeake Bay DPS. We did not agree with the commenter that sand from bank erosion is evidence that hard substrate occurs in the area. However, the literature cited in the comments (*e.g.,* Bushnoe *et al.,* 2005) provides additional information for hard substrate (gravel) in the area. We, therefore, revised the boundary of the York River critical habitat unit by extending critical habitat by

approximately 14 rkm to the Nelson's Bridge Road Route 615 crossing on the Pamunkey River.

We did not revise the upriver boundary of the critical habitat designation on the Mattaponi River. We have considered the information provided by VIMS. While their data analysis suggests to them that the fish moved further upriver, there is no evidence that it moved upriver and, even if it did, these are the movements of just one fish. We cannot determine whether the movements of this fish are representative of all Atlantic sturgeon that occur in the Mattaponi or are movements of a vagrant fish. Additionally, critical habitat is based on the presence of the essential PBFs. VIMS did not provide information that the PBFs of critical habitat occur in the Mattaponi River upriver of the Route 360 Bridge crossing. Therefore, we are not changing the upriver boundary for the York River critical habitat unit in the Mattaponi River.

Comment 26: Maryland Department of Natural Resources (MD DNR) requested amendment of the critical habitat designation for the Chesapeake DPS to include: Marshyhope Creek; Broad Creek; Deep Creek; and, areas of the Nanticoke River above its confluence with the Marshyhope Creek and the lower Nanticoke River down to Chapter Point, MD. The MD DNR provided the 2016 project report for riverbed mapping of the Broad Creek, Marshyhope Creek, and Nanticoke River (Bruce *et al.,* 2016), information on the detection of an adult Atlantic sturgeon in spawning condition, and salinity, water temperature, and DO in Marshyhope Creek, Broad Creek, and the Nanticoke River.

Our Response: The substrate information for Marshyhope Creek and the Nanticoke River was not received in time for us to consider it for inclusion in the proposed rule. However, we were aware that a final report was imminent and alerted the public in the Impacts Analysis and Biological Information Source Document to the proposed rule that the presence of adult sturgeon in spawning condition and at the time when the Chesapeake Bay DPS spawns suggests that the PBFs essential to Atlantic sturgeon reproduction and recruitment are present in Marshyhope Creek. We also alerted the public that after receiving the report, we would assess whether to expand critical habitat to include this area. The final project report was submitted to us by the MD DNR during the public comment period. We reviewed the information as well as other available information for the Nanticoke River, including the MD DNR final report, "Assessment of Critical Habitats for Recovering the Chesapeake Bay Atlantic Sturgeon Distinct Population Segment," funded by the NOAA Species Recovery Grants to States (ESA Section 6 Program). The benthic mapping report does provide information to confirm the presence of hard substrate in low salinity waters of Marshyhope Creek and the Nanticoke River. In addition, the MD DNR Section 6 report provides evidence that the area is likely being used for spawning. This information along with information related to the presence of suitable spawning substrate (Bruce *et al.,* 2016) indicates that there is the potential for spawning and recruitment to occur in the Nanticoke River and Marshyhope Creek.

Our review of this best available information confirmed that critical habitat for the Chesapeake Bay DPS occurs in the Nanticoke River and its tributary, Marshyhope Creek. Designation of the area is a natural outgrowth of the proposed rule given that we stated in the proposed rule that we suspected spawning was occurring in Marshyhope Creek, a tributary of the Nanticoke, and we stated in the Impacts Analysis and Biological Information Source Document that we were awaiting receipt of substrate information and would consider designating critical habitat in the River if we received additional information that confirmed that the PBFs are present. The PBFs may require special management considerations or protection as a result of activities, such as dredging and construction projects (*e.g.,* docks, piers), that may affect the PBFs. Therefore, we are designating critical habitat in the Nanticoke River and Marshyhope Creek for the Chesapeake Bay DPS.

We are not, however, designating critical habitat in the Nanticoke River and Marshyhope Creek as two separate areas as recommended by MD DNR, and we are not designating critical habitat in Broad Creek or Deep Creek. Critical habitat that is designated within the geographical area occupied by the species is based on the presence of the PBFs. While information on salinity and water quality is generally available, information on hard substrate (*e.g.,* gravel, cobble) in low salinity waters is not available for Broad Creek or Deep Creek. The substrate study did indicate the presence of gravel-sand, and sand-gravel in Broad Creek, but hard substrate such as gravel and cobble that provides interstitial spaces for the offspring after hatching is essential for spawning. We will reconsider Broad Creek and Deep Creek as new information becomes available on hard substrate and information to show that these areas could be used by Atlantic sturgeon for spawning (*e.g.,* evidence of spawning adult presence in the area, evidence for the presence of natal offspring).

Based on the PBFs essential to the conservation of the Chesapeake Bay DPS, the Nanticoke River system critical habitat unit consists of the waters of the Nanticoke River from the Maryland State Route 313 Bridge crossing near Sharptown, MD, to where the main stem discharges at its mouth into the Chesapeake Bay as well as Marshyhope Creek from its confluence with the Nanticoke River and upriver to the Maryland State Route 318 Bridge crossing near Federalsburg, MD, for a total of 60 rkm of aquatic habitat.

Comment 27: One commenter requested consideration of additional literature and datasets for determining whether to include the Eastern River, Abagadasset River, Muddy River, Sheepscot River up to Head Tide Dam, Dyer River up to Boynton Trask Dam, Saco River from Cataract Dam downstream to its mouth, Mousam River below the confluence with Fernald Brook, tributaries of Great Bay (Spruce Creek, Berrys Brook, Sagamore Creek, Lubberland Creek, Crommet Creek, Bellamy River, Sturgeon Creek), and Penobscot Bay as critical habitat for the Gulf of Maine DPS. The commenter also indicated that the Taunton River, MA, up to the confluence with the Nemasket River should be included in the critical habitat designation for the New York Bight DPS.

Our Response: We have reviewed the additional information and datasets referenced by the commenter. We are not adding these additional areas to the critical habitat designations. We discussed in our response to Comment 20 why the critical habitat designations for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs do not include bays and sounds that occur between the river mouth and the ocean, such as Penobscot Bay. No information was provided by the commenter that allowed us to identify PBFs in Penobscot Bay.

As described in our regulations at 50 CFR 424.12(b)(1) and the proposed rule, critical habitat must contain the PBFs essential to the conservation of the DPS, and that may require special management or protection. The Cataract Dam is located downriver of freshwater, and Atlantic sturgeon do not pass upriver of the dam. The dam is at the location of a natural falls that would be impassable to Atlantic sturgeon even if the dam was not present. As a result, hard bottom substrate (*e.g.,* rock, cobble,

gravel, limestone, boulder, etc.) in low salinity waters (*i.e.,* 0.0–0.5 ppt range) for settlement of fertilized eggs, refuge, growth, and development of early life stages is not available to Atlantic sturgeon in the Saco River. Therefore, we are not designating critical habitat in the Saco River since the area of the river within the geographical area occupied by the Gulf of Maine DPS does not contain the PBFs essential to successful reproduction and recruitment.

For the other waterways named by the commenter, we do not have information on whether Atlantic sturgeon spawn or spawned in that particular waterway. Atlantic sturgeon can be identified to their river of origin based on genetic analysis, likely due to their strong affinity for natal homing (*i.e.,* adults spawn in the river in which they were spawned). Some straying occurs and recolonization of rivers within a DPS is possible. However, we have no way to determine the likelihood that a particular river will be recolonized or the timespan over which recolonization would occur. Therefore, just as we considered the Union River as described in the Impacts Analysis and Biological Information Source Document, we investigated whether there is any evidence that sturgeon are now using, or have ever used, a particular river or river segment for spawning. The 2007 Status Review for Atlantic Sturgeon (ASSRT, 2007) indicated Atlantic sturgeon historically spawned in the Taunton River, Massachusetts (Table 1 in that document). However, the Status Review report does not provide the reference for this conclusion and we could not locate information to support the conclusion. There is no recent evidence of spawning for the Taunton River. Similarly, the 2007 Status Review report indicated Atlantic sturgeon historically spawned in the Sheepscot River and possibly spawn presently in the Sheepscot River. However, a study of the Kennebec Estuary, including the Sheepscot River, spanning the time period 1977–2001 did not find any evidence of Atlantic sturgeon spawning in the Sheepscot River (Wippelhauser and Squiers, 2015). Based on the best scientific information available, we cannot determine that the Taunton River and Sheepscot River are essential to reproduction or recruitment of the New York Bight and Gulf of Maine DPSs, respectively. Similarly, we do not have evidence that Atlantic sturgeon historically spawned or presently spawn in the other waterways named by the commenter. Based on the best scientific information available, these waterways are not essential to the conservation of the DPSs. Therefore, we cannot designate critical habitat in the Eastern River, Abagadasset River, Muddy River, Dyer River up to Boynton Trask Dam, Mousam River below the confluence with Fernald Brook, or tributaries of Great Bay (Spruce Creek, Berrys Brook, Sagamore Creek, Lubberland Creek, Crommet Creek, Bellamy River, Sturgeon Creek).

Comment 28: A commenter was concerned that the critical habitat designations for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs do not include all of the rivers listed in Table 1 of the 2007 Status Review labeled as historically or presently supporting Atlantic sturgeon spawning, or having Atlantic sturgeon nursery habitat.

Our Response: The regulations for identifying critical habitat differ from the approach used by the Atlantic Sturgeon Status Review Team to label rivers as historically or presently supporting Atlantic sturgeon spawning, or having Atlantic sturgeon nursery habitat. For example, the Status Review Team considered nursery habitat as any habitat used by immature Atlantic sturgeon, including non-natal estuaries used by subadult Atlantic sturgeon. For this critical habitat designation, we consider nursery habitat to be habitat within the natal estuary used by natal juveniles. Therefore, in our approach, a river would only be labeled as having nursery habitat if there was also evidence that it historically or presently supported Atlantic sturgeon spawning. As described in the response to Comment 27, we considered the evidence that the 2007 Status Review cited for whether a river historically supported or presently supports an Atlantic sturgeon spawning population. This information helped to inform whether an area contained the PBFs essential to the conservation of the particular DPS and that may require special management considerations or protection.

Comment 29: A commenter stated tributaries are vital components of the estuarine habitat that Atlantic sturgeon need to reproduce and develop, and conditions in tributaries affect the Hudson River. Therefore, the commenter recommended that we designate critical habitat for the entire length of, or the segment downstream of a dam or impassable rapids, in: Lents Cove, Annsville Creek, Popolopen Creek, Constitution Marsh and Foundry Cove, Moodna Creek below Route 9W, Wappinger Creek below the rapids, Roundout Creek below the dam, Esopus Creek below the dam, Jansen Kill below Route 9G, Ramshorn Creek, Catskill Creek below the rapids, Stockport Creek below the dam, Coxsackie Creek, Schodack Creek, Moordener Kill, Normans Kill, and the Mohawk River below the locks.

Our Response: The commenter did not provide and we do not have information that suggests Atlantic sturgeon spawn or spawned in the waterways, all tributaries of the Hudson River, named by the commenter. Additionally, the commenter did not provide and we do not have information indicating that the features are present in these waterways. Based on information provided in the Atlantic Sturgeon Status Review (ASSRT, 2007) and the Atlantic Sturgeon Stock Assessment, these areas are not essential to the conservation of the DPS, and we cannot designate the areas as critical habitat. However, we do recognize the connection of tributaries to the main stem Hudson River, the importance of a healthy ecosystem to Atlantic sturgeon.

Comment 30: A commenter stated that the frequency and timing of use suggests that PBFs, including foraging areas and cover from predation, may occur within certain bays, estuaries and near-shore marine areas. The commenter acknowledged that PBFs must be defined under the ESA, and that these data are not currently available for the entire range, but should be considered for the areas available. The commenter recommended that we: Consider the DPS-specific references (Calvo *et al.,* 2010; Erickson *et al.,* 2011; and Breece *et al.,* 2016) in the Final Rule; continue to consider this information gap to be a research priority; and, develop a schedule for designating bay and near-shore critical habitats essential to support the successful development, growth and migration of sub-adult and adult Atlantic sturgeon.

Our Response: Our consideration of the best available information to identify potential PBFs for the Atlantic sturgeon DPSs in marine waters, bays, and sounds is described in the proposed rule, Impacts Analysis and Biological Information Source Document, and in our response to Comment 20. This information included research findings described in Calvo *et al.,* 2010, Erickson *et al.,* 2011, and Breece *et al.,* 2016. Based on the best scientific information available for each DPS, and information for Atlantic sturgeon in general, we were not able to identify any PBFs for marine waters, sounds, or bays, other than for those bays that contain the PBFs essential for reproduction and recruitment of the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs and that are included as part of the designated critical habitat.

Critical habitat designations are based on the best available scientific information. We cannot commit to a schedule for designating additional critical habitat for the Gulf of Maine, New York Bight, or Chesapeake Bay DPS because we cannot predict when information will be available to inform any potential future modification of this critical habitat designation or any new designation.

Comment 31: A conservation group pointed to a recent report by Moberg and DeLucia (2016) that recommended minimum values of DO, water temperature, and salinity values to support habitat suitable for successful recruitment of Atlantic sturgeon in the Delaware River. These values are instantaneous DO greater than or equal to 5.0 mg/L, and temperature less than 28 °C when salinity is less than 0.5 ppt. The commenter noted that estuaries are naturally dynamic habitats and the areas that support habitat suitable for successful recruitment could change with migration of the salt front. The commenter recommended that designated critical habitat include river segments that may serve as reproduction and recruitment habitats that accommodate changes in migration of the salt front, DO, and temperature conditions.

Our Response: We agree that estuaries are naturally dynamic habitats. In the Background section of the proposed rule we described that multiple spawning sites have been identified within many of the rivers used for Atlantic sturgeon spawning (Dovel and Berggren, 1983; Van Eenennaam *et al.*, 1996; Kahnle *et al.*, 1998; Bain *et al.*, 2000; Sommerfield and Madsen, 2003; Bushnoe *et al.*, 2005; Simpson, 2008; Hager, 2011; Austin, 2012; Balazik *et al.*, 2012; Breece *et al.*, 2013), and spawning sites at different locations within the tidal-affected river would help to ensure successful spawning, given annual changes in the location of the salt wedge. For example, Breece *et al.* (2016) reported a difference of 30 km in the average location of the Delaware River salt front during adult Atlantic sturgeon occupancy in 2011 compared to 2009 and 2012.

Designating critical habitat that includes multiple potential spawning areas helps to ensure Atlantic sturgeon can select the best spawning site, given the natural annual variations in environmental conditions within the river estuary. When several habitats, each satisfying the requirements for designation as critical habitat, are located in proximity to one another, an inclusive area may be designated as critical habitat (50 CFR 424.12(d)). Therefore, within the geographical area occupied by the DPS in each river, we considered all areas that contained the PBFs that are essential to the particular DPS and identified the boundaries, accordingly. As described in the response to a previous comment, we concluded for purposes of the critical habitat designations that unoccupied habitat was not essential to the conservation of the Gulf of Maine, New York Bight, or Chesapeake Bay DPS.

We are aware of the report by Moberg and DeLucia (2016) that focused on DO levels for survival of Delaware River natal juveniles in low salinity waters. However, the water quality feature for critical habitat is the interrelated variables of salinity, DO, and water temperature that are necessary for use of the habitat rather than fish survival. Fish avoid, when possible, habitats that would result in their death, and studies have shown that fish avoidance of habitat occurs before the DO levels of the habitat have dropped so low as to be deadly (Breitburg 2002; EPA, 2003). Studies have also shown that the DO concentration at which the fish will begin to avoid habitat is approximately equal to the DO concentration that reduces their growth rate. Therefore, identifying the temperature, DO, and salinity values that result in reduced Atlantic sturgeon growth can serve as a proxy for identifying the temperature, DO, and salinity values that result in Atlantic sturgeon habitat avoidance.

We considered the available information on Atlantic sturgeon growth, and temperature, DO, and salinity (Breitburg, 2002; EPA, 2003; Niklitscheck and Secor 2009; Niklitscheck and Secor 2010; Allen *et al.*, 2014) when we developed the examples provided in the proposed rule. Our intent was to provide an example in the proposed rule of a set of conditions that we expect to correlate to Atlantic sturgeon use of an area; it was not our intent to provide an example of the DO levels that are necessary for the survival of any particular age class of Atlantic sturgeon.

Comment 32: A commenter stated that our decision to not designate any estuarine areas as critical habitat is arbitrary and capricious, noting that natal estuaries are attached to a natal river, which makes these estuaries critical and, therefore, they should be designated. The commenter also stated that we should also designate estuaries that it knows are important (*e.g.*, the mouth of the Merrimack and the Saco River).

Our Response: The critical habitat designated for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs includes estuarine waters of the named river. It is a common misconception that all rivers are all freshwater and only bays or sounds are the estuarine waters. We are designating critical habitat in the Merrimack River, downstream of the Essex Dam to the mouth of the Merrimack River. We are not designating critical habitat in the Saco River because the area of the river within the geographical area occupied by the Gulf of Maine DPS does not contain the PBFs essential to the conservation of the DPS. Our response to Comment 20 addresses the best available information for identifying other PBFs in bays and sounds that are essential to the conservation of the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs.

Comment 33: The commenter believes that areas proposed to be designated as critical habitat in the James River exceed what is necessary to protect Atlantic sturgeon and will accomplish little habitat restoration in the Chesapeake Bay DPS. The commenter states that considering the breadth of available information on biological and habitat data, critical habitat in the James River could be more specifically defined.

Our Response: The boundaries of the critical habitat areas are based on the presence of the PBFs essential to the conservation of the Chesapeake Bay DPS, and which may require special management considerations or protection. The PBFs are based on substrate, water quality, open passage, and the transitional salinity zone necessary for Atlantic sturgeon adults to reproduce and juveniles to rear in the natal estuary prior to emigration to the marine environment.

The best available information supports the conclusion that there are two spawning groups of Atlantic sturgeon returning to the James River, one in the spring and one in the fall. Spawning occurs in different areas of the river for each group. Such a difference is not unexpected given changes in the location of an estuary's salt wedge from spring to fall. Even in rivers where only one spawning season is currently known, spawning Atlantic sturgeon may select for the best spawning site in the river estuary, given the environmental conditions at the time (*e.g.*, flow and salinity), which vary depending on weather and other conditions (*e.g.*, more freshwater inflow due to a rainy spring or high snowpack can result in the salt front being farther downstream). Designating critical habitat that includes multiple spawning areas helps to ensure successful spawning, given the natural variations in environmental conditions within the

river estuary. Similarly, critical habitat that encompasses the complete habitat needs of Atlantic sturgeon juveniles is necessary because Atlantic sturgeon offspring select for the habitat with the combined variables of DO, water temperature, and salinity that best support their growth and development. Because estuaries are also dynamic environments with daily and seasonal changes in salinity, Atlantic sturgeon juveniles must be able to move within the natal estuary to remain in or access the salinity zone most suitable for the stage of development. As such, limiting the designation in the James River would not allow for inclusion of all of the PBFs that are essential to the conservation of the DPS.

Comment 34: A commenter stated that we must identify, with specificity and substantial evidence, those areas of the Susquehanna River that we believe exhibit the PBFs essential to the conservation of Atlantic sturgeon. Further, to meet our obligations under the Administrative Procedure Act, we must then provide stakeholders with an additional opportunity to comment on the justifications for the determinations.

Our Response: The ESA and the regulations implementing the critical habitat provision of the ESA (50 CFR part 424) do not require that we provide "substantial evidence" or articulate a particular level of specificity as to where exactly the PBFs may be found in a particular unit. The proposed rule did specify that the area containing the PBFs of critical habitat in the Susquehanna River is the 16 km of the Susquehanna River main stem from the Conowingo Dam to where the river drains at its mouth into the Chesapeake Bay. These are the lowermost 16 km of the river's overall 714 km length.

Upon reexamination of the information for the PBFs, we determined that PBF 2 (*i.e.,* aquatic habitat with a gradual downstream salinity gradient of 0.5 to as high as 30 ppt and soft substrate (*e.g.,* sand, mud) between the river mouth and spawning sites for juvenile foraging and physiological development) is not present in the lowermost 16 rkm of the Susquehanna River that we proposed to designate as critical habitat. In addition, these waters are likely to remain freshwater because saltwater from the ocean generally does not push into the upper Chesapeake Bay, and there is a large volume of freshwater flowing into the upper Bay from the Susquehanna and other rivers (Chesapeake Bay Program, 1987).

The proposed 16 rkm of the Susquehanna River does not have a salinity gradient and is unlikely to have a salinity gradient in the future. Because this PBF is not present in the lowermost 16 rkm of the Susquehanna River, and we determined that the coexistence of all four PBFs is required for successful reproduction and recruitment of the Chesapeake Bay DPS, the lowermost 16 rkm of the Susquehanna River are not included in critical habitat for the Chesapeake Bay DPS. Further information on the salinity, substrate, and water quality below the Conowingo Dam is available at *http://www.exelon corp.com/locations/ferc-license-renewals/Conowingo/Pages/ Documents.aspx.*

Comment 35: A number of commenters, including a coalition, objected to the proposed designations and stated that we provided no data or analysis in support of our conclusions that the essential PBFs we have identified are actually present throughout the expansive areas we have proposed for designation, nor any discussion of the location of essential PBFs within the areas.

Our Response: We are not required to conduct new analyses for critical habitat designations. We are required to use the best available information. The proposed rule, the biological information in the Impacts Analysis and Biological Information Source Document, and our administrative record for the critical habitat designations provide the sources of information for where the PBFs occur within each designated critical habitat area. We balanced the desire to provide detail on each critical habitat designation against the need to provide transparent and concise information. An excessively lengthy document can be perceived as burdensome to read and comment upon. We provided a level of detail that we believe was necessary and desired by the general public. In all cases, we have cited the sources of information for the presence of the PBFs in the specific critical habitat areas.

We also took into account the dynamic environment in which the PBFs occur. Some of the PBFs occur in more than one location or occur in a location at certain times of the year. For example, hard bottom substrate in low salinity waters (0.0 to 0.5 ppt) may be available farther downriver in the spring than in the fall, depending on seasonal changes in freshwater input, or may be available farther downriver in one year compared to another, depending on the freshwater input to the estuary in that particular year. Likewise, the exact boundaries of the transitional salinity zone will fluctuate with seasonal changes in flow, annual changes in flow, and even tide cycles. The boundaries of the critical habitat areas account for these cyclical changes that are reasonably expected to occur based on the best available information for the particular river within which we are designating critical habitat.

Comment 36: A representative for a power operation stated that the area of the Hudson River in the vicinity of the facility should be excluded from the critical habitat designation because: this part of the Hudson River does not possess characteristics of value to Atlantic sturgeon at any life stage, and it is inconceivable that any federally-approved action within the vicinity of Indian Point would ever rise to the level of destruction or adverse modification of critical habitat as the Services have defined it.

Our Response: We are not required to determine that every segment of the critical habitat contains all of the PBFs essential to the conservation of the species, but rather, we demonstrate overall that the designated unit contains the PBFs essential to conservation of the species (See *Home Builders Ass'n of Northern California* v. *U.S. Fish and Wildlife Service,* 616 F.3d 983, 988–989 (9th Cir., 2010)). We recognize in the rule that the location of some PBFs may shift daily, seasonally, or annually. We disagree that the area noted in the comment does not contain the essential PBFs of critical habitat; the area contains soft substrate and is within the salinity gradient necessary for the development of juveniles. It is also an area of the Hudson River where barrier-free passage is necessary for the upstream and downstream movement of adults.

The commenter's determination that activities associated with the Indian Point nuclear facility would not destroy or adversely modify the critical habitat is not a comment on the designation, but rather a conclusion of the effects of the activities that would be considered in an ESA section 7 consultation. Even if we agreed with that conclusion, there is no means to exclude an area based on the potential impacts of the operations of one facility. We also note that the critical habitat designated in the vicinity of Indian Point could be affected by other Federal actions independent of Indian Point (*e.g.,* dredging, water quality regulations, etc.).

We considered impacts of designating critical habitat for the New York Bight DPS, and concluded there was no basis to exclude any particular area from the proposed critical habitat because of the conservation benefits of the critical habitat designations to the species and to society. While we cannot quantify nor monetize these benefits, we believe they

are not negligible and are an incremental effect of the designations. See our response to Comments 51, 52 and 53 for further information on the Impacts Analysis for the Gulf of Maine, Chesapeake Bay and New York Bight DPSs.

Comment 37: A commenter stated that scientifically demonstrated identification of known PBFs needed for physiological development have not been specifically determined for the Atlantic sturgeon, and designating critical habitat in the Delaware River may be premature. The commenter goes on to state that the length and breadth limits of the critical habitat area alone apply assumptions that are not well documented in science, and, in the case of the downstream limit on the Delaware River, arbitrary landmarks were used to identify the beginning and end of the designated critical habitat. The commenter also states that the down-river boundary is demarcated by a land-based, manmade monument that possesses no inherent biological or physiological value indicating that sturgeon reproduction, early growth, and population maintenance begins or ends here.

Our Response: The critical habitat designations are not premature. The ESA requires that we designate critical habitat at the time a species is listed unless designating critical habitat is not prudent for the species (this rarely occurs) or is not determinable. If critical habitat is not determinable at the time of listing, we are allowed one additional year. At the end of that year, we must designate critical habitat based on the best available information.

We concluded that critical habitat was not determinable when the Atlantic sturgeon DPSs were listed as endangered and threatened in 2012. We failed to meet the one-year timeframe for designating critical habitat. We proposed critical habitat in June 2016. We have used the best available information to determine the essential PBFs that may require special management considerations or protection and identify where those PBFs occur to develop the critical habitat designation. While we agree that more information on the exact location of Atlantic sturgeon spawning would be generally informative and could allow us to better manage the species, the absence of this more specific information did not impair our ability to develop the critical habitat designation. This is in part because our critical habitat designation was not designed to include only spawning habitat.

The proposed rule described the PBFs and provided an explanation, in the context of Atlantic sturgeon life history, of why the PBFs are essential to the conservation of the Atlantic sturgeon DPSs. We provided the same background as well as the list of cited literature in the Impacts Analysis and Biological Information Source Document.

All of the PBFs are necessary for successful Atlantic sturgeon spawning and recruitment of offspring to the marine environment. Adults need habitat suitable for spawning, for traveling to and from spawning sites, and for staging, resting, and holding before and after spawning. The offspring need habitats in the natal estuary suitable for rearing. The habitat needed by juvenile Atlantic sturgeon changes as they grow and develop in the natal estuary. All juvenile habitat types in the natal estuary are needed for successful rearing of the offspring. Laboratory studies have shown differences in Atlantic sturgeon growth with different combinations of the combined variables of DO, water temperature, and salinity. Captures of Atlantic sturgeon juveniles in the natal estuary, likewise, reveal differences in the distribution of larger, older Atlantic sturgeon juveniles compared to smaller, younger Atlantic sturgeon juveniles. Therefore, we identified the boundaries of each critical habitat area that encompassed the PBFs essential to the conservation of each Atlantic sturgeon DPS and that may require special management considerations or protection. When several habitats, each satisfying the requirements for designation as critical habitat, are located in proximity to one another, an inclusive area may be designated as critical habitat (50 CFR 424.12(d)).

The boundaries of each critical habitat unit are consistent with how we have designated critical habitat for other species in rivers (*e.g.*, the southern DPS of green sturgeon, Gulf of Maine DPS of Atlantic salmon). One or more of the PBFs occur throughout the identified critical habitat areas. Riverbanks are the lateral boundaries. The downriver boundary is the mouth of the river because that is the downstream limit of the most extensive feature (the transitional salinity zone). The upriver boundary is the beginning of the named river, a manmade structure that is impassable by sturgeon, a natural feature that is impassable by sturgeon, or the upriver extent of tidal influence because, depending on the particular river, that is the upstream extent of the presence of the PBFs that are essential to the conservation of the DPS and that may require special management considerations or protection, or the upstream limit of the occupied area.

We cannot use ephemeral reference points (*e.g.*, trees, sand bars) to clarify or refine the boundaries of critical habitat. We can use physical structures that occur at the boundary of the area containing the PBFs in our regulatory description of the critical habitat areas. Doing so better informs Federal agencies of the area within which they should consider effects of their proposed actions to determine whether they are required to consult with us under section 7 of the ESA.

The Delaware River critical habitat unit extends from the upstream point of tidal influence (identified by a bridge that crosses the river at that boundary) downriver to where the river enters the Delaware Bay. A mouth of a river is often considered to be rkm 0 of that river. However, in this case, New Jersey regulations count the mouth of the Delaware Bay (*i.e.*, where it drains into the Atlantic Ocean) as rkm 0. To avoid confusion, we described the downriver boundary of the critical habitat unit based on the pre-established points and markers that demarcate the Delaware River and the Delaware Bay.

Comments on Impacts Analysis, Exclusions, and INRMPs

Comment 38: Many commenters, including those representing maritime associations, tug and barge operator associations, pilot associations, shipbuilders, and Federal and state agencies, stated we should exclude the Federal navigation channels and dredge disposal sites from the critical habitat designations (*e.g.*, in the Penobscot, Hudson, Delaware, York, and James Rivers). They believe including them will prevent or delay dredging of Federal navigation channels, resulting in impacts to navigation safety, less commerce, and harm to the environment (*e.g.*, by increasing the risk of vessel damage that could cause fuel spills). They also stated that including the Federal navigation channels and dredge disposal sites does not contribute to protecting the Atlantic sturgeon DPSs or their existing habitat.

Our Response: We disagree. The Federal navigation channels and dredge disposal sites are part of the areas that we have identified as critical habitat based on the presence of the PBFs essential to the conservation of the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs, and because those essential PBFs may require special management considerations or protection. There are conservation benefits of the critical habitat designations, both to the species and to

society. While we cannot quantify or monetize these benefits, we believe they are not negligible and are an incremental effect of the designations.

The purpose of designating critical habitat is to contribute to species' conservation (*i.e.,* facilitate recovery of the ESA-listed species for which critical habitat is designated). Because the Federal navigation channels and dredge disposal sites within the critical habitat areas are part of the area containing the essential PBFs, we are not excluding the Federal navigation channels and areas used for dredge disposal.

Critical habitat designations do not stop or prevent Federal agency actions. The sole ESA requirement with respect to designated critical habitat is that Federal agencies consult with us (or the USFWS for species under their jurisdiction) on any Federal agency action (*i.e.,* any action that agency intends to fund, authorize or carry out) that may affect critical habitat. The purpose of the consultation is to ensure that actions taken by Federal agencies are not likely to result in the destruction or adverse modification of critical habitat. ESA section 7 consultation is not required if there is no Federal agency action. For example, section 7 consultation is not required when a private citizen will engage in an activity on private land that does not require any authorization from a Federal agency, and does not include any Federal funds to carry out the activity.

For those activities conducted by private citizens that include a Federal agency action (*e.g.,* the citizen receives funding from a Federal agency or is required to obtain a permit from a Federal agency), the Federal agency taking the action is required to consult with us if the agency determines the proposed action may affect any Atlantic sturgeon DPS, its designated critical habitat, any other ESA-listed species under our jurisdiction, or its designated critical habitat.

Federal agency actions that are necessary to maintain safe navigation (*e.g.,* maintenance dredging) and support commerce are expected to continue to occur following the critical habitat designation. ESA section 7 consultations considering effects to the Atlantic sturgeon DPSs have occurred since the DPSs were listed in 2012. Because Atlantic sturgeon are generally present in the critical habitat areas, designating critical habitat is unlikely to increase the number of ESA section 7 consultations because Federal agencies are already required to consult with us under section 7 for actions that may affect the listed species.

Comment 39: Commenters expressed concern that designating critical habitat would prevent repairs to or new construction of marine terminals, docks, and other port infrastructure, thus impacting commerce. They commented we should exclude parts of the critical habitat areas adjacent to marine terminals, docks, and other port infrastructure to avoid such impacts.

Our Response: Activities such as repairs to or new construction of marine terminals, docks, and other port infrastructure can occur when such structures are within or in proximity to designated critical habitat. Section 7(a)(2) of the ESA requires Federal agencies to consult with us if the agency will fund, authorize, or carry-out an activity that may affect designated Atlantic sturgeon critical habitat. If, during consultation, we determine a Federal agency action is likely to destroy or adversely modify critical habitat, we will work with the Federal agency to identify modifications to the proposed action to remove the likelihood that the action will destroy or adversely modify critical habitat. In that case, we would document our determination in a Biological Opinion and provide one or more Reasonable and Prudent Alternatives for the Federal agency to implement. If we conclude that the proposed activity is not likely to adversely modify or destroy the critical habitat, then we will make that determination in a Biological Opinion and the action can occur as originally proposed.

Comment 40: A representative of Bath Iron Works, a shipbuilder for the Navy, and a representative of Entergy Nuclear Indian Point 2, LLC, Entergy Nuclear Indian Point 3, LLC, and Entergy Nuclear Operations, Inc. (collectively, "Entergy"), an energy company that owns a power plant, had similar concerns for the critical habitat designations in the Kennebec River for the Gulf of Maine DPS, and in the Hudson River for the New York Bight DPS. Both commenters expressed concern that the critical habitat designations would increase operational costs, adversely affect the ability to operate, or otherwise impact national security, and requested that we not designate critical habitat in the vicinity of Bath Iron Works on the Kennebec River or in the vicinity of Indian Point Nuclear Power Plant on the Hudson River.

Our Response: We disagree, and appreciate the opportunity to correct some common misconceptions about critical habitat. The first misconception is what is required or prohibited when critical habitat is designated. Critical habitat designations do not create refuges or preserves where activities cannot occur. Critical habitat designations do require Federal agencies to consult with us if they are funding, authorizing or carrying out an action that may affect designated critical habitat for ESA-listed species under our jurisdiction. A Federal action can occur as proposed if we agree with a Federal agency's determination that a proposed action may affect designated critical habitat, and that all of the anticipated effects are insignificant, discountable, or wholly beneficial. A Federal action can also occur as proposed if we agree with a Federal agency's determination that a proposed action is likely to adversely affect critical habitat, but will not destroy or adversely modify critical habitat. A Federal action is required to be modified if we conclude that the proposed action is likely to destroy or adversely modify critical habitat. In that circumstance, we work with the Federal agency to identify modifications to the proposed action that allow the proposed action to occur without destruction or adverse modification of critical habitat. We do not consult on proposed Federal agency actions that will have no effect on critical habitat, and we do not consult on activities that do not include a Federal agency action (*e.g.,* no Federal funding for the action and no required Federal authorization for the action).

There are also misconceptions about what we can exclude and what we must not include in critical habitat designations. We must not include as part of a critical habitat designation any lands or other geographical areas owned or controlled by the Department of Defense (DOD) or designated for its use, that are subject to an INRMP prepared under section 101 of the Sikes Act, if we determine that such plan provides a conservation benefit to the species, and its habitat, for which critical habitat is proposed for designation. We also do not designate critical habitat within foreign countries or in other areas outside of United States jurisdiction (50 CFR 424.12(h)). We can exclude an area from a critical habitat designation based on economic, national security, or other relevant impacts if the benefits of exclusion outweigh those of inclusion, so long as the exclusion will not result in the extinction of the species concerned. However, we are not required to exclude particular areas from a critical habitat designation based on any of these impacts.

As required, we did consider the economic impacts, impacts to national security, and other relevant impacts of the critical habitat designations, including the conservation benefits of

the designation, both to the species and to society. We concluded that economic impacts of designating critical habitat for each DPS would be low. Our conclusion is based on two determinations. First, the primary source of economic impacts as a result of designating critical habitat for the Atlantic sturgeon DPSs are the administrative costs of conducting ESA section 7 consultations. Second, because Atlantic sturgeon occur throughout the critical habitat areas designated for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs, Federal actions that may affect critical habitat are also likely to affect the fish. Therefore, a single section 7 consultation would consider both the effects to the DPS and to its critical habitat. Our analysis of the economic impacts of designating critical habitat also considered whether modifications were likely to occur. Based on the best available information, including responses from Federal agencies that we are likely to consult with, we concluded that modifications to Federal actions are unlikely to occur as a result of section 7 consultations on effects of the actions to designated Atlantic sturgeon critical habitat.

We considered at the proposed rule stage, the concerns expressed by the Navy that designating critical habitat in the Kennebec River critical habitat unit adjacent to Bath Iron Works, a private shipbuilder for the Navy, would affect the Navy's ability to build and test current and future classes of surface ships, resulting in a risk to military readiness and national security. The Navy described the activities likely to occur as: Flooding and dewatering dry docks, updating and maintaining pier structures, including pile driving, and dredging activities to maintain proper channel and berthing depths. The essential PBFs of critical habitat in the area are salinity suitable for older juveniles, open passage for juveniles suitably developed to leave the natal river, open passage for adults traveling through the area to and from spawning areas, open passage for subadults traveling through the area, and soft substrate. Maintaining and/or updating pier structures may affect open passage and substrate (*e.g.*, placing more pier structures in the area, altering the substrate to make it more suitable for the pier structure). Similarly, dredging to maintain proper channel and berthing depths may affect (*e.g.*, remove) the substrate that supports juvenile foraging, and change the depth affecting the salinity (*e.g.*, as a result of changes to mixing in the estuarine river or the extent of saltwater intrusion). However, the activities also may affect Atlantic sturgeon. For example, construction to maintain or update piers can produce sounds that disrupt normal behaviors such as sturgeon foraging, staging, and spawning. Dredging may injure or kill sturgeon that come into contact with the gear (*e.g.*, older juveniles passing through as they leave the natal river, adults traveling through the area to and from spawning areas, subadults traveling through the area). Because the Navy's activities may also affect the Gulf of Maine DPS of Atlantic sturgeon and sturgeon from other DPSs that can occur in the area, we do not anticipate any ESA section 7 consultations to arise strictly for the purpose of assessing the effects of Navy funded, authorized, or conducted activities on designated critical habitat in the Kennebec River. In addition, based on the best available information, we do not anticipate any ESA section 7 consultations for Navy activities in the Kennebec River will require modifications to avoid destruction or adverse modification of critical habitat based on the past consultation history and the nature of the identified categories of activities in the area. We considered all of the impacts arising from the critical habitat designation for the Gulf of Maine DPS, and determined the impacts would be coextensive with the impacts from listing the DPS. We will continue to work with the Navy to address any concerns about the ESA section 7 consultation process. Finally, should it be necessary, the regulations implementing section 7 of the ESA allow for informal consultation where emergency circumstances mandate the need to consult in an expedited manner, for situations involving acts of God, disasters, casualties, national defense or security emergencies, etc.

The commenter did not establish how the critical habitat designation would impact security zones around private facilities, including the Indian Point nuclear facility in the Hudson River referenced by the commenter, that are meant to keep unauthorized vessel traffic at a distance from a facility. We do not foresee that the existence of the security zone and measures in place to maintain that security zone will affect the PBFs of critical habitat. For example, maintaining the security zone does not alter the substrate or the water temperature, nor does it block passage of Atlantic sturgeon moving through the area. Given that, we do not anticipate any impacts of the critical habitat designation on national security related to the security zone at the nuclear facility on the Hudson River. Given the lack of any impact to national security, and the benefit of designating critical habitat for the New York Bight DPS, we are using our discretion to not exclude the security zone area from the critical habitat designation in the Hudson River.

Comment 41: One commenter stated we should allow for exclusion of designated critical habitat areas following a facility's submission of reports complying with 40 CFR 122.21(r) (*i.e.*, National Pollution Discharge Elimination System (NPDES) Program Requirements for facilities with cooling water intake structures).

Our Response: The ESA does not provide any mechanism or authority to us for establishing criteria that would automatically exclude parts of a critical habitat designation after critical habitat has been designated. We can change a critical habitat designation based on new information regarding the listed species and its habitat. Such changes must be made through rulemaking, in accordance with the same regulations used to initially designate critical habitat for a species, and must include an opportunity for public comment.

Comment 42: The Navy commented that Naval Weapons Station Earle, Naval Support Facility Indian Head, Naval Support Facility Carderock, and Joint Base Anacostia Bolling were described in previous correspondence to us, but were not addressed in the proposed rule. The Navy asked us to confirm that these facilities do not overlap with any of the proposed critical habitat units.

Our Response: We confirm that Naval Weapons Station Earle, Naval Support Facility Indian Head, Naval Support Facility Carderock, and Joint Base Anacostia Bolling do not overlap with any of the proposed critical habitat units. In February 2014, we requested the Department of the Navy identify to us facilities that occurred within areas that we were considering for proposed critical habitat. After sending the letter, we changed the boundaries of the critical habitat areas to better identify the in-water habitat in which the PBFs that may require special management considerations or protection occur. As a result of the change to the boundaries, Naval Weapons Station Earle, Naval Support Facility Indian Head, Naval Support Facility Carderock, and Joint Base Anacostia Bolling do not occur within the critical habitat for the New York Bight or Chesapeake Bay DPSs. Our October 12, 2016, letter to the Deputy Assistant Secretary of the Navy for Environment provided our determinations for these facilities. A copy of that letter is provided in Appendix C of the Impacts Analysis and

Biological Information Source Document.

Comment 43: The Navy also commented on our conclusion regarding the INRMP for Naval Weapons Station Yorktown, a complex of three facilities located on Virginia's Lower Peninsula between the York and James Rivers, and asked for confirmation that Restricted Area 33 CFR 334.260 and Restricted Area 33 CFR 334.270 are included in the 4(a)(3)(B) exemption for the York River critical habitat unit.

Our Response: Yes. As described in section 1.2 of the INRMP for Naval Weapons Station Yorktown, the INRMP's scope comprises all lands, ranges, nearshore areas, and leased areas: Owned by the United States and administered by the Navy; used by the Navy via license, permit, or lease for which the Navy has been assigned management responsibility; or withdrawn from the public domain for use by the Navy for which the Navy has been assigned management responsibility (Navy, 2006).

The regulations at 33 CFR 334.260 describe three areas of the York River associated with Naval Weapons Station Yorktown. Public access is prohibited or restricted in some manner (*e.g.*, vessels may pass through but not anchor, no trawling or net fishing) for each area, and the regulations are enforced by the Commander, Naval Weapons Station Yorktown, Virginia, and such agencies as he/she may designate.

The regulations at 33 CFR 334.270 for waters of the York River adjacent to Cheatham Annex Depot of Naval Weapons Station Yorktown restrict access by the public. No loitering is permitted within the area, and oystermen may work their own leaseholds or public bottom within the area, provided they obtain special permission from the Officer in Charge, Cheatham Annex Depot, Naval Supply Center, Williamsburg, Virginia. The Officer in Charge, Cheatham Annex Depot, is responsible for enforcing the regulations at 33 CFR 334.270.

Based on the information provided in the regulations of Title 33, the areas described by sections 334.260 and 334.270 are controlled by the DOD and are within the scope of the INRMP for Naval Weapons Station Yorktown. We determined that the INRMP provides a conservation benefit to the Chesapeake Bay DPS of Atlantic sturgeon and its habitat, for which critical habitat is proposed for designation. Therefore, critical habitat for the Chesapeake Bay DPS will not include the specific lands or other geographic areas of Naval Weapons Station Yorktown, including the Restricted Areas described in sections 334.260 and 334.270. Consultation under section 7(a)(2) of the ESA is not required for any Federal agency action that may affect the features of Atlantic sturgeon critical habitat occurring within the areas described at 33 CFR 334.260 and 33 CFR 334.270. However, consultation under section 7(a)(2) of the ESA is required for Federal agency actions if the proposed action may affect any ESA-listed species.

Comment 44: The Navy requested that we consider exclusion of Naval Station Norfolk and Portsmouth Naval Shipyard once INRMPs for these facilities are complete and we have reviewed the INRMPs.

Our Response: We cannot designate as critical habitat any lands or other geographical areas owned or controlled by the DOD or designated for its use, that are subject to an INRMP prepared under section 101 of the Sikes Act (16 U.S.C. 670a), if we determine in writing that such plan provides a conservation benefit to the species, and its habitat, for which critical habitat is proposed for designation. Therefore, once any new INRMPs are complete, we will review the documents. If we conclude that the INRMP provides a conservation benefit to the particular Atlantic sturgeon DPS, we will initiate a rulemaking to remove the area from the critical habitat designation.

Comment 45: The Navy disagrees with our determination that consultations for effects of dredging on critical habitat will be fully coextensive with consultations to address impacts to Atlantic sturgeon. The Navy believes that critical habitat can or will result in an additional commitment of resources, and will require modification of proposed actions to prevent adverse effects to critical habitat.

Our Response: We acknowledge that dredging occurring within designated critical habitat may require consultation to ensure Federal actions are not likely to destroy or adversely modify critical habitat. However, since all of the critical habitat areas for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs are occupied habitat, nearly all those additional consultations will be coextensive to consultations that would also occur to consider the impact to the sturgeon that occur in those areas. As described in our response to *Comment 38,* ESA section 7 consultations considering effects to the Atlantic sturgeon DPSs have occurred since the DPSs were listed in 2012. While some existing consultations may need to be reinitiated to consider effects to critical habitat, Atlantic sturgeon are generally present in the critical habitat areas, so designating critical habitat is unlikely to increase the number of ESA section 7 consultations.

Comment 46: The Navy is also concerned that we did not fully consider impacts to national security resulting from the designation of critical habitat in areas that overlap with naval bases and areas owned by naval contractors. A list of areas and additional information was provided, including information that identified areas designated as Restricted Areas and Surface Danger Zones by the U.S. Army Corps of Engineers (USACE) pursuant to 33 CFR part 334. As described by the Navy, Restricted Areas generally provide security for Government property and/or protection to the public from the risks of damage or injury arising from the Government's use of that area, and access is by permission only. Surface Danger Zones may be closed to public access on a full time or intermittent basis.

Our Response: We carefully considered the information provided by the Navy. For the Chesapeake Bay DPS, the Navy provided information on some facilities and training areas that are not part of the James River critical habitat unit. The Lower James River Boat Training Area overlapping with Restricted Areas 33 CFR 334.290, 334.293, and 334.300; Lower James River Precision Anchorage and Buoy Mooring Training Areas that overlap Restricted Area 33 CFR 334.300; and, portions of the Underwater Light Salvage Operations Dive Training Areas (*e.g.*, that overlap with Restricted Areas 33 CFR 334.310, 334.320, 334.350, 334.360, and Danger Zone in § 334.340) do not occur within the James River critical habitat unit. The James River critical habitat unit is that part of the James River from Boshers Dam and downstream to where the main stem river discharges at its mouth. The extent of the critical habitat unit may have been unclear, however, because the regulatory text of the proposed rule correctly described the boundaries of the critical habitat unit, but the map incorrectly depicted the James River critical habitat unit as including Hampton Roads. We have corrected the map.

The remaining part of the Lower James River Boat Training Area (*i.e.*, overlaps with Restricted Area 33 CFR 334.280) and the remaining part of the Underwater Light Salvage Operations Dive Training Area (*i.e.*, overlaps with Restricted Area 33 CFR 334.280) occur within the James River critical habitat unit. In addition, portions of the Underwater Light Salvage Operations Dive Training Area occur within the

York River critical habitat unit (*e.g.*, Restricted Areas 33 CFR 334.260 and 334.270) of the Chesapeake Bay DPS. The Navy also provided information for and requested exclusion of the in-water parts of the Philadelphia Navy Yard Annex Reserve Basin and Piers that occur in the Delaware River critical habitat unit of the New York Bight DPS, and of the Portsmouth Naval Shipyard that occurs in the Piscataqua River critical habitat unit of the Gulf of Maine DPS. We are not excluding any of these from the critical habitat designations.

In their comments, the Navy states that designating critical habitat: could shut down, limit or delay operations as a result of the need to consult under section 7 of the ESA; could increase the frequency and scope of consultation requirements; and would likely result in project delays and additional mitigation requirements or modifications not considered during planning. Our ESA section 7 consultation history with the Navy does not support the Navy's speculation. The consultation history demonstrates that Navy activities, including training, pier maintenance, and dredging, have occurred since the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs were listed under the ESA in 2012. As described above, we expect any consultation necessary to consider the effects of Navy actions on designated critical habitat for these DPSs will be coextensive with consultations on the effects of the proposed action on the sturgeon. Further, the GARFO ESA Section 7 Team has developed methods and tools to help action agencies requesting consultation, and to help expedite the consultation process.

Finally, as described in our response to Comment 38, there are conservation benefits of the critical habitat designations, both to the species and to society. While we cannot quantify or monetize these benefits, we believe they are not negligible. Once we exclude an area from a critical habitat designation, we lose the ability to consider the effects of Federal agency actions that could adversely modify or destroy designated critical habitat. This could allow for actions to proceed that would result in the loss of habitat containing the PBFs essential to the conservation of a DPS, hindering or even preventing recovery of the particular DPS. Therefore, given the benefits of designation, we did not exclude any particular area from the critical habitat units.

Comment 47: The Navy provided an illustration of the upper, middle, and lower danger zones associated with the Potomac River Test Range (PRTR) Complex and explained that the map in the INRMP for Naval Support Facility Dahlgren (NSF Dahlgren) does not show the entire extent of the danger zones. The Navy further commented that we previously determined that the NSF Dahlgren INRMP provides a benefit to Atlantic sturgeon and its habitat and, in accordance with section 4(a)(3)(B) of the ESA, the particular areas of the facility covered under the INRMP will not be part of the designated critical habitat.

Our Response: We thank the Navy for the information. Our consideration of the PRTR was based on the description of the danger zone provided in the regulations at 33 CFR 334.230 and the Water Range Sustainability Environmental Program Assessment for the Potomac River Test Range (May 2013) and the NSF Dahlgren INRMP.

Section 4(a)(3)(B) of the ESA prohibits designating as critical habitat any lands or other geographical areas owned or controlled by the DOD or designated for its use, that are subject to an INRMP prepared under section 101 of the Sikes Act (16 U.S.C. 670a), if the Secretary determines in writing that such plan provides a conservation benefit to the species, and its habitat, for which critical habitat is proposed for designation. We determined that the INRMP for NSF Dahlgren provides a benefit to the Chesapeake Bay DPS and its habitat. However, the PRTR is outside of the scope of that INRMP. The scope of the INRMP for NSF Dahlgren is described as natural resources management on those lands and near-shore areas at Naval Support Facility Dahlgren that are: Owned by the United States and administered by the Navy; used by the Navy via license, permit, or lease for which the Navy has been assigned management responsibility; withdrawn from the public domain for use by the Navy for which the Navy has been assigned management responsibility; and, leased lands on the installation and areas occupied by non-DOD entities. Specifically, the INRMP describes the NSF Dahlgren as divided "into two land masses by Upper Machodoc Creek. Mainside encompasses 2,678 acres on the northern side of Upper Machodoc Creek and is used for operational and support activities and military housing. Pumpkin Neck, located to the south of Upper Machodoc Creek, is 1,641 acres and supports two large testing areas and scattered testing facilities." In addition, the INRMP states that NSF Dahlgren maintains real estate transactions to "18 small range stations located along the Potomac River Test Range (PRTR) to support [its] primary tenant's, Naval Surface Warfare Center, Dahlgren Division (NSWCDD), over water testing activities." The INRMP describes the PRTR Complex which is five land based firing ranges and one water range, the PRTR. However, both the INRMP and the Water Range Sustainability Environmental Program Assessment describe the PRTR as the responsibility of the NSWCDD. The regulations at 33 CFR 334.230 also identify the PRTR as controlled by the NSWCDD, including for closing one or more of the three danger zones on a full-time or intermittent basis in the interest of public safety during hazardous operations.

The Navy, in their comment, described the PRTR as associated with NSF Dahlgren. The INRMP description of the land and nearshore areas for NSF Dahlgren supports use of "associated with" rather than "part of." For example, with the exception of Figure 2–4 depicting the five land based firing ranges and the PRTR, the illustrations in the INRMP do not include the PRTR as part of NSF Dahlgren. Throughout the INRMP, the Potomac River is described as being adjacent to NSF Dahlgren whereas certain Potomac River tidal tributaries are described as within the installation, and NSF Dahlgren is described as having only approximately 6.4 km (4 miles) of Potomac River shoreline.

The INRMP explains that management of the Dahlgren base previously transferred from the NSWCDD to Naval District Washington (NDW), which was re-designated as NDW West Area and, in 2005, became NSF Dahlgren. The Water Range Sustainability Environmental Program Assessment explains that NSF Dahlgren is responsible for oversight and maintenance of the land and all structures assigned and constructed on or in the land, and the NSWCDD controls the PRTR during hazardous operations, in the interest of public safety. Both the INRMP and the Water Range Sustainability Environmental Program Assessment state the Potomac River is under the jurisdiction of the State of Maryland. In August 2016, we contacted the Navy and received confirmation that the Navy does not manage the lands or waters of the Potomac River that are the PRTR.

We agree that the PRTR is designated for use by the Navy. However, based on the INRMP, the regulations, and the Water Range Sustainability Environmental Program Assessment, the PRTR is not part of those lands or near shore areas at NSF Dahlgren that are "owned by the U.S. and administered by the Navy; used by the Navy via license, permit, or lease for which the

Navy has been assigned management responsibility; withdrawn from the public domain for use by the Navy for which the Navy has been assigned management responsibility; or leased lands on the installation and areas occupied by non-DoD entities." We, therefore, concluded that the lands and waters of the PRTR are not subject to the NSF Dahlgren INRMP, and do not meet the requirements of 50 CFR 424.12(h) that would prohibit us from including them as critical habitat.

In revisiting our determination, we considered whether the NSF Dahlgren INRMP provides a conservation benefit to the Chesapeake Bay DPS of Atlantic sturgeon if the lands and waters of the PRTR were subject to the INRMP. We concluded that the INRMP does not because the management practices in the INRMP offer limited protection to the habitat within the PRTR, and the PRTR covers most of the area that we are designating as the Potomac River critical habitat unit. Designating this area as critical habitat provides a benefit to the Chesapeake Bay DPS, and the PBFs in this area are essential to the conservation of the DPS. Therefore, management practices in the INRMP would have to provide a similar conservation benefit, either directly or indirectly addressing the PBFs that may require special management considerations or protection.

Comment 48: Newport News Shipbuilding expressed concern that designating critical habitat in the lower James River would have economic impacts and impacts to national security. The commenter proposed that we make appropriate exclusions for industries that demonstrate insignificant and discountable impact to and/or appropriate mitigations for the Atlantic sturgeon.

Our Response: We considered whether to use our discretion to exclude areas from the critical habitat designations. We declined to exercise our discretion and did not exclude any areas. Critical habitat is the specific areas on which are found the PBFs essential to the conservation of the species and which may require special management considerations or protection. It is the presence of the PBFs and the PBFs' potential need for special management considerations or protection that dictates the designation, not the effect a particular industry at a given point in time may have on the PBFs.

We considered the economic impacts of designating critical habitat in the James River, impacts to national security, and the expected impact to species recovery resulting from the designation. While we have used the best available information and an approach designed to avoid underestimating impacts, many of the potential impacts are speculative and may not occur in the future.

Our conservative identification of potential incremental economic impacts indicates that any such impacts, if they were to occur, would be very small and likely to consist solely of the administrative costs of consultation. We recognize the potential that ESA section 7 consultation stemming from these designations may, sometime in the future, result in project modifications and associated costs. However, discussions with Federal action agencies identified no instances of past project modifications that would have been necessary as a result of Atlantic sturgeon critical habitat having been designated, and these discussions and correspondence with Federal agencies yielded no suggestions that project modifications are likely to result from this designation in the future. Further, even if modifications were to be required to avoid destruction or adverse modification of critical habitat, it is extremely unlikely that modifications that would be required to avoid destruction or adverse modification of critical habitat would not also be required to avoid jeopardizing the species. Therefore, project modification costs resulting solely from these critical habitat designations are likely to be small, if they were to occur.

Comment 49: An industry trade group pointed to our determinations that the majority of the section 7 consultation costs would already be incurred based on the listing of the Atlantic sturgeon itself and that "[i]t is extremely unlikely that [project] modifications that would be required to avoid destruction or adverse modification of critical habitat would not also be required because of adverse effects to the species." They wondered, if there are no categories of permits or other Federal activities that would be impacted solely or even primarily by consultation over impacts to designated critical habitat (rather than impacts to the listed species), what is the purpose of designating critical habitat? They went on to state that if designation of critical habitat is "not prudent," we should not make such a designation.

Our Response: We are required by section 4(a)(3) of the ESA to designate critical habitat when we list a species as endangered or threatened. We may decline to designate critical habitat for a species, if doing so is "not prudent." Our regulations (50 CFR 424.12) explain that designation of critical habitat is not prudent if: (1) The species is threatened by taking or other human activity, and identification of critical habitat can be expected to increase the degree of such threat to the species; or if designation would not be beneficial to the species. The life history of Atlantic sturgeon is fairly well described, so designating critical habitat will not increase the degree of threat to the species from taking or other human activity. In determining whether a designation would not be beneficial, the factors we may consider include but are not limited to: Whether the present or threatened destruction, modification, or curtailment of a species' habitat or range is not a threat to the species, or whether any areas meet the definition of "critical habitat." For Atlantic sturgeon, the present or threatened destruction, modification, or curtailment of a species' habitat or range has been identified as a threat, and the areas we have proposed for designation meet the definition of critical habitat, and, therefore, designation is clearly prudent. In addition, while we have determined that the majority of section 7 consultation costs would already be incurred based on the listing of the species, we determined there will be additional benefits when impacts to critical habitat are assessed during consultations. Designating critical habitat identifies areas where Federal agencies can focus their conservation programs and use their authorities to further the purposes of the ESA. It also helps focus the conservation efforts of other conservation partners, such as State and local governmental organizations, and individuals. In addition, we found that there will be numerous conservation benefits to Atlantic sturgeon, its ecosystem, and to the public, resulting from the designation. Therefore, we believe that designation of critical habitat for Atlantic sturgeon is beneficial to the species.

Comment 50: An industry trade group suggested we had failed to perform the requisite analysis of whether certain areas should be excluded. They believe that to comply with our statutory mandate to consider whether the benefits of excluding areas from the critical habitat designation outweigh the benefits of designation, we must provide some specific analysis of the conservation benefits derived from designating specific areas compared to the economic costs of designating those areas. They indicated we made no attempt to carve out less valuable areas based on economic, national security, or other relevant impacts. They claimed

our analysis is cursory and grossly inadequate, because we do not evaluate whether the benefits of exclusion outweigh the economic costs of designation for particular areas that will be designated (aside from areas of concern to the Navy).

Our Response: The commenters' argument misstates the requirements of the ESA. Section 4(b)(2) of the ESA contains two distinct elements: An initial mandatory consideration of impacts of a designation, and a separate discretionary exclusion provision. The ESA does not require use of any particular methodology in the consideration of impacts, let alone require comparing the benefits of designation to the benefits of excluding certain areas as part of this portion of section 4(b)(2) (see, *e.g., Building Industry Association of the Bay Area* v. *U.S. Department of Commerce,* 792 F.3d 1027 (9th Cir. 2015)). Similarly, the ESA does not require that we carve out "less valuable" areas of critical habitat.

In our proposed rule, we explained our preliminary determination that we would not exercise our discretion to consider exclusions. However, based on input received during the public review process raising concerns about the impacts and uncertainties associated with unoccupied critical habitat, and questions raised about the nature of the conservation values these unoccupied units provide, we determined that conducting a discretionary exclusion analysis for areas of unoccupied critical habitat areas in the Carolina and South Atlantic DPS was warranted. Given that occupied units are currently used by Atlantic sturgeon for reproduction and recruitment, and due to the severely depressed levels of all river populations in all 5 DPSs, occupied units are far too valuable to both the conservation and the continuing survival of Atlantic sturgeon to be considered for exclusion.

Section 4(b)(2) of the ESA provides that the Secretary may exclude any area from critical habitat if he determines that the benefits of such exclusion outweigh the benefits of specifying such area as part of the critical habitat. This is true unless he determines, based on the best scientific and commercial data available, that the failure to designate such area as critical habitat will result in the extinction of the species concerned. The legislative history regarding section 4(b)(2) exclusion analyses suggests that the consideration and weight given to impacts is within the Secretary's discretion (H.R. 95–1625), and the Secretary is not required to give economic or any other 'relevant impact' predominant consideration in his specification of critical habitat.

Based on that analysis, we have elected to exclude the Santee-Cooper river system (CU1) and Savannah River (SAU1) unoccupied units of critical habitat, because the benefits of exclusion (that is, avoiding some or all of the impacts that would result from designation) outweigh the benefits of designation.

Comment 51: A commenter stated the economic analysis discussed in the preamble and supplementary information is focused exclusively on the administrative costs to the Federal agencies of ESA section 7 consultations, and these costs are not inconsequential. They go on to state that, for the New York Bight DPS, the projected medium and high costs are estimated to equal approximately $2.83 and $5.57 million, respectively. The preamble states that "[a]ny incremental economic impacts will consist solely of the administrative costs of consultation; no project modifications are projected to be required to address impacts solely from the proposed critical habitat." The commenter claims that no estimates are presented of costs to applicants for projects funded, authorized or carried out by Federal agencies (for example, projects subject to Clean Water Act actions for which ESA consultations are likely), including analyses of the impacts of a project, the time needed for consultation, and any specific requirements deemed necessary for the project. The commenter also states that the estimated administrative costs, the large number of activities entailing Federal action, and the complexity of the essential PBFs identified and potentially requiring consideration dictate that the final rule should address these additional economic costs.

Our Response: The designation of critical habitat requires Federal agencies to consult with us under section 7 of the ESA if their proposed action may affect critical habitat. Designating critical habitat does not affect the activities of private individuals conducting activities on private land unless those activities are federally-funded or require federal authorization. Therefore, in terms of the economic impacts of a critical habitat designation, the costs are those associated with conducting informal or formal ESA section 7 consultations, including preparation of consultation documents. Preparation of a license application is not a cost of ESA section 7 consultation because the license application is required separate from any critical habitat designation.

The economist who drafted the economic analysis contacted Federal agencies for input on the number and type of modifications that may occur as a result of critical habitat designations. The Federal agencies did not identify any modifications. We used a 10-year history of ESA section 7 consultations to inform the number and type of ESA section 7 consultations likely to occur in the future. To address uncertainty, the economist provided three different scenarios that affected the overall estimated costs associated with the critical habitat designations. Despite receiving information from Federal agencies that no modifications were anticipated, the economist also presented information for modification costs based on consultations for Federal agency actions that may affect ESA-listed salmon species, as salmon were considered a reasonable proxy for Atlantic sturgeon for this analysis. For example, project modifications might include date restrictions, use of silt fences, upland disposal of excavated material, maintenance of all heavy equipment to minimize pollutant release, use of a bubble curtain to minimize sound effects, and pollution and erosion control.

We consider the incremental impacts of critical habitat designations (*i.e.,* the impacts that would occur in the absence of any other action (78 FR 53058; August 28, 2013)). The costs of the critical habitat designations are the costs of conducting ESA section 7 consultations (*i.e.,* the administrative costs of section 7 consultation, which include the projected costs to NMFS, the Federal agency taking the action, and the third party (*e.g.,* applicant), and the cost of completing a biological assessment). Because the Federal agencies would most likely have to consult with us anyway given presence of Atlantic sturgeon and, in many cases, other ESA-listed species within the critical habitat areas, the incremental cost of the critical habitat designations will be low. Therefore, the medium and high cost estimates are not likely representative of the costs of the critical habitat designations. Even the low cost estimates likely overestimate the economic impact of the critical habitat designations for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs because the critical habitat designations are unlikely to result in more ESA section 7 consultations then would have occurred in the absence of critical habitat.

Comment 52: An industry trade group suggested we had significantly underestimated the true costs to a permittee, because we had not included potential costs associated with employing biologists, other consultants, or legal support they believe may be necessary to navigate the consultation

process. They went on to state that consultation could cause project modifications, additional avoidance measures, or require additional mitigation above what was required by the action agency. The commenters reported Sundig (2003) estimated the direct, out-of-pocket costs of section 7 consultation for a single-family housing project to be several thousand dollars per house. Beyond the consultation process itself, the commenters suggested requirements to avoid or mitigate impacts to critical habitat could result in economic losses of millions of dollars. The commenters concluded that by severely underestimating the number of consultations that will be triggered by the proposed designations and the costs of those consultations, we failed to provide a meaningful analysis of section 7 consultation costs.

Our Response: We disagree. In our impacts analyses we did not assert that no project modifications would be required to address impacts to critical habitat. Rather, we concluded that the same project modifications would most likely address any adverse impacts to both sturgeon and to critical habitat, and as such, these costs are not solely attributable to the critical habitat designation. Our impacts analyses discuss the types of project modifications that might be required to address adverse effects to critical habitat for all the Federal activities projected to require consultation over the next 10 years. The commenters stated we did not include potential costs associated with employing biologists, other consultants, or legal support that they believe may be necessary to navigate the consultation process. As noted previously, we anticipate that in nearly all cases, section 7 consultations would likely have been required to consider potential adverse effects to Atlantic and/or shortnose sturgeon for any action potentially affecting Atlantic sturgeon critical habitat. These costs would be incurred even without the designation. However, we also projected that every future consultation will involve additional administrative costs, including costs to third parties such as permittees or applicants, related to the additional analyses added to a consultation to address critical habitat. These costs would depend on the complexity of the consultation and whether the permittee is required to produce a biological assessment (see Economic Analysis for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs, (Table 3–6) and Impacts Analysis of Critical Habitat Designation for the Carolina and South Atlantic DPSs of Atlantic Sturgeon (Industrial Economics, 2014)). In criticizing our impacts analyses, the commenter cites Sundig (2003) and its conclusion that costs of consultation for a single-family housing project are estimated to be several thousand dollars per house. While we find Sundig (2003) to be too hypothetical and generalized to warrant changes in our analysis, as discussed above, our analysis does include estimated permittee costs of consultation not obviously dissimilar to Sundig's (2003) 'several thousand dollars' per permittee. In addition, it does not appear that Sundig (2003) took into account that at least some and possibly most of the impacts and costs described are co-extensive with the listing of the species, and not attributable solely to critical habitat designation. We see no basis to change our impacts analysis based on this comment.

Comment 53: A commenter representing two agency groups stated that the sweeping critical habitat designations would impede critical economic growth, including activities that are necessary to sustain the U.S. economy, without commensurate benefits to the Atlantic sturgeon.

Our Response: We disagree. The economic analysis for designating critical habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon provides information on the economic impacts of the critical habitat designations, and addresses uncertainty by presenting costs for scenarios that are not likely to occur. The draft economic analysis was peer-reviewed by three experts before it was released for public comment at the same time as the proposed rule. Our review of the likely economic impacts of the critical habitat designations is provided in the proposed rule and Impacts Analysis and Biological Information Source Document. As described, the best available information supports that incremental economic impacts as a result of the critical habitat designations for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs will be low.

There are conservation benefits of the critical habitat designations, both to the species and to society. While we cannot quantify nor monetize these benefits, we believe they are not negligible and are an incremental effect of the designations.

Comment 54: A commenter stated that many project impacts are minimal (*e.g.*, placing a pole on an islet or bar to allow an aerial electric line to cross a river) and would not be likely to impact the Atlantic sturgeon, but would trigger time-consuming and costly ESA section 7 consultation requirements if they intersect and may affect areas designated as critical habitat. They stated that consultation with NMFS often results in modification, delay, or other changes to projects, with potentially significant adverse impacts on their customers' access to reliable and secure energy supplies at a reasonable cost, and without commensurate (if any) demonstrated benefit to the listed species.

Our Response: The ESA requires consultation when a Federal agency action may affect a listed species or critical habitat. We agree that many projects have impacts that are minimal. If a project will have no effect on critical habitat, there would be no section 7 consultation on effects to critical habitat. If effects are insignificant or discountable, consultation is completed informally via a letter exchange between the Federal agency and NMFS. We do not expect consultations on small projects to be time consuming or costly for Federal agencies or applicants. The commenter did not provide specific information regarding any consultation that had the potential to significantly impact access to reliable and secure energy supplies at a reasonable cost and we are not sure what consultations the comment refers to, on what types of projects or listed species. The commenter did not provide context or specific examples supporting the comment that consultations with us often result in modification, delay, or other changes to projects and we disagree with this claim. The contracted economist contacted Federal agencies for information on any consultations with us that resulted in project modifications that might be required again in the future due to critical habitat designation. None of the Federal agencies identified any such consultations. In fact, the majority of ESA section 7 consultations with us are concluded informally and never rise to the level of a formal consultation with a biological opinion issued by us, and thus would not involve modifications or delays that result in significant economic impacts.

We disagree with the commenter's claim that consultation with NMFS does not result in demonstrated benefits to listed species. Informal consultation (*i.e.*, concurrence with a not likely to adversely affect determination) is a simple process that confirms that effects of an action will be wholly beneficial, insignificant or discountable. Formal consultation, resulting in a Biological Opinion, allows proposed Federal actions to move forward and even result

in adverse effects to listed species, but requires implementation of measures that minimize the effects of take of listed species. For critical habitat, benefits of consultation include ensuring that critical habitat is not likely to be destroyed or adversely modified, or identifying minor changes to projects that can avoid or minimize adverse effects. The benefits of designating critical habitat as well as the requirement to designate critical habitat are described in the proposed rulesrules for these Atlantic sturgeon critical habitat designations. Recovery of ESA-listed species is often a lengthy process. Progress towards meeting recovery goals of down-listing and de-listing are anticipated benefits of all of the actions taken to recover ESA-listed species, including designating critical habitat.

Comments on ESA Section 7 Consultation

Comment 55: A commenter sought confirmation that the statement, "we determined that any resulting consultations will likely be coextensive" means that there will not be an increased consultation burden for updating or maintaining pier structures (including pile driving), or for new, currently unpermitted dredging, fill, or discharge activities in the Kennebec River, and an Atlantic sturgeon critical habitat designation for the Kennebec River will not provide a basis to reopen existing dredging permits to require additional consultation.

Our Response: For clarification, the requirement to consult under ESA section 7 is for Federal agencies if the agency anticipates taking an action that may affect ESA-listed species or designated critical habitat. Private citizens do not consult with us under ESA section 7 but, as applicants for Federal agency actions (*e.g.*, permits) or potential recipients of Federal funding, private citizens may engage with the action agency (*i.e.*, the Federal agency funding, authorizing, or carrying out an action) during the ESA section 7 consultation with us.

We, as the consulting agency, cannot foresee every circumstance that might require ESA section 7 consultation. However, based on the best available information for the presence of Atlantic sturgeon and other ESA-listed species in the Kennebec River critical habitat unit, information from Federal agencies regarding anticipated agency actions and past modifications to projects as a result of ESA section 7 consultation, and the past 10-year consultation history, we determined the most likely scenario is that agency actions that may affect critical habitat, and thus require ESA section 7 consultation, may also affect listed species, including Atlantic sturgeon. Therefore, designating critical habitat is unlikely to result in an increase in the number of ESA section 7 consultations. Consultation that has been completed may need to be reinitiated if the reinitiation triggers have been met. Reinitiation is required when a new species is listed or critical habitat designated that may be affected by the identified action. We anticipate that consultations will need to be reinitiated once the final rule is effective. However, this does not necessarily mean that permits will be reopened or that actions will need to be modified. Modifications to ongoing activities would only be required where a Federal agency has ongoing discretionary control and when the action is likely to result in the destruction or adverse modification of critical habitat and we issue a biological opinion that includes reasonable and prudent alternatives. It is important to note that in nearly all existing section 7 consultations on Atlantic sturgeon, we have included an analysis of effects to habitat.

We have been working closely with action agencies during the rulemaking process and have provided information on the triggers for reinitiation as well as when conference under section 7(a)(4) of the ESA is necessary. Further information about ESA section 7 consultation is available at *https://www.greateratlantic.fisheries.noaa.gov/protected/section7/index.html.*

Comment 56: The Atlantic States Marine Fisheries Commission stated that we should consider the stock assessment needs and management impacts from ESA section 7 consultations, and conduct ESA section 7 consultations expeditiously to avoid delays in fisheries research or sampling.

Our Response: We acknowledge the concern for the length of time that is sometimes necessary to complete ESA section 7 consultations. We have taken several steps in the past year to address these concerns, including additional online resources for technical assistance, an Expedited Consultation Program, and programmatic approaches to consultations where possible.

Currently, there are two biological opinions for federally funded, authorized, or implemented actions to support fisheries research and sampling in Federal and state waters from Virginia through Maine. These are programmatic consultations for (1) the Northeast Fisheries Science Center's (NEFSC) fisheries and ecosystem research, and (2) surveys undertaken under the USFWS issuance of funds from the Wildlife and Sport Fish Restoration Program to 11 Northeast states and the District of Columbia. Neither of these biological opinions considers effects of the action(s) to proposed critical habitat for any Atlantic sturgeon DPS because the biological opinions were completed before the proposed critical habitat designations.

In a memo to the Greater Atlantic Regional Fisheries Office, the NEFSC determined, following publication of the critical habitat proposed rule, that the actions described in our biological opinion that considered their NEFSC's fisheries and ecosystem research program are not likely to result in the destruction or adverse modification of proposed critical habitat. We concurred with the determination. Therefore, because we do not anticipate any changed circumstances, we do not anticipate the need to reinitiate the NEFSC programmatic consultation at this time. We will continue to work with the NEFSC and the USFWS to expeditiously complete ESA section 7 consultations necessary for fisheries research and fisheries monitoring.

Comment 57: A few commenters, including an industry trade group, expressed concern about potential delays for projects already undergoing consultation that would now have to include an analysis of adverse modification for Atlantic sturgeon critical habitat, as well as previous consultations that may need to be reinitiated based on the new critical habitat designation.

Our Response: We acknowledge delays are possible. We recommend that Federal action agencies work with us to provide the appropriate information as identified at 50 CFR 402.14(c)(1)–(6) to assess impacts to critical habitat as soon as possible to limit delays. We also note that Federal actions undergoing consultation that may affect Atlantic or shortnose sturgeon would already be required to analyze impacts to those species' habitats, whether they are designated as critical habitat or not. Thus, any delays due solely to this rule should not be significant.

Comment 58: The USACE expressed concern that we may be relying on historical (1870s) data that may not reflect current day conditions or documented scientific data, and cautioned that until detailed scientific data are provided that clearly documents the existence of a fall spawning season in the Hudson River upstream of Kingston, New York, no further restriction to the current dredging window is warranted.

Our Response: We do not issue restrictions on the timing of dredging in the Hudson River Federal Navigation Channel. We have worked with the USACE to recommend time of year "windows" in which dredging is least likely to interact with listed species, including Atlantic sturgeon.

The features of Atlantic sturgeon critical habitat are expected to be present year-round. Therefore, "dredge windows" are more effective for avoiding effects to ESA-listed species than for avoiding effects to Atlantic sturgeon critical habitat. Regardless, we would ensure that any recommendations to the USACE or any other party are based on the best available information.

We included mention of the 1870s era data as part of our review of information for the critical habitat designations, and evidence of fall spawning in rivers where Atlantic sturgeon spawn. However, as we stated in the Background section of the proposed rule, spring is the only currently known spawning period for the New York Bight DPS. There is no information that fall spawning currently occurs in the Hudson River.

Comment 59: A commenter asked if consultation is required even if the Federal action does not destroy or adversely modify current habitat. The commenter further directed us to address whether actions that improve the essential PBFs, such as those for improving water quality, are subject to the consultation provisions of section 7(a)(2) of the ESA, and to identify the earliest stage in the regulatory process that such consultation may be initiated.

Our Response: Current habitat is not the same as designated critical habitat. The ESA and the regulations implementing section 4 of the ESA emphasize that, except in those circumstances determined by the Secretary, critical habitat shall not include the entire geographical area which can be occupied by the threatened or endangered species. Once critical habitat is designated, section 7(a)(2) of the ESA requires that a Federal agency, in consultation with us (or with the USFWS for ESA-listed species under their jurisdiction), insure that any action it authorizes, funds, or carries out is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of designated critical habitat.

The Greater Atlantic Region, Protected Resources Division provides information on the ESA section 7 consultation process, including technical assistance, and the Expedited Consultation Program on our Web site. For further information, see *www.greateratlantic.fisheries.noaa.gov/protected/section7/index.html.* Additional information, including links to policies, guidance, and regulations associated with ESA section 7 is available at *www.nmfs.noaa.gov/pr/consultation/.* Briefly, a Federal agency must consult with us if the agency is authorizing, funding or carrying out an action that may affect listed species or critical habitat. An action that results in wholly beneficial effects is not exempt from the requirements of ESA section 7 consultation.

Informal consultation is an optional process that includes all discussions, correspondence, etc., between us and the Federal agency to assist the Federal agency in determining whether formal consultation is required. Informal consultation can be initiated as early as the effects of a proposed Federal action can be identified. We provide information at the web addresses listed above to help Federal agencies determine, at the earliest opportunity, whether and when to initiate consultation with us. We also provide technical assistance to Federal agencies related to questions of whether and where species and designated critical habitat occur to help action agencies determine whether their actions may affect listed species or critical habitat. The ESA section 7 implementing regulations (50 CFR 402.11) address "early consultation" as a preliminary consultation requested by a Federal agency on behalf of a prospective permit or license application prior to the filing of an application for a Federal permit or license. The ESA and its implementing regulations do not identify the earliest opportunity for consultation; however, in practice, the earliest opportunity for entering into formal consultation is when there is a proposed action that is far enough along in development that the effects can be predicted and are reasonably certain to occur.

Comment 60: Two commenters requested we engage with the Virginia Department of Environmental Quality (VADEQ) concerning Dominion's Chesterfield Power Station, which they identified as directly adjacent to Atlantic sturgeon spawning habitat on the James River. They commented that the NPDES Permit (issued by VADEQ) would authorize activities at Chesterfield Power Station that are likely to take endangered species and/or significantly degrade or destroy Atlantic sturgeon critical habitat, and these activities resulted in the entrainment of two Atlantic sturgeon larvae at Chesterfield Power Station in October 2015. The commenters also requested that we require Virginia Power and Electric Company ("Dominion") to submit a habitat conservation plan as soon as possible once the critical habitat designations have been finalized, and that we finalize the proposed rule as soon as practicable.

Our Response: Information posted by the VADEQ provides the background for our response (for the complete text go to *www.deq.virginia.gov/Programs/Water/PermittingCompliance/PollutionDischargeElimination.aspx*). Section 402 of the Clean Water Act established the NPDES program to limit pollutant discharges into streams, rivers, and bays. The U.S. Environmental Protection Agency (EPA) delegates the authority to implement the NPDES program to states where certain conditions have been met. Virginia received authorization from EPA to administer the NPDES base program on March 31, 1975; for Federal facilities on February 9, 1982; for pretreatment on April 14, 1989; and for general permits on May 20, 1991. The VADEQ administers the program as the Virginia Pollutant Discharge Elimination System (VPDES), and issues VPDES permits for all point source discharges to surface waters, to dischargers of stormwater from Municipal Separate Storm Sewer Systems, and to dischargers of storm water from industrial activities. Further, the VADEQ issues Virginia Stormwater Management Program (VSMP) permits to dischargers of stormwater from Construction Activities. The EPA maintains authority to review applications and permits for "major" dischargers, a distinction based on discharge quantity and content.

The VADEQ issued a VPDES permit to Dominion Chesterfield Power Station on September 23, 2016. For further information on this permit, go to *http://www.deq.virginia.gov/Programs/Water/PermittingCompliance/VPDESPermitActions.aspx#Chesterfield.* Because issuance of the permit was a state agency action, not a Federal agency action, there is no requirement for ESA section 7 consultation on issuance of the VPDES permit. A non-Federal entity can apply for an ESA section 10(a)(1)(B) Incidental Take Permit to cover otherwise lawful actions that may result in takes of an ESA-listed species.

A representative of Virginia Power and Electric Company notified us of the incidental entrainment of the two Atlantic sturgeon larvae following their identification. We began discussions with their staff regarding application for an ESA section 10(a)(1)(B) Incidental Take Permit, including submission of a Habitat Conservation Plan (HCP), in

June 2015. While a draft HCP has been submitted to us, we cannot predict when the HCP will be finalized or when an Incidental Take Permit will be issued. We will publish a notice in the **Federal Register** and provide an opportunity for public comment when we determine the application is sufficient.

Other Comments on the Process for Designating Critical Habitat and Comments Outside the Scope of This Rulemaking

Comment 61: A commenter stated the driving force behind the proposed critical habitat designations has been the pressure and deadlines of litigation, not the underlying science or an urgent need to designate critical habitat to protect the Atlantic sturgeon. The commenter concluded that NMFS has not taken sufficient time to make careful critical habitat determinations, nor has it afforded the public a sufficient opportunity for meaningful participation.

Our Response: As described in our response to Comment 37, the ESA requires that we designate critical habitat at the time a species is listed or, if not determinable at that time, within 1 year of listing. The only other exception is if designating critical habitat is not prudent for the species. However, this circumstance rarely occurs. We failed to meet this 1-year deadline and are currently subject to a statutory deadline and a court-order to complete the designation. While we agree that litigation has influenced our timeline, we disagree that we have not made careful determinations or provided the public with opportunities for meaningful participation.

The critical habitat designations for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon were proposed more than 4 years after the DPSs were listed as endangered or threatened. We began the process of designating critical habitat in 2012. We initially provided a comment period of 90 days, 30 days longer than typical for critical habitat designations. In response to requests for extension, we reopened the comment period for an additional 15 days of comment, making the total comment period 105 days.

We must hold a public hearing on a proposed critical habitat designation at the request of the public. Despite receiving no such requests, we chose to hold two public hearings and announced those in the proposed rule and on our Web page, in emails sent to our distribution lists, and a newspaper with regional readership. We made the public hearings available by telephone as well as in person to increase opportunities for the interested public that would otherwise have had to travel to the hearing location. We did not receive any public comments during the public hearings, and we did not receive any requests for additional public hearings. We also held four informational meetings during which we provided an overview of the proposed rule as a slide presentation, answered procedural questions to help the public formulate their comments, and clarified the instructions for submitting comments. Additionally, we posted information on our Web page, including the slide deck presented at the public information meetings and public hearings, and held an informational webinar for Federal agencies. We used our discretion to go beyond the requirements of the ESA and its implementing regulations and provided multiple means for public participation.

Comment 62: A commenter stated there is no substantial value to designating critical habitat which requires additional regulatory burden with limited value to increasing population levels of the species. The commenter stated that each Federal action in the Delaware River associated with permitting considers the presence of shortnose and Atlantic sturgeon, and considers how each aspect of a project will affect the species. The commenter notes that consultation is initiated when appropriate and that the opportunity for any additional benefits associated with critical habitat designation would be limited.

Our Response: The ESA requires that we designate critical habitat for each species (including subspecies and DPSs) that we list under the ESA unless designation is not prudent for the listed species. A determination that critical habitat is not prudent is rare and is made only when the species is threatened by taking or other human activity, and identification of critical habitat can be expected to increase the degree of such threat to the species, or when designation of critical habitat would not be beneficial to the species.

The designation of critical habitat provides a significant regulatory protection—the requirement that Federal agencies ensure, in consultation with the Services under section 7(a)(2) of the ESA, that their actions are not likely to destroy or adversely modify critical habitat. The Federal Government, through its role in water management, flood control, regulation of resource extraction and other industries, Federal land management, and the funding, authorization, and implementation of myriad other activities, may propose actions that may affect critical habitat. The designation of critical habitat ensures that the Federal Government considers the effects of its actions on habitat important to species' conservation and avoids or modifies those actions that are likely to destroy or adversely modify critical habitat. There are conservation benefits of the critical habitat designations, both to the species and to society. While we cannot quantify or monetize these benefits, we believe they are not negligible and are an incremental effect of the designations.

Comment 63: The commenter acknowledged that spawning occurs for shortnose sturgeon in the upper Delaware River and believes that Atlantic sturgeon possibly spawn in the upper Delaware River but stated actual spawning of Atlantic sturgeon has never been directly documented.

Our Response: Atlantic sturgeon are spawning in the Delaware River. There are several lines of evidence demonstrating spawning occurs. First, Atlantic sturgeon less than 1-to 2-years old are captured in the Delaware River. Atlantic sturgeon this young do not have the salinity tolerance to leave the natal estuary and travel through full saline waters to other lower salinity, estuarine waters that are necessary for rearing. Therefore, presence of Atlantic sturgeon less than 2 years old in the Delaware River is evidence that Atlantic sturgeon are spawning in the Delaware.

Genetic analyses have shown that Atlantic sturgeon natal to the Delaware River have a unique genetic structure. Such uniqueness arises when adults characteristically return to spawn in the river in which they were spawned and mixing with other populations is limited.

Year after year, male and female Atlantic sturgeon in spawning condition occur in the Delaware River in areas and at times when spawning would occur. In addition, the reporting and retrieval of dead large, adult Atlantic sturgeon in the Delaware River, sometimes with evidence of spawning condition such as ripe eggs or milt, occurs more frequently in the spring; the time period when we expect Atlantic sturgeon spawn in the Delaware River.

The opportunity to witness sturgeon spawning is difficult given the environment in which they spawn, and human observation of spawning sturgeon is potentially harmful to sturgeon (*e.g.*, as a result of disrupting spawning). Sturgeon researchers are required to minimize harm to Atlantic sturgeon, including minimizing disruptions of spawning behavior, and

the public is cautioned to not approach areas where spawning may be occurring (*e.g.*, as evidenced by breaching sturgeon). The available information is sufficient to establish that spawning occurs in the Delaware River, despite spawning activity, eggs, or larvae, not being observed in the River.

Comment 64: An industry trade group indicated we made no attempt to establish any connection between the threats to Atlantic sturgeon described in the listing rule and critical habitat. They suggested we have not evaluated or explained how designation of critical habitat will benefit the species, or help address injury/death resulting from inshore trawling or overfishing. Additionally, they indicated we have not explained how the designation of "these vast areas would provide new or additional minimization of habitat alteration or destruction."

Our Response: The ESA does not require that critical habitat address the specific threats that led to the listing of the species or avoid injury or death from particular activities. However, in the case of Atlantic sturgeon, designation of critical habitat will help address the present or threatened destruction, modification, or curtailment of the species' habitat or range, which was identified as a threat contributing to the threatened or endangered status for these DPSs. Critical habitat designations identify habitat features and areas essential to the conservation, and thus recovery, of the species. In terms of benefits of critical habitat in providing protection from habitat alteration or destruction, designation of critical habitat also provides significant regulatory protection—the requirement that Federal agencies ensure, during section 7 consultation, that their actions are not likely to destroy or adversely modify critical habitat. Designating critical habitat also identifies areas where Federal agencies can focus their conservation programs and use their authorities under ESA section 7(a)(1) to further the purposes of the ESA by carrying out programs for the conservation of listed species. It also helps focus the conservation efforts of other conservation partners, such as State and local governmental organizations, and individuals. Therefore, we believe that designation of critical habitat for Atlantic sturgeon is beneficial to the species and will directly address habitat alteration and destruction issues.

Comment 65: A commenter stated that even in advance of a final rule, EPA has signaled potential changes to requirements under the Clean Water Act based upon a critical habitat designation that could have a significant effect, along with related costs, on non-Federal government entities, including small governments (municipalities) and private parties. The commenter asked if this will result in unfunded mandates.

Our Response: We are unaware of any changes to the Clean Water Act as a result of a critical habitat designation. We encourage the commenter to discuss their concerns with the EPA.

Comment 66: A commenter stated that development and industrial practices have hindered recovery of Atlantic sturgeon. They stated that there is an immediate need to lower pollution in all tributaries and to eliminate all unnecessary killing of larvae and young sturgeon, and the invertebrates they feed upon and that all facilities that currently draw water from our rivers or bays for cooling purposes should change over to closed-loop operations. In addition, the commenter stated that pollution could be lowered, and DO improved, using natural vegetation in a manner that does not infringe on navigation.

Our Response: We appreciate the information for addressing water quality for Atlantic sturgeon. This comment is beyond the scope of this critical habitat designation. However, once critical habitat is designated, we will work with action agencies if a proposed or ongoing Federal action may affect that habitat. Finally, there are other laws that address water quality, including the Clean Water Act, in areas where Atlantic sturgeon critical habitat occurs. Section 316(b) of the Clean Water Act requires EPA to issue regulations on the design and operation of cooling water intake structures, in order to minimize adverse impacts. Further information can be found on the EPA Web site at *https://www.epa.gov/cooling-water-intakes.*

Comment 67: A commenter stated the Department of Interior must address present-day impacts in Delaware such as beach fill projects, the Delaware River Deepening project, maintenance dredging of the Delaware River for the next 50 years, the proposed ocean outfall off Rehoboth Beach, as well as the impacts of past and present industrial sites which contributed to the decline in water quality. They stated that deepening of the Delaware Bay (2015) and the new USACE sand borrow site Area B (2016) in Delaware have compromised and will undoubtedly continue to compromise the health of the benthic food chain for the sturgeon. The commenter stated that a strong and applicable critical habitat designation and subsequent modification or elimination of the non-Federal project is an essential requirement for preservation and conservation of the species in question.

Our Response: We have been delegated authority from the Secretary of Commerce to carry out the requirements of the ESA for species under our jurisdiction, including the five Atlantic sturgeon DPSs. The consultation process, as described in section 7(a)(2) of the ESA, provides opportunity for us to work with Federal agencies to address impacts of agency actions on the species. If we determine a Federal agency action is likely to jeopardize the continued existence of a listed species (a "jeopardy biological opinion") or result in the destruction or adverse modification of critical habitat (a "destruction or adverse modification" biological opinion), the biological opinion will include reasonable and prudent alternatives to modify the action to avoid the likelihood that the action will jeopardize the continued existence of a listed species or result in the destruction or adverse modification of critical habitat.

Comment 68: A commenter stated that the Final Environmental Impact Statement for the City of Rehoboth Beach proposed ocean outfall incorrectly concludes the outfall will not have an impact on the diversity and density of the benthic region. The commenter stated that establishment of sturgeon critical habitat in this important area should disavow this conclusion, and protect and conserve the benthos.

Our Response: We are not designating critical habitat in marine waters, including marine waters off Rehoboth Beach, Delaware. The marine waters off Rehoboth Beach are part of the geographical area occupied by each of the five Atlantic sturgeon DPSs. To designate critical habitat for one or more of the Atlantic sturgeon DPSs in the marine environment, we must first identify the PBFs essential to the DPSs, and which may require special management considerations or protections. See our response to Comment 20.

Comment 69: A commenter requested that as soon as levels are sustainable, a limited catch and release fishery for Atlantic sturgeon should be established, with a special permit, for once a year use and a high fee, $500 to $1,000, and the fee should be used to enhance that fishery.

Our Response: Consideration of any new Atlantic sturgeon fishery is beyond the scope of this critical habitat designation.

Comment 70: One commenter asked us to ensure that the Salem Nuclear Power Plant, Mercer Generating Station,

and the Delaware City Refinery, which processes 200,000 barrels of petroleum per day, install cooling towers and at the latter refinery, remove intake screens that kill millions of fish and entrains millions more small fish, eggs, and larvae that circulate through the refinery's cooling system pipes and get boiled to death.

Our Response: This comment is beyond the scope of this critical habitat designation. Section 316(b) of the Clean Water Act requires EPA to issue regulations on the design and operation of cooling water intake structures, in order to minimize adverse impacts. Further information can be found on the EPA Web site at *https://www.epa.gov/cooling-water-intakes.*

Comment 71: A commenter representing the interests of two industries provided numerous comments on the recently revised joint Service regulations for designating critical habitat (81 FR 7414; February 11, 2016) and asserted that these critical habitat designations for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon were flawed as a result of relying upon the revised regulations.

Our Response: There was a lengthy public comment period for the revised joint Service regulations. The comments and the Service's responses to the comments were provided with the final rule. It is not within the scope of these critical habitat designations for the Atlantic sturgeon DPSs to revisit the response to comments or recommend changes to the joint Service regulations. All critical habitat designations proposed after March 14, 2016, are required to follow the revised joint Service regulations, and we have done so for the Gulf of Maine, New York Bight, and Chesapeake Bay DPS critical habitat designations.

Comment 72: The U.S. Coast Guard provided comment assuring us that they will consult with us in accordance with section 7 of the ESA for establishing new anchorage grounds on the Hudson River because establishing anchorage grounds may impact Atlantic sturgeon, its habitat, or its critical habitat.

Our Response: We appreciate the U.S. Coast Guard's commitment to ESA section 7 consultation for activities that may affect Atlantic sturgeon and Atlantic sturgeon critical habitat.

Comment 73: A representative of the Rhode Island Department of Environmental Management agreed there are not specific areas within Rhode Island state waters that meet the requirements for designation as critical habitat for Atlantic sturgeon, and concurred with the proposal not to designate any critical habit areas in Rhode Island state waters.

Our Response: We appreciate the input and concurrence from the Department of Environmental Management.

Comments on the Carolina and South Atlantic DPS Critical Habitat Designations (81 FR 36077, June 3, 2016; 81 FR 41926, June 28, 2016)

Comments on Geographical Area Occupied

Comment 74: A few commenters asserted that our designation is inconsistent with section 3(5)(C) of the ESA, which provides that "except in those circumstances determined by the Secretary, critical habitat shall not include the entire geographical area which can be occupied by the threatened or endangered species."

Our Response: The areas being designated do not include the entire geographical area which can be occupied, and include only a portion of the ranges of the two DPSs. These areas do not include rivers that do not support spawning but which may be used for foraging, marine habitats, or estuarine habitats below rkm 0 in each designated river.

Comment 75: An industry trade group believed we inappropriately delineated the "geographical area occupied" by the species as the entire "aquatic habitat (*e.g.*, below the high tide line)" of inland freshwater areas that are currently accessible to the Atlantic sturgeon. These commenters stated that we inappropriately included not just areas where the species has actually been located, but instead we also included wider areas around the species' occurrences and areas that may be used only temporarily or periodically by the species. They stated that "areas identified as occupied include vast areas where there is no evidence the species even occurs, much less occupies."

Our Response: See response to Comment 2.

Comments on the Physical or Biological Features (PBFs)

Comment 76: One commenter asserted that the broad nature of the PBFs fails to provide notice to the regulated public whether the PBFs are present in an area without asking NMFS for case-by-case determinations. The commenters further asserted that the broadness of the PBFs renders them not actually essential to the species and provided the example that for the Biological Opinion for Continued Operations of the Indian Point Generating Station, Units 2 and 3, NER 2012–2252 at 42 (Jan. 30, 2013), NMFS characterized one spawning area for Atlantic sturgeon in the Hudson River as being "freshwater year round with bedrock, silt and clay substrates and water depths of 12–24 m," and another area as having "clay, silt, and sand substrates and water depth of approximately 21–27 meters deep."

Our Response: As we explained in our final rule, Implementing Changes to the Regulations for Designating Critical Habitat (81 FR 7414; February 11, 2016), broadly-defined PBFs are not necessarily inappropriate. The level of specificity in our description of the PBFs is primarily determined by the state of the best scientific information available for the species at issue. As held by the court in *Arizona Cattle Growers* v. *Kempthorne,* 534 F. Supp. 2d 1013, 1025 (D. AZ 2008), so long as we have used the best available information and endeavored to provide as much notice as is practicable to the public as to the nature of the PBFs, specification of some quantitative aspects of the PBFs may be deferred to the consultation process. The commenter did not point to any available information that we should have considered to provide additional specificity in the definition of the PBFs, or why the PBFs as defined by us are not actually essential. Moreover, the commenter overlooked important details in the PBFs that make them readily discernible. For example, the commenter stated that hard bottom substrate in low salinity waters, aquatic habitat with a gradual downstream salinity gradient of 0.5 to 30 ppt and soft substrate downstream of spawning sites, water of appropriate depth and absent physical barriers to passage, and water with the temperature, salinity, and oxygen values that, combined, support spawning, survival, growth, development, and recruitment, are too broad. But our description of the PBFs is more detailed than that. Hard bottom is described as *rock, cobble, gravel, limestone, boulder, etc.* This hard-bottom substrate must be in low salinity waters specified as *0.0–0.5 ppt,* and the substrate must be of a type that can facilitate settlement of fertilized eggs, and refuge, growth and development of early life stages. Transitional salinity zones with a *gradual* downstream gradient of *0.5–30 ppt,* and sand or mud soft substrate between river mouths and spawning sites is designated for juvenile foraging and physiological development (this final rule clarifies the gradient is from 0.5 *up to* 30 ppt). Water must be of an appropriate depth and lack barriers to passage. Appropriate depths

and lack of barriers are those that allow *unimpeded movement of adults to and from spawning sites, seasonal and physiologically-dependent movement of juveniles to appropriate salinity zones within the river estuary, and staging, resting, or holding of subadults or spawning condition adults.* Appropriate depths are explained as *at least 1.2 m,* to facilitate all life stages of sturgeon including effective adult migration and spawning behavior. Barriers that would eliminate or degrade this feature were described in the proposed rule as, *locks, dams, reservoirs, gear,* and are clarified in this final rule to include thermal plumes, sound, and turbidity. Essential water quality is qualified as temperature and DO, especially in the bottom meter of the water column, and illustrative examples of how variations in these parameters can adversely affect sturgeon are provided. The essential PBFs are all common attributes of aquatic habitat that are easy to understand and readily measurable; the various parameters—depth, temperature, DO, salinity, etc., are typically included in assessments of proposed projects' impacts on the environment. Proponents of future projects within Atlantic sturgeon critical habitat will know without consulting us whether their project has the capacity to affect salinity, hard or soft substrate, water depth, openness of river channels, temperature, and DO. Most, if not all, project proponents will be able to determine whether the PBFs exist in their project area, and what their baseline conditions are, without first consulting us. Thus, we believe the PBFs of Atlantic sturgeon critical habitat have been described with appropriate specificity, based on the best scientific information available.

With respect to the example provided by the commenter, the commenter mischaracterized our use of the language cited from the Indian Point Biological Opinion. We provided the text in the biological opinion and cited the source of the information as part of the review of available literature for Atlantic sturgeon in the Hudson River. The best available information that we used to describe the PBFs of Atlantic sturgeon critical habitat is cited in the Background of this rule and in the Impacts Analysis and Biological Source Document for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs.

Comment 77: An industry trade group asserted that we must revise our proposed designation to explain how each specific critical habitat unit to be designated contains the PBFs essential to the conservation of the species, suggesting that our approach should be the same as that taken in the designation of critical habitat for the Southern DPS of green sturgeon (74 FR 52300; October 9, 2009). They also suggested our proposed designation is overly broad, improperly used "ephemeral reference points," and unsupported by facts or science. The commenters suggested we identified and proposed to designate sweeping areas of occupied habitat that undoubtedly capture many areas that do not have, and likely never will have, physical or biological characteristics essential for the conservation of the species. One commenter suggested it appeared we had merely designated entire rivers from the confluence of the Atlantic Ocean back to either some major tributary or some large impoundment or impassable boundary upstream. Several commenters suggested that areas should not be designated as critical habitat because environmental conditions in certain stretches of rivers are poor and would not support the PBFs. Similarly, other commenters stated we had failed to limit the mapped areas in our proposed designation to areas where we believe the PBFs occur.

Our Response: See response to Comment 8.

Comment 78: The North Carolina Water Quality Association (NCWQA) and the South Carolina Water Quality Association (SCWQA) stated that we must include a natural condition provision to reflect natural instream temperature and DO levels that are outside of the temperature and DO critical elements in the proposed rule. They charged that any regulatory requirements must consider the natural condition and not critical temperature/DO elements that are not naturally present. They also suggested that we should have provided more context regarding whether the proposed PBFs for temperature and DO exist in an area most of the time, some of the time, etc.

Our Response: As we discussed in the proposed rule, values of temperature and DO that provide critical habitat functions to sturgeon will vary interdependently, and vary with changes in salinity. Because we are designating known spawning rivers, we are confident the PBFs are present in each unit at a temporal scale necessary to support sturgeon in their reproductive and developmental activities. We agree that the occurrence of the PBFs will fluctuate across, and even within, rivers, and over time, and can be affected by natural and manmade factors. But these fluctuations and the ephemeral nature of the PBFs make it impractical to describe them as static in condition and location. We agree that consideration of the natural conditions and underlying environmental parameters at a given project location will be important in evaluating the impact, if any, of future projects on critical habitat. In this regard, we believe a meaningful evaluation of the natural baseline condition of project area is best done during the site-specific ESA section 7 consultation and not in this final rule.

Comment 79: The NCWQA and SCWQA suggested that we insert information included in the preamble of the GARFO proposed rule to designate critical habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon (81 FR 35701; June 3, 2016) that makes it clear that the "specific oxygen concentration and temperature values are provided as examples and guidance" and that "areas designated as critical habitat based on the 4 features are not expected" to have these oxygen concentrations and temperature values "at all times and within all parts of the area."

Our Response: We believe our regulatory text for the Carolina DPS and South Atlantic DPS makes it clear that the oxygen concentration and temperature values described are examples, and that the presence of PBFs within a river system may vary temporally. Additionally, the preamble to the proposed rule for the Carolina DPS and South Atlantic DPS discussed the variable and ephemeral nature of these environmental features. However, we have added additional text to the preamble of this rule to clarify that the identified values of the PBFs are not required in all parts of designated areas, at all times.

Comment 80: A few commenters noted that environmental conditions (*i.e.,* levels of DO, salinity, and temperature) as well as the location of spawning habitat may be affected by climatic conditions, which could influence the actual location of suitable habitat from week to week or from year to year. Additionally, a few commenters indicated critical habitat should include suspected spawning grounds and nurseries for Atlantic sturgeon. They also believe that because Atlantic, as well as shortnose, sturgeon are excellent colonizers of available habitat, we should more expansively designate spawning habitat. A report cited by these commenters (Kynard, 2016) states that, "Given the typical low subpopulation abundance of the species throughout its range, a poor biological understanding of most subpopulations, a lack of identification of rivers with subpopulations, and increasing threats to successful spawning and rearing in rivers, recovery could likely depend on

many rivers with habitat for all life stages being colonized by non-natal adults." On this basis, Kynard (2016) states that NMFS should include three types of rivers in the critical habitat designation: (1) All rivers with a subpopulation that has freshwater spawning and nursery habitats and estuarine nursery (natal) habitat; (2) all rivers without a current subpopulation but with a documented historical subpopulation, and having freshwater spawning and nursery habitats, and estuarine nursery habitats that can be colonized by non-natal adults; and (3) rivers with no evidence of current or historical populations, but which have freshwater spawning and nursery habitats, as well as estuarine nursery habitats that can be colonized by non-natal adults. Ultimately, the commenters requested we designate critical habitat as widely as possible, and not limit it to just rivers with spawning and rearing habitat, but for all areas "that may serve as these habitats with migration of the salt front, DO, and temperature conditions."

Our Response: As noted in the proposed rule, our conservation objective is to "increase the abundance of each DPS by facilitating increased survival of all life stages . . . by facilitating adult reproduction and juvenile and subadult recruitment into the adult population." Based on the best scientific information available, the biological needs and tolerances of Atlantic sturgeon, and environmental conditions in southeast rivers, we believe we have identified suspected spawning grounds and nursery areas for Atlantic sturgeon; in other words, we do not have reason to suspect Atlantic sturgeon may be spawning and rearing in other rivers. We agree that the conditions and combinations of the PBFs will vary temporally, over short and long timescales. That variation will affect the sturgeon's use of the within-river habitat, including spawning locations, as mentioned by the commenters. Our approach to the designation considered this variation and has included the areas where we anticipate the PBFs occur and will occur. Also, we determined that some areas outside the area occupied by the species are essential to their conservation. We therefore designated unoccupied critical habitats in areas where the spawning portion of the river is limited by dams. We believe we have included rivers in the first two categories Kynard (2016) states should be included in a designation, based on identification of PBFs essential to the species' conservation. We do not believe, however, that inclusion of additional rivers that have no current or historical evidence of supporting spawning is warranted, based on the fidelity of sturgeon to their natal rivers for spawning and because many of the omitted rivers are largely located in the coastal plains and do not provide the range of habitat types known to be used for spawning and juvenile development. Therefore, we are not including additional rivers on the basis of possible future colonization.

Comment 81: Several commenters stated we should designate critical habitat only in areas upriver to a point where flows, eddies, and spawning substrate are available, and we should not designate migratory corridors because they are less critical. One commenter remarked that there is no identified range of water velocity necessary for the conservation of the species, only the need for continuous flow. This commenter asserted that entire stretches of river up to the fall line are not needed to meet the conservation objectives, and that features essential for conservation of the species exist in adequate quantity well downstream of the fall line of some of the rivers.

Our Response: We identified the need to increase the abundance of each DPS by facilitating increased survival of all life stages and facilitating adult reproduction and juvenile and subadult recruitment into the adult population as the conservation objectives for critical habitat. To achieve that objective, we must not only protect upriver spawning sites, but also the in-river habitats that allow adult Atlantic sturgeon to move safely and efficiently to and from those spawning habitats. Additionally, for larval and juvenile Atlantic sturgeon to survive to adulthood and become spawners themselves, habitats downstream from the spawning areas require protection so those life stages can successfully develop. We disagree that we were over-inclusive by setting the unit boundaries to include the fall line (the boundary between an upland region of continental bedrock and an alluvial coastal plain) of the spawning rivers, where applicable, and we realize we were somewhat unclear as to the basis for upstream boundaries on every unit and how that relates to the fall line on each river, so we are clarifying that in this final rule. As we stated in the proposed rule, given the need to maximize the potential for increasing spawning and population sizes, and the fact that Atlantic sturgeon are known to spawn between the salt front and the fall line of large rivers, we endeavored to include the farthest upstream extent of spawning habitat within unit boundaries. The physical characteristics of the fall line provide the conditions that promote successful sturgeon spawning, *e.g.,* well-oxygenated water flowing over hard substrates. Given the severely depressed populations of Atlantic sturgeon, and our conservation objective of facilitating increases in these populations, we believe including all potential spawning areas, up to the fall line as applicable, is appropriate. Finally, we determined that specifying the need for continuous flowing water was more appropriate than attempting to specify water velocities. Water velocity is one specific aspect of flowing water. However, continuous flowing water also influences temperature, oxygen concentrations, turbidity, etc., which are also important features to Atlantic sturgeon. Therefore, given the lack of data on particular velocities that may be needed by Atlantic sturgeon, and the fact that flow regimes vary widely between spawning rivers in the southeast, we believe our focus on continuous flowing water is appropriate.

Comment 82: The North Carolina Department of Transportation (NCDOT) stated that our method for determining areas of critical habitat was flawed because we included areas as critical habitat if any of the PBFs were present, but they believe all PBFs must be present in contiguous segments of rivers for an area to adequately support the life history needs of the species and, thus, be critical to the conservation of the species. They acknowledged there may be specific areas that contain the PBFs essential to conservation of the species, but claim these areas are not specifically identified.

Our Response: All PBFs do not need to be present in a stretch of river for that stretch to be designated as critical habitat. As noted elsewhere, we determined the identified PBFs are essential to the conservation of the DPSs, they may require special management considerations or protection, and they are located on specific areas within the geographical area occupied by the DPSs. There is no requirement that all PBFs occur in a single location or at the same time. Indeed, because our goal was to support all life stages of Atlantic sturgeon, some of our PBFs are mutually exclusive. For example, by definition, the PBF of hard bottom substrate in low salinity (0.0–0.5 ppt) water, can never occur simultaneously with the PBF for transitional salinity zones, inclusive of waters with a gradual downstream gradient of 0.5–up to 30 ppt and soft substrate (*e.g.,* sand, mud) between the

river mouths and spawning sites for juvenile foraging and physiological development. The available scientific evidence on Atlantic sturgeon spawning and spawning behaviors in the designated rivers, and information on habitat characteristics in the ivers, indicates that the PBFs are present in each of the units.

Comment 83: The NCWQA and SCWQA recommended that if we choose to maintain our instantaneous minimum DO levels needed to protect Atlantic sturgeon at 4.3 mg/L, we should revise the temperature trigger for those instantaneous minimum levels from 26 °C to 29 °C. The commenters indicated we justified our selection of 26 °C based on the EPA's 2003 Guidance and two studies cited therein, stating "shortnose sturgeon are more tolerant of higher temperatures than Atlantic sturgeon and the 'high temperature' for Atlantic sturgeon is actually considered 26 °C[.]" The commenters indicated that one of the studies we used to support our decision (Secor and Gunderson, 1998) considered the exposure of YOY Atlantic sturgeon to DO concentrations ranging between 2.8 and 3.3 mg/L over a period of 10 days at 26 °C. The commenters believe that because this "long-term exposure" occurred at DO concentrations far below and less optimal than those required by North and South Carolina regulations, our benchmarks are overly conservative. The commenters believe additional support for their contention that our 26 °C threshold may be too conservative can be found in the EPA's 2003 Guidance, which explains that the difference in temperature sensitivities between the Atlantic and shortnose sturgeons "could be because the shortnose sturgeon were from Savannah River progeny and were held at higher temperatures than the Atlantic sturgeon, which came from Hudson River progeny" (EPA, 2003). The commenters requested that if we choose to maintain an instantaneous DO value (rather than a range of 4.0–4.3 mg/L), we should establish a 29 °C threshold consistent with EPA's 2003 Guidance.

Our Response: We agree with the commenter that Secor and Gunderson (1998) exposed YOY Atlantic sturgeon to DO concentrations ranging between 2.8 and 3.3 mg/L over a period of 10 days at 26 °C. In fact, the experiment actually consisted of two treatments, one in a completely sealed tank and another with access to air at the surface of the tank. Of the 32 YOY exposed to concentrations between 2.8 and 3.3 mg/L over a period of 10 days at 26 °C in the unsealed tanks, only four (12.5 percent) actually survived the entire 10-day trial; 14 (43.8 percent) were dead by Day 4 and 20 (62.5 percent) of the animals were dead by Day 5. Of the 16 YOY exposed to those concentrations in the completely sealed tanks, 15 (93.8 percent) died by the end of Day 1 and all were dead by Day 2. Thus, while the treatments were 10-days, we believe the high mortality rates over the shorter time periods indicate how sensitive small Atlantic sturgeon are to DO. This led to our decision to identify the more conservative value for this endangered species. Similarly, because these mortality rates occurred at the 26 °C temperature threshold, and we have acknowledged that DO and water temperature need to be interdependently assessed, we conclude the PBF as written correctly identifies the environmental conditions necessary to protect this critical life stage.

Comment 84: The NCWQA and SCWQA recommended that if we choose to maintain our instantaneous minimum DO levels needed to protect Atlantic sturgeon at 4.3 mg/L, it should be characterized as an exposure level over a short-term period of several hours, rather than an instantaneous threshold. The commenter indicates the EPA's 2003 Guidance suggests DO levels of greater than 4.3 mg/L for a period of 2 hours at stressful temperatures was found to be protective.

Our Response: First, it must be understood that critical habitat PBFs are essential to the conservation of a species, not just its survival, and a metric that is "protective" in a broad, water quality context may still lead to injury and even mortality of individual organisms, and thus may not be the best metric to foster conservation. We agree that exposure time is a critical consideration. We clarify the information provided in EPA (2003) was based primarily on Campbell and Goodman (2003), who evaluated, among other things, the DO concentrations causing mortality in 50 percent or more of shortnose sturgeon (called "LC_{50}") held under stressful (29 °C) and non-stressful temperatures (22 to 26 °C). Secor and Niklitschek (2001) report shortnose sturgeon are more tolerant of higher temperatures than Atlantic sturgeon. Campbell and Goodman (2003) considered 29 °C a stressful temperature for shortnose sturgeon. Conversely, Secor and Gunderson (1998) report Atlantic sturgeon becoming stressed at a lower temperature of 26 °C. Based on the information provided in Secor and Gunderson (1998), we consider the stressful temperature for Atlantic sturgeon to be 26 °C. The EPA (2003) calculated DO concentrations they believed would be protective of sturgeon exposed to both non-stressful and stressful temperatures based on findings reported in Campbell and Goodman (2003). They estimated a DO concentration of 4.3 mg/L should be protective under stressful temperatures. The EPA (2003) recognized that the LC_{50} DO concentrations reported in Campbell and Goodman (2003) were not instantaneous but occurred within the first 2 to 4 hours of the tests. However, they concluded using their estimated value of 4.3 mg/L as an instantaneous value would be more protective for the species. Additionally, because the EPA estimates produced thresholds that still led to some level of injury or death, we believe more conservative values are appropriate to promote conservation of Atlantic sturgeon.

Comment 85: The NCWQA and SCWQA recommended we change our PBF associated with the instantaneous minimum DO levels needed to protect Atlantic sturgeon in North and South Carolina from 4.3 mg/L to a range of 4.0–4.3 mg/L because it matches the water quality standards in those states. They claimed this recommended range is appropriate because the North and South Carolina water quality standards for DO are a daily average of 5.0 mg/L and instantaneous minimum of 4.0 mg/L, and that the daily average requirement of 5.0 mg/L is more protective than the 30-day average of 5.0 mg/L in the proposed rule. Because there is significantly less potential daily stress to the sturgeon from the daily average DO criterion, the commenters stated that establishing a short-term instantaneous range of 4.0–4.3 mg/L is appropriate and should be fully protective. The commenters indicated this approach would be even more protective if we changed our temperature threshold to 26 °C rather than 29 °C.

Our Response: The values for water temperature and DO, as part of the water quality PBF, are based on the best available scientific information. As discussed in the previous response, we believe that the 4.3 mg/L value for DO is the best interpretation of the presently available scientific information and best supports the conservation of Atlantic sturgeon. DO requirements are dependent on the associated water temperature, the sturgeon's life stage and physiological condition, and the duration of exposure, and the values included in the PBF are examples of appropriate levels and combinations. We recognize that information on all of these combinations is limited, and additional information is likely to refine our understanding of the different

combinations of required values. While we decline to change the DO values presented in the PBF, we are not necessarily saying that DO values in other combinations with temperature, salinity, water flow, exposure duration, and animal age and condition would be unacceptable, depending on the particular circumstances of a proposed project. Additionally, the rule does link the 4.3 mg/L DO value to a temperature threshold of 26 °C rather than 29 °C.

Comment 86: Two commenters stated we failed to consider in a complete and meaningful way, the role certain aspects of aquatic chemistry play on determining whether a river has suitable spawning habitat. The commenters suggested we should have considered pH and levels of calcium (Ca) and magnesium (Mg) ions. They suggested these chemical characteristics can determine whether Atlantic sturgeon will spawn in a particular reach of river, and thus, it is crucial that these features are given special management consideration in future section 7 consultations and, if need be, protected accordingly.

Our Response: See response to Comment 9.

Comments on Special Management Considerations or Protection

Comment 87: An industry trade group believed we failed to provide any assessment of current management or protections in place and whether those are adequate for the conservation of the Atlantic sturgeon. The commenters claimed we must consider whether any of the proposed critical habitat units are presently under special management or protection for Atlantic sturgeon. The commenters acknowledged we have identified a number of initiatives that could protect Atlantic sturgeon, but they believed we must actually assess these initiatives to determine whether they are sufficient and determine what further management actions may benefit from critical habitat designation. The commenters went on to state we should consider each feature and specific area proposed and assess current management measures in place to make an actual determination as to whether special management may be needed in the reasonably foreseeable future, and if so, what that management would be, and how the critical habitat designation would further that management. The commenters concluded that our discussion of special management considerations is limited to general discussion regarding how barriers, water withdrawals, and dredging can generally affect water flow, quality, and depth and/or alter hard substrate, and that we have made non-specific assertions that special management for the essential PBFs may be required "as a result of global climate change."

Our Response: See response to Comment 14.

Comment 88: One commenter requested that we include "clear guidance for considering the effects of a changing climate on critical habitat designation for species recovery in the final rule." The commenter requested we consider "projected changes to salinity, temperature and DO, including changes in sea level rise" and further requested that we document the extent that climate change was considered when assessing the need for the inclusion of currently unoccupied habitat in the final rule.

Our Response: See Response to Comment 17.

Comments on Decision Not To Designate Critical Habitat in Estuarine or Marine Environments

Comment 89: One commenter agreed with our decision not to designate any critical habitat in the marine ecosystem; however, other commenters disagreed. Two commenters indicated we should designate estuarine habitat that not only encompasses natal estuaries, but also certain estuaries that are not natal for a subpopulation, because coastally migrating juveniles use estuaries for foraging, including estuaries with and without spawning subpopulations. They asserted we were waiting for "perfect" information and being overly restrictive, and that the amount of scientific information currently available is enough to determine PBFs in these areas. They also indicated that all estuaries have human activity that requires special management to preserve the estuarine habitat for sturgeon foraging (*i.e.,* management to avoid impacts from dredging, boat strikes, benthic habitat destruction, sediment contamination, cooling water intakes, etc.).

Our Response: We agree with the commenters that estuaries and nearshore marine waters along the Atlantic Coast are important habitat of Atlantic sturgeon; we specifically discussed them in the proposed rule. However, as we described in the proposed rule, we lack sufficient data to identify the specific features in the marine/estuarine environment Atlantic sturgeon are using. We agree that there is scientific information describing environmental correlates with locations of Atlantic sturgeon; however, we do not believe that it is sufficiently informative of the features being used by sturgeon, or the conservation function they serve. More information is provided in the response to comment 20.

Comment 90: Two municipalities commented that our proposed rule suggests erroneously that offshore data are unavailable to determine essential conservation needs. They noted we failed to mention information gathered from the annual offshore striped bass tagging cruises that have tagged numerous adult sturgeon coincident to the fishing grounds of large offshore trawlers, gillnets, and longline fisheries.

Our Response: We are aware of the offshore striped bass tagging cruises. We carefully examined the information available from this study, which included parameters such as location of capture, size of fish, weight of fish, etc. Unfortunately, that information was insufficient to identify PBFs that are essential to the conservation of the species.

Comment 91: One commenter stated that while the "Large Coastal Rivers that Lack Essential Features" section of the proposed rule states: ". . . short coastal plains rivers . . . most likely do not contain suitable habitat for Atlantic sturgeon," these systems may provide foraging habitat for subadult and adult Atlantic sturgeon. The commenter continued by stating that although relatively large numbers of Atlantic sturgeon have been acoustically tagged and their movements recorded in recent years, their numbers are highly depleted relative to historical levels of abundance, and acoustic receiver coverage is relatively sparse. The commenter stated the use of these systems as foraging habitat by subadult and adult fish should not be discounted, once populations are fully restored and population density is higher.

Our Response: We agree that foraging habitat is extremely important. However, as described in the proposed rule, due to the paucity of data on specific habitat or resource utilization, we could not identify any PBFs essential for the conservation of the Carolina and South Atlantic DPSs that support adult and subadult foraging in estuarine or marine environments (see also the response to Comment 20). We did include PBFs related to juvenile foraging and developmental habitat in spawning rivers, downstream of spawning sites, but, as the commenters noted, the non-designated short coastal plain rivers do not support spawning and therefore would not support downstream-migrating, developing juveniles. The limited availability of Atlantic sturgeon tracking data from short coastal plain rivers was not a

factor in our decision not to include those areas in the designation.

Comment 92: Several environmental organizations stated that we incorrectly claimed that we could not designate estuarine or marine areas as critical habitat due to insufficient data and that the best available scientific information supports identification of PBFs in estuarine and marine environments that are essential to Atlantic sturgeon conservation. These commenters said that a growing body of research has identified critical feeding and seasonal aggregation sites, and that the sites identified to date should be designated as critical habitat. The commenters stated there is a scientific consensus that Atlantic sturgeon use marine waters of particular depths as migration corridors; the commenters asserted that available information supports the contention that all 5 DPSs use the same narrow migration corridor and known aggregation sites. The commenters stated that water depth, available prey, substrates, temperature, salinity and seascapes are factors correlated with, and that influence, Atlantic sturgeon use of specific estuarine and marine habitats as feeding or seasonal (winter, summer) aggregations, and migratory corridors, and that these features may require special management considerations or protection. The commenters stated that our regulations, Implementing Changes to the Regulations for Designating Critical Habitat (81 FR 7413, 7414; February 11, 2016), support the use of generally-defined PBFs or an ecosystem approach. Finally, the commenters discussed our previous critical habitat designations for green and Gulf sturgeon as valid models for designating estuarine and marine areas as critical habitat for Atlantic sturgeon.

Our Response: See response to Comment 20.

Comments on Data and Approaches Used in the Proposed Designation, Generally

Comment 93: NCDOT suggested areas of rivers were determined to be critical habitat based on "knowledge" instead of documented data.

Our Response: We considered the best available scientific information, including the 2007 Atlantic sturgeon status review (ASSRT, 2007), the ESA listing rule (77 FR 5914; February 6, 2012), scientific research reports, information and data gathered during the peer-review process, and a database developed by the U.S. Geological Survey that mapped environmental parameters within East Coast rivers to identify sturgeon habitat. We also considered information on the location of sturgeon spawning activity from scientific reports, as active spawning or spawning activity in an area would indicate that the PBF(s) necessary for spawning are likely present. Even in places where information is available, those data may represent a snapshot in time and the exact location of a habitat feature may change over time (*e.g.*, water depth fluctuates seasonally, as well as annually, and even hard substrate may shift position). While the best available information was, at many times, location specific, we worked pursuant to our regulations and identified specific areas at the appropriate scale for critical habitat (*i.e.*, specific rivers), taking into consideration the life history of the species, as described in the preamble of the proposed rule.

Comment 94: An industry trade group indicated we made no attempt to establish any connection between the threats to Atlantic sturgeon described in the listing rule and critical habitat. They suggested we have not evaluated or explained how designation of critical habitat will benefit the species, or help address injury/death resulting from inshore trawling or overfishing. Additionally, they indicated we have not explained how the designation of "these vast areas would provide new or additional minimization of habitat alteration or destruction."

Our Response: See response to Comment 64.

Comment 95: One commenter asked us to explain more clearly in the final rule, why we stopped the upstream extent of some critical habitat units at locks or dams. The commenter acknowledged that in some cases, manmade barriers occur at a natural barrier (impassable falls), and therefore they would not expect the historical species ranges to extend above the location of those barriers. However, the commenter continued by stating the presence of a barrier, in and of itself, should not constitute the upstream extent of critical habitat. The commenter argued that dams could be removed, which would open up those habitats. The commenter requested we reconsider these reaches as essential, but currently unoccupied habitat.

Our Response: Our approach to establishing the upper boundaries of the units was in the first instance to identify and evaluate the upstream extent of available essential spawning habitat features. We evaluated available information on the nature and distribution of likely spawning habitat up to the first impassable barrier, natural or manmade. We also evaluated available information on historical Atlantic sturgeon spawning or occurrence, and current estimated extent of spawning and estimated population status in each river. Thus, the upstream unit boundaries are fact-specific to each river system. We agree that the presence of a barrier does not necessarily correspond with the historical species ranges. However, the barriers denoting the upstream limit of the designation are the same designators as the upstream limit of the occupied areas and barriers that occur at a critical habitat boundary need to provide an easily recognizable landmark for where critical habitat begins or ends. Non-ephemeral reference points (*e.g.*, dams, bridges) can be used in a textual description of the boundaries of critical habitat, thus we believe it is appropriate to use currently impassable dams as the terminus for occupied critical habitat.

Comment 96: An industry trade group indicated we also failed to map potential threats to the Atlantic sturgeon (*e.g.*, manmade structures, dredging areas).

Our Response: See response to Comment 18.

Comments on Designation of Unoccupied Critical Habitat, Generally

Comment 97: Several commenters, including South Carolina Department of Transportation (SCDOT) and South Carolina Department of Natural Resources (SCDNR), asserted that unoccupied critical habitat should not be designated at this time. Some questioned how we could consider these areas critical if animals are not even using them currently. Others suggested it was premature to designate these areas because passage of animals into unoccupied habitats was uncertain or unproven in some areas. Still others suggested we wait to designate these areas as critical habitat until data show Atlantic sturgeon were successfully being passed up to and were using these areas.

Our Response: ESA section 3(5)(A)(ii) defines critical habitat to include specific areas outside the geographical area occupied if the areas are determined to be essential to the conservation of the species. As described in the proposed rule, we determined that there is insufficient spawning and developmental habitat in *occupied* stretches of three river systems: The Cape Fear, Santee-Cooper, and Savannah, and on this basis determined these areas are essential to the species' conservation. However, based on concerns raised about the impacts and uncertainties associated with these unoccupied units, and

questions the commenters raise about the nature of the conservation value these units provide to sturgeon, we determined that conducting a discretionary exclusion analysis on these units was warranted. As a result of that analysis, we have chosen to exercise our discretion under section 4(b)(2) of the ESA and exclude unoccupied units of critical habitat, including the unoccupied Santee-Cooper unit. We determined the benefits of exclusion (that is, avoiding some or all of the impacts that would result from designation) outweigh the benefits of designation.

Comment 98: North Carolina Wildlife Resources Commission (NCWRC) suggested that until we clarify how we will evaluate projects in the unoccupied critical habitat, we should not designate critical habitat in those areas. SCDNR insisted that we remove all unoccupied habitat areas from consideration. However, they requested that if we still intended to designate unoccupied habitat areas, we should clarify how unoccupied versus occupied critical habitat designations will be handled in regards to section 7 consultations for projects.

Our Response: As stated previously, we have chosen to exercise our discretion under section 4(b)(2) of the ESA and exclude the unoccupied units of critical habitat. Therefore, section 7 consultations will not be required based on impacts solely to these unoccupied areas. Section 7 consultation will still be required to assess potential impacts to shortnose sturgeon and its habitats in the area proposed as the unoccupied Santee-Cooper unit, and consultation will be required if effects of actions in the areas previously proposed as unoccupied have effects to sturgeon or their habitats downstream, in occupied areas.

Comments on Designating Specific River Units or River Areas

Carolina Unit Rivers

Comment 99: NCDOT indicated they do not believe that "sparse spawning data justifies an extensive proposed area of critical habitat." They indicated that literature searches they conducted found that spawning in specific areas in the Southeast is rare. The commenter also stated that the proposed rule says, "[t]here are large areas of most rivers where data is still lacking" and "substrate types can change from year to year." Further, the commenter stated in relation to extending "historical habitat" into the "critical area," they should not be required to comply with moratoria and limited construction times, based on habitat that may be critical at some future point in time.

Our Response: We agree that site-specific information describing spawning location in the Southeast is relatively rare. We could not compare our information to that referenced by the commenter as they did not provide their search results. We are designating critical habitat by describing PBFs essential to the conservation of the species. The areas we are including in the final rule have one or more of the PBFs present that are essential to the conservation of the species and which may require special management considerations or protection. Additionally, our regulations at 50 CFR 424.02 support the designation of areas that contain PBFs that may be ephemeral or dynamic. We believe the proposed rule clearly outlines our step-wise approach for how we identified each PBF and the rivers in which they are located. Regarding moratoria or construction restrictions, we reiterate that the critical habitat designation does not create any moratoria, refuges, or closed areas.

Comment 100: One commenter suggested we had not used the best scientific information available, and they believed that the positions taken by SCDNR in their public comments support their conclusion. Specifically, the commenter stated: "[t]he proposed rule was apparently developed with little or no input from [SCDNR] and the scientific data it has collected. SCDNR finds the critical habitat designations to be presumptuous and impertinent. In fact, SCDNR insists that all currently labeled unoccupied habitat be removed."

Our Response: We disagree that we have not used the best scientific information available in this designation. We believe the commenter mischaracterized SCDNR's statements. The SCDNR suggested critical habitat designations were "presumptuous" and "impertinent" until further genetic analyses verify the DPS classification of Atlantic sturgeon. SCDNR commented that "the Carolina DPS is based upon a limited sample of individuals with no representation from the Great Pee Dee, Santee and Cooper Rivers in South Carolina. The samples used to genetically characterize the Carolina DPS were obtained from Albemarle Sound, an area where sturgeon from multiple river basins are known to occur. The limited data input used to define the boundaries of the Carolina DPS causes concern and warrants further genetic sampling to truly define the Carolina DPS. SCDNR finds the critical habitat designations presumptuous and impertinent and advocates that these designations be deferred until further genetic analyses occur to verify the DPS classification of Atlantic sturgeon . . ." The SCDNR is essentially commenting on the determination of DPS identities and boundaries in the 2012 final rule listing the Carolina DPS. A critical habitat designation is not the vehicle to revisit a species listing determination, and so long as a species has been listed, we have a statutory duty to designate critical habitat for the species. Moreover, we believe the DPS listing determinations continue to represent the best scientific information available on the identity and boundaries of the DPSs.

The commenter seems to believe that because our determinations differ from SCDNR's on certain aspects of the designation, for example the use of shortnose sturgeon as a proxy for Atlantic sturgeon or how to interpret the lack of data regarding Atlantic sturgeon presence in certain stretches of a river, our rule did not use the best scientific information available. Our determinations were based on the 2007 Atlantic sturgeon status review (ASSRT, 2007), the ESA listing rules (77 FR 5914; February 6, 2012), scientific research reports, information and data gathered during the peer-review process, a database developed by the U.S. Geological Survey for mapping environmental parameters within East Coast rivers to identify sturgeon habitat, as well as information on the location of sturgeon spawning activity from scientific reports. We also reviewed reports from a NMFS-funded multi-year, multi-state grant on movement and migration of Atlantic sturgeon that included information collected by the SCDNR. Finally, the SCDNR provided a peer-reviewer to evaluate the biological information that went into the proposed rule. The reviewer provided critiques which were incorporated into the proposed rule. Thus, while the SCDNR may disagree with our approach in certain cases (*e.g.*, critical habitat should not be designated without confirmed sturgeon presence), we disagree with the assertion that we did not use the best scientific information available when developing the rule.

Comment 101: Multiple commenters said they believe the inclusion of extensive river reaches, including "unoccupied" areas and reservoirs, for the Carolina DPS of Atlantic sturgeon would result in a poor allocation of conservation resources. They suggested we focus on estuarine environments, spawning aggregations, and fisheries bycatch because it would result in

greater benefits for the conservation of the species.

Our Response: The ESA requires that we designate critical habitat for listed species. As described in the proposed rule, we know Atlantic sturgeon use estuaries for foraging, growth, and movement. We also know subadults and non-spawning adults use estuaries seasonally, likely for foraging. However, the lack of data on specific habitat or resource use by Atlantic sturgeon in the estuaries meant we could not identify any specific PBFs essential for the conservation of the species in these areas. Also, we believe we are protecting the habitat of spawning aggregations with these designations. Because Atlantic sturgeon spawn far upstream on hard bottom substrates in low salinity waters (PBF #1), designating critical habitat protects these habitats. Impacts from fisheries bycatch are direct impacts on the species, not habitat-related effects, and are beyond the scope of critical habitat designation.

As stated previously, we have chosen to exercise our discretion under section 4(b)(2) of the ESA and exclude unoccupied units of critical habitat, including the reservoirs of Lake Moultrie and Lake Marion.

Comment 102: One commenter stated they supported our designation of occupied and unoccupied critical habitat. However, they requested we consider regional datasets and literature sources not cited in the proposed rule that they believe support the inclusion of the Ashepoo River, South Carolina, up to the confluence of Doctors Creek (Route 64 Bridge).

Our Response: We appreciate the commenter bringing these datasets to our attention. We considered designation of the Ashepoo River, South Carolina, as critical habitat. As stated in the proposed rule, our review of the best scientific information available for the Ashepoo (Post *et al.,* 2014) determined it is a short, coastal plain river that most likely does not contain the PBFs suitable to support spawning and juvenile recruitment of Atlantic sturgeon. Although the commenter did not identify which element we failed to fully consider, we evaluated the regional datasets and literature sources suggested by the commenter. Those data sources may show species occurrence in the Ashepoo, but not necessarily sturgeon spawning. We do not disagree that Atlantic sturgeon could use the Ashepoo River; rather we do not believe it contains the necessary PBFs that support our conservation objective for designating critical habitat.

Comment 103: Two municipalities asserted we failed to consider the best available information in the overall analysis because data was only as recent as 2006, and proceeding with critical habitat designations in unconfirmed areas without the benefit of updated and better data is inappropriate. They note that North Carolina has had a gillnet Incidental Take Permit (ITP) for Atlantic sturgeon since around 2012-2013. The commenters stated the Neuse River in North Carolina, described as Area C in the ITP, is allowed very few Atlantic sturgeon interactions prior to closure of the gillnet fishery because of how rare they are in this river system. The commenters state additional information indicated (1) sturgeon abundance, particularly for the Carolina DPS, is far greater than originally believed in areas that have actual, documented spawning aggregations; (2) discard mortality of juveniles taken in traditional fishing gear is very low; and (3) estuarine interactions with adult sturgeon are exceedingly rare as they are not retained in traditional gillnet fishing gear. The commenters concluded that extensive data associated with the ITP were not mentioned in the proposed rule but confirmed there is low Atlantic sturgeon abundance in the Neuse River. Additionally, the commenters concluded that changes in fishing behavior and seasonality have dramatically reduced the potential for bycatch in North Carolina, but this information is also not considered in the proposed rule.

Our Response: When designating critical habitat we are to identify PBFs that are essential to conservation of the species that may require special management considerations or protections, and then identify specific areas in which those PBFs are located. It is unclear how the information the commenter suggests we overlooked (*e.g.,* data on sturgeon abundance, fishing behavior, discard mortality, incidental takes) is in any way informative regarding our PBFs or the areas we are designating as critical habitat. As we have noted, critical habitat designations in occupied areas are based on the presence of PBFs that are essential to a species' conservation, and which may require special management considerations or protections. Specific areas containing these PBFs are then identified, and the impacts of including the specific areas in the designation are considered. Whether sturgeon abundance or interactions with fisheries have changed over time would not affect how we made our critical habitat designations.

Comment 104: Two municipalities stated we provided no evidence of spawning or the presence of Atlantic sturgeon YOY in the Neuse River, North Carolina. They suggested the size of the juveniles collected to date prove nothing in terms of spawning origin as those fish could, and likely did, migrate from other rivers where spawning adult sturgeon have been observed and captured (*e.g.,* Roanoke River, North Carolina). Further, the commenters stated we provided no direct evidence that the Neuse River was used by the Carolina DPS of Atlantic sturgeon when we listed the DPS in 2012, and they suggested there has been no evidence of Atlantic sturgeon in freshwater portions of the river for decades.

Our Response: Following receipt of this comment we had extensive contact with the USFWS staff, as well as with state natural resource managers. They suggested there was additional evidence of YOY occurring in the Neuse River. Specimens available from North Carolina State University indicated three YOY (less than 350 mm) were captured in the Neuse River in 1974 (J. Hightower, NCSU, to A. Herndon, NMFS, pers. comm. March 2017). An additional record of a YOY captured in the Neuse River in 1974, was also provided by the North Carolina Museum of Natural Sciences (G. Hogue, NCMNS, to A. Herndon, NMFS, pers. comm. March 2017). Also, Bain (1997) reports that "early juveniles" (20–440 mm FL) remain in their natal rivers until they become "intermediate juveniles" (450–630 mm FL) and begin gradually emigrating from the river during periods of rapid growth. Hoff (1980) reports sturgeon studies in the Neuse and Pamlico Rivers and Pamlico Sound captured low numbers of small (400–600 mm TL) sturgeon. The North Carolina Division of Marine Fisheries (NCDMF) also provided information collected via observers and during their Independent Gill Net Survey. From 2001–2012, those sources reported 13 Atlantic sturgeon captured in the Neuse that were less than 440 mm FL size range (M. Loeffler, NCDMF, to A. Herndon, NMFS, pers. comm. March 2017). Based on the information in Bain (1997), we believe these animals are unlikely to have strayed into the Neuse River from other river systems, leading us to conclude they were likely born there. Additionally, the final listing rule (77 FR 5914; February 6, 2012) indicates the Neuse River was used by the Carolina DPS at the time of listing and that spawning may be occurring in the river. Moreover, "occupied at the time of listing" in the statute refers to the geographical range, which we have defined to include all marine and freshwaters available to be used by

Atlantic sturgeon, for any life function. Finally, regardless of whether animals have been documented in the freshwater portions of the river, our critical habitat determinations are based on areas where PBF(s) essential to conservation of the species occur; it is not specifically tied to animal presence. Therefore, we believe including the Neuse River in the designation of critical habitat is appropriate.

Comment 105: Two municipalities objected to the designation of proposed critical habitat upstream of rkm 75 on the Neuse River, North Carolina. The commenters stated "the most westward location of a sturgeon [on the Neuse River, North Carolina] was at rkm 75" and, in their opinion, Atlantic sturgeon do not use areas upstream of rkm 75 and critical habitat designation would impose an unnecessary administrative burden on municipalities at or above rkm 75.

Our Response: We considered the information presented by the commenters, and we believe our upstream boundary is appropriate. We have identified critical habitat based on areas where PBF(s) essential to conservation of the species are located, not necessarily where individual animals have been documented. Moreover, our data include an observed Atlantic sturgeon around rkm 80 on the Neuse River and likely suitable spawning substrate at the base of the Milburnie Dam. Additionally, the commenter provided no information suggesting the PBFs are absent above rkm 75. For these reasons, we believe our upstream boundary for the Neuse River is correct.

Comment 106: Two municipalities questioned our decision to consider the Neuse River, North Carolina, as spawning habitat for Atlantic sturgeon. They suggested that substantial water quality concerns call into question the notion that the Neuse River could support the spawning of Atlantic sturgeon. They cited our statement that "hard bottom in fresh water on spawning grounds and sufficient DO are critical needs for spawning success." The commenters stated that without any evidence of spawning activity in the Neuse, it is unknown whether the hard bottom criteria are met. They concluded the required physical spawning conditions have not been shown to exist in the Neuse River because no spawning locations have been identified and the water quality conditions are unlikely to favor the survival of larvae and early juveniles. However, they acknowledged that the upper reaches of the Neuse River at the Milburnie Dam do have areas of suitable substrate, but stated that it is far from the salt wedge around New Bern and any measureable salinity for many river miles under normal conditions. On this point, they concluded that any supposition about the availability of suitable substrate with no knowledge of actual spawning location is erroneous. The commenters stated that flow regimes, critical for spawning success, are significantly manipulated in the Neuse River. They acknowledged that while flow regimes of Milburnie Dam have been increased on occasion to simulate natural conditions on the Neuse River, these flow regimes are not permanently established and could change. They suggested unnatural, manipulated flows are unlikely to change in a measureable way in the future, and thus, establishing the Neuse River as critical habitat for Atlantic sturgeon is not supported by the data. The commenters also suggested the proposed rule does not identify how we determined the water of appropriate depth and absent physical barriers to passage between the mouth and spawning sites and water quality conditions that support spawning and recruitment for larval, juvenile and subadult growth PBFs occur in the Neuse. Finally, they stated that to spawn in the Neuse River, the Atlantic sturgeon must pass through the heavily impaired waters of the lower Neuse River and the Neuse Estuary. They also suggested that the newly hatched sturgeon fry must pass through the same waters on their journey to reach estuarine waters immediately after being hatched. They believed both the Neuse and Pamlico portions of the estuary have been subject to seasonal episodes of anoxia that significantly affect the quality of Atlantic sturgeon nursery habitat.

Our Response: We disagree. As noted in the proposed rule and explained in our response to Comment 104, we believe there is evidence that Atlantic sturgeon spawning has occurred in the Neuse River. The commenter supported our determination that the PBF of substrate to support spawning does exist in the Neuse at the Milburnie Dam. The commenters' confirmation that hard bottom substrate in low salinity waters far from the salt wedge exists in the Neuse River validates our determination that PBF # 2 (transitional salinity zones inclusive of waters with a gradual downstream gradient of 0.5-up to 30 ppt and soft substrate) is present. The commenter also expressed concern over the water quality of the Neuse River and estuary, calling into question its suitability as spawning habitat. However, the information provided by the commenters regarding water quality is not specific to DO or temperature; it discusses nitrogen and phosphorus. The information provided gives no indication of how these nutrients may be affecting DO or temperature in the river, or how these nutrients prevent the PBFs from occurring or becoming established in the future. Similarly, the commenters expressed concerns about water flows on the Neuse River, but did not provide any information regarding how past and future flow manipulations of the Neuse River would affect the PBFs. With respect to our approach to determining that the PBFs occur in the Neuse River, we acknowledged in the proposed rule that there are large areas of most rivers where data are still lacking. The available data also may represent a snapshot in time, and the exact location of a habitat feature may change over time (*e.g.*, water depth fluctuates seasonally and annually, and even hard substrate may shift position). As we described, although habitat features may vary even at the same location, if any of the available data regarding a particular feature fell within the suitable range (*e.g.*, salinity of 0–0.5 ppt or hard substrate [gravel, cobble, etc.]), we considered that the essential PBF is present in the area. When data were not available for certain rivers or portions of occupied rivers, we used our general knowledge of Atlantic sturgeon spawning and applied river-specific information to determine the location of PBFs essential to spawning. For these reasons, we believe designation of the Neuse River as critical habitat is appropriate and supported by the available data.

Comment 107: NCDOT said there are no confirmed data to support designating the Cape Fear River, North Carolina, above Lock and Dam # 1, if there is sufficient spawning habitat below this point. If the habitat is not accessible at the time of listing it is not critical to the survival of the species.

Our Response: The proposed rule describes the information we used to designate occupied areas on the Cape Fear River Lock and Dam #1 includes a newly constructed fish passage feature, and there have been reports of Atlantic sturgeon above the lock and dam. We therefore included the area between Lock and Dam #1 and Lock and Dam #2 as occupied habitat in our proposed designation (Carolina Unit 4). We had proposed to designate the area between Lock and Dam #2 and Lock and Dam #3 as unoccupied critical habitat because we believed it may provide additional spawning habitat that was essential to the conservation of the species. However, further conversations with

USFWS and state resource managers made us uncertain about the conservation value for this specific stretch of the Cape Fear River between Lock and Dam #2 and Lock and Dam #3. Therefore, while we continue to believe that this habitat is important to Atlantic sturgeon, we do not believe the area between Lock and Dam #2 and Lock and Dam #3 is essential to the conservation of the species based on our current understanding of what habitat is likely there. Additional information would be necessary resolve the uncertainty surrounding what portion, if any, of the Cape Fear River above Lock and Dam #2 is essential for the conservation of the species. Therefore, we are not designating unoccupied critical habitat on the Cape Fear River at this time.

Comment 108: The USFWS recommended changing the upstream terminus of Carolina Unoccupied Unit 1—Cape Fear River, North Carolina, by extending the boundary to Duke Energy's Buckhorn Dam, North Carolina, rather than ending at Huske Lock and Dam (Lock and Dam #3) as proposed. The commenter referenced the recent notice by the National Fish and Wildlife Foundation (NFWF) (reference NFWF Agreement #5406) to Bladen County, North Carolina. The notice indicates Bladen County has been awarded funds through the NFWF-Duke Energy Settlement for the Lock and Dams #2 and #3 Project. The project would conduct an extensive alternative analysis and advanced hydraulic modeling, design a weir wall, support continued tagging/telemetry work by the North Carolina Division of Marine Fisheries, conduct anadromous fish egg sampling at all three Locks and Dams, and support a USACE Rivers and Harbors Act section 408 review and coordination. Based on this, the commenter believed upstream passage is reasonably foreseeable. The commenter believed this reach of the Cape Fear River would, when re-opened, provide suitable spawning and migratory habitats needed to facilitate sturgeon reproduction and recruitment. Thus, they believed it is appropriate to extend this unoccupied unit upstream to the next currently impassable barrier.

Our Response: We appreciate the commenter bringing this development to our attention. We were not aware that passage above Lock and Dam #3 may occur in the reasonably foreseeable future. Following receipt of this comment we had extensive contact with USFWS staff, as well as with state natural resource managers. They reiterated input we received during the development of the rule from a state sturgeon expert who stated the type of river bottom and currents most suitable for Atlantic sturgeon spawning would be found above Lock and Dam #3. They also provided information from historical fishing records that report Atlantic sturgeon had been captured far upstream from Lock and Dam #3. We believe the most likely explanation for why Atlantic sturgeon were captured that far upstream historically is because they were attempting to spawn. The indication that suitable spawning habitat exists above Lock and Dam #3, and the historical evidence suggesting Atlantic sturgeon moved that far upstream, suggests to us that spawning likely occurred there in the past and may again in the future, once the animals have access to the area. This information suggests to us that this stretch of the Cape Fear River may be of high conservation value. However, moving the upstream boundary to Buckhorn Dam would be an increase of 115 rkms. We believe this is a significant change that the public was not aware of and on which it did not have an opportunity to provide comment. Therefore, we are not making the change recommended by the commenter at this time.

Comment 109: One commenter questioned our conclusion regarding Atlantic sturgeon spawning migration in the Cape Fear River, North Carolina, specifically our statement that fish passage present at the dam is successful or that fish pass through the lock at Lock and Dam #1. The commenter indicated that unless the policy has changed very recently, locking for fish passage is not conducted at Lock and Dam #1 and tracking of sonic-tagged Atlantic sturgeon has not shown any upstream movement past Lock and Dam #1. The commenter continued, stating upstream passage at the rock arch ramp at Lock and Dam #1 has been good for American shad but poor for striped bass and while neither species is a perfect proxy for Atlantic sturgeon, the results are mixed regarding effectiveness of this rock arch ramp. The commenter added that intensive gillnet sampling did not detect any Atlantic sturgeon above Lock and Dam #1 in 1996–1997 (Moser *et al.*, 1998). The commenter stated the most likely conclusion is that the locks and dams have long hindered or prevented upstream passage of Atlantic sturgeon in the Cape Fear River (and may have increased the importance of the unobstructed Northeast Cape Fear River).

Our Response: We agree that the locks and dams typically provide limited opportunities for passage of Atlantic sturgeon. However, the best scientific information available indicates that sturgeon are passing above Lock and Dam #1 on the Cape Fear River, even as recently as September 2016, and that would have been either through the lock, or over the rock ramp. Additionally, modifications to the rock ramp at Lock and Dam #1 will be completed by 2019, which is anticipated to increase the efficiency of sturgeon passage above the Lock and Dam #1. Thus, we believe our statement about successful passage is correct.

Comment 110: Two utility companies suggested the best scientific data available do not support designation of the area in the vicinity of the Blewett Falls Dam tailrace on the Pee Dee River because this area has previously been disturbed as a result of necessary hydropower operations and maintenance. As a result, this area does not contain the prescribed PBFs for the key habitat-based conservation objectives for spawning and juvenile development habitat. These commenters stated the biological opinion issued for FERC's issuance of the Yadkin-Pee Dee (YPD) hydropower license requires a spawning and incubation habitat characterization assessment for an 88-mile-long reach of the Pee Dee River, downstream from Blewett Falls Dam. The assessment seeks to determine the amount of suitable sturgeon spawning and incubation habitat created as a result of the spring minimum flow requirements and the actual flows provided by YPD under the new license. The commenters believe the assessment should provide scientific data that can be used to pinpoint areas for designation as critical habitat. Until the initial 10-year phase of this assessment is completed, the commenters requested we refrain from designating the area downstream of Blewett Falls Dam within the YPD project area boundary as critical habitat.

Our Response: The commenters suggest we omit areas within the YPD project boundary from critical habitat, but it is not clear what the YPD project boundary is. We believe that the scale and boundaries of the specific areas that we are including in the critical habitat designation are appropriate. For the Pee Dee River unit, aerial imagery suggests spawning habitat does exist immediately downstream from Blewett Falls Dam. Further, we are required to define each critical habitat unit using easily recognized reference points. We agree that the spawning and incubation habitat characterization assessment is likely to provide additional scientific data that will be useful in determining more precisely the location, timing, etc., of the PBFs, though the studies will only be another snapshot in time and

will not account for temporal variability in location of PBFs. Further, when designating critical habitat, our regulations state that we shall designate, at a scale that we determine to be appropriate, the areas that contain the PBFs essential for the conservation of the species. The areas do not need to be limited to only the precise locations where the PBFs have been specifically determined to exist. We believe that we have appropriately used the best scientific information available at this time and have selected an appropriate scale for these designations. The ESA does not allow us to identify areas containing the PBFs and then decline to designate them until better data become available. In identifying and designating the areas containing the PBFs that are essential to the conservation of the Atlantic sturgeon, we are meeting our statutory and regulatory requirements. For these reasons, we have included as critical habitat on the Pee Dee River the area up to the Blewett Falls Dam.

Comment 111: Two utility companies also suggested that the areas around the intakes for two "steam-electric plants" located on the Neuse River, North Carolina, within "Carolina Unit 3 Neuse Unit" and one "steam-electric plant" located on the Cape Fear River, North Carolina, within "Carolina Unit 4 (Cape Fear Unit)," are previously disturbed areas that require dredging in order to maintain the operation of the steam-electric plants, and these areas do not include "ideal habitat" for the Carolina DPS of Atlantic sturgeon; in another part of their letter the commenters stated that the intake areas do not provide spawning habitat. The commenters asserted that the areas around the intakes at the steam-electric plants on the Neuse and Cape Fear Rivers should be excluded from critical habitat in order to minimize the potential burden they expect will result from additional and unnecessary regulatory reviews.

Our Response: We disagree that foregoing designation would alleviate additional cost, complexity, and administrative burden of carrying out activities at these plants. As noted previously, we anticipate that designation of critical habitat will impose only minimal administrative burdens and costs that will be added to ESA consultations that would be required to address impacts to the species even in the absence of critical habitat. The commenters requested that we omit discrete areas around the intakes for three plants on the Cape Fear and Neuse River, but they were not specific regarding the location or sizes of the areas that should be excluded. The commenters also were not specific about their statement that the areas are not ideal habitat for Atlantic sturgeon, other than to say the areas do not provide spawning habitat. However, the commenters did not state that all of the other PBFs are absent from these areas. The commenters suggested that dredging would make the areas less than ideal habitat for sturgeon. But based on our experience with the effects of dredging on aquatic habitat, we do not believe dredging would permanently remove the PBFs such that the areas would not provide conservation value to sturgeon in the periods between dredging events. We believe that we have appropriately used the best scientific information available at this time and have selected an appropriate scale for these designations.

Comment 112: SCDNR said that while telemetry data were not available above Pine Tree Landing on the Black River, South Carolina (Carolina Unit 6), they believed the river is extremely braided in this area and likely provides limited ideal habitat for Atlantic sturgeon. They recommended the upstream limit of designated critical habitat in the Black River should stop at June Burn Road, South Carolina.

Our Response: The comment was unclear as to whether telemetry data were not available because no receivers capable of detecting acoustically tagged sturgeon had been deployed above Pine Tree Landing or if receivers were there, but they just had not ever detected a sturgeon. A review of Post *et al.* (2014) confirms the former. Regardless, we reviewed the geospatial information available around June Burn Road, South Carolina, and agree that the main stem of the Black River becomes increasingly difficult to identify in this area. We were able to consistently identify the main stem of the river up to approximately Interstate 95, upstream of which the main stem is no longer discernable. As a result we have modified the upstream boundary of the Black River (Carolina Unit 6) to be the Interstate 95 Bridge, approximately eight miles southwest of Turbeville, South Carolina. This results in a decrease of 50 rkm for this unit. Aerial imagery does not indicate that any hard bottom substrate is being excluded from the unit by changing this upstream boundary, thus the unit will still provide sturgeon access to the maximum upstream extent of spawning habitat, and the change will not affect the conservation value of the unit in facilitating increased survival of all life stages and facilitating adult reproduction and juvenile and subadult recruitment into the adult population. We are not projecting a decrease in impacts in this unit associated with the decrease in length, given the actions predicted to occur here and require consultation are not location-specific and could still occur within the modified unit boundaries.

Comment 113: Two utility companies suggested we had not used the best available information when we determined there is a spawning run or spawning patterns of movement for the Carolina DPS of Atlantic sturgeon in the Santee River below Wilson Dam (or anywhere in the Santee) in South Carolina. They said there is no evidence of spawning in the Santee River, and very little evidence of YOY Atlantic sturgeon using the river, and those specimens that have been captured were thought to be pushed in from Winyah Bay, South Carolina, via the Intracoastal Waterway. The commenters acknowledged the Santee River downstream of Wilson Dam may be used for feeding and refuge, but they reported Post *et al.* (2014) do not support the conclusion that the Santee River supports a spawning run or a pattern of movement for Atlantic sturgeon, and thus does not support the inclusion of the Santee River as critical habitat. SCDNR questioned our assumption that an Atlantic sturgeon captured at the St. Stephen Fish Lift on the Santee River, South Carolina (Carolina Unit 7), had presumably been making a spawning run. They indicated the direction of travel of this individual animal is unknown. SCDNR said that the exit channel of the fish lift is monitored via three video cameras, two of which are underwater and one that captures images through a viewing window of the exit channel in the lift. They concluded that a review of the video footage could not determine whether the sturgeon entered the lift downstream of the dam or if the sturgeon entered the fish lift via the exit channel in Lake Moultrie.

Our Response: We disagree. Sturgeon movement upstream in the Santee River has clearly been restricted due to the Santee-Cooper Navigation and Hydro-Electric Project, and the operational impacts of the St. Stephen hydropower dam have restricted sturgeon access to or ability to use the Santee River below Wilson Dam. But there is evidence of spawning migration as far as fish can move until they are deterred by impacts of the projects. Further, we do not find the unknown direction of travel of the Atlantic sturgeon captured in the St. Stephen fish lift to undermine our assessment that the fish was moving between the upstream freshwater and the downstream estuarine waters.

Whether the animal was trying to get above the St. Stephen Dam or had been above the dam and was moving downstream, either direction suggests spawning movement.

Prior to the construction of the Santee-Cooper Project, the Santee River system supported a significant spawning population of Atlantic sturgeon. As described in the final listing rule (77 FR 5880; February 6, 2012), based on Secor (2002), the Santee-Cooper system had some of the highest historical landings of Atlantic sturgeon in the Southeast. From 1970–1995, 151 subadult Atlantic sturgeon, including age-1 juveniles, were collected from the Santee River (Collins and Smith, 1997). In 2004, 15 subadult Atlantic sturgeon were captured in surveys targeting shortnose sturgeon in the Santee River estuary with a juvenile Atlantic YOY captured the year prior in the Santee River (77 FR 5880; February 6, 2012). These data, considered the best scientific information available, provide evidence of an existing spawning population in the Santee River. The best scientific information available also indicates the PBFs essential to the conservation and recovery of the species occur in the Santee River, including potential spawning habitat in the reach of the river below Wilson Dam. Fish passage that is a requirement of the new hydropower license to the South Carolina Public Service Authority (SCPSA) will provide access to historical spawning grounds once passage is implemented. Thus, an occupied critical habitat designation is appropriate to protect the PBFs existing below the dams.

Comment 114: Two utility companies suggested the designation of the entirety of the 165,000 acres of lakes within the Santee-Cooper system, South Carolina (Lake Moultrie and Lake Marion, along with the 5-mile-long Diversion Canal that joins the reservoirs), is excessive and unnecessary, and this entire area is unlikely to be used by Atlantic sturgeon. They suggested limiting any critical habitat designation in the reservoirs, once occupied, to a corridor for passage, rather than including 165,000 acres of inferior habitat as "critical habitat," would alleviate many of the burdens on these commenters. The commenters also said we had relied on the collection of a single juvenile in the reservoirs to "verify" that Lake Moultrie and Lake Marion in South Carolina can support successful recruitment of juvenile shortnose sturgeon.

Our Response: We acknowledge, as the commenter suggests, that portions of these areas may not be used at all times, and possibly not at all. However, the collection of three Atlantic sturgeon carcasses from Lake Moultrie during the 1990s confirms that Atlantic sturgeon use the lakes at least for migration (77 FR 5880; February 6, 2012). More recently, an Atlantic sturgeon was documented in Lake Marion in December 2016; it passed from the Cooper River into Lake Marion via the Pinopolis Dam Lock then presumably made its way into Lake Marion via Lake Moultrie and the Diversion Canal (SCDNR pers com., 2017). Additionally, we believe the persistence of a dam-locked population of shortnose sturgeon, a congeneric, in these reservoirs (Collins *et al.*, 2003), indicates appropriate habitat for Atlantic sturgeon is present. However, as stated previously, we have chosen to exercise our discretion under section 4(b)(2) of the ESA and exclude the unoccupied units of critical habitat including Lake Moultrie and Lake Marion.

Comment 115: Two utility companies stated that we should consider whether designating Lake Moultrie and Lake Marion in South Carolina as "unoccupied" critical habitat would preclude any options for fish passage and protection at the Santee-Cooper Project.

Our Response: As part of the re-licensing process for the Santee-Cooper Project, we prescribed fish passage at both the Wilson and Pinopolis Dams. The Federal Power Act (FPA) requires FERC to make fish passage prescriptions mandatory conditions of licenses. We are currently in section 7 consultation with FERC regarding the re-licensing of the Santee-Cooper Project, and that consultation must treat the fish passage prescription as part of the proposed action. Thus, nothing about this rulemaking will affect the fish passage prescription. Regardless, as we stated previously, we have chosen to exercise our discretion under section 4(b)(2) of the ESA and exclude the unoccupied units of critical habitat including Lake Moultrie and Lake Marion.

Comment 116: Several commenters questioned our conclusion that there is "a good deal of data" on sturgeon spawning in the Broad, Congaree, and Wateree Rivers in South Carolina. Other commenters, including SCDNR, questioned our decision to use shortnose sturgeon behavior or likely habitat preferences as a proxy for Atlantic sturgeon when designating critical habitat. We also received comments from SCDNR indicating the only documented shortnose sturgeon spawning was in the Congaree River and none has been documented in the Wateree or Broad Rivers. The commenters stated the evidence we used to support designating unoccupied habitat above the Wilson and Pinopolis Dams in South Carolina as suitable spawning habitat and juvenile habitat for Atlantic sturgeon was based on extremely limited evidence and conjecture. Specifically, they felt we overemphasized the value of the Wateree River as spawning habitat, and inappropriately used information related to shortnose sturgeon spawning in the Congaree River, South Carolina, to assume that the conditions in the Wateree River support spawning of Atlantic sturgeon.

Our Response: We used the best scientific information available (*e.g.*, Collins *et al.*, 2003; Cooke and Leach, 2003; Leach and Cooke, 2006; Shortnose Sturgeon Status Review Team, 2010; conversations with South Carolina state biologists) on habitat preferences and spawning behaviors of shortnose sturgeon to inform our conclusions regarding available spawning habitat and activity in the Broad, Congaree, and Wateree Rivers in South Carolina. We did not mean to suggest there is a good deal of information on spawning per se, but we included spawning type activity and behavior in our assessment. Additionally, because the likely spawning habitats for shortnose sturgeon (Dadswell, 1979; Squires *et al.*, 1993; Kieffer and Kynard, 2011) and Atlantic sturgeon are the same or highly similar (Gilbert, 1989; Smith and Clugston, 1997), we believe it is appropriate to use information available from the shortnose sturgeon to identify Atlantic sturgeon habitat. We acknowledge there is limited information on actual spawning by Atlantic and shortnose sturgeon in the Broad, Congaree, and Wateree Rivers. We also acknowledge the exact location of spawning sites on many rivers in the Southeast is not known and even when known generally, may change from time to time as water depth and substrate availability changes. However, aerial imagery confirms the presence of hard bottom habitat in the Wateree River, and in our biological opinion for the relicensing of the Catawba-Wateree project (NMFS, 2013), we concluded that given the fish passage requirements at the Santee-Cooper project, Atlantic and shortnose sturgeon presence in the Wateree River below the Wateree Dam is reasonably certain to occur. Suitable spawning habitat has been documented in several locations below the Wateree Dam. The flow releases required under the new license were specifically based, in part, on providing more extensive and better quality spawning habitat for

sturgeon. Duke Energy is required to quantify and map spawning habitat available to sturgeon below the Wateree Dam, with implementation of the new flows, as a term and condition of the biological opinion.

Additionally, in March 2011, SCDNR captured 19 adult shortnose sturgeon in the tailrace of the Pinopolis Dam and tagged 18 with acoustic telemetry tags and released them; the other fish had been tagged previously. Two of the tagged shortnose sturgeon moved through Pinopolis Lock, through Lakes Marion and Moultrie, and both fish entered the Wateree River. One shortnose sturgeon was recorded on the receiver at the Wateree Tailrace (approximately ¼ mile [0.4 km] downstream from the Wateree Dam) on both March 16 and 18, 2011, and spent 8 days in the Wateree River. The other was recorded within 4 miles (6.4 km) of the Wateree Dam, and spent 14 days in the Wateree River (NMFS, 2013). This movement is indicative of attempted spawning behavior. Because we have evidence that shortnose sturgeon released near the Pinopolis Dam have moved up to this spawning habitat below the Wateree Dam, we believe Atlantic sturgeon in the future will also use that existing spawning habitat.

There is little information on sturgeon movement in the Congaree River and Broad River. However, biological information was available for us to prescribe sturgeon passage when relicensing the Columbia Hydropower Project in 2002 given: (1) The 1.758 acres (7,115 square meters) of shoal habitats that exist above the project, and (2) the Broad River was likely an important spawning habitat for sturgeons (DOC, 2002).

However, as stated previously, we have decided to exercise our discretion under section 4(b)(2) of the ESA and exclude these unoccupied areas from the designation.

Comment 117: One commenter stated that, based on the assumption that Atlantic sturgeon spawning habitat requirements are likely similar to shortnose sturgeon and because shortnose sturgeon are known to spawn in the Congaree River, South Carolina, downstream of the Interstate 77 bridge, Atlantic sturgeon would likely use spawning habitat in the Congaree River below Interstate 77 as well. Thus, the commenter suggested there is sufficient spawning habitat in the Congaree already, and the Broad River above the Columbia Dam should not be considered essential to the conservation of the species.

Our Response: As stated previously, we have chosen to exercise our discretion under section 4(b)(2) of the ESA and exclude the unoccupied units of critical habitat. Therefore, the areas on the Congaree and Broad rivers are not included in the designation.

Comment 118: One commenter noted that the biological opinion for the Catawba-Wateree Hydroelectric Project requires Duke Energy Carolinas (NMFS, 2013) to quantify and map potential spawning habitat under the new flow regime approved in the project license from the Wateree Dam to the confluence with the Congaree River. The commenter suggested we delay designating critical habitat in this reach until Atlantic sturgeon are present and the information required by the biological opinion has been developed.

Our Response: We agree that the information collected during this study will likely provide additional scientific data that will be useful in determining more precisely the location, timing, etc., of the spawning habitat. Also, as stated previously, we have chosen to exercise our discretion under section 4(b)(2) of the ESA and exclude these unoccupied areas from the critical habitat designation.

Comment 119: Several commenters asserted that we should not designate the Broad River in South Carolina upstream of the Columbia Dam as unoccupied critical habitat because the dam is at the fall line and we said animals do not go above the fall line.

Our Response: The commenter is correct, generally, in that we do believe Atlantic sturgeon cannot pass dams or natural features such as waterfalls and rapids found at the fall line of rivers. However, the geology of the southeastern United States is such that in some cases the fall line is not as pronounced as other areas within the range of the species. We clarified in this final rule where these conditions led to an upstream boundary above the fall line. On the Broad River, we believe the fall line likely did not act as an impediment to sturgeon migration historically. Rather, only manmade features (*e.g.,* dams) are likely blocking access to the historical spawning grounds on this river. However, as stated previously, we have chosen to exercise our discretion under section 4(b)(2) of the ESA and exclude the unoccupied units of critical habitat.

Comment 120: Two utility companies asserted the information in the proposed rule was insufficient to conclude that the failure to designate the "unoccupied" reaches of the Santee and Wateree Rivers in South Carolina as critical habitat will result in the extinction of the species. Similarly, another commenter said not only had we "failed to demonstrate why the proposed unoccupied critical habitat areas are essential to the conservation of the species," but we also "failed to demonstrate why the proposed occupied habitat is inadequate to ensure the conservation of the species."

Our Response: These commenters have applied the wrong standards for unoccupied critical habitat: That unoccupied critical habitat can only be designated if omitting the area will result in the extinction of the species, and that designating unoccupied critical habitat may only occur after first determining that occupied habitat is inadequate to support conservation. ESA section 3(5)(A) defines critical habitat as: The specific areas within the geographical area occupied by the species, at the time it is listed, on which are found those physical or biological features (a) essential to the conservation of the species and (b) which may require special management considerations or protection; and any specific areas outside the geographical area occupied by the species at the time it is listed, upon a determination by the Secretary that such areas are essential for the conservation of the species. The ESA imposes no requirement that we must determine the species will go extinct without unoccupied critical habitat. Similarly, there is no step-wise requirement that we first determine occupied critical habitat is somehow insufficient before designating unoccupied critical habitat. Admittedly, our previous regulations had incorporated such an approach. However, NMFS and the USFWS (the Services) concluded that a rigid step-wise approach does not necessarily serve the best conservation strategy for species. Regardless, we have chosen to exercise our discretion under section 4(b)(2) of the ESA and exclude the unoccupied units of critical habitat.

Comment 121: The Department of the Navy stated that the Final Joint Base Charleston (JBC) INRMP demonstrates a conservation benefit to Atlantic sturgeon and requested critical habitat not be designated in those areas of the Cooper River, South Carolina (Carolina Unit 7), adjacent to JBC properties pursuant to ESA section 4(a)(3)(B).

Our Response: We appreciate the Navy developing an INRMP that includes benefits to Atlantic and shortnose sturgeon. We reviewed the information provided during the comment period and agree the INRMP demonstrates an applicable conservation benefit, as defined in our regulations at 50 CFR 424.12(h). Section 4(a)(3)(B)(i) of the ESA states that we may not designate as critical habitat any

lands or other geographical areas owned or controlled by the DOD, or designated for its use, that are subject to an INRMP prepared under section 101 of the Sikes Act (16 U.S.C. 670a), if the Secretary determines in writing that such plan provides a benefit to the species for which critical habitat is proposed for designation. The ESA further states that this provision does not affect the requirement to consult under section 7(a)(2), nor does it affect the obligation of the DOD to comply with section 9. We have provided our detailed evaluation of the JBC INRMP and how it meets our regulatory requirements in the Application of ESA Section 4(a)(3)(B)(i) (Military Lands) section of this final rule.

Comment 122: The Navy stated that designation of critical habitat in Carolina Unit 3 would affect its ability to conduct training exercises at the Lower Neuse River Small Boat Training Area in North Carolina, forcing units to travel to Norfolk, Virginia, or Camp Lejeune, North Carolina, which increases costs and reduces time for training. They stated this would ultimately cause adverse impacts to national security.

Our Response: Based on the information provided by the Navy, we could not determine the route of effect (*i.e.,* the aspect of the action that could cause direct or indirect impacts on critical habitat) the training exercises would have on any of the PBFs. Therefore, we do not believe that the designation of critical habitat will require consultation under the ESA, and thus, there will be no impact to this training or to national security from this designation.

South Atlantic Unit Rivers

Comment 123: SCDNR and another commenter stated the upstream limits of the Edisto River (South Atlantic Unit 1) should be moved downstream to U.S. Hwy 301. They believed this is appropriate based on telemetry data from 2010–2016 that showed 84 Atlantic sturgeon tagged in the Edisto River did not pass above this area. Similarly, SCDNR said the upstream limits of the Combahee-Salkehatchie River unit (South Atlantic Unit 2) should be moved downstream to U.S. Hwy 21, because they believed the telemetry data from 2010–2014 showed five Atlantic sturgeon tagged in the Combahee River did not pass above this area.

Our Response: It is quite possible no acoustically tagged Atlantic sturgeon have been detected above U.S. Hwy 301. An illustration of acoustic receivers on the Edisto River in Post *et al.* (2014) shows no receivers even reach to U.S. Hwy 301 on the North Fork of the Edisto River. The same illustration does show four receivers at or above U.S. Hwy 301 on the South Fork of the Edisto River. Based on this information, we do not believe a lack of detections on the Edisto above U.S. Hwy 301 is entirely surprising, nor indicative that our upstream boundary is incorrect. Moreover, we determine critical habitat boundaries based on areas where PBF(s) essential to conservation of the species are located, not necessarily where individual animals have been documented. Our data indicate historical spawning likely occurred upstream of U.S. Hwy 301 and suitable spawning substrate likely exists near the fall line in both the North and South Forks of the Edisto River. The commenter provided no information suggesting the PBFs are absent above U.S. Hwy 301. For these reasons, we believe our upstream boundary for the Edisto River is appropriate.

For similar reasons, we believe our upstream boundary on the Combahee-Salkehatchie River is correct. Post *et al.* (2014) reports there are no acoustic receivers above Interstate 95, approximately two miles (3.2 km) (upstream from U.S. Hwy 21). Given the lack of receivers farther upstream, it is not possible to validate the commenter's assertion that sturgeon do not pass U.S. Hwy 21. Additionally, the commenter provided no information contradicting our determination that the PBFs extend above U.S. Hwy 21. For these reasons, we believe our upstream boundary for the Combahee-Salkehatchie River is appropriate.

Comment 124: SCDNR suggested that while it was possible two individual Atlantic sturgeon successfully passed through the NSBL&D on the Savannah River at the Georgia/South Carolina border in 2011, they believed these incidental successes are rare and inconsistent with the fishway description in section 18 of the FPA and the ruling found in section 1701(b) of the National Energy Policy Act that indicate a fishway should be safe, timely, and effective for all life stages of such fish. As a result, the commenter recommended that the upper extent of the critical habitat designation on the Savannah River should be limited to "occupied" habitat ending at the NSBL&D. Additionally, one commenter suggested the area upstream of the NSBL&D should not be considered essential to the conservation of the species because they believed Atlantic sturgeon spawn downstream of NSBL&D between rkm 213 and rkm 301 (Post *et al.,* 2014; Collins and Smith, 1997). This commenter concluded that if Atlantic sturgeon are able to spawn and produce larvae downstream of NSBL&D, then habitat upstream of the dam should not be considered essential to the conservation of the species.

Our Response: As we discussed in the proposed rule, sturgeon are currently frequently seen at the base of the NSBL&D during spawning season, indicating either crowding below the dam or individual motivation to spawn farther upriver, or both. Regardless, as stated previously, we have chosen to exercise our discretion under section 4(b)(2) of the ESA and exclude the unoccupied units of critical habitat.

Comment 125: One commenter pointed out that the proposed rule states Atlantic sturgeon typically cannot pass dams or natural features such as waterfalls and rapids found at the fall line of rivers. Based on this statement, they asserted that if any area upstream of NSBL&D becomes accessible to Atlantic sturgeon, then the fall line near the Interstate 20 Bridge should be considered the upstream limit of Atlantic sturgeon spawning habitat. The commenter concluded that unless the best available information indicates that some other landmark should be used, the fall line should be considered the upper limit of spawning habitat.

Our Response: As we explained in the proposed rule, our objective was to include the farthest upstream extent of spawning habitat essential features within critical habitat unit boundaries. Generally, Atlantic sturgeon cannot pass dams or natural features such as waterfalls and rapids found at the fall line of rivers. However, the geology of the southeastern United States is such that in some cases the fall line is not as pronounced as in other areas within the range of the species and suitable spawning habitat for sturgeon is present above this zone, and we have clarified this reasoning in this final rule. On the Savannah River, we believe the fall line is not likely to act as an impediment to sturgeon migration. Rather, only manmade features (*e.g.,* dams) are likely blocking access to historical spawning grounds. We believe once above NSBL&D, Atlantic sturgeon will be able to continue upstream until the next manmade impediment (*i.e.,* Augusta Diversion Dam). Aerial imagery confirms there are large areas of hard bottom substrate above the Interstate 20 Bridge and at the base of the Augusta Diversion Dam. Once sturgeon gain access to this area in the future, it will likely provide spawning habitat. However, as stated previously, we do not believe the benefits of designating this area as unoccupied critical habitat

at this time will outweigh the benefits of excluding this area from the designation. Thus, we have chosen to exercise our discretion under section 4(b)(2) of the ESA and exclude this area of unoccupied critical habitat.

Comment 126: The Georgia Department of Natural Resources (GADNR) had objections to our upstream boundary on the Ogeechee River, Georgia. They said that the river becomes very shallow and impassable by boats during droughts and low flow periods, and it is possible that sturgeon move upstream of Louisville, Georgia, but only during high flow years. Further, they said they had documented some limited rocky habitat upstream of the U.S. 1 Bridge in Louisville. The commenter also reported two potential physical impediments to sturgeon passage, upstream of State Road 88, at a steep shoal at Shoals, Georgia, (33.253671 degrees lat., −82.756736 degrees long.) where flows do not create 1.2 m depths at any point in the channel and at Mayfield Mill Dam, which is not passable by sturgeon (33.364799 degrees lat., −82.805872 degrees long.). They requested we consider revising the upstream boundary to the crossing at State Road 88 near Davisboro, Georgia.

Our Response: After reviewing the information provided by the commenter, we agree that our upstream boundary should be adjusted downstream by 28 rkm for South Atlantic Unit 4 (Ogeechee River) to the base of the Mayfield Mill Dam (33.364799 degrees lat., −82.805872 degrees long.), north of Mayfield, Georgia. We confirmed the dam is likely to be an impediment to upstream movement of Atlantic sturgeon and fish passage at the dam is not foreseeable. The commenter suggested the shoals at Shoals, Georgia, could act as an impediment to Atlantic sturgeon passage under certain flow conditions; these shoals are located at the fall line. While potentially an impediment, we believe passage could occur during higher flow conditions. Conversely, the Mayfield Mill Dam is impassable and likely represents the extent of upstream spawning habitat on the Ogeechee River. For these reasons, we do not believe Atlantic sturgeon can access habitat above the dam now, or in the foreseeable future. Moreover, the fall line and associated spawning habitat is about 20 rkm downstream of the Mayfield Mill Dam and thus, excluding areas above the dam from critical habitat will not affect our conservation objective for this unit. The commenter suggested we move our upstream boundary to the crossing at State Road 88 near Davisboro, Georgia. However, we could not clearly identify what information they based that suggestion upon. In the absence of clear information suggesting that would be the appropriate boundary, we chose the Mayfield Mill Dam as our revised upstream boundary. Based on this information, we have modified the location of the upstream extent of South Atlantic Unit 4 (Ogeechee River). We are not projecting a decrease in impacts in this unit associated with decreasing the length of the unit; given that the activities we predict will occur and require consultation are not location-specific, they could still occur within the modified unit boundaries.

Comment 127: The GADNR also suggested including the lower Canoochee River, Georgia, up to the confluence of Canoochee Creek at Fort Stewart, Georgia, as critical habitat. The commenter suggested this area because of its large size ("medium-main stem river"), because adult Atlantic sturgeon have been observed in the Canoochee River, and juvenile Atlantic sturgeon have been observed downstream in the Ogeechee River. They stated they believe the Canoochee River has sufficient depth for movement of adult Atlantic sturgeon.

Our Response: We reviewed the information provided by the commenter. We also conferred with state resource agency staff and academic researchers to evaluate the addition of the Canoochee River as critical habitat. We followed the same process in assessing the designation of the Canoochee River as we did with other rivers. To be considered critical habitat, the Canoochee River needed to have information supporting one or more of the following: (1) Capture location and/or tracking locations of Atlantic sturgeon identified to its DPS by genetic analysis; (2) capture location and/or tracking locations of adult Atlantic sturgeon identified to its DPS based on the presence of a tag that was applied when the sturgeon was captured as a juvenile in its natal estuary; (3) capture or detection location of adults in spawning condition (*i.e.,* extruding eggs or milt) or post-spawning condition (*e.g.,* concave abdomen for females); (4) capture or detection of YOY and other juvenile age classes; and (5) collection of eggs or larvae. While the information reviewed and opinions expressed by experts suggested that Atlantic sturgeon may use the Canoochee River, none of these necessary criteria were met for the Canoochee River. Thus, we did not consider it as having met our criteria for a spawning river or for designation as critical habitat.

Comment 128: The GADNR suggested the upstream extents of the Ogeechee, Satilla, and St. Marys Rivers proposed for designation in Georgia were inappropriate because they likely do not contain hard bottom substrate and/or water of appropriate depth that is free of barriers. They referred to a river classification framework developed by the Southeast Aquatic Resources Partnership that classified rivers (from smallest to largest) based on upstream drainage and/or mean annual flow as: Headwaters, Creeks, Small Rivers, Medium Tributary Rivers, Medium Mainstem Rivers, Large Rivers and Great Rivers (*http://southeastaquatics.net/sarps-programs/sifn/instream-flow-resources/river-classification-framework-2*). GADNR stated waterbody size is correlated with river depths and can help approximate the distribution of potential spawning habitat, which occurs "below the fall line of large rivers" as described in the proposed rule. They added that the smallest water body size that Atlantic sturgeon are known to spawn in and migrate through in Georgia is the "medium-main stem river" category in the upper Oconee and Ocmulgee Rivers in Georgia. The commenter indicated some of the upstream reaches we proposed for designation in the Ogeechee and Satilla Rivers in Georgia, and St. Marys Rivers, Florida, are categorized as "small rivers," which is two categories smaller than "medium-main stem river." The commenter suggested the appropriate boundary for the St. Marys River, Florida, should be the confluence with Boone Creek, approximately 5 miles (8 km) north-northeast of St. George, Georgia. The commenter recommended we change the upstream boundary of the Satilla River, Georgia, to the confluence with Hog Creek, approximately 1 mile (1.6 km) east of Talmo, Georgia.

Our Response: Our use of "large" rivers in the proposed rule was not intended to imply a specific classification system. It was meant more colloquially as a way to differentiate the main stem of significant coastal rivers from their smaller tributaries. Our determinations are based on the likelihood that one or more PBFs are present, not on a specific river classification system. GADNR did not provide any site-specific information that the PBFs are not present in these areas, and therefore we are not changing the upstream boundaries on these rivers.

Comment 129: One commenter supported our designation of occupied and unoccupied critical habitat. However, they requested we consider regional datasets including the: Southeastern Aquatic Connectivity

Assessment Project, the National Fish Habitat Partnership (NFHAP) database (Crawford *et al.*, 2016), the Multistate Aquatic Resources Information System (MARIS *http://www.marisdata.org/*), and the North Carolina Museum Collection data (*http://collections.naturalsciences.org/*). They also asked us to consider additional literature sources including Martin *et al.* (2014), ASMFC (2004), and Esselman *et al.* (2013), which they believe support the inclusion of the Satilla River, Georgia, up to its headwater above Route 32 in Georgia.

Our Response: We evaluated the regional datasets and literature sources suggested by the commenter. While the commenter suggested we review ASMFC (2004) and Esselman *et al.* (2013), they did not provide the citation for these references; thus, we could not review those documents. Generally, we found the regional datasets the commenter suggested either referred to species occurrence information (*i.e.*, North Carolina Museum Collection) or wide-ranging subject matter (*i.e.*, MARIS). Both NFHP and Martin *et al.* (2014) provided information focusing on disturbances such as urban land use, dams, crop land use, and impervious surface cover, but neither discuss the proposed PBFs specifically. None of the references provided information indicating the PBFs occur anywhere outside our current designation. The best available information from U.S. Geological Survey (*http://viewer.nationalmap.gov/viewer/*) shows the main stem of the Satilla River runs out well before the fall line. Thus, we believe the upstream extent of spawning habitat in the river is at the confluence of the Satilla and Wiggins Creeks approximately 2 miles (3.2 km) north of the State Route 158 in Georgia, and that the proposed boundaries for critical habitat on the Satilla River are appropriate.

Comment 130: Two commenters suggested our decision not to designate inaccessible parts of the St. Johns River, Florida, is inconsistent with our treatment of other rivers that we designated based on the existence of historical spawning habitat being temporarily blocked by dams, including on the Cape Fear River, North Carolina, the Broad and Wateree Rivers in South Carolina, and the Savannah River at the Georgia/South Carolina border.

In requesting that we designate the St. Johns River, Florida as critical habitat, the commenters contend: (1) The St. Johns River may have historically had a subpopulation of Atlantic sturgeon; (2) freshwater spawning and rearing habitats are available in the Ocklawaha River, a tributary to the St. Johns River; and (3) spawning habitat exists above the Kirkpatrick Dam on the St. Johns River, which would become accessible if the dam were breached or removed. To this latter point, the commenters provided a letter from the U.S. Forest Service indicating the removal of the dam infrastructure and restoration of the Ocklawaha River would result in substantial downstream and upstream benefits. The commenters indicated that while they could not predict exactly when the Ocklawaha River would be accessible to Atlantic sturgeon, the U.S. Forest Service's support for the removal of the dam and restoration of the river creates a reasonable assumption that the Kirkpatrick Dam will be "passable in the future." Further, they suggested designating the area as critical habitat may hasten the restoration of the river to its natural course.

The same commenters also stated the South Atlantic DPS is endangered with only nine rivers listed to produce juveniles over the entire DPS range but listing a tenth (the St. Johns) river would add another river with the potential to produce juveniles in the DPS. They also suggest colonizing juveniles (and adults) are available from the Altamaha River, which is within easy swimming range (about 200 miles; 321 km) from the St. Johns River. Finally, they indicated that fish in the southernmost rivers in the species' range will likely have adaptations important for the entire range of subpopulations in the DPS during the future period of climate warming. They stated, "Subpopulations in the South Atlantic can share genetic adaptations within their DPS and with more northerly DPS during spawning to more quickly adapt the species to a changing environment."

Our Response: Based on available information, the St. Johns River does not meet the criteria we established for inclusion of rivers in this critical habitat designation, outlined in our response to Comment 127. We found historical and/or current information indicating Atlantic sturgeon are using the Cape Fear River, North Carolina, the Santee-Cooper System in South Carolina, and the Savannah River at the Georgia/South Carolina border to spawn. In contrast, we could find no such information for the St. Johns River, Florida, and the commenters did not provide any new information. Thus, the St. Johns River does not meet the criteria to be considered critical habitat for Atlantic sturgeon.

Comments on Impacts Analysis

Comment 131: An industry trade group pointed to our determinations that the majority of the section 7 consultation costs would already be incurred based on the listing of the Atlantic sturgeon itself and that "[i]t is extremely unlikely that [project] modifications that would be required to avoid destruction or adverse modification of critical habitat would not also be required because of adverse effects to the species." They wondered, if there are no categories of permits or other Federal activities that would be impacted solely or even primarily by consultation over impacts to designated critical habitat (rather than impacts to the listed species), what is the purpose of designating critical habitat? They went on to state that if designation of critical habitat is "not prudent," we should not make such a designation.

Our Response: See response to Comment 49.

Comment 132: An industry trade group suggested we had failed to perform the requisite analysis of whether certain areas should be excluded. They believe that to comply with our statutory mandate to consider whether the benefits of excluding areas from the critical habitat designation outweigh the benefits of designation, we must provide some specific analysis of the conservation benefits derived from designating specific areas compared to the economic costs of designating those areas. They indicated we made no attempt to carve out less valuable areas based on economic, national security, or other relevant impacts. They claimed our analysis is cursory and grossly inadequate because we do not evaluate whether the benefits of exclusion outweigh the economic costs of designation for particular areas that will be designated (aside from areas of concern to the Navy).

Our Response: The commenters' argument misstates the requirements of the ESA. The ESA does not require the use of any particular methodology in the consideration of impacts. The ESA also does not require that we carve out "less valuable" areas of critical habitat. However, section 4(b)(2) of the ESA provides that the Secretary may exclude any area from critical habitat if he determines that the benefits of such exclusion outweigh the benefits of specifying such area as part of the critical habitat. This is true unless he determines, based on the best scientific and commercial data available, that the failure to designate such area as critical habitat will result in the extinction of the species concerned. The legislative

history regarding section 4(b)(2) exclusion analyses suggests that the consideration and weight given to impacts is within the Secretary's discretion (H.R. 95–1625) and the Secretary is not required to give economic or any other 'relevant impact' predominant consideration in his specification of critical habitat. In our proposed rule, we explained our preliminary determination that we would not exercise our discretion to consider exclusions. However, based on input received during the public review process, we determined that conducting a discretionary exclusion analysis for areas of unoccupied habitat within the range of the Carolina and South Atlantic DPS was warranted (given that occupied units are currently used by Atlantic sturgeon for reproduction and recruitment, and due to the severely depressed levels of all river populations, occupied units are far too valuable to both the conservation and the continuing survival of Atlantic sturgeon to be considered for exclusion).

Based on that analysis, we have elected to exclude the Santee-Cooper river system (CU1) and Savannah River (SAU1) unoccupied units of critical habitat. We determined the benefits of exclusion (that is, avoiding some or all of the impacts that would result from designation) outweigh the benefits of designation.

Comment 133: Several commenters suggested our DIA was incomplete and largely ignored the costs to permittees associated with ESA consultation. They also believed the DIA underestimated the costs associated with implementing and maintaining changes to facilities and operations required to prevent destruction or degradation of critical habitat. The commenters suggested instead that the DIA focused on the administrative costs to NMFS created by the designation while underestimating the costs incurred by the regulated community and by responsible state agencies. Specifically, one commenter estimated additional costs of $10,000 to $70,000 (related to preparing for and holding stakeholder meetings, developing and executing field studies, etc.) would be incurred during the hydropower relicensing process if the proposed designation were adopted without changes.

Our Response: We do not believe the DIA underestimated the potential costs to state agencies, permittees, or other members of the regulated communities. Economic impacts of the critical habitat designation result through implementation of section 7 of the ESA in consultations with Federal agencies to ensure their proposed actions are not likely to destroy or adversely modify critical habitat. These economic impacts may include both administrative and project modification costs. As stated previously, we examined the ESA section 7 consultation record over the last 10 years to identify the types of Federal activities that may adversely affect proposed Atlantic sturgeon critical habitat. In addition, we contacted Federal agencies that conduct, permit or fund activities in the areas covered by critical habitat and asked them whether our assessment of the types and numbers of activities likely to require consultation over the next 10 years appeared accurate. The only agency that identified specific actions that we should add to our analysis was EPA, and we have added consultations on approval of state water quality standards to the Impacts Analysis.

In terms of costs to permittees, we took a conservative approach in estimating that each type of Federal action that could involve a third-party permittee, would actually involve a permittee in the future, and included estimated administrative costs for those entities in our analysis (see IA, Section 3.3.1).

Our review determined no category of future Federal action would have routes of effects solely to the PBF(s) of critical habitat and not also have potential routes of adverse effects to Atlantic and/or shortnose sturgeon. However, in the case of USACE issuance of permits under section 404 of the CWA or section 10 of the Rivers and Harbors Act (RHA), we conservatively estimated that every one of these future actions would result in incremental impacts because these types of actions could in theory be implemented while migratory sturgeon are not present in a project's action area. Regarding the specific types of costs mentioned by the commenter, it is not clear that these costs would be attributable incrementally to the ESA, and would not instead be a baseline requirement of the FPA that governs the re-licensing process. If the types of activities are identified by FERC as required to comply with the ESA, it is likely that these studies and meetings would address potential impacts to both sturgeon and critical habitat, and as such these costs are part of the baseline requirement to consult to evaluate potential impacts to these species. Thus, we do not agree that designation of critical habitat would create the additional, incremental costs suggested by the commenter.

Comment 134: Two utility companies believed we grossly underestimated both the economic cost and the administrative burden that will be caused by designation of the unoccupied reaches of the Santee River, Lake Moultrie, Lake Marion and, to a lesser extent, the Wateree River in South Carolina. The commenters stated Santee Cooper and Duke Energy Carolinas are responsible for administering FERC licenses for their respective projects. They indicated all FERC licenses include a standard land use article that allows licensees to authorize certain types of use and occupancy of project lands and waters. This standard land use article also allows licensees to grant easements, rights-of-way, or leases of project lands and waters for a number of activities. The standard land use article also allows for more significant types of use and occupancy on project lands or waters if 60-day prior notice is provided to FERC. The commenters stated the proposed rule is unclear on whether FERC and the licensee are protected by any incidental take statement included in the licensee's biological opinion issued for the relicensing of the projects or whether section 7 consultation under the ESA is required for each discrete activity. The commenter suggested that if the latter is the case, then licensees and their designees will be required to prepare the equivalent of a biological assessment to submit a 60-day prior notice to FERC for each of the prior notice activities contemplated by the standard land use article that could affect critical habitat, and FERC will be required to assess the impacts and determine if consultation with us is warranted within this time period. The commenters indicated they believe this could include hundreds of activities over a license term. At a minimum, the commenters request that we clarify that an incidental take statement, issued as part of the FERC licensing process, covers all activities authorized or required pursuant to the FERC license, including activities conducted pursuant to the standard land use article, maintenance activities, and installation of required fish passage. Otherwise, the commenters suggested we must analyze the burden on licensees and agencies in our DIA.

Our Response: Incidental take statements included in biological opinions issued at the conclusion of a formal ESA section 7 consultation pertain to the incidental taking of threatened or endangered species, not for impacts to critical habitat. In any event, when we consult on FERC's proposed issuance of a hydropower license, the incidental take contemplated should include any take associated with the activities the commenter describes, if FERC or the

applicant have identified those types of activities as part of the scope of the action being consulted on. FERC will need to determine whether reinitiation of consultation is required for any biological opinions we have issued, based on determining whether the ongoing action may affect newly-designated critical habitat. Because consultations on a listed species must also evaluate impacts to their habitat, whether designated as critical habitat or not, most or all biological opinions issued may evaluate impacts to habitat features now being included in the critical habitat designation. To be conservative, in our Impacts Analysis we assumed reinitiation would be required on FERC actions. During any reinitiated consultation that they request, FERC should include the standard land use article that allows licensees to authorize certain types of use and occupancy of project lands and waters as part of the Federal action, in which case any impacts from activities under the article over the term of the license would be analyzed under the associated biological opinion and would not require separate consultation. However, as stated previously, we have chosen to exercise our discretion under section 4(b)(2) of the ESA and exclude the unoccupied reaches of the Santee River, Lake Moultrie, Lake Marion and the Wateree River from the designation.

Comment 135: Two commenters suggested the benefits we describe as likely to occur with the proposed designation of "Carolina Unoccupied Unit 2" as critical habitat (*e.g.,* conservation benefit of species recovery, ecosystem health benefits, ecosystem service benefits, use benefits such as commercial and recreational fishing of sturgeon and tourism) are "illusory or likely will not accrue for some time into the future" because Atlantic sturgeon are not currently present in the "unoccupied" reaches of the Wateree and Santee Rivers in South Carolina, and the reservoirs. They further stated many of the ecosystem health and service benefits we identified are already being provided as a result of the requirements of other Federal licenses or state/Federal permit authorizations. They claimed designation would impose considerable economic, administrative, and other burdens on industry and resource agencies. Thus, they believed we should determine that the benefits of excluding "Carolina Unoccupied Unit 2" far outweigh any minor, incremental benefits associated with designation of these areas.

Our Response: When we designate critical habitat we must evaluate the impacts of that designation, both positive (benefits) and negative (costs), whether or not the benefits are immediately realized. We are not required to determine that benefits, or positive impacts, of designation will be significant or accrue over any particular timeframe; however, if we determine it is appropriate to conduct an exclusion analysis on some or all areas of a designation, it is our general practice to exclude areas under section 4(b)2 when the benefits of exclusion outweigh the benefits of inclusion. Following our consideration of the costs and benefits of designating unoccupied critical habitat, we have chosen to exercise our discretion under section 4(b)(2) of the ESA and exclude those areas, which includes Carolina Unoccupied Unit 2.

Comment 136: The USACE suggested our DIA does not adequately address the potential increase in informal consultations. They said the DIA concluded most of the projects considered under General Permits (Nationwide/Regional/Programmatic) issued by the USACE are very small-scale, and the impacts to listed species and designated critical habitat from these types of projects have already been considered under programmatic biological opinions. As a result, future projects will generally not require individual section 7 consultation. The commenter stated that this assumption is not true for every USACE District; not all Districts have programmatic biological opinions in place. They stated the USACE makes effects determinations based on the effect the activity would have on the species and/or critical habitat, not on the type of authorization. Thus, they seemed to indicate some future projects in proposed critical habitat would not have required consultation for potential effects to Atlantic sturgeon, but would now require consultation to consider potential effects to Atlantic sturgeon critical habitat. They suggested our estimate of 20 CWA section 404/RHA section 10 projects permitting construction or dredge and fill in proposed Atlantic sturgeon critical habitat in the DIA is an underestimate. They claimed their information suggests the new designation would lead to at least 20 additional consultations per year in the USACE's Savannah District and at least 17 in the Wilmington, North Carolina, and Charleston, South Carolina Districts per year, or 370 new consultations over a 10-year period across those 3 districts.

Our Response: We used the best scientific information available when determining the likely future section 7 consultations for Federal actions in critical habitat. As noted previously, we queried PCTS, going back 10 years, to identify relevant consultations that occurred in each of the proposed critical habitat areas or units that, if implemented in the future, could affect one or more of the proposed PBF(s), or could affect both the critical habitat and Atlantic sturgeon. We also requested that Federal action agencies, including the USACE, provide us with information on future consultations if we omitted any future actions likely to affect the proposed critical habitat. The USACE's comment enumerates numbers of consultations by USACE district, but not whether those numbers include actions that may occur solely in marine and estuarine environments. It is also unclear from the information provided by the commenter whether the actions they referenced have been ongoing and would affect both the species and critical habitat in the future, but were simply not consulted on for effects to the species. It is also unclear whether these projects were not consulted on because the action agency determined there would be no effect to Atlantic or shortnose sturgeon. The USACE has not provided us tangible information with which to modify our Impacts Analysis. Simply stating that more consultations are expected is not sufficient. As a result, we believe our final Impacts Analysis still accurately reflects the likely number of future consultations.

Comment 137: The NCWQA and SCWQA stated the DIA does not discuss the impacts of the proposed designation on NPDES permit programs, state water quality standards, or Total Maximum Daily Load (TMDL) determinations. They pointed out that these potential impacts were discussed in GARFO's proposed rule to designate critical habitat for the Gulf of Maine, New York Bight and Chesapeake Bay DPSs of Atlantic sturgeon (81 FR 35701; June 3, 2016), and because we did not mention them in our DIA we must republish the "North Carolina proposal."

Our Response: We disagree. Our query of the PCTS database returned no TMDL or NPDES consultations in the southeast within the last 10 years. There are differences between GARFO's and SERO's impacts analyses regarding the potential impacts of critical habitat designation on NPDES permit programs, state water quality standards, or TMDL determinations. Those differences are appropriate due to differences in whether the EPA has delegated authority to particular states to administer programs under the CWA. In the Southeast, the EPA has delegated the authority to administer NPDES programs to the States of Florida, Georgia, South Carolina, and North

Carolina. Upon authorization to states, those NPDES activities are no longer Federal actions. Similarly, the TMDL programs are largely implemented by states, meaning they too are not Federal actions that require consultation. Our DIA determined the primary source of impacts of critical habitat designation is the cost of section 7 consultations. Because ESA section 7 consultations are only required for Federal actions, non-Federal activities are not affected, and were not considered in our DIA or final Impacts Analysis. Additionally, we also contacted the EPA to determine if we had missed any categories of activities likely to occur in the next 10 years that were not reflected in results of PCTS query. The EPA indicated they were not aware of any NPDES permit program or TMDL consultations that should be included in our analysis for southeast rivers. However, they did anticipate 9 nationwide pesticide consultations and an additional 12 consultations over the next 10 years to address state water quality standards; the final Impacts Analysis reflects these consultations. The commenter did not provide any information on potential NPDES permit actions or TMDL approvals that may require consultation in the southeast critical habitat units.

Comment 138: A utility company suggested we failed to mention the additional analysis that may be required to consider critical habitat when they seek to obtain an NPDES permit for the intake and discharge of water by the Cross station into and from Lake Moultrie pursuant to section 316 of the CWA. It was concerned that if "unoccupied" critical habitat is designated near the station, it may be required to prepare an unnecessary biological assessment to ensure that this unoccupied critical habitat is not affected by the activities authorized in the NPDES permit. A separate utility company expressed similar concerns. It suggested we had not identified the power plants described in Comment 111 in our DIA and had not discussed the permitting associated with the plants and the anticipated increase in consultation and delay costs associated with permits issued pursuant to section 316 of the CWA concerning intakes and thermal discharges from power plants through the state NPDES programs. Similarly, two utility companies indicated there can be a lengthy process for review by NMFS with additional time potentially required to find a compromise if the state agency issuing the section 316 permit disagrees with our recommendations. They expressed concern that because a section 7 consultation may include measures to minimize take, but the section 316/NPDES permit does not authorize incidental take, the owners/operators of these plants may also need to obtain a section 10 permit under the ESA authorizing such incidental take if there is any doubt as to whether power plant intakes or discharges may be adversely modifying critical habitat.

Our Response: As noted previously, our DIA and final Impacts Analysis do not consider NPDES activities because they are not Federal actions, thus there would be no consultations and no impacts resulting from this designation associated with NPDES activities.

Section 316(b) of the CWA requires cooling water intake structures (CWIS) to reflect the best technology available (BTA) for minimizing adverse environmental impacts. Adverse environmental impacts include, but are not limited to, impingement and entrainment of organisms at CWIS, and changes in flow regime, caused by the withdrawal of water. Under section 316(b), the EPA is required to issue regulations on the design and operation of intake structures to minimize adverse impacts. The EPA issued its Final Regulations to Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities on August 15, 2014 (79 FR 48300). The following is a summary of EPA's description of the main components of the rule as follows. First, existing facilities that withdraw at least 25 percent of their water from an adjacent waterbody exclusively for cooling purposes and have a design intake flow of greater than 2 million gallons (7.6 million liters) per day (MGD) are required to reduce fish impingement under the final regulations. To ensure flexibility, the owner or operator of the facility will be able to choose one of seven options for meeting best technology available requirements for reducing impingement. Second, existing facilities that withdraw very large amounts of water—at least 125 MGD (473 million liters per day)—are required to conduct studies to help their permitting authority determine whether and what site-specific controls, if any, would be required to reduce the number of aquatic organisms entrained by cooling water systems. This decision process would include public input. Third, new units that add electrical generation capacity at an existing facility are required to add technology that achieves one of two alternatives under the national BTA standards for entrainment for new units at existing facilities. Under the first alternative new unit entrainment standard, the owner or operator of a facility must reduce actual intake flow (AIF) at the new unit, at a minimum, to a level commensurate with that which can be attained by the use of a closed-cycle recirculating system. Under the second alternative new units entrainment standard, the owner or operator of a facility must demonstrate to the permit issuer (*e.g.*, a state) that it has installed, and will operate and maintain, technological or other control measures for each intake at the new unit that achieves a prescribed reduction in entrainment mortality of all stages of fish and shellfish that pass through a sieve with a maximum opening dimension of 0.56 inches.

The commenters did not provide information for us to determine whether and to what extent they are affected by EPA's section 316(b) regulations. Nonetheless, we do not believe this critical habitat designation will increase any impacts to commenters related to section 316(b), for the following reasons. The Services consulted with EPA on the impacts of its nationwide application of the section 316(b) rule and issued a biological opinion concluding the rule would not jeopardize any listed species or destroy or adversely modify any critical habitat under the Services' jurisdictions (USFWS and NMFS, 2014). No additional consultations are required under the biological opinion and EPA's rule; instead, the Services are engaged by permit issuers (EPA, or state or Tribal governments) in a 60-day review of permits under consideration, prior to the permits being published for public comment. A provision of EPA's rule requires affected permit applicants to include threatened or endangered species or critical habitat that may be in the action area of their facilities in the assessments required for their permit applications. The Services may provide recommendations on measures to protect listed species, including measures that would minimize any incidental take of listed species, and/or avoid likely jeopardy to a listed species or destruction or adverse modification of critical habitat. If we reviewed a 316(b) permit application for a CWIS in Atlantic sturgeon critical habitat, we would first evaluate whether there are any routes of adverse effects to listed species or to the critical habitat. Conceivably, CWIS could affect the water quality essential features of water depth, temperature, DO and salinity values, depending on the amount and timing of the water withdrawals/discharges. However, any such effects would also affect listed species including Atlantic and shortnose

sturgeon, and any measures we would recommend to avoid such effects would not be incremental impacts, including delay, attributable to the critical habitat designation. Therefore, any future ESA section 7 or section 10 requirements related to CWA section 316 or NPDES consultation requests for critical habitat would be coextensive to consultations for the listed species; thus, we do not believe there would be any significant delay or costs incurred for the consultations assessing impacts to critical habitat. The commenters' concern about the lack of authorization of incidental take of listed species through the 316/NPDES permit is not a critical habitat issue, and thus there are no impacts attributable to this rule.

Comment 139: A farm-industry trade group expressed concern that the DIA did not comprehensively evaluate the potential economic impacts to private landowners, particularly farmers. They were specifically concerned farmers would bear the burden of additional permit review and regulatory requirements under the ESA, including EPA prohibitions of certain crop protection products, permits for minor impacts to wetlands, and potentially even curtailment of water withdrawals.

Our Response: The requirements to consider potential adverse effects to critical habitat in section 7 consultations only apply to activities funded, carried out, or authorized by Federal agencies. Because these requirements only apply to activities with a "Federal nexus," we do not anticipate the designation of critical habitat to result in additional costs or burden to strictly private or state activities. The commenter is correct that some additional review may be required during Federal permitting to consider the potential effects of a Federal action on designated critical habitat. However, as noted previously, we anticipate any Federal action potentially affecting Atlantic sturgeon critical habitat would have already required ESA section 7 consultation to consider the potential impacts to Atlantic or shortnose sturgeon, and thus any added burden due solely to this rule will be minimal. Our analysis includes a conservative estimate of the consultation impacts due to EPA's authorization of pesticides over the next 10 years, noting these are national consultations that will require evaluating impacts on all NMFS listed species and designated critical habitat. Our conservative estimate is that these consultations would result in $1,474.84 per unit attributable to Atlantic sturgeon critical habitat over 10 years, for Federal agencies and permittees combined. The commenter did not provide information on any particular water withdrawals of concern and whether those would have a Federal nexus to potentially trigger consultation requirements. Similarly, no information on minor impacts to wetlands that may affect Atlantic sturgeon critical habitat and require consultation was provided. If projects with a Federal nexus that impacted wetlands occurred in the past in areas being included in the critical habitat units and required consultation, it would be included in our database and would be included in this analysis, likely under the USACE CWA section 404/RHA section 10 permitting—dredge, fill, construction category. We conservatively assumed these actions could result in fully incremental informal consultations in the future, and assigned them a cost of $7,200 per consultation. Of this, a permittee could incur $1,500-$3,000, depending on whether a biological assessment is required and is prepared by the permittee (see, Impacts Analysis Table 3–19).

Comment 140: Two commenters stated that the area immediately downstream from Blewett Falls Dam on the Pee Dee River at the North Carolina/South Carolina border (Carolina Unit 5) should be excluded from designation as critical habitat. The commenters asserted this area does not offer suitable spawning habitat, and exclusion would alleviate the additional cost, complexity, and administrative burden of carrying out activities authorized or required by the YPD license, including fish passage activities.

Our Response: We disagree. As discussed in our response to Comment 110 above, potential spawning habitat does exist immediately downstream from Blewett Falls Dam, and it was appropriate to set the upstream boundary of the unit at the dam. We also disagree that foregoing designation would alleviate additional cost, complexity, and administrative burden of carrying out activities authorized or required by the YPD license. As noted previously, we do not anticipate the designation of critical habitat will impose additional administrative burdens or costs that would not have already been associated with ESA section 7 consultations to address impacts to Atlantic and shortnose sturgeon.

Comment 141: An industry trade group suggested we had significantly underestimated the true costs to a permittee, because we had not included potential costs associated with employing biologists, other consultants, or legal support they believe may be necessary to navigate the consultation process. They went on to state that consultation could cause project modifications, impose additional avoidance measures, or require additional mitigation above what was required by the action agency. The commenters reported Sundig (2003) estimated the direct, out-of-pocket costs of section 7 consultation for a single-family housing project to be several thousand dollars per house. Beyond the consultation process itself, the commenters suggested requirements to avoid or mitigate impacts to critical habitat could result in economic losses of millions of dollars. The commenters concluded that by severely underestimating the number of consultations that will be triggered by the proposed designations and the costs of those consultations, we failed to provide a meaningful analysis of section 7 consultation costs.

Our Response: We disagree. As explained in our responses to comments 52, 133, 135 and 136 above, we believe our estimate of the numbers of future consultations is correct, and commenters provided no information to the contrary.

Comment 142: Several commenters, including GADNR, SCDNR, and NCDOT, expressed concern that requirements to consult under section 7 of the ESA would increase administrative costs/burdens and cause long delays potentially affecting project costs, timelines, and fisheries management activities.

Our Response: As outlined in the Impacts Analysis and described previously, our review of all Federal actions that may adversely affect designated Atlantic sturgeon critical habitat indicates that none of those types of actions would solely affect the PBFs of critical habitat and not also have potential routes of adverse effects to Atlantic and/or shortnose sturgeon. We acknowledge that actions occurring within designated critical habitat will require an analysis and additional administrative cost to ensure Federal actions are not destroying or adversely modifying critical habitat. Yet, those additional analyses will be added to consultations that would occur anyway to consider potential impacts to sturgeon. Therefore, the designation of critical habitat is not anticipated to cause the significant additional costs or delays suggested by the commenter.

Comment 143: The Navy also expressed concern about potential delays and administrative costs/burdens associated with the designation. The Navy also questioned our determination that impacts of dredging are coextensive with the listing rather than incremental

impacts of this rule, and they identified some areas on the Neuse River that they believe will lead to impacts to national security due to impacts of the designation on training conducted in those areas.

Our Response: See our response to Comment 142 above regarding costs and delays generally. As we discussed in the proposed rule, dredging to maintain navigation channels may affect several of the essential PBFs of Atlantic sturgeon critical habitat. Dredging to deepen or widen navigation channels may involve removing rock, gravel, or soft substrate that is providing adult sturgeon spawning habitat or juvenile foraging habitat. Extensive dredging for harbor expansion may allow saltwater to intrude farther up a river, and adversely impact the area containing the salinity range necessary for young sturgeon. Other potential effects of dredging projects on the essential PBFs of Atlantic sturgeon critical habitat are increased siltation on spawning substrate, and the blockage of migratory pathways through channels and inlets.

At the same time, dredging may adversely affect Atlantic and shortnose sturgeon. The types of adverse effects are not likely to be temporary and limited to periods of sturgeon absence, and they are likely to be implemented in lower parts of the units where sturgeon can be expected to be present year-round. Thus, adverse effects of navigation maintenance dredging activities are likely to involve coextensive formal consultations to address impacts to both the species and the essential PBFs. Removal or covering of spawning substrate could interfere with the services this PBF is designed to provide—settlement of fertilized eggs and refuge, growth and development of early life stages. These effects to the essential PBF would also be adverse effects to sturgeon eggs, larvae and early life stages that were not able to settle, grow, develop or seek refuge. Project modifications to address both these impacts to the PBF and the sturgeon could involve limiting the amount or location of substrate removed, or turbidity controls to prevent sediment deposition on hard substrate. Similarly, adverse effects of dredging in removing the soft substrate PBF that would interfere with provision of juvenile foraging services, could also injure or kill juveniles seeking to use that foraging habitat. Coextensive project modifications might be similar to those mentioned for impacts to the hard substrate feature. Changing the salinity regime by deepening harbors and parts of rivers would remove portions of the transitional salinity zone feature that is being designated to provide foraging and developmental habitat services to juveniles; loss of portions of this habitat could impede development of juveniles using the remaining habitat, or prevent the habitat from supporting some juveniles. Coextensive project modifications that might be required to prevent or lessen these impacts could involve changes in the depth of deepening a harbor, port, or river. The deepening of harbors and ports may also create hypoxic zones which would impact the water quality PBF that is designed to ensure survival of sturgeon. Coextensive project modifications that might be required to prevent hypoxic zones could include limiting the amount of deepening or requiring the use of aeration systems. Thus, we did not assert there would be no project modifications to avoid adverse effects to critical habitat, but as described above, project modifications would address adverse impacts to both critical habitat and sturgeon, thus the costs of such modifications would not be incremental impacts of this rule.

The Navy described training activities that occur on the lower Neuse River as including small boat launch and recovery, high-speed boat tactics training, small boat defense drills, and small arms fire. We do not see a route of potential effects from these activities to the PBFs of critical habitat, and thus there would be no additional consultation burdens beyond any requirements to address impacts to the species. Thus, the designation would not impact military training related to national security in these areas.

Comment 144: Several commenters, including SCDNR, asserted that designation of critical habitat (both unoccupied and occupied) means projects that previously would have qualified for USACE Nationwide Permits or General Permits would no longer qualify, resulting in individual project review/analysis/certification.

Our Response: Whether a project is permitted by the USACE under a Nationwide or General Permit or another permitting mechanism, the USACE must assess the effects of the project on listed species and critical habitat and consult with us if listed species and/or designated critical habitat may be affected. As previously stated, our review of all previously consulted-on Federal actions that may adversely affect designated Atlantic sturgeon critical habitat determined that none of those types of actions would solely affect the PBFs of critical habitat and not also have potential routes of adverse effects to Atlantic and/or shortnose sturgeon. We acknowledge that actions occurring within designated critical habitat will require an analysis to ensure Federal actions are not likely to destroy or adversely modify critical habitat. Yet, those additional analyses will be added to consultations that would be required anyway, to consider potential impacts to sturgeon.

Comment 145: NCWRC and SCDOT requested that we develop programmatic ESA section 7 consultations or allocate additional resources to reduce the time associated with addressing new consultations.

Our Response: We cannot require a Federal action agency to consult on a programmatic basis, as it is up to the action agency to define the scope of a programmatic activity. However, we are committed to continue working with our Federal partners as we have in the past to identify opportunities for streamlining consultations or ways to increase efficiencies in the consultation process. Within SERO, we are already fully committing the available resources to ESA section 7 consultations, and we agree that investigating the possibility for programmatic consultations is a valuable tool.

Comment 146: A few commenters, including an industry trade group, expressed concern about potential delays for projects already undergoing consultation that would now have to include an analysis of adverse modification for Atlantic sturgeon critical habitat, as well as previous consultations that may need to be reinitiated based on the new critical habitat designation.

Our Response: See response to Comment 57.

Comment 147: One commenter worried that important research projects funded through time-limited Federal grants, occurring within proposed critical habitat units, may be delayed. The commenter expressed concern over the length of time required to complete section 7 consultations. The commenter expressed the belief that the timely completion of section 7 consultations will help to ensure these projects can provide data under the grant deadlines.

Our Response: We agree with the commenter that delays of important research projects within proposed critical habitat units should be avoided if possible. We are committed to working with action agencies to complete section 7 consultations as a quickly as possible.

Comment 148: SCDNR requested that we develop guidance and Best Management Practices for how in-water work should be conducted in critical habitat.

Our Response: We appreciate the recommendation.

Comment 149: SCDNR recommended we establish a list of activities authorized by the USACE Nationwide Permits that would not affect this species or its critical habitat and thus not require the section 7 consultation.

Our Response: It is the responsibility of the USACE, as the Federal action agency for the Nationwide Permits, to make determinations about their actions and request consultation if species and/or critical habitat may be affected. We are available to provide technical assistance and consultation, if requested by the USACE or other action agencies. We have information readily available on our Web sites for all Federal action agencies, and the public, providing guidance on effects determinations. Additionally, SERO and GARFO are jointly drafting a consultation framework specific to analyzing impacts to Atlantic sturgeon critical habitat to assist USACE and other agencies with consultations.

Comment 150: NCDMF and North Carolina Division of Coastal Management (NCDCM) suggested that even minor modifications to trawl sampling designs can affect the comparability of survey results across time series, which may span multiple decades. They requested we consider the importance of maintaining consistency across sampling programs if any new consultations are required due to the proposed critical habitat designations. The commenter also expressed concern that other bottom disturbing activities such as cultch planting and artificial reef and oyster reef construction could be impacted by our habitat designation. They concluded that while the critical habitat designations may not impact these activities, additional consultations for critical habitat (either formal or informal) will be required.

Our Response: We agree that there is great value in consistency across sampling programs and do not seek to change them without cause. However, if we determine through section 7 consultation that a sampling program funded or permitted by a Federal agency may adversely affect sturgeon or their habitats, including critical habitat, the Federal agency is required to ensure the action is not likely to jeopardize listed species or destroy or adversely modify critical habitat. In the extreme case that a sampling program is found to be likely to destroy or adversely modify critical habitat, we would be required to work with the parties involved to develop a reasonable and prudent alternative to that program, that would still achieve the sampling program's objectives but avoid destruction or adverse modification of the critical habitat.

With respect to the consultation requirements for the bottom disturbing activities identified, as outlined in the IA, our review of all Federal actions that may adversely affect designated Atlantic sturgeon critical habitat determined none of those types of actions, including federally-permitted fishery research, would solely affect the PBFs of critical habitat and not also have potential routes of adverse effects to Atlantic and/or shortnose sturgeon. We acknowledge that actions occurring within designated critical habitat will require an analysis and additional administrative cost to ensure Federal actions are not likely to destroy or adversely modify critical habitat. Yet, those additional analyses will be added to consultations that would occur anyway, to consider potential impacts to sturgeon. Therefore, the designation of critical habitat is not anticipated to cause the significant additional costs or delays suggested by the commenter.

Comment 151: One commenter expressed concern that the proposed designation could prevent in-water construction, dredging and bridge work needed to: (1) Maintain safety margins for large, ocean-going vessels navigating into and out of port, (2) transit near or under bridges, and (3) moor/unmoor safely at marine terminals, from receiving Federal funding. The commenter stated that section 7(a)(2) of the ESA requires Federal agencies to ensure actions they fund, authorize, or carry out are not likely to destroy or adversely modify that habitat, and pointed out we have determined a wide variety of activities may affect critical habitat. The commenter seems to imply that because we have indicated one or more of the activities above may have effects to critical habitat, we could impose a blanket moratorium on any such activity and/or block those activities from gaining Federal funding in the future. They believed stopping these projects would not only have a dramatic economic impact, but would also have a severe negative impact on navigation safety. The commenter requested we explicitly state in the final rule that all "federally-improved dredged channels" and areas adjacent to marine terminals are excluded from critical habitat.

Our Response: We agree that the proper maintenance of bridges, shipping channels, and marinas is not only important to ensure the flow of commerce, but also to ensure safety. The commenter is also correct that the ESA requires Federal agencies to ensure that actions they fund, authorize, or carry out are not likely to destroy or adversely modify critical habitat. However, section 7 of the ESA is written to ensure that federally-funded projects go forward, so long as they do not destroy or adversely modify critical habitat. Even if a proposed action is likely to destroy or adversely modify critical habitat, the section 7 consultation process is specifically designed so that a reasonable and prudent alternative, consistent with intended scope of proposed action, could be identified that would allow the action to proceed but without the same degree of impact to critical habitat. Thus, we do not believe it is necessary to exclude all "federally-improved dredged channels" and areas adjacent to marine terminals from critical habitat on the basis that such actions may be prevented from being implemented in the future.

Comment 152: The EPA stated we underestimated the number of section 7 consultations, and associated costs, likely to occur by failing to include their triennial state water quality standard reviews.

Our Response: After reviewing the information provided by the EPA regarding future water quality standard consultations, per their request we added three consultations for each of the states covered by this designation to the impacts analysis.

Comment 153: An electric cooperative requested that we confirm that the proposed rule does not contemplate any change in flow regime for the USACE's projects on the Roanoke River, North Carolina, and the Savannah River at the South Carolina/Georgia Border. They stated that any changes to the flow regimes would require an update or revision to the Water Control Manuals, which in turn would require an analysis of the environmental impact of the proposed rule under the National Environmental Policy Act (NEPA). They asked for this confirmation because they believe our DIA makes a number of references to the relation of river flows to critical habitat needs without providing any details on whether the rule specifically contemplates changes to flow regimes.

Our Response: The designation of critical habitat would impose no direct regulatory requirements and would not, in and of itself, have any effect on existing flow patterns. It is possible that flows may need to be altered to address adverse effects to critical habitat if such effects were identified during ESA section 7 consultation on a new or ongoing Federal action that affects water flows in a way that also affects the PBFs of critical habitat. Additionally,

environmental analysis under NEPA is not required for critical habitat designations (see, *Markle Interests, L.L.C.* v. *U.S. Fish and Wildlife Serv.*, 827 F.3d 452 (5th Cir. 2016); *Bldg. Indus. Ass'n of the Bay Area* v. *U.S. Dept. of Commerce*, 792 F.3d 1027 (9th Cir. 2015); *Douglas County* v. *Babbitt*, 48 F.3d 1495 (9th Cir. 1995), cert. denied, 116 S.Ct. 698 (1996)).

Comment 154: One commenter suggested the proposed rule was unclear regarding whether hydropower projects occurring outside, but upstream, of proposed critical habitat units may need to be altered to facilitate the objective of the critical habitat designation. The commenter asserted that if we intended to require alterations to existing flow patterns in the geographical units currently under consideration for designation as critical habitat, then our analysis in the proposal was deficient. They requested that we clarify our intentions on this point.

Our Response: Dams and regulation of water releases upstream of occupied critical habitat could affect the PBFs downstream, even if the dams themselves are not located within the critical habitat area. However, these downstream impacts occurring within occupied critical habitat units will also affect sturgeon, and consultation would be required even without the designation. In all of our past consultations on dams immediately above habitat used by sturgeon, we found that only the structure operated or authorized by the action agency at hand and undergoing consultation would have adverse effects on sturgeon and their habitats. Thus, but for additional administrative costs, the majority of the costs of these consultations are not incremental impacts of this rule. It is possible that flow regimes may need to be altered if current regimes are adversely affecting sturgeon and the essential PBFs of critical habitat, if such effects are identified during ESA section 7 consultation.

We evaluated all existing dams and other structures that are upstream of the proposed upper boundaries of all of the critical habitat units. We found that for the specific existing facilities at issue, dams outside of critical habitat and upstream from a dam that forms the boundary of critical habitat are not expected to have adverse effects to either unoccupied or occupied critical habitat and would not require consultation. This is due to large distances between upstream dams and the dams that form the boundary of critical habitat, and the presence of intervening structures, dams, or water bodies that dilute the effects of upstream dams relative to the effects of dams on the border of critical habitat.

Comment 155: The Navy expressed concern over our determination that consultations for effects of dredging on critical habitat will be fully coextensive with consultations to address impacts to Atlantic sturgeon. They believe designation of critical habitat can or will result in an additional commitment of resources and expected requirements to modify proposed actions to prevent adverse effects to critical habitat.

Our Response: We believe dredging may affect critical habitat, but we believe consultations to consider those effects on critical habitat will be fully-coextensive with consultations to address impacts to sturgeon (both shortnose and Atlantic). The effects of dredging on the PBF(s) would also result in injury or death to individual sturgeon, and thus constitute take. Removal or covering of spawning substrate could prevent effective spawning or result in death of eggs or larvae that are spawned. Changing the salinity regime by deepening harbors and parts of rivers could result in permanent decreases of available foraging and developmental habitat for juveniles. These types of adverse effects are not likely to be temporary and limited to periods of sturgeon absence. Thus, adverse effects of dredging activities identified by the Navy would be likely to be coextensive in formal consultations to address impacts to both the species and the PBF(s), and thus no new requirements or project modifications are anticipated as a result of the critical habitat designation.

In our long history of past and ongoing consultations, we have considered the effects that in-river activities (including dredging) would have on both Atlantic and shortnose sturgeon and their shared habitats, where applicable. A main focus of all our past consultations on Federal actions in rivers (*e.g.*, dredging, hydropower permitting) has been on expected impacts to these species' habitats. Adverse effects to habitat, including critical habitat, that will result in either injury or mortality of individual sturgeon of any life stage constitute take of the species. We have regularly determined that projects with adverse effects to sturgeon habitat will result in take of the species. It is this consultation history and experience that leads us to project that if actions in areas occupied by Atlantic and/or shortnose sturgeon affect their habitats, those actions would have the same effects on Atlantic sturgeon critical habitat, and the consultations and impacts would be largely coextensive.

Comments on Our Coastal Zone Management Act Determinations

Comment 156: NCDMF–NCDCM suggested our consistency determination regarding designating critical habitat is incomplete and does not meet the requirements of the Coastal Zone Management Act, 16 U.S.C. 1451, *et seq.* (CZMA) and its implementing regulations. They maintained that we submitted an incomplete negative determination, because we had not provided an evaluation of the North Carolina coastal program's enforceable policies.

Our Response: We disagree. While we recognize the State's goals of coastal resource protection and economic development, we determined that any effects of the proposed action on North Carolina's coastal uses and resources are not reasonably foreseeable at this time. As indicated in our negative determination, this designation of critical habitat will not restrict any coastal uses, affect land ownership, or establish a refuge or other conservation area; rather, the designation only affects the ESA section 7 consultation process for Federal actions. Through the ESA consultation process, we will receive information on proposed Federal actions and their effects on listed species and this critical habitat upon which we base our biological opinions. It will then be up to the Federal action agencies to decide how to comply with the ESA in light of our opinion, as well as to ensure that their actions comply with the CZMA's Federal consistency requirement.

Comments on Executive Order 13211—Statement of Energy Effects

Comment 157: One commenter indicated we failed to meet the requirements of Executive Order 13211 to prepare a Statement of Energy Effects. The commenter indicated changes in utility facilities and operations required by Federal ESA section 7 consultations, as a result of this critical habitat designation, have the potential to adversely affect in a material way the productivity and prices in the energy sector within the region.

Our Response: We disagree. The commenter provided no information, aside from the conclusion that the designation has the potential to adversely affect in a material way, productivity and prices in the energy sector within the region, on which we can base changes in our impacts analysis. The only Federal actions on which we may consult that have

material effects on energy are FERC hydropower licensing actions. These actions have the potential to adversely affect sturgeon as well as critical habitat, and thus most of the impacts of these consultations will result from the ESA listing of the Atlantic sturgeon rather than incremental impacts of the designation. Moreover, the FPA, which FERC implements in issuing hydropower licenses, has independent requirements to avoid adverse effects on fisheries resources and habitats, and thus modifications to hydropower facilities to avoid impacts to critical habitat may also be coextensive with the FPA, rather than from incremental impacts of the designation.

General Support or Disapproval of the Proposed Designation

Comment 158: We received five comments from the general public that were generally unsupportive of protecting sturgeon, their habitats, or their ecosystem.

Our Response: We appreciate the time these commenters took to provide input to us.

Comment 159: We received approximately 300 comments from the general public that were generally supportive of protecting sturgeon, their habitats, or their ecosystem. We received an additional two comments of general support from non-governmental organizations.

Our Response: We appreciate the supportive feedback received from these commenters.

Necessary Editorial Changes

Comment 160: One commenter pointed out that we cited Flowers and Hightower (2015) but that reference was not included in the list of references.

Our Response: We agree with the commenter. We erroneously omitted that reference from our list of references. We have updated the list of references to include this citation.

Comment 161: One commenter pointed out that we cited Smith *et al.* (2014) in several locations, but the reference did not appear in the list of references; however, Smith *et al.* (2015) does. The commenter suggested we may have erroneously referred to Smith *et al.* (2014) as Smith *et al.* (2015), in which case the citation needed to be updated, or the former is missing from the list of references and should be added.

Our Response: We appreciate the commenter bringing this discrepancy to our attention. While cited differently, both citations actually refer to the same document. This final rule has been updated to reflect the proper citation as Smith *et al.* (2015). As a result of this comment, we reviewed the final rule to ensure the literature cited section was accurate and complete, and made changes when necessary.

Comment 162: One commenter pointed out that we had erroneously cited them as a source of information in a personal communication, when the source was someone else.

Our Response: We agree with the commenter and apologize. We erroneously cited the commenter as the source for information indicating that Atlantic sturgeon had passed above Lock and Dam #1 on the Cape Fear River, North Carolina, and we have corrected that error in this final rule.

Comment 163: SCDNR and another commenter pointed out that we stated: "The capture of 151 subadults, including age-one fish in 1997 indicates a population exists in the Santee River (Collins and Smith, 1997)." They indicated that the Collins and Smith's 1997 publication was a synthesis of all historical and recent records of both Atlantic and shortnose sturgeons in South Carolina waters from 1970–1995. Thus, the number reported, 151, was not collected in a single year, 1997, but instead was a sum of all Atlantic sturgeon records from 1970–1995.

Our Response: We agree with the commenters. We erroneously characterized the capture of 151 subadults, including age-1 fish, as occurring in a single year when those captures actually occurred from 1970–1995 and we have corrected this error.

Comment 164: SCDNR noted the difference between the Columbia Dam and the Columbia Canal Diversion Dam, indicating the names are not interchangeable and both are part of the Columbia Hydroelectric Project. They stated "the Columbia Dam has a constructed fishway that allows for the passage of American shad, blueback herring and American eel; although 'sturgeon-friendly' features were incorporated in its design, to date, no sturgeon have been documented utilizing this fishway nor have sturgeon been documented in surveys above the Columbia Dam."

Our Response: We appreciate the commenter bringing this to our attention. We believe we properly referred to the Columbia Dam and associated fish passage in the proposed rule.

Comment 165: SCDNR pointed out that the proposed rule erroneously stated the St. Stephen Powerhouse was on the Santee River, South Carolina, when it is actually located on the Rediversion Canal.

Our Response: We appreciate the commenter bringing this discrepancy to our attention. We have updated the final rule to reflect this correction.

Summary of Changes From the Proposed Rules

Based on the comments received for the proposed rule, Designation of Critical Habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic Sturgeon (81 FR 35701; June 3, 2016), we have made several changes in the final rule:

1. The boundary for the upstream extent of the Pamunkey River, has been moved upstream by 14 rkm. This change was based on a comment we received from the Virginia Institute of Marine Science that, based on new data, the area with suitable hard bottom substrate and used by spawning Atlantic sturgeon in the York River System extends farther upstream on the Pamunkey River than what we proposed. This supplements the existing data we relied upon for the proposed rule. We determined that the additional 14 km of Pamunkey River habitat was essential to the conservation of the Chesapeake Bay DPS and should be part of the designated critical habitat for the York River System. The York River System critical habitat unit now includes 206 rkm instead of 192 rkm.

2. The 16 rkm of the proposed Susquehanna River Critical Habitat Unit are not designated as critical habitat. We received comments requesting removal of the Susquehanna River critical habitat unit and comments requesting inclusion of the upper Chesapeake Bay. Upon review, we determined that PBF number 2 (a salinity gradient to support juvenile growth and physiological development) is not present in the Susquehanna River unit, and is not likely to be present in the future. Therefore, because we determined that the coexistence of all four features is essential to reproduction and recruitment, based on the information available, the lowermost 16 rkm of the Susquehanna River do not contain the PBFs essential to the reproduction or recruitment of the Chesapeake Bay DPS and we are not designating this area as Chesapeake Bay DPS critical habitat.

3. The 60 rkm of the Nanticoke River from the Maryland State Route 313 Bridge crossing near Sharptown, MD, to where the main stem discharges at its mouth into the Chesapeake Bay as well as Marshyhope Creek from its confluence with the Nanticoke River and upriver to the Maryland State Route 318 Bridge crossing near Federalsburg, MD, are designated as critical habitat for the Chesapeake Bay DPS, and it will be called the Nanticoke River critical habitat unit. We announced in the supplementary document for the

proposed rule that we did not have substrate information for the Nanticoke River and Marshyhope Creek, MD, but that a study was ongoing to obtain that information. We received the information through public comment from the MD DNR. Based on the new information and existing information discussed in the proposed rule related to the presence of Atlantic surgeon in spawning condition at a time spawning would occur, we determined that portions of the Nanticoke River and Marshyhope Creek are essential to the conservation of the Chesapeake Bay DPS and should be designated as critical habitat.

4. We corrected the map for the James River critical habitat unit. The map used in the proposed rule incorrectly placed the downriver boundary of critical habitat in the area of Hampton Roads. The textual description of the James River critical habitat in the proposed rule was correct.

5. The table describing the states and counties in which critical habitat is being designated has been updated. It now includes Dorchester and Wicomico Counties on the Nanticoke River.

6. The description of PBF number 2 includes two changes. The phrase "between the river mouths and spawning sites" replaces "downstream of spawning sites." As previously written, we were concerned the public might construe "downstream of spawning sites" to include bays or sounds below rkm 0; this was not our intent. We believe the change more accurately reflects the boundaries of critical habitat. Additionally, the words "up to as high as " were added after 0.5 and before 30 to clarify acceptable salinity ranges. Because the freshwater inputs vary from year to year, and river to river, it is possible that during a high freshwater flow year, the salinity levels within a unit may never reach 30 ppt. As previously written, the wording suggested that the gradual downstream gradient would have to encompass the entire 0.5–30 ppt salinity range; this was not our intent. This change is meant to acknowledge that the entire salinity range is not required.

7. In PBF number 3, the examples of what may constitute barriers were expanded, and the phrase "at least 1.2 m" replaces "≥1.2 m" for clarity.

8. The phrase "between the river mouths and spawning sites" was inserted in the language of PBF number 4. This change clarifies the areas designated as critical habitat as described under PBF number 2. Additionally, for clarity of the example, the phrase "6 mg/L DO or greater" replaces "6 mg/L dissolved oxygen."

9. We have included and clarified in regulatory provisions for all five DPSs that manmade structures that do not provide the essential PBFs are not included in critical habitat.

Based on the comments received for the proposed rule, Critical Habitat for the Endangered Carolina and South Atlantic DPSs of Atlantic Sturgeon (81 FR 36077; June 3 2016), we have made several changes in the final rule:

10. The boundary for the upstream extent of the Ogeechee River has been moved downstream by 28 rkm, from the confluence of North Fork and South Fork Ogeechee Rivers to Mayfield Mill Dam; the Unit now includes 420 rkm instead of 448 rkm.

11. The boundary for the upstream extent of the Black River, South Carolina, has been moved downstream by 50 rkm from Interstate Highway 20 to Interstate Highway 95; the Unit now includes 203 rkm instead of 253 rkm.

12. The description of South Atlantic Unit 3 has been updated to include a number of significant branches of the Savannah River that we intended to be considered critical habitat, and were included in the maps of the critical habitat unit, but were not specifically mentioned in the regulatory text. The unit description now includes: The Back River, Middle River, Front River, Little Back River, South River, Steamboat River, and McCoy's Cut.

13. Carolina Unoccupied Unit 1 has been removed due to uncertainty regarding whether that stretch of the Cape Fear River contains spawning habitat that would make it essential to the conservation of the species.

14. We have chosen to exercise our discretion under section 4(b)(2) of the ESA and exclude Carolina Unoccupied Unit 2 and South Atlantic Unoccupied 1,

15. The table describing the states and counties in which critical habitat is being designated has been updated. It now includes Monroe and Wilcox counties on the Ocmulgee River, Treutlen County on the Oconee River, and Warren County on the Ogeechee River. All four counties occur in Georgia and were inadvertently omitted from the table. Additionally, we changed the upstream boundary of the Black River, South Carolina, and the Ogeechee River, Georgia, and removed all three unoccupied critical habitat units entirely. As a result of these changes, Calhoun, Fairfield, Kershaw, Lee, Lexington, New Berry, Sumter, Orangeburg, and Richland counties, South Carolina; Columbia, Edgefield and Taliaferro counties, Georgia; and Bladen County, North Carolina, will no longer be affected; those counties have been removed from the table. We also removed Irwin and Jasper counties, Georgia, from the list because they are not affected by any critical habitat unit.

16. The description of PBF number 1 initially referred to "suitable hard bottom substrate (*e.g.*, rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (*i.e.*, 0.0–0.5 parts per thousand [ppt] range) . . ." The word "suitable" was dropped because the term suggests there may be hard bottom that is unsuitable for spawning, which is not the case.

17. The description of PBF number 2 includes three changes. Initially it said "[t]ransitional salinity zones inclusive of waters with a gradual downstream gradient of 0.5–30 ppt and soft substrate (*e.g.*, sand, mud) downstream of spawning sites for juvenile foraging and physiological development." The phrase "aquatic habitat" replaces the phrase "transitional salinity zone" because the latter was redundant with "gradual downstream gradient," and we believe the revision better illustrates the river areas we intended to include. Additionally, the phrase "between the river mouths and spawning sites" replaces "downstream of spawning sites." As previously written, we were concerned the public might construe "downstream of spawning sites" to included bays or sounds below rkm 0; this was not our intent. We believe the change more accurately reflects the boundaries of critical habitat. Finally, the words "up to as high as" were added after 0.5 and before 30 to clarify acceptable salinity ranges. Because the freshwater inputs vary from year to year, and river to river, it is possible that during a high freshwater flow year, the salinity levels within a unit may never reach 30 ppt. As previously written, the wording suggested that the gradual downstream gradient would have to encompass the entire 0.5–30 ppt salinity range; this was not our intent. This change is meant to acknowledge that the entire salinity range is not required.

18. In PBF number 3, we were concerned the term "physical" might be confusing to the public with regards to the full suite of potential barriers that can impede sturgeon movement. As a result, we provided additional examples of physical barriers, including thermal plumes, turbidity, and sound.

19. The phrase "between the river mouths and spawning sites" replaces "downstream of spawning sites" in the language of PBF number 4. This change clarifies the areas designated as critical habitat as described under PBF number 2.

20. For the Carolina and South Atlantic DPSs, paragraph (iii) of PBF

number 4 initially used the terms "optimal" and "suboptimal" when discussing DO and temperature range examples. We were concerned the use of those terms may be misinterpreted as establishing specific, exclusive values. Because there is no single DO level or temperature range that is best for Atlantic sturgeon in terms of habitat avoidance or use, we replaced those terms. The example now states "For example, 6.0 mg/L DO or greater likely supports juvenile rearing habitat, whereas DO less than 5.0 mg/L for longer than 30 days is less likely to support rearing when water temperature is greater than 25 °C." Our example language for temperature ranges has also been updated to state: "Temperatures of 13 to 26 °C likely support spawning habitat."

Additionally, an example used in paragraph (iii) of PBF number 4 referenced a single value of DO that was likely to support juvenile rearing habitat (*i.e.,* "For example, 6.0 mg/L DO for juvenile rearing habitat . . ."). The modifier "or greater" has been added to "6.0 mg/L DO" because without it, the current language suggests only a single value of DO is likely to support juvenile rearing habitat, whereas anything above 6.0 mg/L would also be beneficial for the species as discussed in the preamble of the proposed rule.

21. Seven rkms of the Cooper River, South Carolina, are no longer being designated as critical habitat pursuant to section 4(a)(3)(B) of the ESA. Our analysis determined the Joint Base Charleston base has an INRMP that provides an applicable benefit to the species that would have been otherwise afforded by critical habitat, and therefore the area of the Cooper River is not eligible for designation as critical habitat for Atlantic sturgeon.

22. We have clarified our reasoning for determining the upstream extent of each unit in the descriptions of each river.

Critical Habitat Identification and Designation

We used the same approach to identify and designate critical habitat for the five DPSs of Atlantic sturgeon. However, our approach for designating critical habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon was described in the supplemental information to the Impacts Analysis, whereas our approach for designating critical habitat for the Carolina and South Atlantic DPSs of Atlantic Sturgeon was described in the proposed rule (81 FR 36077; June 3, 2016). Therefore, much of the information in the Impacts Analysis and proposed rule is repeated in this final rule that designates critical habitat for the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs of Atlantic sturgeon to show that we used the same approach for all five DPSs.

Critical habitat represents the habitat that contains the PBFs that are essential to the conservation of the listed species and that may require special management considerations or protection (78 FR 53058; August 28, 2013). For example, specifying the geographical location of critical habitat facilitates implementation of section 7(a)(1) of the ESA by identifying areas where Federal agencies can focus their conservation programs and use their authorities to further the purposes of the ESA by carrying out programs for the conservation of listed species. Designating critical habitat also provides a significant regulatory protection by ensuring that the Federal Government considers the effects of its actions in accordance with section 7(a)(2) of the ESA and avoids or modifies those actions that are likely to destroy or adversely modify critical habitat. This requirement is in addition to the section 7 requirement that Federal agencies ensure that their actions are not likely to jeopardize the continued existence of ESA-listed species. Critical habitat requirements do not apply to citizens engaged in activities on private land that do not involve a Federal agency. However, designating critical habitat can help focus the efforts of other conservation partners (*e.g.,* State and local governments, individuals and nongovernmental organizations).

Critical habitat is defined by section 3 of the ESA as (1) the specific areas within the geographical area occupied by the species, at the time it is listed, on which are found those physical or biological features (a) essential to the conservation of the species and (b) which may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species at the time it is listed, upon a determination by the Secretary that such areas are essential for the conservation of the species (16 U.S.C. 1532(5)(A)). Conservation is defined in section 3 of the ESA as "to use and the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this chapter are no longer necessary" (16 U.S.C. 1532(3)). Therefore, critical habitat includes specific areas within the occupied geographical area of the species at the time of listing that contains the features essential for the species' recovery. Critical habitat may also include unoccupied areas determined to be essential to species' conservation and recovery. However, section 3(5)(C) of the ESA clarifies that except in those circumstances determined by the Secretary, critical habitat shall not include the entire geographical area which can be occupied by the threatened or endangered species.

To identify and designate critical habitat, we considered information on the distribution of Atlantic sturgeon, the major life stages, habitat requirements of those life stages, and conservation objectives that can be supported by identifiable PBFs. In the final rule listing the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon (77 FR 5880; February 6, 2012), destruction, modification or curtailment of habitat, overutilization, lack of regulatory mechanisms for protecting the fish, and other natural or manmade factors (*e.g.,* vessel strikes) were found to be the threats contributing to the threatened status of the Gulf of Maine DPS, and the endangered status of the New York Bight and Chesapeake Bay DPS. In the final rule listing the Carolina and South Atlantic DPSs of Atlantic sturgeon (77 FR 5978; February 6, 2012), habitat curtailment and alteration, bycatch in commercial fisheries, and inadequacy of existing regulatory mechanisms were found to be the threats contributing to the endangered status of both DPSs. The Carolina and South Atlantic DPSs were found to be at 3 percent and 6 percent of their historical abundances, respectively, due to these threats. Therefore, we evaluated PBFs of the marine, estuarine, and riverine habitats of Atlantic sturgeon to determine what PBFs are essential to the conservation of each DPS.

Accordingly, our step-wise approach for identifying potential critical habitat areas for the five Atlantic sturgeon DPSs was to determine: The geographical area occupied by each DPS at the time of listing; the PBFs essential to the conservation of the DPSs; whether those PBFs may require special management considerations or protection; the specific areas of the occupied geographical area where these PBFs occur; and, whether any unoccupied areas are essential to the conservation of any DPS.

Geographical Area Occupied by the Species

"Geographical area occupied by the species" in the definition of critical habitat is interpreted to mean the entire

range of the species at the time it was listed, inclusive of all areas they use and move through seasonally (81 FR 7413; February 11, 2016). The marine ranges of the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs of Atlantic sturgeon extend from the Hamilton Inlet, Labrador, Canada, to Cape Canaveral, Florida, USA (77 FR 5880 and 77 FR 5978; February 6, 2012). We did not consider geographical areas within Canadian jurisdiction (*e.g.*, Minas Basin, Bay of Fundy), because we cannot designate critical habitat areas outside of U.S. jurisdiction (50 CFR 424.12(g)).

The listing rules identified the known spawning rivers for each of the Atlantic sturgeon DPSs but did not describe the in-river ranges for the DPSs. The river ranges of each DPS consist of all areas downstream of the first obstacle to upstream migration (*e.g.*, the lowest dam without fish passage for sturgeon or significant waterfalls at the fall line) on each river within the range of the DPS. We identified the Gulf of Maine DPS in-river range as occurring in the watersheds from the Maine/Canadian border and extending southward to include all associated watersheds draining into the Gulf of Maine as far south as Chatham, Massachusetts. We identified the New York Bight DPS in-river range as occurring in the watersheds that drain into coastal waters, including Long Island Sound, the New York Bight, and Delaware Bay, from Chatham, Massachusetts to the Delaware-Maryland border on Fenwick Island. We identified the Chesapeake Bay DPS in-river range as occurring in the watersheds that drain into the Chesapeake Bay and into coastal waters from the Delaware-Maryland border on Fenwick Island to Cape Henry, Virginia. We identified the Carolina DPS in-river range as occurring in the watersheds (including all the rivers and tributaries) from Albemarle Sound, North Carolina, to Charleston Harbor, South Carolina. We identified the South Atlantic DPS in-river range as occurring in the watersheds (including all the rivers and tributaries) from the Ashepoo-Combahee-Edisto (ACE) Basin in South Carolina to the St. Johns River, Florida.

Physical or Biological Features Essential for Conservation That May Require Special Management Considerations or Protection

Within the geographical area occupied by the species, critical habitat consists of specific areas on which are found those PBFs essential to the conservation of the species and that may require special management considerations or protection. PBFs are defined as the features that support the life-history needs of the species, including water characteristics, soil type, geological features, sites, prey, vegetation, symbiotic species, or other features. A feature may be a single habitat characteristic, or a more complex combination of habitat characteristics. Features may include habitat characteristics that support ephemeral or dynamic habitat conditions. Features may also be expressed in terms relating to principles of conservation biology, such as patch size, distribution distances, and connectivity (50 CFR 424.02).

The ability of subadults to find and access food is necessary for continued survival, growth, and physiological development to the adult life stage. Likewise, given that Atlantic sturgeon mature late and do not necessarily spawn annually, increased adult survival would improve the chances that adult Atlantic sturgeon spawn more than once. We determined that facilitating increased survival of all Atlantic sturgeon life stages as well as successful adult reproduction, and juvenile and subadult recruitment into the adult population, would likely increase the abundance of each DPS. We considered these conservation objectives to help us identify the physical or biological features of the critical habitat designations when we reviewed the literature describing the various types of habitat used by the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs of Atlantic sturgeon for the various life functions.

Within the area occupied by Atlantic sturgeon, we considered the various types of habitat used by the DPSs for various life functions. Atlantic sturgeon spend the majority of their adult lives in offshore marine waters. They are known to travel extensively up and down the East Coast. As summarized in a number of summary documents, including the Atlantic Sturgeon Status Review (ASSRT, 2007) and the ASMFC's review of Atlantic coast diadromous fish habitat (Green *et al.*, 2009), Atlantic sturgeon are benthic foragers and prey upon a variety of species in marine and estuarine environments (Bigelow and Schroeder, 1953; Scott and Crossman, 1973; Johnson *et al.*, 1997; Guilbard *et al.*, 2007; Savoy, 2007; Dzaugis, 2013; McLean *et al.*, 2013). In the ocean, Atlantic sturgeon typically occur in waters less than 50 m deep, travel long distances, exhibit seasonal coastal movements, and aggregate in estuarine and ocean waters at certain times of the year (Vladykov and Greeley, 1963; Holland and Yelverton 1973; Dovel and Berggren, 1983; Dadswell *et al.*, 1984; Gilbert, 1989; Johnson *et al.*, 1997; Rochard *et al.*, 1997; Kynard *et al.*, 2000; Savoy and Pacileo, 2003; Eyler *et al.*, 2004; Stein *et al.*, 2004; Dadswell, 2006; Eyler, 2006; Laney *et al.*, 2007; ASSRT, 2007; Dunton *et al.*, 2010; Erickson *et al.*, 2011; Dunton *et al.*, 2012; Oliver *et al.*, 2013; Wirgin *et al.*, 2015). Several winter congregations of Atlantic sturgeon in the marine environment are known to occur, though the exact location and importance of those areas in the southeast is not known, nor whether Atlantic sturgeon are drawn to particular areas based on PBFs of the habitat. While we can identify general movement patterns and behavior in the marine environment (*e.g.*, aggregating behavior), due to the paucity of data on the DPSs' offshore needs and specific habitat utilization, we could not at this time identify PBFs essential to conservation in the marine environment for any of the DPSs.

Atlantic sturgeon use estuarine areas for foraging, growth, and movement. Atlantic sturgeon subadults and adults in non-spawning condition use estuarine waters seasonally, presumably for foraging opportunities, although evidence in the form of stomach content collection and analysis is limited (Savoy and Pacileo, 2003; Dzaugis, 2013). We considered all studies that have collected Atlantic sturgeon stomach contents. All of the prey species identified are indicative of benthic foraging, but different types of prey were consumed and different substrates were identified for the areas where Atlantic sturgeon were foraging (Bigelow and Schroeder, 1953; Johnson *et al.*, 1997; ASSRT, 2007; Guilbard *et al.*, 2007; Savoy, 2007; Dzaugis, 2013; McLean *et al.*, 2013). Adding to our uncertainty of the PBF(s) that support successful foraging for growth and survival of subadults and adults, Atlantic sturgeon move between estuarine environments in the spring through fall and can occur in estuarine environments during the winter as well (Collins *et al.*, 2000; Savoy and Pacileo, 2003; Simpson, 2008; Balazik *et al.*, 2012). Subadult Atlantic sturgeon spawned in one riverine system may use multiple estuaries for foraging and growth, including those not directly connected to their natal river. The benthic invertebrates that comprise the diet of Atlantic sturgeon are found in soft substrates that are common and widespread in most estuaries. Limited data are available to differentiate areas of preferred prey items or higher prey abundance within or across estuaries. Due to the paucity of data on specific

habitat or resource utilization, we could not at this time identify any specific PBFs essential for the conservation of any of the DPSs that support adult and subadult foraging in estuarine or marine environments.

Atlantic sturgeon spawning behavior and early life history have been extensively studied and are fairly well understood, though the exact location of spawning sites on many rivers (particularly in the Southeast) is not known or can change from time to time as water depth and substrate availability changes. However, there is substantial information in the scientific literature indicating the physical characteristics of Atlantic sturgeon spawning and early life history habitat. Therefore, to evaluate potential critical habitat, we focused on identifying the PBFs that support Atlantic sturgeon reproduction and survival of early life stages.

The scientific literature indicates that Atlantic sturgeon spawning occurs well upstream, at or near the fall line of rivers, over hard substrate consisting of rock, pebbles, gravel, cobble, limestone, or boulders (Gilbert, 1989; Smith and Clugston, 1997). Hard substrate is required so that highly adhesive Atlantic sturgeon eggs have a surface to adhere to during their initial development and young fry can use the interstitial spaces between rocks, pebbles, cobble, etc., to hide from predators during downstream movement and maturation (Gilbert, 1989; Smith and Clugston, 1997).

Very low salinity (*i.e.*, 0.0–0.5 ppt) is another important feature of Atlantic sturgeon spawning habitat. Exposure to even low levels of salinity can kill Atlantic sturgeon during their first few weeks of life; thus, their downstream movement is limited until they can endure brackish waters (Bain *et al.*, 2000). Shortnose sturgeon tend to spawn 200–300 km upriver, preventing the youngest life stages from salt exposure too early in their development (Parker and Kynard, 2005; Kynard, 1997). Parker and Kynard (2005) also noted that long larval/early juvenile downstream movement is common in both shortnose sturgeon from the Savannah River and Gulf sturgeon (a sub-species of Atlantic sturgeon), and that this may be a widespread adaptation of sturgeon inhabiting river systems in the southern United States. Due to their similar life history, Atlantic sturgeon most likely adapted a similar spawning strategy. Therefore, it is essential that the spawning area has low salinity, and that the spawning location is far enough upstream to allow newly-spawned Atlantic sturgeon to develop and mature during their downstream movement before encountering saline water. During their downstream movement, it is important for developing fish to forage in areas of soft substrate and to encounter transitional salinity zones to allow physiological adaptations to higher salinity waters.

Minimum water depths for Atlantic sturgeon spawning are necessary to: (1) Allow adult fish to access spawning substrate, (2) adequately hydrate and aerate newly deposited eggs, and (3) facilitate successful development and downstream movement of newly spawned Atlantic sturgeon. However, water depth at these important spawning areas in the Southeast can be dynamic and portions of rivers may be dry or have little water at times due to natural seasonal river fluctuations, temporary drought conditions, and/or regulation by manmade structures such as dams; thus, these sites require protection to provide consistent services for sturgeon. The scientific literature indicates that Atlantic sturgeon spawn in water depths from 3–27 m (9.8–88.6 ft) (Borodin, 1925; Leland, 1968; Scott and Crossman, 1973; Crance, 1987; Bain *et al.*, 2000). However, much of this information is derived from studies of Atlantic sturgeon in northern United States and Canadian river systems. Atlantic sturgeon in the Southeast are likely spawning in much shallower water depths based on repeated observations by biologists of sturgeon with lacerations on their undersides from moving into extremely shallow water to spawn on hard substrate. Based on the available information, and the body depth and spawning behavior of Atlantic sturgeon, water depths of at least 1.2 m (4 ft) are deep enough to accommodate Atlantic sturgeon spawning.

We considered fluid dynamic features as another potential essential feature of Atlantic sturgeon spawning critical habitat. The scientific literature provides information on the importance of appropriate water velocity within Atlantic sturgeon spawning habitat and provides optimal flows for some rivers. Atlantic sturgeon spawn directly on top of gravel in fast flowing sections often containing eddies or other current breaks. Eddies promote position holding between spawning individuals, trap gametes facilitating fertilization, and diminish the probability of egg dislocation by currents—facilitating immediate adhesion of eggs to the gravel substrate (Sulak and Clugston, 1999). However, velocity data are lacking for many rivers, and where data are available, the wide fluctuations in velocity rates on a daily, monthly, seasonal, and annual basis make it difficult to identify a range of water velocity necessary for the conservation of the species. However, we do know that water flow must be continuous.

Adult Atlantic sturgeon must be able to safely and efficiently move from downstream areas into upstream spawning habitats in order to successfully spawn. In addition, larvae and juvenile Atlantic sturgeon must be able to safely and efficiently travel from the upstream spawning areas downstream to nursery and foraging habitat. Therefore, an essential PBF for Atlantic sturgeon spawning is unobstructed migratory pathways for safe movement of adults to and from upstream spawning areas as well as safe movement for the larvae and juveniles moving downstream. An unobstructed migratory pathway means an unobstructed river or a dammed river that still allows for passage.

Water quality can be a critically limiting factor to Atlantic sturgeon in the shallow, warm, poorly oxygenated rivers of the southeast United States. Conditions in these river systems can change rapidly, particularly in rivers managed for hydropower production, and conditions can quickly become suboptimal or lethal for sturgeon. We considered essential water quality PBFs that support movement and spawning of adults and growth and development of juvenile Atlantic sturgeon. The distribution of Atlantic sturgeon juveniles in the natal estuary is a function of physiological development and habitat selection based on water quality factors of temperature, salinity, and DO, which are inter-related environmental variables. In laboratory studies with salinities of 8 to 15 ppt and temperatures of 12 and 20 °C, juveniles less than a year old had reduced growth at 40 percent DO saturation, grew best at 70 percent DO saturation, and selected conditions that supported growth (Niklitschek and Secor, 2009 I; Niklitschek and Secor, 2009 II). Results obtained for age-1 juveniles (*i.e.*, greater than 1 year old and less than 2 years old) indicated that they can tolerate salinities of 33 ppt (*i.e.*, a salinity level associated with seawater), but grow faster in lower salinity waters (Niklitschek and Secor, 2009 I; Allen *et al.*, 2014). The best growth for both age groups occurred at DO concentrations greater than 6.5 mg/L. While specific DO concentrations at temperatures considered stressful for Atlantic sturgeon are not available, instantaneous minimum concentrations of 4.3 mg/L protect survival of shortnose sturgeon at temperatures greater than 29 °C (EPA, 2003). Secor and Niklitschek (2001) report shortnose sturgeon are

more tolerant of higher temperatures than Atlantic sturgeon. This is why Campbell and Goodman (2003) considered 29 °C a stressful temperature for shortnose sturgeon, while Secor and Gunderson (1998) report Atlantic sturgeon becoming stressed at a lower threshold of 26 °C.

In summary, within the area occupied by Atlantic sturgeon, we considered the various types of habitat used by the species for various life functions. We determined that Atlantic sturgeon spend the majority of their adult lives in offshore marine waters where they are known to travel extensively up and down the East Coast. However, we could not identify any PBFs in marine waters essential to the conservation of the species. We also determined Atlantic sturgeon subadults and adults use estuarine areas for foraging, growth, and movement. The ability of subadults to find and access food is necessary for continued survival, growth, and physiological development to the adult life stage. Likewise, given that Atlantic sturgeon mature late and do not necessarily spawn annually, increased adult survival would improve the chances that adult Atlantic sturgeon spawn more than once. Therefore, we determined a conservation objective for the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs is to increase the abundance of each DPS by facilitating increased survival of all life stages. After examining the information available on spawning and early life history behavior and habitat, we also concluded that facilitating adult reproduction and juvenile and subadult recruitment into the adult population are other conservation objectives for the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs of Atlantic sturgeon. We could not identify any specific PBFs essential to the conservation of the species that support adult and subadult foraging in estuarine or marine environments. We determined that protecting spawning areas, juvenile development habitat, the in-river habitats that allow adults to reach the spawning areas and newly spawned sturgeon to make a safe downstream migration, and water quality to support all life stages, will facilitate meeting the conservation objectives discussed above.

Given the biological needs and tolerances, and environmental conditions for Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon as summarized previously, and the habitat-based conservation objectives, we identified the following PBFs essential to their conservation. As we have discussed, these PBFs may be ephemeral or vary spatially across time. Thus, areas designated as critical habitat are not required to have the indicated values at all times and within all parts of the area:

- Hard bottom substrate (*e.g.*, rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (*i.e.*, 0.0–0.5 ppt range) for settlement of fertilized eggs, refuge, growth, and development of early life stages;
- Aquatic habitat with a gradual downstream salinity gradient of 0.5 up to as high as 30 ppt and soft substrate (*e.g.*, sand, mud) between the river mouth and spawning sites for juvenile foraging and physiological development;
- Water of appropriate depth and absent physical barriers to passage (*e.g.*, locks, dams, thermal plumes, turbidity, sound, reservoirs, gear, etc.) between the river mouth and spawning sites necessary to support: Unimpeded movements of adults to and from spawning sites; seasonal and physiologically dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary, and; staging, resting, or holding of subadults or Spawning condition adults. Water depths in main river channels must also be deep enough (*e.g.*, at least 1.2 m) to ensure continuous flow in the main channel at all times when any sturgeon life stage would be in the river, and
- Water, between the river mouth and spawning sites, especially in the bottom meter of the water column, with the temperature, salinity, and oxygen values that, combined, support: Spawning; annual and interannual adult, subadult, larval, and juvenile survival; and larval, juvenile, and subadult growth, development, and recruitment (*e.g.*, 13 °C to 26 °C for spawning habitat and no more than 30 °C for juvenile rearing habitat, and 6 mg/L or greater DO for juvenile rearing habitat).

Given the biological needs and tolerances, and environmental conditions for Atlantic sturgeon in rivers of the Southeast as summarized previously, and the habitat-based conservation objectives, we identified the following PBFs essential to Atlantic sturgeon conservation. As we have discussed, these PBFs may be ephemeral or vary spatially across time. Thus, areas designated as critical habitat are not required to have the indicated values at all times and within all parts of the area:

- Hard bottom substrate (*e.g.*, rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (*i.e.*, 0.0–0.5 ppt range) for settlement of fertilized eggs and refuge, growth, and development of early life stages;
- Aquatic habitat inclusive of waters with a gradual downstream gradient of 0.5 up to as high as 30 ppt and soft substrate (*e.g.*, sand, mud) between the river mouths and spawning sites for juvenile foraging and physiological development;
- Water of appropriate depth and absent physical barriers to passage (*e.g.*, locks, dams, thermal plumes, turbidity, sound, reservoirs, gear, etc.) between the river mouth and spawning sites necessary to support: (1) Unimpeded movement of adults to and from spawning sites; (2) seasonal and physiologically dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary; and (3) staging, resting, or holding of subadults and spawning condition adults. Water depths in main river channels must also be deep enough (at least 1.2 m) to ensure continuous flow in the main channel at all times when any sturgeon life stage would be in the river.
- Water quality conditions, especially in the bottom meter of the water column, between the river mouths and spawning sites with temperature and oxygen values that support: (1) Spawning; (2) annual and inter-annual adult, subadult, larval, and juvenile survival; and (3) larval, juvenile, and subadult growth, development, and recruitment. Appropriate temperature and oxygen values will vary interdependently, and depending on salinity in a particular habitat. For example, 6.0 mg/L DO or greater likely supports juvenile rearing habitat, whereas DO less than 5.0 mg/L for longer than 30 days is less likely to support rearing when water temperature is greater than 25 °C. In temperatures greater than 26 °C, DO greater than 4.3 mg/L is needed to protect survival and growth. Temperatures of 13 to 26 °C likely support spawning habitat.

Specific Areas Containing the Essential Features Within the Geographical Area Occupied by the Species

The definition of critical habitat instructs us to identify specific areas on which the PBFs essential to the species' conservation are found. Our regulations state that critical habitat will be defined by specific limits using reference points and lines on standard topographic maps of the area, and referencing each area by the state, county, or other local governmental unit in which it is located (50 CFR 424.12(c)). To identify where the PBF(s) occur within areas occupied by Atlantic sturgeon, we reviewed the best scientific information available,

including the 2007 Atlantic sturgeon status review (ASSRT, 2007), the ESA listing rules (77 FR 5880 and 77 FR 5914; February 6, 2012), scientific research reports, information and data gathered during the peer-review process, and a database developed by the U.S. Geological Survey for mapping environmental parameters within East Coast rivers to identify sturgeon habitat. We also considered information on the location of sturgeon spawning activity from scientific reports, as active spawning in an area would indicate that the PBF(s) necessary for spawning are likely present. As noted previously, while we used the same approach for designating critical habitat for the five DPSs, the Impacts Analysis and Biological Source Document for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs describes that approach for those DPSs and therefore is not repeated here. Because the critical habitat designation approach and information on specific rivers within the range of the Carolina and South Atlantic DPSs was described in the proposed rule, and not in a separate document, it is provided here for reference.

Information on documented spawning in specific areas in the Southeast is rare, but some does exist. For example, large sections of the Altamaha River have been found to support Atlantic sturgeon spawning activities for many years (Peterson *et al.*, 2006; Peterson *et al.*, 2008). We reviewed reports from a NMFS-funded multi-year, multi-state research project on movement and migration of Atlantic sturgeon (Species Recovery Grant number NA10NMF4720036, Post *et al.*, 2014). In these reports, researchers determined which portions of Southeastern rivers support spawning activities by looking at the upriver extent of sturgeon movements during spawning season.

There are large areas of most rivers where data are still lacking. The available data also may represent a snapshot in time, while the exact location of a habitat feature may change over time (*e.g.*, water depth fluctuates seasonally, as well as annually, and even hard substrate may shift position). For example, some data indicate a change in substrate type within a given location from year to year (*e.g.*, from sand to gravel). It is not always clear whether such changes are due to an actual shift in substrate sediments or if the substrate sample was collected in a slightly different location between samplings. Although the habitat features may vary even at the same location, if any of the available data regarding a particular feature fell within the suitable range (*e.g.*, salinity of 0–0.5 ppt or hard substrate [gravel, cobble, etc.]), we considered that the essential PBF is present in the area.

For Southeast rivers, when data were not available for certain rivers or portions of occupied rivers, we used our general knowledge of Atlantic sturgeon spawning and applied river-specific information to determine the location of PBFs essential to spawning. We considered salinity tolerance during the earliest life stages to determine appropriate habitat for larvae to develop as they mature. Available telemetry data suggest that most Atlantic sturgeon spawning activity in the Savannah and Altamaha Rivers starts around rkm 100 (Post *et al.*, 2014). Similar evidence from the Edisto, Neuse, and Tar-Pamlico Rivers indicates spawning activity starts around rkm 80. Peer review comments on the Draft Economic and Biological Information to Inform Atlantic Sturgeon Critical Habitat Designation (for the Carolina and Southeast DPSs) indicated that Atlantic sturgeon spawn below the fall line, unlike shortnose sturgeon that may spawn well above the fall line.

To encompass all areas important for Atlantic sturgeon spawning, reproduction, and recruitment within rivers where spawning is believed to occur or may occur, we identified specific areas of critical habitat from the mouth (rkm 0) of each spawning river to the upstream extent of the spawning habitat. For rivers that are not dammed and do not reach the fall line, an easily identifiable landmark (*e.g.*, a dam or a bridge) was located to serve as the upstream boundary of the units. Similarly, the ordinary high water mark on the banks of the rivers encompasses all areas that are expected to contain one or more of the PBFs and provides an easily identifiable lateral boundary for the units.

To identify specific habitats used by an Atlantic sturgeon DPS in occupied rivers, we considered the best scientific information available that described: (1) Capture location and/or tracking locations of Atlantic sturgeon identified to its DPS by genetic analysis; (2) capture location and/or tracking locations of adult Atlantic sturgeon identified to its DPS based on the presence of a tag that was applied when the sturgeon was captured as a juvenile in its natal estuary; (3) capture or detection location of adults in spawning condition (*i.e.*, extruding eggs or milt) or post-spawning condition (*e.g.*, concave abdomen for females); (4) capture or detection of YOY and other juvenile age classes; and (5) collection of eggs or larvae.

Several large coastal rivers within the geographical area occupied by the Carolina and South Atlantic DPSs of Atlantic sturgeon do not appear to support spawning and juvenile recruitment or to contain suitable habitat features to support spawning. These rivers are the Chowan and New Rivers in North Carolina; the Waccamaw (above its confluence with Bull Creek which links it to the Pee Dee River), Sampit, Ashley, Ashepoo, and Broad-Coosawhatchie Rivers in South Carolina; and the St. Johns River in Florida. We have no information, current or historical, of Atlantic sturgeon using the Chowan and New Rivers in North Carolina. Recent telemetry work by Post *et al.* (2014) indicates that Atlantic sturgeon do not use the Sampit, Ashley, Ashepoo, and Broad-Coosawhatchie Rivers in South Carolina. These rivers are short, coastal plains rivers that most likely do not contain suitable habitat for Atlantic sturgeon. Post *et al.* (2014) also found Atlantic sturgeon only use the portion of the Waccamaw River downstream of Bull Creek. Due to manmade structures and alterations, spawning areas in the St. Johns River are not accessible and therefore do not support a reproducing population. For these reasons, we are not designating these coastal rivers, or portions of the rivers, as critical habitat. For rivers we are proposing to designate as critical habitat, we have historical or current information that they support spawning and juvenile recruitment as described below.

Roanoke River

The Roanoke River was identified as a spawning river for Atlantic sturgeon based on the capture of juveniles, the collection of eggs, and the tracking location of adults. Further, there was information indicating the historical use of the Roanoke River by Atlantic sturgeon.

Atlantic sturgeon were historically abundant in the Roanoke River and Albemarle Sound, but declined dramatically in response to intense fishing effort in the late 1800s (Armstrong and Hightower, 2002). There is still a population present in the Albemarle Sound and Roanoke River (Armstrong and Hightower, 2002; Smith *et al.*, 2015). DNA analyses of juveniles captured in Albemarle Sound indicate that these fish are genetically distinct from Atlantic sturgeon collected in other systems (Wirgin *et al.*, 2000; King *et al.*, 2001).

Historical records and recent research provide accounts of Atlantic sturgeon spawning within the fall zone (rkm 204–242) of the Roanoke River (Yarrow, 1874; Worth, 1904; Armstrong and Hightower, 2002; Smith *et al.*, 2015).

Atlantic sturgeon remains from archaeological sites on the Roanoke River have been found as far upstream as rkm 261, approximately 19 miles (30.5 km) above the upper end of the fall zone (VanDerwarker, 2001; Armstrong and Hightower, 2002); however, that was prior to the construction of dams now located throughout the river. The farthest downstream dam, the Roanoke Rapids Dam, is located near the fall line at rkm 221. No fish passage exists at this dam, so all Atlantic sturgeon are restricted to the lower 17 rkm of fall zone habitat, which extends from the Roanoke Rapids Dam to Weldon, North Carolina at rkm 204 (Armstrong and Hightower, 2002; Smith *et al.*, 2015).

Historical and current data indicate that spawning occurs in the Roanoke River, where both adults and small juveniles have been captured. Since 1990, the NCDMF has conducted the Albemarle Sound Independent Gill Net Survey (IGNS). From 1990 to 2006, 842 sturgeon were captured ranging from 15.3 to 100 cm fork length (FL), averaging 47.2 cm FL. One hundred and thirty-three (16 percent) of the 842 sturgeon captured were classified as YOY (41 cm total length (TL), 35 cm FL); the others were subadults (ASSRT, 2007). A recent study by Smith *et al.* (2015), using acoustic telemetry data and egg collection during the fall of 2013, identified a spawning location near Weldon, North Carolina (rkm 204). The location contains the first shoals encountered by Atlantic sturgeon as they move upstream to spawn (Smith *et al.*, 2015). The channel in this area is approximately 100 m wide and the substrate is primarily bedrock, along with fine gravel and coarse sediments in low-flow areas (Smith *et al.*, 2015). During the study, 38 eggs were collected during 21 days that spawning pads were deployed (Smith *et al.*, 2015).

A scientific survey also shows the presence of adult Atlantic sturgeon in the Roanoke River. Using side-scan sonar, Flowers and Hightower (2015) conducted surveys near the freshwater-saltwater interface with repeated surveys performed over 3 days. The surveys detected 4 Atlantic sturgeon greater than 1 m TL. Based on these detections, an abundance estimate for riverine Atlantic sturgeon of 10.9 (95 percent confidence interval 3–36) fish greater than 1 m was calculated for the Roanoke River. This estimate does not account for fish less than 1 m TL, occurring in riverine reaches not surveyed, or in marine waters.

Tar-Pamlico River

The Tar-Pamlico River was identified as a spawning river for Atlantic sturgeon based on the evidence of spawning and the capture of juveniles. The Tar-Pamlico River, one of two major tributaries to Pamlico Sound, is dammed. However, all riverine spawning habitat is accessible to Atlantic sturgeon in the Tar-Pamlico River, because the lower-most dam, the Rocky Mount Mill Pond Dam (rkm 199), is located at the fall line.

Evidence of spawning was reported by Hoff (1980), after the capture of very young juveniles in the Tar River. Two juveniles were observed dead on the bank of Banjo Creek, a tributary to the Pamlico System (ASSRT, 2007). A sampling program similar to the Albemarle Sound IGNS collected 14 Atlantic sturgeon in 2004. These fish ranged in size from 460 to 802 mm FL and averaged 575 mm FL. The NCDMF Observer Program reported the capture of 12 Atlantic sturgeon in the Pamlico Sound from April 2004 to December 2005; these fish averaged 600 mm TL (ASSRT, 2007).

Neuse River

The Neuse River was identified as a spawning river for Atlantic sturgeon based on the capture of small juveniles. Bain (1997) reports that "early juveniles" (20–440 mm FL) remain in their natal rivers until they become "intermediate juveniles" (450–630 mm FL) and begin gradually emigrating from the river during periods of rapid growth. Hoff (1980) reports sturgeon studies in the Neuse and Pamlico Rivers and Pamlico Sound captured low numbers of small (400–600 mm TL) sturgeon. The NCDMF Observer Program and an independent gill net survey report the captures of Atlantic sturgeon in the Neuse River were low during the period 2001–2003, ranging from zero to one fish/year. However, in 2004, this survey collected 5 Atlantic sturgeon ranging from 470–802 mm FL; none could be classified as early juveniles and 3 could be classified as intermediate juveniles. In 2005, 23 Atlantic sturgeon were captured ranging from 365–650 mm FL; 9 could be classified as early juveniles and 14 could be classified as intermediate juveniles. From 2006–2013, another nine Atlantic sturgeon were captured ranging in size from 480–2,300 mm FL; the most caught in any given year during that period was four (2004). Of those nine animals, none would be classified as early juveniles but four could be classified as intermediate juveniles. One 720 mm TL Atlantic sturgeon was captured in 2014. Seventeen Atlantic sturgeon were caught in 2015 ranging in size from 365–1,435 mm FL; four could be classified as early juveniles and eight could be classified as intermediate juveniles. In 2016, three Atlantic sturgeon were captured ranging in size from 464–656 mm FL; none could be classified as early juveniles and two could be classified as intermediate juveniles (M. Loeffler, NCDMF, to A. Herndon, NMFS, pers. comm. March 2017). From 2002–2003, four Atlantic sturgeon (561–992 mm FL) were captured by North Carolina State University personnel sampling in the Neuse River (Oakley, 2003). Similarly, the NCDMF Observer Program documented the capture of 12 Atlantic sturgeon in the Pamlico Sound from April 2004 to December 2005; none of these were YOY or spawning adults, averaging approximately 600 mm TL (ASSRT, 2007). Three additional specimens of YOY captured in the Neuse River in 1974 were found in a collection at North Carolina State University (J. Hightower, NCSU, to A. Herndon, NMFS, pers. comm. March 2017). An additional record of a YOY captured in the Neuse River in 1974, was provided by the North Carolina Museum of Natural Sciences (G. Hogue, NCMNS, to A. Herndon, NMFS, pers. comm. March 2017). Because sturgeon cannot pass above the Milburnie Dam, we believe that dam is likely the farthest upstream extent of spawning habitat accessible to Atlantic sturgeon.

Cape Fear River System

The Cape Fear and Northeast Cape Fear Rivers were identified as spawning rivers for Atlantic sturgeon based on the capture of juveniles, the capture of adults in spawning condition, and the tracking location of adults, and information indicating the historical use by Atlantic sturgeon. In the late 1800s, the Cape Fear River had the largest landings of sturgeon in the southeastern United States (Moser and Ross, 1995). While species identification (*i.e.*, shortnose or Atlantic sturgeon) is not possible, these landings suggest large populations of both species. The Cape Fear River is tidally influenced by diurnal tides up to at least rkm 96, and is also dredged extensively to maintain a depth of 12 m up to rkm 49 and then a depth of 4 m up to Lock and Dam #1. There are numerous deep holes (>10 m) throughout this extent.

A gill net survey for adult shortnose and juvenile Atlantic sturgeon was conducted in the Cape Fear River drainage from 1990 to 1992, and replicated from 1997 to 2005. Each sampling period included two overnight sets. The 1990–1992 survey captured 100 Atlantic sturgeon below Lock and Dam #1 (rkm 95). In 1997, 16 Atlantic sturgeon were captured below Lock and

Dam #1, an additional 60 Atlantic sturgeon were caught in the Brunswick (a tributary of the Cape Fear River), and 12 were caught in the Northeast Cape Fear River (Moser *et al.* 1998). Additionally, Ross *et al.* (1988 in Moser and Ross, 1995) reported the capture of a gravid female in the Cape Fear River.

Recent telemetry work conducted in the Cape Fear and Northeast Cape Fear Rivers showed that subadult Atlantic sturgeon movement and distribution followed seasonal patterns (Loeffler and Collier in Post *et al.*, 2014). During summer months, Atlantic sturgeon distribution was shifted upriver with limited large-scale movements; during the coldest time of year, subadult fish were absent from the rivers and had migrated to the estuary or ocean (Loeffler and Collier in Post *et al.*, 2014). The high inter-annual return rates of tagged fish to the system demonstrate that Atlantic sturgeon have fidelity to these rivers; this implies that the Cape Fear River system may be the natal system for these fish (Loeffler and Collier in Post *et al.*, 2014).

Further evidence of the importance of this system is demonstrated by the movement patterns of one of five adult Atlantic sturgeon tagged during the study that has shown site fidelity. This individual fish was in ripe and running condition at the time of tagging. This fish subsequently returned to the Cape Fear River system each of the following years (2013 and 2014) and has been detected farther upstream in both the Cape Fear (rkm 95) and Northeast Cape Fear (rkm 132) rivers than any tagged subadult fish during this study. This fish did not use the fish passage rock arch ramp at Lock and Dam #1; however, at the time when it was present at the base of the dam, the rock arch ramp structure was only partially complete. In all years of the study this fish had movement patterns that are consistent with spawning behavior, and this demonstrates that both the Northeast Cape Fear and Cape Fear Rivers may be important spawning areas. While telemetry data have not indicated Atlantic sturgeon presence above Lock and Dam #1, we believe the fish passage present at the dam is successful or that fish pass through the lock. We base this determination on reports of Atlantic sturgeon above Lock and Dam #1 (F. Rohde, NMFS, pers. comm. to J. Rueter, NMFS, July 14, 2015). Because sturgeon cannot currently pass above the Lock and Dam #2, we believe that dam is likely the farthest upstream extent of spawning habitat currently accessible to Atlantic sturgeon in the occupied unit of the river. The Northeast Cape River is not dammed and does not extend all the way to the fall line. For these reasons we used an easily identifiable landmark (*e.g.*, upstream side of Rones Chapel Road Bridge) to serve as the upstream boundary.

Pee Dee River System

The Pee Dee River System was identified as providing spawning habitat used by Atlantic sturgeon based on the capture of juveniles, the capture of adults in spawning condition, and the tracking location of adults. Captures of age-1 juveniles from the Waccamaw River during the early 1980s suggest that a reproducing population of Atlantic sturgeon existed in that river, although the fish could have been from the nearby Pee Dee River (Collins and Smith 1997). Additionally, telemetry data from tagged adult Atlantic sturgeon appear to show individuals making spawning runs into the Pee Dee River by traveling up the Waccamaw River, through Bull Creek, and into the Pee Dee River. (B. Post, SCDNR, pers. comm. to J. Rueter, NMFS, July 9, 2015).

Based on preliminary analyses of sturgeon detections during their study, Post *et al.* (2014) concluded the Pee Dee River system appears to be used by Atlantic sturgeon for summer/winter seasonal habitat as well as for spawning. From 2011 to 2014, 41 sturgeon were detected in upstream areas of the Pee Dee River that were considered to be spawning areas. All 10 Atlantic sturgeon that were originally implanted with transmitters in the Pee Dee System were later detected displaying upstream and downstream movement. Distinct movement patterns were evident for these fish as similar patterns were observed each year of the study period. Two of the 10 fish originally tagged in the Pee Dee System and many tagged fish from other systems made spawning runs in the Pee Dee River (Post *et al.*, 2014). The fall line is located approximately 35 rkm below Blewett Falls Dam, which is impassable to sturgeon. Thus, we believe the dam represents the upstream extent of spawning habitat accessible to Atlantic sturgeon on the Pee Dee River system.

Black River, South Carolina

The Black River was identified as a spawning river for Atlantic sturgeon based on the capture of juveniles and the tracking location of adults. During a telemetry study from 2011 to 2014, Post *et al.* (2014) detected 10 juveniles and 10 adults using the Black River. An adult male was detected at the last receiver station in the river one year (rkm 70.4) and the next to last receiver station in a subsequent year. While the receiver stations were not at the fall line, they were very far upriver, and it is likely that the only reason this fish traveled so far upriver was to spawn (B. Post, SCDNR, pers. comm. to J. Rueter, NMFS PRD, July 9, 2015). Juveniles were located as far upstream as rkm 42.1, suggesting the Black River is also an important foraging/refuge habitat. The main stem of the Black River becomes braided before reaching the fall line and is no longer identifiable above Interstate Highway 95. Thus, setting the boundary at that highway includes the upstream extent of spawning habitat within the unit.

Santee and Cooper Rivers

The Santee-Cooper River system was identified as a spawning river system for Atlantic sturgeon based on the capture of YOY. The Santee River basin is the second largest watershed on the Atlantic Coast of the United States; however, with the completion of Wilson Dam in the 1940s, upstream fish migrations were restricted to the lowermost 145 rkms of the Santee River. Following construction of the Wilson and Pinopolis Dams, the connectivity between the coastal plain and piedmont was lost. In the 1980s, a fish passage facility at the St. Stephen powerhouse, designed to pass American shad and blueback herring, was completed that attempted to restore connectivity throughout the system. The passage facility has not been successful for Atlantic sturgeon (Post *et al.*, 2014). However, in 2007 an Atlantic sturgeon entered the fish passage facility at the fishway to the lift, presumably in an attempt to migrate upstream to spawn, and was subsequently physically removed and then released downstream into the Santee River (A. Crosby, SCDNR, pers. comm.).

Historically, the Cooper River was a small coastal plain river that fed into Charleston Harbor. The completion of the Santee Cooper hydropower project in the 1940s dramatically changed river discharge in the Cooper River. From the 1940s into the 1980s, nearly all river discharge of the Santee River was diverted through the Santee Cooper project, run through the hydroelectric units in Pinopolis Dam, and discharged down the Tailrace Canal and into the Cooper River. In the 1980s, the Rediversion Project redirected part of the system's discharge back to the Santee River; however, a significant discharge of freshwater still flows into the Cooper River. The Cooper River provides the dominant freshwater input for the Charleston Harbor and provides 77 rkm of riverine habitat (Post *et al.*, 2014).

The capture of 151 subadults, including age-1 fish, from 1970–1995 indicates a population exists in the Santee River (Collins and Smith, 1997). Four juvenile Atlantic sturgeon, including YOY, were captured in the winter of 2003, one in the Santee and three in the Cooper Rivers (McCord, 2004). These data support the existence of a spawning population, but SCDNR biologists working in the Santee-Cooper system believe the smaller fish are pushed into the system from the Pee Dee and/or Waccamaw Rivers during flooding conditions (McCord, 2004). This hypothesis is based on the lack of access to suitable spawning habitat due to the locations of the Wilson Dam on the Santee River, the St. Stephen Powerhouse on the Rediversion Canal, and the Pinopolis Dam on the Cooper River. Nonetheless, the Santee-Cooper River system appears to be important foraging and refuge habitat and could serve as important spawning habitat once access to historical spawning grounds is restored through a fishway prescription under the FPA (NMFS, 2007). In addition, hard substrate that could be used for spawning exists in the reach of the Santee River below the Wilson Dam, but has been rendered inaccessible by inadequate flow regimes below the dam. We anticipate this will be addressed in the new hydropower license for the Santee-Cooper project.

In a recent telemetry study by Post *et al.* (2014), four Atlantic sturgeon were tagged in the Santee River from 2011 to 2014. Of these four, one was detected in the river, one was detected at the mouth of the river, and the other two have not been detected in the Santee River system since being tagged. There was no detectable spawning run or pattern of movement for the tagged fish that remained in the Santee River (Post *et al.*, 2014). There were no Atlantic sturgeon captured in the Cooper River during the Post *et al.* (2014) study. There were seven Atlantic sturgeon detected in the Cooper River that had been tagged in other systems. The Atlantic sturgeon that were detected in the Cooper River were more commonly detected in the saltwater tidal zone, with the exception of one that made a presumed spawning run to Pinopolis Dam in the fall of 2013 (Post *et al.*, 2014). The upstream extents of potential spawning habitat available to Atlantic sturgeon in the occupied portions of the Santee and Cooper Rivers are at the Wilson and Pinopolis Dams, respectively.

Edisto River

The Edisto is the largest river in the Ashepoo, Combahee, Edisto (ACE) Basin. It begins in the transition zone between piedmont and coastal plain and is unimpeded for its entire length. It is the longest free flowing blackwater river in South Carolina. During excessive rainy seasons it will inundate lowlands and swamps, and the flow basin increases to a mile (1.6 km) wide or more. The Edisto River was identified as a spawning river for Atlantic sturgeon based on the capture of an adult in spawning condition and capture location and tracking of adults.

Spawning adults (39 in 1998) and YOY (1,331 from 1994–2001) have been captured in the ACE basin (Collins and Smith, 1997; ASSRT, 2007). One gravid female was captured in the Edisto River during sampling efforts in 1997 (ASSRT, 2007). Seventy-six Atlantic sturgeon were tagged in the Edisto River during a 2011 to 2014 telemetry study (Post *et al.*, 2014). After tagging, 58 of the 76 Atlantic sturgeon tagged were detected again in the Edisto River during the study. Distinct movement patterns of Atlantic sturgeon were evident. Fish entered the river between April and June and were detected in the saltwater tidal zone until water temperature decreased below 25 °C. They then moved into the freshwater tidal area, and some fish made presumed spawning migrations in the fall around September–October. Spawning migrations were thought to be occurring based on fish movements upstream to the presumed spawning zone between rkm 78 and 210. Fish stayed in these presumed spawning zones for an average of 22 days. The tagged Atlantic sturgeon left the river system by November. A number of tagged individuals were detected making such movements during multiple years of the study. Only those fish that were tagged in the Edisto River were detected upstream near presumed spawning grounds, while fish detected in the Edisto River, but tagged elsewhere, were not detected near the presumed spawning areas. In the winter and spring, Atlantic sturgeon were generally absent from the system except for a few fish that remained in the saltwater tidal zone (Post *et al.*, 2014). The North and South Forks of the Edisto River represent the upstream boundary for the Edisto River. Both forks occur at or very near the fall line, and likely represent the upstream extent of spawning habitat accessible to Atlantic sturgeon on the Edisto River.

Combahee-Salkehatchie River

The Combahee-Salkehatchie River was identified as a spawning river for Atlantic sturgeon based on capture location and tracking locations of adults and the spawning condition of an adult. Spawning adults (39 in 1998) and YOY (1,331 from 1994–2001) have been captured in the ACE basin (Collins and Smith, 1997; ASSRT, 2007). One running ripe male was captured in the Combahee River during a sampling program in 1997 (ASSRT, 2007). Seven Atlantic sturgeon were captured and five were tagged during a 2010 and 2011 telemetry study (Post *et al.*, 2014). Atlantic sturgeon that were tagged in the Combahee River were absent from the system for the majority of the study period. An Atlantic sturgeon that was tagged in June of 2011 left the system in the fall of 2011, returned in July 2012 and left the system again in the fall of 2012. This fish was detected the farthest upstream of any tagged Atlantic sturgeon in the Combahee River (rkm 56). Another individual was identified as a running ripe male at capture in the Combahee River in March 2011, was detected again exhibiting spawning behavior in the North East Cape Fear River, North Carolina, in March 2012, and in 2014 was detected from February–April in the Pee Dee System. The main stem of the Combahee-Salkehatchie River runs out well before the fall line. Thus, we believe the upstream extent of spawning habitat in the rivers is at the confluence of the Buck and Rosemary Creeks, which also marks the upstream boundary for the Combahee-Salkehatchie River.

Savannah River

The Savannah River was identified as a spawning river for Atlantic sturgeon based on capture location and tracking locations of adults and the collection of larvae. Forty-three Atlantic sturgeon larvae were collected in upstream locations (rkm 113–283) near presumed spawning locations (Collins and Smith, 1997). Seven Atlantic sturgeon were also tagged from 2011 to 2014 and distinct movement patterns were evident (Post *et al.*, 2014). In 2011, one individual was detected travelling upstream in mid-April and remained at a presumed spawning area (rkm 200–301) through mid-September. Two Atlantic sturgeon migrated into the system and upstream to presumed spawning grounds in 2012. The first entered the system in mid-August and returned downriver in mid-September; the other entered the system in mid-September and returned downriver in mid-October. Four Atlantic sturgeon entered the Savannah River and migrated upstream during the late summer and fall months in 2013. Two Atlantic sturgeon previously tagged in the Savannah River made upstream spawning movements; this was the second year (2011) one of these fish was

detected making similar upstream movements. These two fish were also detected immediately upstream of the NSBL&D (rkm 301). It is unknown if they passed through the lock or swam over the dam during high flows. There is a strong possibility that one fish may have been detected by the receiver directly upstream while still remaining downstream of the dam and while flow control gates were in a full open position. Atlantic sturgeon in the Savannah River were documented displaying similar behavior 3 years in a row—migrating upstream during the fall and then being absent from the system during spring and summer. Because sturgeon cannot currently pass above the NSBL&D, we believe that dam is the farthest upstream extent of spawning habitat accessible to Atlantic sturgeon in the occupied reaches of the river.

Ogeechee River

The Ogeechee River was identified as a spawning river for Atlantic sturgeon based on tracking of adults and YOY. Seventeen Atlantic sturgeon (each measuring less than 30 cm TL) considered to be YOY were collected in 2003 by the Army's Environmental and Natural Resources Division (AENRD) at Fort Stewart, Georgia. An additional 137 fish were captured by the AENRD in 2004. Nine of these fish measured less than 41 cm TL and were considered YOY. During a telemetry study from 2011 to 2014, there were no capture or tagging efforts conducted in the Ogeechee River; however, 40 Atlantic sturgeon were detected in the Ogeechee River (Ingram and Peterson, 2016). A rock shoal exists at the fall line on the Ogeechee River. However, it is possible that during certain high flow periods Atlantic sturgeon could pass above those shoals. Instead, the impassable Mayfield Mill Dam likely represents the extent of upstream spawning habitat accessible to Atlantic sturgeon on the Ogeechee River.

Altamaha River

The Altamaha River and its major tributaries, the Oconee and Ocmulgee Rivers, were identified as spawning rivers for Atlantic sturgeon based on capture location and tracking of adults and the capture of adults in spawning condition. The Altamaha River supports one of the healthiest Atlantic sturgeon subpopulations in the Southeast, with over 2,000 subadults captured in trammel nets in a 2003–2005 study, 800 of which were nominally age-1 as indicated by size (ASSRT, 2007). A survey targeting Atlantic sturgeon was initiated in 2003 by the University of Georgia. By October 2005, 1,022 Atlantic sturgeon had been captured using trammel and large gill nets. Two hundred and sixty-seven of these fish were collected during the spring spawning run in 2004 (74 adults) and 2005 (139 adults). From these captures, 308 (2004) and 378 (2005) adults were estimated to have participated in the spring spawning run, representing 1.5 percent of Georgia's historical spawning stock (females) as estimated from U.S. Fish Commission landing records (Schueller and Peterson, 2006; Secor 2002).

In a telemetry study by Peterson *et al.* (2006), most tagged adult Atlantic sturgeon were found between rkm 215 and 420 in October and November when water temperatures were appropriate for spawning. There are swift currents and rocky substrates throughout this stretch of river (Peterson *et al.*, 2006). Two hundred thirteen adults in spawning condition were captured in the Altamaha system in 2004–2005 (Peterson *et al.*, 2006).

Forty-five adult Atlantic sturgeon were captured and tagged from 2011 to 2013 (Ingram and Peterson, 2016). Telemetry data from the tagged individuals indicated that the fish were present in the system from April through December. Twenty-six fish made significant (>160 rkm) migrations upstream with eight fish making the migration in at least two of the years and four making the migration in all three years of the study. No site fidelity was apparent based on these data; however, an upriver site near the confluence of the Ocmulgee (rkm 340–350) was visited by multiple fish in multiple years. Fish migrated upstream into both the Ocmulgee and Oconee Rivers, but the majority entered the Ocmulgee River. The maximum extent of these upriver migrations was rkm 408 in the Ocmulgee River and rkm 356 in the Oconee River (Ingram and Peterson, 2016).

Two general migration patterns were observed for fish in this system. Early upriver migrations that began in April–May typically occurred in two steps, with fish remaining at mid-river locations during the summer months before continuing upstream in the fall. The late-year migrations, however, were typically initiated in August or September and were generally non-stop. Regardless of which migration pattern was used during upstream migration, all fish exhibited a one-step pattern of migrating downstream in December and early January (Ingram and Peterson, 2016). Sinclair Dam is approximately 15 rkm above the fall line on the Oconee River and represents the upstream boundary of critical habitat on the river. The Juliette Dam on the Ocmulgee River is approximately 40 rkm above the fall line and represents the upstream boundary of critical habitat on the river.

Satilla River

The Satilla River was identified as a spawning river for Atlantic sturgeon based on the capture of adults in spawning condition. Ong *et al.* (1996) captured four reproductively mature Atlantic sturgeon on spawning grounds during the spawning season in the Satilla River. The main stem of the Satilla River runs out well before the fall line. Thus, we believe the upstream extent of spawning habitat in the river is at the confluence of the Satilla and Wiggins Creeks.

St. Marys River

The St. Marys River was identified as a spawning river for Atlantic sturgeon based on the capture of YOY Atlantic sturgeon. Atlantic sturgeon were once thought to be extirpated in the St. Marys River. However, nine Atlantic sturgeon were captured in sampling efforts between May 19 and June 9, 2014. Captured fish ranged in size from 293 mm (YOY) to 932 mm (subadult). This is a possible indication of a slow and protracted recovery in the St. Marys (D. Peterson, UGA, pers. comm. to J. Rueter, NMFS PRD, July 8, 2015). The main stem of the St. Marys River runs out well before the fall line. Thus, we believe the upstream extent of spawning habitat in the river is at the confluence of the Middle Prong St. Marys and St. Marys Rivers.

Using this information, we identified 14 areas within the geographical area occupied by the Carolina and South Atlantic DPSs, at the time of listing, that contain the PBFs essential to conservation of the species. Our descriptions of the critical habitat units and PBFs for the Carolina and South Atlantic DPSs use both the terms "river mouth" and "rkm 0." Those terms are interchangeable and we use them as such.

The ordinary high water mark on each bank of the river and shorelines is the lateral extent of the following occupied critical habitat units:

Carolina Unit 1 includes the Roanoke River main stem from the Roanoke Rapids Dam downstream to rkm 0;

Carolina Unit 2 includes the Tar-Pamlico River main stem from the Rocky Mount Millpond Dam downstream to rkm 0;

Carolina Unit 3 includes the Neuse River main stem from the Milburnie Dam downstream to rkm 0;

Carolina Unit 4 includes the Cape Fear River main stem from Lock and

Dam #2 downstream to rkm 0 and the Northeast Cape Fear River from the upstream side of Rones Chapel Road Bridge downstream to the confluence with the Cape Fear River;

Carolina Unit 5 includes the Pee Dee River main stem from Blewett Falls Dam downstream to rkm 0, the Waccamaw River from Bull Creek downstream to rkm 0, and Bull Creek from the Pee Dee River to the confluence with the Waccamaw River;

Carolina Unit 6 includes the Black River main stem from Interstate Highway 95 downstream to rkm 0;

Carolina Unit 7 includes the Santee River main stem from the Wilson Dam downstream to the fork of the North Santee River and South Santee River distributaries, the Rediversion Canal from the St. Stephen Powerhouse downstream to the confluence with the Santee River, the North Santee River from the fork of the Santee River and South Santee River downstream to rkm 0, the South Santee River from the fork of the Santee River and North Santee River downstream to rkm 0, the Tailrace Canal from Pinopolis Dam downstream to the West Branch Cooper River, the West Branch Cooper River from the Tailrace Canal downstream to the confluence with the East Branch Cooper River, and the Cooper River from the confluence of the West Branch Cooper River and East Branch Cooper River tributaries downstream to rkm 0;

South Atlantic Unit 1 includes the North Fork Edisto River from Cones Pond downstream to the confluence with the South Fork Edisto River, the South Fork Edisto River from Highway 121 downstream to the confluence with the North Fork Edisto River, the Edisto River main stem from the confluence of the North Fork Edisto River and South Fork Edisto River tributaries downstream to the fork at the North Edisto River and South Edisto River distributaries, the North Edisto River from the Edisto River downstream to rkm 0, and the South Edisto River from the Edisto River downstream to rkm 0;

South Atlantic Unit 2 includes the main stem Combahee—Salkehatchie River from the confluence of Buck and Rosemary Creeks with the Salkehatchie River downstream to the Combahee River, and the Combahee River from the Salkehatchie River downstream to rkm 0;

South Atlantic Unit 3 includes the main stem Savannah River from the New Savannah Bluff Lock and Dam downstream to rkm 0;

South Atlantic Unit 4 includes the main stem Ogeechee River from the Mayfield Mill Dam downstream to rkm 0;

South Atlantic Unit 5 includes the main stem Oconee River from Sinclair Dam downstream to the confluence with the Ocmulgee River, the main stem Ocmulgee River from Juliette Dam downstream to the confluence with the Oconee River, and the main stem Altamaha River from the confluence of the Oconee River and Ocmulgee River downstream to rkm 0;

South Atlantic Unit 6 includes the main stem Satilla River from the confluence of Satilla and Wiggins Creeks downstream to rkm 0; and

South Atlantic Unit 7 includes the main stem St. Marys River from the confluence of Middle Prong St. Marys and the St. Marys Rivers downstream to rkm 0.

Need for Special Management Considerations or Protection

We concluded that each of the PBFs defined above for the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs of Atlantic sturgeon may require special management considerations or protection. Barriers (*e.g.*, dams, tidal turbines) to generate power or control water flow in rivers used by Atlantic sturgeon can damage or destroy bottom habitat needed for spawning and rearing of juveniles, restrict movement of adults to and from spawning grounds, prevent juveniles from accessing the full range of salinity in the natal estuary, and alter water quality parameters, including water depth, temperature and DO, to the detriment of sturgeon reproduction, growth, and survival. Water withdrawals can similarly adversely impact water quality for Atlantic sturgeon spawning, recruitment, and development. Land development and commercial and recreational activities on a river can contribute to sediment deposition that affects water quality necessary for successful spawning and recruitment. A build-up of fine sediments may, for example, reduce the suitability of hard spawning substrate for Atlantic sturgeon egg adherence and reduce the interstitial spaces used by larvae for refuge from predators. Dredging to remove sediment build-up, to deepen harbors and facilitate vessel traffic, or to mine construction materials may remove or alter hard substrate that is necessary for egg adherence and that serves as refuge for larvae or soft substrate needed for juvenile foraging, and may change the water depth, resulting in shifts in the salt wedge within the estuary, or change other characteristics of the water quality (*e.g.*, temperature, DO) necessary for the developing eggs, larvae, and juveniles.

The PBFs essential for successful Atlantic sturgeon reproduction and recruitment may also require special management considerations or protection as a result of global climate change. Conditions in the rivers of the Southeast used by sturgeon already threaten the species' survival and recovery due to exceedances of temperature tolerances and the sensitivity of sturgeon to low DO levels; these impacts will worsen as a result of global climate change and predicted warming of the U.S. Atlantic Coast. Many communities and commercial facilities withdraw water from the rivers containing the PBFs essential to Atlantic sturgeon reproduction. Water withdrawals during drought events can affect flows, depths, and the position of the salt wedge, further impacting the water flow necessary for successful sturgeon reproduction, and they can also affect DO levels. Attempts to control water during floods (*e.g.*, spilling water from dams upriver of Atlantic sturgeon spawning and rearing habitat) can similarly alter flows to the point of dislodging fertilized eggs, washing early life stages downstream into more saline habitat before being developmentally ready, and creating barriers (*e.g.*, from debris) to upstream and downstream passage of adults and juveniles. We therefore conclude that the PBFs essential to the conservation of the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs may require special management considerations or protections.

Unoccupied Areas

ESA section 3(5)(A)(ii) defines critical habitat to include specific areas outside the geographical area occupied if the areas are determined by the Secretary to be essential for the conservation of the species. Our regulations at 50 CFR 424.12(g) also state: "The Secretary will not designate critical habitat within foreign countries or in other areas outside of the jurisdiction of the United States."

There are riverine areas outside of the geographical area occupied by the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs as a result of dams and natural falls. We considered whether these unoccupied areas were essential to the conservation of the respective DPSs and concluded that they were not essential because nearly all known historical habitat is accessible to the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs (ASSRT, 2007; 77 FR 5880; February 6, 2012) and, because additional unoccupied habitat is not necessary in light of any

anticipated impacts of climate change. Therefore, we are not designating critical habitat within any unoccupied areas for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs.

For the Carolina and South Atlantic DPS, we had proposed to designate areas of unoccupied critical habitat. However, based on input received during the public review process, we reconsidered those proposals. After discussion with USFWS and state resource managers, we are uncertain whether the Cape Fear River unoccupied unit (*i.e.*, the area between Lock and Dam #2 and Lock and Dam #3) contains spawning habitat that would make it essential for the conservation of species. In addition,, following the conclusion of our discretionary exclusion analysis we have elected to exercise our discretion under section 4(b)(2) of the ESA and exclude the Santee-Cooper river system and Savannah River unoccupied units of critical habitat. We determined the benefits of exclusion (that is, avoiding some or all of the impacts that would result from designation) outweigh the benefits of designation.

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Critical Habitat Unit Name	DPS Nomenclature	Water Body	State	Upper extent	Total River kilometers	Total River miles
Roanoke	Carolina Unit 1 (C1)	Roanoke River	North Carolina	Roanoke Rapids Dam	213	132
Tar - Pamlico	Carolina Unit 2 (C2)	Tar - Pamlico River	North Carolina	Rocky Mount Mill Pond Dam	199	124
Neuse	Carolina Unit 3 (C3)	Neuse River	North Carolina	Milburnie Dam	345	214
Cape Fear	Carolina Unit 4 (C4)	Cape Fear River	North Carolina	Lock and Dam #2	151	94
		Northeast Cape Fear River	North Carolina	Upstream side of Rones Chapel Road Bridge	218	136
Pee Dee	Carolina Unit 5 (C5)	Pee Dee River	North Carolina/South Carolina	Blewett Falls Dam	310	192
		Waccamaw River	South Carolina	Bull Creek (a.k.a. Big Bull Creek)	35	22
		Bull Creek (a.k.a. Big Bull Creek)	South Carolina	Pee Dee River	17	11
Black	Carolina Unit 6 (C6)	Black River	South Carolina	Interstate Highway 95	203	126
Santee - Cooper	Carolina Unit 7 (C7)	Santee River	South Carolina	Wilson Dam	114	71
		Rediversion Canal	South Carolina	St. Stephens Dam	8	5
		North Santee River	South Carolina	Confluence of Santee River	29	18
		South Santee River	South Carolina	Confluence of Santee River	27	17
		Tailrace Canal - West Branch Cooper River	South Carolina	Pinopolis Dam	29	18
		Cooper River	South Carolina	Confluence of the West Branch Cooper and East Branch Cooper Rivers	41	25
Edisto	South Atlantic Unit 1 (SA1)	North Fork Edisto River	South Carolina	Cones Pond just north of I-20 (Approximately 33.8035 N, 80.4702 W)	155	96
		South Fork Edisto River	South Carolina	State Hwy 121	175	109
		Edisto River	South Carolina	Confluence of the North Fork Edisto and South Fork Edisto Rivers	163	101
		North Edisto River	South Carolina	Edisto River	29	18
		South Edisto River	South Carolina	Edisto River	31	19
Combahee - Salkehatchie	South Atlantic Unit 2 (SA2)	Combahee - Salkehatchie River	South Carolina	Confluence of Buck and Rosemary Creeks with (Approximately 33.2906 N, 81.4326 W)	185	115
Savannah	South Atlantic Unit 3 (SA3)	Savannah River	South Carolina/Georgia	New Savannah Bluff Lock and Dam	338	210
Ogeechee	South Atlantic Unit 4 (SA4)	Ogeechee River	Georgia	Mayfield Mill Dam (Approximately 33.364799 N, 82.805872 W)	420	261
Altamaha	South Atlantic Unit 5 (SA5)	Oconee River	Georgia	Sinclair Dam	227	141
		Ocmulgee River	Georgia	Juliette Dam	363	226
		Altamaha River	Georgia	Confluence of Oconee and Ocmulgee Rivers	216	134
Satilla	South Atlantic Unit 6 (SA6)	Satilla River	Georgia	Confluence of Satilla and Wiggins Creeks (Approximately 31.5041 N, 83.0818 W)	378	235
St. Marys	South Atlantic Unit 7 (SA7)	St. Marys River	Georgia/Florida	Confluence of Middle Prong St. Marys and St. Marys Rivers (Approximately 30.4233 N, 82.2094 W)	203	126

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Application of ESA Section 4(a)(3)(B)(i) (Military Lands)

Section 4(a)(3)(B)(i) of the ESA prohibits designating as critical habitat any lands or other geographical areas owned or controlled by the DOD, or designated for its use, that are subject to an INRMP prepared under section 101 of the Sikes Act (16 U.S.C. 670a), if the Secretary determines in writing that such plan provides a benefit to the species for which critical habitat is proposed for designation. The legislative history to this provision explains:

> The conferees would expect the [Secretary] to assess an INRMP's potential contribution to species conservation, giving due regard to those habitat protection, maintenance, and improvement projects and other related activities specified in the plan that address the particular conservation and protection needs of the species for which critical habitat would otherwise be proposed. Consistent with current practice, the Secretary would establish criteria that would be used to determine if an INRMP benefits the listed species for which critical habitat would be proposed. (Conference Committee report, 149 Cong. Rec. H. 10563 (November 6, 2003)).

Our regulations at 50 CFR 424.12(h) provide that in determining whether an applicable benefit is provided, we must consider:

(1) The extent of the area and features present;

(2) The type and frequency of use of the area by the species;

(3) The relevant elements of the INRMP in terms of management objectives, activities covered, and best management practices, and the certainty that the relevant elements will be implemented; and

(4) The degree to which the relevant elements of the INRMP will protect the habitat from the types of effects that would be addressed through a destruction-or-adverse-modification analysis.

In accordance with section 4(a)(3)(B)(i) of the ESA, the particular areas of the U.S. Military Academy—West Point, New York, Joint Base Langley—Eustis, Virginia, Marine Corps Base Quantico, Virginia, Naval Support Facility Dahlgren, and Naval Weapons Station Yorktown, that overlap with a New York Bight DPS or Chesapeake Bay DPS critical habitat unit are not part of the designated critical habitat unit because the INRMP for each facility provides a benefit to the respective Atlantic sturgeon DPS and its habitat. A copy of the letter providing our determination for each facility is provided in Appendix C of the Impacts Analysis and Biological Source Document for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon. That Appendix also includes our analysis supporting the conclusion that the relevant INRMPs provide the types of benefits to Atlantic sturgeon described in our regulations (50 CFR 424.12(h)); therefore, that analysis is not repeated here.

Consideration of Whether the Joint Base Charleston INRMP Provides a Conservation Benefit to the Carolina DPS

Joint Base Charleston (JBC) in South Carolina is the only installation controlled by the DOD which coincides with any area under consideration for critical habitat for the Carolina DPS. Prior to development of the proposed rule, we asked JBC to determine if they owned or controlled any lands that should not be designated as critical habitat pursuant to section 4(a)(3)(B)(i) of the ESA. They responded stating they did not believe they owned or controlled any lands eligible for section 4(a)(3)(B)(i) non-inclusion. However, during the public comment period, the Navy requested in writing that the restricted area on the Cooper River, South Carolina (defined at 33 CFR 334.460), not be designated as critical habitat, citing that it is covered by the 2015 INRMP for JBC and should not be included pursuant to ESA section 4(a)(3)(B)(i).

The regulations at 33 CFR 334.460 identify 16 specific areas, including some far from JBC. We determined the areas described in those regulations fall into three categories: (1) Areas outside the boundaries of critical habitat and therefore ineligible for non-designation consideration under section 4(a)(3)(B)(i) and not included in critical habitat (no need to request that these areas not be included); (2) areas within the boundaries of critical habitat, but not subject to an INRMP, and thus ineligible for non-designation consideration; and (3) areas within critical habitat, subject to an INRMP, which are eligible for non-designation consideration.

Of the 16 areas identified in 33 CFR 334.460, we determined seven entire areas (33 CFR 334.460 (a)(2), (3), (7), (8)(i), (11)–(13)), and a portion of another (33 CFR 334.460 (a)(1)—Noisette Creek), did not meet the definition of critical habitat and were ineligible for non-designation consideration. We determined four additional areas (33 CFR 334.460 (a)(1), (4)–(6)) were in the second category and also ineligible for non-designation consideration.

However, we did conclude the five remaining areas (33 CFR 334.460 (a)(8)(ii)–(iv), (9), (10)) fell under the JBC INRMP and were eligible for non-designation consideration. The JBC INRMP covers the lands encompassed by JB CHS Air (formerly Joint Base Charleston Air Force Base) in Charleston County and lands encompassed by JB CHS Weapons (formerly Naval Weapons Station Charleston) in Charleston and Berkeley Counties. JB CHS Air also includes North Auxiliary Airfield in Orangeburg County. Within the area covered by the INRMP, three of the four PBF(s) could be present (all but the spawning substrate). Atlantic sturgeon are expected to use the features in this area in the same way that they would all other areas of designated critical habitat; in other words, there is nothing unique or limiting about the critical habitat in this area.

The INRMP for JBC acknowledges that the estuarine waters of the Cooper River in the vicinity of JBC Weapons provide foraging and migratory habitat for Atlantic sturgeon. The INRMP notes that water pollution at JBC Weapons is a concern due to the large amount of essential fish habitat on and around the installation. The INRMP discusses that there are 26 water quality monitoring stations in the vicinity of JBC that are on the Clean Water Act section 303(d) list of impaired waterbodies, that these stations are located in a designated TMDL watershed, and that 16 of the stations are located within the Cooper River drainage surrounding JBC Weapons. While none of the monitoring stations have a TMDL, in 2013 the State of South Carolina revised their TMDL for DO for Charleston Harbor, and the Cooper, Ashley and Wando Rivers (SCDHEC, 2013). In the revised TMDL, the South Carolina Department of Health and Environmental Control (SCDHEC) notes that a number of monitoring stations in the covered area, including the Cooper River, are designated as not supporting aquatic life use due to low DO. SCDHEC also notes that available data and modeling indicate that regulated and unregulated stormwater and nonpoint sources are not contributing to allowable DO depression on main stem segments in Charleston Harbor, or the Cooper, Ashley, and Wando Rivers. JBC Weapons has three NPDES permits—one industrial and two stormwater. JBC is implementing a Stormwater Management Plan that addresses water quality for the entire storm sewer collection system.

Section 7.4 of the INRMP addresses management of threatened and endangered species, species of concern, and their habitats. In the subsection for Atlantic sturgeon, the INRMP

appropriately acknowledges that the Atlantic sturgeon requires access to expansive areas of high quality freshwater habitats and that the waters of the Cooper River in the vicinity of JBC Weapons provide foraging and migratory habitat for the species. The INRMP describes a number of management activities that benefit Atlantic sturgeon and its habitat. The INRMP summarizes the benefits of this suite of activities as follows: "Management activities would improve water quality by identifying, correcting, or preventing pollution or sediment discharges; limiting substrate disturbance; maintaining DO content by reducing nutrients entering the water that result in an increased biological oxygen demand from organisms processing the nutrients; and maintaining or improving water clarity by reducing erosion and limiting sediment in runoff." These objectives are directly relevant to protection of the transitional salinity, soft substrate, and water quality facets of the PBFs of Atlantic sturgeon critical habitat. We identified several management activities discussed in the INRMP that we believe can help accomplish these objectives, including:

(1) Repairing/revitalizing stormwater drainage systems;

(2) Updating the Stormwater Pollution Prevention Plan and the Stormwater Management Plan;

(3) Repairing forestry roads and culverts;

(4) Including performance-based goals in grounds maintenance to help minimize erosion and sediment transport to the Cooper River;

(5) Implementing BMPs to improve water quality discharged to the Cooper River, including training, identifying and correcting illicit discharges, enforcing erosion and sedimentation controls;

(6) Limiting dredge operations in the Nuclear Power Training Unit ship channel and other shipping/receiving facilities to the minimum extent required;

(7) Maintaining and/or developing protective buffer strips where feasible around wetlands along streams; and

(8) Practicing ecologically-sound forest management.

These activities provide a benefit to the PBFs identified in the critical habitat designations, particularly the transitional salinity zone/soft substrate and water quality PBFs, by reducing sediment and nutrient discharges into nearshore waters, which addresses some of the conservation and protection needs that critical habitat would afford. These activities are similar to those that we describe below as project modifications for avoiding or reducing adverse effects to the critical habitat. Therefore, were we to consult with the DOD on the activities in the INRMP that may affect the critical habitat, we would likely not require any project modifications based on the best management practices in the INRMP. Further, the INRMP includes provisions for monitoring and evaluating conservation effectiveness, which will ensure continued benefits to the species. The INRMP must be reviewed by participating Federal and state resource management agencies on a regular basis, but not less often than every five years. JB CHS will also provide us an opportunity to review the INRMP, as protected species under our jurisdiction (*i.e.,* Atlantic and shortnose sturgeon) may be affected by measures in the INRMP. We believe the JBC INRMP provides the types of benefits to Atlantic sturgeon described in our regulations (50 CFR 424.12(h)) and, thus, the restricted areas in the Cooper River covered by the INRMP should not be included in designated critical habitat.

Application of ESA Section 4(b)(2)

Section 4(b)(2) of the ESA requires that we consider the economic impact, impact on national security, and any other relevant impact, of designating any particular area as critical habitat. Additionally, the Secretary has the discretion to consider excluding any area from critical habitat if [s]he determines, based upon the best scientific and commercial data available, the benefits of exclusion (that is, avoiding some or all of the impacts that would result from designation) outweigh the benefits of designation. The regulations at 50 CFR 424.19(h) provide the framework for how we intend to implement section 4(b)(2) of the ESA. These regulations were revised in 2016 (81 FR 7413; February 11, 2016). In particular, Congress has authorized the Secretary to "exclude any area from critical habitat if [s]he determines that the benefits of exclusion outweigh the benefits of specifying such area as part of the critical habitat, unless [s]he determines, based on the best scientific and commercial data available, that the failure to designate such area as critical habitat will result in the extinction of the species concerned" (ESA section 4(b)(2)). Because the authority to exclude is discretionary, exclusion is not required for any particular area, under any circumstances; however, under the final policy (81 FR 7226; February 11, 2016), if NMFS determines it is appropriate to conduct an exclusion analysis on some or all areas of a designation, it is our general practice to exclude an area when the benefits of exclusion outweigh the benefits of inclusion.

The ESA provides the Services with broad discretion in how to consider impacts. See, H.R. Rep. No. 95–1625, at 17, reprinted in 1978 U.S.C.C.A.N. 9453, 9467 (1978) ("Economics and any other relevant impact shall be considered by the Secretary in setting the limits of critical habitat for such a species. The Secretary is not required to give economics or any other 'relevant impact' predominant consideration in his specification of critical habitat . . . The consideration and weight given to any particular impact is completely within the Secretary's discretion."). Courts have noted the ESA does not contain requirements for any particular methods or approaches. See, *e.g., Bldg. Indus. Ass'n of the Bay Area et al..* v. *U.S. Dep't. of Commerce et al..,* No. 13–15132, 9th Cir., July 7, 2015 (upholding district court's ruling that the ESA does not require the agency to follow a specific methodology when designating critical habitat under section 4(b)(2)). For this final rule, we followed the same approach to describing and evaluating impacts as we have for other recent critical habitat rulemakings.

The following discussion of impacts summarizes the analysis contained in our final Impacts Analysis and Biological Source Document for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon. The administrative cost of conducting ESA section 7 consultations was determined to be the primary source of economic impacts as a result of designating critical habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs. The number of incremental consultations over the next 10 years will likely be relatively small, because Atlantic sturgeon of a given life stage are likely to be either directly or indirectly affected by the Federal activities projected to occur within the proposed critical habitat. Since nearly all, if not all, the ESA section 7 consultations we anticipate to occur over the next 10 years will need to evaluate potential effects to both the Atlantic sturgeon DPS(s) present in the area and the critical habitat, the impacts will be coextensive. Therefore, the low administrative cost estimates are the most realistic cost estimates. The projected low administrative costs of designating all of the Gulf of Maine DPS critical habitat units total $816,574.20 over the next 10 years. The projected low administrative costs for the New York Bight DPS critical habitat units total $1,418,299.30 over the next 10

years. The projected low administrative costs of designating all of the Chesapeake Bay DPS critical habitat units total $501,774.20 over the next 10 years. Currently, there is no information indicating that any of the ESA section 7 consultations expected to result from the critical habitat designations will result in project modifications. However, because we cannot predict every Federal action that will be proposed in the future or what the impacts of those actions will be on critical habitat, we recognize that there may be some future costs associated with project modifications. The timing of the ESA section 7 consultation process, which is designed to occur as early as possible in the action planning process and before there have been any irreversible or irretrievable commitment of resources, minimizes the potential for the outcome of a consultation to be costly project modifications.

We considered information provided by the Navy for impacts to national security the Navy expects to result from critical habitat designation for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs. We determined that any resulting ESA section 7 consultations for Navy activities within the critical habitat areas will likely be coextensive and that based on this, as well as the types of activities the Navy will undertake in the critical habitat, there will be no impacts to national security resulting from the designation of critical habitat for the Gulf of Maine, New York Bight or Chesapeake Bay DPS.

There are a number of potential beneficial impacts of designating critical habitat that extend beyond the conservation benefits to Atlantic sturgeon. Because it is often difficult to quantify the benefits of designating critical habitat, Executive Order (EO) 12866, Regulatory Planning and Review, provides guidance on assessing costs and benefits. The EO directs Federal agencies to assess all costs and benefits of available regulatory alternatives, and to select those approaches that maximize net benefits.

The designation of critical habitat will provide conservation benefits such as improved education and outreach by informing the public about areas and features important to the conservation of the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs. Specifying the geographical location of critical habitat facilitates implementation of section 7(a)(1) of the ESA by identifying areas where Federal agencies can focus their conservation programs and use their authorities to further the purposes of the ESA. Designating critical habitat can also help focus the efforts of other conservation partners (*e.g.,* State and local governments, individuals and nongovernmental organizations), and could be beneficial to the ecosystem by protecting features that are also necessary for the conservation of other species.

Based on our consideration of impacts, we are not excluding any areas from the critical habitat designations for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon based on economic, national security, or other relevant impacts. The designation of critical habitat will provide conservation benefits such as improved education and outreach by informing the public about areas and features important to the conservation of the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs. There are also a number of potential beneficial impacts of designating critical habitat that extend beyond the conservation benefits to Atlantic sturgeon. For example, protecting essential PBFs of sturgeon habitat, including preserving water quality and natural flow regimes, will benefit other organisms that are co-located in these areas. While we cannot quantify nor monetize the benefits, we believe they are not negligible and would be an incremental benefit of this designation. Therefore, we have declined to exercise our discretion to exclude any particular area from the proposed critical habitat units for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon.

The Impacts Analysis and Biological Source Document for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs provides specific information on the Economic, National Security and Other Relevant Impacts considered for the critical habitat designations for these DPSs and therefore is not repeated here. Specific information for these impacts as well as the determination for Discretionary Exclusions under section 4(b)(2) for the critical habitat designations for the Carolina and South Atlantic DPSs is provided below.

The following discussion of impacts summarizes the analysis contained in our final "Impacts Analysis of Critical Habitat Designation for the Carolina and South Atlantic Distinct Population Segments of Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*)" (IA), which identifies the economic, national security, and other relevant impacts that we projected would result from including each of the 14 occupied and 2 unoccupied specific areas in the critical habitat designation. We considered these impacts when deciding whether to exercise our discretion to propose excluding particular areas from the designation. Both positive and negative impacts were identified and considered (these terms are used interchangeably with benefits and costs, respectively). Impacts were evaluated in quantitative terms where feasible, but qualitative appraisals were used where that is more appropriate to particular impacts. The final Impacts Analysis is available on our Web site at *http://sero.nmfs.noaa.gov/protected_resources/sturgeon/index.html.*

The primary impacts of a critical habitat designation result from the ESA section 7(a)(2) requirement that Federal agencies ensure their actions are not likely to result in the destruction or adverse modification of critical habitat, and that they consult with us in fulfilling this requirement. Determining these impacts is complicated by the fact that section 7(a)(2) also requires that Federal agencies ensure their actions are not likely to jeopardize the species' continued existence. One incremental impact of designation is the extent to which Federal agencies modify their proposed actions to ensure they are not likely to destroy or adversely modify the critical habitat beyond any modifications they would make because of listing and the results of a jeopardy analysis. When the same modification would be required due to impacts to both the species and critical habitat, the impact of the designation is coextensive with the ESA listing of the species (*i.e.,* attributable to both the listing of the species and the designation critical habitat). Relevant, existing regulatory protections are referred to as the "baseline" and are also discussed in the Impacts Analysis. In this case, notable baseline protections include the ESA listings of not only Atlantic sturgeon, but the co-occurring endangered shortnose sturgeon.

The Impacts Analysis describes the projected future Federal activities that would trigger section 7 consultation requirements because they may affect the PBF(s), and consequently may result in economic costs or negative impacts. The report also identifies the potential national security and other relevant impacts that may arise due to the critical habitat designation, such as positive impacts that may arise from conservation of the species and its habitat, state and local protections that may be triggered as a result of designation, and education of the public to the importance of an area for species conservation.

Economic Impacts of Designating Critical Habitat for the Carolina and South Atlantic DPSs

Economic impacts of the critical habitat designation result through implementation of section 7 of the ESA in consultations with Federal agencies to ensure their proposed actions are not likely to destroy or adversely modify critical habitat. These economic impacts may include both administrative and project modification costs; economic impacts that may be associated with the conservation benefits of the designation are described later.

When identifying costs, we examined the ESA section 7 consultation record over the last 10 years, as compiled in our PCTS database, to identify the types of Federal activities that may adversely affect Atlantic sturgeon critical habitat. We also requested that Federal action agencies provide us with information on future consultations if we omitted any future actions likely to affect the proposed critical habitat. No new categories of activities were identified through this process. Of the types of past consultations that "may affect" some or all of the PBF(s) in any unit of critical habitat, we determined that no activities would solely affect the PBFs essential for conservation. That is, all categories of the activities we identified that could impact the PBFs also had the potential of "take" resulting from the listing of the species.

In the proposed rule we identified 15 categories of activities implemented by 10 different Federal entities as likely to recur in the future and have the potential to affect the PBF(s). Based on comments from EPA, we added a category for EPA for the triennial approval of state water quality standards. Listed below is the agency, description of the activity, and total number of projected consultations anticipated over the next 10 years indicated in parentheses:

1. USACE—Navigation maintenance dredging, harbor expansion (14);
2. USACE—Water Resources Development Act (WRDA) flood control, ecosystem restoration studies (6);
3. USACE—WRDA dam operations, repair, fishway construction (3);
4. USACE—Clean Water Act (CWA) section 404/Rivers and Harbors Act (RHA) section 10 permitting—dredge, fill, construction (20);
5. Federal Highway Administration (FHWA)—Bridge repair, replacement (67);
6. U.S. Coast Guard (USCG)—Bridge repair, replacement permitting (3);
7. FERC—Hydropower licensing (5);
8. FERC—Liquefied Natural Gas (LNG) facilities, pipelines authorization (5);
9. Nuclear Regulatory Commission (NRC)—Nuclear power plant construction/operation licensing (8);
10. NMFS—ESA research and incidental take permitting (section 10) (46);
11. USFWS—Fishery management grants (11);
12. EPA—Nationwide pesticide authorizations (9);
13. EPA—State water quality standard reviews (12);
14. Federal Emergency Management Agency (FEMA)—Disaster assistance/preparation grants (5); and
15. Department of Energy (DOE)—Nuclear fuel management (3).

In total, we estimated that 217 activities would require section 7 consultation over the next 10 years to consider impacts to Atlantic sturgeon critical habitat for the Carolina and South Atlantic DPSs. As discussed in more detail in our final IA, all the activities identified as having the potential to adversely affect one or more of the PBF(s) also have the potential to take Atlantic sturgeon. For most, if not all, of the projected future activities, if the effects to critical habitat will be adverse and require formal consultation, those effects would also constitute adverse effects to the species, either directly when they are in the project area, or indirectly due to the effects on their critical habitat. This is due to the ecological functions of these PBFs. For example, water quality is being identified as an essential PBF to facilitate successful spawning, annual and inter-annual adult, larval, and juvenile survival, and larval, juvenile and subadult growth, development, and recruitment. Effects to the water quality PBF that impede that conservation objective could injure or kill individual Atlantic sturgeon, for example, by preventing adult reproduction, or rendering reproduction ineffective or resulting in reduced growth or mortality of larvae, juveniles or subadults. In these circumstances, the same project modifications would be required to address effects to both the species and effects to the critical habitat. Thus, projects that adversely affect the PBF(s) are likely to always also take the species and the project impacts would not be incremental.

For some of the projected activities, it may be feasible to conduct the action when sturgeon are out of the action area. If effects to critical habitat are temporary such that the PBF(s) return to their pre-project condition by the time the sturgeon return and rely on the PBFs, there might not be any adverse effects to either the species or the critical habitat. In these circumstances, consultations would be fully incremental consultations only on critical habitat, and the consultations would be informal (*i.e.*, impacts to critical habitat would not be permanent and would not be significant). This would likely only apply to actions that affect spawning habitat in the upper parts of the rivers, as sturgeon of various ages are present year-round in the lower reaches of the rivers and the estuaries. The costs of fully incremental, informal consultations are higher than the marginal costs of adding critical habitat analyses to coextensive, formal consultations. Thus, to be conservative and avoid underestimating incremental impacts of this designation, and based on the activities we identified, we assumed that two categories of activities could result in incremental, informal consultations. Those activities, both implemented by the USACE, are CWA section 404/Rivers and Harbors Act permitting and WRDA dam operations/repair. Administrative costs include the cost of time spent in meetings, preparing letters, and in some cases, developing a biological assessment and biological opinion, identifying and designing reasonable and prudent measures (RPMs), and so forth. For this impacts report, we estimated per-project administrative costs based on critical habitat economic analyses by Industrial Economics, Inc. (IEc) (2014). This impacts report estimates administrative costs for different categories of consultations as follows: (1) New consultations resulting entirely from critical habitat designation; (2) new consultations considering only adverse modification (unoccupied habitat); (3) reinitiation of consultation to address adverse modification; and (4) additional consultation effort to address adverse modification in a new consultation. Most of the projected future consultations we project to result from this final rulemaking will be coextensive formal consultations on new actions that would be evaluating impacts to sturgeon as well as impacts to critical habitat, and the administrative costs for these 194 consultations would be in category 4 above. The remaining 23 actions are projected to involve incremental informal consultation due to impacts to critical habitat alone. Based on the IEc reports (2014), we project that each formal consultation will result in the following additional costs to address critical habitat impacts: $1,400 in costs to us; $1,600 in action agency costs; $880 in third party (*e.g.*, permittee) costs, if applicable; and $1,200 in costs to the action agency or third party to prepare a biological assessment. Costs for the incremental informal consultations would be as follows: $1,900 in costs to us; $2,300 in action agency costs; $1,500 in third party (*e.g.*,

permittee) costs, if applicable; and $1,500 in costs to the action agency or third party to prepare a BA.

Costs of the nine EPA nationwide pesticide consultations were treated differently. These consultations will involve all listed species and all designated critical habitat under our jurisdiction, and thus costs attributable solely to this final rule designating critical habitat for Atlantic sturgeon are expected to be only a very small part of that cost. To be conservative, we added nine consultations to each critical habitat unit for all five DPSs. We spread the costs of these 9 consultations ($5,080 each) evenly across all 31 critical habitat units. This resulted in a total cost of $1,474.84 per unit over 10 years.

The 12 consultations on EPA approval of state water quality standards were also treated differently. EPA expects to conduct three statewide consultations regarding their approval of state water quality standards in each of the four states covered by the designation of critical habitat for the Carolina and South Atlantic DPSs. For these two DPSs, we have split the incremental administrative costs of 3 statewide consultations ($15,240) equally across all the units within each state, added these costs to the 10-year totals, and derived the annual totals from these figures, because these are not annual actions. We added the costs projected across two states to units that occur in two states. Total costs for these consultations are $3,048 per unit in North Carolina, $2,540 per unit in Georgia, and $2,177.14 in South Carolina. Costs for units bordering 2 states are $5,225.14 in the Pee Dee River unit, $4,717.14 in the Savannah River unit, and $17,780 in the St. Marys unit (the costs of the 3 statewide water quality standards (WQS) consultations in Florida are attributed wholly to this single unit in the state, added to the costs of Georgia WQS consultations). We have added three consultations to the number expected in each unit, but the total number of consultations for each DPS consists of three consultations per each state with units in that DPS. This approach avoids underestimating the costs in any unit but would overestimate the total costs expected.

In our impacts analysis, we concluded that none of the projected future activities are likely to require project modifications to avoid adverse effects to critical habitat PBFs that would be different from modifications required to avoid adverse effects to sturgeon. In other words, we projected no incremental costs for actions in a critical habitat unit other than the administrative costs of section 7 consultations. While there may be serious adverse impacts to critical habitat from projected future projects that require project modifications to avoid destroying or adversely modifying critical habitat, impacts of these magnitudes to the PBF(s) as defined would also result in adverse effects to Atlantic sturgeon, either directly when they are in the project area, or indirectly as harm, resulting from impacts to their habitat that result in injury or death. The same project modifications would be required to avoid destroying or adversely modifying critical habitat and avoiding jeopardy, or minimizing take of Atlantic sturgeon caused by impacts to its habitat.

Based on our final Impacts Analysis for the Carolina and South Atlantic DPSs, we project that the costs that will result from the designation of critical habitat will total $1,154,475 over the next 10 years. The total incremental cost resulting from the designation for the Carolina DPS is $526,447, and the total incremental cost resulting from the designation for the South Atlantic DPS is $628,027, over 10 years. The annual cost per-unit ranges widely from $873 (Carolina Unit 6—Black River, Carolina DPS) to $23,523 (South Atlantic Unit 3—Occupied Savannah River, South Atlantic DPS).

National Security Impacts of Designating Critical Habitat for the Carolina and South Atlantic DPSs

Previous critical habitat designations have recognized that impacts to national security result if a designation would trigger future ESA section 7 consultations because a proposed military activity "may affect" the PBFs essential to the listed species' conservation. Anticipated interference with mission-essential training or testing or unit readiness, through the additional commitment of resources to an adverse modification analysis and expected requirements to modify the action to prevent adverse modification of critical habitat, has been identified as a negative impact of critical habitat designations. (See, *e.g.*, Proposed Designation of Critical Habitat for Southern Resident Killer Whales; 69 FR 75608, Dec. 17, 2004, at 75633.)

On February 14, 2014, and again in October 7, 2015, we sent letters to the DOD and the Department of Homeland Security requesting information on national security impacts of the proposed critical habitat designations, and we received responses from the Navy, Air Force, Army, and USCG. We discuss the information contained within the responses thoroughly in the Impacts Analysis, and we summarize the information below.

The Navy's first submission provided information on its facilities and operations. However, the Navy was not able to make a full assessment of whether there would be any national security impacts. The Navy indicated that as we define our PBF(s) and areas more precisely, they would be able to provide a more detailed response to our requests and would update their INRMPs as necessary for the protection of Atlantic sturgeon and its critical habitat. The Navy's second submission noted that Naval Submarine Base Kings Bay was adjacent to the South Atlantic DPS critical habitat unit in the St. Marys River. The Navy stated it did not own or control any land or waters within the St. Marys channel, but that the TRIDENT-class submarines used 4.9 km of the waterway transiting to and from the Atlantic Ocean. The Navy stated that any operational or dredging restrictions that would impede maintenance of the channel from the Intracoastal Waterway and St. Marys channel intersection, downstream, could pose a national security risk. Typically we consult with the USACE for dredging actions, and in this case the Navy would be the permit applicant. We determined that dredging has the potential to affect critical habitat, but we also concluded that consultations for effects of dredging on critical habitat will be fully-coextensive with consultations to address impacts to sturgeon (both shortnose and Atlantic). The effects of dredging on PBF(s) would also result in injury or death to individual sturgeon, and thus constitute take. Removal or covering of spawning substrate could prevent effective spawning or result in death of eggs or larvae that are spawned. Changing the salinity regime by deepening harbors and parts of rivers could result in permanent decreases of available foraging and developmental habitat for juveniles. These types of adverse effects are not likely to be temporary and limited to periods of sturgeon absence. Thus, adverse effects of dredging activities identified by the Navy would be likely to be coextensive in formal consultations to address impacts to both the species and the PBF(s), and thus no new requirements or project modifications are anticipated as a result of the critical habitat designation. Therefore, after considering the action identified by the Navy at Kings Bay, we find there will be no impact on national security as a consequence of the critical habitat designation for these actions.

Both the Navy and Air Force expressed concern that designating the Cooper River, including the riverine

area on the west bank adjacent to the Joint Base Charleston Naval Weapons Station, could have significant impacts on the Navy's ability to adequately support mission-essential military operations, thereby impacting national security. The Navy and Air Force were concerned that designation of critical habitat could affect training facilities and the maintenance of their facilities. Additional concerns were expressed regarding shipping and receiving operations from two waterfront facilities. Because no specifics were given on how designation of critical habitat could affect these activities, and because we determined there are no routes of effects to PBF(s) from these activities based on the information provided, we concluded that designation of critical habitat will have no impact on these activities and thus will not result in impacts to national security. Upon further discussion with the Navy, we determined the area was covered by the 2015 INRMP and should not be included as critical habitat pursuant to ESA section 4(a)(3)(B)(i) (see *Consideration of Whether the Joint Base Charleston INRMP Provides a Conservation Benefit to the Carolina DPS* above).

The Army noted that Military Ocean Terminal-Sunny Point was located on the Cape Fear River, North Carolina, and Fort Stewart was located on the Ogeechee River, Georgia. The Army was not able to make a full assessment whether there would be any national security impacts and concluded that technical assessments to occur between the installations and NMFS at the regional level would identify any specific impacts.

The USCG provided information on its facilities and operations. The USCG was not able to make a full assessment whether there would be any national security impacts. The USCG indicated that as we develop our PBF(s) and areas more precisely in the final rule, they would be able to provide a more detailed response to our requests. Our PCTS database indicated the USCG consulted with us three times on authorizations for bridge repairs or replacements. In developing this final rule we determined if those actions were conducted in the future, the activities may affect critical habitat PBFs, but the effects would be fully coextensive with effects to the listed sturgeons. Based on this information regarding potential future USCG action in Atlantic sturgeon critical habitat, we do not expect any national security impacts as a consequence of the critical habitat designation.

Based on a review of our PCTS database, and the information provided by the Navy, Air Force, Army, and USCG on their activities conducted within the specific areas being designated as Atlantic sturgeon critical habitat, we determined that only one military action identified as a potential area of national security impact has routes of potential adverse effects to PBF(s)—river channel dredging. As discussed, this activity will require consultation due to potential impacts to listed Atlantic and shortnose sturgeon, and any project modifications needed to address impacts to these species would also address impacts to critical habitat. Thus, no incremental project modification impacts are expected due to this designation. On this basis, we conclude there will be no national security impacts associated with the critical habitat designation for the Carolina and South Atlantic DPSs of Atlantic sturgeon.

Other Relevant Impacts

Other relevant impacts of critical habitat designations can include conservation benefits to the species and to society, and impacts to governmental and private entities. The Impacts Analysis for the designation of critical habitat for the Carolina and South Atlantic DPSs discusses conservation benefits of designating the 14 occupied and 2 unoccupied areas, and the benefits of conserving the Carolina and South Atlantic sturgeon DPSs to society, in both ecological and economic metrics.

As discussed in the Impacts Analysis for the Carolina and South Atlantic DPSs and summarized here, Atlantic sturgeon currently provide a range of benefits to society. Given the positive benefits of protecting the PBFs essential to the conservation of these DPSs, this protection will in turn contribute to an increase in the benefits of this species to society in the future as the species recovers. While we cannot quantify nor monetize these benefits, we believe they are not negligible and would be an incremental benefit of this designation. However, although the PBFs are essential to the conservation of Atlantic sturgeon DPSs, critical habitat designation alone will not bring about the recovery of the species. The benefits of conserving Atlantic sturgeon are, and will continue to be, the result of several laws and regulations.

The Impacts Analysis identifies both consumptive (*e.g.*, commercial and recreational fishing) and non-consumptive (*e.g.*, wildlife viewing) activities that occur in the areas being designated as critical habitat. Commercial and recreational fishing are components of the economy related to the ecosystem services provided by the resources within Atlantic sturgeon critical habitat areas. The PBF(s) contribute to fish species diversity.

Education and awareness benefits stem from the critical habitat designation when non-Federal government entities or members of the general public responsible for, or interested in, Atlantic sturgeon conservation change their behavior or activities when they become aware of the designation and the importance of the critical habitat areas and features. Designation of critical habitat raises the public's awareness that there are special considerations that may need to be taken within the area. Similarly, state and local governments may be prompted to carry out programs to complement the critical habitat designation and benefit the Carolina and South Atlantic DPSs of Atlantic sturgeon. Those programs would likely result in additional impacts of the designation. However, it is impossible to quantify the beneficial effects of the awareness gained or the secondary impacts from state and local programs resulting from the critical habitat designation.

Discretionary Exclusions Under Section 4(b)(2) for the Carolina and South Atlantic DPSs

In our proposed rule, we described our preliminary determination that we would not perform a discretionary exclusion analysis. Input received during the public comment period resulted in our determination that an exclusion analysis for the unoccupied Santee-Cooper and Savannah River units was warranted. On the other hand, given that occupied units are currently used by Atlantic sturgeon for reproduction and recruitment, and due to the severely depressed levels of all river populations, occupied units are far too valuable to both the conservation and the continuing survival of Atlantic sturgeon to be considered for exclusion.

Based on the analysis included in our IA, the likely benefits of excluding the unoccupied Santee-Cooper and Savannah river units include avoiding consultation costs of $23,972 and $11,272 over ten years, respectively. In addition, there may be ancillary benefits of exclusion to Federal agencies that would conduct activities in these areas, and to their project applicants.

Our qualitative analysis of the benefits derived from designation include benefits associated with section 7 consultations (*e.g.*, proactive coordination with other federal agencies

to avoid impacts to critical habitat); increased likelihood of specifically protecting habitat necessary for Atlantic sturgeon recovery; and opportunities for federal agency conservation programs under section 7(a)(1) of the ESA. These benefits would be limited in the unoccupied Santee-Cooper and Savannah River units, given the low number of unique federal agency actions projected to require consultation over the next ten years (4 and 1 action, respectively). Other benefits of designation include ancillary benefits to other commercially-important aquatic species associated with Atlantic sturgeon habitat; non-use values for sturgeon and their habitats; and increased state, local and public awareness of the importance of these areas, that could generate non-federal conservation efforts and benefits. As we discuss in the IA, given the particular facts and circumstances for these DPSs and this critical habitat designation, it is likely that many or most of these benefits will result from baseline protections for sturgeon and their habitats, even if the unoccupied areas are excluded from the designation. As such, we do not conclude that conservation and recovery of the Carolina and South Atlantic DPSs would be impaired by excluding these areas from the designation.

We determined the potential economic impacts of the designation of unoccupied critical habitat are relatively small. We determined there are significant conservation benefits associated with designation of unoccupied critical habitat, but we could not conclude that these benefits are incremental impacts of including the unoccupied units in the designation. Therefore, it is our judgment that the benefits of excluding the unoccupied Santee-Cooper and Savannah River units outweigh the benefits of including these units in the designation.

Exclusion of these unoccupied units will not result in the extinction of the Carolina or South Atlantic DPS of Atlantic sturgeon. Atlantic sturgeon will need the additional spawning habitat in these units to increase their reproductive success and population growth in order to recover, and thus if these habitats were lost to sturgeon they would not recover. However, based on the Federal actions expected to occur in these areas over the next ten years, and because the areas are protected through a number of baseline requirements including the listing of shortnose sturgeon, we do not expect impacts to these areas would prevent them from supporting Atlantic sturgeon conservation once fish passage to these areas is established in the near future.

We also note that FERC and USACE submitted some significant new information late during the interagency review process on the final rule, outside of the public comment period. One agency suggested exclusion of unoccupied critical habitat was needed to prevent third party litigation seeking fish passage or removal of dams the agency owns and operates on the Cape Fear River to allow migration of sturgeon. That agency estimated the average cost to provide fish passage would range from $8 million and $15 million. The other agency submitted hypothetical costs that might result if consultation were required solely to protect unoccupied critical habitat from the effects of numerous facilities they regulate in the watersheds extending hundreds of miles above the proposed unoccupied units. Cost estimates provided by that agency ranged from $0 to over $1.7 million annually for the range of facilities identified. Those estimates were projected based on past environmental compliance costs for similar facilities. We decided to remove the unoccupied Cape Fear unit because it is not essential to sturgeon conservation. Because we decided to exclude the unoccupied Santee-Cooper and Savannah River units based on the impacts identified in our proposed impacts assessment, and because the public was not afforded an opportunity to review and comment on the new cost information and assumptions, consideration of this late input was not necessary and did not play a role in our determinations. If the types of impacts identified by these agencies would be potential impacts of including the unoccupied units in the designation, it would bolster our conclusion that the benefits of exclusion outweigh the benefits of inclusion.

Final Determinations and Critical Habitat Designation

We conclude that specific areas meet the definition of critical habitat for the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs of Atlantic sturgeon, that a critical habitat designation is prudent, and that critical habitat is determinable.

We found approximately 244 km (152 miles) of aquatic habitat within the Penobscot, Kennebec, Androscoggin, Piscataqua, Cocheco, Salmon Falls, and Merrimack Rivers are critical habitat for the Gulf of Maine DPS of Atlantic sturgeon. We found approximately 547 km (340 miles) of aquatic habitat within the Connecticut, Housatonic, Hudson, and Delaware Rivers are critical habitat for the New York Bight DPS of Atlantic sturgeon. We found approximately 773 km (480 miles) of aquatic habitat within the Potomac, Rappahannock, York, Pamunkey, Mattaponi, James, Nanticoke Rivers and Marshyhope Creek are critical habitat for the Chesapeake Bay DPS of Atlantic sturgeon.

We found approximately 1,939 km (1,205 miles) of aquatic habitat within the Roanoke, Tar-Pamlico, Neuse, Cape Fear, Northeast Cape Fear, Waccamaw, Pee Dee, Black, Santee, North Santee, South Santee, and Cooper Rivers and Bull Creek are critical habitat for the Carolina DPS of Atlantic sturgeon.

Likewise, we found approximately 2,883 km (1,791 miles) of aquatic habitat within the Edisto, Combahee-Salkehatchie, Savannah, Ogeechee, Altamaha, Ocmulgee, Oconee, Satilla, and St. Marys Rivers are critical habitat for the South Atlantic DPS of Atlantic sturgeon.

Activities That May Be Affected

Section 4(b)(8) of the ESA requires that to the maximum extent practicable, we describe briefly and evaluate, in any proposed or final regulation to designate critical habitat, those activities that may destroy or adversely modify such habitat or that may be affected by such designation. As described in our Impacts Analysis and Biological Source Document for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon, and in our final Impacts Analysis for the Carolina and South Atlantic DPSs of Atlantic sturgeon, a wide variety of activities may affect critical habitat and, when carried out, funded, or authorized by a Federal agency, will require an ESA section 7 consultation because they may affect one or more of the PBFs of critical habitat. Such activities include in-water construction for a variety of Federal actions, dredging for navigation, harbor expansion or sand and gravel mining, flood control projects, bridge repair and replacement, hydropower licensing, natural gas facility and pipeline construction, ESA research and incidental take permits or fishery research grants, and CWA TMDL program management. Private entities may also be affected by these critical habitat designations if they are a proponent of a project that requires a Federal permit, Federal funding is received, or the entity is involved in or receives benefits from a Federal project. Future activities will need to be evaluated with respect to their potential to destroy or adversely modify critical habitat. For example, activities may adversely modify the substrate essential PBF by removing or altering the

substrate. The open passage PBF may be adversely modified by the placement of structures such as dams and tidal turbines, research nets, or altering the water depth so that fish cannot swim. The salinity PBF may be adversely modified by activities that impact fresh water input such as operation of water control structures and water withdrawals, and impacts to water depth such as dredging. The water quality PBF may be adversely modified by land development as well as commercial and recreational activities on rivers that contribute to nutrient loading that could result in decreased DO levels and increased water temperature, and increased sediment deposition that reduces Atlantic sturgeon egg adherence on hard spawning substrate and reduces the interstitial spaces used by larvae for refuge from predators. Dredging to remove sediment build-up or to facilitate vessel traffic may remove or alter hard substrate that is necessary for egg adherence and as refuge for larvae, and may change the water depth resulting in shifts in the salt wedge within the estuary or change other characteristics of the water quality (*e.g.*, temperature, DO) necessary for the developing eggs, larvae, and juveniles. These activities would require ESA section 7 consultation when they are implemented, funded, or carried out by a Federal agency.

We believe this critical habitat designation provides Federal agencies, private entities, and the public with clear notification of critical habitat for the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs of Atlantic sturgeon, the PBF(s), and the boundaries of those habitats. These designations allow Federal agencies and others to evaluate the potential effects of their activities on critical habitat to determine if ESA section 7 consultation with us is needed, given the specific definition of each PBF.

Information Quality Act and Peer Review

On December 16, 2004, the Office of Management and Budget (OMB) issued its Final Information Quality Bulletin for Peer Review (Bulletin), establishing minimum peer review standards, a transparent process for public disclosure of peer review planning, and opportunities for public participation. The OMB Bulletin, implemented under the Information Quality Act (Pub. L. 106–554), is intended to enhance the quality and credibility of the Federal Government's scientific information and applies to influential scientific information or highly influential scientific assessments disseminated on or after June 16, 2005. The biological information describing the Atlantic sturgeon DPSs, and the information in the draft economic impacts analyses supporting the critical habitat designation for the five DPSs is considered influential scientific information and subject to peer review. To satisfy our requirements under the OMB Bulletin, we obtained independent peer review of the biological information and the information used to draft the impacts analyses. We incorporated the peer review comments into the proposed rules prior to dissemination. Comments received from peer reviewers were summarized and are available on the web at: *http://www.cio.noaa.gov/services_programs/prplans/ID294.html* and *http://www.cio.noaa.gov/services_programs/prplans/ID336.html.*

Classification

National Environmental Policy Act

We have determined that an environmental analysis as provided for under the National Environmental Policy Act of 1969 for critical habitat designations made pursuant to the ESA is not required. See *Markle Interests, L.L.C.* v. *U.S. Fish and Wildlife Serv.*, 827 F.3d 452 (5th Cir. 2016); *Bldg. Indus. Ass'n of the Bay Area* v. *U.S. Dept. of Commerce*, 792 F.3d 1027 (9th Cir. 201); *Douglas County* v. *Babbitt*, 48 F.3d 1495 (9th Cir. 1995), cert. denied, 116 S.Ct. 698 (1996).

Regulatory Flexibility Act Determinations

The ESA does not require use of any particular methodology in the consideration of impacts pursuant to section 4(b)(2) (see, *e.g.*, *Building Industry Association of the Bay Area* v. *U.S. Department of Commerce*, 792 F.3d 1027 (9th Cir. 2015)). In preparing the rules proposing critical habitat for the Atlantic sturgeon DPSs, we used different methodologies to conduct the respective impacts analyses. While those differences in analyses are reflected below, we note the conclusions are the same, *i.e.*, that designation of critical habitat for the five DPSs of Atlantic sturgeon will not have significant economic impacts on small entities. The Final Regulatory Flexibility Analyses (FRFA) were prepared pursuant to section 604 of the Regulatory Flexibility Act (5 U.S.C. 601, *et seq.*). A FRFA includes: A statement of the need for, and objectives of, the rule; a statement of the significant issues raised by the public comments in response to the initial regulatory flexibility analysis (IRFA), a statement of the assessment by the agency of such issues, and a statement of any changes made in the proposed rule as a result of such comments; the response of the agency to any comments filed by the Chief Counsel for Advocacy of the Small Business Administration (SBA) in response to the proposed rule, and a detailed statement of any change made to the proposed rule in the final rule as a result of the comments; a description of and an estimate of the number of small entities to which the rule will apply or an explanation of why no such estimate is available; a description of the projected reporting, recordkeeping and other compliance requirements of the rule, including an estimate of the classes of small entities which will be subject to the requirement and the type of professional skills necessary for preparation of the report or record; and, a description of the steps the agency has taken to minimize the significant economic impact on small entities consistent with the stated objectives of applicable statutes, including a statement of the factual, policy, and legal reasons for selecting the alternative adopted in the final rule and why each one of the other significant alternatives to the rule considered by the agency which affect the impact on small entities was rejected. We received no comments specifically on the IRFAs from the public or from the Chief Counsel for Advocacy of the SBA. The FRFA for the Regulatory Flexibility Act determinations for the Gulf of Maine, New York Bight and Chesapeake Bay DPSs and the FRFA for the Regulatory Flexibility Act determinations for the Carolina and South Atlantic DPSs of Atlantic sturgeon analyze the impacts of this rule on small entities, are included as Appendix A of the respective Impacts Analysis, and are available upon request (see **ADDRESSES**). A summary of each analysis follows.

Regulatory Flexibility Act Determinations for the Gulf of Maine, New York Bight and Chesapeake Bay DPSs (5 U.S.C. 601 et seq.)

As explained in the FRFA for the Gulf of Maine, New York Bight and Chesapeake Bay DPSs, the economic analysis described and estimated the number of small entities to which this rule may apply. These estimates are based on the best available information and take into account uncertainty. Using the number of employees as the criteria for determining whether or not an establishment is a small business, on average, 99 percent of businesses in the counties and cities in which the

proposed Atlantic sturgeon critical habitat units occur are considered small businesses. For purposes of projecting the impacts of administrative ESA section 7 costs on small businesses in each critical habitat unit, it was assumed that the percentage of private entities that are involved in those consultations that are small businesses is the same as the percentage of businesses that are small businesses in counties that include critical habitat units.

To address uncertainty, costs were estimated as low, medium, and high. However, this approach likely overestimates the costs because the majority of consultations have been informal and, thus, have lower costs than formal consultations. In addition, this analysis was based on the critical habitat areas as defined by hydrographic unit codes. We subsequently revised and narrowed how we define the boundaries of the critical habitat units. As a result, fewer small businesses are likely to be affected by the critical habitat designations than were projected based on the information available to the economist at that time. Finally, because Atlantic sturgeon are present in the areas that we are designating as critical habitat, consultation is likely to have occurred even if critical habitat was not designated. Therefore, the section 7 consultation costs attributed to the designation of critical habitat, alone, are likely to be very small.

We considered the effect to small businesses throughout our analysis and, as stated above, there will be no significant economic impact to small businesses; therefore, it was unnecessary to make any changes from the proposed rule with the goal of minimizing any significant economic impacts on small entities. It is unlikely that the rule will significantly reduce profits or revenue for small businesses. The administrative costs of ESA section 7 consultation are likely to be small given, in the absence of critical habitat designation, nearly the same number and type of consultations would have occurred to consider the effects of Federal actions on the Atlantic sturgeon DPSs.

In the IRFA, we considered the alternative of not proposing critical habitat for the Gulf of Maine, New York Bight, or Chesapeake Bay DPS. We rejected this alternative because we determined the PBFs forming the basis for the critical habitat designations are essential to the conservation of the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs. The lack of protection of the critical habitat PBFs from adverse modification and/or destruction could result in continued declines in abundance of these Atlantic sturgeon DPSs, would not provide for the conservation of the DPSs, and would not meet the legal requirements of the ESA.

We also analyzed designating a subset of the identified critical habitat areas. We rejected this alternative because designating only some of the areas containing the PBFs that are essential to the conservation of each DPS would not provide for the conservation of the DPSs and, thus, this alternative does not meet the legal requirements of the ESA.

Finally, we analyzed designating all critical habitat areas identified for the DPS. We analyzed the economic, national security, and other relevant impacts of designating critical habitat. Our conservative identification of potential, incremental, economic impacts indicates that any such impacts, if they were to occur, would be very small. Any incremental economic impacts will consist solely of the administrative costs of consultation; no project modifications are projected to be required to address impacts solely to the proposed critical habitat. There are conservation benefits of the critical habitat designations, both to the species and to society. While we cannot quantify nor monetize these benefits, we believe they are not negligible and are an incremental effect of the designations.

This final rule does not introduce any new reporting, record-keeping requirements, or other compliance requirements.

Regulatory Flexibility Act Determinations for the Carolina and Southeast DPSs

As explained in the FRFA for the Carolina and Southeast DPSs, this final rule is needed to comply with the ESA's requirement to designate critical habitat to the maximum extent prudent and determinable when species are listed as threatened or endangered. The objective of this rule is to identify Atlantic sturgeon habitat areas and features, the protection of which will support the conservation of these endangered DPSs.

The FRFA estimates the number of small entities to which the rule may apply, based on the information in the Impacts Report. The SBA has established size standards for all for-profit economic activities or industries in the North American Industry Classification System (13 CFR 121.201; 78 FR 37398; June 20, 2013; 78 FR 77343, December 23, 2013; 79 FR 33467, June 12, 2014) (*https://www.sba.gov/sites/default/files/files/Size_Standards_Table.pdf*).

Businesses in North American Industry Classification System (NAICS) Subsector 325320, Pesticide and Other Agricultural Chemical Manufacturing, could be involved in 5 projected nationwide pesticide authorization consultations. A small business in this subsector is defined by the SBA as having 1,000 employees. Businesses in NAICS Sector 22 (Utilities) could be involved in 14 consultations projected to occur for hydropower licensing, LNG facility or pipelines authorization, or nuclear power plant construction/operation licensing. For hydropower generation and natural gas distribution enterprises, a small business is defined by the SBA as one having a total of 500 employees. For nuclear power generation, a small business is defined by the SBA as one having a total of 750 employees. Businesses in NAICS Sector 54 could be involved as contractors assisting with ESA section 7 consultation in any of the 155 projected future Federal actions that could involve third parties. Relevant subsectors could include 541370, Surveying and Mapping, 541620, Environmental Consulting Services, or 541690, Other Scientific and Technical Consulting Services. A small business in any of these subsectors is defined by the SBA as one having average annual receipts of $15 million.

Businesses in NAICS Sector 23, Construction, could be involved in a number of categories of projected future actions, where they could incur administrative costs of construction. These could include businesses from the subsector 237120, Oil and Gas Pipeline and Related Structures Construction, or subsector 237310, Highway, Street, and Bridge Construction. A small business in subsector 237120 has average annual receipts of $36.5 million, and a small business in subsector 237310 has average annual receipts of $36.5 million. Businesses in subsector 238, Other Specialty Trade Contractors, could be involved as construction contractors in 20 future USACE section 404/RHA permitting actions and 5 FEMA disaster assistance actions. Small businesses in this subsector have average annual receipts of $15 million.

Cities could be involved in many of the 70 projected bridge repair or replacement projects, and some proportion of the 20 projected section 404/RHA permitting actions. The SBA defines a small governmental jurisdiction as cities, counties, towns, townships, villages, school districts, or special districts with a population of less than 50,000.

Our consultation database does not track the identity of past third parties involved in consultations, or whether the third parties were small entities; therefore we have no basis to determine the percentage of the 155 third parties that may potentially be involved in future consultations due to impacts to critical habitat that may be small businesses, small nonprofits or small government jurisdictions.

There is no indication in the data evaluated in the Impacts Analysis Report, which serves as the basis for this FRFA, that the designation would place small entities at a competitive disadvantage compared to large entities. Incremental economic impacts due to the designation for the Carolina and South Atlantic DPSs will be minimal overall. These costs will result from participation in the Section 7 consultation process, and will be spread over 14 critical habitat units totaling over 2,996 river miles (4,822 rkm) in 4 states. Federal agencies will bear the majority of the costs (59 percent to 83 percent), which will be limited to administrative costs of consultation for all parties involved. There are no apparent concentrations of costs. For most if not all of the Federal activities predicted to occur in the next 10 years, if the effects to critical habitat will be adverse and require formal consultation, those effects would also constitute adverse effects to Atlantic sturgeon or shortnose sturgeon, either directly when they are in the project area, or indirectly due to the effects on their habitat, and these consultations would be coextensive formal consultations. Assuming a third party would be involved and incur costs for each of the 179 projects in all of the categories of Federal activity that involved third parties in the past, the costs to third parties that could be involved in the projected future consultations other than those with EPA would be between $880 and $2,080 for each action for coextensive formal consultations, and between $1,500 and $3,000 for each of the 23 fully incremental informal consultations we conservatively estimated could be required due to the rule. The total costs over the next 10 years to all third parties for these 2 classes of actions would be between $30,000 and $60,000 for the incremental informal consultations and between $136,400 and $322,400 for the coextensive formal consultations. The total costs over the next 10 years to third parties involved in the EPA pesticides consultations are conservatively estimated to be $25,072 across all units.

There are no record-keeping or reporting requirements associated with the rule. Third parties would only be required to keep records or submit reports pursuant to ESA section 7 consultations on future proposed projects that may affect critical habitat. Similarly, there are no other compliance requirements in the rule. There are no professional skills necessary for preparation of any report or record.

We considered the effect to small businesses throughout our analysis and, as stated above, there will be no significant economic impact to small businesses. Changes from the proposed rule that would minimize significant economic impacts on small entities were therefore unnecessary.

In the IRFA, we considered the alternative of not proposing new critical habitat for the Carolina and South Atlantic DPSs of Atlantic sturgeon. We rejected this alternative because we determined designating critical habitat for Atlantic sturgeon is prudent and determinable, and the ESA requires critical habitat designation in that circumstance. In the IRFA, we also analyzed the alternative of including all large coastal rivers from the North Carolina/Virginia border southward to the St Johns River, Florida, in the designation, instead of just documented spawning rivers. This alternative would likely have involved many more consultations on Federal actions each year, potentially impacting many more small entities. Several large coastal rivers within the geographical area occupied by the Carolina and South Atlantic DPSs of Atlantic sturgeon do not appear to support spawning and juvenile recruitment or to contain suitable habitat features to support spawning and we determined it would not promote Atlantic sturgeon conservation by including those rivers in the rule.

Consultation and Coordination With Indian Tribal Governments (Executive Order 13175)

The longstanding and distinctive relationship between the Federal and tribal governments is defined by treaties, statutes, executive orders, judicial decisions, and agreements, which differentiate tribal governments from the other entities that deal with, or are affected by, the Federal Government. This relationship has given rise to a special Federal trust responsibility involving the legal responsibilities and obligations of the United States toward Indian Tribes and the application of fiduciary standards of due care with respect to Indian lands, tribal trust resources, and the exercise of tribal rights.

Executive Order 13175, Consultation and Coordination with Indian Tribal Governments, outlines the responsibilities of the Federal Government in matters affecting tribal interests. If NMFS issues a regulation with tribal implications (defined as having a substantial direct effect on one or more Indian tribes, on the relationship between the Federal Government and Indian tribes, or on the distribution of power and responsibilities between the Federal Government and Indian tribes), we must consult with those governments or the Federal Government must provide funds necessary to pay direct compliance costs incurred by tribal governments. The critical habitat designations for Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs do not have tribal implications because designated critical habitat will not have a substantial direct effect on one or more Indian tribes, on the relationship between the Federal Government and Indian tribes, or on the distribution of power and responsibilities between the Federal Government and Indian tribes.

Takings (Executive Order 12630)

Under E.O. 12630, Federal agencies must consider the effects of their actions on constitutionally protected private property rights and avoid unnecessary takings of property. A taking of property includes actions that result in physical invasion or occupancy of private property, and regulations imposed on private property that substantially affect its value or use. In accordance with E.O. 12630, this rule would not have significant takings implications. The designation of critical habitat for the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs of Atlantic sturgeon will not impose additional burdens on land use or affect property values. Therefore, a takings implication assessment is not required.

Environmental Justice (Executive Order 12898)

The designation of critical habitat is not expected to have a disproportionately high effect on minority populations or low-income populations.

Unfunded Mandates Reform Act (2 U.S.C. 1501 et seq.)

This final rule will not produce a Federal mandate. The designation of critical habitat does not impose a legally-binding duty on non-Federal government entities or private parties. The only regulatory effect is that Federal agencies must ensure that their actions

do not destroy or adversely modify critical habitat under section 7 of the ESA. Non-Federal entities which receive Federal funding, assistance, permits or otherwise require approval or authorization from a Federal agency for an action may be indirectly impacted by the designation of critical habitat, but the Federal agency has the legally binding duty to avoid destruction or adverse modification of critical habitat.

This rule will not significantly or uniquely affect small governments. Therefore, a Small Government Action Plan is not required.

Regulatory Planning and Review (Executive Orders 12866 and 13771)

The OMB determined that this final rule is significant under Executive Order 12866 because it may create a serious inconsistency or otherwise interfere with an action taken or planned by another agency. Final Economic and Regulatory Impact Review Analyses and 4(b)(2) analyses as set forth and referenced herein have been prepared to support the exclusion process under section 4(b)(2) of the ESA. To review these documents see **ADDRESSES** section above.

In addition, as explained above, OMB classified this rule as significant under E.O. 12866. Therefore, this final rule is considered an E.O. 13771 regulatory action. This rule is not subject to the requirements of E.O. 13771 because this rule results in no more than *de minimis* costs.

Federalism (Executive Order 13132)

Pursuant to the Executive Order on Federalism, E.O. 13132, we determined that this final rule does not have significant federalism effects and that a federalism assessment is not required. However, in keeping with Department of Commerce policies and consistent with ESA regulations at 50 CFR 424.16(c)(1)(ii), we requested information from, and coordinated this critical habitat designation with, appropriate state resource agencies in Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Delaware, Maryland, Virginia, the District of Columbia, North Carolina, South Carolina, Georgia, and Florida.

Coastal Zone Management Act

Under section 307(c)(1)(A) of the Coastal Zone Management Act (CZMA) (16 U.S.C. 1456(c)(1)(A)) and its implementing regulations, each Federal activity within or outside the coastal zone that has reasonably foreseeable effects on any land or water use or natural resource of the coastal zone shall be carried out in a manner which is consistent to the maximum extent practicable with the enforceable policies of approved State coastal management programs. We have determined that any effects of this designation of critical habitat on coastal uses and resources in Maine, New Hampshire, Massachusetts, Connecticut, New York, New Jersey, Delaware, Pennsylvania, Maryland, Virginia, North Carolina, South Carolina, Georgia and Florida are not reasonably foreseeable at this time. However, the State of North Carolina suggested SERO's consistency determination regarding designating critical habitat was incomplete and did not meet the requirements of the CZMA and its implementing regulations. The State maintained SERO submitted an incomplete negative determination, because it had not provided an evaluation of the North Carolina coastal program's enforceable policies; SERO disagrees. While SERO recognizes the State's goals of coastal resource protection and economic development, it determined that any effects of the proposed action on North Carolina's coastal uses and resources are not reasonably foreseeable at this time. As indicated in SERO's negative determination, this designation of critical habitat will not restrict any coastal uses, affect land ownership, or establish a refuge or other conservation area; rather, the designation affects only the ESA section 7 consultation process for Federal actions. These consultations will consider effects of Federal actions on coastal uses and resources to the extent they overlap with critical habitat. We considered the range of Federal actions that this designation may affect (*e.g.*, dredging, bridge construction/repair, water withdrawals) and which may affect coastal uses and resources in the affected States. However, we do not have sufficient information on the specifics of any future activities (*e.g.*, when, where and how they will be carried out) to characterize any of these as reasonably foreseeable. Therefore, because the effects are not reasonably foreseeable, we cannot make a determination as to whether the Federal activities will be consistent with any enforceable policies of approved State coastal management programs. Through the consultation process, we will receive information on proposed Federal actions and their effects on listed species and the designated critical habitat. Any related biological opinions will analyze this information. It will then be up to the Federal action agencies to decide how to comply with the ESA in light of our biological opinion, as well as to ensure that their actions comply with the CZMA's Federal consistency requirement. At this time, we do not anticipate that this designation is likely to result in any additional management measures by other Federal agencies.

Energy Supply, Distribution, and Use (Executive Order 13211)

Executive Order 13211 requires agencies to prepare Statements of Energy Effects when undertaking an action expected to lead to the promulgation of a final rule or regulation that is a significant regulatory action under E.O. 12866 and is likely to have a significant adverse effect on the supply, distribution, or use of energy. OMB Guidance on Implementing E.O. 13211 (July 13, 2001) states that significant adverse effects could include any of the following outcomes compared to a world without the regulatory action under consideration: (1) Reductions in crude oil supply in excess of 10,000 barrels per day; (2) reductions in fuel production in excess of 4,000 barrels per day; (3) reductions in coal production in excess of 5 million tons per year; (4) reductions in natural gas production in excess of 25 million cubic feet per year; (5) reductions in electricity production in excess of 1 billion kilowatt-hours per year or in excess of 500 megawatts of installed capacity; (6) increases in energy use required by the regulatory action that exceed any of the thresholds above; (7) increases in the cost of energy production in excess of one percent; (8) increases in the cost of energy distribution in excess of one percent; or (9) other similarly adverse outcomes. A regulatory action could also have significant adverse effects if it: (1) Adversely affects in a material way the productivity, competition, or prices in the energy sector; (2) adversely affects in a material way productivity, competition or prices within a region; (3) creates a serious inconsistency or otherwise interferes with an action taken or planned by another agency regarding energy; or (4) raises novel legal or policy issues adversely affecting the supply, distribution or use of energy arising out of legal mandates, the President's priorities, or the principles set forth in E.O. 12866 and 13211. We do not believe this rule will have a significant adverse effect on the supply, distribution, or use of energy. The only Federal actions we may consult on that may have material effects on energy are FERC hydropower licensing and Nuclear Regulatory Commission actions. These actions have the potential to adversely affect sturgeon as well as its

critical habitat, and thus most of the impacts of these consultations will not be incremental impacts of this rule. Moreover, the FPA, which FERC implements in issuing hydropower licenses, has independent requirements to avoid adverse effects on fisheries resources and habitats, and thus modifications to hydropower facilities to avoid impacts to critical habitat may also be coextensive with the FPA, and not incremental impacts of the designation. Therefore, we have not prepared a Statement of Energy Effects.

Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.)

This final rule does not contain any new or revised collection of information. This rule, if adopted, would not impose recordkeeping or reporting requirements on State or local governments, individuals, businesses, or organizations.

References Cited

A complete list of all references cited in this rulemaking can be found on our Web sites at *http://sero.nmfs.noaa.gov/protected_resources/sturgeon/index.html* and *https://www.greateratlantic.fisheries.noaa.gov/protected/atlsturgeon/* and is available upon request from the NMFS SERO and GARFO offices (see **ADDRESSES**).

List of Subjects in 50 CFR Part 226

Endangered and threatened species.

Dated: August 10, 2017.

Samuel D Rauch III,

Deputy Assistant Administrator for Regulatory Programs, National Marine Fisheries Service.

For the reasons set out in the preamble, we amend 50 CFR part 226 as follows:

PART 226—DESIGNATED CRITICAL HABITAT

■ 1. The authority citation for part 226 continues to read as follows:

Authority: 16 U.S.C. 1533.

■ 2. Add § 226.225 to read as follows:

§ 226.225 Critical habitat for the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic distinct population segments (DPSs) of Atlantic Sturgeon.

Critical habitat is designated for the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs of Atlantic sturgeon as described in paragraphs (a) through (h) of this section. The maps, clarified by the textual descriptions in paragraphs (d) through (h) of this section, are the definitive source for determining the critical habitat boundaries.

(a) *Critical habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon.* The physical features essential for the conservation of Atlantic sturgeon belonging to the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs are those habitat components that support successful reproduction and recruitment. These are:

(1) Hard bottom substrate (*e.g.*, rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (*i.e.*, 0.0–0.5 parts per thousand range) for settlement of fertilized eggs, refuge, growth, and development of early life stages;

(2) Aquatic habitat with a gradual downstream salinity gradient of 0.5 up to as high as 30 parts per thousand and soft substrate (*e.g.*, sand, mud) between the river mouth and spawning sites for juvenile foraging and physiological development;

(3) Water of appropriate depth and absent physical barriers to passage (*e.g.*, locks, dams, thermal plumes, turbidity, sound, reservoirs, gear, etc.) between the river mouth and spawning sites necessary to support:

(i) Unimpeded movement of adults to and from spawning sites;

(ii) Seasonal and physiologically dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary; and

(iii) Staging, resting, or holding of subadults or spawning condition adults. Water depths in main river channels must also be deep enough (*e.g.*, at least 1.2 meters) to ensure continuous flow in the main channel at all times when any sturgeon life stage would be in the river;

(4) Water, between the river mouth and spawning sites, especially in the bottom meter of the water column, with the temperature, salinity, and oxygen values that, combined, support:

(i) Spawning;

(ii) Annual and interannual adult, subadult, larval, and juvenile survival; and

(iii) Larval, juvenile, and subadult growth, development, and recruitment (*e.g.*, 13 to 26 °C for spawning habitat and no more than 30 °C for juvenile rearing habitat, and 6 milligrams per liter (mg/L) or greater dissolved oxygen for juvenile rearing habitat).

(5) Pursuant to ESA section 4(a)(3)(B)(i), critical habitat for the New York Bight and Chesapeake Bay DPSs of Atlantic sturgeon does not include the following areas owned or controlled by the Department of Defense, or designated for its use, that are subject to an integrated natural resource management plan prepared under section 101 of the Sikes Act (16 U.S.C. 670a), and for which we have determined that such plan provides a conservation benefit to the species, and its habitat, for which critical habitat is designated.

(i) The Department of the Army, U.S. Military Academy—West Point, NY;

(ii) The Department of the Air Force, Joint Base Langley—Eustis, VA;

(iii) The Department of the Navy, Marine Corps Base Quantico, VA;

(iv) The Department of the Navy, Naval Weapons Station Yorktown, VA; and,

(v) The Department of the Navy, Naval Support Facility Dahlgren, VA.

(6) Pursuant to ESA section 3(5)(A)(i), critical habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon does not include existing (already constructed), as of September 18, 2017, manmade structures that do not provide the physical features such as aids-to-navigation (ATONs), artificial reefs, boat ramps, docks, or pilings within the legal boundaries of designated critical habitat.

(b) *Critical habitat for the Carolina and South Atlantic DPSs of Atlantic sturgeon.* The physical features essential for the conservation of Atlantic sturgeon belonging to the Carolina and South Atlantic DPSs are those habitat components that support successful reproduction and recruitment. These are:

(1) Hard bottom substrate (*e.g.*, rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (*i.e.*, 0.0–0.5 parts per thousand range) for settlement of fertilized eggs and refuge, growth, and development of early life stages;

(2) Aquatic habitat inclusive of waters with a gradual downstream gradient of 0.5 up to as high as 30 parts per thousand and soft substrate (*e.g.*, sand, mud) between the river mouth and spawning sites for juvenile foraging and physiological development;

(3) Water of appropriate depth and absent physical barriers to passage (*e.g.*, locks, dams, thermal plumes, turbidity, sound, reservoirs, gear, etc.) between the river mouth and spawning sites necessary to support:

(i) Unimpeded movement of adults to and from spawning sites;

(ii) Seasonal and physiologically dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary; and

(iii) Staging, resting, or holding of subadults or spawning condition adults. Water depths in main river channels must also be deep enough (at least 1.2 meters) to ensure continuous flow in the

main channel at all times when any sturgeon life stage would be in the river;

(4) Water quality conditions, especially in the bottom meter of the water column, with temperature and oxygen values that support:

(i) Spawning;

(ii) Annual and inter-annual adult, subadult, larval, and juvenile survival; and

(iii) Larval, juvenile, and subadult growth, development, and recruitment. Appropriate temperature and oxygen values will vary interdependently, and depending on salinity in a particular habitat. For example, 6.0 mg/L dissolved oxygen or greater likely supports juvenile rearing habitat, whereas dissolved oxygen less than 5.0 mg/L for longer than 30 days is less likely to support rearing when water temperature is greater than 25 °C. In temperatures greater than 26 °C, dissolved oxygen greater than 4.3 mg/L is needed to protect survival and growth. Temperatures of 13 to 26 °C likely support spawning habitat.

(5) Pursuant to ESA section 4(a)(3)(B)(i), critical habitat for the Carolina DPS of Atlantic sturgeon does not include certain waters of the Cooper River, South Carolina, adjacent to Joint Base Charleston. These areas are described in 33 CFR 334.460(a)(8)(ii)–(iv), 33 CFR 334.460(a)(9), and 33 CFR 334.460(a)(10).

(6) Pursuant to ESA section 3(5)(A)(i), critical habitat for the Carolina and the South Atlantic DPSs of Atlantic sturgeon does not include existing (already constructed), as of September 18, 2017, manmade structures that do not provide the physical features such as aids-to-navigation (ATONs), artificial reefs, boat ramps, docks, or pilings within the legal boundaries of designated critical habitat.

(c) *States and counties affected by this critical habitat designation.* Critical habitat is designated for the following DPSs in the following states and counties:

DPS	State—Counties
Gulf of Maine	ME—Androscoggin, Cumberland, Kennebec, Lincoln, Penobscot, Sagadahoc, Somerset, Waldo, and York. NH—Rockingham and Stafford. MA—Essex.
New York Bight	CT—Fairfield, Hartford, Litchfield, Middlesex, New Haven, New London, and Tolland. NJ—Bergen, Burlington, Camden, Cape May, Cumberland, Gloucester, Hudson, Mercer, Monmouth, and Salem. NY—Albany, Bronx, Columbia, Dutchess, Greene, Kings, New York, Orange, Putnam, Queens, Rensselaer, Richmond, Rockland, Saratoga, Ulster, and Westchester. DE—Kent, New Castle, and Sussex. PA—Bucks, Delaware, and Philadelphia.
Chesapeake Bay	DC—District of Columbia. MD—Charles, Dorchester, Montgomery, Prince George's, St. Mary's, and Wicomico. VA—Arlington, Caroline, Charles City, Chesterfield, Dinwiddie, Essex, Fairfax, Gloucester, Hanover, Henrico, Isle of Wight, King George, James City, King and Queen, King William, Lancaster, Loudoun, Middlesex, New Kent, Northumberland, Prince George, Prince William, Richmond, Spotsylvania, Stafford, Surry, Westmoreland, and York.
Carolina	NC—Anson, Bertie, Beaufort, Brunswick, Carteret, Columbus, Craven, Duplin, Edgecombe, Halifax, Hyde, Johnston, Lenoir, Martin, Nash, New Hanover, Northampton, Pamlico, Pender, Pitt, Richmond, Wake, Washington, and Wayne. SC—Berkeley, Charleston, Chesterfield, Clarendon, Darlington, Dillon, Florence, Georgetown, Horry, Marion, Marlboro, and Williamsburg.
South Atlantic	SC—Aiken, Allendale, Bamberg, Barnwell, Beaufort, Charleston, Colleton, Dorchester, Edgefield, Hampton, and Jasper. GA—Appling, Atkinson, Baldwin, Ben Hill, Bibb, Bleckley, Brantley, Bryan, Bulloch, Burke, Camden, Charlton, Chatham, Coffee, Dodge, Effingham, Emanuel, Glascock, Glynn, Hancock, Houston, Jeff Davis, Jefferson, Jenkins, Johnson, Jones, Laurens, Long, McIntosh, Monroe, Montgomery, Pierce, Pulaski, Richmond, Screven, Tattnall, Telfair, Toombs, Treutlen, Twiggs, Ware, Warren, Washington, Wayne, Wheeler, Wilcox, and Wilkinson. FL—Baker and Nassau.

(d) *Critical habitat boundaries for the Gulf of Maine DPS.* Critical habitat for the Gulf of Maine DPS of Atlantic sturgeon is the waters of:

(1) Penobscot River main stem from the Milford Dam downstream to where the main stem river drainage discharges at its mouth into Penobscot Bay;

(2) Kennebec River main stem from the Ticonic Falls/Lockwood Dam downstream to where the main stem river discharges at its mouth into the Atlantic Ocean;

(3) Androscoggin River main stem from the Brunswick Dam downstream to where the main stem river drainage discharges into Merrymeeting Bay;

(4) Piscataqua River from its confluence with the Salmon Falls and Cocheco rivers downstream to where the main stem river discharges at its mouth into the Atlantic Ocean as well as the waters of the Cocheco River from its confluence with the Piscataqua River and upstream to the Cocheco Falls Dam, and waters of the Salmon Falls River from its confluence with the Piscataqua River and upstream to the Route 4 Dam; and

(5) Merrimack River from the Essex Dam (also known as the Lawrence Dam) downstream to where the main stem river discharges at its mouth into the Atlantic Ocean.

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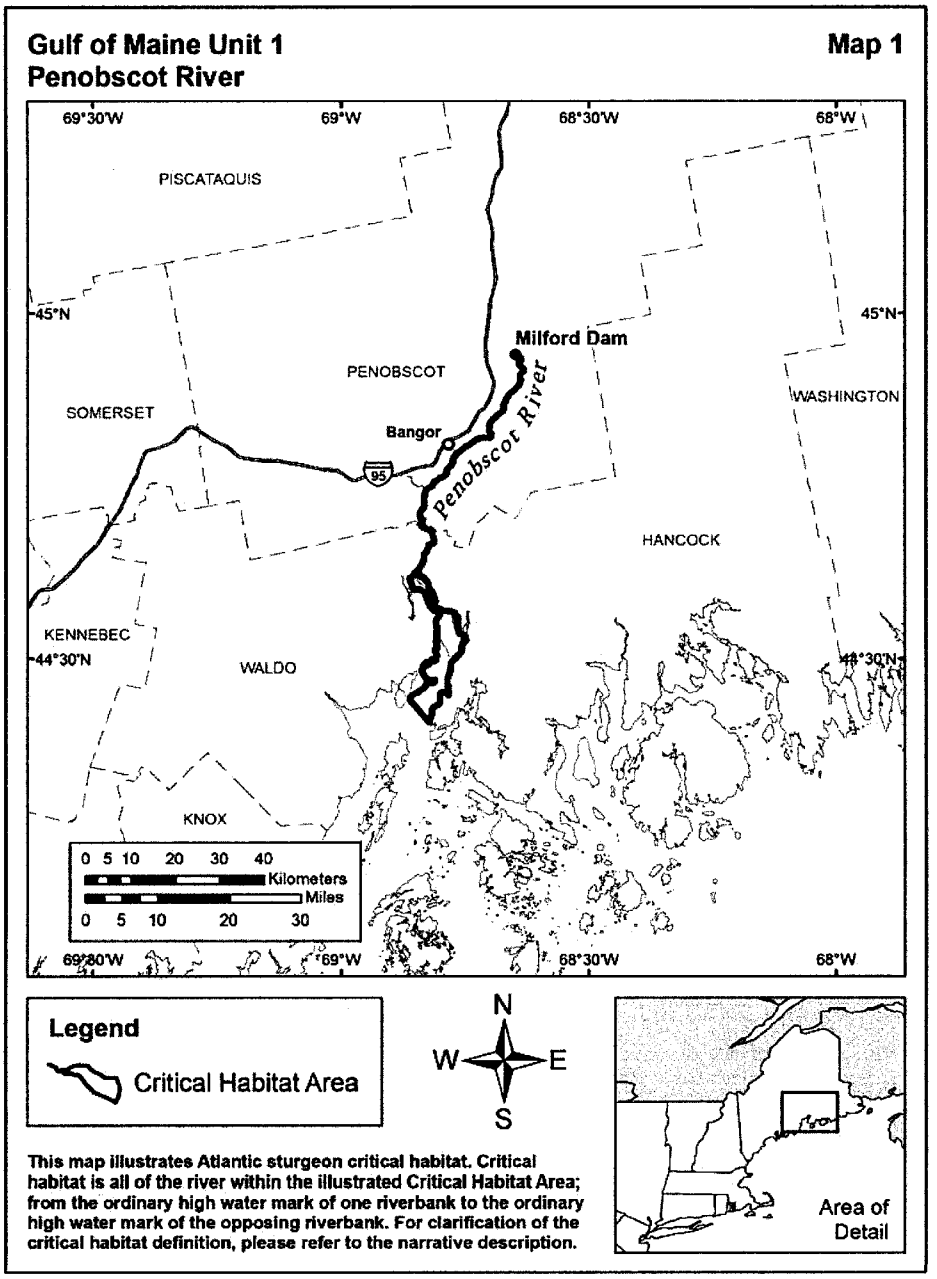
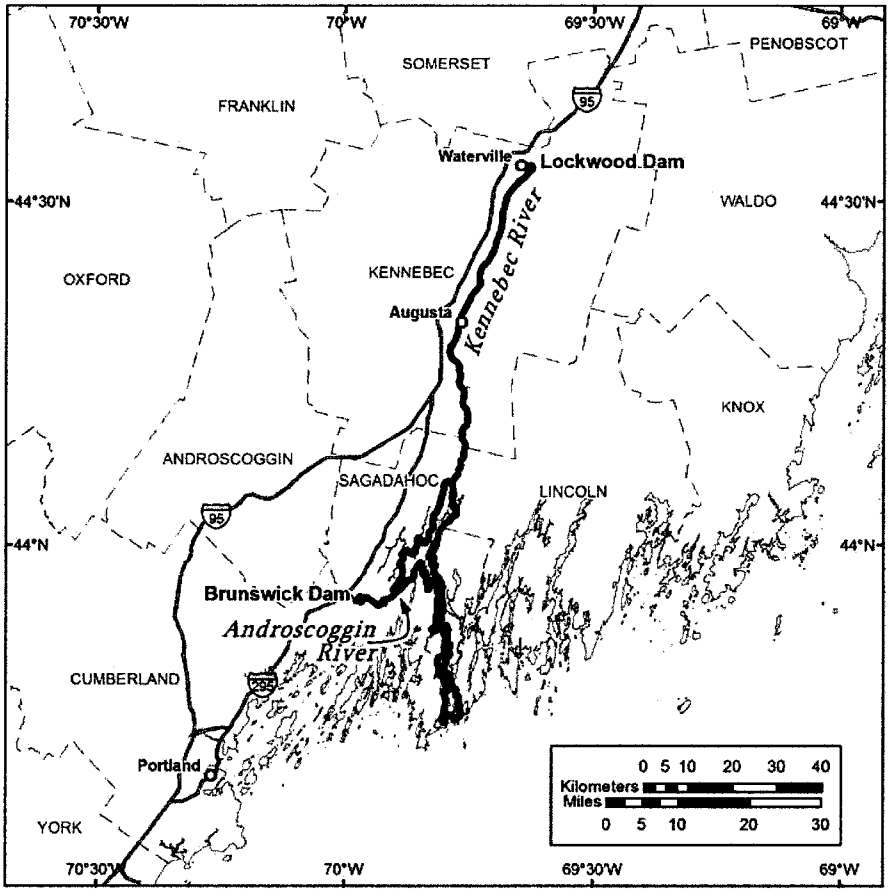
(6) Maps of the Gulf of Maine DPS follow:

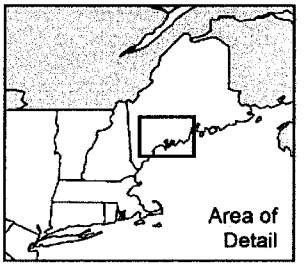


Gulf of Maine Units 2 and 3 **Map 2**
Kennebec River and Androscoggin River

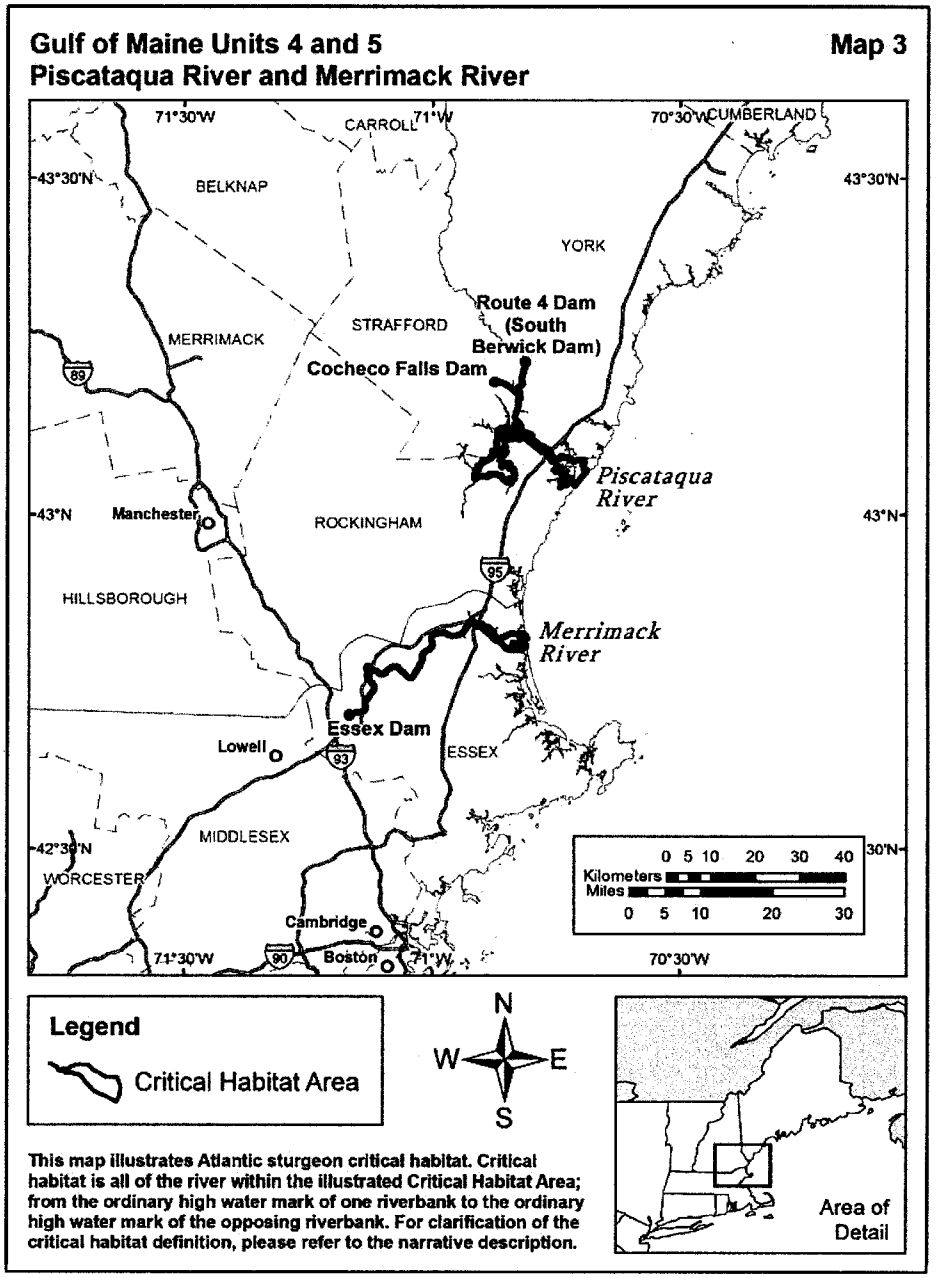


Legend

Critical Habitat Area



This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area; from the ordinary high water mark of one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.



(e) *Critical habitat boundaries of the New York Bight DPS.* Critical habitat for the New York Bight DPS of Atlantic sturgeon is the waters of:

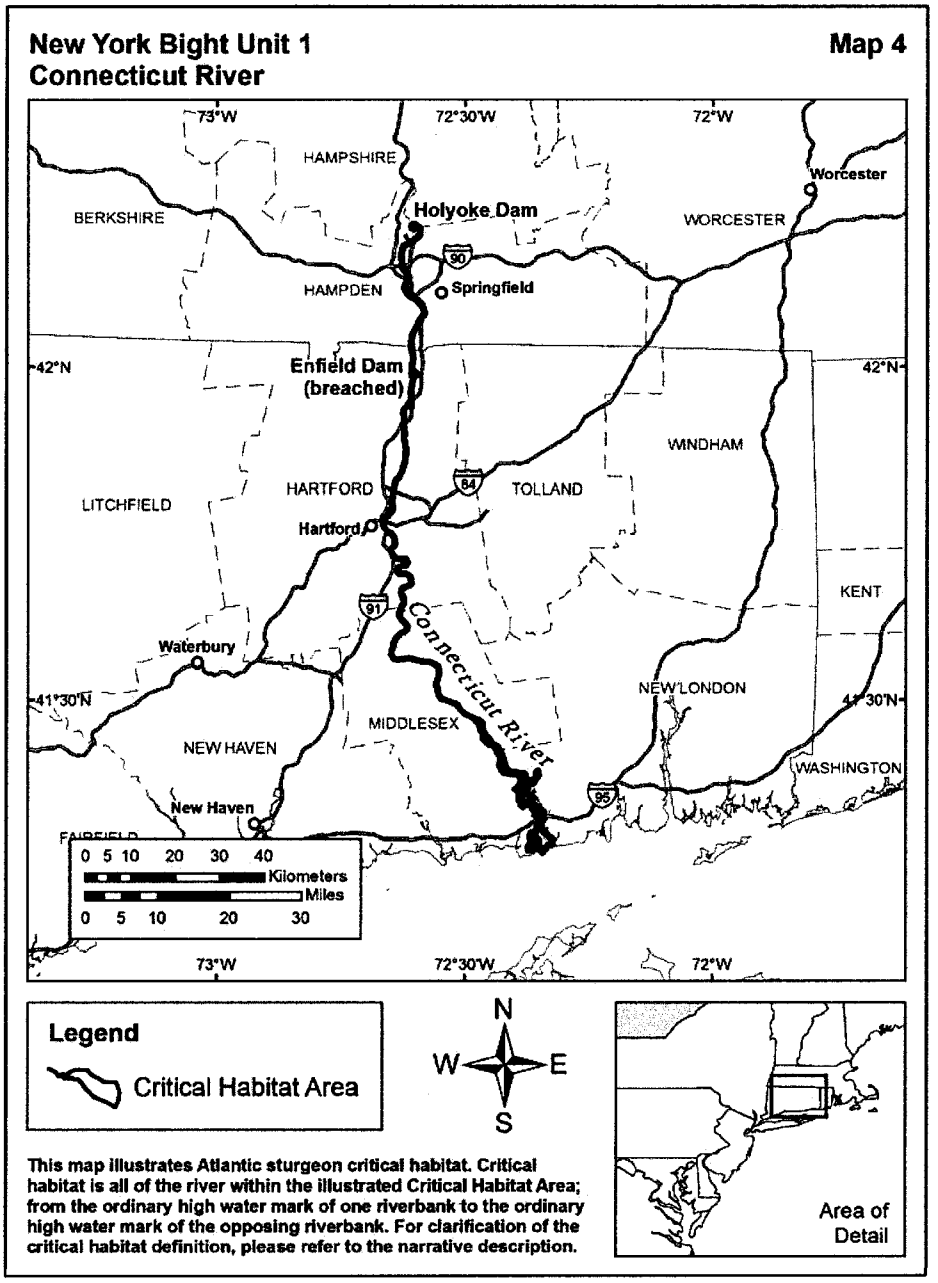
(1) Connecticut River from the Holyoke Dam downstream to where the main stem river discharges at its mouth into Long Island Sound;

(2) Housatonic River from the Derby Dam downstream to where the main stem discharges at its mouth into Long Island Sound;

(3) Hudson River from the Troy Lock and Dam (also known as the Federal Dam) downstream to where the main stem river discharges at its mouth into New York City Harbor; and

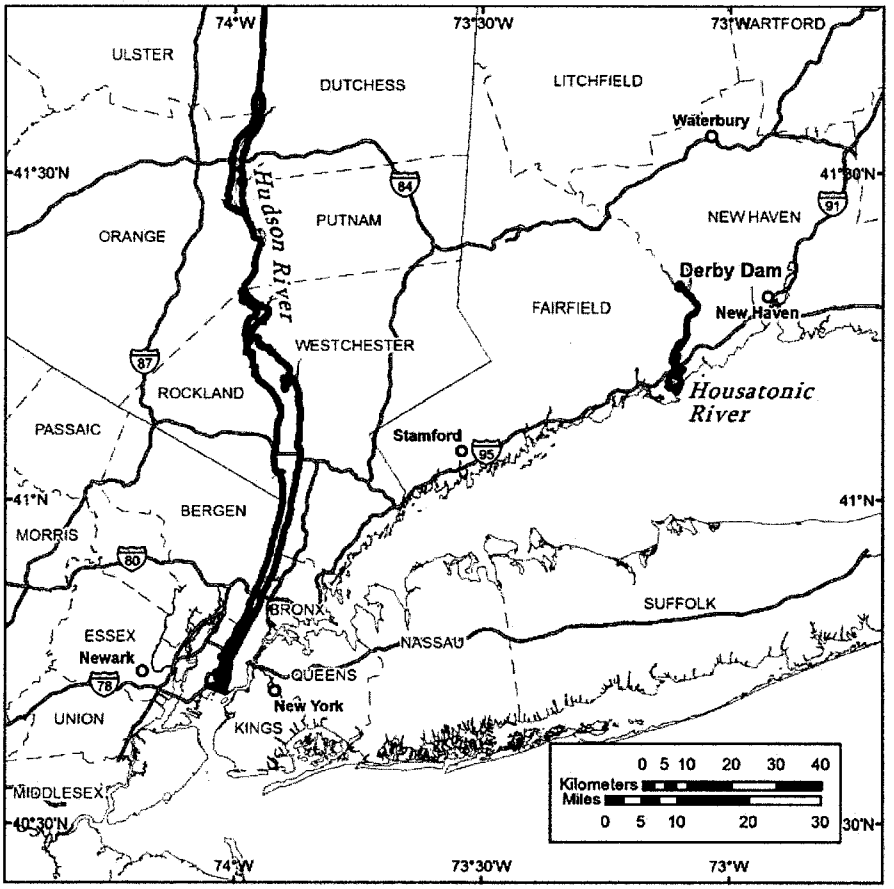
(4) Delaware River at the crossing of the Trenton-Morrisville Route 1 Toll Bridge, downstream to where the main stem river discharges at its mouth into Delaware Bay.

(5) Maps of the New York Bight DPS follow:



New York Bight Units 2 and 3
Housatonic River and Hudson River (Part A)

Map 5



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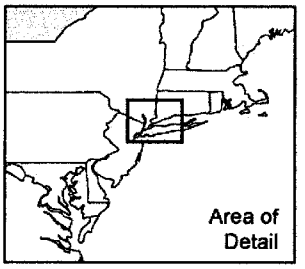
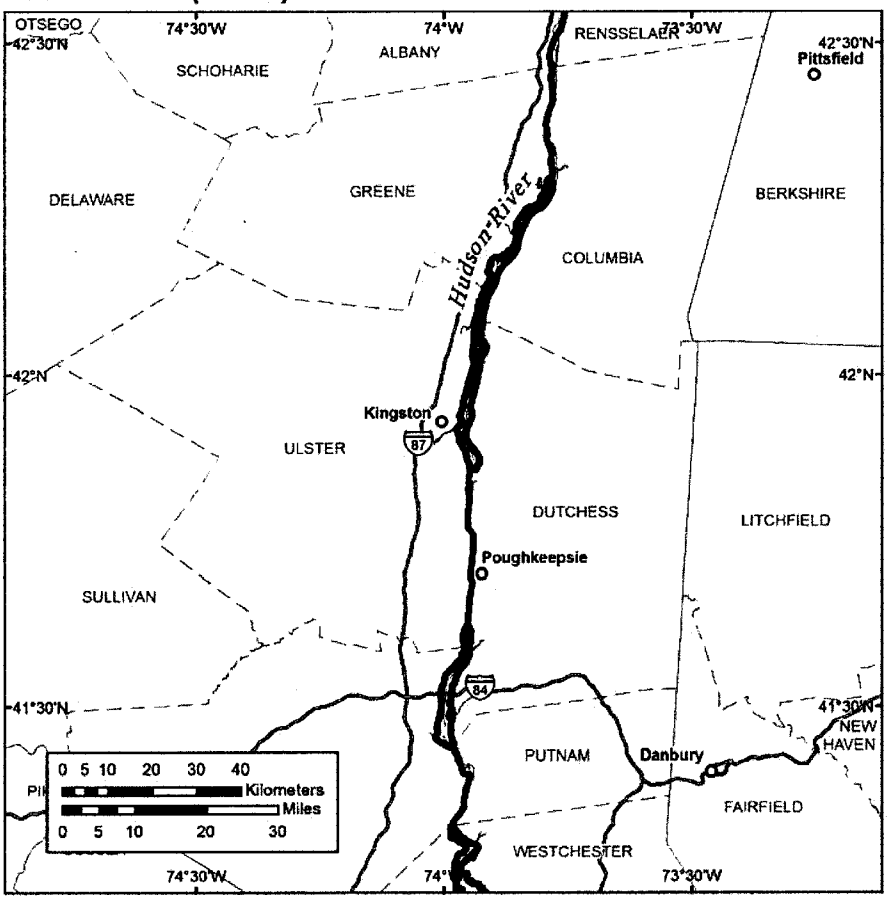
Critical Habitat Area



This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area; from the ordinary high water mark of one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

New York Bight Unit 3
Hudson River (Part B)

Map 6



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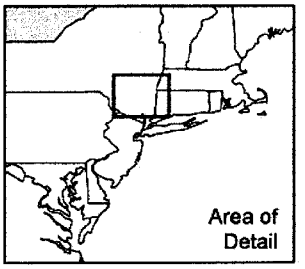
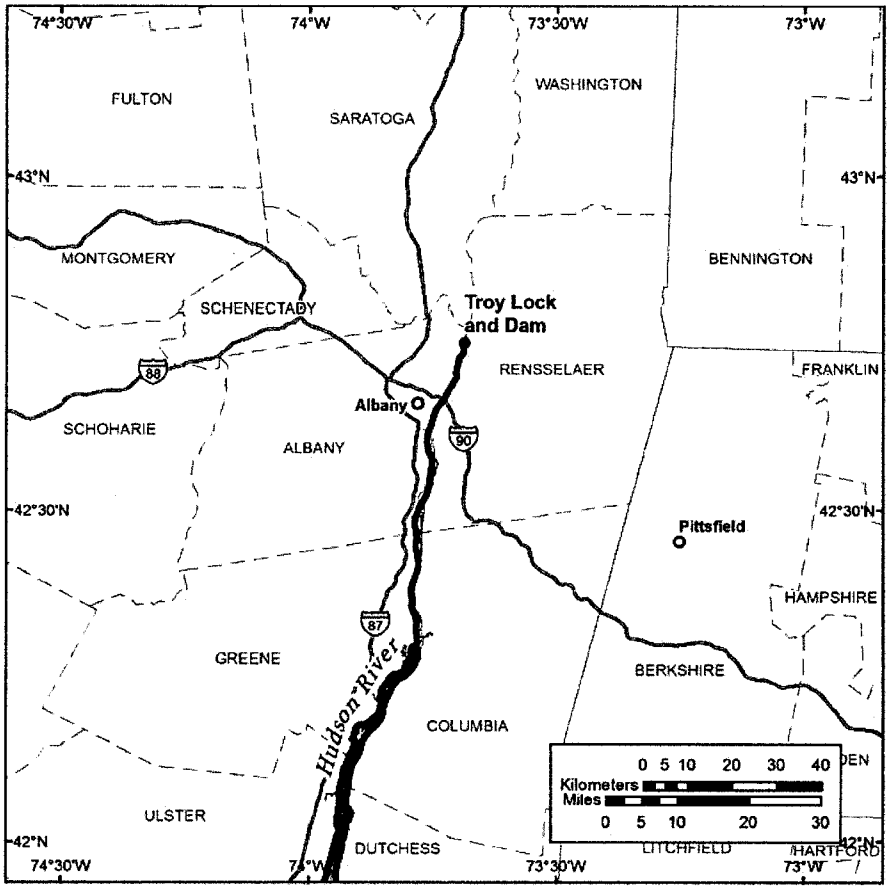
Critical Habitat Area



This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area; from the ordinary high water mark of one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

New York Bight Unit 3
Hudson River (Part C)

Map 7



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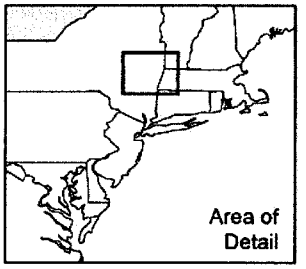
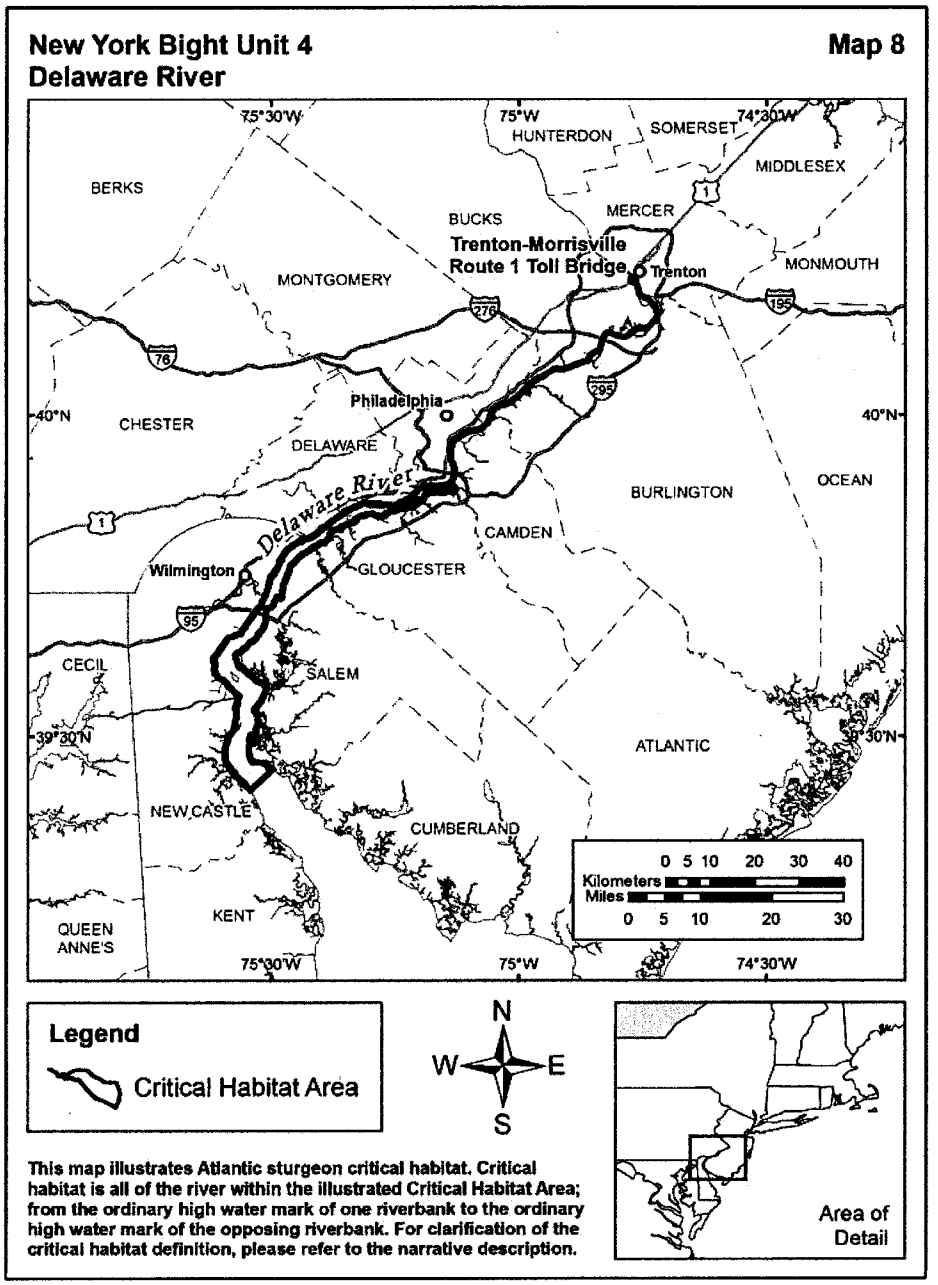
Critical Habitat Area



This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area; from the ordinary high water mark of one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.



(f) *Critical habitat boundaries of the Chesapeake Bay DPS.* Critical habitat for the Chesapeake Bay DPS of Atlantic sturgeon is the waters of:

(1) Potomac River from the Little Falls Dam downstream to where the main stem river discharges at its mouth into the Chesapeake Bay;

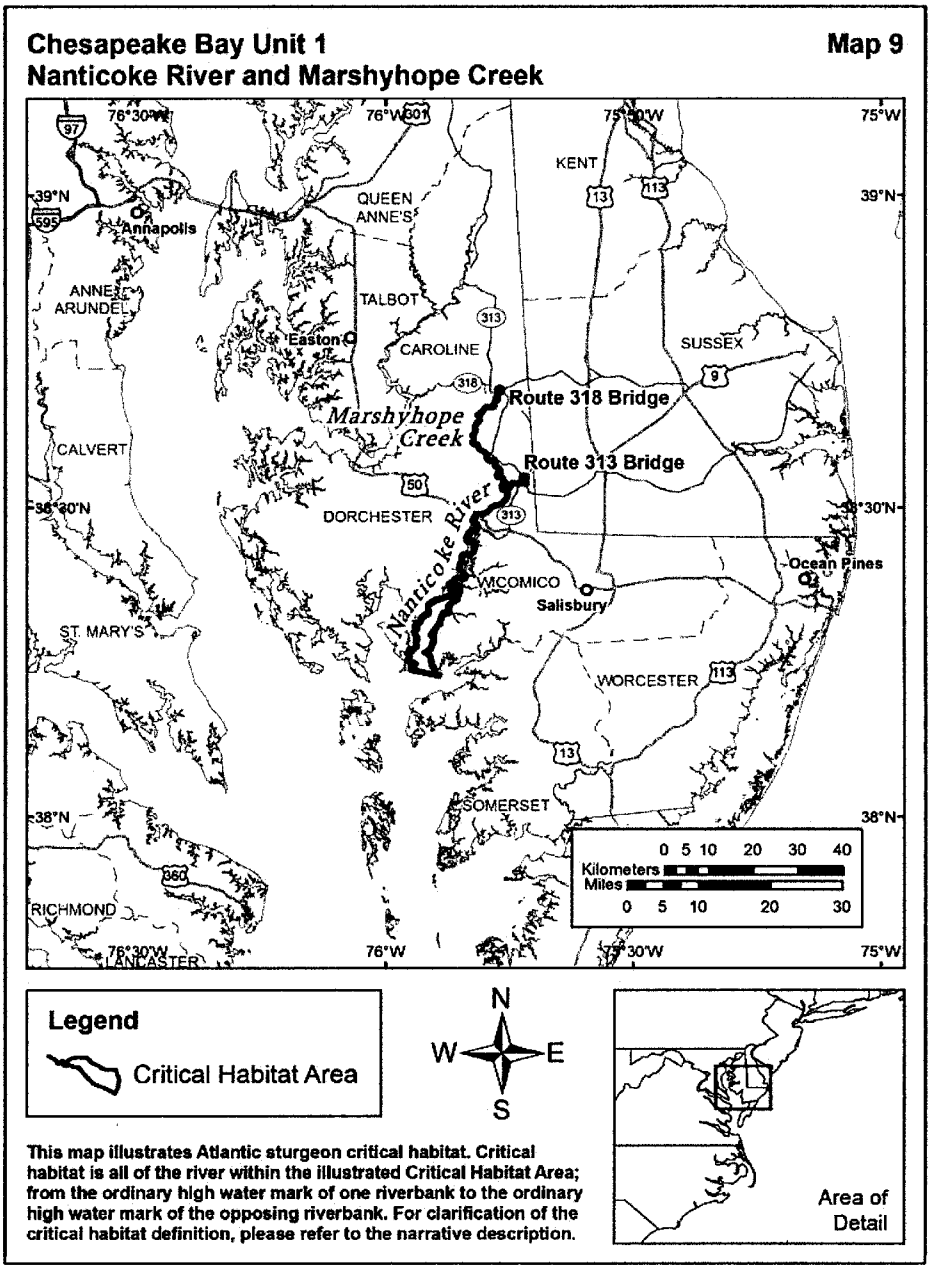
(2) Rappahannock River from the U.S. Highway 1 Bridge, downstream to where the river discharges at its mouth into the Chesapeake Bay;

(3) York River from its confluence with the Mattaponi and Pamunkey rivers downstream to where the main stem river discharges at its mouth into the Chesapeake Bay as well as the waters of the Mattaponi River from its confluence with the York River and upstream to the Virginia State Route 360 Bridge of the Mattaponi River, and waters of the Pamunkey River from its confluence with the York River and upstream to the Nelson's Bridge Road Route 615 crossing of the Pamunkey River;

(4) James River from Boshers Dam downstream to where the main stem river discharges at its mouth into the Chesapeake Bay at Hampton Roads; and

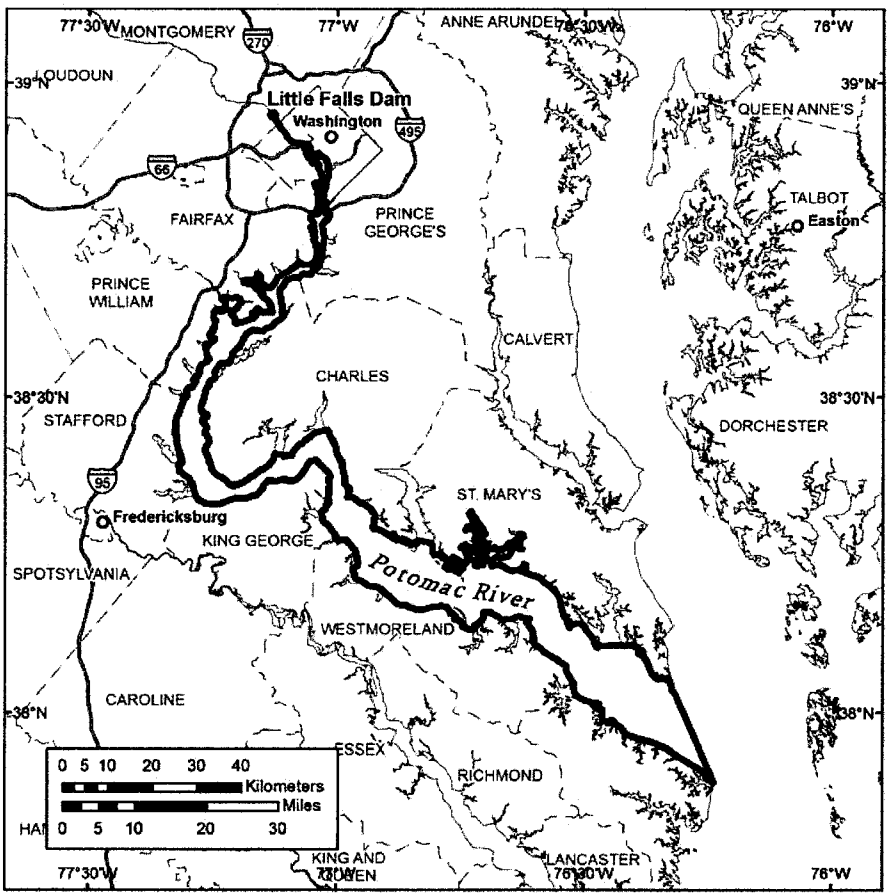
(5) Nanticoke River from the Maryland State Route 313 Bridge crossing near Sharptown, MD to where the main stem discharges at its mouth into the Chesapeake Bay as well as Marshyhope Creek from its confluence with the Nanticoke River and upriver to the Maryland State Route 318 Bridge crossing near Federalsburg, MD.

(6) Maps of the Chesapeake Bay DPS follow:



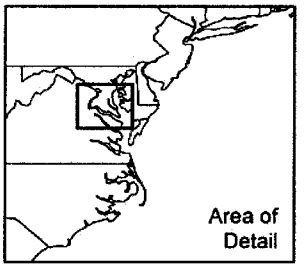
Chesapeake Bay Unit 2
Potomac River

Map 10



Legend

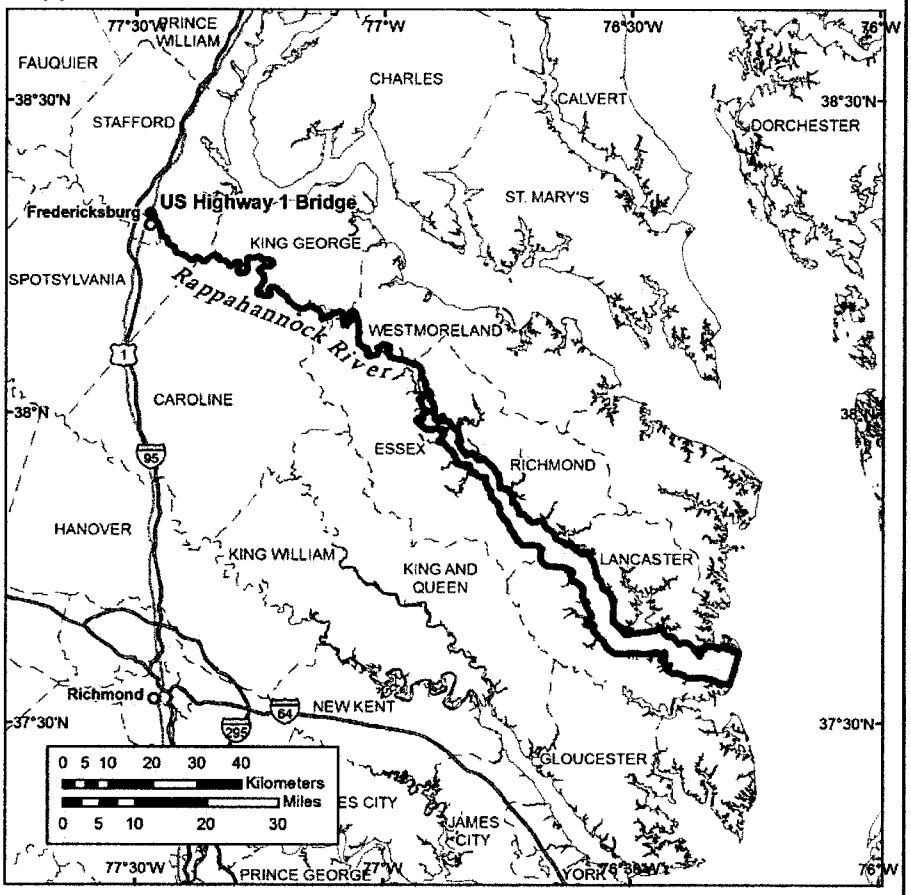
Critical Habitat Area



This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area; from the ordinary high water mark of one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

Chesapeake Bay Unit 3
Rappahannock River

Map 11



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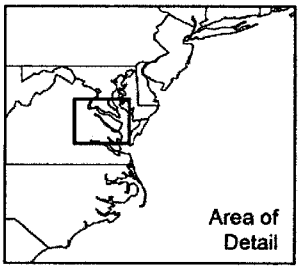
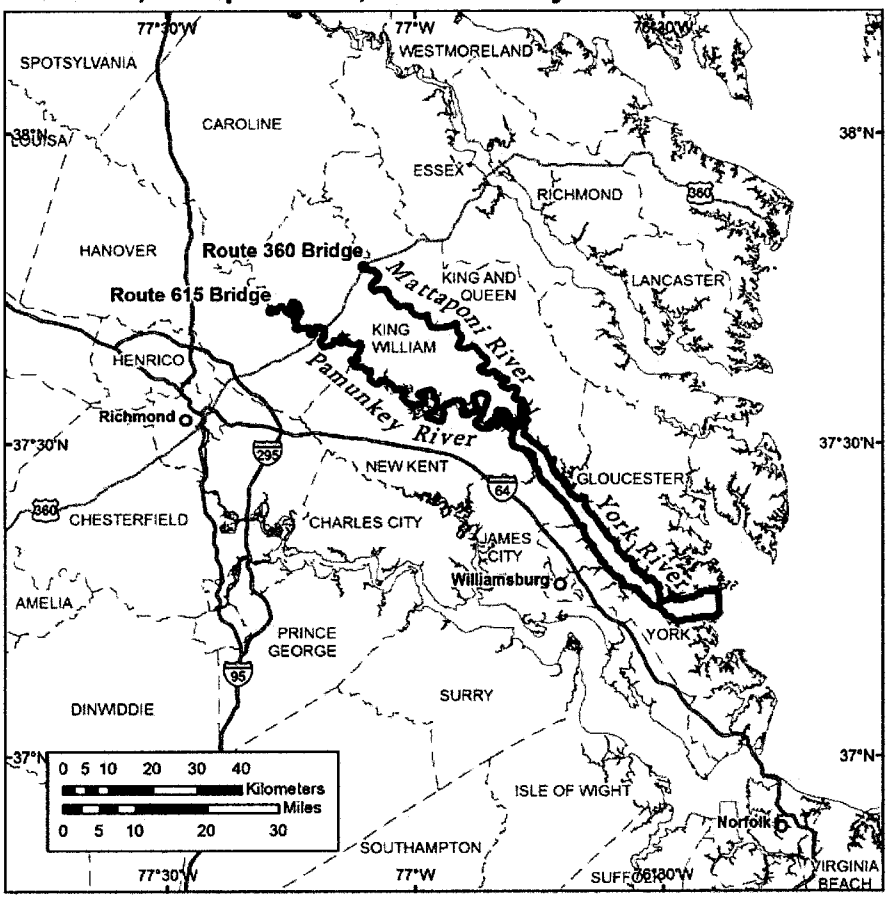
Critical Habitat Area



This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area; from the ordinary high water mark of one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

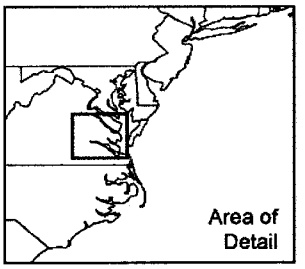
Chesapeake Bay Unit 4 **Map 12**

York River, Mattaponi River, and Pamunkey River

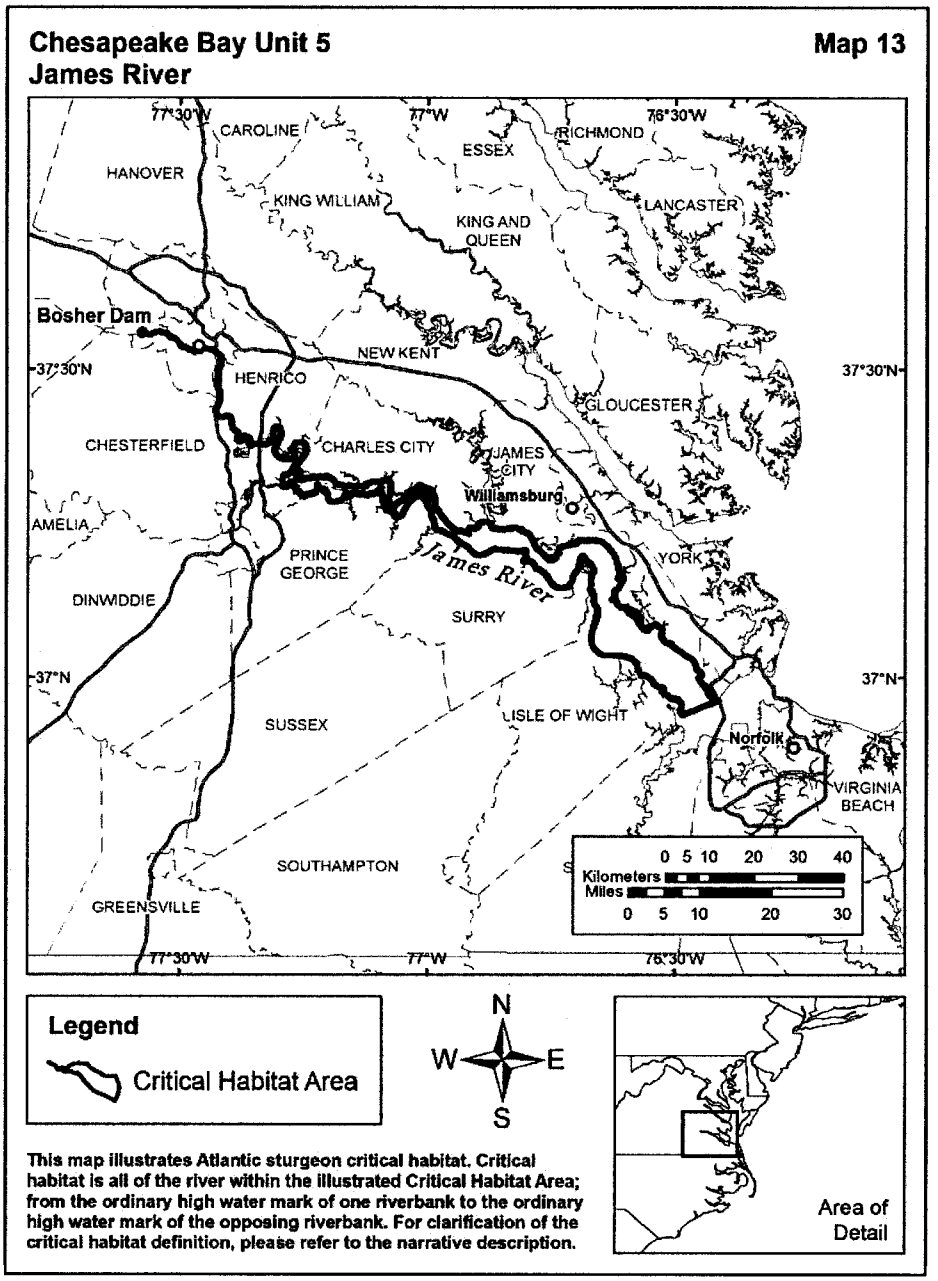


Legend

Critical Habitat Area



This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area; from the ordinary high water mark of one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.



(g) *Critical habitat boundaries of the Carolina DPS*. The lateral extent for all critical habitat units for the Carolina DPS of Atlantic sturgeon is the ordinary high water mark on each bank of the river and shorelines. Critical habitat for the Carolina DPS of Atlantic sturgeon is:

(1) Carolina Unit 1 includes the Roanoke River main stem from the Roanoke Rapids Dam downstream to rkm 0;

(2) Carolina Unit 2 includes the Tar-Pamlico River main stem from the Rocky Mount Millpond Dam downstream to rkm 0;

(3) Carolina Unit 3 includes the Neuse River main stem from the Milburnie Dam downstream to rkm 0;

(4) Carolina Unit 4 includes the Cape Fear River main stem from Lock and Dam #2 downstream to rkm 0 and the Northeast Cape Fear River from the upstream side of Rones Chapel Road Bridge downstream to the confluence with the Cape Fear River;

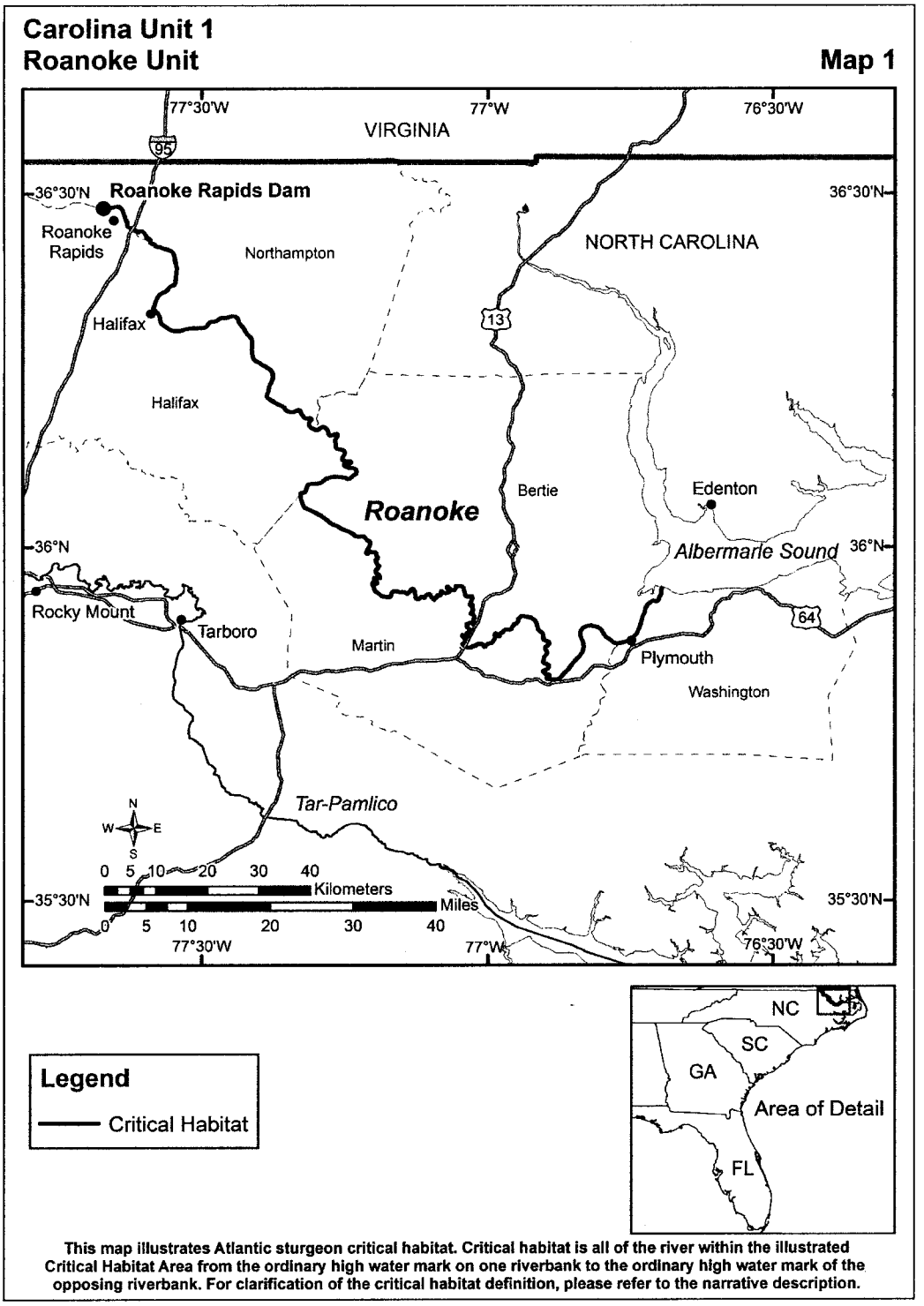
(5) Carolina Unit 5 includes the Pee Dee River main stem from Blewett Falls Dam downstream to rkm 0, the Waccamaw River from Bull Creek downstream to rkm 0, and Bull Creek from the Pee Dee River to the confluence with the Waccamaw River;

(6) Carolina Unit 6 includes the Black River main stem from Interstate Highway 95 downstream to rkm 0 (the confluence with the Pee Dee River); and

(7) Carolina Unit 7 includes the Santee River main stem from the Wilson Dam downstream to the fork of the North Santee River and South Santee River distributaries, the Rediversion Canal from the St. Stephen Powerhouse downstream to the confluence with the Santee River, the North Santee River from the fork of the Santee River and South Santee River downstream to rkm

0, the South Santee River from the fork of the Santee River and North Santee River downstream to rkm 0, the Tailrace Canal from Pinopolis Dam downstream to the West Branch Cooper River, the West Branch Cooper River from the Tailrace Canal downstream to the confluence with the East Branch Cooper River, and the Cooper River from confluence of the West Branch Cooper River and East Branch Cooper River tributaries downstream to rkm 0, not including the area described in paragraph (b)(5) of this section.

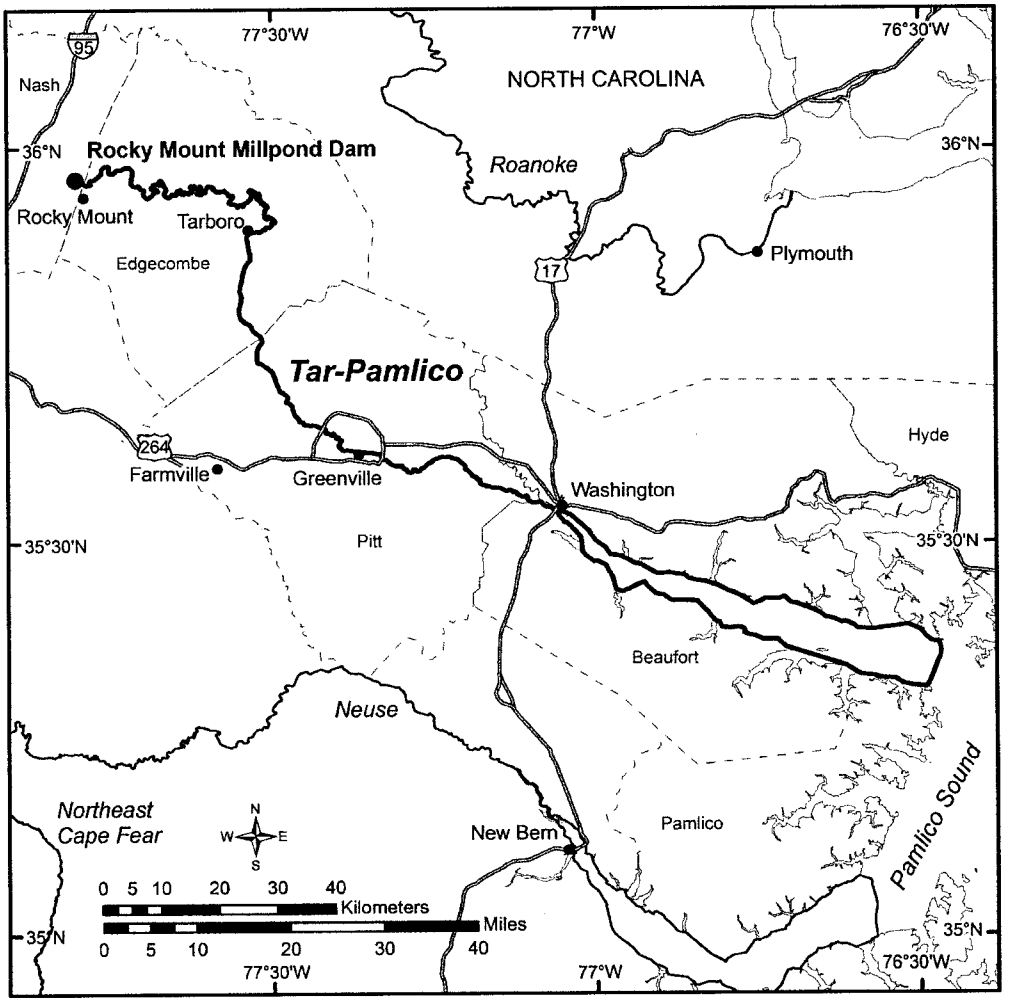
(8) Maps of the Carolina DPS follow:

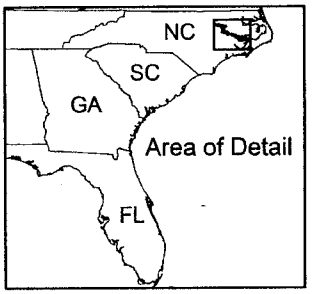


This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area from the ordinary high water mark on one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

Carolina Unit 2
Tar-Pamlico Unit

Map 2





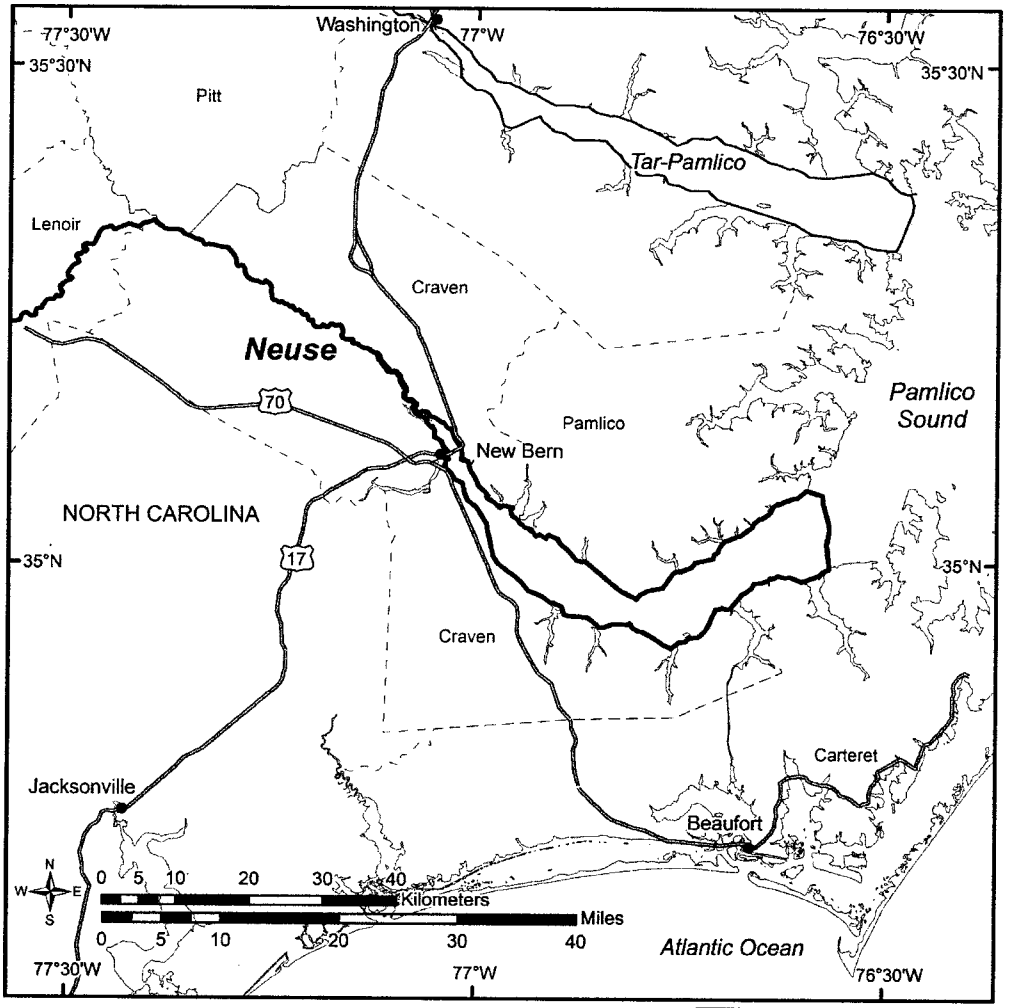
Legend

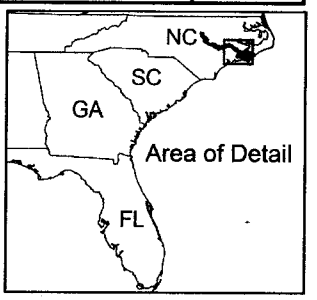
Critical Habitat Area

This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area from the ordinary high water mark on one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

Carolina Unit 3
Neuse Unit

Map 3.1





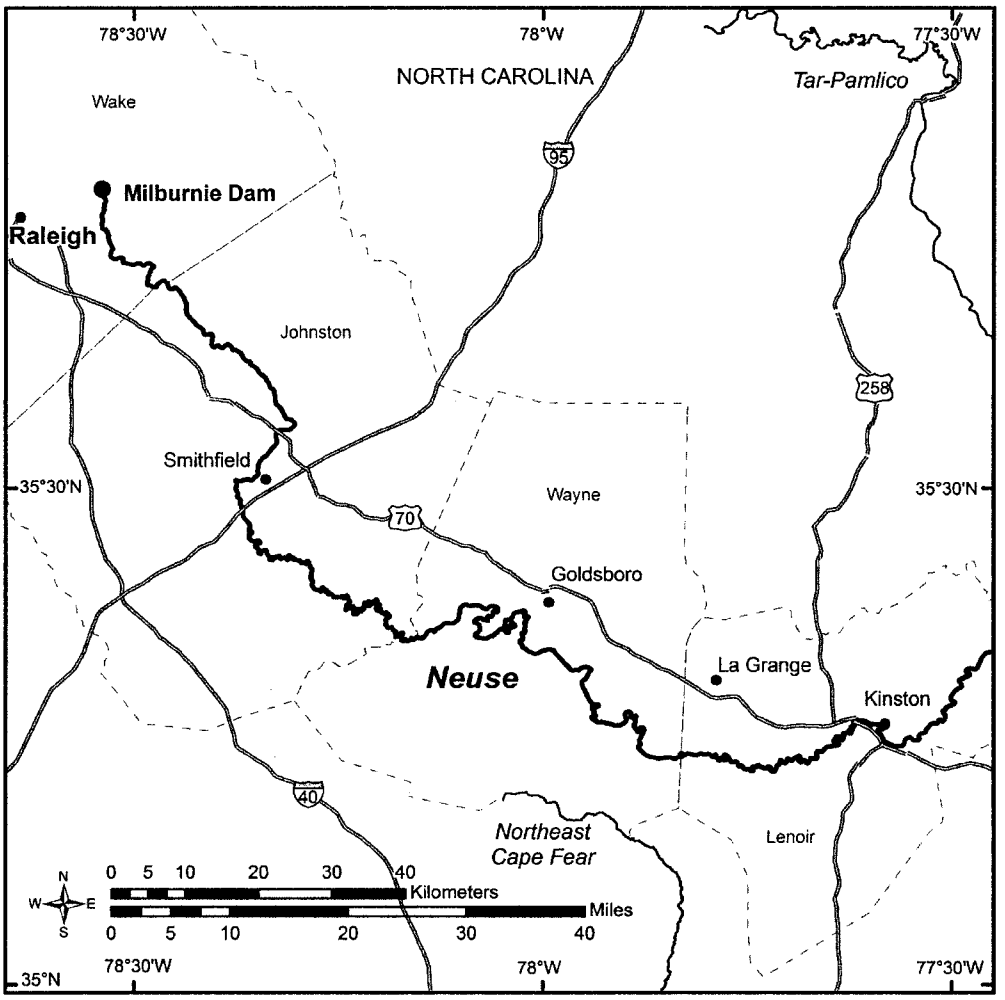
Legend

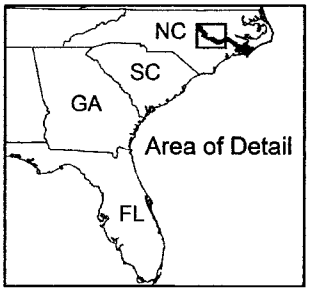
Critical Habitat Area

This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area from the ordinary high water mark on one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

Carolina Unit 3
Neuse Unit

Map 3.2





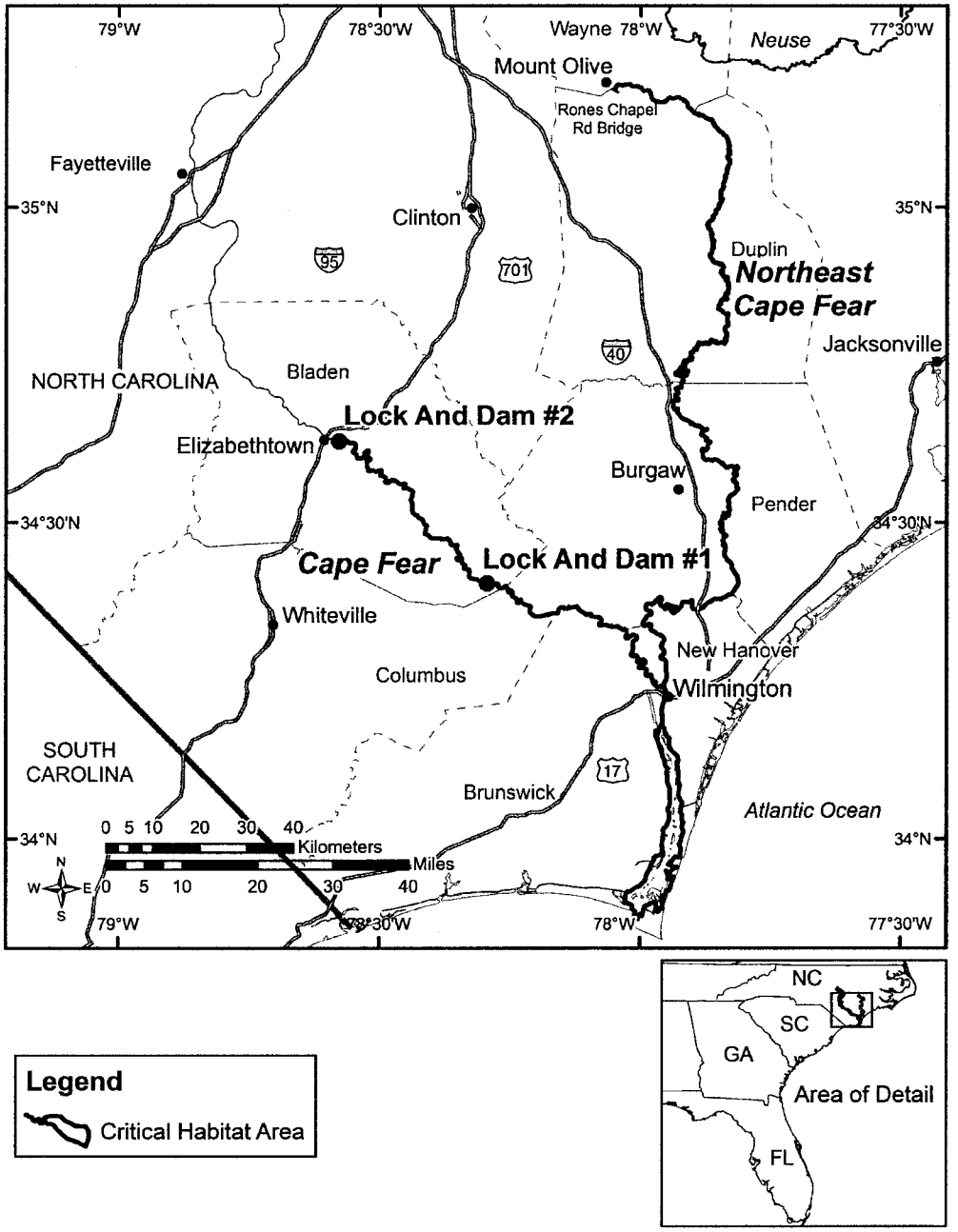
Legend

Critical Habitat

This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area from the ordinary high water mark on one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

Carolina Unit 4
Cape Fear Unit

Map 4



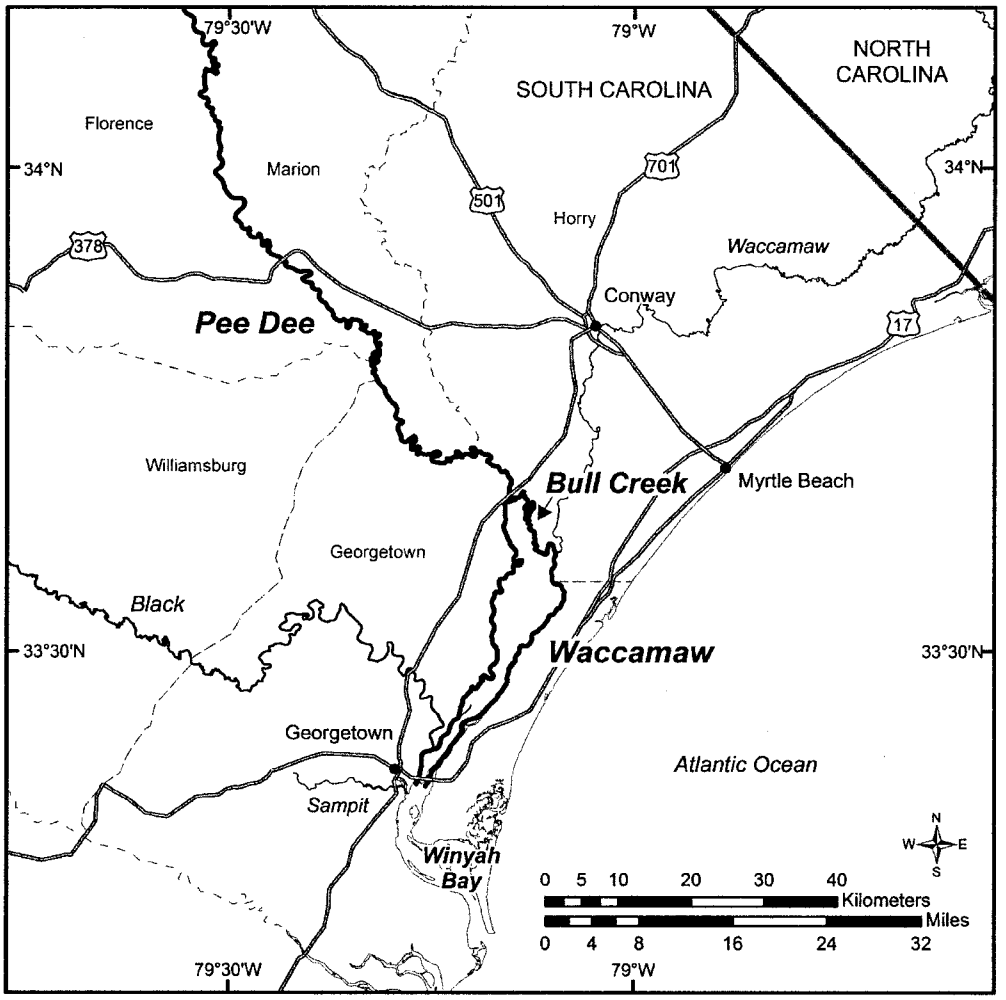
Legend

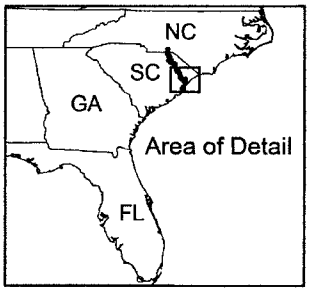
Critical Habitat Area

This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area from the ordinary high water mark on one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

Carolina Unit 5
Pee Dee Unit

Map 5.1





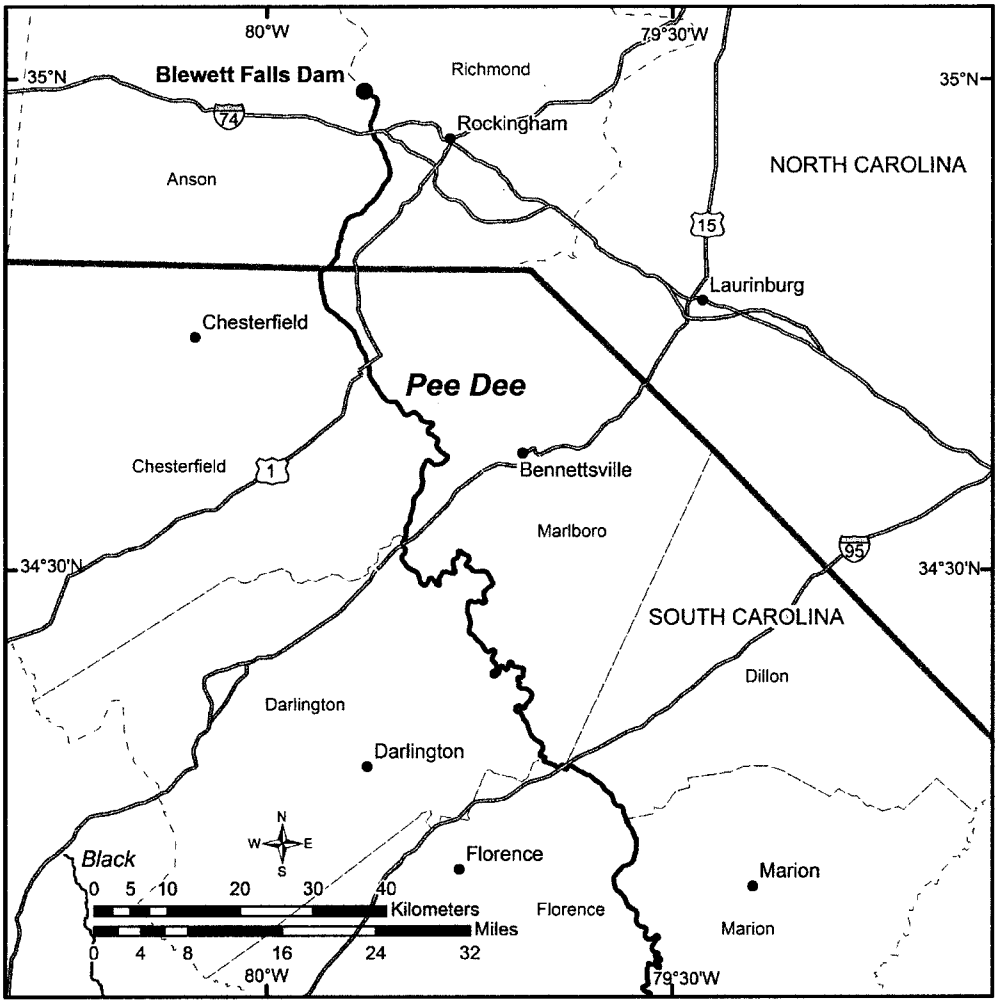
Legend

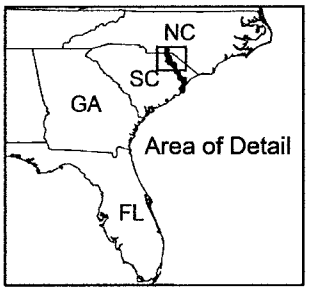
Critical Habitat

This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area from the ordinary high water mark on one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

Carolina Unit 5
Pee Dee Unit

Map 5.2





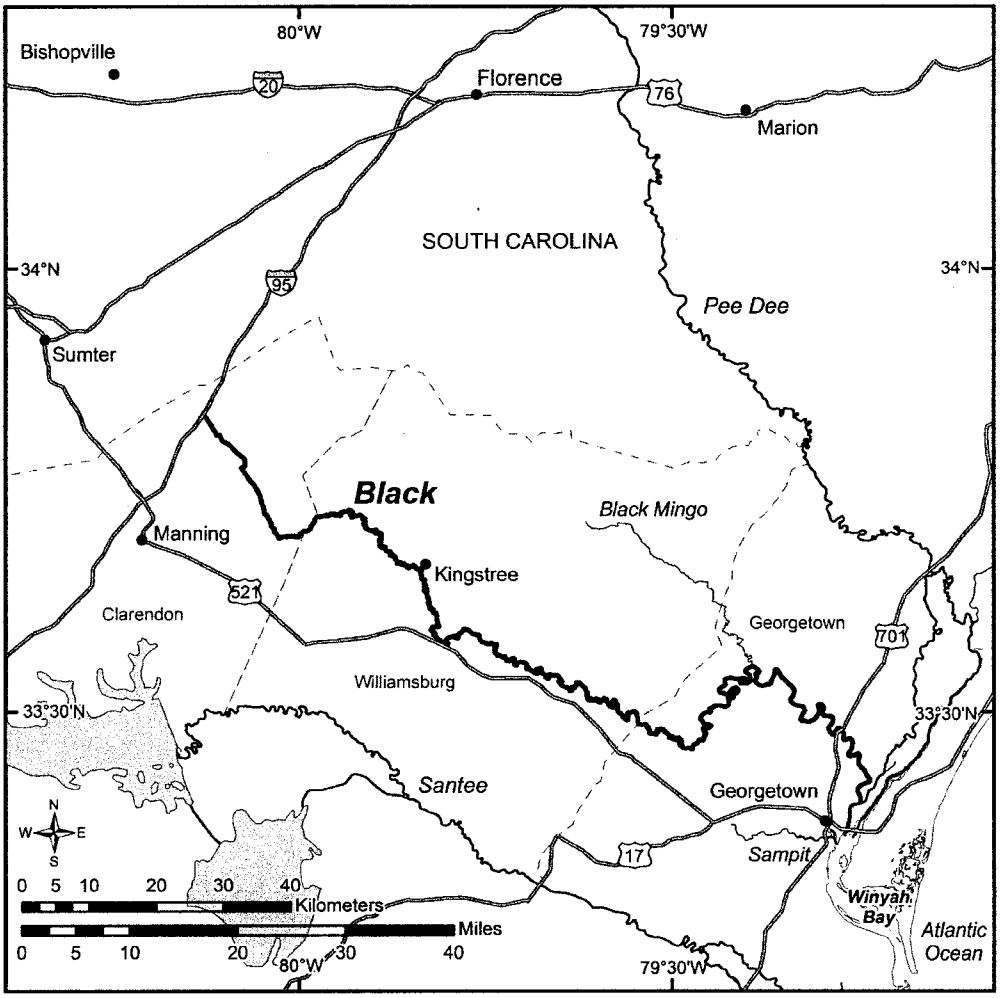
Legend

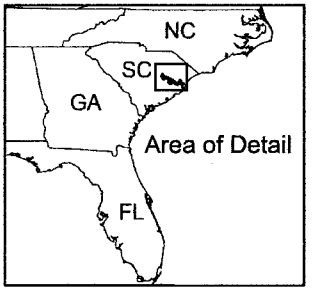
Critical Habitat

This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area from the ordinary high water mark on one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

Carolina Unit 6
Black Unit

Map 6





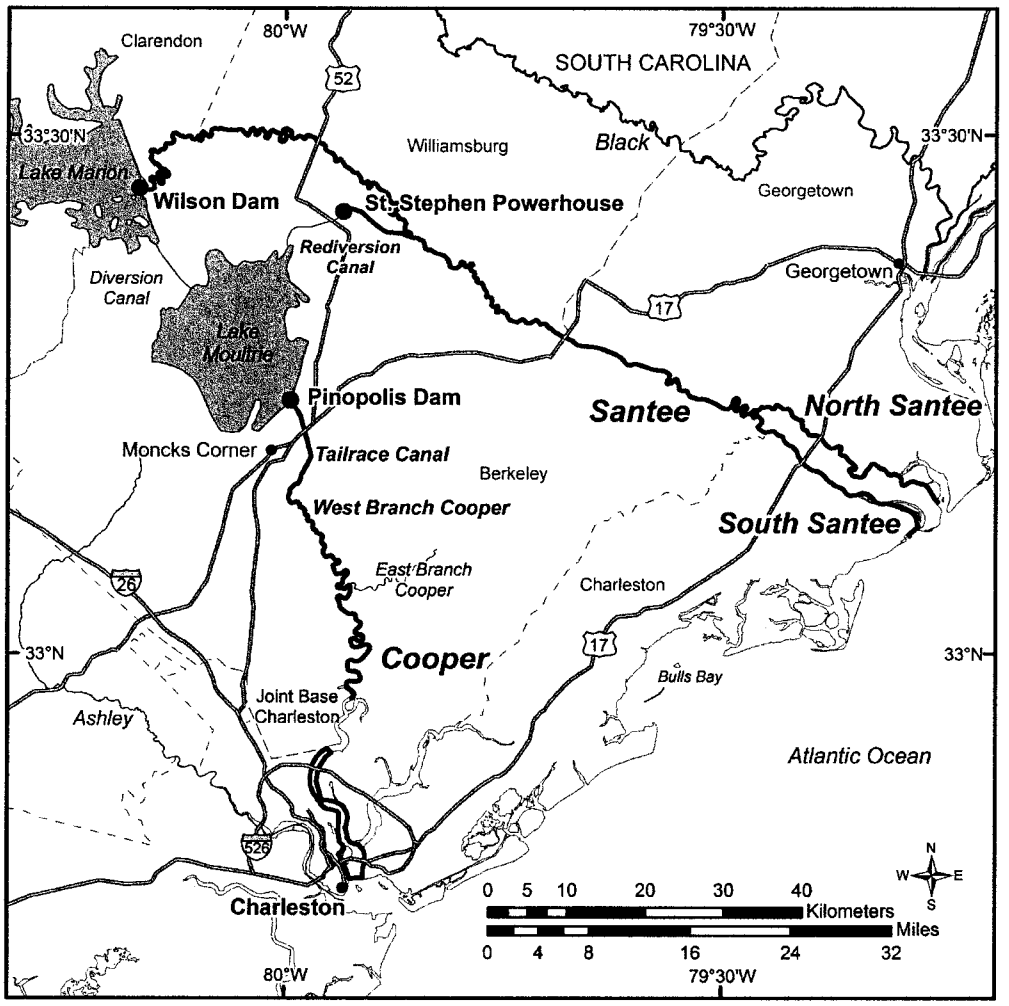
Legend

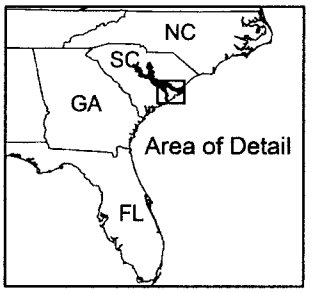
Critical Habitat

This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area from the ordinary high water mark on one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

Carolina Unit 7
Santee - Cooper Unit

Map 7





Legend

Critical Habitat Area

This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area from the ordinary high water mark on one riverbank to the ordinary high water mark of the opposing riverbank, with the exception of U.S. Department of Defense sites determine to be ineligible for designation. For clarification of the critical habitat definition, please refer to the narrative description.

(h) *Critical habitat boundaries of the South Atlantic DPS.* The lateral extent for all critical habitat units for the South Atlantic DPS of Atlantic sturgeon is the ordinary high water mark on each bank of the river and shorelines. Critical habitat for the South Atlantic DPS of Atlantic sturgeon is:

(1) South Atlantic Unit 1 includes the North Fork Edisto River from Cones Pond downstream to the confluence with the South Fork Edisto River, the South Fork Edisto River from Highway 121 downstream to the confluence with the North Fork Edisto River, the Edisto River main stem from the confluence of the North Fork Edisto River and South Fork Edisto River tributaries downstream to the fork at the North Edisto River and South Edisto River distributaries, the North Edisto River from the Edisto River downstream to rkm 0, and the South Edisto River from the Edisto River downstream to rkm 0;

(2) South Atlantic Unit 2 includes the main stem Combahee–Salkehatchie River from the confluence of Buck and Rosemary Creeks with the Salkehatchie River downstream to the Combahee River, the Combahee River from the Salkehatchie River downstream to rkm 0;

(3) South Atlantic Unit 3 includes the main stem Savannah River (including the Back River, Middle River, Front River, Little Back River, South River, Steamboat River, and McCoy's Cut) from the New Savannah Bluff Lock and Dam downstream to rkm 0;

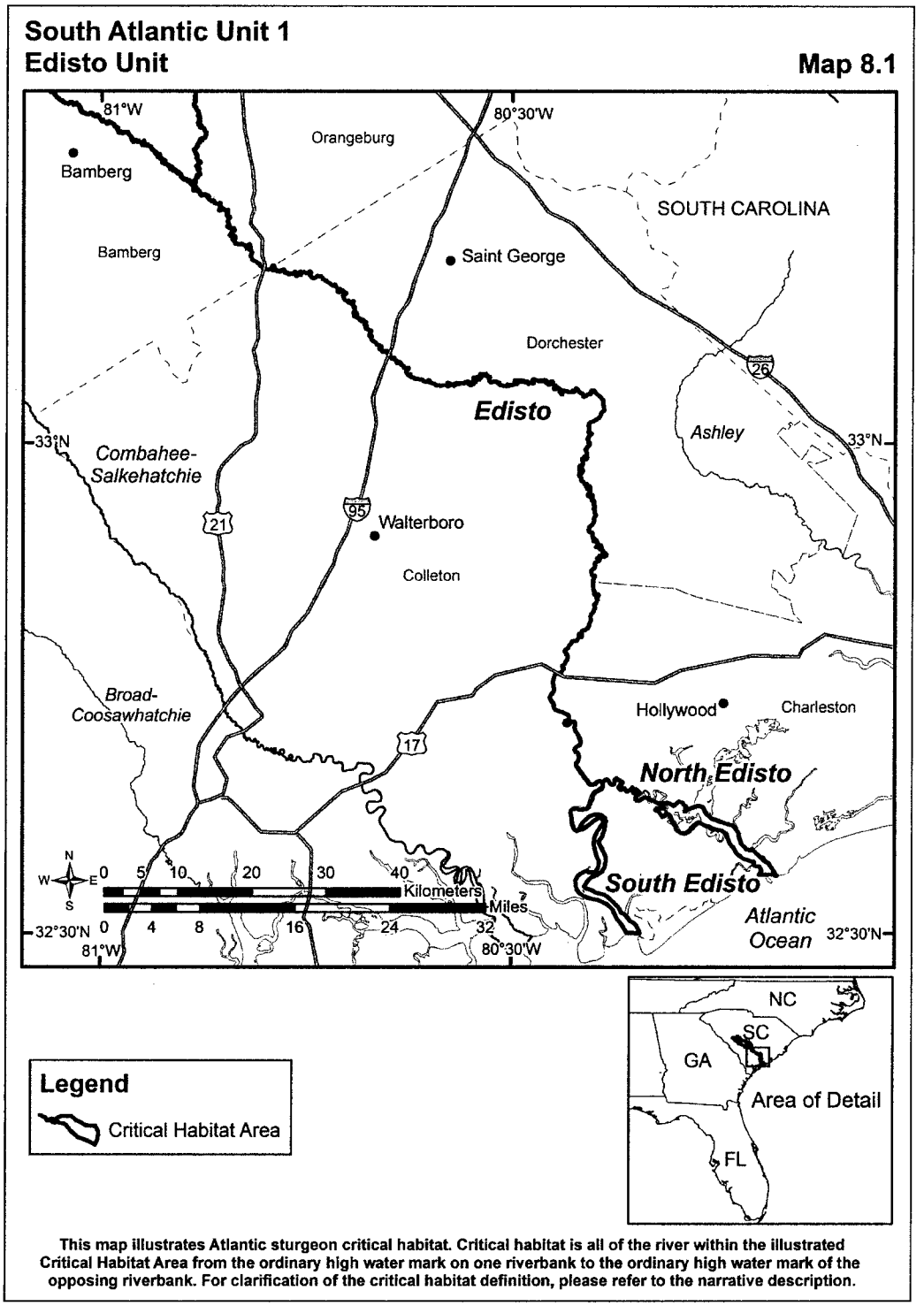
(4) South Atlantic Unit 4 includes the main stem Ogeechee River from the Mayfield Mill Dam downstream to rkm 0;

(5) South Atlantic Unit 5 includes the main stem Oconee River from Sinclair Dam downstream to the confluence with the Ocmulgee River, the main stem Ocmulgee River from Juliette Dam downstream to the confluence with the Oconee River, and the main stem Altamaha River from the confluence of the Oconee River and Ocmulgee River downstream to rkm 0;

(6) South Atlantic Unit 6 includes the main stem Satilla River from the confluence of Satilla and Wiggins Creeks downstream to rkm 0; and

(7) South Atlantic Unit 7 includes the main stem St. Marys River from the confluence of Middle Prong St. Marys and the St. Marys Rivers downstream to rkm 0.

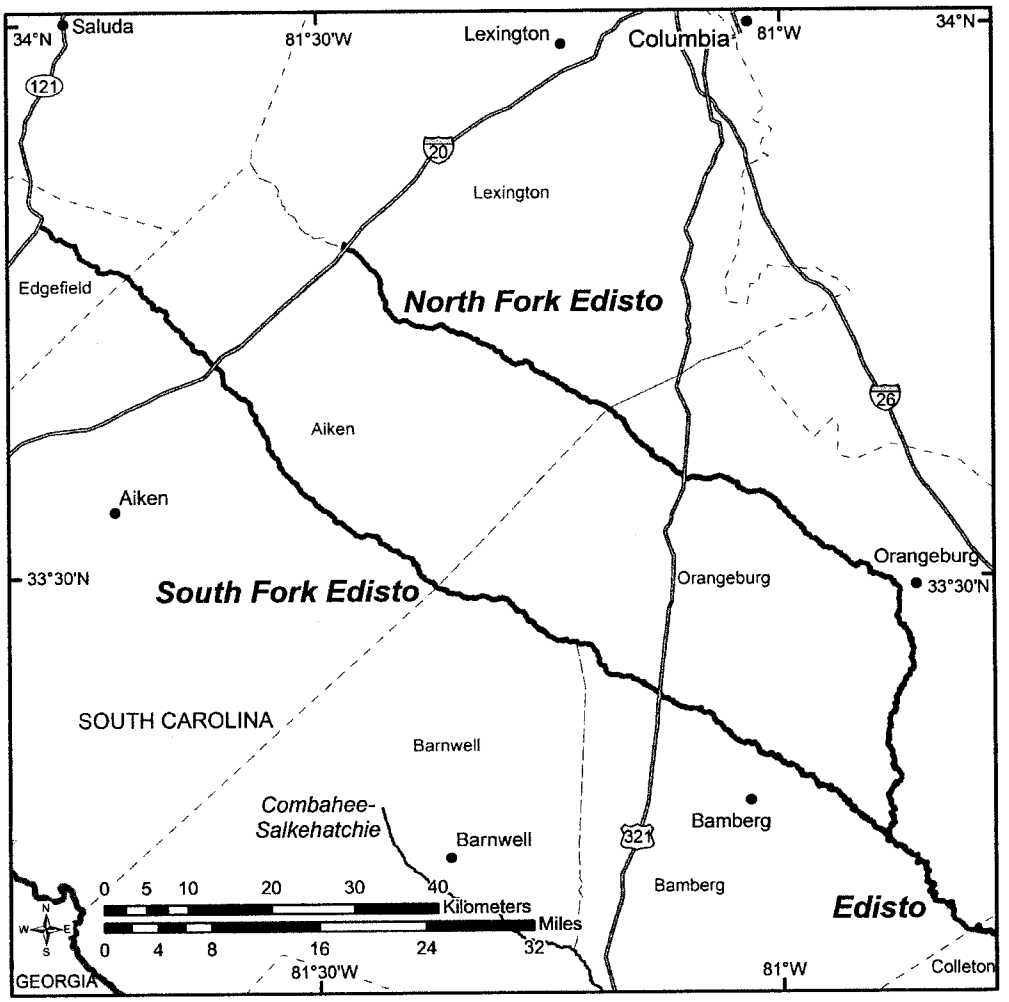
(8) Maps of the South Atlantic DPS follow:

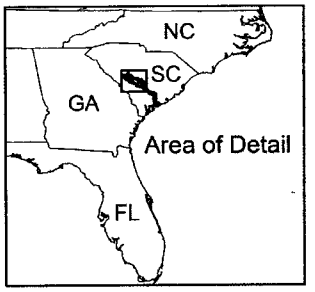


This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area from the ordinary high water mark on one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

South Atlantic Unit 1
Edisto Unit

Map 8.2





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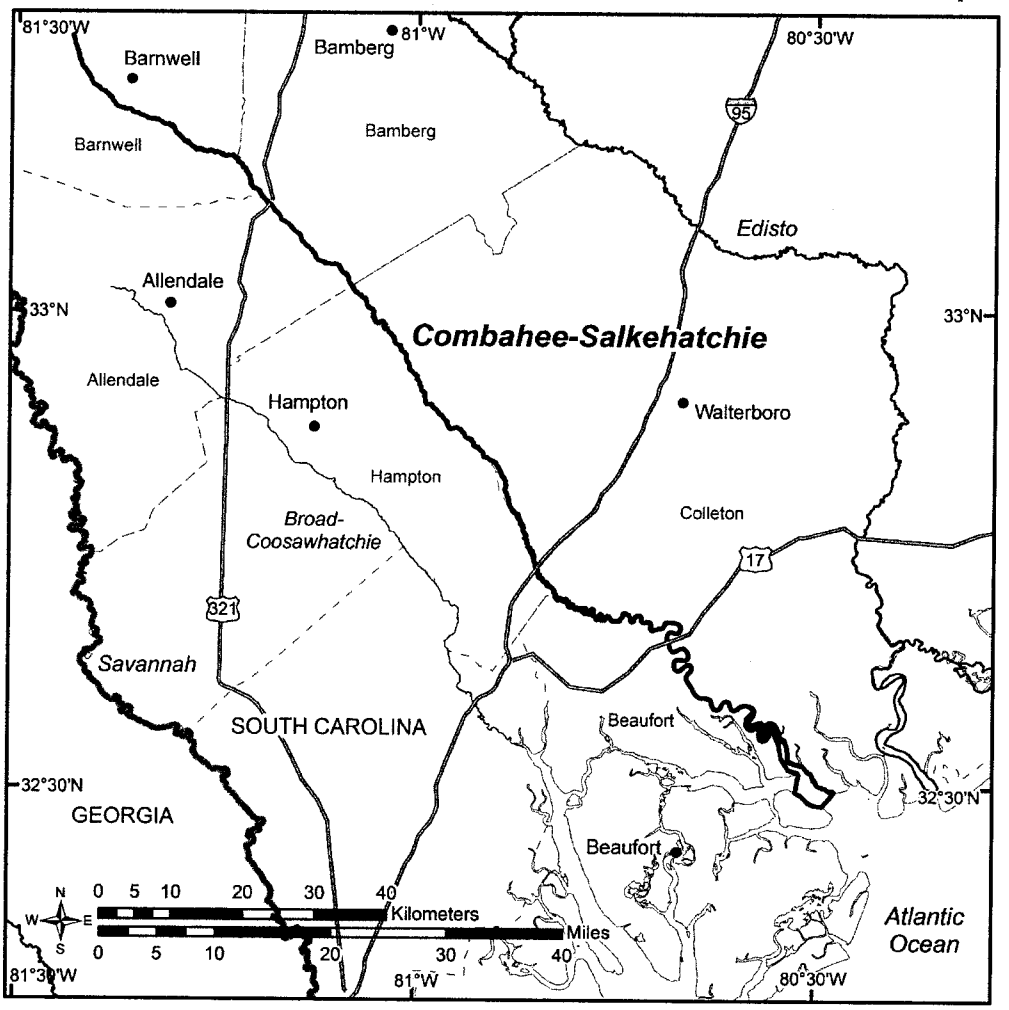
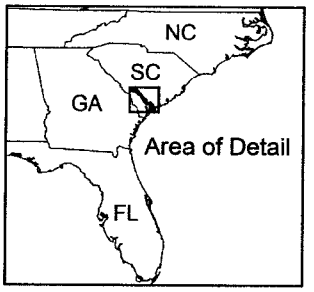
South Atlantic Unit 2
Combahee - Salkehatchie Unit

Map 9





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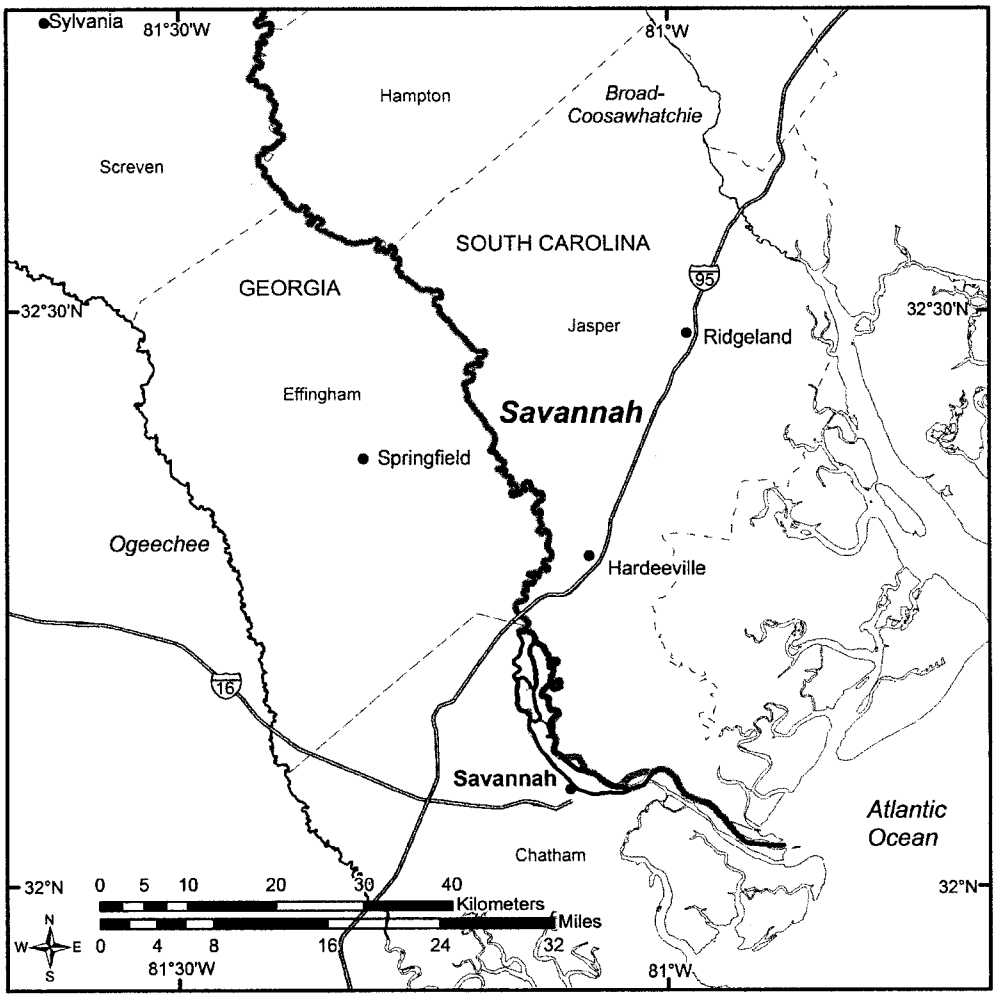
South Atlantic Unit 3
Savannah Unit

Map 10.1



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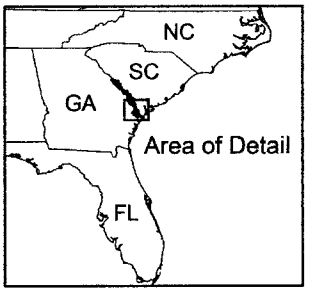
Critical Habitat

SC/GA State Line



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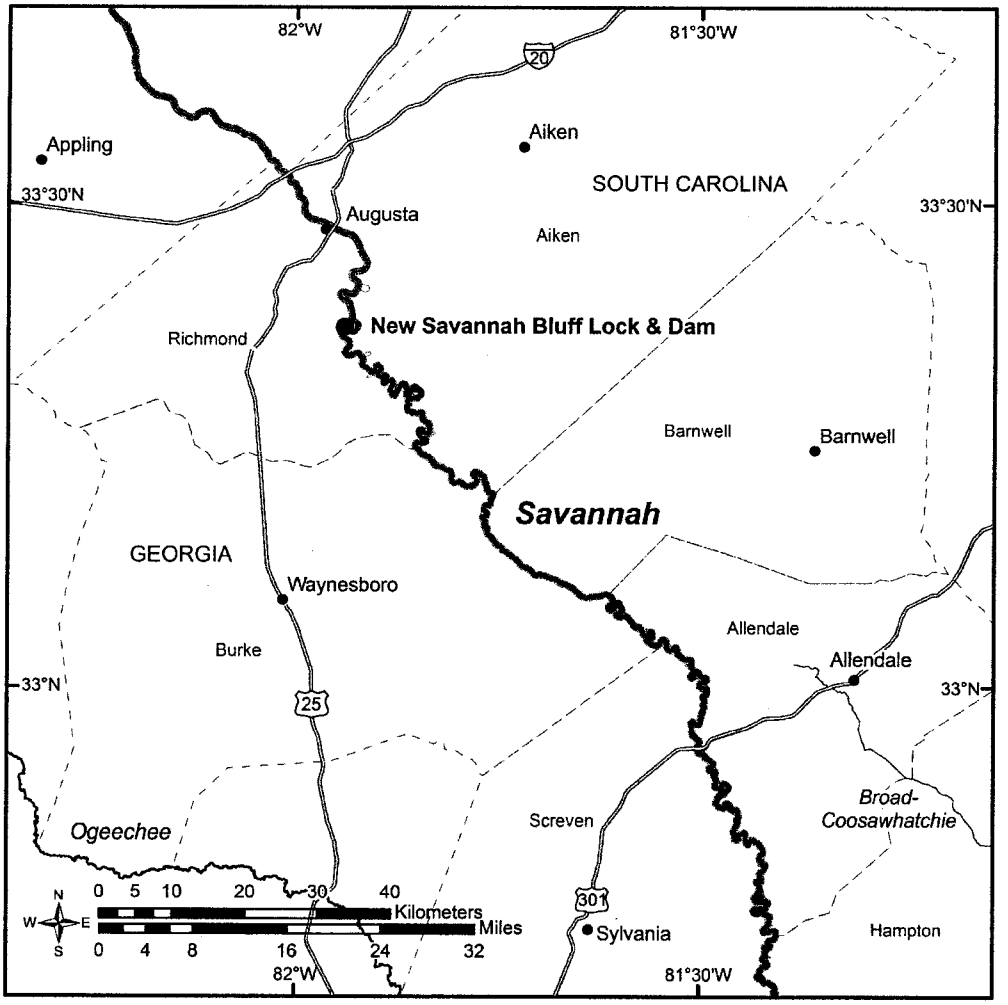
South Atlantic Unit 3
Savannah Unit

Map 10.2



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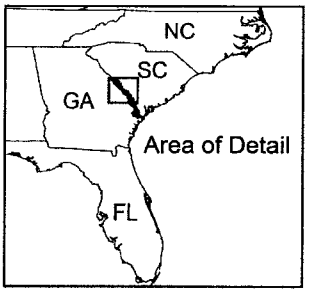
Critical Habitat

SC/GA State Line



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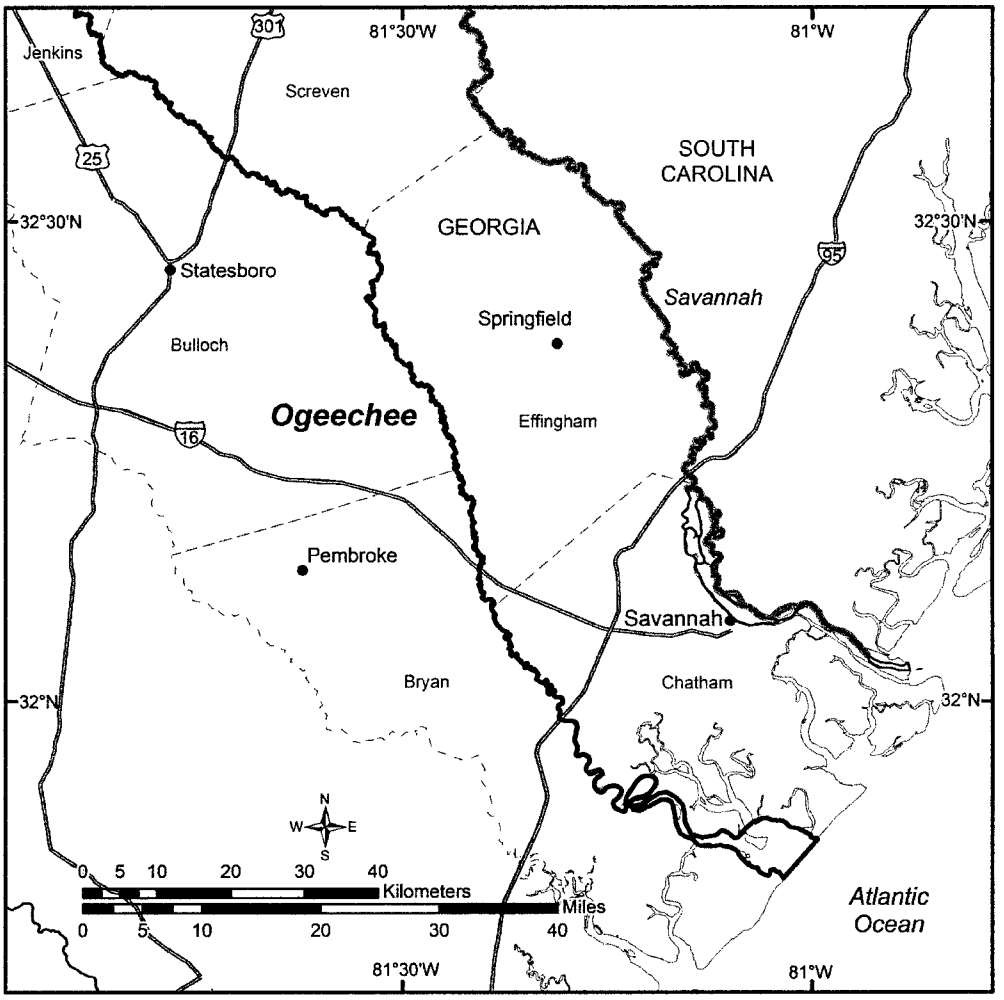
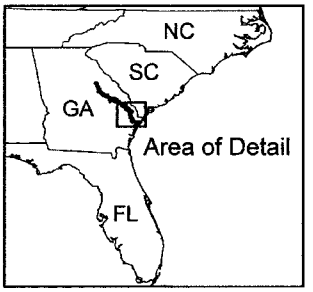
South Atlantic Unit 4
Ogeechee Unit

Map 11.1





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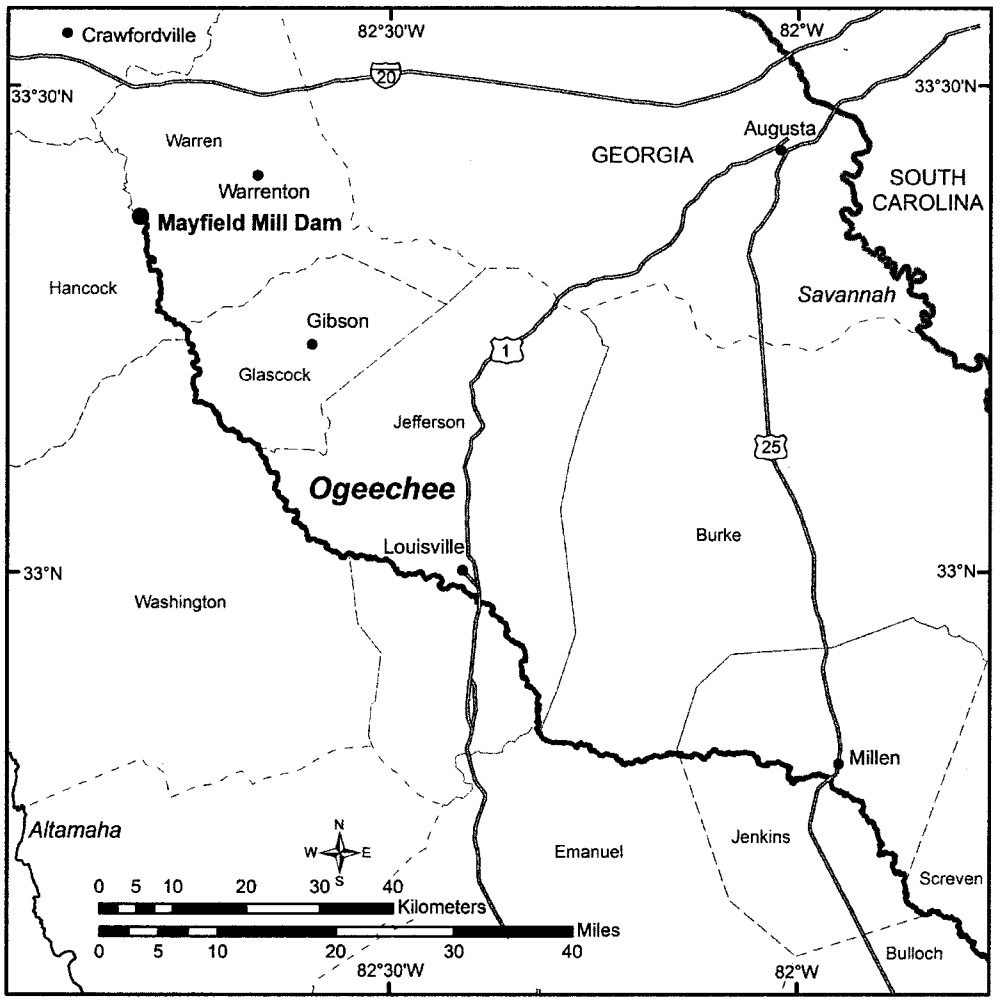
South Atlantic Unit 4
Ogeechee Unit

Map 11.2



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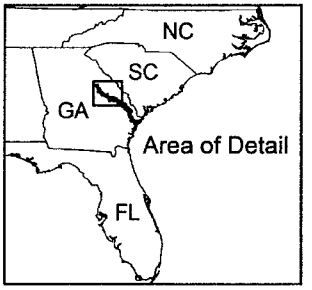
Critical Habitat



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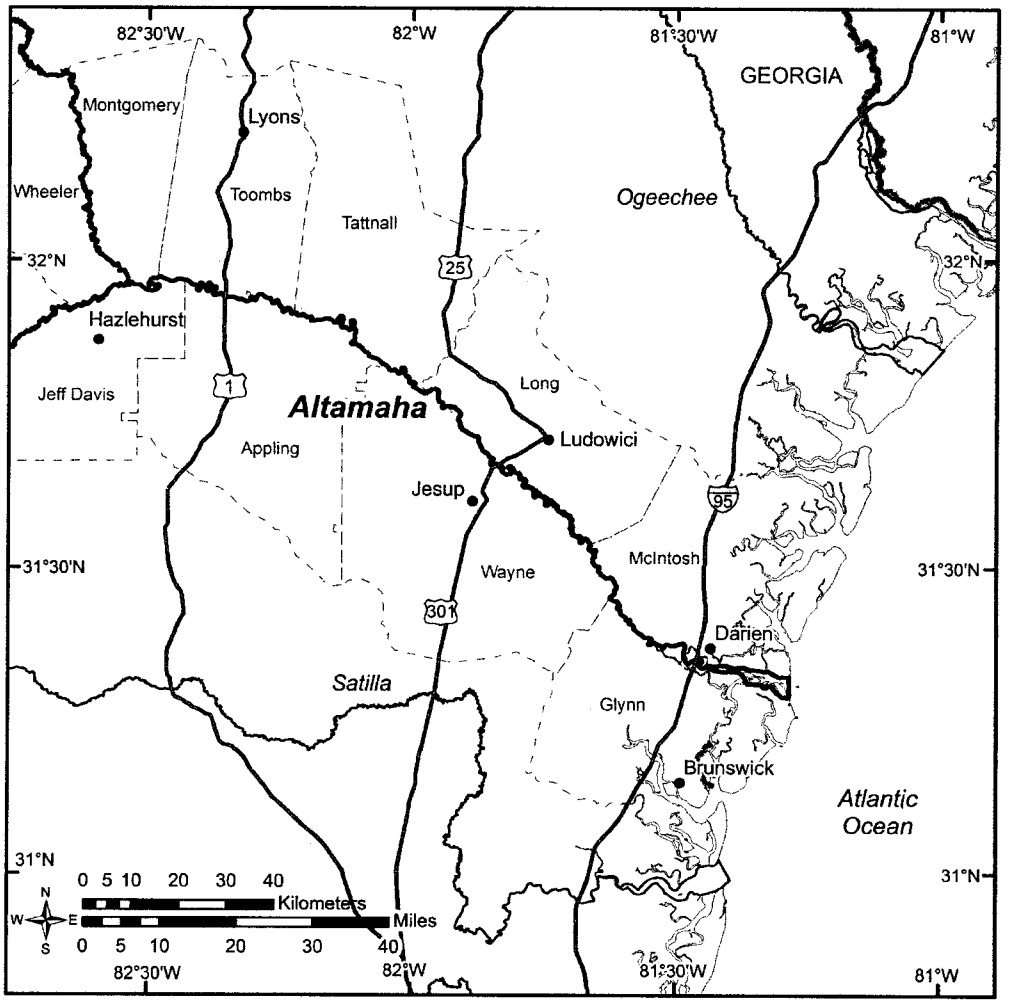
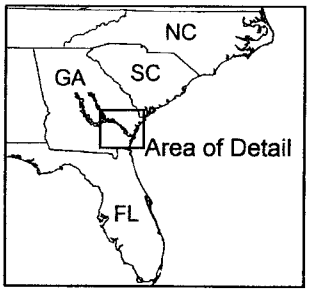
South Atlantic Unit 5
Altamaha Unit

Map 12.1





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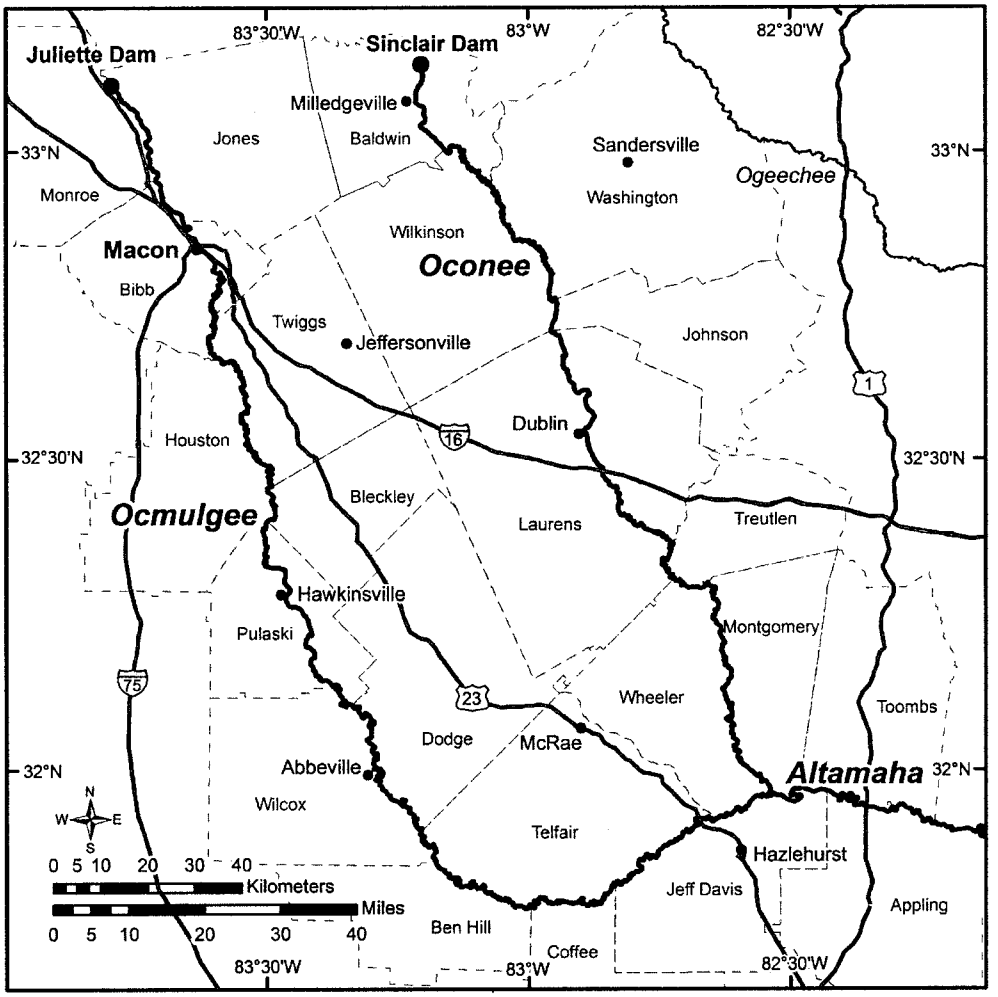
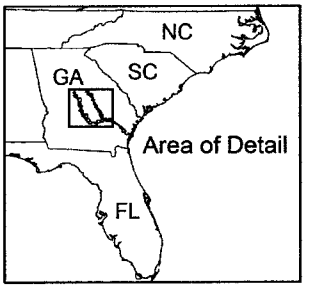
South Atlantic Unit 5
Altamaha Unit

Map 12.2





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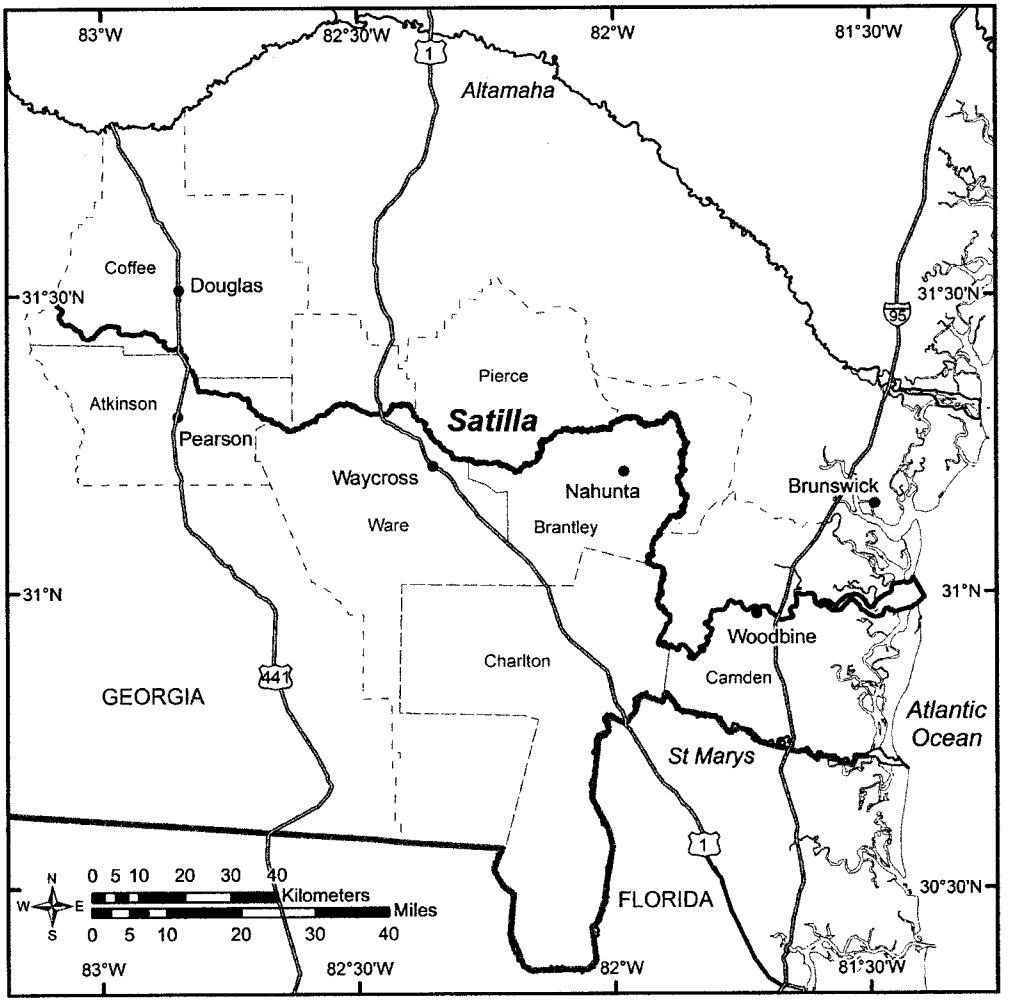
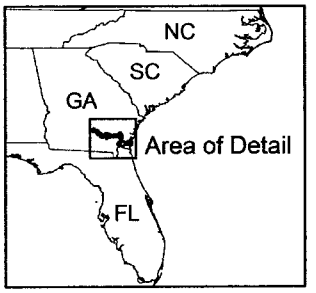
South Atlantic Unit 6
Satilla Unit

Map 13





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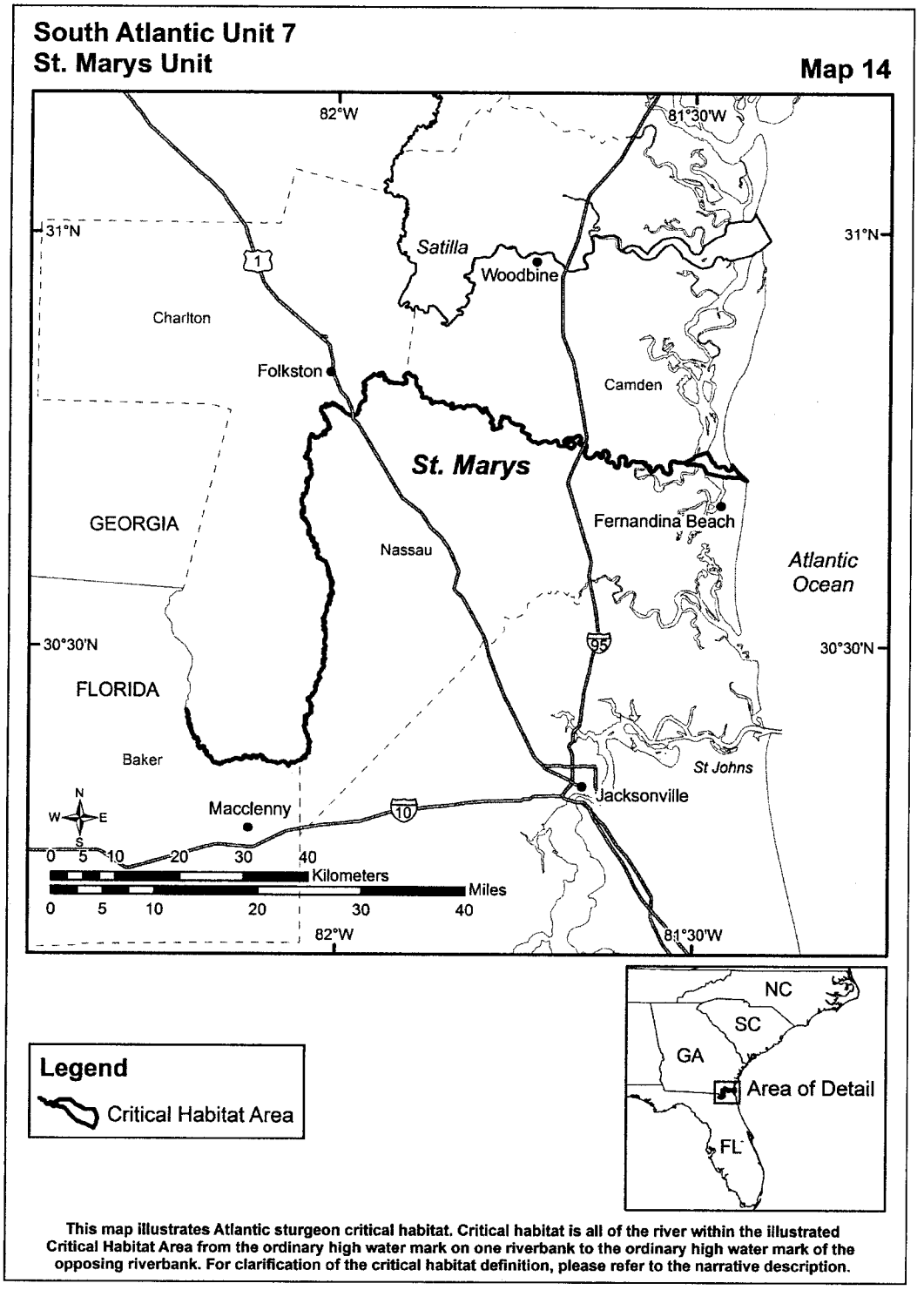

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[FR Doc. 2017–17207 Filed 8–16–17; 8:45 am]
BILLING CODE 3510–22–C

STATE OF NORTH CAROLINA
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

REPORT OF PROCEEDINGS ON THE PROPOSED RECLASSIFICATION OF A CAPE FEAR RIVER SEGMENT, IN BRUNSWICK AND NEW HANOVER COUNTIES (BROAD RIVER BASIN) FROM SC TO SC Sw WITH A WATER QUALITY MANAGEMENT PLAN

PUBLIC HEARING
FEBRUARY 5, 2015
WILMINGTON, NORTH CAROLINA

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SUMMARY AND RECOMMENDATION

SUMMARY

The Lower Cape Fear River Program requested that a Cape Fear River segment in Brunswick and New Hanover Counties be reclassified in order to receive the supplemental Class Swamp (Sw) designation (request package attached as pages a-2 through a-64). The reclassification request for these waters states that "... the DO standard of 5 mg/L for the LCFRE [Lower Cape Fear River Estuary] is not appropriate since it is not achieved a significant portion of the time as a result of natural drainage from riverine wetlands and salt marshes." In addition, the request states that "from a regulatory standpoint, a straightforward way to deal with this issue is to reclassify the area with the supplemental Sw classification."

The subject waters are proposed to be reclassified from Class SC to Class SC Sw with a water quality management plan. The SC classification is a primary classification whereas the Sw classification is a supplemental classification that can accompany a primary classification. The standards that must be met before tidal salt waters can be classified to Sw are outlined in Rule 15A NCAC 2B .0220, Tidal Salt Water Quality Standards for Class SC Waters (rule attached as pages a-65 through a-67). These standards include, for Sw waters, dissolved oxygen levels of less than 5.0 mg/l if caused by natural conditions and pH levels of as low as 4.3 if resulting from natural conditions. The conditions to be met before waters can receive a water quality management plan are outlined in Rule 15A NCAC 02B .0227, Water Quality Management Plans (rule attached as page a-68). 15A NCAC 02B .0227 states that "In implementing the water quality standards to protect the existing uses...of the waters of the state or the water quality which supports those uses, the Commission shall develop water quality management plans on a priority basis to attain, maintain or enhance water quality throughout the state. Additional specific actions deemed necessary by the Commission to protect the water quality or the existing uses of the waters of the state shall be specified in...this Rule. These actions may include anything within the powers of the Commission." The actions proposed within 15A NCAC 02B .0227 for the subject waters codify the current permitting policy already in place for new individual NPDES wastewater discharges and expansion of existing individual NPDES wastewater discharges to the subject waters, which is designed to address water quality and existing uses of these waters.

This proposal concerns the portion of the Cape Fear River from the mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut, where the Intracoastal Waterway (ICW) meets the river (Figure 1 on Page 2 and Table 1 on Page 3). In these waters as well as adjacent waters, there are several tidal saltwater species, including the federally endangered Shortnose Sturgeon and Atlantic Sturgeon, and the related Marine Fisheries Commission designations of Primary Nursery Area, or PNA, for these species; PNA waters are by definition High Quality Waters, or HQW, per 15A 2B .0101. In addition, the types of land cover occurring adjacent to the proposed river segment are comprised of wetlands, some developed lands, other open waters, forest lands, and shrub/scrub lands. Furthermore, the segments of the Cape Fear River directly above and below the river segment to be reclassified are classified C Sw and SC, respectively. The named tributaries flowing to this river segment are currently classified either SC Sw, SC, Water Supply-IV Critical Area, or C Sw, and the majority of these tributaries carry

the Sw designation. Within the subject waters, there are eight existing individual NPDES wastewater discharges. Lastly, according to the 2014 North Carolina 303(d) list, the most recently EPA approved list, the river segment has been determined to be impaired for water quality parameters including dissolved oxygen and pH.

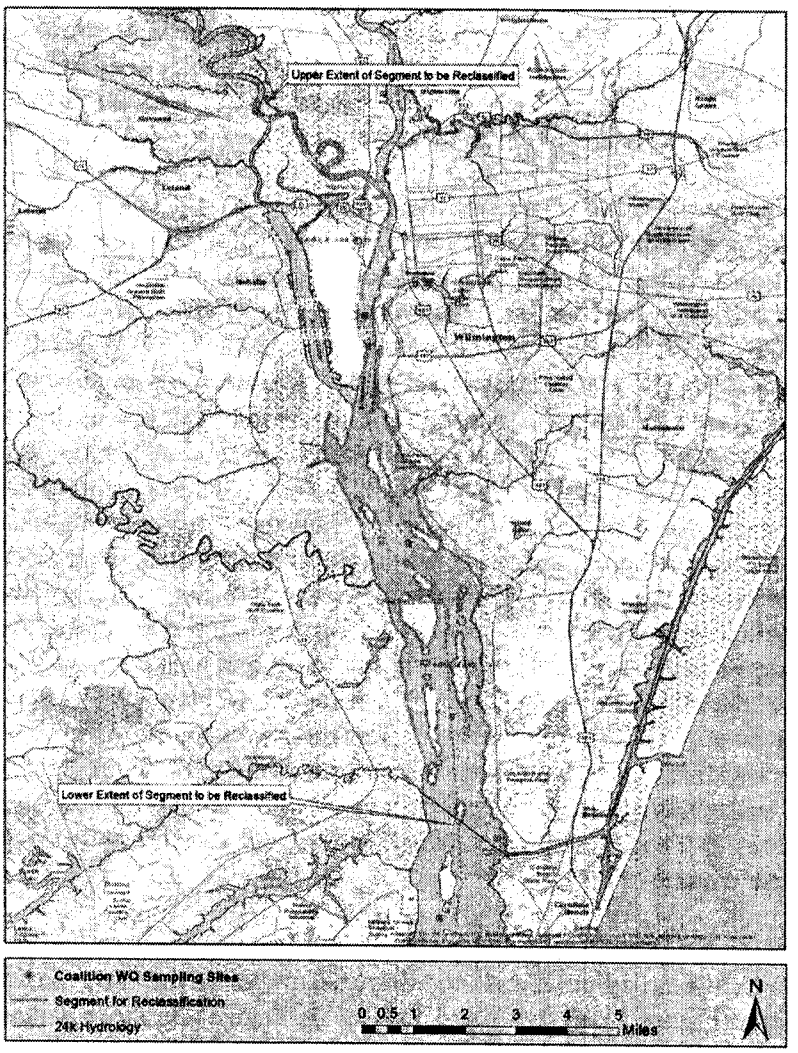


Figure 1.
Requested portion of Lower Cape Fear River Estuary for Consideration for Supplemental Swamp Classification

TABLE 1. PROPOSED AMENDMENT TO THE CAPE FEAR RIVER BASIN SCHEDULE OF CLASSIFICATIONS AS REFERENCED IN TITLE 15A NORTH CAROLINA ADMINISTRATIVE CODE 02B .0311				
Name of Stream	Description	Existing Class	Description of Recommended Segment	Recommended Class
Cape Fear River	From upstream mouth of Toomers Creek to a line across the river from Snows Point (through Snows Marsh) to Federal Point	SC	From upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut	SC Sw
			From a line across the river between Lilliput Creek and Snows Cut to a line across the river from Snows Point (through Snows Marsh) to Federal Point	SC

Standards applicable to Class SC waters, which include the subject segment, provide a base of protection to all of the state's tidal salt waters. The supplemental Sw classification allows lower DO levels, where such levels result from natural conditions, below the 5 mg/l standard for Class SC waters. The Sw supplemental classification also allows pH to reach as low as 4.3, provided it is the result of natural conditions. Standard allowable range for pH in Class SC waters is from 6.8 – 8.5.

The proposed management plan to accompany the proposed Sw designation contains effluent limits that new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges within the river segment would have to meet regarding oxygen consuming wastes. These limits are similar to the limits for High Quality Waters, because as mentioned above, the subject waters are HQW by virtue of being designated as a Primary Nursery Area. The proposed water quality management plan is consistent with and codifies the current permitting policy already in place for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters. The proposed reclassification in partnership with the proposed management plan provides a path forward for these discharges and enables the community to plan accordingly.

There are currently no known planned new individual NPDES wastewater discharges and one planned expansion of an existing individual NPDES wastewater discharge in the subject waters, which already meets the proposal's requirements for expansions of existing individual NPDES wastewater discharges. A fiscal analysis for this proposal was prepared and there was no quantifiable cost or benefit determined to be a result of the proposal. The fiscal analysis with the proposed rules is attached as pages a-69 through a-77.

The estimated effective date of this reclassification is November 1, 2015.

Implications of the Proposed Reclassification and Water Quality Management Plan

Water quality standards for Class Sw waters as well as specific waters with water quality management plans are outlined in the following rules (pages a-65 through a-68):

- 15A NCAC 2B .0220 Tidal Salt Water Quality Standards for Class SC Waters
- 15A NCAC 2B .0227 Water Quality Management Plans

Rule 15A NCAC 2B .0220 Tidal Salt Water Quality Standards for Class SC Waters, describes regulations pertaining to Class SC waters (rule attached as pages a-65 through a-67). This rule features regulations regarding the best usage of these waters, conditions related to best usage, quality standards applicable to all tidal salt waters (for parameters such as radioactive substances, salinity, temperature and turbidity) and action levels for toxic substances (such as copper, silver, and zinc). This rule also includes DO as well as pH standards for Class SC waters, and allows for deviation from those standards for those two parameters if caused by natural conditions in Class Sw waters. Currently the dissolved oxygen standard is 5 mg/l, and the pH standard is a range of 6.8-8.5 for Class SC waters. The standards associated with the Sw designation are narrative standards, which supplement the SC numeric standards.

The result of a Sw reclassification for the Lower Cape Fear segment of interest, per the portions of this rule that address standards in Sw waters, will be the allowance, if caused by natural conditions, for the pH of the subject waters to reach as low as 4.3 and, if caused by natural conditions, the DO to be lower than 5 mg/l. Thus, if reclassified, additional ambient DO & pH standards will apply in the subject waters under natural conditions. Table 2 summarizes and compares the requirements of the existing and proposed classifications.

TABLE 2. SUMMARY AND COMPARISON OF EXISTING AND PROPOSED CLASSIFICATIONS' STANDARDS

Classification	pH	Dissolved Oxygen (DO)
Class SC (Existing)	6.8 – 8.5	5.0 mg/l
Class SC Sw (Proposed)	6.8 – 8.5, but as low as 4.3 if result of natural conditions	5.0 mg/l, but lower than 5.0 mg/l if caused by natural conditions

Rule 15A NCAC 2B .0227 Water Quality Management Plans, allows the Environmental Management Commission to develop water quality management plans tailored to protection of existing uses or quality of waters in specific waters (rule attached as page a-68). Specific additional actions that the EMC considers necessary to protect the existing quality or uses of specific waterbodies are described in this rule, and can include any actions within the Commission's powers. Currently there is one management plan within this rule, and it is for the Lockwoods Folly River Area within the Lumber River Basin.

The proposed management plan to accompany the proposed Sw supplemental classification contains effluent limits that new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges within the river segment would have to meet regarding oxygen consuming wastes. These limits are more stringent than the standards regarding oxygen consuming wastes for Class SC or Class Sw waters, and in fact, are very similar to the limits for one of the state's most restrictive supplemental classifications, High Quality Waters, because as mentioned above, the subject waters are HQW by virtue of being designated as a Primary Nursery Area.

For non-industrial facilities, effluent limits of 5 mg/l for Biological Oxygen Demand $(BOD)_5$, 1 mg/l for Ammonia, and 6 mg/l for dissolved oxygen would apply according to the proposed management plan. For industrial discharges, site-specific best available technology on a case-by-case basis would be utilized to determine the limits for BOD_5, Ammonia and DO according to 15A NCAC 02B .0404 and .0406.

For new and expanded individual NPDES wastewater facilities, the management plan includes consideration of seasonal effluent limits on a case-by-case basis, and also includes the following stipulation: Any new or expanded permitted pollutant discharge of oxygen consuming waste shall not cause the dissolved oxygen of the receiving water to drop more than 0.1 mg/l below the modeled in-stream dissolved oxygen at total permitted capacity.

Please note that the proposed management plan just described is consistent with and codifies the current permitting policy already in place for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters. Furthermore, there are currently no known planned new individual NPDES wastewater discharges and one planned expansion of an existing individual NPDES wastewater discharge in the subject waters, which already meets the proposal's requirements. Existing & future communities in this area and above-mentioned facilities also would be affected by this proposal from the perspective that the proposal would aid them in planning for the future, because it would let them know what to expect in terms of permitting.

The proposed reclassification and water quality management plan would not impact the following activities: forestry practices, docks and other water dependent structures, development activities, recreational use, agricultural activities, animal operations, land application activities, landfill operations, and dam and water resource projects. Lastly, it is unknown if and/or to what extent the Sw supplemental standards and water quality management plan would affect the subject water's ambient dissolved oxygen and pH levels; future water quality monitoring and analysis would help address this issue.

Public Hearing Process and Comments Received

In accordance with North Carolina General Statutes, a public hearing was held on February 5th, 2015, in Wilmington, North Carolina (New Hanover County). Notice of the proposal and hearing, including the proposed rule amendment, was published in the January 2nd, 2015, *North Carolina Register* (Volume 29, Issue 13) (proposed rule amendment attached as pages a-73 through a-77).

Announcements of the public hearing (announcement attached as pages a-78 and a-79) were sent to the Water Resources Rule-Making Announcements mailing list, the Division of Water Resources Rules e-mail list, staff (including library staff) of the local governments with jurisdiction over land adjacent to the subject waters, wastewater facilities discharging directly to the subject waters, and to other persons potentially interested in the proposal, including staff of interest groups such as The Nature Conservancy, Cape Fear River Watch, Waterkeeper Alliance, and Cape Fear River Assembly, staff of federal and state agencies, and legislators within North Carolina. The public announcement and request for publication were submitted on January 9, 2015 to five local newspapers, *Coastal Review Online, Brunswick Beacon, Star News, Wilmington Journal,* and *Port City Daily* (newspaper request for publication attached as page a-80).

Julie Wilsey, a member of the Environmental Management Commission, served as hearing officer (hearing officer designation letter attached as page a-81).Twenty-four people registered at the public hearing (list of attendees attached as page a-82). Of those 24 people, all but two people were representing themselves or provided the organization they were representing on their registration forms: Aqua NC, Cape Fear River Partnership, Cape Fear River Watch, Cape Fear Public Utility Authority (CFPUA), CH2M Hill, City of Wilmington, Duke Environmental Policy Clinic, General Electric Company, International Paper, New Hanover County, University of North Carolina – Wilmington and Vopak Terminals.

Opening comments and slides were presented by DWR staff to provide a brief overview of the DWR classification program and detailed information about the proposed reclassification and water quality management plan. Then public comments on the proposal were taken.

Ten individuals registered to make comments at the hearing and all 10 people did provide oral comments. The speakers stated that they represented Cape Fear River Watch, CFPUA, Cape Fear Riverkeeper, CH2M Hill, Duke Environmental Policy Clinic, Lower Cape Fear River Program (LCFRP), themselves, and Waterkeeper Alliance. Four of the 10 speakers supported the proposal, and the remaining speakers were against the proposal.

Written comments were accepted for the proposal from January 2, 2015 through March 3, 2015, and a total of 312 written comments were received. Seven distinct letters providing a positive position were received from representatives of the CFPUA, LCFRP, City of Wilmington, and NC Farm Bureau Federation, Inc. (letters providing a positive position attached as pages a-83 through a-98). Two of these positive comments were written by one person who, along with three others who provided a positive position in their written comments, spoke at the hearing. In addition, two letters providing a neutral position from the U.S. EPA and U.S. Fish and Wildlife Service were received (letters providing a neutral stance attached as pages a-99 through a-103). Lastly, 303 letters providing a negative position were received (letters providing a negative stance attached as pages a-104 through a-217). Within the 303 letters were four template letters utilized by citizens. More specifically, 69 copies of one template letter and eight variations of it, 55 copies of a second template letter and 13 variations of it, 71 copies of a third template letter and 12 variations of it, and 66 copies of a fourth template letter and three variations of it were received for a total of 297 letters; 12 people each submitted two of these letters, and one person submitted four of these letters. The remaining six distinct letters providing a negative position were received from parties representing Waterkeeper Alliance, Cape Fear River Watch, Cape Fear Riverkeeper, NC Conservation Network, American Rivers, NC Division of Coastal Management, and two citizens; two of these comments were from people who spoke at the

hearing. (The six distinct letters are attached as pages a-104 through a-176, one copy of the first template letter is attached as page a-177 followed by the eight variations of it on pages a-178 through a-186, one copy of the second template letter is attached as page a-187 followed by the 13 variations of it on pages a-188 through a-200, one copy of the third template letter is attached as page a-201 followed by the 12 variations of it on page a-202 through a-213, and one copy of the fourth template is attached as page a-214 followed by three variations of it on page a-215 through a-217.) DWR has retained and will continue to retain all comment letters received during the comment period.

Summary of Concerns & Staff Responses

The comments received did contain several issues of concern. Each issue of concern (in *italics*), with a few comments demonstrating that concern, is provided below, and is followed by a DWR response:

1. ***Concern:*** *Purpose of proposal is flawed*
   - *Proposal is trying to sweep away the acts of big corporations.*
   - *DWR is proposing to reclassify because its efforts to control pollution from point sources will not allow segment to meet present DO standard.*
   - *Petitioners do not want to implement pollution controls.*
   - *Proposal is attempt to save money and factory farms.*

   Response: The purpose of the reclassification and water quality management plan is three-fold: (1) to add ambient DO and pH standards applicable under natural conditions to the subject waters, (2) to codify current permitting policy already in existence for new individual NPDES wastewater discharges and expansions of individual NPDES wastewater discharges; and (3) to provide a path forward for dischargers' and communities' planning efforts.

2. ***Concern:*** *Request lacks scientific support to show low DO due to natural conditions*
   - *Major sources of oxygen-demanding materials are due to pollution from human activities consisting of point sources including CAFOs, especially swine livestock waste.*
   - *Non-Point Sources of oxygen-demanding materials are large & reduce DO levels.*
   - *Bowen Model does not support that natural conditions cause low DO, & shows 70% load reduction of oxygen-demanding materials leads to 1% summer DO violations.*

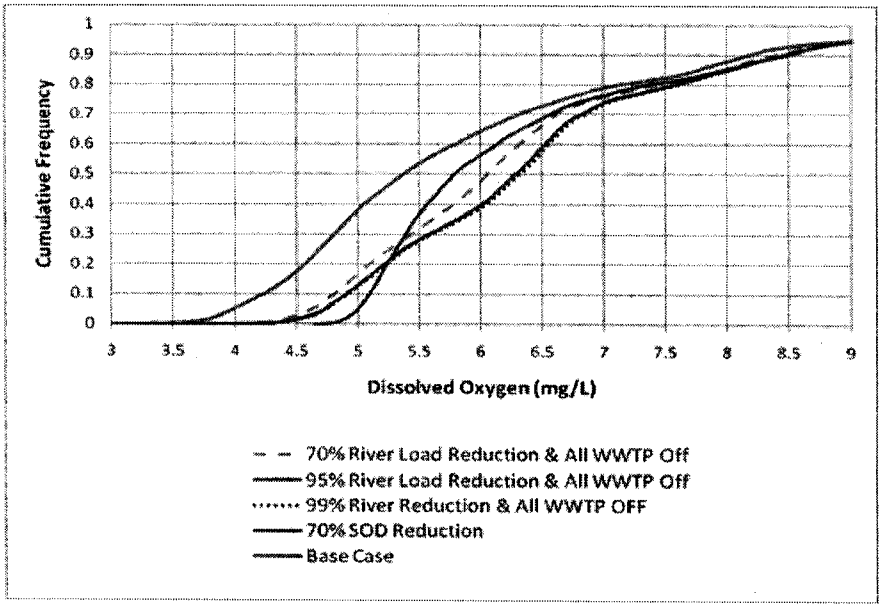
   Response: The following DWR comments are based on a model sensitivity test described in the Lower Cape Fear Modeling Report* that reduced both river loading and sediment oxygen demand (SOD) by the same percentage (70%). It is important to note that SOD is not predicted by the model, but rather is set by the user based on limited data. The report recognizes that "reductions in river loading would probably also reduce sediment oxygen demand in the long-term but with prescribed SOD there was no way to predict the

magnitude of the changes in SOD, or the time scale of those changes." Therefore, the model is not an appropriate tool to evaluate the impact of upstream load reduction on SOD.

The DWR Modeling and Assessment Branch has run model scenarios reducing only loading from the upstream boundary conditions as well as wastewater treatment plants (WWTPs) within the model domain to evaluate the impact of loading without changing SOD. Results are included in the figure below.

As can be seen in the figure, reducing upstream loading by 95% or even 99% and turning loading from WWTPs within the model domain completely off, there is still more than a 10% exceedance in the DO standard of 5 mg/L. This underscores the significant impact SOD has on DO in this system.

* Development and Use of a Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the Lower Cape Fear River Estuary, North Carolina. James D. Bowen, et al. Oct 2009.



Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer2004 for the Base Case and Four River Load Reduction Scenarios. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

3. ***Concern:*** *Not meeting regulatory requirements to reclassify*
   - *Waters are not swamp waters per state's definition (velocity, pH, and adjacent stream characteristics).*
   - *Best uses will not be attained via the proposal and required UAA (Use Attainability Analysis) would show uses can be met.*

- *Proposal will reduce water quality standards, leading to discharges eliminating protections, and more pollution, water quality standard violations, degradation, and jeopardization of uses.*
- *Fiscal Analysis contains inaccuracies and does not address all costs and benefits.*
- *Commission has not considered all pertinent matters prior to granting reclassification request.*
- *Proposal does not fulfill duties entrusted to Commission by the state's laws and violates those laws to protect and conserve waters.*

Response: It is important to note that the majority of the tributaries to the subject waters as well as the part of the Cape Fear River upstream and adjacent to the subject waters carry the Sw supplemental classification, and that other segments of large rivers in coastal North Carolina and the tributaries associated with those river segments carry the Sw supplemental classification. Just because these waters carry the Sw classification does not mean that the pH of these waters is 4.3 or that the DO is less than 5.0 mg/l. As a reminder, in Sw waters, dissolved oxygen levels of less than 5.0 mg/l are only allowed if caused by natural conditions and pH levels as low as 4.3 are only allowed if caused by natural conditions.

A UAA is required when a state proposes to remove a use and associated protections, including standards, from a waterbody. This proposal will not remove a use or associated protections from the subject waters; it will provide supplemental water quality standards that will be applicable if caused by natural conditions. Therefore, a UAA is not required for this proposal, the proposal is not violating state laws that govern the duties of the Commission regarding protection of waters, and the Commission has been provided all needed information that is typically provided for reclassification rule-making requests. This information includes a fiscal analysis, which was completed according to state requirements using available fiscal information to assess costs and benefits to potentially impacted parties using the subject waters.

4. ***Concern:*** *Proposal does not correct or reduce pollution*
   - *Proposal is an attempt to evade CWA charge to correct water quality problems through TMDL.*
   - *Proposal fails to correct water pollution created by upstream animal operations causing the DO impairments and does not address hogs in upper watershed and manure that's been brought here.*
   - *Reclassification would cover failure of DENR regarding animal farms.*
   - *The reclassification does not adequately address non-point contributions of BOD or nutrients; the plan does not address non-point sources. Any reclassification must include language aimed at reducing non-point pollution sources.*
   - *It would be helpful if the management plan included a path forward on how to improve lower Cape Fear River DO concentrations through watershed-wide waste load modeling, land use planning, and permitting.*
   - *The plan includes no reduction of the effects of pollutant loading by existing point sources or nonpoint sources.*

Response: There are on-going efforts in the Cape Fear River Basin to assess pollution sources and investigate ways to address pollution sources, i.e. as discussed in the Cape Fear Basinwide Plan and Nutrient Criteria Development Plan (NCDP). The proposed reclassification and water quality management plan are designed to add supplemental ambient DO and pH standards that will be applicable if caused by natural conditions, and codify permitting requirements for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters for planning purposes, respectively. The proposal does not include language about correcting or reducing pollution as it is not designed to be a water quality restoration plan.

5. ***Concern:*** *Dredging may impact DO conditions*
   - *The reclassification request mentions that further channel dredging "also showed a significant impact [on DO conditions.]" Can the State provide additional information on this analysis and how it was considered?*

Response: The statement cited in the request was a typo and should have stated that the impact of further channel dredging on DO conditions was evaluated and considered insignificant. Furthermore, the proposed Sw reclassification and water quality management plan would have no impact on dredging.

6. ***Concern:*** *Removal of Sw reclassification in 1980's was done correctly*
   - *The state removed the Sw class as it was immediately upstream of SA waters and admitted the original Sw designation was due to inadequate consideration of uses.*
   - *In the October 6, 1981 report of proceedings, a staff representative indicated that the streams "had improved enough so that [the streams can] meet the C standard without being allowed the designated exception." It is recommended that the state further address this previous change which removed the swamp classification as it relates to the proposed change, reverting it back to a swamp classification.*

Response: The above-mentioned October 6, 1981 document addresses specific waters in the Cape Fear River Basin, but those waters do not include any portion of the Cape Fear River, and those waters are located in counties within the Piedmont portion of the state. Furthermore, in an April 7, 1981 report of proceedings, several waters were proposed to be reclassified to remove the Sw designation from waters that also had the SA designation because of the difference between the pH standards for SA waters and Sw waters. Some waters that were included in this process, including the subject waters, were classified as SC Sw, rather than SA Sw, before this process yet their Sw classification was removed due to this process. No information regarding why the Sw class was removed from the subject waters is available in the April 7, 1981 report of proceedings or has been found by DWR staff who researched this issue.

7. ***Concern:*** *Questions and suggestions for proposed language regarding implementation*
   - *Natural Conditions and DO Bound*
     i. *Who decides what are natural conditions and by what criteria?*
     ii. *The management plan should discuss how DO use support determinations will be made. In short, some way to define a new floor with which to evaluate monitoring and compliance data should be established.*
     iii. *Is there any limitation on the duration or frequency by which a measured DO level can be below the 5 mg/L criterion? How will the assessment of the exceedances below 5 mg/L be determined to be based on natural conditions? Consider providing clarity through the adopted revisions.*
     iv. *The State could consider a specific lower bound for DO, or alternatively a seasonally, or specific month(s), based lower bound for DO.*
     The State could consider revising the DO and pH language indicating that sources which are not natural will still need to be considered and addressed during activities which consider in-stream and downstream water quality, like permitting or future criteria development efforts.

   - **Response:** The state's current use assessment methodology is not contained within the state's rules, and thus, language to address this methodology is not included in the proposed rules. In order to do a use support assessment of these waters, a method would need to be developed that accounts for management strategy targets and the Sw reclassification. As a reminder, in Sw waters, dissolved oxygen levels of less than 5.0 mg/l are only allowed if caused by natural conditions and pH levels as low as 4.3 are only allowed if caused by natural conditions. In addition, as a reminder, the purpose of the management plan is to codify current permitting policy already in existence for new individual NPDES wastewater discharges and expansions of individual NPDES wastewater discharges and to provide a path forward for dischargers' and communities' planning efforts.

   - *Monitoring*
     i. *How frequently will water be monitored? The plan includes no monitoring.*
     ii. *The State could clarify whether the 4.3 (for pH) represents an instantaneous measurement; if something different is intended that should also be documented and supported.*
     iii. *Ensure that the influence from anthropogenic sources is still addressed and continues to be monitored.*
     iv. *How will the state identify the cause of potential future decreases of DO levels?*

   - **Response:** No changes to the current monitoring strategy as well as the current permitting and compliance strategies for the subject waters will occur due to this proposal; thus, pH will continue to be measured in an instantaneous manner. As mentioned above, there are on-going efforts in the Cape Fear River Basin to assess pollution sources and investigate ways to address pollution sources, i.e. as

discussed in the Cape Fear Basinwide Plan and Nutrient Criteria Development Plan (NCDP).

- *Point Sources*
  - *i. The petition seems to indicate that point sources will have waste load allocations developed for them.*
  - *ii. The management plan should include the means by which the 0.1 mg/L cap on lowered DO will be determined. Important details to establish and get reviewed by stakeholders include the model to be used, input parameters, season to be modeled, location of compliance, and whether compliance is to be based on instantaneous versus average conditions.*
  - *iii. How will prohibition against causing DO decreases be enforced it at all?*
  - *iv. Replace "Any" with "All" (at the start of the last sentence of the proposed management plan) so that the cumulative impact of all additional permitted oxygen consuming waste is a diminishment of less than 0.1 mg/L.*
  - *v. Shouldn't allow any discharges to drop the DO levels; require whatever necessary to prevent that. 10 discharges could drop it 1 mg/l.*
  - *vi. Need to set limits on industrial facilities' discharges as with non-industrial discharges.*

- **Response:** The language within the following response is not proposed to be incorporated into the rule, but to provide information on how the dissolved oxygen impact from new or expanding discharges will most likely be assessed by the Division.

  The model to be used will be the most currently available three dimensional water quality model, which at this time, is the Lower Cape Fear dissolved oxygen model, http://portal.ncdenr.org/c/document_library/get_file?uuid=a84477db-4d83-4cc0-a9b9-f7da7a6a51f9&groupId=38364. The model was finalized on October 2009 by the Division of Water Quality (now known as the Division of Water Resources). The model is calibrated to 2004 observed data and meteorological conditions. Model inputs are described in the report. The most critical season when dissolved oxygen is expected to be impacted is April-October, and this season will be the focus for model comparison.

  The model will first be run with all existing discharges at full permitted capacity. This run will establish a baseline model for comparison. The baseline model will then be run with the addition of the proposed new or expanding discharge. Results from the two model runs will then be evaluated to determine the impact of a new or expanding discharge, and the entire area that is impacted by the discharge will be evaluated. If at any time there is a difference between these two model runs greater than 0.1 mg/L, the discharge will not be allowed. So, this approach will basically be a time-series comparison based on model output, and prohibition against causing DO decreases will be enforced via permit requirements stated in the proposed water quality management plan.

When modeling is conducted for a new or expanded discharge (as described directly above), the term "total permitted capacity" as stated in the proposed water quality management plan is to include all existing discharges as operating at their full permit limits plus the new or expanded discharge operating at its full permit limits. Rather than making the suggested language replacement as noted in the above fourth comment regarding point sources, DWR proposes to provide clarity to this issue by adding the following phrase to the end of the last sentence of the management plan: "for all discharges." Thus, the final sentence of the management plan would read as follows: "Any new or expanded permitted pollutant discharge of oxygen consuming waste shall not cause the DO of the receiving water to drop more than 0.1 mg/l below the modeled in-stream DO at total permitted capacity for all discharges."

RECOMMENDATION

It is the recommendation of the Hearing Officer that the reclassification of the segment of the Cape Fear River and associated water quality management plan, as proposed herein, be approved by the Environmental Management Commission in its entirety along with the above-mentioned additional language shown below in green. In making this recommendation, the Hearing Officer has considered the requirements of General Statutes 150B-21.2, 143-214.1, 143-215, and 143-215.3(a)(1), and Rules 15A NCAC 2B .0100 Procedures for Assignment of Water Quality Standards, 15A NCAC 2B .0220 Tidal Salt Water Quality Standards for Class SC Waters, and 15A NCAC 2B .0227 Water Quality Management Plans. In addition, the existing water quality conditions, the need to codify the current permitting policy already in existence for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters, the desire for a path forward for these discharges and associated local communities to plan for the future, and all comments received by DWR were considered.

In taking this action, Rule 15A NCAC 2B .0311, which references the Schedule of Classifications for the Cape Fear River Basin, will show that the Environmental Management Commission has revised the schedule for a portion of the Cape Fear River [Index No. 18-(71)] from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut from Class SC to Class SC Sw. A site-specific management strategy is outlined in 15A NCAC 02B .0227.

In addition, in taking this action, Rule 15A NCAC 2B .0227, which references Water Quality Management Plans, will show that the Environmental Management Commission has added to this rule a site-specific management strategy for a part of the Cape Fear River [Index No. 18-(71)] from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut, which is described as follows:

All new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges shall be required to provide treatment for oxygen consuming wastes as described in Parts (A) through (C) of this Subparagraph.

(A) Effluent limitations shall be as follows: BOD_5 = 5 mg/l, NH_3-N = 1 mg/l and DO = 6 mg/l, or site-specific best available technology on a case-by-case basis for industrial discharges.

(B) Seasonal effluent limits for oxygen consuming wastes will be considered on a case-by-case basis in accordance with Rule .0404 of this Subchapter.

(C) Any new or expanded permitted pollutant discharge of oxygen consuming waste shall not cause the dissolved oxygen of the receiving water to drop more than 0.1 mg/l below the modeled in-stream dissolved oxygen at total permitted capacity for all discharges.

The proposed effective date of this reclassification is November 1, 2015.

APPENDICES

ADVISORY BOARD

BLADEN COUNTY

BRUNSWICK COUNTY

CAPE FEAR COAST CONVENTION AND VISITORS BUREAU

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EX-OFFICIO MEMBERS

CHAIR, TECHNICAL COMMITTEE, LOWER CAPE FEAR RIVER PROGRAM

NC REGULATORY AGENCIES

US ARMY CORPS OF ENGINEERS

March 5, 2014

Mr. Tom Reeder
Director, Division of Water Resources
NC Department of Environment and Natural Resources
1611 Mail Service Center
Raleigh, NC 27699-1611

Subject: Request for Reclassification of a Portion of the Lower Cape Fear River with the Supplemental Swamp Classification

Dear Mr. Reeder:

The purpose of this letter is to formally request that the Division of Water Resources (DWR) recommend to the Environmental Management Commission (EMC) that portions of the Lower Cape Fear River Estuary (LCFRE) that are currently classified as Class SC Waters be reclassified to include the supplemental Swamp (Sw) classification. This would recognize the influence of natural drainage from riverine wetland and salt marsh systems that are ubiquitous throughout the Lower Cape Fear River, Northeast Cape Fear River and Black River watersheds on water quality conditions in the river. This would be consistent with the classifications of immediate upstream segment of the Cape Fear River and the tributaries which all currently carry the supplemental Sw classification.

Information typically requested by DWR for reclassification requests is included in Table 1 and a map showing the area being requested for consideration for the Sw supplemental classification is included as Figure 1. An additional map based on the US Geological Survey 7.5 minute topographic maps will be included in the hard copy of this letter and attachments.

Information typically requested by DWR for reclassification requests is included in Table 1 and a map showing the area being requested for consideration for the Sw supplemental classification is included as Figure 1. An additional map based on the US Geological Survey 7.5 minute topographic maps will be included in the hard copy of this letter and attachments.

This letter provides additional background on the Lower Cape Fear River Program (LCFRP) and this specific request and a summary of supporting technical papers that have been prepared.

Background on LCFRP and LCFRE

The Lower Cape Fear River Program is an integrative effort which brings together a coalition of citizens groups, industry, business, local, regional, and state government, and the university community. The Lower Cape Fear River Program (LCFRP) was formed in May, 1994 to develop an understanding of the fundamental scientific processes shaping and controlling the Cape Fear River Estuary and provide a mechanism for information exchange and public education. It is administered in cooperation with the University of North Carolina Wilmington's Center for Marine Science.

Since the group was formed, comprehensive data to assess ecological conditions in the river has been collected. The LCFRP was one of the first coalition monitoring groups established through a memorandum of agreement (MOA) with NC Department of Environment and Natural Resources (DENR) that relieves NPDES permit holders of individual requirements to perform instream monitoring and replaces that with a comprehensive and coordinated monitoring program. Currently, there are 17 NPDES permit holders that are party to the MOA, but many other advisory board members from throughout the lower basin as listed on the border on the first page of this letter. All of the monitoring data is submitted to DENR in accordance with the MOA. The program also has an interactive data base available on the internet where the LCFRP data can be accessed. This site also includes data from the Middle and Upper Cape Fear River Basin coalition groups for a comprehensive tool to review water quality conditions for the entire river basin.

Beginning in 1998, the section of the LCFRE from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut has been listed on the State of North Carolina's 303d List as impaired for DO. In 2006, DENR added pH as impaired for this segment, and in 2008, DENR added copper and turbidity to the listing, as well. The draft 2014 303d List maintains these impairments despite some changes to the listing methodology (DENR, 2014).

Until recently, DENR had been pursuing development of a total maximum daily load (TMDL) to establish what were originally believed to be reduction needs for oxygen-

demanding pollutants, including biochemical oxygen demand (BOD) and ammonia nitrogen (NH_3-N). An extensive effort had gone into developing a three-dimensional hydrodynamic and water quality model (using the Environmental Fluid Dynamics Code, or EFDC, model) between 2000 and 2009. This model provides an excellent tool for evaluating water quality conditions in the LCFRE. Based on the modeling analysis, the DENR determined that developing a TMDL using the existing standard for the Class SC portion of the LCFRE of 5 milligrams per liter (mg/L) (at all times) would not be appropriate because the modeling results indicate that point-source discharges have a relatively minor impact on DO levels, and that even significant reductions in background (both natural and nonpoint source) loads would not result in attainment of the current standard for considerable periods of time during the summer. Recently, DENR indicated that changes to the classification of the LCFRE might be appropriate to recognize the influence of natural drainage from riverine and saltwater marsh systems in the watershed on DO concentrations. A reclassification with the supplemental Sw classification would allow the water quality standards for DO and pH to be interpreted with narrative portion of the standard [from 15A NCAC 2B .0220 (3)]:

> *(b) Dissolved oxygen: not less than 5.0 mg/l, except that swamp waters, poorly flushed tidally influenced streams or embayments, or estuarine bottom waters may have lower values if caused by natural conditions;*
>
> *(g) pH: shall be normal for the waters in the area, which generally shall range between 6.8 and 8.5 except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions;*

It is recognized that with this classification change, DWR will still require the development of implementation procedures for determining allowable waste load allocations for point source discharges.

Supporting Information

There is a wealth of research and technical assessment studies that have been conducted on the LCFRE since the formation of the LCFRP in 1995, as well as during the 40 years prior to that time. In discussing this reclassification request with DWR staff, it was suggested that a summary of information be prepared to support the reclassification request. Four Technical Memoranda (TM) have been prepared in support of this reclassification request and are included as Attachments to this letter. The following is a brief summary of each TM.

TM 1 - Summary of Background Information and Previous Studies for the Lower Cape Fear River

This TM served to review available background information for the LCFRE dating back to original studies in the 1950s where water quality and pollutions sources were assessed and initial recommendations on stream classifications were made. Key studies and assessments up to the present time were also reviewed and a bibliography or studies and research papers was also included. A several of the key points from this TM include:

- Swamp influences were identified even during the early studies and the entire LCFRE and tributaries were recommended and subsequently classified with the supplemental Sw classification

- The supplemental Sw classification was removed from the Class SC portion of the Cape Fear River in 1981 without extensive evaluation for the basis of this change

- LCFRP monitoring in the mid to late 1990s documented the impact of swamp drainage following hurricanes, similar to what was documented during the 1990s

- The EFDC hydrodynamic and water quality model completed in 2009 demonstrated that the point sources had a minor contribution to the DO deficit and that even with 30 to 70 percent reductions in loadings of oxygen demanding materials from tributaries and wetlands/marsh systems (a combination of anthropogenic and natural sources), the DO standard of 5 mg/L could not be achieved between 20 and 30 percent of the time.

TM 2 - Updated Trend Analysis of DO Conditions and Pollutant Loading from Point Sources

This TM was an update of an analysis done in 2003. The previous DO trend analysis found no statistically significant trend for DO for the period of 1984 through 2002 for DO conditions at several stations within or immediately adjacent to the 303(d) listed portion of the LCFRE. The same conclusion was drawn for the period of 1991 through 2002, despite a statistically significant reduction in major point source ultimate biochemical oxygen demand (BODu) load of approximately 25 percent for that period. The updated analysis used monitoring data and information on point source loading from 1994 through 2013. The updated point source analysis focused on International Paper and Cape Fear Public Utilities Authority (CFPUA) Northside and Southside discharges since these facilities comprise over 90 percent of the point source loading to the local watershed. This analysis also showed no significant trend in DO levels in the LCFRE over the 20 year period while the loading of BODu from these three facilities declined by 23 percent over the same time period. This analysis confirms model results indicating that point sources are having a minor impact on DO levels in the LCFRE.

TM 3 - Analysis of Long-term Data near the Limits of the Tidal Influence for the Cape Fear River, Black River, and NE Cape Fear River

This TM presents an analysis of water quality parameters at the sampling stations representative of inflows to the system, with the purpose of examining issues related to a supplemental Sw classification for the estuary. Data was examined for several key parameters, including nutrients, pH, and DO, that are related to the occurrence of low DO in the Cape Fear River. The evaluation of water quality data at the boundary conditions supports the concept that inflows from the swamp areas have a significant impact on water quality in the Cape Fear River. The levels of nutrients, DO, and pH are consistently different between the station at Lock & Dam 1 (L&D1) on the main stem of the Cape Fear River, and in the major blackwater tributaries – the Black River and the NE Cape Fear River. A distinct response from these inflows can be seen in the levels for these parameters in the portion of the Cape Fear River near Navassa, providing additional supporting evidence that water quality in the Cape Fear River is significantly influenced by the conditions found in the swamp areas tributary to the river downstream of L&D1.

TM 4 - An Analysis of Model Results to Assess the Relative Impact of Riparian Wetlands and Salt Marshes versus other Tributary Loadings

This TM used the results of the two modeling efforts with the EFDC model in the 2000s to examine the technical basis for a supplemental Sw classification for the LCFRE. The two modeling studies included the initial EFDC model developments by Tetra Tech on behalf of the City of Wilmington and New Hanover County and the follow up work by the University of North Carolina – Charlotte on behalf of NC DENR. Both modeling efforts demonstrated that the impact from point source loads in the LCFRE contributes to less than 10 percent of the DO deficit in the LCFRE. The 2001 modeling effort demonstrated that an accurate calibration could not be achieved without representing the wetting and drying of adjacent low elevation wetland and salt marsh areas. That modeling estimated that wetland/marsh and sediment oxygen demand (SOD) sources accounted for between 75 and 80 percent of all oxygen demand in the LCFRE. The 2009 modeling effort validated and expanded the influence of adjacent marshland based on more detailed analysis. Further, application of the 2009 model that simulated up to 70 percent of nonpoint source load reduction demonstrated that even with such large pollutant loading reductions, DO concentrations would be expected to be below 5 mg/L approximately 20 percent of the time in the LCFRE during the summer. Therefore, the 2001 and 2009 modeling analyses provide further weight of evidence collectively that flow and oxygen-demanding loads from wetlands/marsh systems SOD are driving low DO during the summer period and suggest that reinstitution of the supplemental Sw designation for the LCFRE should be considered by DENR and the EMC.

Summary

It is clear from the data collection, modeling and technical analyses that the DO standard of 5 mg/L for the LCFRE is not appropriate since it is not achieved a significant portion of the time as a result of natural drainage from riverine wetlands and salt marshes. From a regulatory standpoint, a straightforward way to deal with this issue is to reclassify the area with the supplemental Sw classification. The information summarized in this letter and the attached TMs support this classification action.

Our organization appreciates DENR and the EMC's consideration of this request. We are also willing to provide further information and analysis related to this request as needed.

Sincerely,

Chris May
Chair Lower Cape Fear River Program Advisory Board and
Executive Director, Cape Fear River Council of Governments

Reclassification Request Letter_Final_03062014.docx

c: LCFRP Advisory Board and Technical Committee Members
Bill Kreutzberger/CH2M HILL
Trevor Clements/Tetra Tech

Table 1.
DWR Requested Information in Support of Reclassification Requests

Date of Request	March 6, 2014
Requested by	Lower Cape Fear River Program
River Basin and Counties	Cape Fear River Basin New Hanover and Brunswick Counties
Water bodies requested for Reclassification	Water Body: *Cape Fear River* Description: *From a point upstream Toomers creek to a line across the river from Snows Point (through Snows Marsh) to Federal Point* Index No.: *18-(71)* Current Classification: *SC* Requested Classification: *SC Sw*
Map	See Figure 1 from 7.5 minute USGS GIS Information
Rationale for Request	See text of letter and attached Technical Memoranda
Local Champions for Request	Lower Cape Fear River Program Members

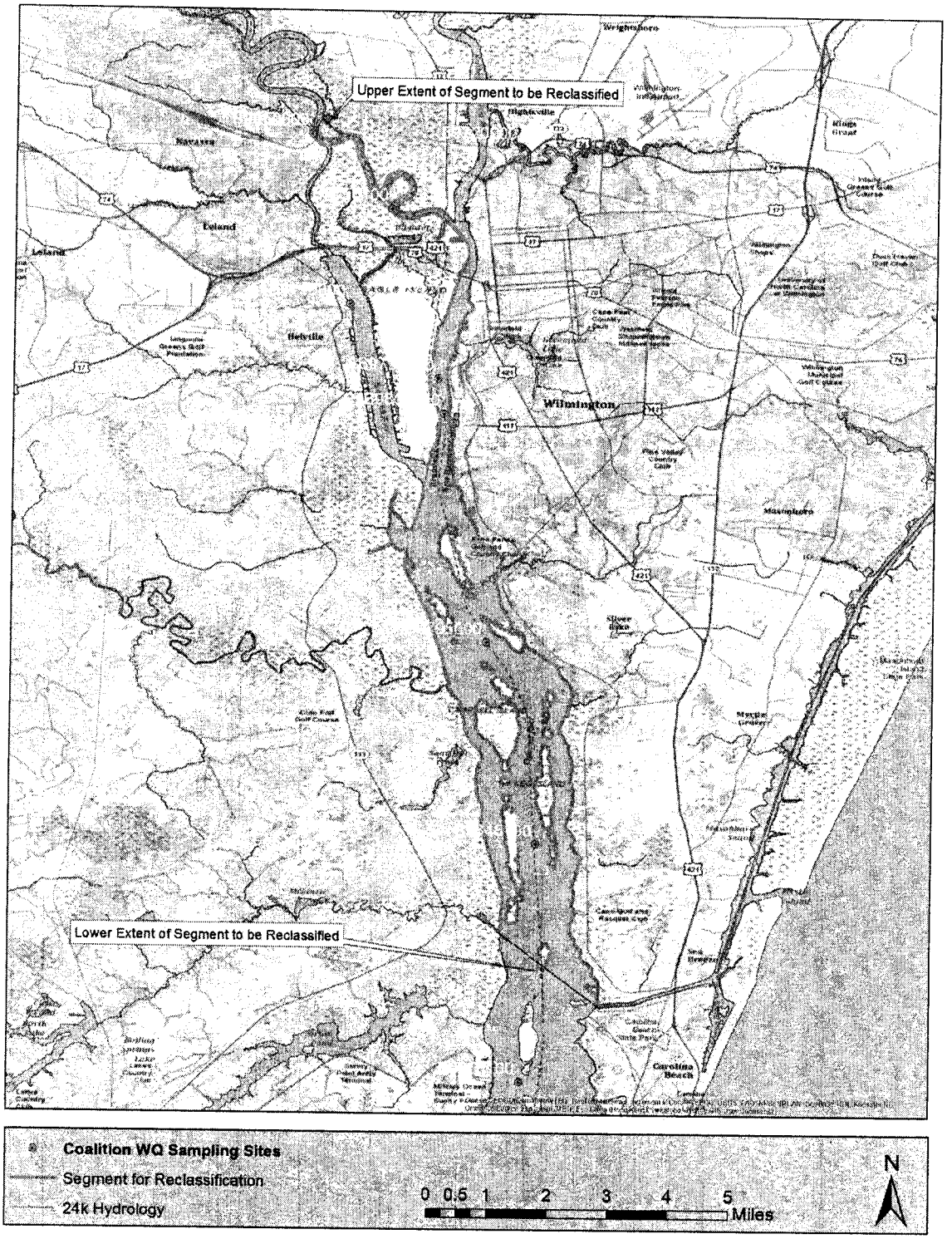

Figure 1.
Requested portion of Lower Cape Fear River Estuary for Consideration for Supplemental Swamp Classification

Attachments

TM 1 - Summary of Background Information and Previous Studies for the Lower Cape Fear River

TM 2 - Updated Trend Analysis of DO Conditions and Pollutant Loading from Point Sources

TM 3 - Analysis of Long-term Data near the Limits of the Tidal Influence for the Cape Fear River, Black River, and NE Cape Fear River

TM 4 - An Analysis of Model Results to Assess the Relative Impact of Riparian Wetlands and Salt Marshes versus other Tributary Loadings

Technical Memo: Task 1 – Summary of Background Information and Previous Studies for the Lower Cape Fear River

Prepared for

Lower Cape Fear River Program

Prepared by

CH2MHILL®

February 25, 2014

1 Introduction

The purpose of this technical memorandum (TM) is to identify available data and studies pertaining to the Lower Cape Fear River Estuary (LCFRE), and highlight key information pertaining to the influence of natural drainage from riverine and saltwater marsh systems in the watershed on dissolved oxygen (DO) conditions. This information is being summarized at a high level, for further consideration as the North Carolina Department of Environment and Natural Resources (DENR) and Environmental Management Commission consider appropriate stream classification and associated water quality criteria for the Cape Fear River.

1.1 BACKGROUND

The Lower Cape Fear River Program (LCFRP) was established in 1995 as a collaborative effort by public, private, and academic interests to collect data and research information on the LCFRE and its coastal watershed. Since the group was formed, comprehensive data to assess environmental conditions in the river has been collected.

Beginning in 1998, the section of the LCFRE from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut has been listed on the State of North Carolina's 303d List as impaired for DO. In 2006, DENR added pH as impaired for this segment, and in 2008, DENR added copper and turbidity to the listing, as well. The draft 2014 303d List maintains these impairments despite some changes to the listing methodology (DENR, 2014).

Until recently, DENR had been pursuing development of a total maximum daily load (TMDL) to establish what were originally believed to be reduction needs for oxygen-demanding pollutants, including biochemical oxygen demand (BOD) and ammonia nitrogen (NH_3-N). However, the DENR has recently determined that, based on the technical information compiled and assessed to date, developing a TMDL using the existing standard for the LCFRE of 5 milligrams per liter (mg/L) (at all times) would not be appropriate because the modeling results indicate that point-source discharges have a relatively minor impact on DO levels, and that even significant reductions in background (both natural and nonpoint source) loads would not result in attainment of the current standard for considerable periods of time during the summer. Recently, DENR indicated that changes to the classification of the LCFRE might be appropriate to recognize the influence of natural drainage from riverine and saltwater marsh systems in the watershed on DO concentrations.

There is a wealth of research and technical assessment studies that have been conducted on the LCFRE since the formation of the LCFRP in 1995, as well as during the 40 years prior to that time. Over the years, many technical studies of the LCFRE have been conducted by the LCFRP, DENR, other agencies and academic researchers, and consultants. As a result, an extensive technical foundation of knowledge on the LCFRE has been created, including information on physical, chemical, and biological features and processes.

1.2 SUMMARY OF AVAILABLE INFORMATION

A comprehensive listing of studies and research related to the LCFR has been included in the Attachment to this TM. In reviewing this information, it was decided to start with the early study of the river used to determine the stream classification and water quality standards and then move forward to the present. The following is a summary of this available information related to understanding the LCFRE, especially as it relates to assessing DO concentrations..

1.2.1 Original North Carolina State Board of Health Studies

Beginning in the mid-1950s and continuing until the early 1960s, the Division of Water Pollution Control of the State Board of Health conducted sanitary surveys of all the river basins in North Carolina, and made recommendations for stream classifications to be included in state water quality standards. The Cape Fear River Basin was sampled in 1955 and 1956, and the study report was published in 1957 (State Stream Sanitation Committee, 1957). This report includes analytical results from stream sampling and documented pollution loads from major sources of pollution.

The setting at the time of this study was that many towns and cities did not have any treatment, and industries varied from having no treatment to primary treatment facilities. There were no major impoundments in the Cape Fear Basin, so the basin experienced extreme ranges in flow conditions, depending on precipitation and hurricane conditions, which were apparent during 1955 when three hurricanes impacted eastern North Carolina.

In the lower river, there were two principal sources of pollution identified, the Riegel Paper Corporation (Riegel) and the City of Wilmington, plus numerous other smaller communities and industrial facilities. The following table summarizes the treatment and loads from the primary facilities.

Table 1. Primary Facility Treatment and Load Summary

Facility	Type of Treatment	Estimated Load (PE)
Riegel	Primary (13% efficient)	330,000
City of Wilmington	None	44,700
Timmie Manufacturing	Lagoon (20% efficient)	1,144
Wilmington Packing	Grease removal (20% efficient)	3,850
Wanet Sausage Co.	Grease removal (20% efficient)	3,200

Note:
PE - population equivalent

These loads cannot be directly transferred to the way oxygen-demanding loads are measured today. However, assuming 0.17 pounds per day (lb/d) of $CBOD_5$ per PE, this translates to about 65,000 lb/d of $CBOD_5$ discharged as highly reactive raw or primary treated waste. No information was presented in the study to estimate the nitrogenous (organic nitrogen and ammonia) oxygen demand load. This is estimated to be about 10 times greater than the current loading of $CBOD_5$ based on comparison with current discharger monitoring data. The water quality data demonstrated impacts on DO conditions in the river. Summertime DO levels from downstream of Riegel to downstream of Wilmington typically ranged from 2 to 3 mg/L, with some values considerably less than that. The highly reactive wastewater resulted in a double DO sag beginning just a few miles below the Riegel discharge to downstream of Wilmington.

Despite the significant impacts from untreated and poorly treated wastewater under low to moderate flow conditions in the river, two different situations influencing DO condition were also described in the report:

1. High flows from the Black and NE Cape Fear Rivers, and moderate flow from the Cape Fear River (data from August 30, 1955):
   - Low DO (1.3 to 2 mg/L) and low pH (5 to 6) coming from NE Cape Fear and Black Rivers
   - Resulting in low DO (1.3 to 2.2 mg/L) and low pH (5.8 to 6) in the typically brackish area below Wilmington
2. High flows from the Cape Fear River, and moderate flows from the NE Cape Fear and Black Rivers (data from July 23-24, 1956):
   - DO (2.8 to 4.9 mg/L and pH 6.8 to 7.2) conditions in lower river were moderate

They concluded that under some situations, swamp drainage conditions could significantly influence DO and pH conditions in the river, and recommended that the freshwater portion of the Lower Cape Fear River (LCFR) be Class C-Swamp (C-Sw) from the Riegel water intake to Toomers Creek, and Class SC-Swamp (SC-Sw) from Toomers Creek to the mouth of the Cape Fear River. These recommendation were adopted in 1962.

1.2.2 Reclassification in 1981

In 1981, a rule-making proceeding was initiated to remove the "Swamp" designation from waters classified as Class SA (for shellfishing). The record includes little basis for the removal of the Swamp designation from

tidal saltwater classes other than statements that the designation is inconsistent with a shellfishing designation. There was little other discussion of the changes and nothing specific to Class SC waters. Based on the lack of objection, the Swamp designation was removed from a substantial portion of all tidal saltwaters in North Carolina in 1981 in conjunction with some other stream/coastal water classification changes (DEM, 1981). This action changed the classification of the Cape Fear River from "upstream of the mouth of Toomers creek to Atlantic Ocean" from Class SC Sw to Class SC. However, the Sw designation was not removed from the Class SC portion of the NE Cape Fear River by this action. As a result of this reclassification, the DO standard of not less than 5 mg/L at all times and pH standard not less than 6.8 became effective for the Class SC portion of the Cape Fear River, with no recognition of the potential influence of natural conditions.

1.2.3 Initial Water Quality Modeling

Despite significant improvement in wastewater treatment throughout the basin since the initial studies in the 1950s, there was a recognition that water quality conditions in the Cape Fear River might limit future industrial and urban growth. In addition, hydrological conditions in the basin had changed with the filling of Jordan Lake in 1981. This lake has a watershed of approximately 1,700 square miles (mi^2), and has authorized purposes of flood damage reduction, water supply, water quality control, fish and wildlife conservation, and outdoor recreation. With this changed hydrology, and significant urban and industrial growth in the Wilmington area, the Division of Environmental Management (DEM) initiated the development of a water quality model using a program called the Georgia Estuary Model (DEM, 1984). The U.S. Environmental Protection Agency (USEPA) and Georgia Environmental Protection Division had been promoting the model as a useful tool for coastal river/estuary systems and were in the process of applying the model to the Lower Savannah River along the Georgia-South Carolina border. Although the report was finalized in 1984, the model was not apparently used for any major permitting decisions for the river.

1.2.4 Federal Paperboard Co. Studies

In 1990, Federal Paperboard Co., the current owner of the facility formerly called the Riegel Paper Corporation, conducted a series of studies in order to resolve a long-time permit dispute. While the facility had greatly expanded treatment with the installation of an aerated stabilization basin (ASB) system, the facility and DEM could not agree on appropriate permit limits for the facility. This included development of a water quality model for the LCFR (Hydroscience, 1990) and extensive biological surveys on the LCFRE, as well as lower portions of the Black River and NE Cape Fear River (CH2M HILL, 1992).

The water quality model was developed as a slack-tide calibrated QUAL 2E model, recognizing that this was a conservative approach for modeling the impacts of the Federal Paperboard Co. discharge, since it did not consider dilution provided by tidal exchange. The DEM developed a similar model of the river, and both models indicated that there was only a small DO sag resulting from the Federal Paperboard Co. discharge under this conservative modeling approach (Kreutzberger and Wakild, 1993).

Biological investigations of the river, including habitat characteristics, benthic macroinvertebrates, and fisheries, indicated that the aquatic life uses of the river were not impaired as a result of wastewater discharges. Habitat characteristics of the Cape Fear River related to basin hydrology and historical dredging were determined to be primary factors affecting variability in biological characteristics in the river (CH2M HILL, 1992; Kreutzberger and Wakild, 1993; Sacco et al., 1993).

Information provided by these studies allowed the National Pollutant Discharge Elimination System (NPDES) permit issues for Federal Paperboard Co. to be resolved with a permit issued and a Special Order by Consent (SOC) to achieve those limits by 1999. International Paper purchased the mill in 1996 and continues to operate this facility today.

1.2.5 1996 Cape Fear River Basinwide Water Quality Management Plan

In the mid-1990s, the DENR began development of basinwide water quality management plans for each of the river basins in the state, with plans to update them every 5 years. They also rearranged permit expiration schedules so that these plans could then guide all of the permitting in each basin. In the 1996 Plan, the LCFRE was not considered impaired, and there was no specific water quality management strategy presented. However, because portions of the estuary were designated as Primary Nursery Areas (PNA) by the Division of Marine Fisheries, this area was subject to High Quality Waters (HQW) requirements according to the plan.

This actually includes significant portions of the currently impaired areas. Based on this requirement, all new and expanding dischargers were required to meet advanced treatment requirements for oxygen-consuming wastes for which the specific limitations have evolved over the years (DENR, 1996).

1.2.6 Lower Cape Fear River Program Studies

As noted in the background, the LCFRP was established in 1995 and has been providing excellent data on ambient conditions in the river, as well as a wide variety of targeted research efforts. The annual and special reports, as well as published research papers, are listed in the attachment. A comprehensive review of the efforts is beyond the scope of this TM. The following provides a brief overview of the consistent findings over the years and a few highlighted observations that seem pertinent to consideration of the appropriate classification for the LCFRE.

In reviewing annual reports over the nearly 20 years of monitoring, the characterization of the LCFRE and tributaries has been fairly consistent. The LCFR has been characterized as experiencing periodically high turbidity with moderate to high levels of inorganic nutrients. The estuary also has two major blackwater tributaries (the Black and Northeast Cape Fear Rivers) that generally exhibit low levels of turbidity, lower levels of inorganic nutrients, and high levels of color. Despite the high levels of nutrients, algal blooms are typically limited in the rivers due to a combination of limited light as a result of turbidity and flushing in the Cape Fear River, or limited light because of the highly colored waters in the tributaries. During periods of low flow, discussed later in this section, chlorophyll a levels increase because water clarity increases and flushing decreases, allowing more time for algal populations to develop. Some major algal blooms have been observed in tributaries where point-source influences have been noted. Blackwater swamps and agricultural areas have been characterized as periodically having high pollutant levels (Mallin et al., 2013).

In addition to the overall summary of conditions, the LCFRP has documented water quality conditions following major hurricanes and during two extreme droughts. The following summarizes some observations during these periods.

The early years of the monitoring effort allowed for extensive documentation of hurricane effects similar to those observed during the initial water quality surveys in 1955. In the summer of 1996, eastern North Carolina experienced the effects of Hurricane Bertha (July 1996) and Hurricane Fran (September 1996). The ongoing LCFRP was able to document the water quality response from Hurricane Fran in particular, where hurricane-induced flooding resulted in significant inputs from riparian wetlands, especially in the NE Cape Fear River. The DO in the NE Cape Fear River fell to about zero for approximately 3 weeks, and there were also documented fish kills. The DO levels in the mainstem of the Cape Fear River were as low as 2 mg/L but recovered faster due to flushing from flows originating from the upper part of the watershed. It is important to note that while inputs from riparian wetlands were significant contributors to the tremendous loads of oxygen-demanding materials, there were also significant inputs of raw and partially treated sewage as a result of power failures, as well as significant inputs of swine waste from breached lagoon storage systems. Therefore, the natural inputs from wetlands could not be separated from anthropogenically derived inputs, which were concluded to be especially significant in the NE Cape Fear River system based on monitoring results for BOD and ammonia (Mallin et al., 1997).

Much of North Carolina and the Cape Fear River basin, in particular, experienced a severe drought in 2001 and 2002 that ended in 2003. The LCFRP documented higher salinity levels and extended low DO conditions in the main river during the summer of 2002. Several tributaries, Angola Creek, the upper portion of the NE Cape Fear River, and the upper South River were noted to have extremely low DO levels. Turbidity levels were lower than the mean conditions for the period of record in the Cape Fear River and the upper estuary, but algal blooms were not documented in the major rivers but were observed in some small streams (Mallin et al., 2003).

Another severe drought occurred during 2007. Observations were similar for the 2001-2002 drought in terms of low DO levels and lower than typical levels of turbidity in the Cape Fear River. While algal blooms were not observed in the Cape Fear River, some severe blooms were observed in many small tributaries where turbidity levels were also significantly lower than the long-term trend (Mallin et al., 2008).

This is just a brief summary of the extensive assessment efforts conducted by the LCFRP. There has also been a wide variety of published papers. The assessment reports and other publications are listed in the Attachment A.

1.2.7 City of Wilmington/New Hanover County Studies

In the period between 2000 and 2001, efforts were made on behalf of the City of Wilmington and New Hanover County to develop an initial application of a three-dimensional hydrodynamic model (the Environmental Fluid Dynamics Code, or EFDC, model), with the intention of meeting several objectives deemed important at the time (Tetra Tech, 2001). This model was an important step in developing an assessment tool for the river. However, DENR and stakeholders determined that more data for development and calibration were required to support development of a model that could be used to determine a TMDL for the impaired portions of the river. This effort is discussed in this section relative to the University of North Carolina (UNC)-Charlotte Water Quality Model.

In addition to the initial EFDC model development, a trend analysis was also conducted of available data to determine whether there was any significant change in DO levels in the impaired portion of the river during a period when significant reductions in point-source loadings of oxygen-consuming wastes occurred (Doll and Clements, 2003). The previous DO trend analysis found no statistically significant trend for DO for the period of 1984 through 2002. The same conclusion was drawn for the period of 1991 through 2002, despite a statistically significant reduction in major point-source ultimate biochemical oxygen demand (BODu) load of approximately 25 percent for that period. This analysis has been updated with recent data and is presented in TM A-2 (Tetra Tech, 2014).

1.2.8 UNC-Charlotte Water Quality Model

As an extension of the effort started by consultants to the City of Wilmington and New Hanover County (Tetra Tech, 2001), DENR contracted with UNC-Charlotte to further develop the hydrodynamic model and water quality model using EFDC (Bowen et al., 2009). The objective of the study was to develop a water quality model of the LCFRE that would be suitable for use in developing a TMDL to address DO impairment. This model generally covers the tidally influenced areas of the Cape Fear River, Black River, and NE Cape Fear River, and extends to the mouth of the Cape Fear River with the Atlantic Ocean. The final report documents the details of the model development and calibration.

Analyses were conducted upon completion of model development, and calibration including the following eight scenarios:

1. Eliminating wastewater point-source loadings
2. Reducing river, creek, and wetland loadings
3. Changing wastewater loadings for various values of sediment oxygen demand
4. Reducing river, creek, and wetland loadings, and sediment oxygen demand
5. Eliminating ammonia inputs from wastewater point sources
6. Increasing wastewater inputs to maximum permitted values
7. Deepening of the navigation channel
8. Changing Brunswick County wastewater loadings

The following are a few highlights of major observations for some scenarios based on a simulation period to include April through October during a relatively low flow year – 2004.

1.2.8.1 Eliminating Wastewater Point-source Loadings

The sensitivity of the system to point sources was performed by running the model under different point-source conditions, including one with all point sources removed. Results from this analysis are shown in Figure 1 for the impaired portion of the Cape Fear River as a cumulative frequency diagram illustrating the percentage of the time the DO was above a certain level. Key findings include:

- During the period of lowest DO (selected as the 10th percentile), turning off all point-source discharges resulted in an increase in the DO from about 4.3 to 4.6 mg/L.

- DO levels were less than the standard of 5 mg/L approximately 32 percent of the time with the point-source discharges, and 27 percent of the time when these loadings were turned off.

1.2.8.2 Reducing River, Creek, and Wetland Loadings

Nonpoint-source reduction scenarios were also run by reducing the loading of oxygen-demanding pollutants for the tributaries and wetland cells by 30, 50, and 70 percent. These results indicate the following:

- During the period of lowest DO (selected as the 10th percentile), the difference between the base case with all calibrated pollutant loading and a 70 percent reduction in tributary/wetland loading resulted in an increase in DO of about 4.3 to 4.7 mg/L.
- DO levels were less than the standard of 5 mg/L approximately 32 percent of the time for the base case, 24 percent of the time with a 30 percent reduction in tributary/wetland loads, 20 percent of the time with a 50 percent reduction in tributary/wetland loads, and 18 percent of the time with a 70 percent reduction of tributary wetland loads.

1.2.8.3 Eliminating Ammonia Inputs from Wastewater Point Sources

The model results indicated that elimination of ammonia from point sources resulted in an approximate 0.1 mg/L increase in DO for periods when the DO was less than 5 mg/L.

Based on the results of the UNC-Charlotte modeling study, DENR determined that it could not move forward with development of a TMDL because it was apparent that point sources contributed a relatively small portion of the observed DO impairment based on the DO standard of 5 mg/L. DENR also concluded that although natural sources appeared to be a significant contributor to the low DO conditions, they could not differentiate what portion of the DO deficit was due to natural sources versus anthropogenic sources.

April through October Simulated Dissolved Oxygen Concentrations in the Impaired Area, Lower Cape Fear River Estuary

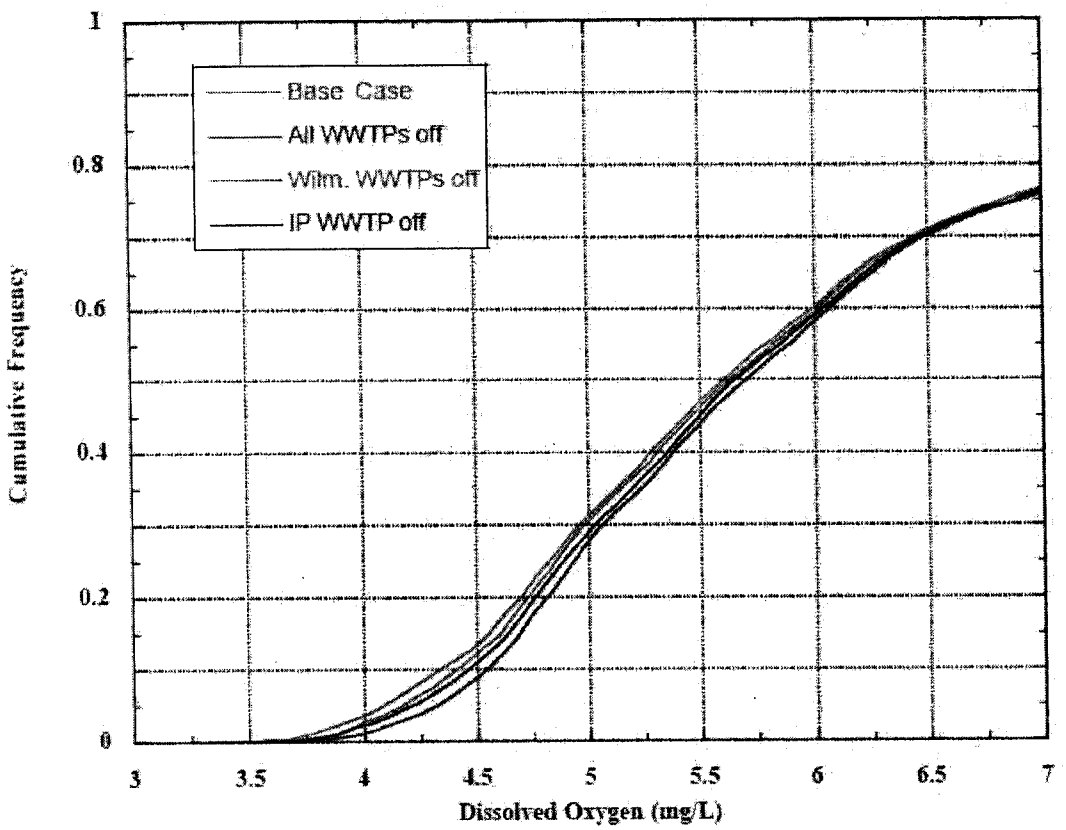

Figure 1. Cumulative frequency of model-predicted DO concentrations (April through October 2004) in the impaired portion of the LCFRE for the base case and three reduction scenarios for WWTP loads (reproduced from Bowen et al., 2009)

The three analyses highlighted above demonstrate the LCFRE lack of sensitivity to changes in point source loads. It should also be pointed out that the modeling also showed a significant impact of further channel dredging on DO conditions in the river.

2 Summary

There is a vast amount of data, research, technical analysis, and modeling for the LCFRE. While discharges from point sources and nonpoint sources appear to have some contribution to the DO deficit, it is also clear that natural drainage from riparian wetlands, salt marshes, and blackwater tributaries are more significant contributors to DO conditions not meeting the assigned standard of 5 mg/L and the pH minimum of 6.8 at all times for Class SC waters (see TM 4 for additional technical details on relative impact of sources on DO deficit) (Tetra Tech, 2014). The supplemental "Swamp" classification appears appropriate for these areas to recognize the natural source contributions to deviations in these parameters.

Other TMs prepared in conjunction with this summary address other aspects of these issues, including:

- TM 2 - Updated trend analysis of DO conditions and pollutant loading from point sources
- TM 3 - Analysis of long-term data near the limits of the tidal influence for the Cape Fear River, Black River, and NE Cape Fear River, which are approximate boundaries in the EFDC model
- TM 4 - An analysis of model results to assess the relative impact of riparian wetlands and salt marshes versus other tributary loadings

3 References

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin, and J. Williams. 2009. *Development and Use of a Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the Lower Cape Fear River Estuary, North Carolina.* Charlotte, North Carolina: Department of Civil and Environmental Engineering, University of North Carolina at Charlotte.

CH2M HILL. 1992. *Biological Assessment in the Cape Fear River Watershed.* Atlanta, Georgia: CH2M HILL.

Department of Environment and Natural Resources (DENR). 1996. *Cape Fear River Basinwide Water Quality Management Plan.* Raleigh, North Carolina.

Department of Environment and Natural Resources (DENR). 2014. *2014 Draft Category 5 Water Quality Assessments-303(d) List.* Raleigh, North Carolina.

Division of Environmental Management (DEM). 1981. *Proceedings of the Reclassification of Tidal Saltwaters.* Raleigh, North Carolina.

Division of Environmental Management (DEM). 1984. *Water Quality Analysis and Model Lower Cape Fear River.* North Carolina Division of Natural Resources (NCDNR) and Community Development. Report No. 84-08.

Doll, J., and T. Clements. 2003. *Results of Dissolved Oxygen and Pollutant Loading Trend Analyses.* Research Triangle Park, North Carolina: Tetra Tech.

Hydroscience. 1990. *Water Quality Model of the Lower Cape Fear River.* Report submitted to Federal Paperboard Company, Riegelwood, North Carolina. June.

Kreutzberger, W., and C. Wakild. 1993. "Water quality and biological investigation of the lower cape fear basin." *Tappi Journal*. Vol. 76(7). July.

Mallin, M.A., M.H. Posey, M.L. Moser, G.C. Shank, M.R. McIver, T.D. Alphin, S.H. Ensign, and J.F. Merritt. 1997. *Water Quality in the Lower Cape Fear River System, 1996-1997*. Wilmington, North Carolina: University of North Carolina – Wilmington, Center for Marine Science Research.

Mallin, M., M. McIver, H. Wells, M. Williams, T. Lankford, and J. Merritt. 2003. *Environmental Assessment of the Lower Cape Fear River System, 2002-2003*. CMSR Report No. 03-03, Center for Marine Science Research. Wilmington, North Carolina: University of North Carolina Wilmington. October.

Mallin, M., M. McIver, and J. Merritt. 2008. *Environmental Assessment of the Lower Cape Fear River System, 2007*. CMSR Report No. 08-03, Center for Marine Science Research. Wilmington, North Carolina: University of North Carolina Wilmington. December.

Mallin, M., M. McIver, and J. Merritt. 2013. *Environmental Assessment of the Lower Cape Fear River System, 2012*. CMSR Report No. 13-02, Center for Marine Science. Wilmington, North Carolina: University of North Carolina Wilmington. October.

Sacco, P., T. Simpson, and W. Kreutzberger. 1993. Adapting the EPA Rapid Bioassessment Protocol for Use Attainability Study in the Cape Fear River. *Proceedings of the 1993 Georgia Water Resources Conference*. Kathryn J. Hatcher, ed. Athens, Georgia: The University of Georgia, Institute of Natural Resources. April 20 and 21.

State Stream Sanitation Committee. 1957. *Cape Fear River Basin Pollution Survey Report 1957 (1954-1956)*. Raleigh, North Carolina: North Carolina State Board of Health, Division of Water Pollution Control.

Tetra Tech. 2001. *3-Dimensional EFDC Water Quality Model of the Lower Cape Fear River and its Estuary*. Prepared for the City of Wilmington and New Hanover County, North Carolina. May.

Tetra Tech. 2014. *Technical Memo: The Relationship of Adjacent Wetlands and Salt Marsh to Dissolved Oxygen in the Lower Cape Fear River Estuary*. Prepared for the Lower Cape Fear River Program. February (Draft).

Attachment A – Bibliography of Studies Pertinent to Water Quality Conditions in the Lower Cape Fear River

Lower Cape Fear River Program Related Reports and Publications

Benedetti, M.M., M.J. Raber, M.S. Smith, and L.A. Leonard. 2006. *Physical Geography*. 27: 258-281.

Burkholder, J. M., Dickey, D. A., Kinder, C. A., Reed, R. E., Mallin, M. A., McIver, M. R., Cahoon, L. B., Melia, G., Brownie, C., Smith, J., Deamer, N., Springer, J., Glasgow, H. B., and D. Toms. 2006. *Limnology and oceanography*. 51:463-487.

Cahoon, L.B., J.A. Mikucki, and M.A. Mallin. 1998. "Nutrient imports to the Cape Fear and Neuse River basins on animal feeds." *Manure Management in Harmony with Environment and Society*. Ames, Iowa: Soil and Water Conservation Service. pp. 228-232.

Cahoon, L.B., J.A. Mickucki, and M.A. Mallin. 1999a *Environmental Science and Technology*. 33:410-415.

Cahoon, L.B., J.A. Mikucki, and M.A. Mallin. 1999b. *Environmental Science and Technology*. 33: 410-415.

Dafner, E.V., M.A. Mallin, J.J. Souza, H. A. Wells, and D.C. Parsons. 2007. *Marine Chemistry*. 103: 289-303.

Dame, R., M. Alber, D. Allen, M. Mallin, C. Montague, A. Lewitus, A. Chalmers, R. Gardner, C. Gilman, B. Kjerfve, J. Pinckney, and N. Smith. 2000. *Estuaries*. 23: 793-819.

Lin, J., L. Xie, L.J. Pietrafesa, J. Shen, M.A. Mallin, M.J. Durako. 2006. *Estuarine Coastal and Shelf Science*. 70: 423-437.

Mallin, M., M. McIver, and J. Merritt. 2013. *Environmental Assessment of the Lower Cape Fear River System, 2012*. CMS Report No. 13-02. Wilmington, North Carolina: Center for Marine Science, University of North Carolina Wilmington. October.

Mallin, M.A. 1994. *Estuaries*. 17: 561-574.

Mallin, M.A. 2000. "Impacts of industrial-scale swine and poultry production on rivers and estuaries." *American Scientist*. 88:26-37.

Mallin, M.A., and C.A. Corbett. 2006. *Estuaries and Coasts*. 29: 1046-1061.

Mallin, M.A., G.C. Shank, M.R. McIver, and J.F. Merritt. 1996. *Water Quality in the Lower Cape Fear Watershed, 1995-1996*. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington.

Mallin, M.A., G.C. Shank, M.R. McIver, L.B. Cahoon, and D.C. Parsons. 1996. Spatial and temporal nutrient patterns in the Lower Cape Fear River system. *Solutions: Proceedings of a technical conference on water quality*. Raleigh, North Carolina: North Carolina State University. March 19-21.

Mallin, M.A., J.M. Burkholder, G.C. Shank, M.R. McIver, and H.B. Glasgow, Jr. 1996. Effects of animal waste spills on receiving waters. *Solutions: Proceeding of a technical conference on water quality*. Raleigh, North Carolina: North Carolina State University. March 19-21.

Mallin, M.A., J.M. Burkholder, M.R. McIver, G.C. Shank, H.B. Glasgow, Jr., B.W. Touchette, and J. Springer. 1997. "Comparative effects of poultry and swine waste lagoon spills on the quality of receiving streamwaters." *Journal of Environmental Quality*. 26:1622-1631.

Mallin, M.A., L.B. Cahoon, D.C. Parsons, and S.H. Ensign. 1998. *Effect of organic and inorganic nutrient loading on photosynthetic and heterotrophic plankton communities in blackwater rivers*. Report No. 315. Raleigh, North Carolina: Water Resources Research Institute of the University of North Carolina.

Mallin, M.A., L.B. Cahoon, M.R. McIver, D.C. Parsons, and G.C. Shank. 1997. *Nutrient limitation and eutrophication potential in the Cape Fear and New River Estuaries*. Report No. 313. Raleigh, North Carolina: Water Resources Research Institute of the University of North Carolina.

Mallin, M.A., L.B. Cahoon, M.R. McIver, D.C. Parsons, and G.C. Shank. 1999. *Estuaries*. 22:985-996.

Mallin, M.A., M.H. Posey, G.C. Shank, M.R. McIver, S.H. Ensign, and T.D. Alphin. 1999. *Ecological Applications*. 9:350-362.

Mallin, M.A., M.H. Posey, M.L. Moser, G.C. Shank, M.R. McIver, T.D. Alphin, S.H. Ensign, and J.F. Merritt. 1997. *Environmental Assessment of the Lower Cape Fear River System, 1996-1997*. CMSR Report No. 97-01. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington.

Mallin, M.A., M.H. Posey, M.L. Moser, G.C. Shank, M.R. McIver, T.D. Alphin, S.H. Ensign, and J.F. Merritt. 1998. *Environmental Assessment of the Lower Cape Fear River System, 1997-1998*. CMSR Report No. 98-02. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington.

Mallin, M.A., M.H. Posey, M.L. Moser, L.A. Leonard, T.D. Alphin, S.H. Ensign, M.R. McIver, G.C. Shank, and J.F. Merritt. 1999. *Environmental Assessment of the Lower Cape Fear River System, 1998-1999*. CMSR Report No. 99-01. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington.

Mallin, M.A., M.H. Posey, M.R. McIver, S.H. Ensign, T.D. Alphin, M.S. Williams, M.L. Moser, and J.F. Merritt. 2000. *Environmental Assessment of the Lower Cape Fear River System, 1999-2000*. CMS Report No. 00-01. Wilmington, North Carolina: Center for Marine Science, University of North Carolina at Wilmington.

Mallin, M.A., M.H. Posey, T.E. Lankford, M.R. McIver, H.A. CoVan, T.D. Alphin, M.S. Williams, and J.F. Merritt. 2002. *Environmental Assessment of the Lower Cape Fear River System, 2001-2002*. CMS Report No. 02-01. Wilmington, North Carolina: Center for Marine Science, University of North Carolina at Wilmington.

Mallin, M.A., M.H. Posey, T.E. Lankford, M.R. McIver, S.H. Ensign, T.D. Alphin, M.S. Williams, M.L. Moser, and J.F. Merritt. 2001. *Environmental Assessment of the Lower Cape Fear River System, 2000-2001*. CMS Report No. 01-01. Wilmington, North Carolina: Center for Marine Science, University of North Carolina at Wilmington.

Mallin, M.A., M.R. McIver, H.A. Wells, M.S. Williams, T.E. Lankford, and J.F. Merritt. 2003. *Environmental Assessment of the Lower Cape Fear River System, 2002-2003*. CMS Report No. 03-01. Wilmington, North Carolina: Center for Marine Science, University of North Carolina at Wilmington.

Mallin, Michael A., Lawrence B. Cahoon, John J. Manock, James F. Merritt, Martin H. Posey, Troy D. Alphin, Douglas C. Parsons, and Tracy L. Wheeler. 1998. *Environmental Quality of Wilmington and New Hanover County Watersheds 1997-1998*. CMSR Report No. 98-03. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington. November.

Mallin, Michael A., Lawrence B. Cahoon, John J. Manock, James F. Merritt, Martin H. Posey, Ronald K. Sizemore, W. David Webster, and Troy D. Alphin. 1998. *A Four Year Environmental Analysis of New Hanover County Tidal Creeks 1993-1997*. CMSR Report No. 98-01. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington.

Mallin, Michael A., Scott H. Ensign, Douglas C. Parsons, and Tracy L. Wheeler. 1999. *Environmental Quality of Wilmington and New Hanover County Watersheds 1998-1999*. CMSR Report No. 99-02. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington. December.

Mallin, Michael, Matthew R. McIver, and James F. Merritt. 2008. *Environmental Assessment of the Lower Cape Fear River System, 2007*. CMSR Report No. 08-03. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington. December.

Mallin, Michael, Matthew R. McIver, and James F. Merritt. 2012. *Environmental Assessment of the Lower Cape Fear River System, 2011*. CMSR Report No. 12-03. Wilmington, North Carolina: Center for Marine Science Research, University of North Carolina at Wilmington. September.

Padgett, D.E., M.A. Mallin, and L.B. Cahoon. 2000. "Evaluating the use of ergosterol as a bioindicator for assessing water quality." *Environmental Monitoring and Assessment* 00:1-12.

Xia, M., L. Xie. and L.J. Pietrafesa. 2007. *Estuaries and Coasts*. 30: 698-709.

State and Federal Government Studies

Hackney CT, Posey M, Leonard LL, Alphin T, and Avery GB. 2002. *Monitoring Effects of a Potential Increased Tidal Range in the Cape Fear River Ecosystem Due to Deepening Wilmington Harbor, NC, Year 1: August 1, 2000-July, 2001.* Prepared for the U.S. Army Corps of Engineers, Wilmington District. Contract No. DACW 54-00-R-0008. April.

National Oceanic and Atmospheric Administration (NOAA). 1979. *Circulation and Hydrodynamics of the LCFR, NC. National Ocean Survey*. U.S. Department of Commerce. August.

North Carolina Department of Environment and Natural Resources (DENR). 1995. *Cape Fear River Basinwide Assessment Report*. Raleigh, North Carolina.

North Carolina Department of Environment and Natural Resources. (DENR). 1996. *Cape Fear River Basinwide Water Quality Management Plan*. Raleigh, North Carolina.

North Carolina Department of Environment and Natural Resources (DENR). 2000. *Cape Fear River Basinwide Assessment Report*. Raleigh, North Carolina.

North Carolina Department of Environment and Natural Resources (DENR). 2001. *Cape Fear River Basinwide Water Quality Management Plan*. Raleigh, North Carolina.

North Carolina Department of Environment and Natural Resources (DENR). 2005. *Cape Fear River Basinwide Assessment Report*. Raleigh, North Carolina.

North Carolina Department of Environment and Natural Resources (DENR). 2006. *Cape Fear River Basinwide Water Quality Management Plan*. Raleigh, North Carolina.

North Carolina Department of Environment and Natural Resources, Water Quality (DWQ). 1998. *Basinwide Wetland and Riparian Restoration Plan for the Cape Fear River Basin*. NC Wetlands Restoration Program.

North Carolina Department of Environment and Natural Resources, Water Quality (DWQ). 2001. *Watershed Restoration Plan for the Cape Fear River Basin*. NC Wetlands Restoration Program.

North Carolina Department of Natural Resources and Community Development. 1984. *Water Quality Analysis and Model, Lower Cape Fear River*. Report No 84-08. Division of Environmental Management. June.

North Carolina Department of Natural Resources and Community Development, and U.S. Water Resources Council. 1983a. *Status of Water Resources in the Cape Fear River Basin*. Cape Fear River Basin Study. June.

North Carolina Department of Natural Resources and Community Development, and U.S. Water Resources Council. 1983b. *Wetlands Technical Memorandum 1.1 Cape Fear River Basin*. Cape Fear River Basin Study. September.

North Carolina Department of Natural Resources and Community Development, and U.S. Water Resources Council. 1984. *Summary Report: Cape Fear River Basin Study, 1981-84*.

North Carolina Division of Environmental Management (DEM). 1981. *Proceedings of the Reclassification of Tidal Saltwaters*. Raleigh, North Carolina.

North Carolina Division of Water Pollution Control. 1962. Proceedings of the Classification of the Waters of the Cape Fear River Basin.

State Stream Sanitation Committee. 1957. *Cape Fear River Basin Pollution Survey Report 1957 (1954-1956)*. Raleigh, North Carolina: North Carolina State Board of Health, Division of Water Pollution Control.

Other Studies

Becker, May Ling. 2006. Hydrodynamics Behavior of the Cape fear River Estuarine System, NC. Doctoral dissertation. University of North Carolina at Charlotte.

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin, and J. Williams. 2009. *Development and Use of a Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the Lower Cape Fear River Estuary, North Carolina.* Charlotte, North Carolina: Department of Civil and Environmental Engineering, University of North Carolina at Charlotte.

Carolina Power and Light. 1973-2008.. *Brunswick Nuclear Power Plant Biological Monitoring Report and Other Studies, 1973 to 2008.*

CH2M HILL. 1992. *Biological Assessment in the Cape Fear River Watershed.* Report prepared for Federal Paper Board Co. Atlanta, Georgia: CH2M HILL.

Doll, J., and T. Clements. 2003. *Results of Dissolved Oxygen and Pollutant Loading Trend Analyses.* Research Triangle Park, North Carolina: Tetra Tech.

Henry Von Oesen and Associates, Inc. 1984. *Lower Cape fear River Water Quality Problems, Impacts and Alternatives for Remedial Action.* Prepared for Wilmington Industrial Development, Inc. July..

Hydroscience, 1990. *Water Quality Model of the Lower Cape Fear River.* Report submitted to Federal Paperboard Co., Riegelwood, North Carolina. June.

Kreutzberger, W., and C. Wakild. 1993. "Water quality and biological investigation of the lower cape fear basin." *TAPPI Journal.* Vol. 76(7). July.

Sacco, P., T. Simpson, and W. Kreutzberger. 1993. Adapting the EPA Rapid Bioassessment Protocol for Use Attainability Study in the Cape Fear River. *Proceedings of the 1993 Georgia Water Resources Conference.* Kathryn J. Hatcher, ed. Athens, Georgia: The University of Georgia, Institute of Natural Resources. April 20 and 21.

Tetra Tech, Inc. 2001. *3-Dimensional EFDC Water Quality Model of the Lower Cape Fear River and its Estuary.* Prepared for the City of Wilmington and New Hanover County, North Carolina. May.

Technical Memo: Dissolved Oxygen Trend Analysis for the Lower Cape Fear River Estuary

Prepared for

The Lower Cape Fear River Program

Prepared by

TETRA TECH

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February 21, 2014

1 Introduction

The Lower Cape Fear River Program (LCFRP) is a large-scale water quality and environmental assessment program covering the Cape Fear River Estuary and a large portion of the lower Cape Fear River watershed. The LCFRP represents a collaboration of academia, government, industry, and the public, which has been coordinating with the North Carolina Department of Environment and Natural Resources (DENR) since 1995. The purpose of this memo is to update a previous (Tetra Tech, 2003) statistical trend analysis performed on dissolved oxygen (DO) data collected in the Lower Cape Fear River Estuary (LCFRE) portion of the basin. The current memo was prepared as part of a joint LCFRP-DENR effort to summarize the existing body of technical evidence for submission to the North Carolina Environmental Management Commission (EMC) requesting reclassification of portions of the LCFRE into a supplemental "Swamp" designation— a designation which had been applied to the LCFRE from the late 1950's until the early 1980's.

The previous DO trend analysis found no statistically significant trend for DO for the period of 1984 through 2002. The same conclusion was drawn for the period of 1991 through 2002, despite a statistically significant reduction in major point source ultimate biochemical oxygen demand (BODu) load of approximately 25 percent for that period. For this updated review, advanced statistical analyses were performed to determine if ambient DO data or major point source BODu loads exhibit significant trends over an extended period of time in the LCFRE (i.e., extending the data reviewed out to 2013). Monitoring data compilation, preparation, and analysis methods and results are summarized below.

2 Monitoring Data

The first step for the extended trend analysis involved obtaining ambient DO data and major point source data relevant for the LCFRE. The following subsections describe what data were compiled and how the data were processed to address outliers and fill gaps in preparation for the statistical tests.

2.1 Dissolved Oxygen

DO data were obtained from STORET (EPA's online data storage and retrieval resource) for five monitoring stations in the Cape Fear Estuary (Table 1 and Figure 1). These stations were chosen for the analysis because they offered the longest available period of monitoring records and because they are each located either directly within or immediately adjacent to the 303(d) listed portion of the Cape Fear Estuary. Note that the names of the last two stations in the table have changed since the first trend analysis memo was produced in 2003, due apparently to renumbering of the channel markers. The station IDs, and thus the locations, are identical.

Table 1. Ambient Monitoring Stations Used in the DO Trend Analysis

Station ID	Station Name	Selected Period of Record
B902000	Cape Fear River downstream Hale Point Landing near Phoenix	January 1992 – April 2013
B905000	Cape Fear River at Navassa	May 1984 – April 2013
B974000	Northeast Cape Fear River at NC 133 at Wilmington	January 1981 – April 2013
B980000	Cape Fear River at Channel Marker 61 at Wilmington	January 1985 – April 2013
B982000	Cape Fear River at Channel Marker 56 near Wilmington	January 1981 – April 2013

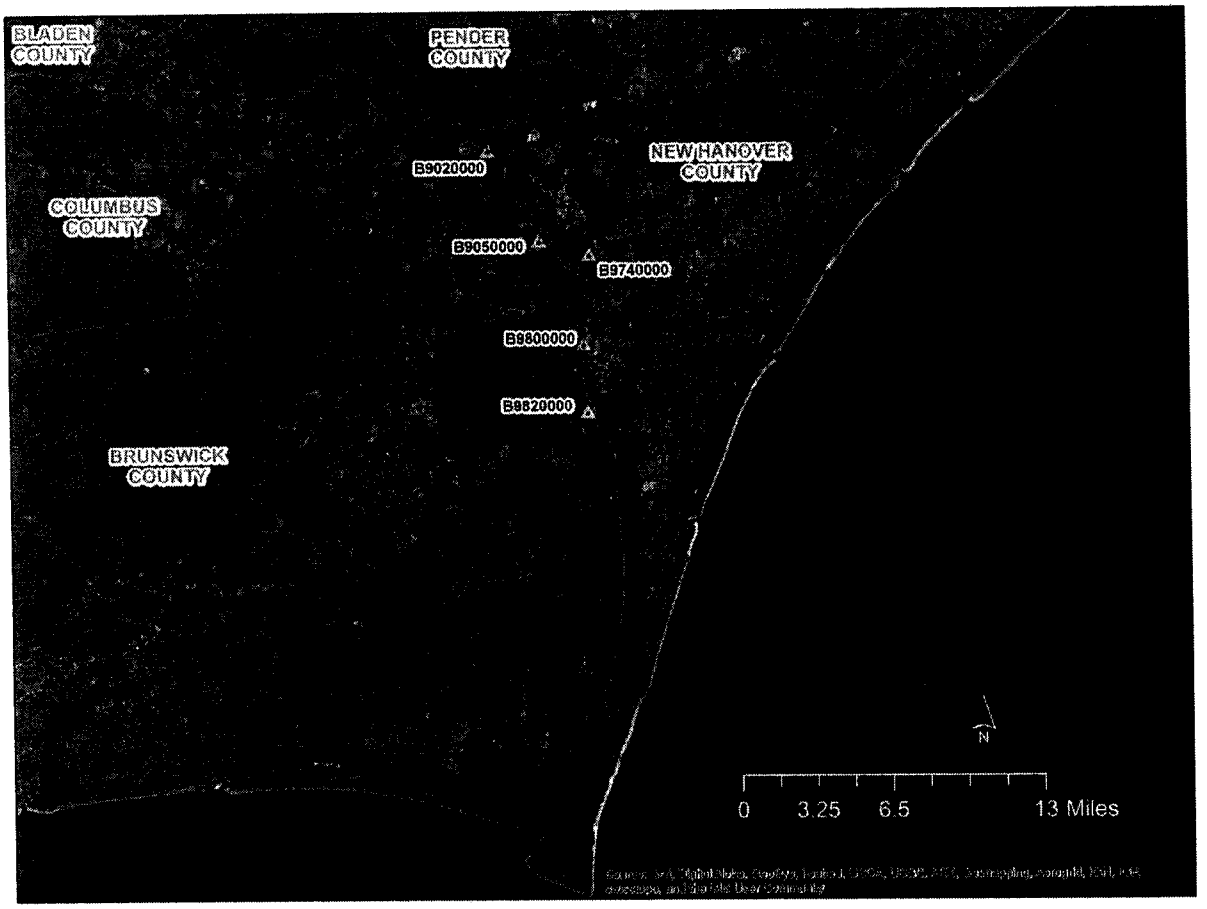


Figure 1. Locations of Ambient Monitoring Stations Used in the DO Trend Analysis

Only DO measurements within one foot the water surface were evaluated, because historical depth stratified monitoring data has consistently indicated strong mixing with little vertical stratification in the estuary. As was done with the previous analysis, one outlier was removed from the dataset; 0.4 mg/l from February 1998 at the Northeast Cape Fear River station. Observations associated with major hurricane events that affected the Cape Fear Estuary were also removed. Following Hurricane Bertha on July 12, 1996 and Hurricane Fran on September 5, 1996, prolonged periods of depressed instream dissolved oxygen levels in the Cape Fear Estuary followed each storm (Mallin et al., 1997). The Mallin report indicated conditions approached anoxia at several monitoring locations after Fran, likely due to significant undocumented "point sources" including pump station and WWTP failures as well as hog lagoon breaches. After each storm, dissolved oxygen levels did not return to normal until about two months following each event. Two other hurricanes were identified that struck in the vicinity of the Cape Fear Estuary – Hurricane Bonnie on August 27, 1998 and Hurricane Floyd on September 16, 1999. Based on the recovery period reported by Mallin et al., observations were removed from each of the datasets for a period of two months following each of the four hurricanes. Figure 2 through Figure 6 show the dissolved oxygen observations for the five stations. The hurricane event observations that were omitted from the analysis are shown in red; the impact of the hurricanes on DO is visible in many cases.

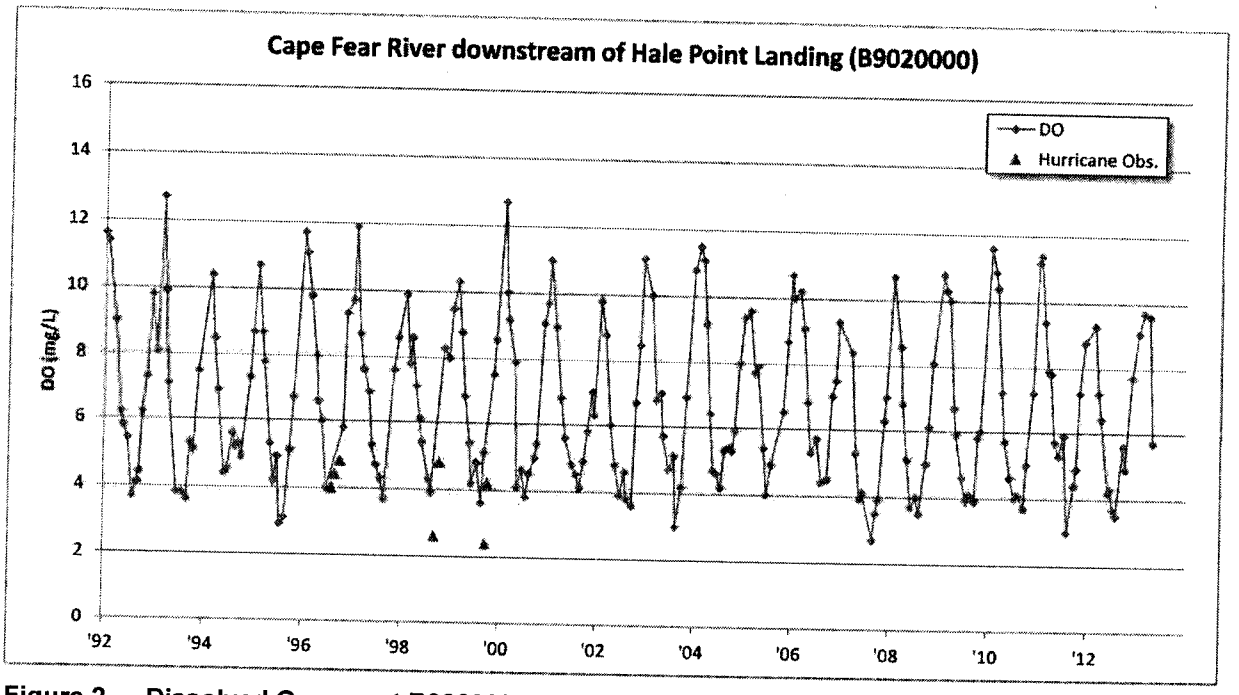


Figure 2. Dissolved Oxygen at B9020000, Cape Fear River Downstream of Hale Point Landing

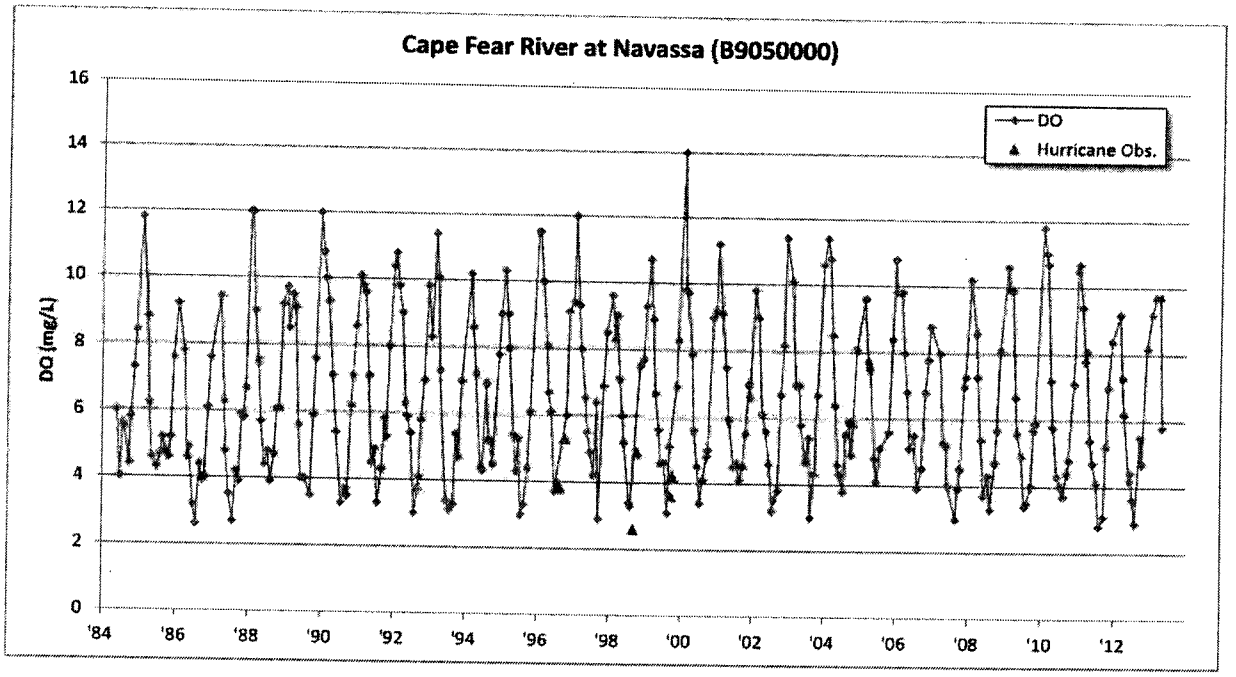


Figure 3. Dissolved Oxygen at B9050000, Cape Fear River at Navassa

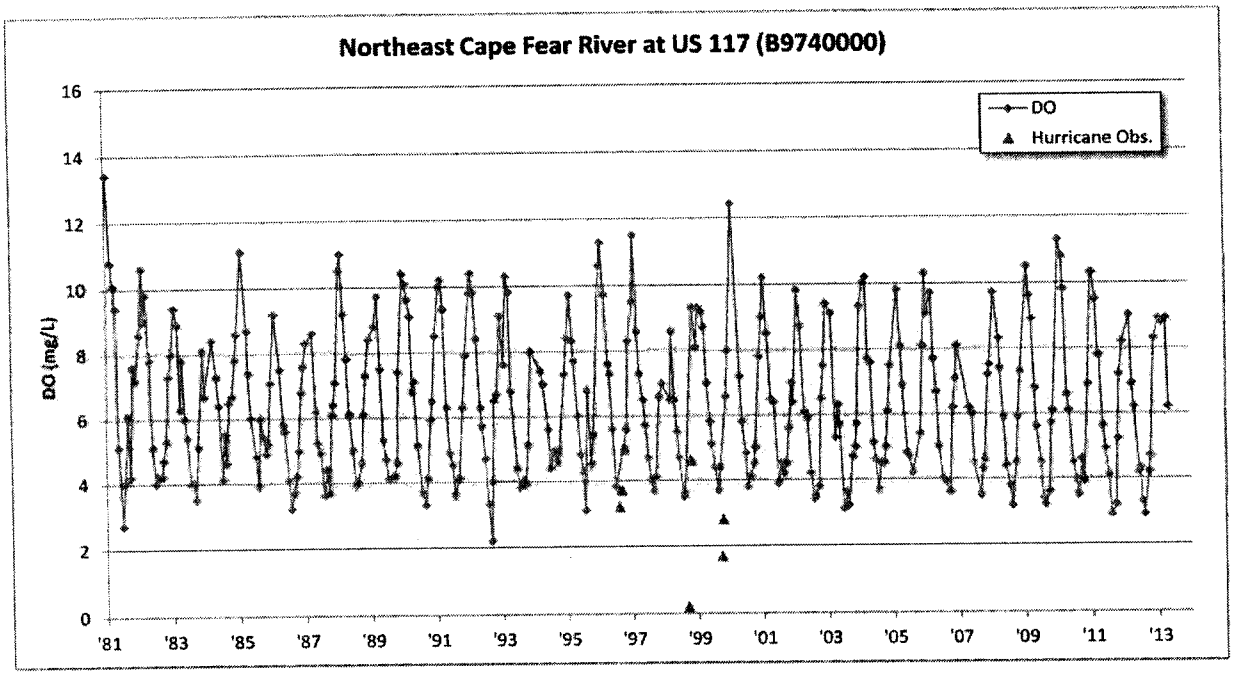


Figure 4. Dissolved Oxygen at B9740000, Northeast Cape Fear River at US 117

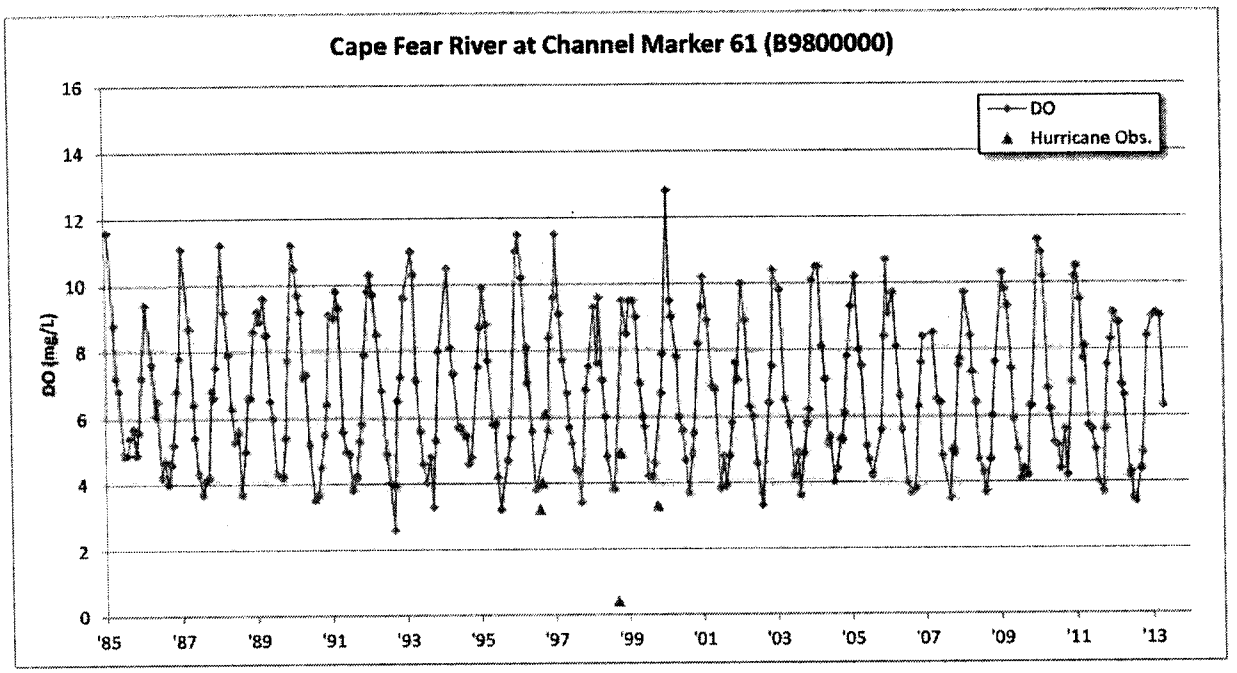


Figure 5. Dissolved Oxygen at B9800000, Cape Fear River at Channel Marker 61

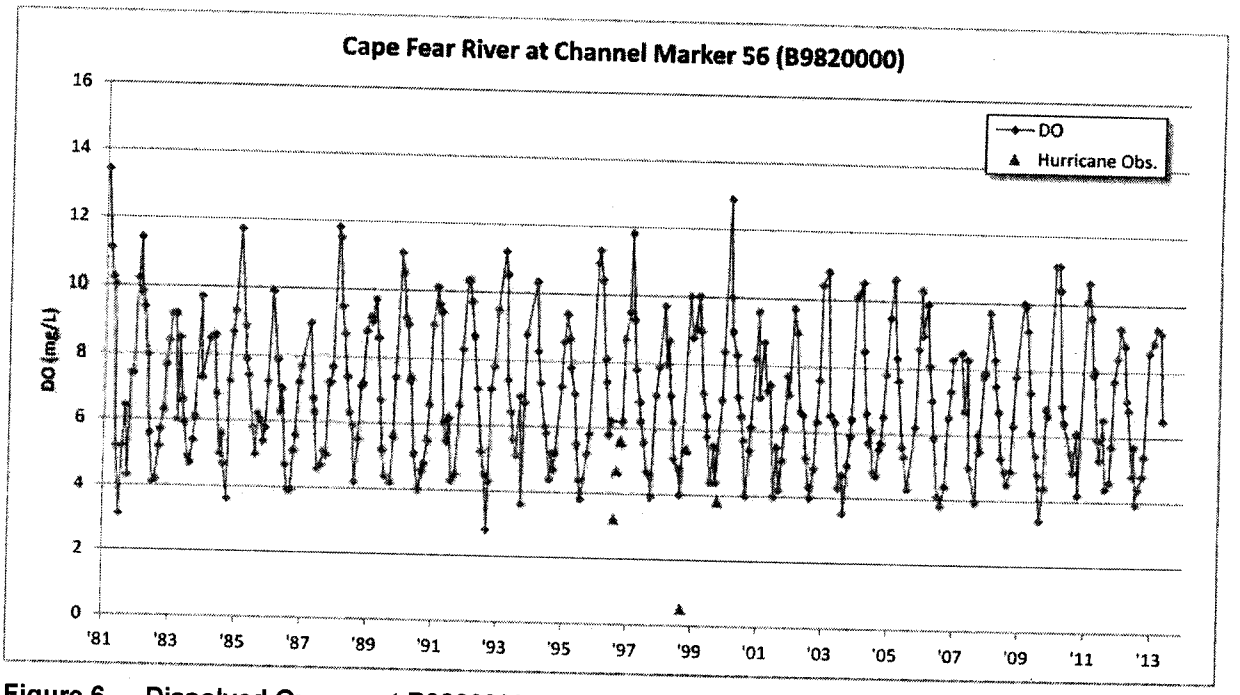


Figure 6. Dissolved Oxygen at B9820000, Cape Fear River at Channel Marker 56

2.2 Point Source Data

Data were obtained from DENR for major facilities discharging oxygen demanding waste from January of 1994 through November of 2013. Previous point source pollutant loading assessments by DENR (1999) have shown that, based on actual summer effluent data from 1998 and 1999, 90% of the total point source based oxygen demanding pollutant load to the estuary comes from three facilities – International Paper (NPDES NC0003298), Wilmington Northside WWTP (NPDES NC0003298), and Wilmington Southside WWTPs (NPDES NC0003298). Brief correspondence with the DENR NPDES Permitting Unit indicated that these facilities remain the bulk of total discharge in the LCFRE. For that reason, the analysis is focused on those three point sources.

For each of the facilities, monthly loads of BOD5 and ammonia were estimated using monitoring data. In most cases, BOD5 and ammonia were reported as a daily concentration. Daily load was calculated on days where both daily concentration and daily flow data existed. The one exception was BOD5 from International Paper, which was already reported as a daily load. These daily loads were then averaged on a monthly basis, and multiplied by the number of days in the month to obtain the monthly load. There were a few cases where monthly loads had to be estimated differently:

- Daily discharge data for BOD5 and ammonia were not available from DENR for the Wilmington Southside facility during 1999. As a result, City of Wilmington monthly discharge data were used for this period. The 1999 monthly loads were estimated for the previous 2003 trend analysis memo, and were used in this analysis as well.
- Ammonia data were not reported on a routine basis between January 1994 and January 1997 at International Paper; rather, three monthly values were available during each of the three years spanning 1994 – 1996. Yearly averages were calculated from the available months, and missing values were set equal to the average from the same year; January 1997 was set equal to the average for 1996. A total of 28 values were estimated using these methods.

- Data were not available to estimate BOD5 during November 2001 at International Paper and May 2005 at Wilmington Southside. There was also an apparent reporting error for January 1997 at International Paper, with average BOD5 reported about two orders of magnitude lower than typical values. In each case, values were estimated by taking the average of the value for the previous month and the subsequent month.

Monthly BOD5 loads were converted to CBODu using multipliers inferred from graphs provided in Bowen et al. (2009). A multiplier of 5.65 was used for International Paper based on the combined average from two long term BOD studies. The multiplier for the Wilmington Southside facility long term BOD measurement was estimated as 3.0. The near detection low level of long term BOD measurement for the Wilmington Northside facility prevented estimating a multiplier from the graph with sufficient confidence, so 3.0 was used to be consistent with the Southside value. Monthly ammonia loads were converted to NBODu using a multiplier of 4.5 (the stoichiometric ratio for the amount of DO required for the oxidation of ammonia). The estimated monthly CBODu loads for each of the three facilities are shown in Figure 7 through Figure 9, and monthly NBODu loads are shown in Figure 10 through Figure 12.

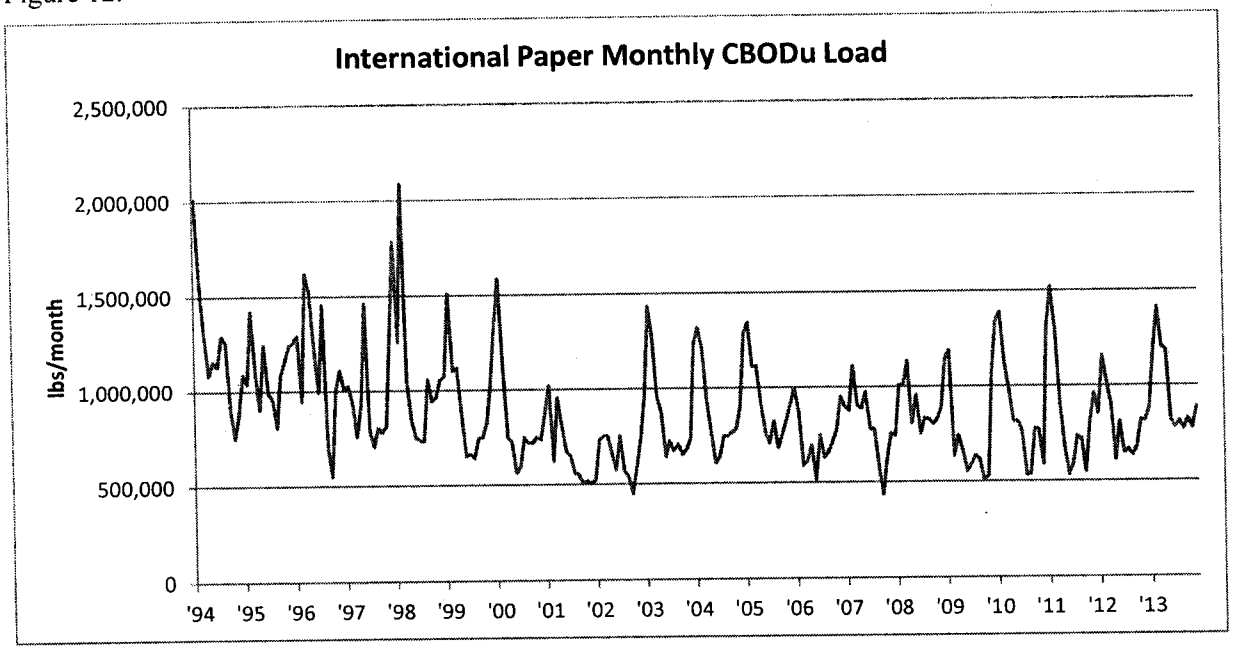


Figure 7. Estimated Monthly CBODu for International Paper

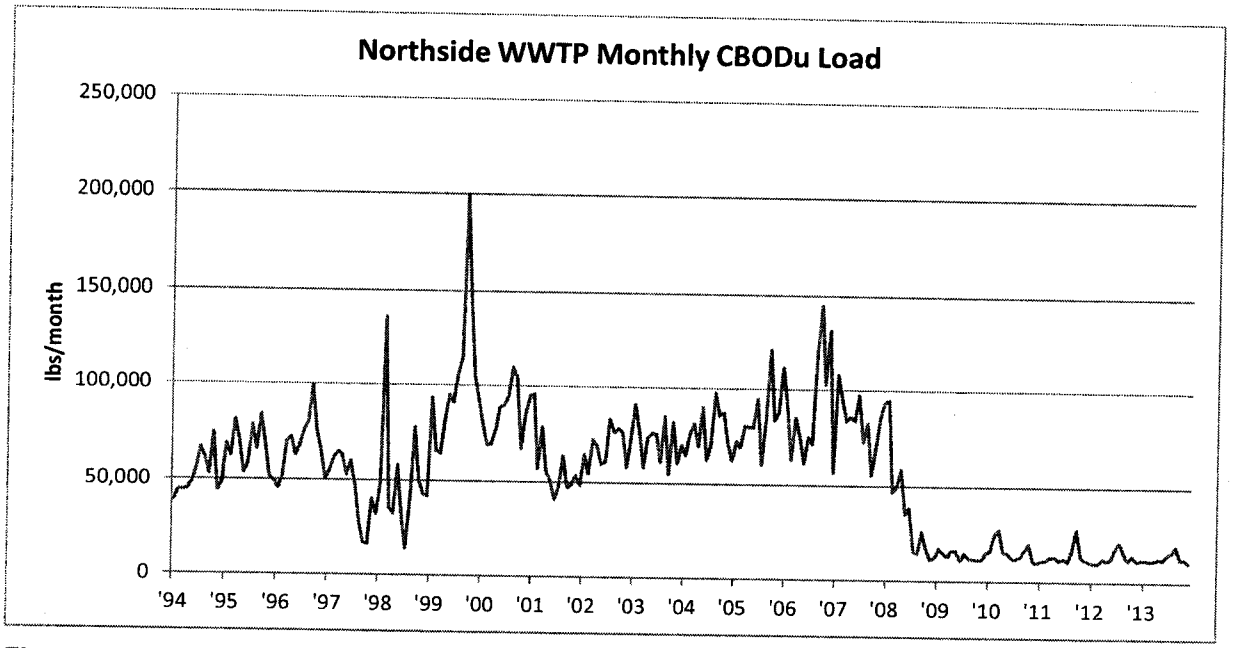


Figure 8. Estimated Monthly CBODu for Northside WWTP

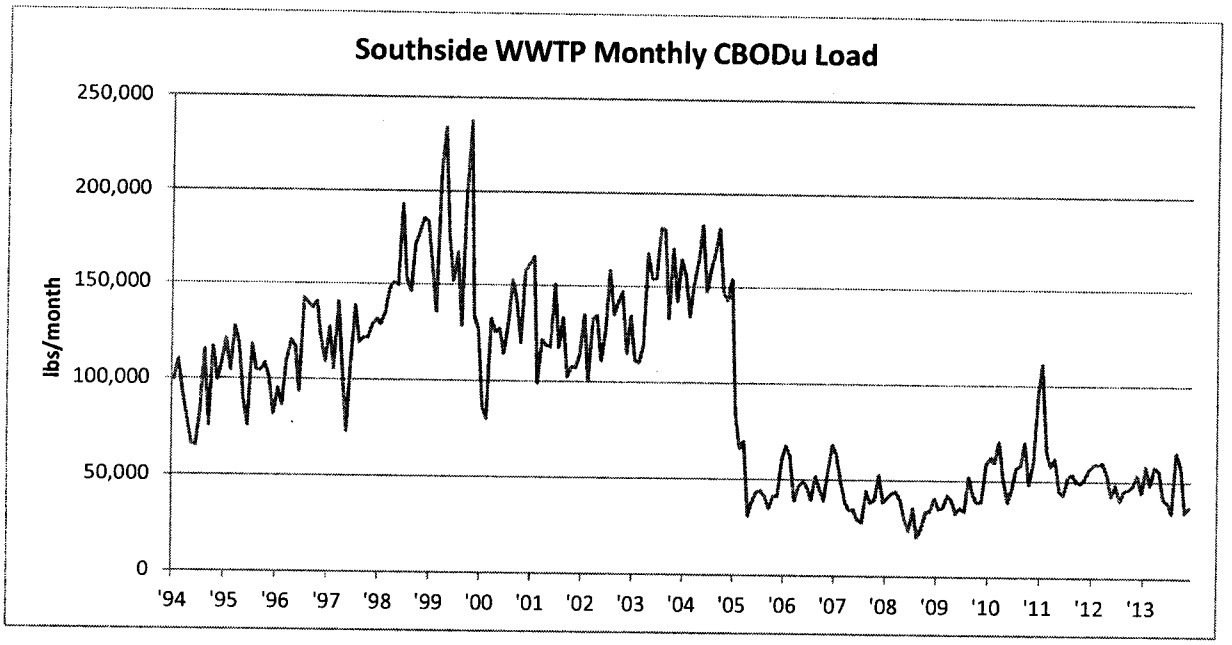


Figure 9. Estimated Monthly CBODu for Southside WWTP

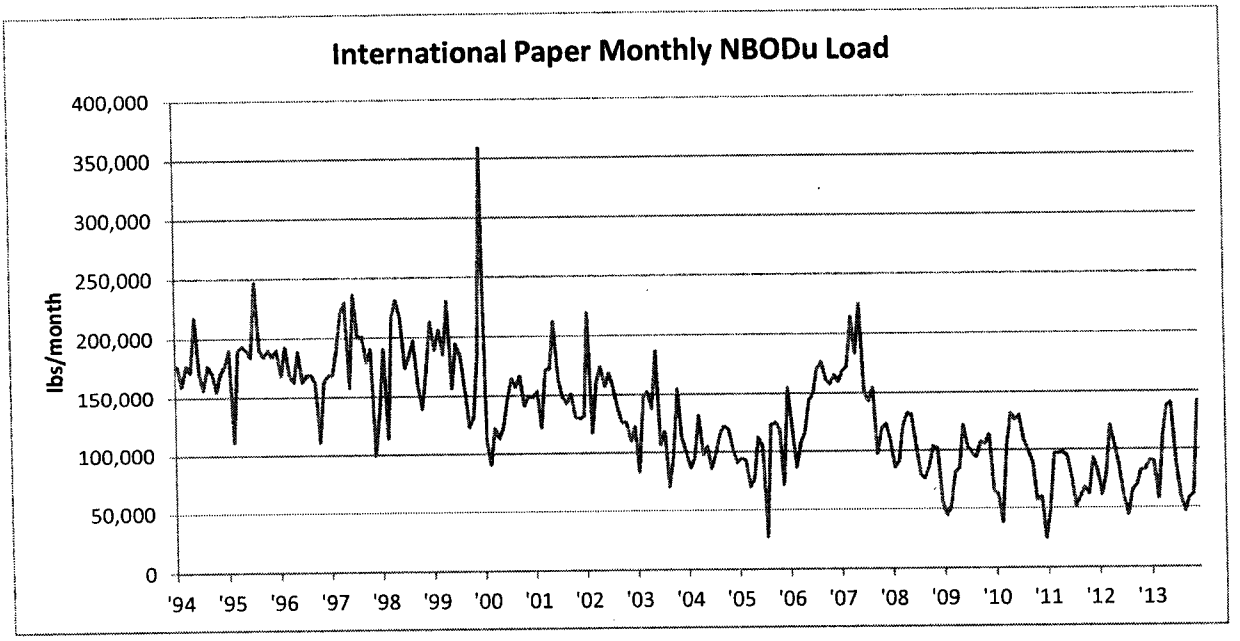


Figure 10. Estimated Monthly NBODu for International Paper

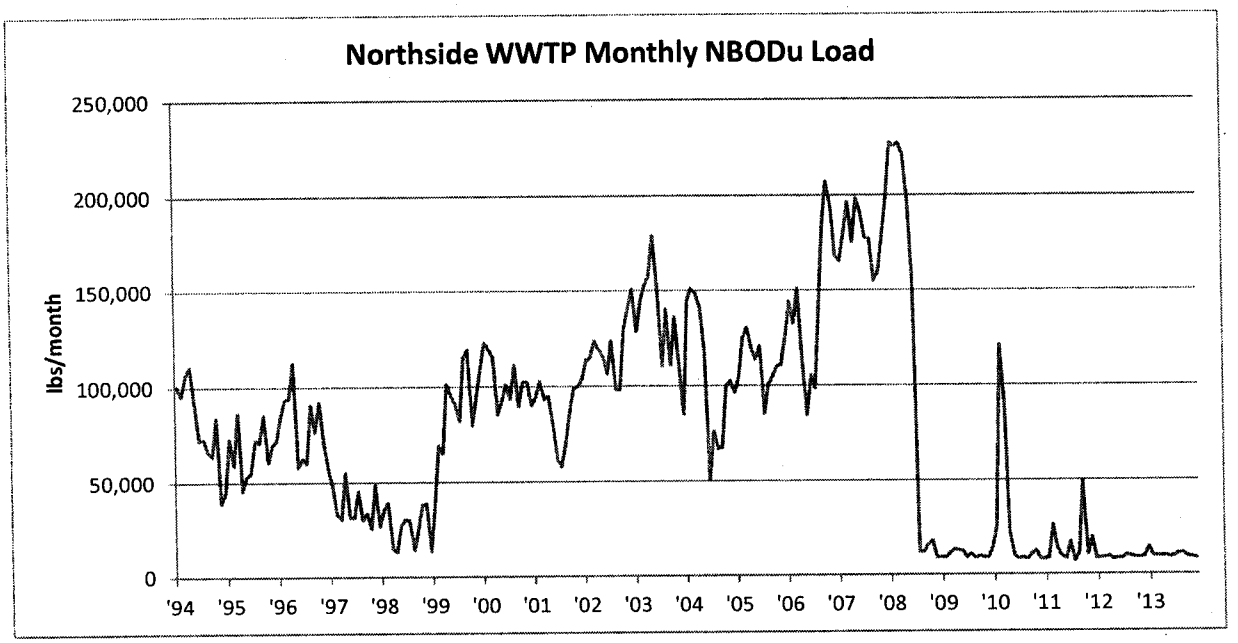


Figure 11. Estimated Monthly NBODu for Northside WWTP

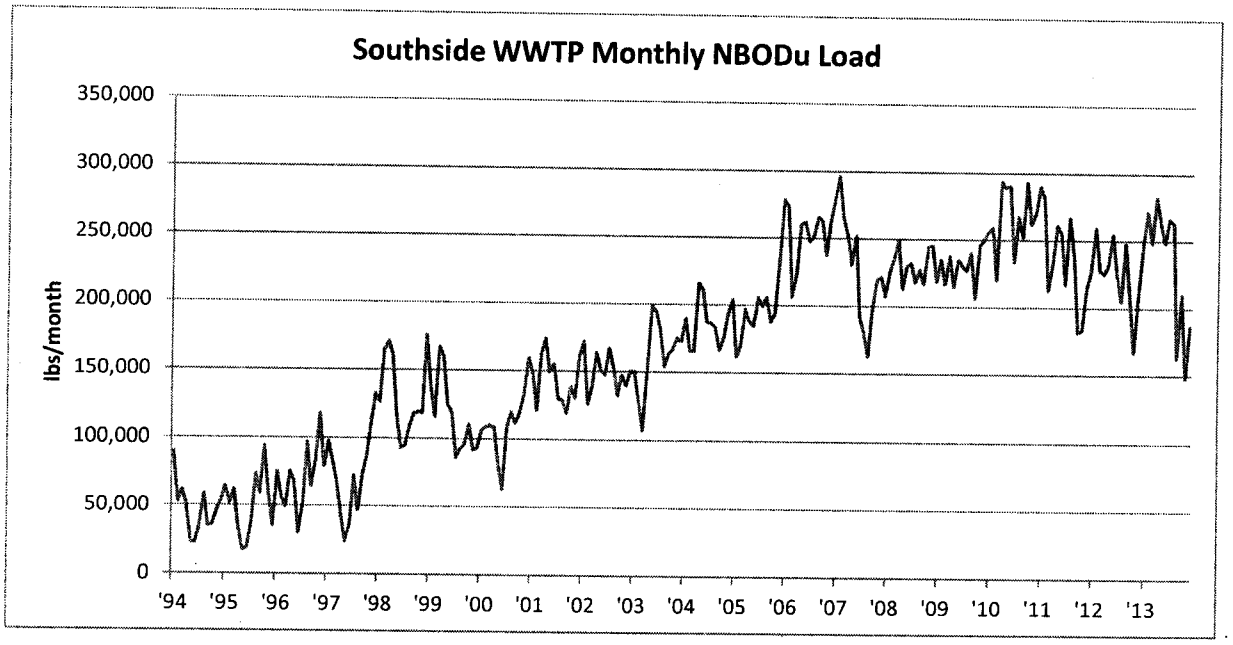


Figure 12. Estimated Monthly NBODu for Southside WWTP

3 Trend Analysis

3.1 Statistical Tests

The USGS Kendall Program (Helsel et al., 2006) was used to perform the statistical trend analysis on the DO and BODu monitoring data. Specifically, the Seasonal Kendall test was selected within the USGS Kendall Program for the trend analysis because seasonality is present in the both the ambient DO and BODu data, and the Seasonal Kendall test accounts for autocorrelation across seasons. Also, the Seasonal Kendall test allows for missing values and does not require complete years of data (i.e., bias in not introduced). Additional background on the statistical methods applied is provided in Attachment A. DO is known to show a seasonal pattern, but seasonality in BOD should be confirmed prior to conducting the test. CBODu and NBODu were summed across the three point sources to develop an overall point source estimated BODu time series. Average monthly BODu was then calculated across the monitoring period of 1994 – 2013. As seen in Figure 13, there is clearly a seasonal pattern in BODu loads to the Cape Fear Estuary.

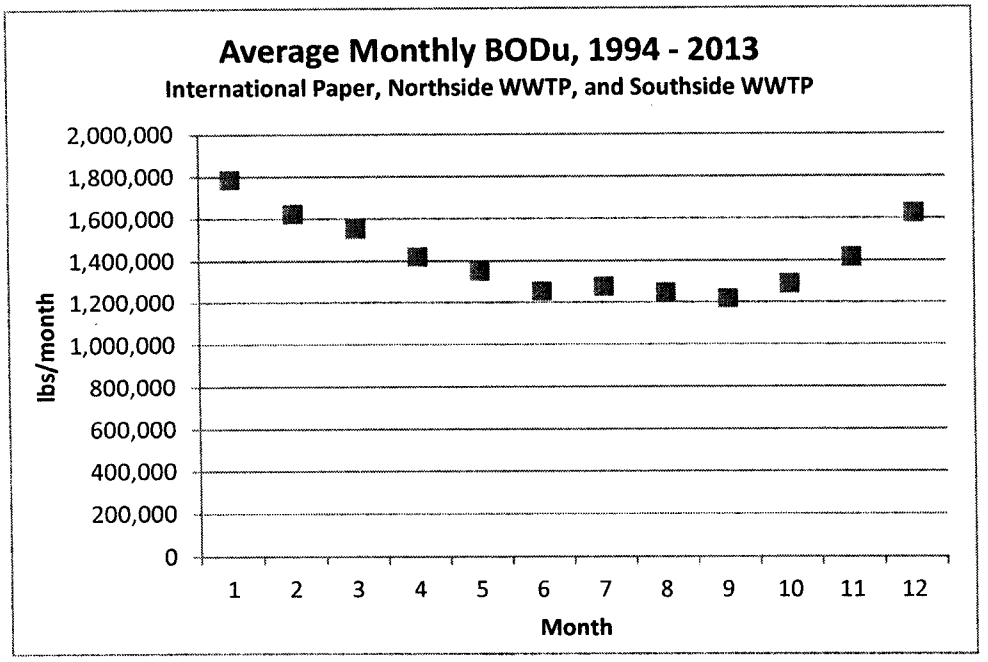


Figure 13. Estimated Average Total Monthly BODu to Cape Fear Estuary, 1999 - 2013

The Seasonal Kendall test was performed on the total BODu time series, using "seasons" defined by months. Monthly seasons are typically used for the Seasonal Kendall test; while seasons of a different duration can be used (e.g., bi-weekly, quarterly), the Seasonal Kendall test was developed using monthly data, and much of the guidance on minimum period of record and adjusting for autocorrelation is focused on using monthly data (Hirsch et al., 1981). In the previous trend analysis, quarterly data were used to reduce seasonal autocorrelation associated with monthly data. However, the USGS Kendall program calculates a modified version of the test statistic that accounts for the autocorrelation, so the data did not require any adjustment for the analyses conducted for this memorandum.

For total BODu, the Seasonal Kendall test indicated a trend of strong statistical significance, with a *p*-value adjusted for autocorrelation of 0.0034; any *p*-value less than 0.05 is considered significant with 95 percent confidence. The trend calculated using Sen's slope estimator (Sen, 1968) was -18,340 lbs/month; in other words an overall annual reduction of 220,080 lbs/yr. A plot of estimated total BODu with the trend superimposed is shown in Figure 14. An additional test was conducted using BODu for a reduced time period (2003 – 2013) to check whether the trend has continued since publication of the previous trend analysis. The adjusted *p*-value was 0.0143, indicating a highly significant trend for the reduced time period, and the magnitude was actually higher at -32,730 lbs/month.

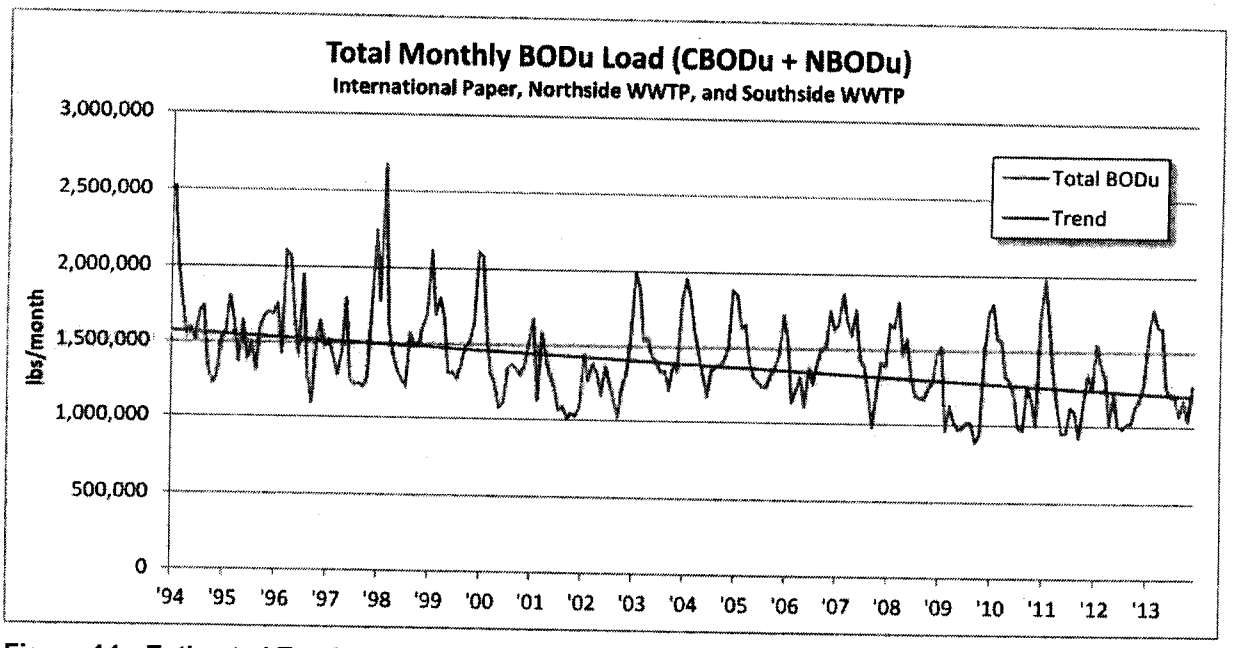


Figure 14. Estimated Total Monthly BODu to Cape Fear Estuary, with Reported Trend

Seasonal Kendall tests were then performed for DO at each of the five stations for the periods of record shown in Table 1. In all cases, the null hypothesis of no trend could not be rejected – in other words, a finding of no trend. The *p*-values adjusted for autocorrelation did not indicate anything close to statistical significance (Table 2). The tests were repeated for reduced time periods of 2003 – 2013 to test for any trend following publication of the previous trend analysis. Again, no trends were found and all the adjusted *p*-values did not show any statistical significance.

Table 2. Results of DO Trend Analysis Showing No Trend of Significance

Station ID	*p*-value, full period of record	*p*-value, 2003 – 2013
B9020000	0.5026	0.9238
B9050000	0.6853	0.4310
B9740000	0.1532	0.9334
B9800000	0.4823	0.9159
B9820000	0.1342	0.8636

3.2 CONCLUSIONS

This memorandum supports the same finding as the previous analysis conducted in 2003. A significant downward trend was detected in the total oxygen demanding pollutant loads from the three facilities that comprise roughly 90 percent of all point source loads to the LCFRE, while no corresponding trend was found in DO monitoring data at five separate LCFRE stations. During the 20 years of point source load monitoring included in this analysis, the total estimated BODu load from the three facilities has declined about 23 percent as indicated by the trend estimate.

References

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin, and J. Williams. 2009. *Development and Use of a Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the Lower Cape Fear River Estuary, North Carolina.* Department of Civil and Environmental Engineering, University of North Carolina at Charlotte.

Helsel, D.R., D.K. Mueller, and J.R. Slack. 2006. *Computer Program for the Kendall Family of Trend Tests.* Scientific Investigations Report 2005-5275. U.S. Geological Survey. Reston, VA.

Hirsch, R.M., J.R. Slack, and R.A Smith. 1982. Techniques of trend analysis for monthly water quality data. *Water Resources Research.* 18:107-121.

Mallin, M.A., M.H. Posey, M.L. Moser, G.C. Shank, M.R. McIver, T.D. Alphin, S.H. Ensign, and J.F. Merritt. 1997. *Water Quality in the Lower Cape Fear River System, 1996-1997.* University of North Carolina – Wilmington, Center for Marine Science Research. 255 pp.

North Carolina DENR. 1999. Point Source Loading Analysis Table prepared by Andy McDaniel for Presentation to Lower Cape Fear River Program Technical Committee. 2 pp.

Sen, P.K. 1968. Estimates of the regression coefficient based on Kendall's tau. *Journal of the American Statistical Association.* 63:1379-1389.

Tetra Tech. 2003. Technical Memorandum: Results of Dissolved Oxygen and Pollutant Loading Trend Analyses. Submitted to Hugh Caldwell, Ken Vogt, and Wyatt Blanchard from Trevor Clements and Jason Doll. January 16, 2003.

Attachment A – Background on Statistical Methods

The Seasonal Kendall test (Hirsch et al., 1982) and Sen's nonparametric slope estimator (Sen, 1968) were used to test for the presence of a statistically significant trend. Background information outlining the technical basis for the selection of these methods is provided below.

The nonparametric Mann-Kendall test for trend (Mann, 1945; Kendall, 1975) forms the basis of a method that is frequently used for trend analyses performed on water quality monitoring data – the Seasonal Kendall Test. The method was developed and popularized by USGS researchers throughout the 1980s (Hirsch et al., 1991), and USGS published computer code supporting its use.

Mann-Kendall is especially useful for detecting trends in environmental variables for several reasons:

- The test is nonparametric, and the data do not need to be normally distributed.
- Missing values are allowed; gaps are simply ignored.
- Data reported at the detection limit can be used without censoring, so long as the values are set lower than the smallest observation.

This is all possible because Mann-Kendall looks only at the relative magnitudes of sequential data, so the type of distribution, gaps, and the assumptions used for non-detects become irrelevant. The test does, however, assume that the data are not serially correlated, an assumption frequently violated by environmental monitoring data. Serial correlation (also called autocorrelation) occurs when data points are not independent from each other. Monitoring data tend to show positive serial correlation, meaning that positive errors (about the mean) in one time period are associated with positive errors in adjacent time periods (and negative errors are associated with adjacent negative errors).

The Seasonal Kendall test is a generalization of the Mann-Kendall test, developed by Hirsch et al. (1982). In its original application, data were divided into 12 "seasons", with each month representing a season. Missing values are allowed (as is the case with the Mann-Kendall test), and complete years of all 12 seasons are not required. The Mann-Kendall test statistic and its variance are calculated separately on each season. The statistics are summed and a Z statistic computed, which is compared to the standard normal tables. The null hypothesis HO is there is no trend, while the alternative hypothesis HA is either an upland or downward trend (a two-tailed test). Serial correlation among values within a season can be addressed by a modification of the test statistic (Hirsch and Slack, 1984). The modification is recommended in cases where there are 10 or more observations per season (i.e., 10 years of data if seasons are defined monthly) due to difficulties accurately determining covariance for fewer data.

A slope can be calculated as well for the Seasonal Kendall test. The slope is based on Sen's nonparametric slope estimator (Sen, 1968). The method estimates a series of slopes between values from the same season. The Seasonal Kendall slope is the median of this series of slopes.

The USGS Kendall Program (Helsel et al., 2006) was developed to address a gap in publically available software for estimating trends using the Seasonal Kendall test and other Kendall tests. In the 1980s USGS popularized Kendall methods, and USGS published computer code supporting its use in popular statistical packages. However, in later years as statistical analysis moved to desktop computing, the code became difficult to execute without purchase of commercial statistical software. As a result, USGS repackaged the code into an executable program which can be used on computers supporting DOS or DOS emulation. The USGS Kendall program is freely available from a USGS website.

Helsel, D.R., D.K. Mueller, and J.R. Slack. 2006. *Computer Program for the Kendall Family of Trend Tests.* Scientific Investigations Report 2005-5275. U.S. Geological Survey. Reston, VA.

Hirsch, R.M., J.R. Slack, and R.A Smith. 1982. Techniques of trend analysis for monthly water quality data. *Water Resources Research*. 18:107-121.

Hirsch, R.M., R.B. Alexander, and R.A. Smith. 1991. Selection of methods for the detection and estimation of trends in water quality. *Water Resources Research*. 27:803–813.

Kendall, M.G. 1975. *Rank Correlation Methods*. 4th ed. Charles Griffin, London.

Mann, H.B. 1945. Non-parametric test against trend. *Econometrica*. 13:245-259.

Sen, P.K. 1968. Estimates of the regression coefficient based on Kendall's tau. *Journal of the American Statistical Association*. 63:1379-1389.

Technical Memo: Task 3 - Analysis of Water Quality Data at Cape River Estuary Model Boundaries

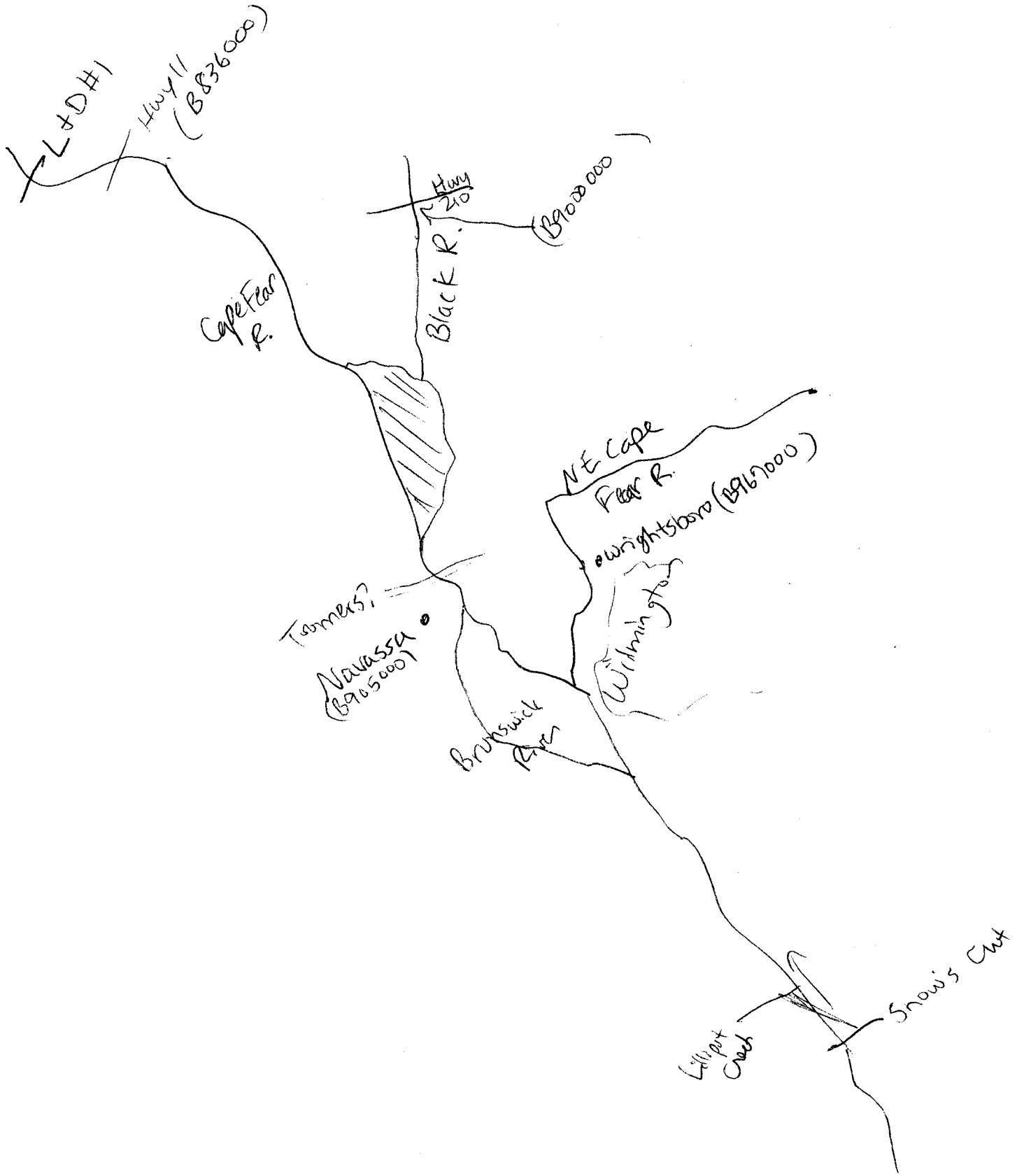
Prepared for

Lower Cape Fear River Program

Prepared by

CH2MHILL®

February 25, 2014


L&D#1
Hwy 11
(B836000)
Hwy 210
(B9000000)
Black R.
Cape Fear R.
NE Cape Fear R.
Wrightsboro (B967000)
Wilmington
Tromers?
Navassa
(B905000)
Brunswick River
Snow's Cut
Lilliput Creek

1 Introduction

Since 1998, the section of the Lower Cape Fear River Estuary (LCFRE) from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut has been listed on the State of North Carolina's 303d List as impaired for dissolved oxygen (DO). Since the original listing for DO, many technical studies of the LCFRE have been conducted by the North Carolina Department of Environment and Natural Resources (DENR), the Lower Cape Fear River Program (LCFRP), other agencies and academic researchers, and consultants. As a result, an extensive technical foundation of knowledge on the LCFRE has been created, including information on physical, chemical, and biological features and processes. Monitoring programs have provided insight regarding ambient conditions over many years on water quality, benthos, and fish. Additionally, sophisticated three-dimensional (3D), hydrodynamic modeling tools have been developed for the entire estuary and the portion of the river beginning at Lock and Dam #1 (L&D1) (Tetra Tech, 2001; Bowen et al., 2009).

The modeling results indicate that point-source discharges have little impact on DO levels, and that even significant reductions in background (both natural and nonpoint source) loads would not result in attainment of the current standard at all times. DENR has also agreed with representatives of the LCFRP that a more thorough understanding of natural and anthropogenic sources of oxygen deficit is needed.

This technical memorandum (TM) presents an analysis of water quality parameters at the points representative of inflows to the system, with the purpose of examining issues related to a supplemental DENR "Swamp" classification for the estuary. This TM examines data related to key parameters, including nutrients, pH, and DO, that are related to the occurrence of low DO in the Cape Fear River.

1.1 Data Sources and Processing

The LCFRP has conducted monitoring in coordination with DENR since 1995, and a considerable amount of data is available prior to that. There has also been extensive data collected by the Middle Cape Fear Basin Association (MCFBA) upstream of L&D1 since mid-1998 and the Upper Cape Fear Basin Association (UCFBA) since about 2000. Data for this evaluation were downloaded from the Cape Fear River Basin Monitoring Coalitions Water Quality Data website (accessible at http://www.cormp.org/CFP/CFP_map.php) and the U.S. Environmental Protection Agency's (USEPA's) STOrage and RETrieval (STORET) Data Warehouse (2012accessible at http://www.epa.gov/storet/). The primary stations of interest for this evaluation were:

- B8360000 Cape Fear River at NC 11 near East Arcadia (downstream of L&D1)
- B9670000 Northeast (NE) Cape Fear River near Wrightsboro
- B9000000 Black River at NC 210 at Still Bluff
- B9050000 Cape Fear River at Navassa (same station on pgs. a-27(A-43), a-29(A-45))

see p. a-27
B902000
B974000
B980000
B982000

These stations (shown in Figure 1) represent the water quality conditions at the main inflows to the system: the Middle Cape Fear River, the Black River, and the NE Cape Fear River, and coincide with the boundary conditions of the 3D hydrodynamic model developed for the system. The station at L&D1 represents water quality in the Cape Fear River as water leaves the Sandhills and enters the coastal area. The NE Cape Fear and Black River stations measure water quality as water leaves areas currently classified as swamps. The Cape Fear monitoring station at Navassa is included in the analysis, as it reflects the changes in water quality as a result of the confluence of the middle Cape Fear River and Black River. While data is available at a number of other stations, such as B980000 (Cape Fear River at Channel Marker 61), they were not used for this analysis. The data would also capture the changes as a result of the inflow of the NE Cape Fear River, but would also more directly reflect the influence of tidal flows.

Figure 1. Location of Stations used for Evaluation of Boundary Conditions

The data were downloaded from the Cape Fear River Basin Monitoring Coalition's Water Quality Data and USEPA's STORET websites in February 2014. Data downloaded included all data available for these sites at that time. Parameters evaluated for this analysis include DO, nitrate-nitrite (NO_2-NO_3), total Kjeldahl nitrogen (TKN), pH, total phosphorus (TP), and ammonia (NH_3). Data were processed to identify measurements collected during the summer period (April through October) to focus on critical DO periods. The dataset was also processed to only evaluate surface grab samples. Depth-stratified monitoring showed little vertical stratification, and inclusion of all data would have skewed results toward deeper locations with more samples per event. Finally, data were averaged on a monthly basis to simplify the comparison and reduce the effects of any outliers.

1.2 RESULTS

The water quality monitoring data was evaluated using basic statistics, as well as time series plots. The statistics provide a long-term evaluation of water quality; whereas, the time series plots allow for identification of key periods and the relative difference in water quality between stations in more detail. Table 1 provides a summary of the basic monthly summer (April through October) statistics for the stations of interest.

Review of the data shows distinct differences in water quality between the Cape Fear River at L&D1 and the major tributaries, the Black River, and NE Cape Fear River. The average summer (April through October) monthly DO level at L&D1 is greater than 7 mg/L; whereas, as the DO levels in the Black River are nearly 2 mg/L lower at 5.19 mg/L and more than 2 mg/L less in the NE Cape Fear River at 4.96 mg/L. This primarily reflects the low DO found in these swamp areas but it is important to note that the DO below L&D 1 maybe somewhat influenced by reaeration from the dam.

The influence of the Black River and the NE Cape Fear River on the Cape Fear River mainstem can also be seen in the summer (April through October) monthly average NO_2-NO_3 and TP values. Concentrations of both of these constituents are higher at L&D1 when compared to the other stations. The addition of the flows from the tributaries significantly reduces the concentrations, as is seen at Navassa.

A number of time series plots were generated to assess changes in these constituents over time and to also provide a method to compare stations in a more detailed fashion. The plots for each constituent and a brief discussion is provided in Figures 2 through 7.

The DO time series (Figure 2) shows that summer (April through October) DO levels at L&D1 are greater than 5 mg/L the majority of the time. Only one event fell below 4 mg/L, which corresponded to Hurricane Fran. Summer (April through October) DO levels in the NE Cape Fear River are significantly lower at all times. The lowest observed DO in the NE Cape Fear River coincides with Hurricane Fran in 1996, Hurricane Bonnie in 1998, and Hurricane Floyd in 1999. While DO levels at L&D1 show some decrease during these events, a more significant effect is seen at the tributary stations and at Navassa. In general, the NE Cape Fear River shows the lowest DO levels, with levels at Navassa being second lowest. This suggests that inflow from the NE Cape Fear River and the swamps it drains has a significant impact on DO levels in the Cape Fear River mainstem. DO in the Black River tends to be more moderate, typically being less than concentrations at L&D1 but not as low as in the NE Cape Fear River. Inflow from the Black River is likely to have an impact but of a lesser magnitude. DO does not appear to show a negative or positive trend if the excursions related to hurricanes in the late 1990s are excluded.

Summer (April through October) nitrate-nitrite levels (Figure 3) are the highest at L&D1, receiving nitrate loading from upstream sources and atmospheric deposition. Nitrate is readily utilized in anoxic systems, such as swamps, as an oxygen source and can often fall below 0.1 mg/L. This is reflected in the low values seen in the Black River and the NE Cape Fear River. The levels at Navassa reflect the inflow from these low nitrate areas, with levels in the Cape Fear River dropping from those seen at L&D1. Nitrate-nitrite concentrations appear to show a slight positive trend in recent years at L&D1 and Navassa.

Table 1. Summary of Monthly Water Quality Statistics for Summer Periods (April through October)

	Cape Fear River at L&D1	Black River at NC 210 at Still Bluff	Cape Fear River at Navassa	NE Cape Fear River near Wrightsboro
DO				
Minimum (mg/L)	3.60	1.20	0.85	0.10
Maximum (mg/L)	10.10	8.00	9.20	8.50
Average (mg/L)	7.14	5.19	5.10	4.96
NO_2+NO_3-N				
Minimum (mg/L)	0.01	0.01	0.00	0.01
Maximum (mg/L)	1.58	0.52	1.14	0.51
Average (mg/L)	0.64	0.14	0.42	0.23
TKN-N				
Minimum (mg/L)	0.10	0.20	0.10	0.10
Maximum (mg/L)	2.00	2.00	1.50	2.10
Average (mg/L)	0.69	0.81	0.72	0.78
pH				
Minimum (mg/L)	5.30	4.80	5.60	5.00
Maximum (mg/L)	7.35	7.80	7.90	7.30
Average (mg/L)	6.61	6.13	6.87	6.63
TP				
Minimum (mg/L)	0.08	0.04	0.04	0.05
Maximum (mg/L)	0.61	0.36	0.31	0.36
Average (mg/L)	0.18	0.10	0.14	0.12
NH_3-N				
Minimum (mg/L)	0.01	0.01	0.01	0.01
Maximum (mg/L)	0.22	0.20	0.20	0.30
Average (mg/L)	0.07	0.05	0.07	0.05

Note:
mg/L - milligram per liter

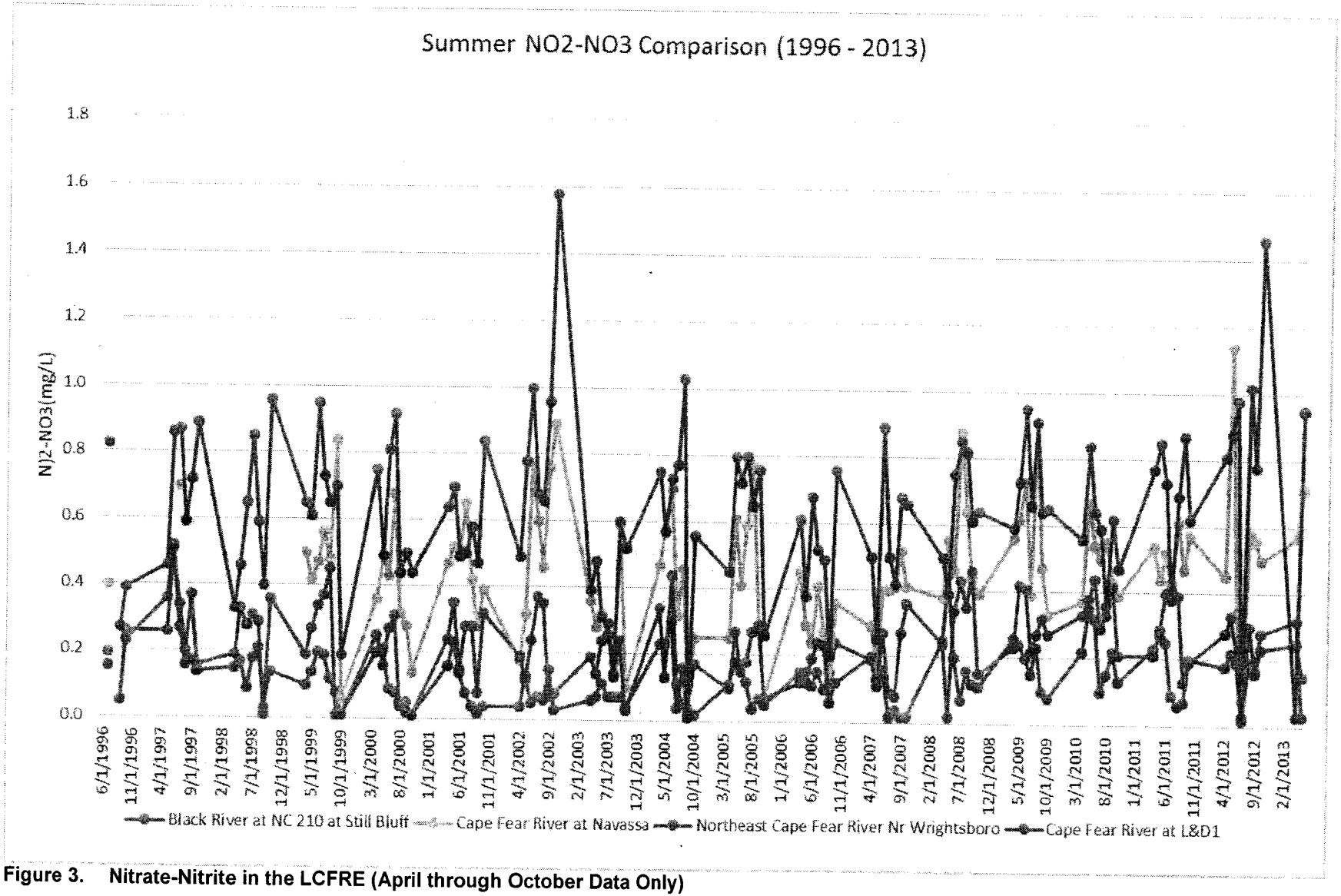


Figure 3. Nitrate-Nitrite in the LCFRE (April through October Data Only)

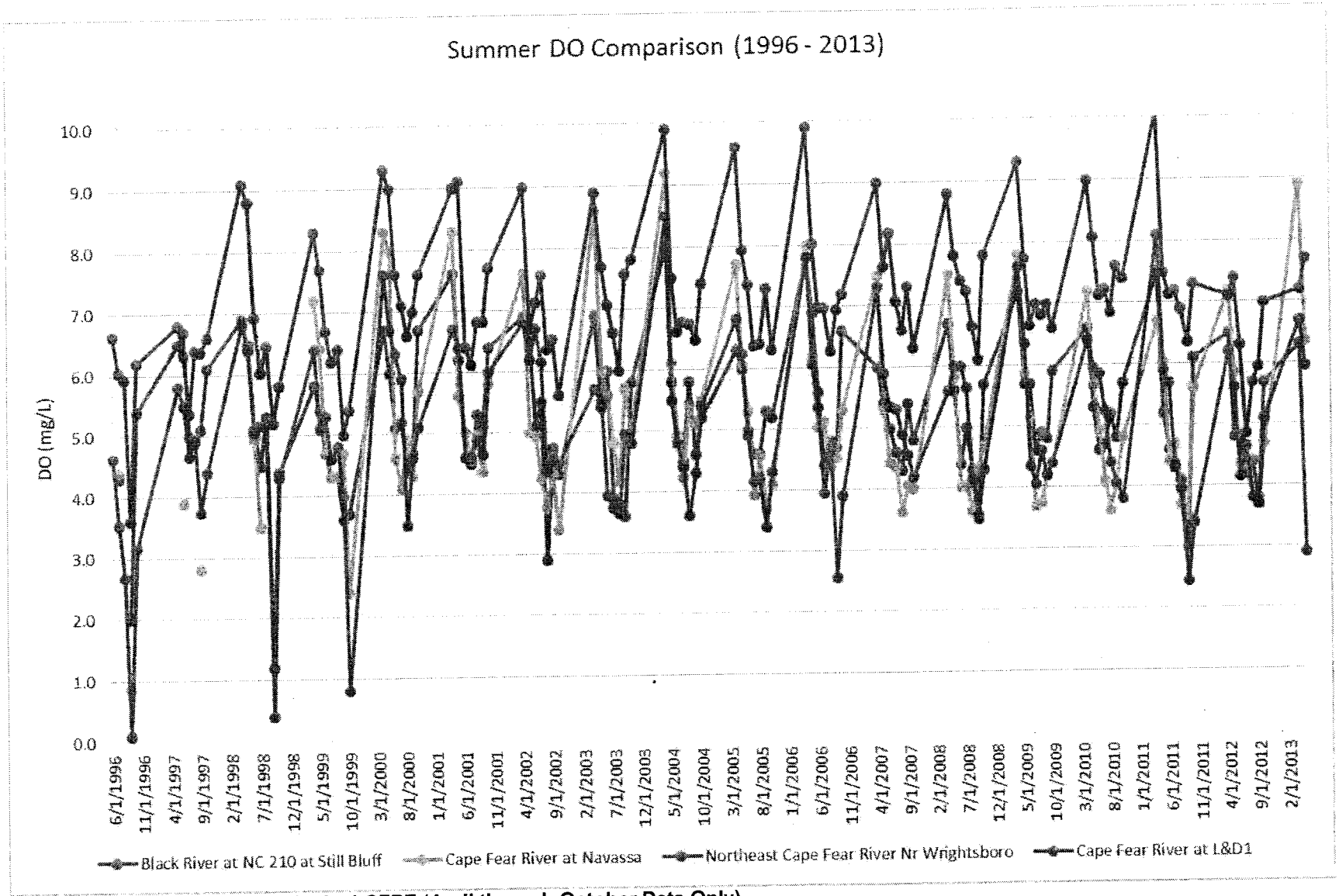


Figure 2. Dissolved Oxygen in the LCFRE (April through October Data Only)

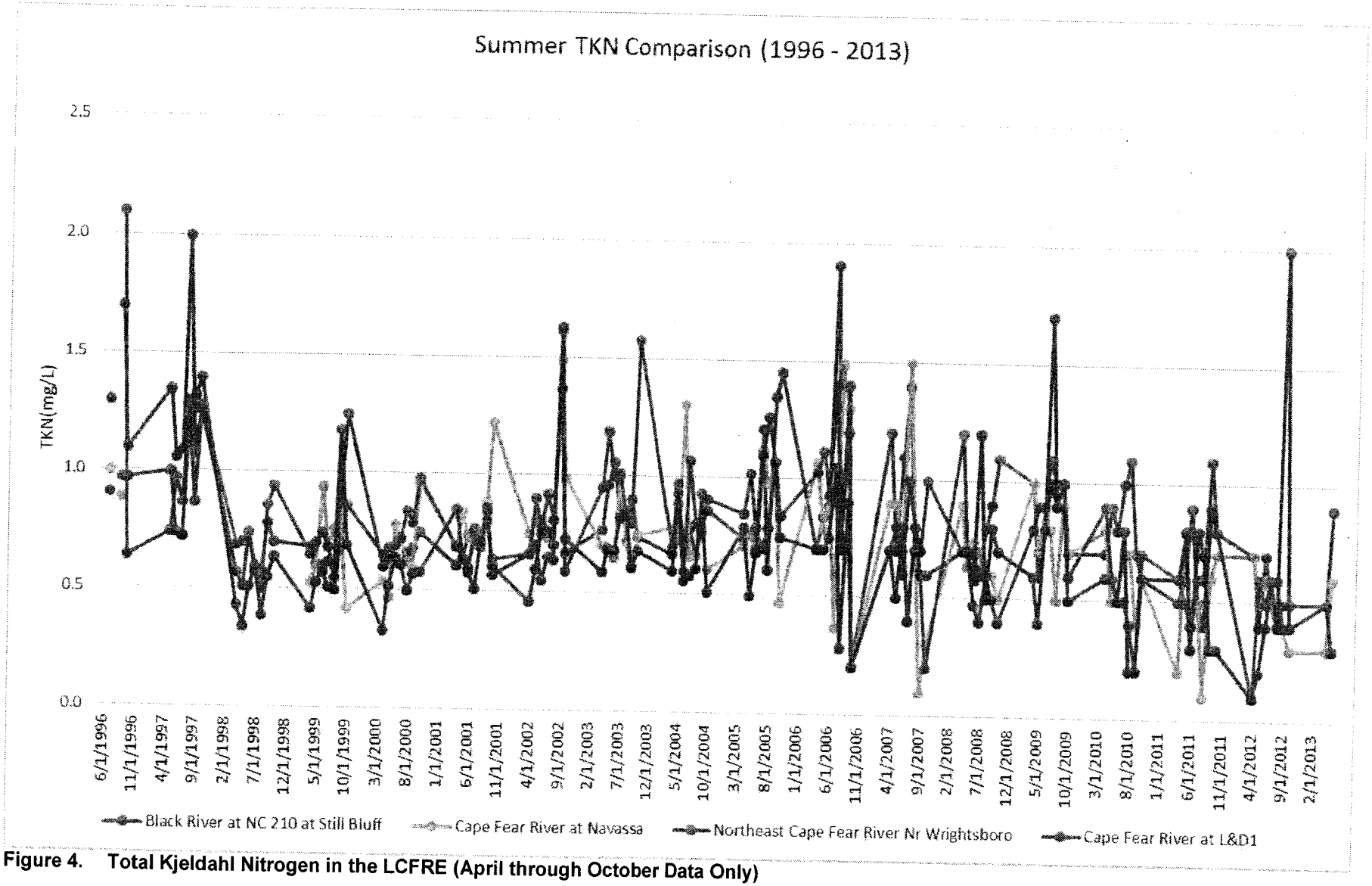


Figure 4. Total Kjeldahl Nitrogen in the LCFRE (April through October Data Only)

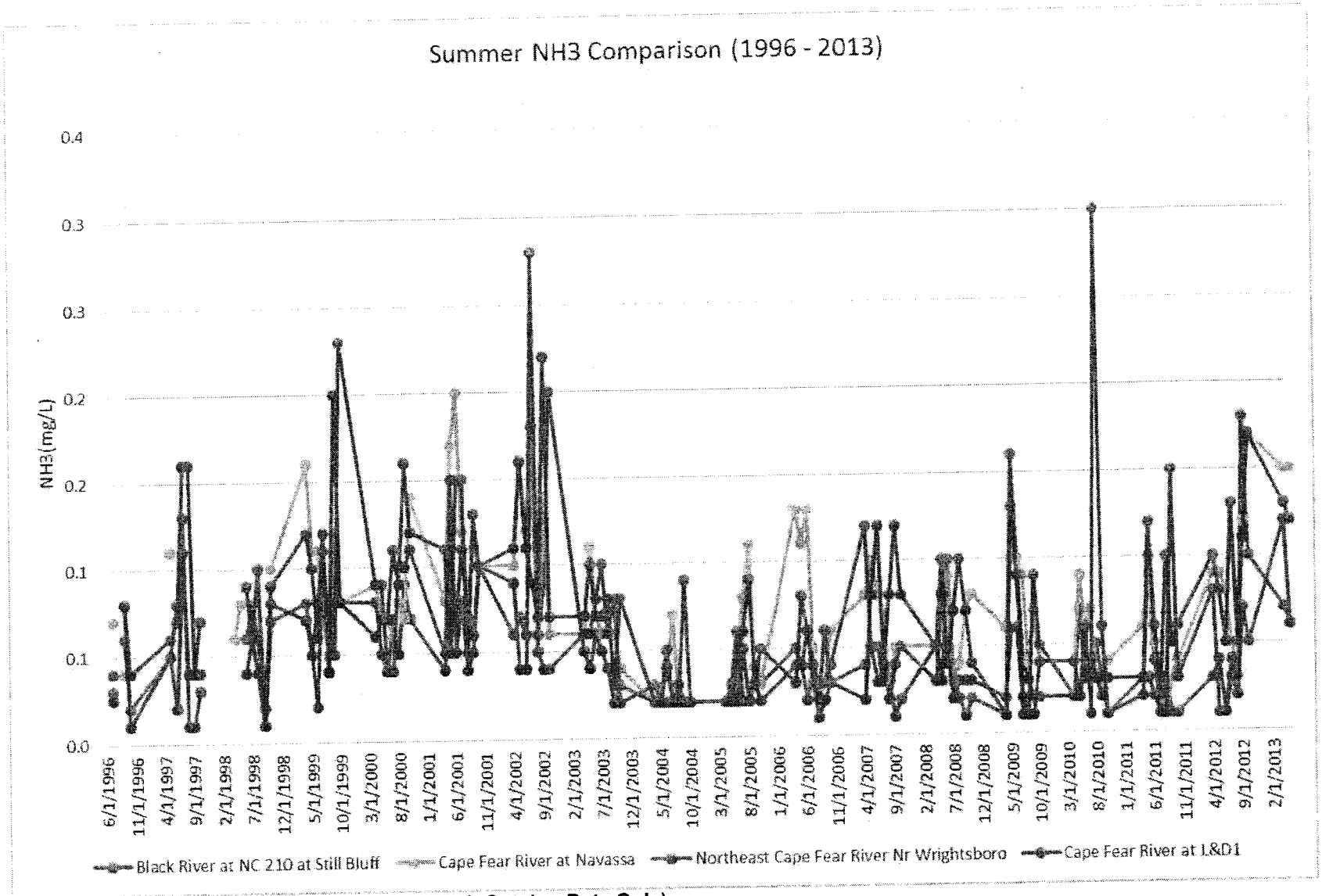


Figure 5. Ammonia in the LCFRE (April through October Data Only)

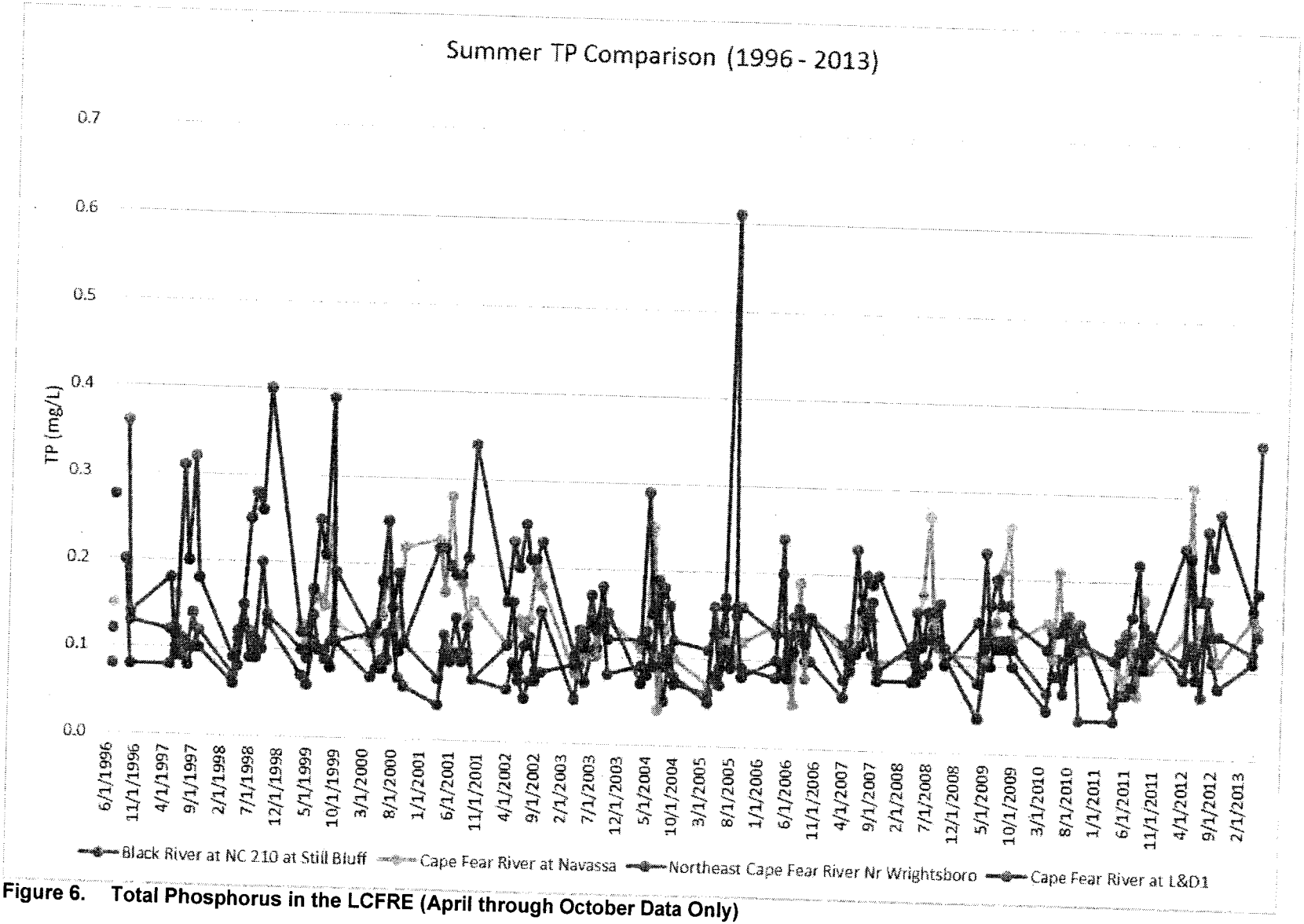


Figure 6. Total Phosphorus in the LCFRE (April through October Data Only)

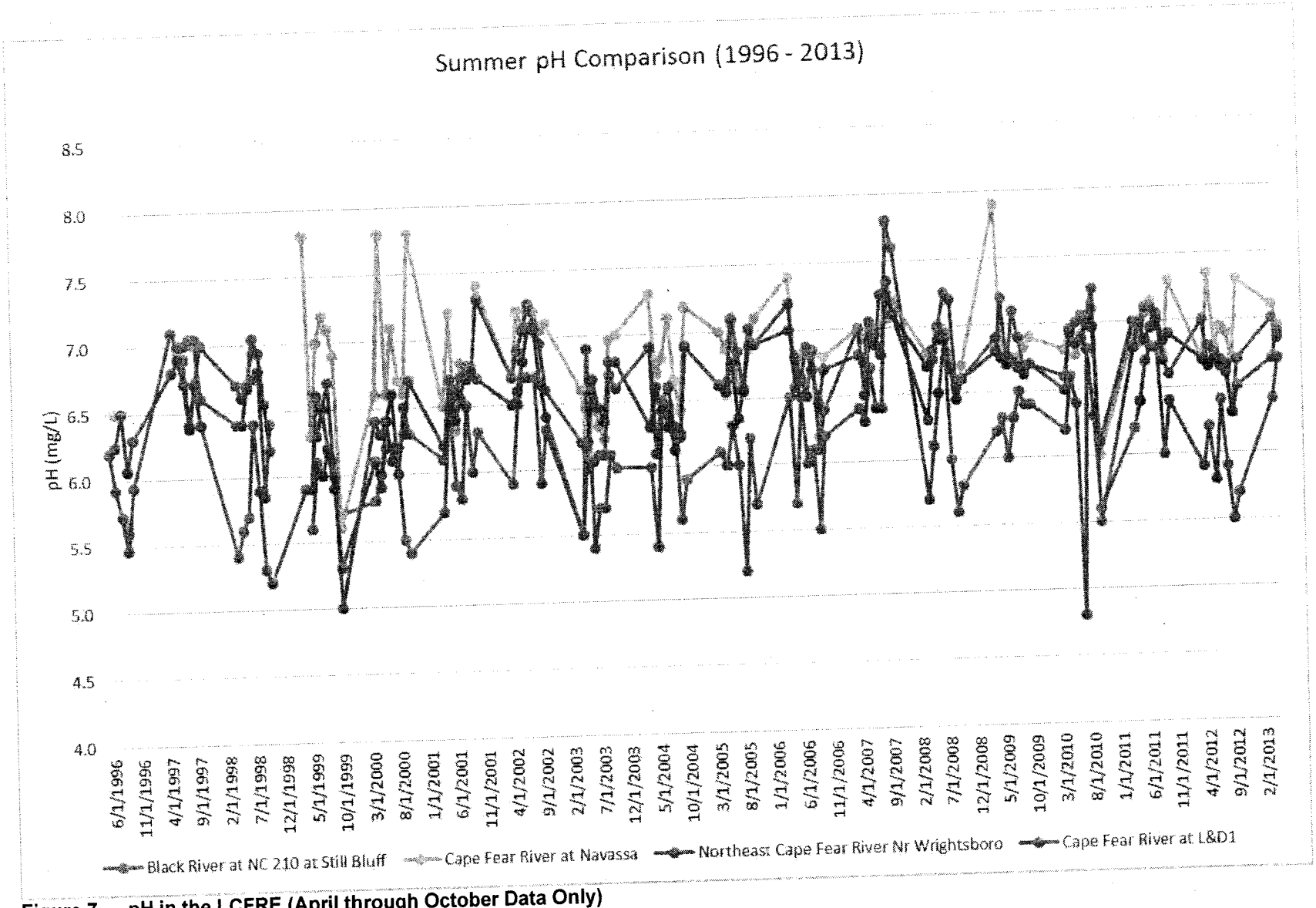


Figure 7. pH in the LCFRE (April through October Data Only)

The highest levels of summer (April through October) TKN (Figure 4) are typically seen in the Black River and reflect the organic load generated by the high biological productivity of the adjacent marsh areas. Levels at L&D1 are consistently the lowest, although a few high values do occur at this station. TKN levels appear to be trending lower in recent years.

Summer (April through October) ammonia levels (Figure 5) at all stations were relatively similar and typically less than 0.1 mg/L. Ammonia is readily utilized for primary production, so ammonia loads are quickly transformed into organic matter. Ammonia levels appear to have dropped since 2002, with a slight increase in 2012.

Summer (April through October) phosphorus levels (Figure 6) at all stations were relatively similar and typically less than 0.2 mg/L. Phosphorus is utilized for primary production but is not the limiting nutrient in estuarine systems. Phosphorus levels in the Cape Fear River appear to have dropped since 2002, with a slight increase in 2012.

The sum er summer (April through October) pH levels (Figure 7) at the boundary stations show an interesting pattern. The lowest levels are consistently seen in the Black River with levels often less than 6 standard units. This is typical for swamp areas where decomposition of organic matter results in the occurrence of high levels of humic acids. Levels in the NE Cape Fear River are higher than in the Black River, suggesting that the vegetation and substrate is different between the two drainages. The highest levels are at Navassa. The pH at L&D1 and NE Cape Fear are fairly similar, with the L&D1 values being approximately 0.5 standard units higher. The Cape Fear River is listed for pH impairment. A review of Figure 7 shows that the low pH excursions may be naturally occurring. Levels in the Black River are typically less than 6.5 standard pH units, and frequently fall below 6.0 standard units. A coinciding drop of pH at Navassa is seen during these periods, supporting the conclusion that low pH in the Cape Fear is driven by an influx of low pH waters from adjacent swamp areas.

2 Conclusions

The evaluation of water quality data at the boundary conditions supports the concept that inflows from the swamp areas have a significant impact on water quality in the Cape Fear River. The levels of nutrients, DO, and pH are consistently different between the station at L&D1, and in the Black River and the NE Cape Fear River. A distinct response from these inflows can be seen in the levels at Navassa for these parameters, supporting the idea that water quality in the Cape Fear River is dominated by the conditions found in the swamp areas below L&D1.

3 Works Cited

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin, and J. Williams. 2009. Development and Use of a *Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the Lower Cape Fear River Estuary, North Carolina.* Department of Civil and Environmental Engineering, University of North Carolina at Charlotte.

Cape Fear River Basin Monitoring Coalition. Water Quality Data website. http://www.cormp.org/CFP/CFP_map.php. Accessed February 3, 2014.

Tetra Tech. 2001. 3-Dimensional EFDC Water Quality Model of the Lower Cape Fear River and its Estuary. Prepared for the City of Wilmington and New Hanover County, North Carolina. May, 2001.

U.S. Environmental Protection Agency (USEPA). 2012. STOrage and RETrieval (STORET) Data Warehouse. April 20. http://www.epa.gov/storet/. Accessed February 3, 2014.

Technical Memo: The Relationship of Adjacent Wetlands and Salt Marsh to Dissolved Oxygen in the Lower Cape Fear River Estuary

Prepared for

The Lower Cape Fear River Program

Prepared by

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February 21, 2014

1 Introduction

The Lower Cape Fear River Program (LCFRP) is a large-scale water quality and environmental assessment program covering the Cape Fear River Estuary and a large portion of the lower Cape Fear River watershed. The LCFRP represents a collaboration of academia, government, industry, and the public, which has been coordinating with the North Carolina Department of Environment and Natural Resources (DENR) since 1995. The purpose of this memo is to summarize previous water quality modeling performed to analyze the impact that adjacent wetlands and salt marsh areas in the Lower Cape Fear River Estuary (LCFRE) portion of the basin have on dissolved oxygen (DO) concentrations in that region. The memo was prepared as part of a joint LCFRP-DENR effort to summarize the existing body of technical evidence for submission to the North Carolina Environmental Management Commission (EMC) requesting reclassification of portions of the LCFRE into a supplemental "Swamp" designation— a designation which had been applied to the LCFRE from the late 1950's until the early 1980's.

Contents of the memo focus on two relatively extensive modeling studies. The first was completed in 2001 by Tetra Tech on behalf of the City of Wilmington and New Hanover County, prior to the formation of the Cape Fear Public Utility Authority (CFPUA). In that study, the physical link between wetlands, salt marshes, the main channel, water movement, and contributions to dissolved oxygen (DO) deficit was established (Tetra Tech, 2001). Follow up work by the University of North Carolina – Charlotte on behalf of NC DENR both confirmed and expanded on the link (Bowen, et. Al., 2009). The results of these modeling studies are summarized here to provide a significant part of the technical basis for reclassifying the portions of the LCFR with the supplemental "Swamp" designation.

2 Preliminary Modeling Effort (2001)

In the period between 2000 and 2001, efforts were made on behalf of the City of Wilmington and New Hanover County to develop an initial application of a three-dimensional hydrodynamic model (the Environmental Fluid Dynamics Code, or EFDC, model) with the intention of meeting several objectives deemed important at the time (Tetra Tech, 2001):

- Simulation of the mixing and transport of the existing and proposed future Wilmington Northside and Wilmington Southside wastewater treatment plant effluents.
- Simulation of the impact of existing and proposed future Northside and Southside facility pollutant loads for oxygen-demanding substances.
- Evaluation of multiple sources and cumulative loads of oxygen-demanding substances to the lower Cape Fear River estuary.
- Analysis of the various processes affecting dissolved oxygen and their relative contribution to ambient dissolved oxygen deficit levels.

EFDC was selected because it is versatile, peer reviewed, accepted and endorsed by the USEPA, available in the public domain, and could be used for 1, 2, or 3-dimensional (3-D) simulation of rivers, lakes, estuaries, coastal regions and wetlands. The 2001 model development was considered a scoping level effort with an end goal of providing model results to guide further, more expansive model development supporting long term water quality management of the LCFRE. Specifically, an important question at the time was whether a 3-D model or 2-D model would be needed for the anticipated Total Maximum Daily Load (TMDL) development planned for the estuary because of its inclusion on the State's 303(d) list of impaired waters for low dissolved oxygen in 1998 with low pH added in 2006.

2.1.1 Preliminary Model Approach

A vast amount of data characterizing the LCFRE system available from numerous agencies and organizations was drawn upon to set up, calibrate, and validate the initial 3-D EFDC model. An overview of the data used in the preliminary model setup and calibration listed by sources and associated types is provided below:

- National Oceanic and Atmospheric Administration – digital bathymetry, land surface elevations, and tide data.
- US EPA– Reach File 1.0 cross-sectional data; Reach File 3.0 river shoreline data.
- National Weather Service – atmospheric data including observations of wind speed, wind direction, barometric pressure, air temperature, rainfall and cloud cover.
- US Army Corps of Engineers – electronic navigational survey data; water level, current, temperature, and salinity data collected during extensive 3 month intensive survey in 1993.
- US Geological Survey – daily river flow data; dye dispersion study.
- LCFRP – ambient water quality data.
- NC DENR – ambient water quality data; NPDES discharge data; Long-term BOD analyses; Sediment Oxygen Demand (SOD) in-situ measurements.

Additionally, two extensive dye studies were conducted in December 1999 (Tetra Tech, 2001). Approximately 1,300 samples were collected for dye, salinity, and temperature throughout the estuary during the two studies. A fixed station was also monitored for water level, salinity, and temperature at 15-minute intervals for 10 days. In addition to providing data to support calibration of the hydrodynamic portion of the model, the dye studies provided a basis for examining near field mixing and far field transport of the existing effluents. During these initial field studies, movement of water into adjacent wetlands and salt marshes during flood portions of the tide, and drainage of these areas during the ebb portion of tides, was observed.

In the course of the subsequent EFDC model calibration, the previously set up model grid was enhanced through the addition of several areas of swamp grid cells to better represent the wetting and drying of floodplain wetlands and their effect on in-stream dissolved oxygen levels (Figure 1). Out of the revised total of 950 cells, 146 (~15%) were "marsh" cells with the remaining 804 modeled as "channel" cells. To evaluate the sensitivity of the model to the presence of the swamp areas, the model was run without the additional grid cells. Although there were not specific model calibration points in swamp only areas, the main model calibration points showed substantial improvement of model performance with the added representation of the marsh cells.

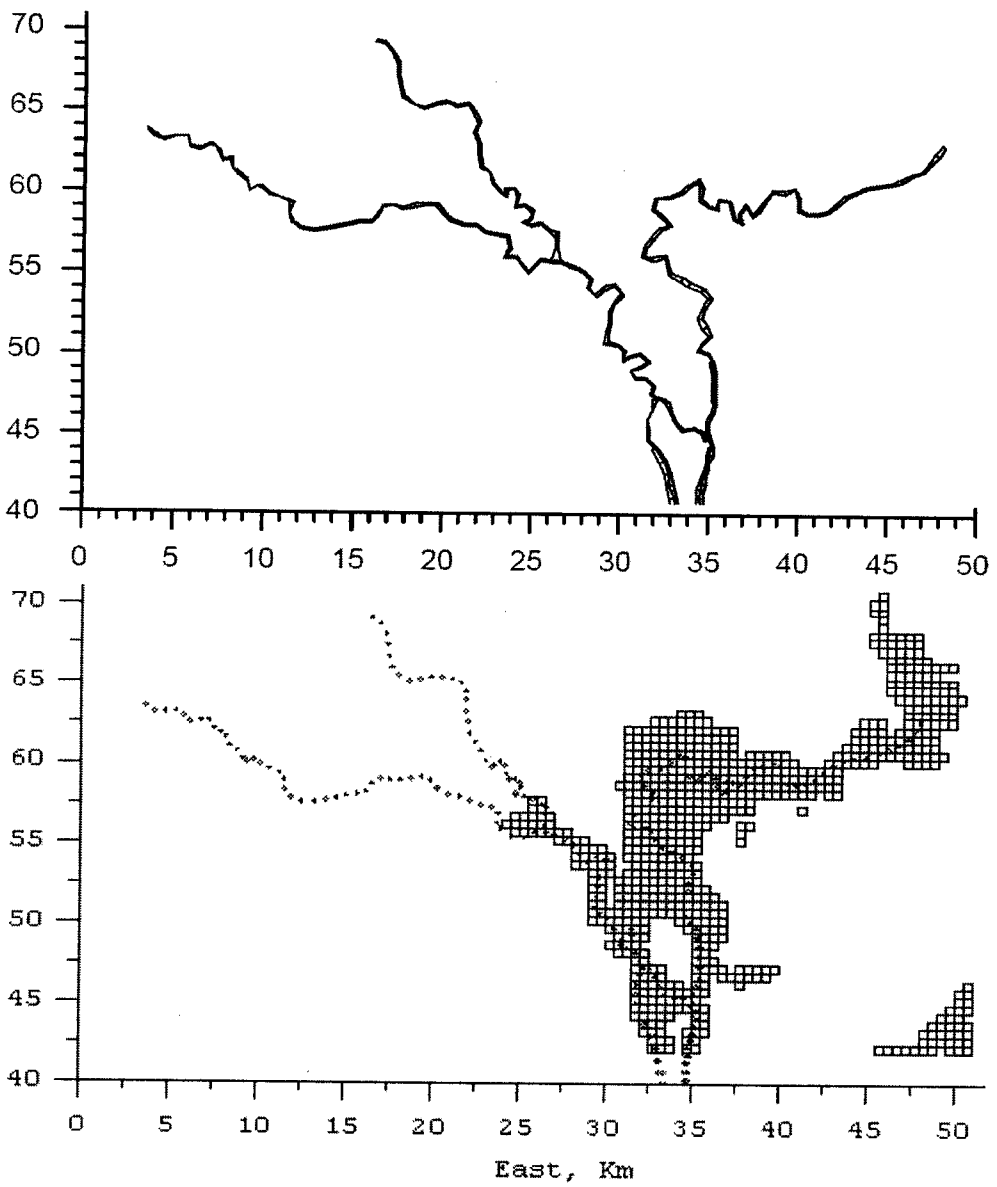

Figure 1. Upper Section of 2001 EFDC Model Grid Without, and With, Swamp Areas Delineated on the Basis of Elevation from the NOAA Coastal Relief Database

2.1.2 Preliminary Model Results

Results of multiple sensitivity analyses performed with the 2001 EFDC model for the LCFRE provided for a type of DO deficit component analysis. Results for July 19, 1998 were graphed in the study, and are shown below in Figure 2. July 19, 1998 was selected because it represented the day of lowest predicted DO for the baseline analysis prior to the effect of Hurricane Bonnie (i.e., a summer critical condition day). Each bar graph displays the model-predicted relative effect of each source of oxygen demand at five separate stations in the LCFRE for the simulated day of July 19. The bar graphs for the Navassa and Northeast Cape Fear River mouth stations (where observed DO concentrations are often the lowest during summer critical periods) show that SOD and swamp oxygen demand are predicted to account for between 73 and 84 percent of the total oxygen demand at those stations. SOD and swamp oxygen demand also comprised the majority of the total oxygen demands at other stations showing the importance of these

sources. Overall, the combined effect of SOD and swamp oxygen demand was predicted to be between 3 and 4 times greater than the combined impact of loading from point source and tributary BOD loads during a summer critical condition day. This was one of the first demonstrations that the low DO occurring in the LCFRE was driven by exchange with the bottom sediment and naturally occurring low DO from adjacent marsh/swamp lands and not from loads from point source discharges and major tributaries including the mainstem above Lock and Dam No. 1.

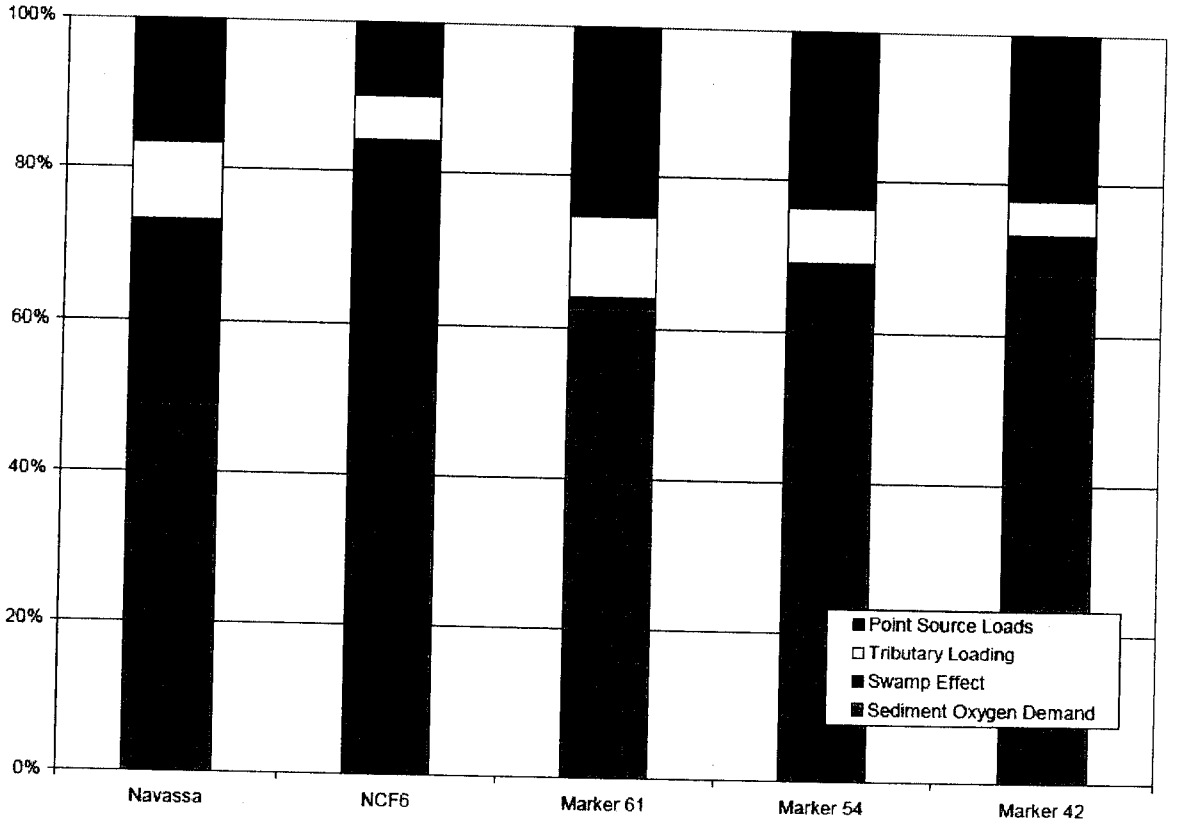

Figure 2. Predicted Relative Impact of Sources of Oxygen Demand in the Estuary (July 19, 1998)

Although the 2001 EFDC modeling demonstrated that a significant portion of the DO deficit near Navassa and down through Channel Marker 61 could be attributed to the combined effects of instream SOD and the oxygen demand from adjacent decaying marsh and swamp vegetation, it was acknowledged that uncertainty remained regarding the precise allocation to the two different oxygen demanding sources because of limited field data on each. The 2001 study recommended that additional study be performed on the LCFRE system to help delineate marsh impacts from instream SOD, which could help further refine the modeling assumptions for these parameters.

3 Subsequent Modeling Effort (2009)

To support the State's regulatory program for dissolved oxygen management in the LCFRE, a detailed monitoring and modeling program was conducted in the mid-2000s culminating with an updated EFDC modeling study (Bowen, et. al., 2009). As with the 2001 modeling effort, existing pertinent data were gathered to support model development, calibration, and validation. Two recommendations from the

earlier 2001 modeling effort—that additional information be gathered on the bathymetry within the estuary, and that additional work be done to quantify the effect of the riparian wetlands within the estuary—were undertaken during the updated hydrodynamic model calibration.

Twenty-one river cross-sections were surveyed by NC DENR and the additional bathymetric information was incorporated into the updated specification of the model grid. Additional grid work was also performed to specify the location and size of "wetland" cells that adjoin the main river channel. The overall strategy in determining wetland surface area was to use the information on the attenuation of the tidal amplitude to determine the distribution and overall area of the fringing marshes while considering the wetland delineations performed by the NC Division of Coastal Management in1999. As a result, the 2009 EFDC model included 100 additional model grid cells, of which 95 were "marsh" cells (Figure 3). This modification brought the number of marsh cells up to 241, approximately 23 percent of the model's total cell count of 1050 (up from 15 percent of 2001 model's total cell count).

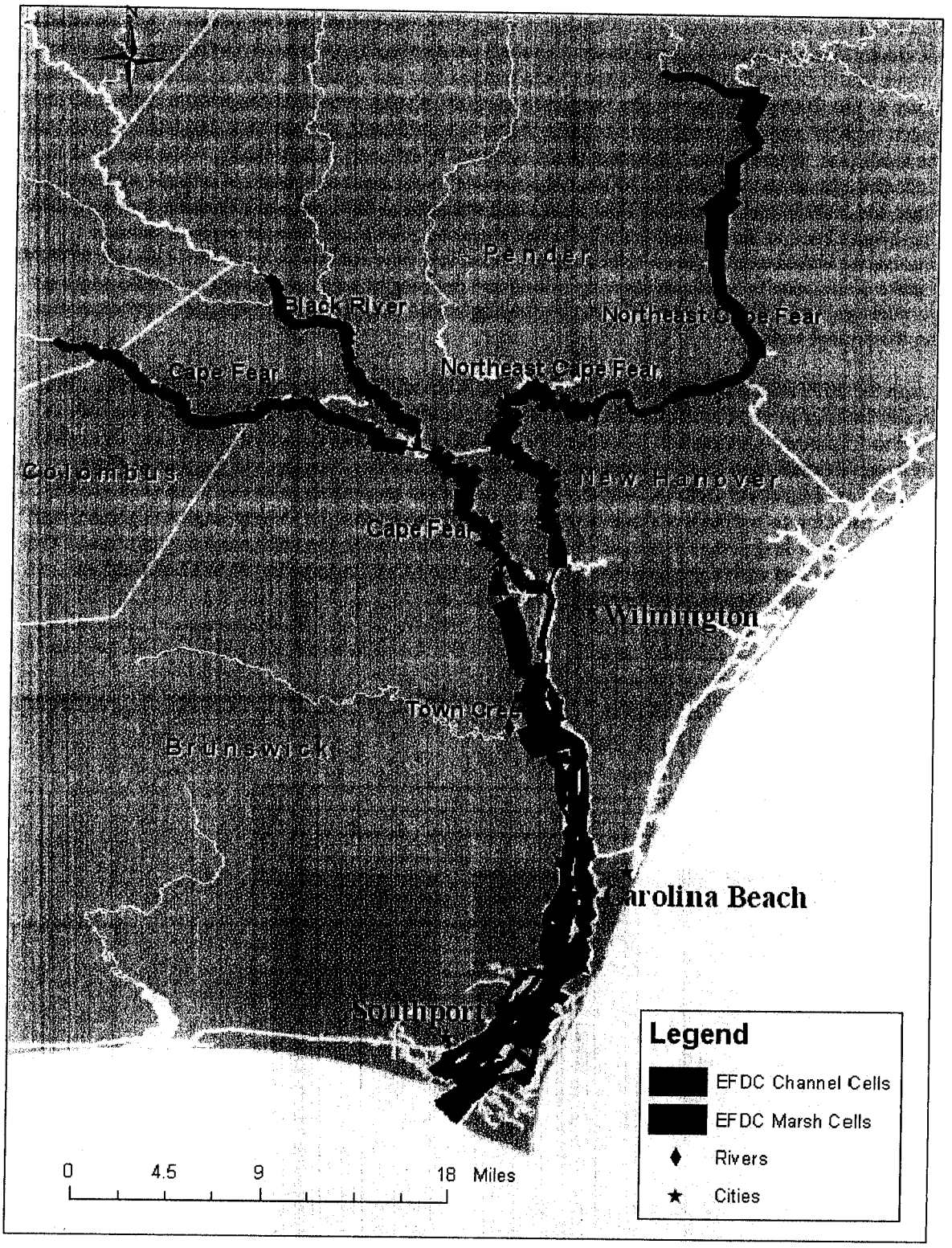

Figure 3. 2009 EFDC Model Grid Showing Location and Size of Marsh Cells; (map image extracted from Bowen, et al., 2009)

Results from the 2009 modeling effort showing average DO concentrations and deficit sources predicted for the model summer period (April through October) are displayed in Figure **4**. Unlike the 2001 effort, the swamp and tributary loading predictions were lumped into one category, "Riv Load Def." as labeled in Figure **4**. The 2009 modeling results, similar to the 2001 results, show that the portion of the DO deficit attributed to SOD and river loadings of organic matter is significantly greater than that attributed to point source loads (i.e., Waste Water Treatment Plant, or WWTP, effluent). Additionally, while the 2001 model considered wetlands to be a sink of DO but did not model these areas as sources of organic matter (OM) loadings, the 2009 model considered tidal creeks and wetlands as both sinks of DO and a source of OM and freshwater back to the channel cells. Note that since the 2009 results are for average summer conditions; we would expect the contributions at critical low flow conditions within the summer to show even more dominance by wetlands since the filling and draining of adjacent marshland would continue due to tidal cycle while the amount of tributary loading would decrease with freshwater flow decreases during the critical period.

Although the 2009 model results combine riverine and wetland loads, the updated model configuration physically links even more area to wetland and salt marsh sources than the 2001 model (23 percent as opposed to 15 percent previously). Since the 2001 model results already showed greater impact on DO deficit from wetlands than riverine loadings at key locations such as Navassa and the mouth of the Northeast Cape Fear River (refer back to Figure 2), one might reasonably infer that with even greater physical attribution to wetlands and salt marsh in the 2009 model that the swamp impact is greater than the river load regarding deficit in the LCFRE hot spots. Additionally, the 2009 modeling confirmed that DO deficit associated with the total point source load in the LCFRE (noted by "WWTP deficit" in Figure **4**) is less than 10 percent of the total DO deficit.

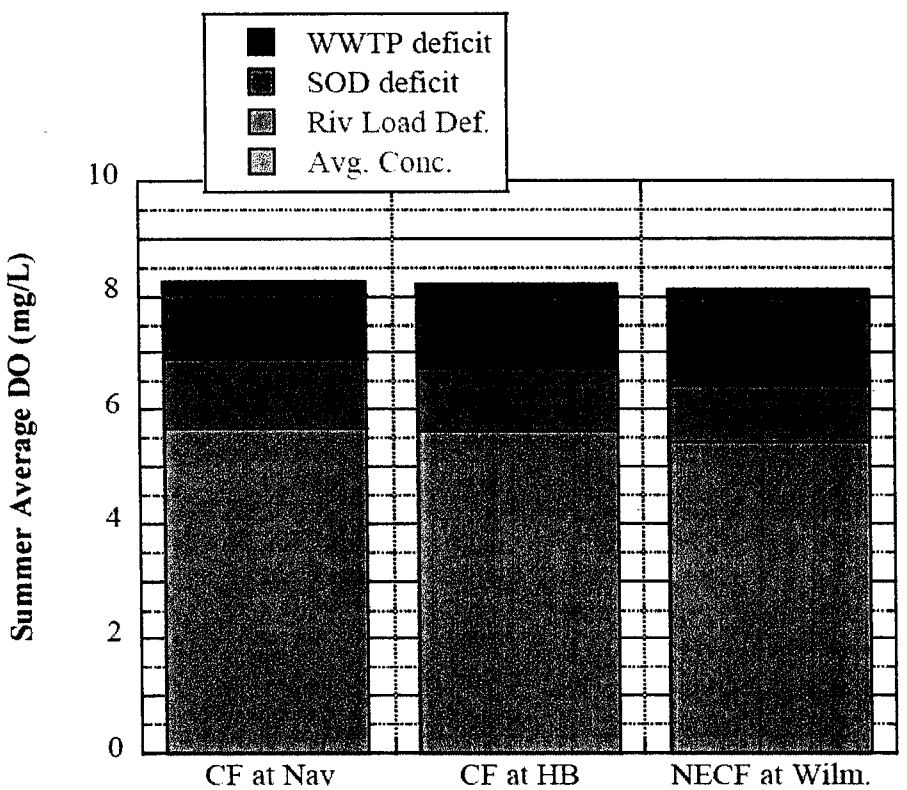

Figure 4. Summer Season (Apr-Oct) Time-Averaged Model Predicted DO Concentrations (image from Bowen, et al., 2009)

Additional scenario testing performed by Bowen et. al. (2009) simulated conditions in the LCFRE with up to 70 percent of the riverine (nonpoint source) oxygen demanding load being removed. The results indicated that even with such a large nonpoint source load reduction, DO concentrations are predicted to be less than the current water quality standard of 5 mg/L roughly 20 percent of the time during summer conditions. The 2009 modeling study therefore added further weight of evidence that other local, naturally occurring sources of oxygen demand (i.e., marshland and SOD) are driving low DO during the summer period.

4 Summary

At the time of the initial 1998 303(d) listing of the LCFRE as impaired due to low dissolved oxygen, NC DENR used a DO standard of 5 mg/L to make its assessment and the reason for impairment was thought to be a combination of point source discharge and nonpoint source pollutant loadings. The setup, calibration, validation, and independent application of two EFDC hydrodynamic water quality models for the LCFRE (Tetra Tech, 2001, and Bowen et.al., 2009) provide a strong scientific basis for isolating primary influences on DO concentrations in the LCFRE. Both modeling efforts demonstrated that the impact from point source loads in the LCFRE contributes to less than 10 percent of the DO deficit in the LCFRE. The 2001 modeling effort demonstrated that an accurate calibration could not be achieved without representing the wetting and drying of adjacent low elevation wetland and salt marsh areas. That modeling estimated that wetland/marsh and SOD sources accounted for between three quarters and four fifths of all oxygen demand in the LCFRE. The 2009 modeling effort validated and expanded the influence of adjacent marshland based on more detailed analysis. Further, application of the 2009 model that simulated up to 70 percent of nonpoint source load reduction demonstrated that even with such large pollutant loading reductions, DO concentrations would be expected to be below 5 mg/L 20 percent of the time in the LCFRE during the summer. Therefore, the 2001 and 2009 modeling analyses provide further weight of evidence collectively that other local, naturally occurring sources of oxygen demand (i.e., marshland and SOD) are driving low DO during the summer period and suggest that reinstitution of the supplemental "Swamp" designation for the LCFRE should be considered by NC DENR and the Environmental Management Commission.

References

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin, and J. Williams. 2009. Development And Use Of A Three-Dimensional Water Quality Model To Predict Dissolved Oxygen Concentrations In The Lower Cape Fear River Estuary, North Carolina. Department of Civil and Environmental Engineering, University of North Carolina at Charlotte. Prepared for NCDENR.

Tetra Tech. 2001. 3-Dimensional EFDC Water Quality Model of the Lower Cape Fear River and its Estuary. Prepared for the City of Wilmington and New Hanover County, North Carolina. May, 2001.

15A NCAC 02B .0220 TIDAL SALT WATER QUALITY STANDARDS FOR CLASS SC WATERS

General. The water quality standards for all tidal salt waters shall be the basic standards applicable to Class SC waters. Additional and more stringent standards applicable to other specific tidal salt water classifications are specified in Rules .0221 and .0222 of this Section. Action Levels, for purposes of National Pollutant Discharge Elimination System (NPDES) permitting, are specified in Item (20) of this Rule.

(1) Best Usage of Waters: any usage except primary recreation or shellfishing for market purposes; usages include aquatic life propagation and maintenance of biological integrity (including fishing, fish and functioning Primary Nursery Areas (PNAs)), wildlife, and secondary recreation;

(2) Conditions Related to Best Usage: the waters shall be suitable for aquatic life propagation and maintenance of biological integrity, wildlife, and secondary recreation. Any source of water pollution that precludes any of these uses, including their functioning as PNAs, on either a short-term or a long-term basis shall be considered to be violating a water quality standard;

(3) Chlorophyll a (corrected): not greater than 40 ug/l in sounds, estuaries, and other waters subject to growths of macroscopic or microscopic vegetation. The Commission or its designee may prohibit or limit any discharge of waste into surface waters if, in the opinion of the Director, the surface waters experience or the discharge would result in growths of microscopic or macroscopic vegetation such that the standards established pursuant to this Rule would be violated or the intended best usage of the waters would be impaired;

(4) Cyanide: 1 ug/l;

(5) Dissolved oxygen: not less than 5.0 mg/l, except that swamp waters, poorly flushed tidally influenced streams or embayments, or estuarine bottom waters may have lower values if caused by natural conditions;

(6) Enterococcus, including Enterococcus faecalis, Enterococcus faecium, Enterococcus avium and Enterococcus gallinarium: not to exceed a geometric mean of 35 enterococci per 100 ml based upon a minimum of five samples within any consecutive 30 days. For purposes of beach monitoring and notification, "Coastal Recreational Waters Monitoring, Evaluation and Notification" regulations (15A NCAC 18A .3400), available free of charge at: http://www.ncoah.com/, are hereby incorporated by reference including any subsequent amendments;

(7) Floating solids, settleable solids, or sludge deposits: only such amounts attributable to sewage, industrial wastes, or other wastes, as shall not make the waters unsafe or unsuitable for aquatic life and wildlife, or impair the waters for any designated uses;

(8) Gases, total dissolved: not greater than 110 percent of saturation;

(9) Metals:

(a) With the exception of mercury and selenium, tidal salt water quality standards for metals shall be based upon measurement of the dissolved fraction of the metals. Mercury and selenium shall be based upon measurement of the total recoverable metal;

(b) Compliance with acute instream metals standards shall only be evaluated using an average of two or more samples collected within one hour. Compliance with chronic instream metals standards shall only be evaluated using averages of a minimum of four samples taken on consecutive days, or as a 96-hour average;

(c) Metals criteria shall be used for proactive environmental management. An instream exceedence of the numeric criterion for metals shall not be considered to have caused an adverse impact to the aquatic community without biological confirmation and a comparison of all available monitoring data and applicable water quality standards. This weight of evidence evaluation shall take into account data quality and the overall confidence in how representative the sampling is of conditions in the waterbody segment before an assessment of aquatic life use attainment, or non-attainment, is made by the Division. Recognizing the synergistic and antagonistic complexities of other water quality variables on the actual toxicity of metals, with the exception of mercury and selenium, biological monitoring shall be used to validate, by direct measurement, whether or not the aquatic life use is supported.

(d) Acute and chronic tidal salt water quality metals standards are as follows:

(i) Arsenic, acute: WER· 69 ug/l;

(ii) Arsenic, chronic: WER· 36 ug/l;

(iii) Cadmium, acute: WER· 40 ug/l;

(iv) Cadmium, chronic: WER· 8.8 ug/l;
(v) Chromium VI, acute: WER· 1100 ug/l;
(vi) Chromium VI, chronic: WER· 50 ug/l;
(vii) Copper, acute: WER· 4.8 ug/l;
(viii) Copper, chronic: WER· 3.1 ug/l;
(ix) Lead, acute: WER· 210 ug/l;
(x) Lead, chronic: WER· 8.1 ug/l;
(xi) Mercury, total recoverable, chronic: 0.025 ug/l;
(xii) Nickel, acute: WER· 74 ug/l;
(xiii) Nickel, chronic: WER· 8.2 ug/l;
(xiv) Selenium, total recoverable, chronic: 71 ug/l;
(xv) Silver, acute: WER· 1.9 ug/l;
(xvi) Silver, chronic: WER· 0.1 ug/l;
(xvii) Zinc, acute: WER· 90 ug/l; and
(xviii) Zinc, chronic: WER· 81 ug/l;

With the exception of mercury and selenium, acute and chronic tidal saltwater quality aquatic life standards for metals listed above apply to the dissolved form of the metal and apply as a function of the pollutant's water effect ratio (WER). A WER expresses the difference between the measures of the toxicity of a substance in laboratory waters and the toxicity in site water. The WER shall be assigned a value equal to one unless any person demonstrates to the Division's satisfaction in a permit proceeding that another value is developed in accordance with the "Water Quality Standards Handbook: Second Edition" published by the US Environmental Protection Agency (EPA-823-B-12-002), free of charge, at http://water.epa.gov/scitech/swguidance/standards/handbook/, hereby incorporated by reference including any subsequent amendments. Alternative site-specific standards may also be developed when any person submits values that demonstrate to the Commissions' satisfaction that they were derived in accordance with the "Water Quality Standards Handbook: Second Edition, Recalculation Procedure or the Resident Species Procedure", hereby incorporated by reference including subsequent amendments at http://water.epa.gov/scitech/swguidance/standards/handbook/.

This material is available free of charge;

(10) Oils, deleterious substances, colored, or other wastes: only such amounts as shall not render the waters injurious to public health, secondary recreation, aquatic life, and wildlife or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated uses. For the purpose of implementing this Rule, oils, deleterious substances, colored, or other wastes shall include substances that cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines pursuant to 40 CFR 110.3;

(11) Pesticides:
(a) Aldrin: 0.003 ug/l;
(b) Chlordane: 0.004 ug/l;
(c) DDT: 0.001 ug/l;
(d) Demeton: 0.1 ug/l;
(e) Dieldrin: 0.002 ug/l;
(f) Endosulfan: 0.009 ug/l;
(g) Endrin: 0.002 ug/l;
(h) Guthion: 0.01 ug/l;
(i) Heptachlor: 0.004 ug/l;
(j) Lindane: 0.004 ug/l;
(k) Methoxychlor: 0.03 ug/l;
(l) Mirex: 0.001 ug/l;
(m) Parathion: 0.178 ug/l; and
(n) Toxaphene: 0.0002 ug/l;

(12) pH: shall be normal for the waters in the area, which range between 6.8 and 8.5, except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions;

(13) Phenolic compounds: only such levels as shall not result in fish-flesh tainting or impairment of other best usage;

(14) Polychlorinated biphenyls: (total of all PCBs and congeners identified) 0.001 ug/l;

(15) Radioactive substances:

(a) Combined radium-226 and radium-228: The average annual activity level (based on at least one sample collected per quarter) for combined radium-226, and radium-228 shall not exceed five picoCuries per liter;

(b) Alpha Emitters. The average annual gross alpha particle activity (including radium-226, but excluding radon and uranium) shall not exceed 15 picoCuries per liter;

(c) Beta Emitters. The average annual activity level (based on at least one sample collected per quarter) for strontium-90 shall not exceed eight picoCuries per liter; nor shall the average annual gross beta particle activity (excluding potassium-40 and other naturally occurring radionuclides exceed 50 picoCuries per liter; nor shall the average annual activity level for tritium exceed 20,000 picoCuries per liter;

(16) Salinity: changes in salinity due to hydrological modifications shall not result in removal of the functions of a PNA. Projects that are determined by the Director to result in modifications of salinity such that functions of a PNA are impaired shall be required to employ water management practices to mitigate salinity impacts;

(17) Temperature: shall not be increased above the natural water temperature by more than 0.8 degrees C (1.44 degrees F) during the months of June, July, and August nor more than 2.2 degrees C (3.96 degrees F) during other months and in no cases to exceed 32 degrees C (89.6 degrees F) due to the discharge of heated liquids;

(18) Trialkyltin compounds: 0.007 ug/l expressed as tributyltin;

(19) Turbidity: the turbidity in the receiving water shall not exceed 25 Nephelometric Turbidity Units (NTU); if turbidity exceeds this level due to natural background conditions, the existing turbidity level shall not be increased. Compliance with this turbidity standard can be met when land management activities employ Best Management Practices (BMPs) [as defined by Rule .0202 of this Section] recommended by the Designated Nonpoint Source Agency (as defined by Rule .0202 of this Section). BMPs shall be in full compliance with all specifications governing the proper design, installation, operation, and maintenance of such BMPs;

(20) Action Levels for Toxic Substances Applicable to NPDES Permits:

(a) Copper, dissolved, chronic: 3.1 ug/l;

(b) Silver, dissolved, chronic: 0.1 ug/l;

(c) Zinc, dissolved, chronic: 81 ug/l

If the action levels for any of the substances listed in this Item (which are generally not bioaccumulative and have variable toxicity to aquatic life because of chemical form, solubility, stream characteristics, or associated waste characteristics) shall be determined by the waste load allocation to be exceeded in a receiving water by a discharge under the 7Q10 flow criterion for toxic substances, the discharger shall monitor the chemical or biological effects of the discharge; efforts shall be made by all dischargers to reduce or eliminate these substances from their effluents. Those substances for which action levels are listed in this Item shall be limited as appropriate in the NPDES permit if sufficient information (to be determined for metals by measurements of that portion of the dissolved instream concentration of the action level parameter attributable to a specific NPDES permitted discharge) exists to indicate that any of those substances may be a causative factor resulting in toxicity of the effluent.

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1);*
Eff. October 1, 1995;
Amended Eff. January 1, 2015; May 1, 2007; August 1, 2000.

15A NCAC 02B .0227 WATER QUALITY MANAGEMENT PLANS

(a) In implementing the water quality standards to protect the existing uses [as defined by Rule .0202 of this Section] of the waters of the state or the water quality which supports those uses, the Commission shall develop water quality management plans on a priority basis to attain, maintain or enhance water quality throughout the state. Additional specific actions deemed necessary by the Commission to protect the water quality or the existing uses of the waters of the state shall be specified in Paragraph (b) of this Rule. These actions may include anything within the powers of the Commission. The Commission may also consider local actions which have been taken to protect a waterbody in determining the appropriate protection options to be incorporated into the water quality management plan.

(b) All waters determined by the Commission to be protected by a water quality management plan are listed with specific actions as follows:

The Lockwoods Folly River Area (Lumber River Basin), which includes all waters of the lower Lockwoods Folly River in an area extending north from the Intracoastal Waterway to a line extending from Genoes Point to Mullet Creek, shall be protected by the specific actions described in Subparagraphs (1) through (5) of this Paragraph.

(1) New development activities within 575' of the mean high water line which require a Sedimentation Erosion Control Plan or a CAMA major development permit must comply with the low density option of the coastal Stormwater Runoff Disposal Rules [as specified in 15A NCAC 2H .1005(2)(a)].

(2) New or expanded NPDES permits shall be issued only for non-domestic, non-industrial process type discharges (such as non-industrial process cooling or seafood processing discharges). A public hearing is mandatory for any proposed (new or expanded) NPDES permit to this protected area.

(3) New non-discharge permits shall be required to meet reduced loading rates and increased buffer zones, to be determined on a case-by-case basis.

(4) New or expanded marinas must be located in upland basin areas.

(5) No dredge or fill activities shall be allowed where significant shellfish or submerged aquatic vegetation bed resources occur, except for maintenance dredging, such as that required to maintain access to existing channels and facilities located within the protected area or maintenance dredging for activities such as agriculture.

History Note: *Authority G.S. 143-214.1; 143-215.8A;*
Eff. October 1, 1995;
Amended Eff. January 1, 1996.

Fiscal Analysis

Rule Citation Numbers: 15A NCAC 2B .0227 Water Quality Management Plans and 15A NCAC 2B .0311 Cape Fear River Basin

Rule Topic: Proposed Reclassification of a Segment of the Cape Fear River in New Hanover and Brunswick Counties (Cape Fear River Basin) from Class SC to Class SC Sw with a Water Quality Management Plan

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Impact Summary:

State government:	No
Local government:	No
Private entities:	No
Substantial Impact:	No
Federal government:	No

Necessity: The proposed water quality management plan associated with the proposed reclassification codifies the current permitting policy already in existence for new individual NPDES wastewater discharges and expansions of existing individual National Pollutant Discharge Elimination System (NPDES) wastewater discharges to the subject waters. In addition, the proposed reclassification in partnership with the proposed management plan provides a path forward for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges, thus enabling the local community to plan accordingly.

1. **Summary**

The Lower Cape Fear River Program has submitted a surface water reclassification request for a portion of the Cape Fear River. This portion of the Cape Fear River of interest is proposed to be reclassified from Class SC to Class SC Swamp with a water quality management plan.

The proposal codifies the current permitting policy already in place for new wastewater discharges and expansions of existing wastewater discharges to the subject waters. In addition, the proposal provides a path for the subject water's discharges, and thus for local communities, for future planning purposes. Finally, the proposal may positively impact the subject water's current water quality impairments.

There are no quantifiable impacts of the proposed rulemaking according to this fiscal analysis. The expected reclassification effective date is November 1, 2015.

2. Background

The area that would be impacted by this proposal is the portion of the Cape Fear River from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut. This river segment flows along the border of Brunswick and New Hanover counties. In these waters as well as adjacent waters, there are several tidal saltwater species, including the federally endangered Shortnose Sturgeon and Atlantic Sturgeon, and the associated Marine Fisheries Commission designations of Primary Nursery Area, or PNA; PNA waters are by definition High Quality Waters, or HQW, per 15A NCAC 2B .0101. In addition, the types of land cover occurring adjacent to the proposed river segment are comprised of wetlands, some developed lands, other open waters, forest lands, and shrub/scrub lands. Furthermore, the segment of the Cape Fear River directly above and below the river segment to be reclassified is classified C Swamp and SC, respectively, and the named tributaries flowing to this river segment are currently classified either SC Swamp, WS-IV, SC, or C Swamp.

Several tidal saltwater species, including the federally endangered Shortnose Sturgeon and federally endangered Atlantic Sturgeon, and the striped bass live in the subject waters. The NC Division of Marine Fisheries (DMF) has a tagging program for striped bass and sturgeon in this vicinity. This is an area of diverse and abundant fish use, partially since salinity fluctuates widely. When salinity is lower, fresh-brackish water species such as catfish and gar can be found, while during high salinity times, spotted red drum and spadefish have been documented.

There are currently eight NPDES individual permitted wastewater discharges within this segment. According to the 2012 North Carolina 303(d) list, the river segment is impaired for water quality parameters including dissolved oxygen (DO) and pH.

According to the reclassification request, "...the DO standard of 5 mg/l for the Lower Cape Fear River Estuary is not appropriate since it is not achieved a significant portion of the time as a result of natural drainage from riverine wetlands and salt marshes. Modeling results indicate that the current DO standard of 5 mg/L is not attained about 30 percent of the time during the summer months and that point sources in this segment are a minor contributor to overall dissolved oxygen depletion. Subsequent modeling and data analyses have indicated that drainage and the wetting and drying of floodplain wetlands and salt marshes are the most significant contributor to the waterbody's not meeting the DO standard for non-swamp classified waters. From a regulatory standpoint, a straightforward way to recognize the natural influence on standards is to reclassify the area with the supplemental Sw classification. "

The regulations applicable to Class SC waters, which include the subject waters, provide a base of protection to all of the state's tidal saltwaters and allow for lower dissolved oxygen and pH values under natural conditions for SC waters that carry the supplemental Swamp designation. For Class SC waters, currently the dissolved oxygen standard is 5 mg/l, and the pH standard is a range between 6.8-8.5; if this segment is reclassified to include the Swamp designation, then the pH can be as low as 4.3 if caused by natural conditions, and the dissolved oxygen can be lower than 5.0 mg/l if caused by natural conditions. These regulations are located in rule, 15A NCAC 02B .0220.

The proposed management plan to accompany the proposed Swamp designation contains effluent limits that new individual NPDES wastewater discharges and expansions of existing individual NPDES

wastewater discharges within the river segment would have to meet regarding oxygen consuming wastes. These limits are similar to the limits for High Quality Waters (HQW), and the subject waters are HQW by virtue of being designated as Primary Nursery Areas. Effluent limits of 5 mg/l for biochemical oxygen demand (BOD), 1 mg/l for Ammonia, and 6 mg/l for dissolved oxygen would apply. For industrial discharges, site specific best available technology on a case by case basis would be utilized to determine the limits for BOD, Ammonia and DO.

For new individual NPDES facilities and expansions of existing individual NPDES facilities, the management plan includes consideration of seasonal effluent limits on a case by case basis in accordance with 15A NCAC 2B .0404. The plan also includes the following stipulation: Any new or expanded individual NPDES pollutant discharge of oxygen-consuming waste shall not cause the dissolved oxygen of the receiving water to drop more than 0.1 mg/l below the modeled in-stream dissolved oxygen at total permitted capacity.

The proposed management plan is consistent with the current permitting policy already in place for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters. Furthermore, there is no known plans for new NPDES wastewater discharges and there is one planned expansion of an existing NPDES wastewater discharge in the reclassification area (Cape Fear Public Utility Authority Southside Wilmington, NC), which already meets the proposal's requirements. Finally, the proposed management plan in conjunction with the Swamp designation provides a path for the subject waters' dischargers, and thus for local communities, for future planning purposes, and also may, in a positive fashion, impact the subject water's current impairments. As a result, this proposal serves the environment and public interest per Executive Order #70 and complies with G.S. 150B-19.1.

3. Costs

(i.) New and Existing Individual NPDES Wastewater Discharges

There are eight existing individual NPDES wastewater discharges. For now, there are currently no known planned new individual NPDES wastewater discharges and one planned expansion of an existing individual NPDES wastewater discharge in the reclassification area, which already meets the proposal's requirements. The proposed management plan to accompany the proposed Swamp designation contains effluent limits that new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges within the river segment would have to meet regarding oxygen consuming wastes. These limits are similar to the limits for High Quality Waters, and the subject waters are HQW by virtue of being designated as Primary Nursery Areas. Effluent limits of 5 mg/l for BOD, 1 mg/l for Ammonia, and 6 mg/l for dissolved oxygen would apply. For industrial discharges, site specific best available technology on a case by case basis would be utilized to determine the limits for BOD, Ammonia and DO. In sum, the proposed regulations would not have any impact on current or future wastewater discharges.

(ii.) Implementing Agencies

The proposed rulemaking will have no cost to the State implementing agency (DWR/DENR). These amendments will not require DWR to revise its existing procedures nor will they require DWR to procure additional staff. Therefore, this proposed rulemaking will have no economic impact to the implementing agency.

(iii.) Environment/Ecosystem

Like it was mentioned in the summary above, according to the reclassification request, "...the DO standard of 5 mg/l for the Lower Cape Fear River Estuary is not appropriate since it is not achieved a significant portion of the time as a result of natural drainage from riverine wetlands and salt marshes. From a regulatory standpoint, a straightforward way to recognize the natural influence on standards is to reclassify the area with the supplemental Sw classification...." As a result of the Sw reclassification, ambient (in-situ) standards for DO and pH would be allowed to reflect natural conditions rather than standards reflected solely by the SC classification. Water quality monitoring may reflect DO and pH at levels below solely SC requirements. It is uncertain if and/or to what extent the DO and pH levels will change over time once the proposal becomes effective.

4. Benefits

(i.) Humans

This reclassification does not provide a direct benefit to humans. No changes to local government programs are required, and there are no existing or proposed activities affected by the proposal.

(ii.) New Individual NPDES and Existing Individual NPDES Wastewater Discharges

New individual NPDES and existing individual NPDES wastewater discharges will not incur any direct benefits from the proposal, other than more accurately describing the characteristics of the waters in this river. There are no existing or known proposed discharges affected by the proposal. However, the proposed management plan codifies the current permitting policy already in place for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters, cementing permitting expectations for those discharges. In addition, the proposed management plan in conjunction with the Swamp designation provides a path for the subject waters' discharges, and thus for local communities, for future planning purposes. Finally, as a result of the Sw reclassification, ambient (in-situ) standards for DO and pH would be allowed to reflect natural conditions rather than standards reflected solely by the SC classification. Water quality monitoring may reflect DO and pH at levels solely below SC requirements. Discharges may in the future be granted additional wasteload allocations; the amount, if any, of additional wasteload allocations can only be determined with additional water quality monitoring and analysis. This analysis would also reflect if the reclassification has any positive impact on the subject water's current impairments. It is uncertain if and/or to what extent the DO and pH levels will change over time once the proposal becomes effective.

5. Total Economic Impact

The economic impacts of the proposed rulemaking, both in terms of cost and benefit, are not quantifiable as measured from the baseline conditions. Consequently, there were no specific cost or benefit estimations to report in this fiscal note.

Appendix

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15A NCAC 02B .0227 WATER QUALITY MANAGEMENT PLANS

(a) In implementing the water quality standards to protect the existing uses [as defined by Rule .0202 of this Section] of the waters of the state or the water quality which supports those uses, the Commission shall develop water quality management plans on a priority basis to attain, maintain or enhance water quality throughout the state. Additional specific actions deemed necessary by the Commission to protect the water quality or the existing uses of the waters of the state shall be specified in Paragraph (b) of this Rule. These actions may include anything within the powers of the Commission. The Commission may also consider local actions which have been taken to protect a waterbody in determining the appropriate protection options to be incorporated into the water quality management plan.

(b) All waters determined by the Commission to be protected by a water quality management plan are listed with specific actions as follows:

The Lockwoods Folly River Area (Lumber River Basin), which includes all waters of the lower Lockwoods Folly River in an area extending north from the Intracoastal Waterway to a line extending from Genoes Point to Mullet Creek, shall be protected by the specific actions described in Subparagraphs (1) through (5) of this Paragraph.

(1) New development activities within 575' of the mean high water line which require a Sedimentation Erosion Control Plan or a CAMA major development permit must comply with the low density option of the coastal Stormwater Runoff Disposal Rules [as specified in 15A NCAC 2H .1005(2)(a)].

(2) New or expanded NPDES permits shall be issued only for non-domestic, non-industrial process type discharges (such as non-industrial process cooling or seafood processing discharges). A public hearing is mandatory for any proposed (new or expanded) NPDES permit to this protected area.

(3) New non-discharge permits shall be required to meet reduced loading rates and increased buffer zones, to be determined on a case-by-case basis.

(4) New or expanded marinas must be located in upland basin areas.

(5) No dredge or fill activities shall be allowed where significant shellfish or submerged aquatic vegetation bed resources occur, except for maintenance dredging, such as that required to maintain access to existing channels and facilities located within the protected area or maintenance dredging for activities such as agriculture.

A part of the Cape Fear River (Cape Fear River Basin) comprised of a section of 18-(71) from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut shall be protected by the Class SC Sw standards as well as the site-specific action described in Subparagraph (1) of this Paragraph:

(1) All new individual NPDES wastewater discharges and expansions of existing NPDES wastewater discharges shall be required to provide the treatment described below:

(A) Oxygen consuming wastes: Effluent limitations shall be as follows: BOD_5= 5 mg/l, NH_3-N = 1 mg/l and DO = 6 mg/l, or site-specific best available technology on a case-by-case basis for industrial discharges. Seasonal effluent limits for oxygen-consuming wastes will be considered on a case-by-case basis in accordance with 15A NCAC 2B.0404. Any new or expanded permitted pollutant discharge of oxygen-consuming waste shall not cause the dissolved oxygen of the receiving water to drop more than 0.1 mg/l below the modeled in-stream dissolved oxygen at total permitted capacity.

History Note: *Authority G.S. 143-214.1; 143-215.8A;*
Eff. October 1, 1995;
Amended Eff. November 1, 2015; January 1, 1996.

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15A NCAC 02B .0311 CAPE FEAR RIVER BASIN

(a) Effective February 1, 1976, the adopted classifications assigned to the waters within the Cape Fear River Basin are set forth in the Cape Fear River Basin Schedule of Classifications and Water Quality Standards, which may be inspected at the following places:

(1) the Internet at http://portal.ncdenr.org/web/wq/ps/csu/rules; and

(2) the North Carolina Department of Environment and Natural Resources:

(A) Winston-Salem Regional Office
585 Waughtown Street
Winston-Salem, North Carolina

(B) Fayetteville Regional Office
225 Green Street
Systel Building Suite 714
Fayetteville, North Carolina

(C) Raleigh Regional Office
3800 Barrett Drive
Raleigh, North Carolina

(D) Washington Regional Office
943 Washington Square Mall
Washington, North Carolina

(E) Wilmington Regional Office
127 Cardinal Drive Extension
Wilmington, North Carolina

(F) Division of Water Quality
Central Office
512 North Salisbury Street
Raleigh, North Carolina.

(b) The Cape Fear River Basin Schedule of Classification and Water Quality Standards was amended effective:

(1) March 1, 1977;
(2) December 13, 1979;
(3) December 14, 1980;
(4) August 9, 1981;
(5) April 1, 1982;
(6) December 1, 1983;
(7) January 1, 1985;
(8) August 1, 1985;
(9) December 1, 1985;
(10) February 1, 1986;
(11) July 1, 1987;
(12) October 1, 1987;
(13) March 1, 1988;
(14) August 1, 1990.

(c) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective June 1, 1988 as follows:

(1) Cane Creek [Index No. 16-21-(1)] from source to a point 0.5 mile north of N.C. Hwy. 54 (Cane Reservoir Dam) including the Cane Creek Reservoir and all tributaries has been reclassified from Class WS-III to WS-I.

(2) Morgan Creek [Index No. 16-41-1-(1)] to the University Lake dam including University Lake and all tributaries has been reclassified from Class WS-III to WS-I.

(d) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective July 1, 1988 by the reclassification of Crane Creek (Crains Creek) [Index No. 18-23-16-(1)] from source to mouth of Beaver Creek including all tributaries from C to WS-III.

(e) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective January 1, 1990 as follows:

(1) Intracoastal Waterway (Index No. 18-87) from southern edge of White Oak River Basin to western end of Permuda Island (a line from Morris Landing to Atlantic Ocean), from the eastern mouth of Old Topsail Creek to the southwestern shore of Howe Creek and from the southwest mouth of Shinn Creek to channel marker No. 153 including all tributaries except the King Creek Restricted Area, Hardison Creek, Old Topsail Creek, Mill Creek, Futch Creek and Pages Creek were reclassified from Class SA to Class SA ORW.

(2) Topsail Sound and Middle Sound ORW Area which includes all waters between the Barrier Islands and the Intracoastal Waterway located between a line running from the western most shore of Mason Inlet to the southwestern shore of Howe Creek and a line running from the western shore of New Topsail Inlet to the eastern mouth of Old Topsail Creek was reclassified from Class SA to Class SA ORW.

(3) Masonboro Sound ORW Area which includes all waters between the Barrier Islands and the mainland from a line running from the southwest mouth of Shinn Creek at the Intracoastal Waterway to the southern shore of Masonboro Inlet and a line running from the Intracoastal Waterway Channel marker No. 153 to the southside of the Carolina Beach Inlet was reclassified from Class SA to Class SA ORW.

(f) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective January 1, 1990 as follows: Big Alamance Creek [Index No. 16-19-(1)] from source to Lake Mackintosh Dam including all tributaries has been reclassified from Class WS-III NSW to Class WS-II NSW.

(g) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 3, 1992 with the reclassification of all water supply waters (waters with a primary classification of WS-I, WS-II or WS-III). These waters were reclassified to WS-I, WS-II, WS-III, WS-IV or WS-V as defined in the revised water supply protection rules, (15A NCAC 02B .0100, .0200 and .0300) which became effective on August 3, 1992. In some cases, streams with primary classifications other than WS were reclassified to a WS classification due to their proximity and linkage to water supply waters. In other cases, waters were reclassified from a WS classification to an alternate appropriate primary classification after being identified as downstream of a water supply intake or identified as not being used for water supply purposes.

(h) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective June 1, 1994 as follows:

(1) The Black River from its source to the Cape Fear River [Index Nos. 18-68-(0.5), 18-68-(3.5) and 18-65-(11.5)] was reclassified from Classes C Sw and C Sw HQW to Class C Sw ORW.

(2) The South River from Big Swamp to the Black River [Index Nos. 18-68-12-(0.5) and 18-68-12(11.5)] was reclassified from Classes C Sw and C Sw HQW to Class C Sw ORW.

(3) Six Runs Creek from Quewhiffle Swamp to the Black River [Index No. 18-68-2] was reclassified from Class C Sw to Class C Sw ORW.

(i) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective September 1, 1994 with the reclassification of the Deep River [Index No. 17-(36.5)] from the Town of Gulf-Goldston water supply intake to US highway 421 including associated tributaries from Class C to Classes C, WS-IV and WS-IV CA.

(j) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 1, 1998 with the revision to the primary classification for portions of the Deep River [Index No. 17-(28.5)] from Class WS-IV to Class WS-V, Deep River [Index No. 17-(41.5)] from Class WS-IV to Class C, and the Cape Fear River [Index 18-(10.5)] from Class WS-IV to Class WS-V.

(k) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective April 1, 1999 with the reclassification of Buckhorn Creek (Harris Lake)[Index No. 18-7-(3)] from the backwaters of Harris Lake to the Dam at Harris Lake from Class C to Class WS-V.

(l) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective April 1, 1999 with the reclassification of the Deep River [Index No. 17-(4)] from the dam at Oakdale-Cotton Mills, Inc. to the dam at Randleman Reservoir (located 1.6 mile upstream of U.S. Hwy 220 Business), and including tributaries from Class C and Class B to Class WS-IV and Class WS-IV & B. Streams within the Randleman Reservoir Critical Area have been reclassified to WS-IV CA. The Critical Area for a WS-IV reservoir is defined as 0.5 mile and draining to the normal pool elevation of the reservoir. All waters within the Randleman Reservoir Water Supply Watershed are within a designated Critical Water Supply Watershed and are subject to a special management strategy specified in 15A NCAC 02B .0248.

(m) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 1, 2002 as follows:

(1) Mill Creek [Index Nos. 18-23-11-(1), 18-23-11-(2), 18-23-11-3, 18-23-11-(5)] from its source to the Little River, including all tributaries was reclassified from Class WS-III NSW and Class WS-III B NSW to Class WS-III NSW HQW@ and Class WS-III B NSW HQW@.

(2) McDeed's Creek [Index Nos. 18-23-11-4, 18-23-11-4-1] from its source to Mill Creek, including all tributaries was reclassified from Class WS III NSW and Class WS-III B NSW to Class WS-III NSW HQW@ and Class WS-III B NSW HQW@.

The "@" symbol as used in this Paragraph means that if the governing municipality has deemed that a development is covered under a "5/70 provision" as described in Rule 15A NCAC 02B .0215(3)(b)(i)(E) (Fresh Surface Water Quality Standards for Class WS-III Waters), then that development is not subject to the stormwater requirements as described in rule 15A NCAC 02H .1006 (Stormwater Requirements: High Quality Waters).

(n) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective November 1, 2004 as follows:

(1) the portion of Rocky River [Index Number 17-43-(1)] from a point 0.3 mile upstream of Town of Siler City upper reservoir dam to a point 0.3 mile downstream of Lacy Creek from WS-III to WS-III CA.

(2) the portion of Rocky River [Index Number 17-43-(8)] from dam at lower water supply reservoir for Town of Siler City to a point 65 feet below dam (site of proposed dam) from C to WS-III CA.

(3) the portion of Mud Lick Creek (Index No. 17-43-6) from a point 0.4 mile upstream of Chatham County SR 1355 to Town of Siler City lower water supply reservoir from WS-III to WS-III CA.

(4) the portion of Lacy Creek (17-43-7) from a point 0.6 mile downstream of Chatham County SR 1362 to Town of Siler City lower water supply reservoir from WS-III to WS-III CA.

(o) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective November 1, 2007 with the reclassifications listed below, and the North Carolina Division of Water Quality maintains a Geographic Information Systems data layer of these UWLs.

(1) Military Ocean Terminal Sunny Point Pools, all on the eastern shore of the Cape Fear River [Index No. 18-(71)] were reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(2) Salters Lake Bay near Salters Lake [Index No. 18-44-4] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(3) Jones Lake Bay near Jones Lake [Index No. 18-46-7-1] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(4) Weymouth Woods Sandhill Seep near Mill Creek [18-23-11-(1)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(5) Fly Trap Savanna near Cape Fear River [Index No. 18-(71)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(6) Lily Pond near Cape Fear River [Index No. 18-(71)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(7) Grassy Pond near Cape Fear River [Index No. 18-(71)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(8) The Neck Savanna near Sandy Run Swamp [Index No. 18-74-33-2] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(9) Bower's Bog near Mill Creek [Index No. 18-23-11-(1)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(10) Bushy Lake near Turnbull Creek [Index No. 18-46] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(p) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective January 1, 2009 as follows:

(1) the portion of Cape Fear River [Index No. 18-(26)] (including tributaries) from Smithfield Packing Company's intake, located approximately 2 miles upstream of County Road 1316, to a point 0.5 miles upstream of Smithfield Packing Company's intake from Class C to Class WS-IV CA.

(2) the portion of Cape Fear River [Index No.18-(26)] (including tributaries) from a point 0.5 miles upstream of Smithfield Packing Company's intake to a point 1 mile upstream of Grays Creek from Class C to Class WS-IV.

(q) The schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 11, 2009 with the reclassification of all Class C NSW waters and all Class B NSW waters upstream

of the dam at B. Everett Jordan Reservoir from Class C NSW and Class B NSW to Class WS-V NSW and Class WS-V & B NSW, respectively. All waters within the B. Everett Jordan Reservoir Watershed are within a designated Critical Water Supply Watershed and are subject to a special management strategy specified in 15A NCAC 02B .0262 through .0273.

(r) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective September 1, 2009 with the reclassification of a portion of the Haw River [Index No. 16-(28.5)] from the Town of Pittsboro water supply intake, which is located approximately 0.15 mile west of U.S. 15/501, to a point 0.5 mile upstream of the Town of Pittsboro water supply intake from Class WS-IV to Class WS-IV CA.

(s) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective March 1, 2012 with the reclassification of the portion of the Haw River [Index No. 16-(1)] from the City of Greensboro's intake, located approximately 650 feet upstream of Guilford County 2712, to a point 0.5 miles upstream of the intake from Class WS-V NSW to Class WS-IV CA NSW, and the portion of the Haw River [Index No. 16-(1)] from a point 0.5 miles upstream of the intake to a point 0.6 miles downstream of U.S. Route 29 from Class WS-V NSW to Class WS-IV NSW.

(t) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective November 1, 2015 with the reclassification of a section of 18-(71) from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut from Class SC to Class SC Sw. A site-specific management strategy is outlined in 15A NCAC 02B .0227.

History Note: *Authority G.S. 143-214.1; 143-215.1; 143-215.3(a)(1);*
Eff. February 1, 1976;
Amended Eff. November 1, 2015; March 1, 2012; September 1, 2009; August 11, 2009; January 1, 2009; November 1, 2007; November 1, 2004; August 1, 2002; April 1, 1999; August 1, 1998; September 1, 1994; June 1, 1994; August 3, 1992; August 1, 1990.

PROPOSED SWAMP RECLASSIFICATION WITH WATER QUALITY MANAGEMENT PLAN FOR PART OF CAPE FEAR RIVER: PUBLIC HEARING SET FOR FEBRUARY 2015

The Cape Fear River Class SC waters shown on the map below are proposed to be assigned the supplemental Swamp (Sw) classification, and would be subject to the provisions of the Sw designation as well as the provisions of a water quality management plan that is also proposed to be assigned to these waters.

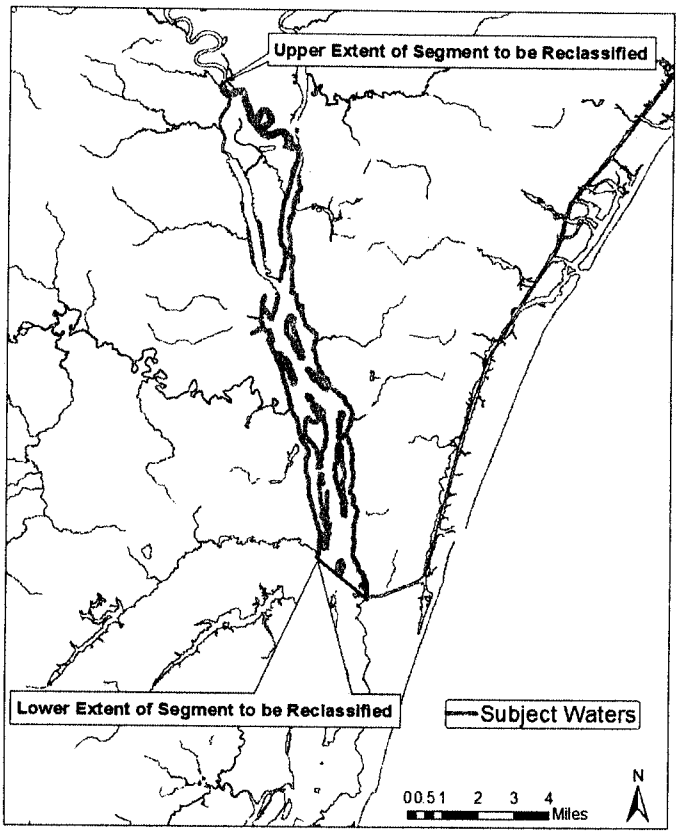
PUBLIC HEARING

Location: USS North Carolina Battleship
1 Battleship Road Northeast
Wilmington, NC 28401

Time & Date: 6:30 p.m., Thursday, February 5, 2015

Purpose: to receive public comments on a proposed reclassification and water quality management plan for a section of the Cape Fear River in Brunswick and New Hanover Counties (Cape Fear River Basin)

Proposed Swamp Reclassification and Water Quality Management Plan
Cape Fear River, Brunswick and New Hanover Counties, NC



NCDENR-Division of Water Resources
Water Planning Section
November 24, 2014

WATERS AFFECTED BY PROPOSED RECLASSIFICATION & WATER QUALITY MANAGEMENT PLAN

The proposed reclassification and water quality management plan concern the portion of the Cape Fear River from the upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut, where the Intracoastal Waterway (ICW) meets the river. No tributaries to this section of the Cape Fear River are to be affected by the proposed actions. Wetlands, developed lands, other open waters, forest lands, shrub/scrub lands, and primarily Class Sw tributaries exist directly adjacent to the subject waters. Several tidal saltwater species, including the federally endangered shortnose sturgeon and federally endangered Atlantic sturgeon, live in these waters. Within the subject waters, there are eight (8) existing NPDES wastewater discharges.

REGULATIONS INVOKED BY PROPOSED RECLASSIFICATION & WATER QUALITY MANAGEMENT PLAN

If the proposed reclassification and management plan become effective, then the pH standard applicable to these waters can be as low as 4.3 if caused by natural conditions, and the dissolved oxygen (DO) standard applicable to these waters can be lower than 5.0 mg/l if caused by natural conditions; currently the DO standard is 5 mg/l, and the pH standard is a range between 6.8-8.5, for the subject waters. In addition, new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges in the subject waters would have to meet specific effluent limits for oxygen consuming wastes. For such domestic facilities, effluent limits of 5 mg/l for BOD_5, 1 mg/l for ammonia, and 6 mg/l for DO would apply. For industrial discharges, site specific best available technology on a case by case basis would be utilized to determine the limits for BOD_5, ammonia and DO. For new individual NPDES wastewater facilities and expansions of existing individual NPDES wastewater discharges, the management plan would include consideration of seasonal effluent limits on a case by case basis, and the following stipulation: Any new or expanded permitted pollutant discharge of oxygen-consuming waste shall not cause the DO of the receiving water to drop more than 0.1 mg/l below the modeled in-stream DO at total permitted capacity.

The proposed management plan is consistent with the current permitting policy for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters. There are currently no known planned new individual NPDES wastewater discharges and one (1) planned expansion of an existing individual NPDES wastewater discharge in the subject waters, which already meets the proposal's requirements. The proposed water quality management plan in conjunction with the Sw designation provides a path forward for the subject waters' dischargers, and thus for local communities, for future planning purposes. Finally, it is unknown how the Sw standards will affect the current DO and pH impairment status of these waters.

A fiscal analysis for this proposal has been completed, and revealed no quantifiable cost or benefit to the ecosystem, humans, implementing agencies, new individual NPDES wastewater discharges, and expansions of existing individual NPDES wastewater discharges.

MEETING FEDERAL TRIENNIAL REVIEW REQUIREMENTS

The public hearing and comment period are to be held in accordance with the federal Clean Water Act that requires States, at least every three years, to review and revise water quality standards. These standards are provided in existing rules NCAC 15A 02B .0100 and .0201 through .0228. The process is in accordance with the Triennial Review and includes an assessment and revision of the designated uses of waters (classifications) and the water quality criteria (standards), which are based on the designated uses. More specifically, this public hearing and comment period are to address the potential assignment of a Sw classification and water quality management plan to a portion of the Cape Fear River. This proposal will result in additional water quality standards applicable to the subject waters.

HOW TO SUBMIT COMMENTS

You may attend the public hearing and provide verbal comments that specifically address the proposed reclassification and water quality management plan for the subject portion of the Cape Fear River. The Hearing Officer may limit the length of time that you may speak at the public hearing, if necessary, so that all those who wish to speak may have an opportunity to do so. In addition, written comments addressing the proposed reclassification and water quality management plan for the Cape Fear River segment will be accepted until March 3, 2015.

All persons interested and potentially affected by the proposal are encouraged to read this announcement and make comments on the proposal. The EMC may not adopt a rule that differs substantially from the text of the proposed rule published in the North Carolina Register unless the EMC publishes the text of the proposed different rule and accepts comments on the new text. The proposed effective date for this proposed reclassification is November 1, 2015. Written comments on the proposed reclassification and water quality management plan for the Cape Fear River segment may be submitted to Elizabeth Kountis of the Division of Water Resources Planning Section at the postal address, e-mail address, or fax number listed below.

FOR ADDITIONAL INFORMATION

This announcement and a map of the subject waters are located on the internet via http://portal.ncdenr.org/web/wq/event-calendar (look under "2015-02-5"). In the case of inclement weather on the day of the scheduled public hearing, please contact the telephone number below for a recorded message regarding any changes to the location, date, or time of the hearing. Further explanations and details on reclassifications may be obtained by writing or calling:

Elizabeth Kountis, DENR-Division of Water Resources, Planning Section
1611 Mail Service Center, Raleigh, NC 27699-1611
phone (919) 807-6418, fax (919) 807-6497, e-mail elizabeth.kountis@ncdenr.gov

To learn more about how the Division of Water Resources protects water quality in North Carolina, go to http://portal.ncdenr.org/web/wq/home/wyk.

NCDENR

North Carolina Department of Environment and Natural Resources

Pat McCrory
Governor

Donald R. van der Vaart
Secretary

January 9, 2015

TO: Major Newspapers of NC

FROM: Ms. Elizabeth Kountis
Environmental Senior Specialist
N.C. Department of Environment and Natural Resources
Division of Water Resources

SUBJECT: Publication of Announcement for Proposed Swamp Reclassification and Water Quality Management Plan for Cape Fear River

Attached is an announcement for the Proposed Swamp Reclassification and Water Quality Management Plan for the Cape Fear River. The legal requirements for notice as required by G.S. 150B-21.2 have been met by publishing this notice in the *NC Register*. Publishing this notice in newspapers is not a statutory requirement and has therefore been recently cut from the Department's budget as non-essential spending. However, we do recognize that newspapers are one of the most effective methods to convey information to the public, and many newspapers contain a public announcement (or similar) section that does not charge a fee to service its readers with public announcements. Therefore, we are presenting the attached announcement to you for your information to publish at your discretion.

Should you decide to publish this information, it would be greatly appreciated if you would notify us. I can be contacted at any of the following:

By Email: Elizabeth.Kountis@ncdenr.gov
By Fax #: (919) 807-6497
By postal mail:
Ms. Elizabeth Kountis
NCDENR-DWR-Planning Section
1611 Mail Service Center, Raleigh, NC 27699-1611
By phone: (919) 807-6418

If you should have any questions, please do not hesitate to contact me. Thank you sincerely for your consideration.

Enclosure

ENVIRONMENTAL MANAGEMENT COMMISSION

Benne C. Hutson
Chairman
Kevin Martin
Vice Chairman

NORTH CAROLINA
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

Pat McCrory, Governor
John Skvarla, Secretary

David W. Anderson
Gerard P. Carroll
Charles Carter
Tommy Craven
Daniel E. Dawson
Charles B. Elam
E. O. Ferrell
Manning Puette
Dr. Lawrence W. Raymond
Dr. Albert R. Rubin
Clyde E. Smith, Jr.
Steve W. Tedder
Julie A. Wilsey

November 13, 2014

MEMORANDUM

TO: Julie A. Wilsey

FROM: Benne C. Hutson

SUBJECT: Hearing Officer Appointment, Lower Cape Fear River Reclassification

I hereby designate you to serve as hearing officer for the public hearing to be held on the proposed reclassification of the Lower Cape Fear River in New Hanover and Brunswick Counties (Cape Fear River Basin) from Class SC to Class SC Sw with a water quality management plan. Staff will be contacting you to discuss the process and establish the date, time, and location of the public hearing. Please present your findings and recommendations to the Environmental Management Commission.

Thank you for your assistance and service.

cc: Tom Reeder
Tom Fransen
Jeff Manning
Elizabeth Kountis
Lois Thomas

An Equal Opportunity Affirmative Action Employer

LIST OF ATTENDEES

PROPOSED RECLASSIFICATION AND WATER QUALITY MANAGEMENT PLAN FOR CAPE FEAR RIVER SEGMENT

PUBLIC HEARING: FEBRUARY 5, 2015, WILMINGTON, NC

Hearing Officer

Wilsey	Julie	Environmental Magagement Commissioner

Div. of Water Resources (CSRRB = Classifications & Standards Rules Review Branch)

Kountis	Elizabeth	Senior Environmental Specialist, CSRRB, Water Planning Section
Kreiser	Gary	Groundwater Vairance and Rulemaking, CSRRB, Water Planning Section
Manning	Jeff	Chief, CSRRB, Water Planning Section
Weaver	Adriene	Senior Environmental Specialist, CSRRB, Water Planning Section
Deamer	Nora	Cape Fear River Basin Planner, Basin Planning Branch, Water Planning Section
Rajbhandari	Narayan	Modeler, Modelling and Assessment Branch, Water Planning Section
Kroeger	Steve	Supervisor, Ecosystems Branch, Water Sciences Section
Ruhlman	Carrie	Monitoring Coalition Coordinator, Ecosystems Branch, Water Sciences Section
Tracy	Bryn	Fish Community Assessments and Environmental Fish Reviews, Biological Assessment Branch, Water Sciences Section
Gregson	Jim	Regional Supervisor, Wilmington Regional Office, Water Qual. Regional Operations Section
Garrett	Stephanie	Water Quality Monitoring, Wilmington Regional Office, Water Qual. Regional Operatons Section
Massengale	Susan	Public Information Officer

Department of Environment and Natural Resources

Bromby	Craig	Assistant General Counsel

Citizens in Attendance (*=made verbal comments)

Last Name	First Nam	Entity Representing	City	County	State
Feller	Donald	Aqua NC	Wilmington	New Hanover	NC
Williams	Donald	Aqua NC	Hampstead	Pender	NC
York	Dawn	Cape Fear River Partnership	Wilmington	New Hanover	NC
Sargent	Dana	Cape Fear River Watch	NA	NA	NA
Yelverton	Frank	Cape Fear River Watch	Wilmington	New Hanover	NC*
Vogt	Ken	CFPUA	Wilmington	New Hanover	NC*
Kreutzberger	Bill	CH2M Hill	Charlotte	Mecklenberg	NC*
McEwen	Tony	City of Wilmington	NA	NA	NA
Thompson	Dacia	Duke Environmental Policy Clinic	Durham	Durham	NC*
Sebastian	Abiles	Duke Environmental Policy Clinic	Durham	Durham	NC*
Longest	Ryke	Duke Environmental Policy Clinic	Durham	Durham	NC*
O'Connor	Shawn	General Electric Company	Wilmington	New Hanover	NC
Kreul	Edward	International Paper	Riegelwood	Columbus	NC*
Henderson	Emily	International Paper	Riegelwood	Columbus	NC
Merritt	James	LCFRP - UNCW	Wilmington	New Hanover	NC*
Tomlin	Andrew	NA	Wilmington	New Hanover	NC
Becker	May	NA	Chapel Hill	Orange	NC
Hasvell	Dianne	New Hanover County	NA	NA	NC
O'Connor	Jennifer	self	Leland	Brunswick	NC
Gattett	Rick	self	Burgaw	Pender	NC
Mallin	Michael	UNCW	Wilmington	New Hanover	NC*
McIver	Matthew	UNCW	Wilmington	New Hanover	NC*
Shew	Roger	UNCW	Wilmington	New Hanover	NC
Alexander	Mike	Vopak Terminals	Wilmington	New Hanover	NC

Kountis, Elizabeth

From: Glenn Harbeck
Sent: Wednesday, January 07, 2015 12:03 PM
To: Sterling Cheatham; Richard King
Cc: Tony Caudle; Margaret Haynes; elizabeth.kountis@ncdenr.gov
Subject: RE: Comment Period and Hearing for Lower Cape Fear River Proposed Sw Reclassification and Water Quality Management Plan

Just a clarification. Phil is not the voting member serving on the Cape Fear River Program. At the time the vote was cast, it was either Council Member Laura Padgett or Council Member Margaret Haynes, if Ms. Haynes was the City's rep at the time of the most recent vote. Sorry for the clumsy wording!

Glenn

Glenn Harbeck, AICP
Director of Planning, Development & Transportation
City of Wilmington
305 Chestnut Street
P.O. Box 1810
Wilmington, NC 28402-1810
910-341-5808 glenn.harbeck@wilmingtonnc.gov

CITY-BUILDING:
The most constructive way to view the relationship between the planning agency and the development community is as PARTNERS in the business of city-building. The planning agency helps its citizens and leaders create a clear vision of the future city. The developer helps implement the city's vision.

WILMINGTON NORTH CAROLINA
www.wilmingtonnc.gov

From: Glenn Harbeck
Sent: Wednesday, January 07, 2015 11:48 AM
To: Sterling Cheatham; Richard King
Cc: Tony Caudle; Margaret Haynes; 'elizabeth.kountis@ncdenr.gov'
Subject: RE: Comment Period and Hearing for Lower Cape Fear River Proposed Sw Reclassification and Water Quality Management Plan

Wilmington Senior Planner Phil Prete advises that, as a voting member of the Lower Cape Fear River Program, we as the City of Wilmington, have expressed our support for the reclassification by our vote for the measure. However, if we need to reiterate our support on the City's letterhead, signed by the Mayor or Council's rep to the LCFRP. we can certainly do so. As the City's technical rep, Phil plans to attend the hearing on February 5th at the Battleship.

Glenn

Glenn Harbeck, AICP
Director of Planning, Development & Transportation
City of Wilmington
305 Chestnut Street

PROPOSED SWAMP RECLASSIFICATION WITH WATER QUALITY MANAGEMENT PLAN FOR PART OF CAPE FEAR RIVER:
PUBLIC HEARING - FEBRUARY 2015

Good evening. My name is Ed Kreul. I work for International Paper and have been involved with the Lower Cape Fear River Program since 1997.

The potential water quality impairment of the Lower Cape Fear River has been a topic of discussion my entire time with the program. I am here to speak in support of this proposed reclassification as it is strongly indicated by the technical information and resolves a long standing regulatory issue affecting municipal and industrial wastewater dischargers.

First I would like to provide a little more background on the Lower Cape Fear River Program

- The Program was formed in May 1994 as one of the first water quality monitoring coalitions established through a memorandum of agreement (MOA) with the North Carolina Department of Environment and Natural Resources (DENR). These coalitions use comprehensive and coordinated monitoring programs rather than individual NPDES permit requirements to perform in-stream monitoring.
- This collective approach provides substantially more data than individual permittees would, facilitates developing a better understanding of the Lower Cape Fear River and provides a mechanism for information exchange and public education.
- In cooperation with the University of North Carolina Wilmington's Center for Marine Science, the program has collected data to assess chemical and ecological conditions in the river since 1995.
- Currently, there are 17 National Pollutant Discharge Elimination System (NPDES) permit holders that are party to the MOA and many other members of the Lower Cape Fear River Program representing a range of governmental and non-governmental organizations form the Cape Fear area.

Now I would like to give a little history of the work on dissolved oxygen in the estuary and what I see will be the results of the proposed changes.

- Since 1998, the section of the Lower Cape Fear River estuary from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut has been listed on the State of North Carolina's impaired waters list for dissolved oxygen (DO). In 2006, DENR added pH as impaired for this segment.
- DENR had been pursuing development of a total maximum daily load (TMDL) to address low DO by further limiting oxygen demanding pollutants from point source discharges.
- Toward that end, the agency undertook an extensive effort to develop a three-dimensional hydrodynamic and water quality response model for this section of the River. That modeling work showed that even under natural conditions, the 5 milligrams per liter (mg/L) standard for dissolved oxygen would not be met during considerable periods of time in the summer. The modeling also showed that point-source discharges have a relatively minor impact on dissolved oxygen.
- Supplementing the current "SC" classification of the river with a swamp designation, just as upstream fresh waters are classified, will recognize the influence of natural drainage from riverine and saltwater marsh systems. The agency can then take these natural conditions into account in permitting decisions.
- Meanwhile, Lower Cape Fear River Program members and all new and expanding NPDES dischargers will continue to meet highly protective discharge limits for oxygen consuming wastes.
- This proposal will clarify discharge permit administration and further codify the high treatment standards for point source wastewater discharges. I support this classification and the Division of Water Resources taking actions to protect the high quality waters of the Lower Cape Fear River estuary.

.....

Statement by Bill Kreutzberger

CH2M HILL

Consultant to Lower Cape Fear River Program

Feb. 5, 2015

I am Bill Kreutzberger, Fellow Technologist with CH2M HILL and a consultant to the Lower Cape Fear River Program. I am here to speak in favor of the proposed reclassification to add the supplemental Swamp designation to a portion of the estuary and the proposed management strategy for point sources.

I have been involved with water quality issues in the Lower Cape Fear River for nearly the past 30 years as a consultant and in my prior employment with the state's water quality program. There have been a number of comments made this evening in support and against the proposed reclassification. I want to emphasize a few key points:

1. The swamp designation allows the state to evaluate whether natural or man-made effects are contributing to any deviation to the assigned water quality criteria for dissolved oxygen and pH – it does not say that all deviations are natural

2. The swamp designation for the lower Cape Fear River estuary in no way limits the ability of the state to address nonpoint source contributions of nutrients and other pollutants

3. The coastal wetlands drainage contributions to low DO and pH conditions in the estuary have been recognized for a long time and the supplemental swamp designation was originally included when the classification and water quality standards for the Cape Fear River Basin were first adopted in the early 1960s. The swamp designation was removed in 1982 without any supporting technical analysis.

4. While we certainly acknowledge and strongly support the work done by researchers within the Lower Cape Fear River Program focusing on impacts of agricultural activities and animal operations, the DO

conditions in the area being affected by the reclassification have not appreciatively changed in the last 20 years – a period in which the agricultural animal populations increased dramatically.

5. In regard to the specific role of sediment oxygen demand and conclusions of the modeling report, I believe earlier statements inappropriately interpreted the report. The sediment oxygen demand rates in the model are based on measured values – and are actually quite low and typical of many river and estuarine systems in North Carolina. So the statement that these rates can be appreciably reduced is not consistent with the measurements done to support the model development. We will provide additional technical comment on this issue.

6. The low DO conditions of the lower Cape Fear River estuary is not unique – and there is considerable effort to evaluate appropriate DO conditions for coastal rivers and estuaries from Florida to New England – with strong recognition that natural conditions contribute to the low DO.

In conclusion, the proposed reclassification and the management strategy aimed at point sources dischargers assists in resolving a regulatory issue that some members of the Lower Cape Fear River Program and the State have been dealing with for more than 15 years. This reclassification and strategy recognizes the minimal effect point sources have on DO in the river and provides certainty as facilities move forward in planning for the future.

Use attainability analysis

Cape Fear River SC to SC Swamp Reclassification

02.05.2015 NCDENR Public Hearing

CFPUA Position Statement

Good evening. My name is Kenneth L. Vogt Jr., PE, BCEE, and I serve as Wastewater Treatment Superintendent for the Cape Fear Public Utility Authority (CFPUA). I have been authorized by CFPUA to present this position on their behalf.

The CFPUA was formed in 2008 to manage the water treatment, water distribution, wastewater collection, and wastewater treatment functions previously performed by the City of Wilmington and New Hanover County. Since about 1998, while serving in the referenced capacity, I also had the opportunity to become involved with the Lower Cape Fear River Program (LCFRP) and its TMDL-related sub-committees. I'm here this evening to represent the Authority's position in support of the reclassification of selected sections of the Cape Fear River from Class SC to SC - Swamp and to provide justification for adopting this position.

Initially, the City of Wilmington (COW) and New Hanover County (NHC) and, subsequently, the CFPUA, have been interested in dissolved oxygen (DO) depletion within the Cape Fear River since 1998 when a significant portion of the Lower Cape Fear River estuary was declared impaired and placed upon the 303d list. These determinations cast doubt not only upon the river's assimilative capacity to receive wastewater treatment plant (WWTP) effluent but also the overall ability of the area to meet designated uses and to sustain a favorable quality of life due to deteriorating water quality.

Any TMDL for low DO instituted within the estuary is believed to exert far-reaching influences over many watershed activities. DO depletion can be attributed to numerous influences including virtually all forms of anthropogenic (man-made) activities such as agricultural and urban land development as well as certain natural conditions. Furthermore, causes for low DO within the estuary are not limited to being physically located within the estuary. Therefore, not only sources within the impaired reaches but sources of DO depletion throughout the entire Cape Fear River watershed would likely be subject to a low DO TMDL's restrictions.

In conjunction with COW NPDES permitting, in 2000/2001 COW undertook extensive modeling which revealed that point sources (such as WWTP discharges) within the estuary comprised a relatively minor/insignificant basis for DO depletion. Subsequent follow-up efforts conducted by NCDENR culminated in 2009 with similar findings. Collectively, these studies suggest that anthropogenic sources were not the most significant cause for DO depletion and perhaps non-anthropogenic (natural) sources predominated and exerted a more pronounced effect upon DO depletion within the estuary. It is now apparent to both the regulators and the regulated community that imposition and enforcement of additional controls were unlikely to yield a corresponding improvement in DO sufficient to achieve the mandated 5.0 mg/l DO standard.

Of several options considered, the one selected as being most feasible was reclassification of a section of the Cape Fear River estuary from Class SC to SW - Swamp together with implementation of a water quality management plan. While recognizing the DO-depleting tendencies of natural conditions, it imposes stringent levels of treatment upon new and expanding NPDES discharges in addition to prescribing that these discharges will not cause the receiving water DO to drop more than 0.1 mg/l below modeled in-stream DO levels at permitted capacities. This measure clarifies, stabilizes, and resolves much of the uncertainty which existed concerning management of current and future NPDES permitting. While this proposal may seem to be a partial solution inasmuch as it addresses primarily point sources, NCDENR has indicated it will continue to assess and address non-point sources potentially contributing to oxygen depletion or other sources of pollution through ongoing water quality programs.

CFPUA supports the proposed action consisting of reclassification of a section of the Cape Fear River estuary with the addition of the supplemental SW - Swamp classification together with implementation of a water quality management plan as a reasonable solution to the long standing and pending Cape

Fear River low DO TMDL. It accepts its responsibility for its NPDES point sources to conform to the high level of treatment stipulated within the proposed action. The proposal codifies point source discharge requirements to a high level of treatment and does not limit further efforts toward addressing other sources of oxygen depleting materials. In so doing, we believe the aggregated effect of the proposed action will enhance the long term health of the estuary and improve the quality of life enjoyed by its inhabitants.

My name is James Merritt and I am here speaking on behalf of the Lower Cape Fear River Program. I have served as coordinator for the program since its inception in 1994. The LCFRP is an ongoing research and monitoring program that is supported by the Center for Marine Science at UNCW, citizens groups, industry, business, and local, regional and state government.

I would especially like to thank NCDENR and the Division of Water Resources for encouraging the establishment of this program and the other similar ones working on other sections of the Cape Fear River and other river water sheds in North Carolina.

The Lower Cape Fear River Program represents a positive collaboration between academia, industry, NCDENR and the public.

The objectives are to develop an understanding of the fundamental scientific processes shaping and controlling the Cape Fear River Estuary and provide a mechanism for information exchange and public education.

The foundation of the Program is a large-scale water quality and biota assessment program developed in collaboration with DENR and covering the estuary and a large portion of the lower watershed.

Numerous physical, chemical, and biological measurements are being collected on a regular basis at many key locations to supplement data collected by DENR.

The availability of regular, replicated, long-term data covering a wide area of this large system is extremely valuable to biologists, chemists, physicists, and geologists working in near shore marine environments, estuarine waters and freshwater.

This basic information and understanding is available to public officials and environmental managers to help increase the effectiveness of management practices designed to improve the river water quality, maintain sustainable economic development and protect the overall ecosystem of the Cape Fear River by stimulating ecologically friendly practices by all people living in the watershed.

The Program has an Advisory Board,(Chairman Chris May) and a Technical committee (Chairman Ed. Kreul) which consists of representatives from environmental groups, regulatory agencies, local government, industries, agriculture, the business community, and academia. Meetings are held bimonthly to discuss data and other issues regarding the program.

The Lower Cape Fear River Program has been working the NCDENR Division of Water Resources since 1998 on the EPA mandated TMDL for the Dissolved oxygen violation in the Lower Cape Fear River. The subcommittee working with the DWR and using all data available proposed a plan of action to help determine a solution and resolve this issue. The Lower Cape Fear River Program submitted a recommendation for this reclassification March 5, 2014 including a packet of data supporting the recommendation . I therefore I support the current recommendation under consideration

James F Merritt, Ph. D

NORTH CAROLINA
FARM BUREAU FEDERATION, INC.

PO Box 27766, Raleigh, NC 27611 Phone: 919-782-1705 Fax: 919-783-3593 www.ncfb.org

March 3, 2015

Ms. Elizabeth Kountis
NC Division of Water Resources
Water Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611

Delivered via email: elizabeth.kountis@ncdenr.gov

Dear Ms. Kountis,

The North Carolina Farm Bureau (NCFB) is North Carolina's largest general farm organization, representing the interests of farm and rural people in our State. This letter is to comment on the proposed reclassification of a portion of the Lower Cape Fear River from Class SC to Class SC Sw waters by the Environmental Management Commission (EMC). This reclassification request was submitted by the Lower Cape Fear River Program, of which NCFB is an Advisory Board member. NCFB supports the reclassification request as proposed by the EMC.

The Lower Cape Fear River is currently on the 303(d) list as an impaired waterbody due to low dissolved oxygen. However, studies and modeling performed on behalf of the Lower Cape Fear River Program have established that the low dissolved oxygen is due to natural conditions. Specifically, natural drainage from riverine wetlands and marshes of the Black and Northeast Cape Fear Rivers results in dissolved oxygen levels less than 5 mg/l in the Lower Cape Fear River. Both the Black and Northeast Cape Fear Rivers currently have the supplemental Sw designations, and contribute significant flow to the Cape Fear River.

The supplemental Sw designation would allow dissolved oxygen to be less than 5 mg/l and the pH to be as low as 4.3, if caused by natural conditions. As demonstrated by the Lower Cape Fear River Program and discussed below, even significant reductions in both point and nonpoint source loadings would not result in attainment of the dissolved oxygen standard of 5 mg/l during summer months.

The Lower Cape Fear River Program developed a series of technical memos to support the reclassification request. Memo number two analyzes dissolved oxygen trends in the river since 1984. The analysis shows that dissolved oxygen levels have remained constant even with a 25 percent reduction in BOD loading from point sources over the same period. This analysis supports the conclusion that the dissolved oxygen impairment is a result of natural conditions. Memo number three analyzes water quality monitoring data at various locations in the watershed. The analysis shows that dissolved oxygen levels are consistently lower in the Black and Northeast Cape Fear Rivers (which currently carry the Sw designation) than at Lock and Dam 1 on the main stem of the Cape Fear. This analysis shows that dissolved oxygen levels in

the Lower Cape Fear River are negatively influenced by the natural swamp conditions of the Black and Northeast Cape Fear Rivers.

Memo number four summarizes two modeling efforts by Tetra Tech. The first model indicates that wetland/marsh and sediment oxygen demand accounts for 75 percent of oxygen demand in the Lower Cape Fear River. The second model shows that even with a 70 percent reduction in nonpoint source loading, the Lower Cape Fear River would still have dissolved oxygen levels below 5 mg/l 20 percent of the time in summer months. This memo demonstrates that natural conditions are the main contributor to the low dissolved oxygen levels of the lower Cape Fear River, and supports the Sw classification.

The proposed rule includes a point source management strategy. Due to existing requirements of the Primary Nursery Area designation and the accompanying HQW limits, DWR determined that there would be no additional cost to implement the point source strategy.

We recommend that no nonpoint source strategy be included in the final rule. Based on recent nutrient strategies (Jordan and Falls Lakes), any nonpoint source strategy will include all nonpoint source categories (agriculture, development, stormwater, etc.). Based on Tetra Tech models, even a 70% reduction in oxygen demanding load from nonpoint sources would not change the impaired status. However, adding a nonpoint source strategy would impose significant costs to the state for implementation, as well as to landowners, local governments, and farmers, without significant benefit.

NCFB supports this reclassification request as proposed, and encourages approval by the EMC without changes. As summarized above, the reclassification is warranted because the natural conditions of the Lower Cape Fear River, and the influence of the swamp waters of the Black and Northeast Cape Fear Rivers, result in dissolved oxygen levels below 5 mg/l.

Thank you for the opportunity to provide comments on the proposed Lower Cape Fear River reclassification. If you have questions about any of our comments or would like more information, you can contact me by phone at (919) 987-1257 or by email at keith.larick@ncfb.org.

Sincerely,

Keith Larick
Special Projects Director

March 3, 2015

Elizabeth Kountis
DENR-Division of Water Resources, Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611

Subject: Additional Comments Regarding the Proposed Reclassification of the Lower Cape Fear River with Supplemental "Swamp" Classification and Proposed Water Quality Management Plan

Dear Ms. Kountis:

On behalf of representatives of the Lower Cape Fear River Program (LCFRP) that testified at the public hearing, I am writing to provide some additional comments in support of the proposed subject reclassification and water quality management plan.

At the public hearing on February 5, we had four speakers speak on behalf of the program including:

- Ken Vogt – Wastewater Superintendent for Cape Fear Public Utility Authority
- Ed Kreul - Manager - Environment, Health, Safety and Sustainability for International Paper
- Bill Kreutzberger – Consultant with CH2M HILL
- Jim Merritt – Executive Director of the Lower Cape Fear River Program

The speakers discussed the coordinated efforts of the LCFRP and the Department of Environment and Natural Resources (DENR) to assess the issues in the estuary, the technical justification for the propose reclassification and water quality management plan, and the benefits of this action. Written copies of comments were submitted at the hearing.

Based on some comments made at the public hearing, we want to provide some supplemental information and to offer some clarifying language to the water quality management plan language as proposed.

Responses to Comments in Opposition

Overview

Several of the commenters opposed the reclassification primarily because of concern about nonpoint sources - specifically agricultural runoff related to animal operations. The concern was that the proposal did nothing to address agricultural nonpoint sources and that these were a major contributor to the low DO situation in the estuary. In making these comments, commenters were either unaware of or misinterpreted prior studies that have occurred since the Lower Cape Fear River estuary (LCFRE) was listed as impaired in 1998. The LCFRP formally made the request for reclassification in March 2014 and in support of the request included technical information that summarized and interpreted historical data as well as recent water quality modeling studies completed in 2009 by Dr. James Bowen of UNC-Charlotte under contract to DENR. This information was incorporated in four technical memoranda that were included with the reclassification request. Some of the key points from that submittal include the following:

- Swamp influences were identified even during the early studies of the river/estuary in the 1950s and the entire LCFRE and tributaries were recommended and subsequently classified with the supplemental "Swamp" classification in the early 1960s which was later removed from the estuary with no technical justification.

- The hydrodynamic and water quality model completed in 2009 demonstrated that the point sources have a minor contribution to the DO deficit and that even with 30 to 70 percent reductions in loadings of oxygen demanding materials from tributaries and wetlands/marsh systems (a combination of anthropogenic and natural sources), the DO standard of 5 mg/L could not be achieved between 20 and 30 percent of the time.
- An updated trend analysis of DO conditions in the LCFRE showed no significant trend in DO levels over the 20 year period from 1994 through 2013 while the loading of ultimate Biochemical Oxygen Demand (BODu) from major point sources declined by 23 percent over the same time period confirming model results indicating that point sources are having a minor impact on DO levels in the LCFRE.
- The evaluation of water quality data at the boundary conditions supports the conclusion that inflows from the swamp areas have a significant impact on water quality in the Cape Fear River. The levels of nutrients, DO, and pH are consistently different between the station at Lock & Dam 1 (L&D1) on the main stem of the Cape Fear River, and in the major blackwater tributaries – the Black River and the NE Cape Fear River.
- Modeling analyses conducted in 2001 and 2009 provide further weight of evidence collectively that flow and oxygen-demanding loads from wetlands/marsh systems and SOD are driving low DO during the summer period and suggest that reinstitution of the supplemental "Swamp" designation for the LCFRE should be considered by DENR and the EMC.

Attachment 1 to this letter summarizes these Technical Memoranda and the major technical points that support the reclassification.

Impact of Nonpoint Sources

There were several comments that pointed out the significant animal population in coastal counties in the Cape Fear River watershed as well as highlighting that the waste exceeded the ability of soils and crops to utilize the nutrients. We believe that this information is anecdotal and indicative of potential for water quality problems to occur. The main way these nutrients could impact dissolved oxygen in the portion of the estuary modeled is through increases in algal productivity that could impact daily DO variations as well as generate organic material that can degrade and impact DO either directly or through accumulation in sediments and generating sediment oxygen demand (SOD). The water quality modeling completed by Dr. James Bowen of UNC-Charlotte (a recent appointee to the Science Advisory Committee to aid DENR's Nutrient Criteria Development Plan) indicates in the modeling report that nutrients and associated algal productivity is currently having a minor impact on the DO regime in the Lower Cape Fear River Estuary.

Importance of Sediment Oxygen Demand

There were some comments that specifically pointed out that Dr. Bowen's modeling report indicated sensitivity of the model to SOD and that runoff from animal operations was a significant contributor to SOD through a direct contribution of long term BOD and through contribution to algal productivity. It was indicated that this sensitivity analysis specifically showed the importance of SOD and if SOD rates were reduced, presumably through more controls on agricultural runoff, DO concentration in the river would be above 5 mg/L a substantial portion of the time.

In considering this comment, it is important to review the modeling information and specifically SOD. In Technical Memorandum 4, submitted in support of the reclassification request and summarized in Attachment 1, it was concluded that "wetland/marsh and sediment oxygen demand (SOD) sources accounted for between 75 and 80 percent of all oxygen demand in the LCFRE". However, it is also important to note that SOD rates were a calibrated value in the model which was set after reviewing measurements conducted by DENR. The applied rate in the model is 0.4 gm/m2/day which is actually quite low. The

following is a summary of measured SOD rates (using the average concentration in $g/m^2/day$ at each location normalized to 20 degrees C) for the Cape Fear River Basin as a whole and the portion of the basin downstream of Lock & Dam No. 1:

All 67 locations In Cape Fear River Basin	
Min	0.19
Median	1.11
Max	6.48
Std. Dev	0.95

16 locations below L&D 1	
Min	0.19
Med	0.48
Max	6.48
Std. Dev	1.47

Dr. Bowen's applied SOD rate of 0.4 is already below the median for both the entire river basin and the area below L&D 1 datasets. We believe these low rates indicate that while the model showed sensitivity to SOD rates, the rates used in the model indicate there is little opportunity to further reduce these rates through management of nonpoint sources. A 50 percent reduction in SOD from 0.4 would place the resulting rate (0.2) as the second lowest rate measured in the entire river basin. Based on the DENR data, this is not a likely scenario.

The point of Technical Memorandum 4 is to demonstrate the relative importance of wetlands and salt marsh to accurately predicting DO in the LCFRE in the modeled areas. First hypothesized by Tetra Tech (Tt) in 2001, Dr. Bowen's work demonstrated an even greater impact from the wetlands and salt marsh using more areal coverage and reducing SOD rates (from those applied by Tt during earlier scoping level modeling) and causing the wetlands and salt marsh to have an even larger impact than originally hypothesized. This information clearly supports that view that there is a significant "natural" contribution to the observed low DO values in the river and supports the proposed action to reclassify the river as "swamp" waters.

A Use Attainability Analysis is Required to Reclassify the Lower Cape Fear River as "Swamp"

One commenter indicated that a use attainability analysis was required to support the proposed action. US EPA water quality standards regulations included in 40 CFR 131.10 (j) states:

> *(j) A State must conduct a use attainability analysis as described in § 131.3(g) whenever:*
> *(1) The State designates or has designated uses that do not include the uses specified in section 101(a)(2) of the Act, or*
> *(2) The State wishes to remove a designated use that is specified in section 101(a)(2) of the Act or to adopt subcategories of uses specified in section 101(a)(2) of the Act which require less stringent criteria.*

The proposed action to classify a portion of the estuary as "Swamp" is not impacting the designated use of the estuary (which do meet the uses specified in the Clean Water Act) nor does it remove a use or require less stringent water quality criteria. The current DO and pH criteria remain in effect for the area designated as "Swamp". However, the narrative portion of the standard allows the State to make a determination as to whether any deviation from these criteria is due to natural causes. If this determination is made, values below the numerical criteria are not considered a deviation from the water quality standard.

The Proposed Action is to Get Around the Development of a Total Maximum Daily Load (TMDL)

Generally, most commenters agreed that point source dischargers have little impact on DO levels in the estuary. However, one commenter specifically indicated that the proposed action was to get around the development of a TMDL. On the contrary, the LCFRP and DENR worked towards development of a TMDL from about 2000 through 2010. At that point, DENR determined that development of a TMDL was not feasible due to the apparent natural contribution to DO levels below the standard of 5 mg/L. The request for reclassification developed from this effort. DENR staff has determined that the proposed reclassification supplemented with the proposed water quality management plan is an appropriate way to address this issue.

Clarification to the Proposed Water Quality Management Plan Language

In discussions that lead to the proposed water quality management plan requirements, it was clear that this language was to apply to sources of domestic and industrial wastewater. To completely clarify this, the following additions are suggested to the proposed language, marked in red, as follows:

(1) All new individual NPDES wastewater discharges and expansions of existing NPDES wastewater discharges permitted in accordance with 15A NCAC 02H .0102 (1), (2) and (3) shall be required to provide the treatment described below:

(A) Oxygen consuming wastes: Effluent limitations shall be as follows: BOD_5= 5 mg/l, NH_3-N = 1 mg/l and DO = 6 mg/l, or site-specific best available technology on a case-by-case basis for industrial discharges. Seasonal effluent limits for oxygen-consuming wastes will be considered on a case-by-case basis in accordance with 15A NCAC 2B.0404. Any new or expanded permitted pollutant discharge of oxygen-consuming waste shall not cause the dissolved oxygen of the receiving water to drop more than 0.1 mg/l below the modeled in-stream dissolved oxygen at total permitted capacity.

This completes our supplemental comments on the proposed reclassification of a portion of the Lower Cape Fear River estuary to include the supplemental "Swamp" classification and the proposed water quality management plan specified as part of 15A NCAC 2B .0227. We strongly support adoption of this classification and the management plan, with the clarifying language, by the Environmental Management Commission.

Sincerely,

CH2M HILL

William A. Kreutzberger
Vice President

c: Jim Merritt/UNCW
Ken Vogt/CFPUA
Ed Kreul/International Paper

Attachment 1

Technical Memoranda Submitted in Support of the Reclassification Request

Supporting Information

There is a wealth of research and technical assessment studies that have been conducted on the LCFRE since the formation of the LCFRP in 1995, as well as during the 40 years prior to that time. In discussing this reclassification request with DWR staff, it was suggested that a summary of information be prepared to support the reclassification request. Four Technical Memoranda (TM) have been prepared in support of this reclassification request and are included as Attachments to this letter. The following is a brief summary of each TM.

TM 1 - Summary of Background Information and Previous Studies for the Lower Cape Fear River

This TM served to review available background information for the LCFRE dating back to original studies in the 1950s where water quality and pollutions sources were assessed and initial recommendations on stream classifications were made. Key studies and assessments up to the present time were also reviewed and a bibliography or studies and research papers was also included. A several of the key points from this TM include:

- Swamp influences were identified even during the early studies and the entire LCFRE and tributaries were recommended and subsequently classified with the supplemental Sw classification
- The supplemental Sw classification was removed from the Class SC portion of the Cape Fear River in 1981 without extensive evaluation for the basis of this change
- LCFRP monitoring in the mid to late 1990s documented the impact of swamp drainage following hurricanes, similar to what was documented during the 1990s
- The EFDC hydrodynamic and water quality model completed in 2009 demonstrated that the point sources had a minor contribution to the DO deficit and that even with 30 to 70 percent reductions in loadings of oxygen demanding materials from tributaries and wetlands/marsh systems (a combination of anthropogenic and natural sources), the DO standard of 5 mg/L could not be achieved between 20 and 30 percent of the time.

TM 2 - Updated Trend Analysis of DO Conditions and Pollutant Loading from Point Sources

This TM was an update of an analysis done in 2003. The previous DO trend analysis found no statistically significant trend for DO for the period of 1984 through 2002 for DO conditions at several stations within or immediately adjacent to the 303(d) listed portion of the LCFRE. The same conclusion was drawn for the period of 1991 through 2002, despite a statistically significant reduction in major point source ultimate

biochemical oxygen demand (BODu) load of approximately 25 percent for that period. The updated analysis used monitoring data and information on point source loading from 1994 through 2013. The updated point source analysis focused on International Paper and Cape Fear Public Utilities Authority (CFPUA) Northside and Southside discharges since these facilities comprise over 90 percent of the point source loading to the local watershed. This analysis also showed no significant trend in DO levels in the LCFRE over the 20 year period while the loading of BODu from these three facilities declined by 23 percent over the same time period. This analysis confirms model results indicating that point sources are having a minor impact on DO levels in the LCFRE.

TM 3 - Analysis of Long-term Data near the Limits of the Tidal Influence for the Cape Fear River, Black River, and NE Cape Fear River

This TM presents an analysis of water quality parameters at the sampling stations representative of inflows to the system, with the purpose of examining issues related to a supplemental Sw classification for the estuary. Data was examined for several key parameters, including nutrients, pH, and DO, that are related to the occurrence of low DO in the Cape Fear River. The evaluation of water quality data at the boundary conditions supports the concept that inflows from the swamp areas have a significant impact on water quality in the Cape Fear River. The levels of nutrients, DO, and pH are consistently different between the station at Lock & Dam 1 (L&D1) on the main stem of the Cape Fear River, and in the major blackwater tributaries – the Black River and the NE Cape Fear River. A distinct response from these inflows can be seen in the levels for these parameters in the portion of the Cape Fear River near Navassa, providing additional supporting evidence that water quality in the Cape Fear River is significantly influenced by the conditions found in the swamp areas tributary to the river downstream of L&D1.

TM 4 - An Analysis of Model Results to Assess the Relative Impact of Riparian Wetlands and Salt Marshes versus other Tributary Loadings

This TM used the results of the two modeling efforts with the EFDC model in the 2000s to examine the technical basis for a supplemental Sw classification for the LCFRE. The two modeling studies included the initial EFDC model developments by Tetra Tech on behalf of the City of Wilmington and New Hanover County and the follow up work by the University of North Carolina – Charlotte on behalf of NC DENR. Both modeling efforts demonstrated that the impact from point source loads in the LCFRE contributes to less than 10 percent of the DO deficit in the LCFRE. The 2001 modeling effort demonstrated that an accurate calibration could not be achieved without representing the wetting and drying of adjacent low elevation wetland and salt marsh areas. That modeling estimated that wetland/marsh and sediment oxygen demand (SOD) sources accounted for between 75 and 80 percent of all oxygen demand in the LCFRE. The 2009 modeling effort validated and expanded the influence of adjacent marshland based on more detailed analysis. Further, application of the 2009 model that simulated up to 70 percent of nonpoint source load reduction demonstrated that even with such large pollutant loading reductions, DO concentrations would be expected to be below 5 mg/L approximately 20 percent of the time in the LCFRE during the summer. Therefore, the 2001 and 2009 modeling analyses provide further weight of evidence collectively that flow and oxygen-demanding loads from wetlands/marsh systems and SOD are driving low DO during the summer period and suggest that reinstitution of the supplemental Sw designation for the LCFRE should be considered by DENR and the EMC.

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MAR 02 2015

Ms. Elizabeth Kountis
Division of Water Resources Planning Section
North Carolina Department of Environment
and Natural Resources
1611 Mail Service Center
Raleigh, NC 27699-1611

Dear Ms. Kountis:

Following receipt of the hearing announcement for the "Proposed Swamp Reclassification with Water Quality Management Plan for Part of the Cape Fear River," the EPA reviewed several documents prepared in support of the subject reclassification. The EPA found these documents summarized well how the reclassification came to be requested, along with summaries of the existing studies that have been completed, to better understand the cause(s) behind the dissolved oxygen (DO) levels which on occasion are below the currently applicable 5 mg/L DO criterion. These documents also discuss whether there is any longer a need for the development of a Total Maximum Daily Load (TMDL). After reading these documents, we thought it would be beneficial to make specific comments to ensure that the resulting final criteria, or more specifically the possibility for lower pH and DO values, are adequately protective of the waterbody. Additionally, EPA supports the State's continued efforts to make improvements in water quality that still may be desired, such as through decreases from anthropogenic sources, following the change in reclassification.

The EPA provides the following comments to the State, grouped by topic. These comments are also being made to ensure the State provides the necessary supporting documentation at the time of submittal as well as consider possible revisions to the proposal where indicated below.

Natural versus Anthropogenic Influences and Swamp Classification

1) The fourth technical memorandum indicates that modeling estimates 75-80% of the oxygen demand in the Lower Cape Fear River comes from wetland/marsh and SOD sources. While the analysis of the non-anthropogenic sources is useful to supporting the proposed swamp classification, when making the argument that alternative criteria are appropriate for a given waterbody, particularly on the basis of natural background, the EPA must consider whether a condition is exacerbated by other influences which are not considered natural. As indicated in the first technical memorandum, when eliminating the wastewater point source loadings the 10th percentile DO did increase. The State could consider a revision to the DO and pH language indicating that sources which are not natural will still need to be considered and addressed during activities which consider in-stream and downstream water quality, like permitting or future criteria development efforts. Additional comments on DO and pH are discussed later.

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2) Within the materials, it was noted that swamp classification was removed from this segment in 1981. In the October 6, 1981 report of proceedings, a staff representative indicated the streams "had improved enough so that [the streams can] meet the C standard without being allowed the designated exception." EPA recommends the state further address this previous change which removed the swamp classification as it relates to the proposed change, reverting it back to a swamp classification.
3) As described in the definition for swamp waters, such waters "have very low velocities and other characteristics which are different from adjacent streams draining steeper topography." Since this relates to the proposed classification, the State should provide additional documentation indicating the velocities and other characteristics that make the swamp classification appropriate for the Lower Cape Fear River.

Allowance for DO less than 5 mg/L

1) As an alternative to including the type of language suggested in item one above, the State could consider some specific lower bound be selected for DO, as is the case with pH. Future assessments of the waterbody will be much more streamlined and reproducible if a specific DO criterion minimum is in place. Also, for dischargers that are not new or expanding, and therefore not covered by the management plan, it will be simpler to determine reasonable potential if a specific criterion for the waterbody is in place. As another alternative the State could consider a seasonally, or specific month(s), based lower bound for DO to more accurately represent known data from the period of record and modeling efforts.
2) Without a lower bound for DO, is there any limitation on the duration or frequency by which a measured DO level can be below the 5mg/L criterion? How will the assessment of the exceedances below 5 mg/L be determined to be based on natural conditions? EPA encourages the State to consider providing additional clarity through the adopted revisions to ensure proper implementation of the classification if adopted.

pH of 4.3

1) In general the support for the change to pH appears to have less supporting documentation than DO. The EPA recommends the State provide data documentation from the historical monitoring efforts for this segment to justify the conclusion that values as low as 4.3 are appropriate, as well as protective. Although describing upstream data, the information shown for pH provides monthly averages on page D-45. Unless monthly average was intended, it may be more useful to present data in a different way, to match the intended duration for the 4.3 value.
2) The EPA suggests that the State clarify whether the 4.3 represents an instantaneous measurement, typically referred to as a "shall not exceed" value. If something different is intended, that should also be documented and supported.

Threatened and Endangered Species

1) The EPA is aware that Ms. Kountis worked with the Services in advance of this proposal. This upfront coordination and consideration of the Service's comments is important and EPA greatly appreciates the State's effort to do this. As part of the State's final documentation, the EPA recommends the materials include a discussion on how the water quality requirements (such as DO levels) were considered and will result in a designated use, with its corresponding water quality criteria, that will be protective of the two sturgeon species that could be present in the segment.

TMDL and/or Restoration Efforts

1) Although information has been provided to describe natural sources of lower DO and pH values, it will be important to ensure that the influence from anthropogenic sources is still addressed and continues to be monitored to ensure anthropogenic sources are not contributing to lower DO or pH levels.
2) As noted on page D-3 of the materials, the petition seems to indicate that point sources will have waste load allocations developed for them. The EPA supports this conclusion.
3) The first technical memorandum mentions that further channel dredging "also showed a significant impact [on DO conditions]." Can the State provide the EPA with additional information on this analysis and how it was considered?

General Documentation

1) We encourage the State to provide specific documentation to EPA no later than the time of the State's submittal to EPA for 303(c) review to ensure a timely final review. EPA staff are also available to review any supplemental information in advance if that is the State's preference.

If you have any questions, please contact me at (404) 562-9967 or have a member of your staff contact Ms. Lauren Petter at (404) 562-9272.

Sincerely,

Annie Godfrey, Chief
Water Quality Standards Section

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

March 3, 2015

Ms. Elizabeth Kountis
DENR/ Division of Water Resources, Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611

Dear Ms. Kountis:

This letter conveys the U.S. Fish and Wildlife Service's (Service) comments on proposed reclassification of a section of the Cape Fear River (Brunswick and New Hanover Counties) from Class SC to Class SC Swamp (Sw) with a water quality management plan. The Division of Water Resources (DWR), on behalf of the Environmental Management Commission, seeks comments on the proposed changes which were detailed in a January 12, 2015 public hearing notice.

The Service is the principal Federal agency responsible for conserving, protecting and enhancing fish, wildlife and plants and their habitats for the continuing benefit of the American people. Among our priorities is the health and restoration of diadromous fish stocks in the area, including striped bass (*Morone saxatilis*), American shad (*Alosa sapidissima*), hickory shad (*Alosa mediocris*), blueback herring (*Alosa aestivalis*), alewife (*Alosa pseudoharengus*), shortnose sturgeon (*Acipenser brevirostrum*), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), and American eel (*Anguilla rostrata*). All diadromous species have complex life cycles entailing use of freshwater and marine habitats, so the proposed reclassification of the lower Cape Fear River is of interest to us and partners working on fish restoration.

We appreciate DWR's early coordination with us on the proposal. At your request, on April 23, 2014 we emailed references documenting 1) protected aquatic species and species of special management importance in the lower Cape Fear River, with emphasis on the lifestages present in late spring, summer and early fall when dissolved oxygen (DO) would be lowest (and therefore potentially most affected by a Sw reclassification); 2) DO tolerances of fish species of management concern, including references demonstrating adverse effects to fish early lifestages at DO concentrations less than the standard of 5 mg/L; and 3) concern that a Sw classification, allowing lower DO if caused by natural conditions, might make it more difficult to determine use support related to DO in the future without some mechanism to define a new lower bound on DO indicative of background conditions. The three April 23, 2014 emails are incorporated here by reference.

Last summer, a biologist with our Coastal Program (which is integrally involved in Cape Fear River fisheries and habitat restoration) met with reclassification proponents and consultants. From those meetings, supporting technical memoranda, and water quality modeling reports, we better understand the intention of the reclassification -- to document the large influence of

wetlands and sediment and lesser influence of local point sources on local DO conditions. That should allow stakeholders to refocus restoration efforts on those factors which have the greatest impact, including anthropogenic sources of oxygen consuming waste upstream of the reclassified reach. We offer four technical suggestions for DWR's consideration:

1) The proposed management plan concludes with "Any new or expanded permitted pollutant discharge of oxygen-consuming waste shall not cause the DO of the receiving water to drop more than 0.1 mg/l below the modeled in-stream DO at total permitted capacity." We suggest replacing "Any" with "All" so that the cumulative impact of all additional permitted oxygen consuming waste is a diminishment of less than 0.1 mg/L. This is important because the monitoring and modeling confirm the reach has essentially no assimilative capacity given DO already low due to natural conditions.

2) The management plan should include the means by which the 0.1 mg/L cap on lowered DO will be determined. Important details to establish and get reviewed by stakeholders include the model to be used, input parameters, season to be modeled, location for compliance, and whether compliance is to be based on instantaneous versus average conditions.

3) Modeling reports note that reductions of oxygen consuming waste upstream of the modeled reach could appreciably improve DO in the modeled reach -- reducing excursions below the 5 mg/L standard. In other words, upstream water quality improvements could positively influence DO in the lower Cape Fear River. The reclassification may help in addressing important anthropogenic sources upstream of the modeled reach (e.g., CAFO associated waste from the Northeast Cape Fear River; large BOD point sources upstream of the modeled reach). It would be helpful if the management plan included a path forward on how to improve lower Cape Fear River DO concentrations through watershed-wide waste load modeling, land use planning, and permitting so water quality restoration is linked to the reclassification.

4) The management plan should discuss how DO use support determinations will be made if there is no lower bound on the frequency and magnitude of DO concentrations. It would help to explain how natural conditions will be differentiated from other conditions such that DO impairments can be identified and remedied. In short, some way to define a new floor with which to evaluate monitoring and compliance data should be established.

There are no federally- listed threatened or endangered species under Service jurisdiction in the affected reach. Shortnose sturgeon and Atlantic sturgeon are under the jurisdiction of NOAA Fisheries' Protected Species Division and may be affected by the action, so we encourage your continued coordination with them.

We will be glad to further explore these suggestions so that the outcome results in restoration of water quality for the benefit of fish and people. If you would like additional detail on any of our recommendations, please contact me at 919-856-4520 x.21.

Sincerely,

Tom Augspurger
Ecologist

Memo to: NC Division of Water Resources, and NC Environmental Management Commission

From: Dr. Michael A. Mallin, Research Professor, Center for Marine Sciences, University of North Carolina Wilmington, Wilmington, NC, 28409

Date: February 9, 2015

Subject: Comment on the proposed reclassification of the lower Cape Fear River and Estuary to Class Sc-Swamp (Sw) classification.

1) I am very supportive of the statement in the reclassification proposal that states that any further municipal point sources will require the highest level of treatment in North Carolina. I would ask for more specifics regarding industrial discharges – at the least setting some limits on biochemical oxygen demanding agents such as biochemical oxygen demand (BOD), ammonia, total nitrogen (TN) and total phosphorus (TP).

2) An important statement that needs to be clarified is found in the narrative standards where it states that DO should not be less than 5.0 mg/L except that "swamp waters, poorly flushed tidally influenced streams or embayments, or estuarine bottom waters may have lower values if caused by natural conditions" . The issue that requires clarification is who decides, and by what criteria, if such a deviation is caused by "natural" conditions.

3) The proposed CFR reclassification does not adequately address non-point contributions of BOD or nutrients (which lead to BOD increases). If focus on non-point sources potentially contributing to oxygen depletion is continued to be addressed by on-going water quality programs; based on the summer blue-green algal blooms that occurred annually from 2009-2012, this approach has been inadequate and will continue to be inadequate.

4) In the lower Cape Fear River and Estuary, peer-reviewed research published in *Limnology and Oceanography* has demonstrated that BOD is driven by a number of biological and chemical factors (Mallin et al. 2004; Tables 4, 5 and 6) see the following:

- Chlorophyll *a* (the principal measure of algal bloom strength) has been positively correlated with BOD5 in the mainstem river at Lock and Dam #1 ($r = 0.55$, $p = 0.0001$), Browns Creek ($r = 0.45$, $p = 0.007$), Hammond Creek ($r = 0.45$, $p = 0.004$), Great Coharie Creek ($r = 0.51$, $p = 0.001$), Colly Creek ($r = 0.64$, $p = 0.0001$), Barnards Creek ($r = 0.37$, $p = 0.040$), Motts Creek ($r = 0.42$, $p = 0.020$), and Smith Creek ($r = 0.57$, $p = 0.0009$). I note that Browns, Hammond, Barnards and Smith Creeks drain directly into the mainstem river or estuary, while Colly and Great Coharie creeks drain into the lower Black River, a major 5th order tributary of the 6th order Cape Fear River.
- TN has been positively correlated with either BOD5 or BOD20 or both in the 5th-order Northeast Cape Fear River ($r = 0.30$, $p = 0.02$), the Black River ($r = 0.45$, $p = 0.0003$), Hammond Creek ($r = 0.47$, $p = 0.0003$), Six Runs Creek ($r = 0.54$, $p = 0.0005$), Great

Coharie Creek ($r = 0.44$, $p = 0.006$), Little Coharie Creek ($r = 0.52$, $p = p = 0.0008$), and Colly Creek ($r = 0.54$, $p = 0.0005$).

- TP has been positively correlated with either BOD5, BOD20 or both in the Northeast Cape Fear River ($r = 0.34$, $p = 0.008$) the Black River ($r = 0.33$, $p = 0.010$), Browns Creek ($r = 0.40$, $p = 0.012$), Hammond Creek ($r = 0.42$, $p = 0.009$), Six Runs Creek ($r = 0.49$, $p = 0.002$), Great Coharie Creek ($r = 0.66$, $p = 0.0001$), and Colly Creek ($r = 0.39$, $p = 0.015$).
- Chlorophyll *a* represents algal blooms, which upon death and decomposition become highly labile sources of BOD. Nutrients drive BOD in two ways: directly and indirectly. A peer-reviewed article in *Ecological Applications* by Mallin et al. (2004) showed that for streams in the Black and Northeast Cape Fear River basins, inputs of dissolved phosphorus directly stimulate BOD5 and BOD20, as well as natural bacteria abundance (the direct driver of BOD). The data also showed that inputs of dissolved nitrogen (nitrate ammonium, and urea) significantly stimulate algal growth, which in turn significantly stimulates BOD. Thus, the correlation between nutrient loading and BOD is not surprising.

5) The proposed reclassification is based on the Bowen (2009) model predicting DO concentrations in the lower Cape Fear River Estuary

- The Bowen model concludes that further reduction of current point sources would have little effect on DO concentrations – I will accept the model's conclusions on that matter.
- But, Bowen's model shows that reducing nutrient, carbon and BOD loads from the incoming rivers, creeks and wetlands by 30% and 70% would <u>increase</u> median DO from 5.6 mg/L to 5.85 and 6.2 mg/L, respectively – and this assumes sediment oxygen demand (SOD) stays the same regardless of reductions! See Bowen (2009) pages 6-4, 6-8, and 6-22 in particular for more on this topic.
- Assuming that such BOD load reduction would similarly reduce SOD, than the model says summer DO violations would decrease from 45% to 22% violations (30% reduction case), down to 7% (with 50% reduction) and down to only 1% violations (70% reduction case).
- I further note that SOD cannot simply be considered "natural" only. A year-long study of several tidal creeks in New Hanover County was published in the peer-reviewed journal *Hydrobiologia* (MacPherson et al. 2007). Results demonstrated that chlorophyll *a* concentrations were positively correlated with SOD ($r = 0.35$, $p < 0.05$), as well as BOD5 ($r = 0.50$, $p < 0.05$).

6) I note that Bowen does not discuss non-point source pollution sources specifically.

7) Yet, non-point runoff plays a major role in the middle to lower basin of the mainstem Cape Fear River, from crop agriculture, urban runoff and some livestock production. In the lower Cape Fear system I note that livestock waste pollution and crop agriculture are the predominant non-point nutrient and BOD sources in the Black and Northeast Cape Fear River basins.

8) Livestock manures as waste inputs were *not even mentioned* in Bowen's model! However, 2012 livestock counts for Brunswick, Pender, Duplin, Sampson, Cumberland

and parts of Bladen and Onslow Counties (Cape Fear lower watershed) are as follows (information for counties that are partially within the basin, Bladen and Onslow, are estimates):

- Hogs: approximately 5,000,000
- Turkeys: approximately 21,500,000
- Broiler chickens: > 122,000,000
- Other chickens: > 870,000
- Cattle: approximately 72,000

(from NCDA website September 2014)

Livestock wastes are clearly the largest source of BOD-forcing pollutants in the Cape Fear Basin – and remain virtually unregulated (i.e. no required streamside buffers, no required control of ammonia off gassing, etc.).

9) Industrialized swine farms (CAFOs) are a source of large-scale chronic nitrogen and phosphorus loading to nearby soils and receiving water bodies, nutrients which have been directly correlated to BOD in the blackwater streams and rivers of the Cape Fear Basin (Mallin et al. 2006). An peer-reviewed analysis by Cahoon et al. (1999) published in *Environmental Science and Technology* found that vast quantities of nitrogen and phosphorus feed are imported into the watershed annually to feed swine, poultry, and cattle in production facilities (CAFOs), which in turn annually load large quantities of nutrients as waste into the watershed. This analysis found that for the Cape Fear River basin alone, CAFOs produce 82,700 tons of nitrogen and 25,950 tons of phosphorus annually into this watershed. Thus, N and P enter the state as animal feed from elsewhere, but much of it leaves the livestock as manure (or carcasses) and enters soils or waters of the Coastal Plain.

10) Finally, swine waste lagoons, as well as lagoons servicing egg-laying poultry CAFOs, produce copious amounts of ammonia to the atmosphere; NC Division of Air Quality estimates a swine ammonia emission factor of 9.21 kg/hog-year. 9.21 x 5,000,000 head of swine = 46,050,000 kg or 46,050 metric tons of ammonia released to the airshed of the Cape Fear River basin (and coastal ocean) <u>per</u> <u>year</u>, much of which comes to earth within 60 miles of the source (Walker et al. 2000; Costanza et al. 2008). Ammonia is well-known in the environmental engineering literature to exert an oxygen demand (nitrogenous BOD) on waters – that is why it is regulated in wastewater discharges (Clark et al. 1977). Efforts need to be made to control this major source of oxygen-demanding wastes to the Cape Fear system as well.

11) Clearly, non-point sources of BOD, nitrogen, and phosphorus entering the waters of the lower Cape Fear River system are very large and lead to reduced dissolved oxygen levels.

I conclude that the proposed reclassification, as it stands, will be inadequate to produce or maintain proper dissolved oxygen concentrations in the lower Cape Fear River and Estuary due to the lack of attention to non-point sources of nutrients and BOD. The source of much of this pollution is industrial livestock production, along with unknown inputs from traditional agriculture, and some urban runoff in the Fayetteville and Wilmington areas. **Any**

proposed reclassification of the lower Cape Fear River and Estuary must include strong language specifically aimed at reducing such non-point sources of pollution.

Literature Cited

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin and J. Williams. 2009. Development and use of a three-dimensional water quality model to predict dissolved oxygen concentrations in the lower Cape Fear Estuary, North Carolina. Department of Civil Engineering, University of North Carolina Charlotte.

Cahoon, L.B., J.A. Mickucki and M.A. Mallin. 1999. Nutrient imports to the Cape Fear and Neuse River basins to support animal production. *Environmental Science and Technology* 33:410-415.

Clark, J.W., W. Viessman, Jr. and M.J. Hammer. 1977. Water Supply and Pollution Control, 3rd Edition. IEP-A Dun-Donnelley Publisher, New York.

Costanza, J.K., S.E. Marcinko, A.E. Goewert and C.E. Mitchell. 2008. Potential geographic distribution of atmospheric nitrogen deposition from intensive livestock production in North Carolina, USA. *Science of the Total Environment* 398:76-86.

MacPherson, T.A., M.A. Mallin and L.B. Cahoon. 2007. Biochemical and sediment oxygen demand: patterns of oxygen depletion in tidal creeks. *Hydrobiologia* 586: 235-248.

Mallin, M.A., M.R. McIver, S.H. Ensign and L.B. Cahoon. 2004. Photosynthetic and heterotrophic impacts of nutrient loading to blackwater streams. *Ecological Applications* 14:823-838.

Mallin, M.A., V.L. Johnson, S.H. Ensign and T.A. MacPherson. 2006. Factors contributing to hypoxia in rivers, lakes and streams. *Limnology and Oceanography* 51:690-701.

Walker, J., V. Aneja and D. Dickey. 2000. Atmospheric transport and wet deposition of ammonium in North Carolina. *Atmospheric Environment* 34:3407-3418.

1 of 3 re: Lower Cape Fear River

Augspurger, Tom <tom_augspurger@fws.gov> Wed, Apr 23, 2014 at 10:44 AM
To: "Kountis, Elizabeth" <elizabeth.kountis@ncdenr.gov>, adriene.weaver@ncdenr.gov

Hello Elizabeth,

Thank you for the opportunity to suggest resources and contacts to inform NC DWR's consideration of the request to reclassify a portion of the Cape Fear River to Swamp (Sw). From the map you sent, it appears the area being considered includes the Cape Fear River between Cartwheel Branch (near Navassa) to Snow's Cut (about 17 river miles).

This is the first of three e-mails to convey information. This one provides resources and contacts to identify important aquatic species (either protected or of special management importance) in this reach, with an emphasis on the lifestages that would be present in late spring, summer and early fall when dissolved oxygen (DO) would be lowest (and therefore potentially most affected by an Sw reclassification which could lower the water quality standard for DO).

I have attached a report which is a great quick reference to species of management importance in NC estuaries. The Cape Fear River estuary is included. See the tables in the back of the report, which break out species, and life stages, by season. The references therein will also be useful.

The Fish and Wildlife Service (FWS) is particularly interested in the health and restoration of diadromous fish stocks in the area, including striped bass (*Morone saxatilis*), American shad (*Alosa sapidissima*), hickory shad (*Alosa mediocris*), blueback herring (*Alosa aestivalis*), alewife (*Alosa pseudoharengus*), shortnose sturgeon *(Acipenser brevirostrum)*, Atlantic sturgeon *(Acipenser oxyrinchus oxyrinchus)*, and American eel (*Anguilla rostrata*). All diadromous species have complex life cycles entailing use of both freshwater and marine habitats and require collaborative interjurisdictional management to ensure their sustainability. All these species are managed by the states and federal agencies acting through the Atlantic States Marine Fisheries Commission (ASMFC; also the Great Lakes Fishery Commission for American eel). All of them were historically important commercially within coastal NC. All of them are the focus of significant restoration efforts by the ASMFC, the state commissions (NC Marine Fisheries Commission and NC Wildlife Resources Commission) and other management bodies such as the Mid-Atlantic and New England Fishery Management Councils (MAFMC, NEFMC). The report I attached includes life history information for these species relative to the Cape Fear River.

Additional reports and data are at this website, but I think the attached report should give you a great start: http://ccma.nos.noaa.gov/ecosystems/estuaries/elmr.aspx#products

There are no federally-protected endangered species under FWS management which occur in the area and which would be affected by the action, but the American eel is under status review (review on whether listing as

threatened or endangered is warranted). The shortnose sturgeon and Atlantic sturgeon are both federally-listed endangered species known from the area and may be affected by the action under consideration; those species are under the purview of NOAA-National Marine Fisheries Service, and the appropriate contact is:

Fritz Rohde
NMFS/SER/SERO/HCD/AB

101 Pivers Island Road
F/SER47
Beaufort, NC 28516
Phone: (252) 838-0828
fritz.rohde@noaa.gov

Please let me know if you have any questions about this information. The next email will have information on the DO requirements and other habitat needs for species of management concern.

Regards,

Tom

Tom Augspurger
Ecologist / Environmental Contaminants Specialist
U.S. Fish and Wildlife Service
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Raleigh NC 27606
919-856-4520 x21
tom_augspurger@fws.gov

On Tue, Apr 15, 2014 at 1:10 PM, Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov> wrote:

Thank you for talking with me today. Per our conversation, the Division of Water Resources has recently received a request to reclassify a portion of the Cape Fear River to Swamp (Sw); the portion of the river requested to be reclassified is a part of Index #18-(71), which is shown on the map below and is currently Class SC. We are trying to assess the potential impacts of such a reclassification prior to rulemaking, and need USFWS' help in doing so for the aquatic species in the requested waterbody. As a reminder, Sw waters may have DO values lower than 5.0 mg/l, and Sw waters may have a pH as low as 4.3, according to 15A NCAC 02B .0220.

Please forward this email to USFWS staff you think would be interested in it and could provide input on this matter. Please also provide the contact information for any other folks on the Federal level who could contribute information on this issue, i.e. NOAA.

Lastly, if you, and any other USFWS staff you forward this email to, could please respond to this email within a week's time (by Tuesday, 4/22/2014), I would greatly appreciate it.

2 of 3 re: Lower Cape Fear River

Augspurger, Tom <tom_augspurger@fws.gov> Wed, Apr 23, 2014 at 11:44 AM
To: "Kountis, Elizabeth" <elizabeth.kountis@ncdenr.gov>, "adriene.weaver" <adriene.weaver@ncdenr.gov>

Hi again,

Here is information on the dissolved oxygen (DO) tolerances of the diadromous species we noted in the last e-mail; the references will also have information on other water quality parameters that may be affected by an Sw classification. A pdf copy of ASMFC Habitat Management Series No. 9 is attached; there are text and tables in each species chapter which provide DO information by life stage, to the extent that the authors were able to find them in the literature. This seems the most relevant to your request.

Additional detail is available in life history profiles (http://www.nwrc.usgs.gov/wdb/pub/hsi/hsiintro.htm) for species we listed as well as freshwater species expected to use upper reaches of the area. See the DO sections, for example in McMahon and Terrell (1982), Stuber et al. (1982) and Krieger et al. (1983) which note larval mortality, altered growth, and behavioral changes at DO concentrations less than the current standard.

Experience in fish culture, where the objective is to ensure robust spawning and survival of young (rather than providing conditions below which stress and other adverse effects are readily apparent) is relevant to this issue. Fish culturists identify DO concentrations >6 mg/l as desirable with optimal development of embryos and fry at or near the point of oxygen saturation (Piper et al. 1989; Nicholson et al. 1990).

Taken with the life history profiles, published information on desirable levels of dissolved oxygen for good striped bass reproduction indicate survival of striped bass eggs and larvae are reduced at dissolved oxygen levels from 4 to 5 mg/l (Bain and Bain 1982) and that optimal ranges for larvae and juveniles are >6 to 12 mg/l (Hill et al. 1989; Nicholson et al. 1990).

Other sources of synthesized literature and recommendations on DO are the USEPA criteria documents. They indicate that DO concentrations higher than the standard of 5 mg/l are desirable for spawning areas. The national dissolved oxygen criteria for sensitive life-stages in non-salmonid waters is a daily minimum of 5 mg/l and a weekly average of 6 mg/l (http://www.epa.gov/waterscience/criteria/wqctable/index.html, USEPA 1986b; http://www.epa.gov/waterscience/criteria/library/goldbook.pdf). The national criteria is based on the sensitivity of early lifestages of fishes and foresees "moderate production impairment" to early life stage non-salmonid fishes (USEPA 1986a; http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=00001MSS.txt). At concentrations below these, larval mortality, altered growth, and behavioral changes have been reported in both field and lab studies. Accordingly, the national criteria document also includes a DO concentration required for "no effect" on sensitive early life stage non-salmonid fishes of 6.5 mg/l (USEPA 1986a, b). That should at least be considered for any waters which are known to be critically important spawning and nursery areas.

Finally, the collaboratively produced *Cape Fear River Basin Action Plan for Migratory Fish* (http://www.habitat.noaa.gov/protection/capefear/) has water quality targets for some of the species of management interest.

If you have any difficulty retrieving the primary references used in these synthesis reports or the pertinent sections of the hatchery manuals I referenced, please let me know and I will be glad to help track them down for you.

More soon,

Tom

References:

Bain, M.B. and J.L. Bain. 1982. Habitat suitability index models: coastal stocks of striped bass. U.S. Fish and Wildlife Service. FWS/OBS-82/10.1. http://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-001.pdf

Hill, J., J.W. Evans, M.J. Van Den Avyle. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Atlantic) – striped bass. U.S. Fish and Wildlife Service Biological Report 82(11.118). U.S. Army Corps of Engineers TR EL-82-4. Vicksburg, MS. http://www.nwrc.usgs.gov/wdb/pub/species_profiles/82_11-118.pdf

Krieger, D. A., J. W. Terrell, and P. C. Nelson. 1983. Habitat suitability information: yellow perch. U.S. Fish and Wildlife Service. FWS/OBS-83/10.55. http://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-055.pdf

McMahon, T.E. and J. W. Terrell. 1982. Habitat suitability index models: channel catfish. USDOI Fish and Wildlife Service. FWS/OBS-82/10.2. http://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-002.pdf

Nicholson, L.C., L.C. Woods, III and J.G. Woiwode. 1990. Intensive culture techniques for the striped bass and its hybrids. Pages 141-157 In: R.M. Harrell, J.H. Kerby and R.V. Minton (eds.), Culture and Propagation of Striped Bass and its Hybrids. American Fisheries Society, Bethesda, MD.

Piper, R.G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler and J.R. Leonard. 1989. Fish Hatchery Management. U.S. Fish and Wildlife Service and American Fisheries Society, Bethesda, MD.

Stuber, R. J., G. Gebhart, and O. E. Maughan. 1982. Habitat suitability index models: largemouth bass. USDOI Fish and Wildlife Service. FWS/OBS-82/10.16. http://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-016.pdf

U.S. Environmental Protection Agency. 1986a. Ambient water quality criteria for dissolved oxygen. EPA 440/5-86-003.Office of Water Regulations and Standards, Washington, DC. http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=00001MSS.txt

U.S. Environmental Protection Agency. 1986b. Quality Criteria for Water 1986 (The Gold Book). EPA 440/5-86-001 Office of Water Regulations and Standards, Washington, DC. http://www.epa.gov/waterscience/criteria/library/goldbook.pdf

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HMS9_Diadromous_Habitat_2009.pdf
8770K

Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov> Wed, Apr 23, 2014 at 3:15 PM
To: "Augspurger, Tom" <tom_augspurger@fws.gov>

Just wanted to let you know I got the 2 very useful emails so far that you sent ("1 of 3" and "2 of 3") plus the first "heads-up" email; I have not received a "3 of 3" email yet.

Thanks!

Elizabeth Kountis

Senior Environmental Specialist

Classifications & Standards/Rules Review Branch

NC DENR Division of Water Resources

Tel: (919) 807.6418 FAX: (919) 807.6497

E-mail correspondence to and from this address may be subject to the NC Public Records Law and may be disclosed to third parties.

From: Augspurger, Tom [mailto:tom_augspurger@fws.gov]

3 of 3 re: Lower Cape Fear River

Augspurger, Tom <tom_augspurger@fws.gov> Wed, Apr 23, 2014 at 4:43 PM
To: "Kountis, Elizabeth" <elizabeth.kountis@ncdenr.gov>, adriene.weaver@ncdenr.gov

Hi Elizabeth,

Just a couple observations for your consideration and some contacts you likely already know about... use whatever is helpful:

1) I haven't had time to look at the consolidated long-term record of DO data for the lower river but encourage that be done as a foundation of learning the appropriateness of a Sw classification. It would be important to discern if any low DO events in the area are natural or significantly influenced by point and nonpoint source pollutant loads. In short, some assessment ought to be done to determine whether any water quality less than current standards calls more for a reclassification or for a water quality restoration plan.

2) I'd be concerned that a reclassification could lead to further (or more prolonged) degradation in the lower river and therefore potentially adversely affect important nursery habitats for many species, including those we highlighted in the earlier emails. I perceive that the reclassification isn't exactly in keeping with the plan that the Cape Fear River Partnership has developed for restoration of the river (a link in the second email form this morning).

3) From work on the lower Roanoke River, I've been concerned that the Sw classification in rivers (as opposed to swamps) makes it difficult to set a ceiling on the amount of BOD and a floor on the concentration of DO. The DO standard states that swamp waters, lake coves or backwaters, and lake bottom waters may have lower DO values if caused by natural conditions, but how much lower isn't defined. Something that defines true background or reference conditions seems important in a Sw reclassification. Also, it seems that in Sw ("waters which have low velocities and other natural characteristics which are different from adjacent streams") that assimilative capacity needs to be wholly reconsidered (does it even make sense that such areas have assimilative capacity if they have characteristics which lead to low DO?).

4) Fritz Rohde with NOAA National Marine Fisheries Service will be a good contact for you (information in the first email). You probably already know the local NC WRC and DMF contacts for the area, and the current or former UNC-W researchers with primary data for the area like Mike Malin, Courtney Hackney and Larry Cahoon. Tom Hoban with Cape Fear River Assembly may be another good contact. If you want contact information for any of them, please let me know and I'll provide it.

Have a good rest of the week, and please let me know if we can help further,

BISON CONNECT

Augspurger, Tom <tom_augspurger@fws.gov>

preliminary follow-up

Augspurger, Tom <tom_augspurger@fws.gov> Thu, May 15, 2014 at 1:10 PM
To: "Kountis, Elizabeth" <elizabeth.kountis@ncdenr.gov>

Hi Elizabeth,

I'm following up on my call to you on the fisheries and dissolved oxygen information we provided in response to possible reclassification of the lower Cape Fear River.

Fritz Rohde's (NOAA Fisheries) cell number is [redacted].

Information Redacted pursuant to 5 U.S.C. Section 552 (b)(6), Personal Privacy

Also, below is a preliminary list of sturgeon DO information; let me know if you need copies of any of these and I'll get them to you. More soon on your other questions (status of sturgeon populations in the river, DO requisites of sturgeons, interplay of DO magnitude, frequency and duration in setting instream targets).

Regards,

Tom

Campbell JG, Goodman LR. 2004. Acute sensitivity of juvenile shortnose sturgeon to low dissolved oxygen concentrations. Transactions of the American Fisheries Society 133:772-776.

Jenkins WE, Smith TIJ, Heyward LD, Knott DM. 1993. Tolerance of shortnose sturgeon, *Acipenser brevirostrum*, juveniles to different salinity and dissolved oxygen concentrations. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 47: 476-484.

Niklitschek EJ, Secor DH. 2009. Dissolved oxygen, temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon in estuarine waters: I. Laboratory results. Journal of Experimental Marine Biology and Ecology 381, Supplement(0): S150-S160.

Niklitschek EJ, Secor DH. 2009. Dissolved oxygen, temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon in estuarine waters: II. Model development and testing. Journal of Experimental Marine Biology and Ecology 381, Supplement(0): S161-S172.

Secor DH, Gunderson TE. 1998. Effects of hypoxia and temperature on survival, growth, and respiration of juvenile Atlantic sturgeon, *Acipenser oxyrinchus*. Fishery Bulletin 96(3): 603-613.

Secor DH, Niklitschek EJ. 2001. Hypoxia and Sturgeons: Report to the Chesapeake Bay Program Dissolved Oxygen Criteria Team. UMCES Tech. Ser. No. TS-314-01-CBL Ref. No. [UMCES] CBL 01-0080.

Secor DH, Niklitschek EJ. 2002. Sensitivity of sturgeons to environmental hypoxia: a review of physiological and ecological evidence. In: Thurston, R.V. (ed.) Fish Physiology, Toxicology, and Water Quality. Proceedings of the 6th International symposium. Athens, GA, Environmental Protection Agency, pp. 61-78.

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Petter, Lauren

From: Apanian, David M.
Sent: Wednesday, February 04, 2015 5:17 PM
To: Petter, Lauren
Cc: Apanian, David M.
Subject: RE: NC permitting and compliance
Attachments: Permits - Parameter Occurrance-Cape Fear.xlsx

This is your first file. It contains a summary table of all parameters that are on the 41 permits. This list is based on the current version of the permits, and does not take into account what parameters may have been on prior issuances of the permits. I am going to try to run a report to return the limit information, but in the event that ICIS chokes from too large a file, we will have to whittle down the list of parameters to a more manageable number.

Dave.

==========
David M. Apanian, P.E., MSCEE
ICIS-NPDES Data Administrator
Clean Water Enforcement Officer
EPA Region 4 - Water Protection Division
Phone: (404) 562-9477
apanian.david@epa.gov
==========

From: Petter, Lauren
Sent: Wednesday, February 04, 2015 3:22 PM
To: Apanian, David M.
Subject: RE: NC permitting and compliance

Here you go! I would only do all 41 if it is easy to query the permit and the handful of parameters limits I mentioned in my initial message though. If it's not easy then here are the 3 biggest:

NC0003298 International Paper Company
NC0023965 City of Wilmington Northside WWTP
NC0023973 City of Wilmington Southside WWTP

Thanks,
Lauren

From: Apanian, David M.
Sent: Wednesday, February 04, 2015 2:23 PM
To: Petter, Lauren
Cc: Apanian, David M.
Subject: RE: NC permitting and compliance

Do you have the list of 41 permits in the subbasin handy?

==========

David M. Apanian, P.E., MSCEE
ICIS-NPDES Data Administrator
Clean Water Enforcement Officer
EPA Region 4 - Water Protection Division
Phone: (404) 562-9477
apanian.david@epa.gov
==========

From: Petter, Lauren
Sent: Wednesday, February 04, 2015 2:11 PM
To: Apanian, David M.
Subject: RE: NC permitting and compliance

Comments are due to the state by 3/5 so I would like to have any info by 2/19 so I can get clearance from my management for any comments I do prepare. Let me know if that is not enough time or if you have any follow up questions.

Thanks,
Lauren

From: Apanian, David M.
Sent: Wednesday, February 04, 2015 2:06 PM
To: Petter, Lauren
Cc: Ireland, Laurie; Apanian, David M.
Subject: RE: NC permitting and compliance

Lauren,
What is your timeframe for this?
Dave

==========
David M. Apanian, P.E., MSCEE
ICIS-NPDES Data Administrator
Clean Water Enforcement Officer
EPA Region 4 - Water Protection Division
Phone: (404) 562-9477
apanian.david@epa.gov
==========

From: Petter, Lauren
Sent: Monday, February 02, 2015 12:04 PM
To: Ireland, Laurie; Apanian, David M.
Subject: NC permitting and compliance

Laurie and David-

I'm reviewing a draft designated use change for North Carolina in which the subject water, Lower Cape Fear River, will change from SC to SC Swamp. The change in designation would mean that pH and DO levels can be as low as 4.3, and less than 5.0, respectively, if caused by natural conditions. The submission would also include a provision codifying a rule (supposedly current policy) to make NPDES dischargers use limits of 5/1/6 for BOD/Ammonia/DO, but only for new or expanded dischargers.

As of 2005, there were 41 individual NPDES wastewater discharge permits in this subbasin so there is a large universe that may just be maintaining their current discharge levels. I did see in one document that 90% of total point source based oxygen demanding pollutant load comes from the 3 biggest facilities (International Paper and two Wilmington facilities comprise). NPDES NC0003298 is listed for International Paper and the Wilmington facilities so not sure if that is a typo or it is a consortium or something.

So what I need help with is... I'm curious to see what their current permit limits are, and if you are familiar with these facilities, any insight on whether they have compliance issues or some other interesting information that would be good for me to know as I decipher the impacts of anthropogenic versus natural sources in this waterbody. In general, I want to be clear that any acceptance of lower levels is indeed only for natural causes and that point sources should continue to be considered and lessened to improve water quality even though they believe this change will remove their need to pursue a TMDL.

Thanks,
Lauren

Lauren Petter, Environmental Scientist
Water Protection Division
U.S. Environmental Protection Agency Region 4
61 Forsyth Street, SW
Atlanta, GA 30303
P: (404) 562-9272
F: (404) 562-9224
Email: petter.lauren@epa.gov

Petter, Lauren

From: Gordon, Lisa Perras
Sent: Friday, December 19, 2014 10:54 AM
To: Petter, Lauren
Subject: FW: 1 of 3 re: Lower Cape Fear River

From: Wicker, Mike [mailto:mike_wicker@fws.gov]
Sent: Wednesday, May 21, 2014 1:24 PM
To: Gordon, Lisa Perras
Subject: Fwd: 1 of 3 re: Lower Cape Fear River

---------- Forwarded message ----------
From: **Mallin, Michael A.** <mallinm@uncw.edu>
Date: Wed, May 21, 2014 at 12:04 PM
Subject: RE: 1 of 3 re: Lower Cape Fear River
To: "Wynne, Bennett" <bennett.wynne@ncwildlife.org>, "Wicker, Mike" <mike_wicker@fws.gov>, Fritz Rohde - NOAA Federal <fritz.rohde@noaa.gov>
Cc: Tom <tom_augspurger@fws.gov>, "Cahoon, Larry" <cahoon@uncw.edu>, Dawn York <dyork@dialcordy.com>, Kemp Burdette <kemp@cfrw.us>, "Wilson Laney (Wilson_Laney@fws.gov)" <wilson_laney@fws.gov>

I think a site-specific classification that addresses non-point loading in the upper and middle basin, and nutrient inputs would be generally supported by the discharger community in the LCFRP. They are afraid of a designation that would simply try to lower BOD discharges further, as the Jim Bowen model from UNCC showed it would not increase summer DO. They would be open to something else that is science-based. Perhaps FWS should attend a meeting of LCFRP to express the concerns as such. Smithfield is not in the LCFRP by the way. I do not know if they have a relationship with the middle discharger group,
Mike

From: Wynne, Bennett [bennett.wynne@ncwildlife.org]
Sent: Wednesday, May 21, 2014 10:48 AM
To: Wicker, Mike; Fritz Rohde - NOAA Federal
Cc: Tom; Cahoon, Larry; Mallin, Michael A.; Dawn York; Kemp Burdette; Wilson Laney (Wilson_Laney@fws.gov)
Subject: RE: 1 of 3 re: Lower Cape Fear River

My off-the-cuff thought (not necessarily my agency's at this point) is the 15 NCAC 02B .0110 Considerations for Federally-Listed Threatened or Endangered Aquatic Species would be the more effective of the two. It's simpler, cleaner, and invokes the federal authority of the ESA. Crafting the necessary language for the other one could be akin to negotiating a state level minefield in this political climate, but I could be wrong.

But agree best defense can be a good offense.

From: Wicker, Mike [mailto:mike_wicker@fws.gov]
Sent: Wednesday, May 21, 2014 9:41 AM
To: Fritz Rohde - NOAA Federal
Cc: Tom; Cahoon, Larry; Wynne, Bennett; Mallin, Michael A.; Dawn York; Kemp Burdette; Wilson Laney (Wilson_Laney@fws.gov)
Subject: Re: 1 of 3 re: Lower Cape Fear River

Instead of reclassification to Sw which would create enough assimilative capacity to site a major pulp and paper mill near Wilmington (imagine that - you could smell the lower Cape Fear from 30 miles away - likely drive down property values and turn the Cape Fear into a lost cause two more appropriate classifications are available. Please take a look and see if there is one that the group would support. Fritz, please look with particular interest at 15 NCAC 02B .0110 Considerations for Federally-Listed Threatened or Endangered Aquatic Species

The two water classifications are on the 2nd and 3rd page of the attached pdf and would help achieve a better river instead of a much much worse one. Let's work toward a better river. Not a worse one. After all isn't that what the partnership and plan are all about.

On Tue, May 20, 2014 at 12:57 PM, Fritz Rohde - NOAA Federal <fritz.rohde@noaa.gov<mailto:fritz.rohde@noaa.gov>> wrote:
I sent this to Elizabeth Kountis.
---------- Forwarded message ----------
From: Stephania Bolden - NOAA Federal <stephania.bolden@noaa.gov<mailto:stephania.bolden@noaa.gov>>
Date: Tue, May 20, 2014 at 10:24 AM
Subject: Re: 1 of 3 re: Lower Cape Fear River
To: Fritz Rohde - NOAA Federal <fritz.rohde@noaa.gov<mailto:fritz.rohde@noaa.gov>>
Cc: Kelly Shotts - NOAA Federal <Kelly.Shotts@noaa.gov<mailto:Kelly.Shotts@noaa.gov>>, David Bernhart - NOAA Federal <David.Bernhart@noaa.gov<mailto:David.Bernhart@noaa.gov>>

Hi Fritz

I attach a table I made a few years back on DO impacts to shortnose sturgeon. Feel free to share.

Take at look at these two documents as there is also information about DO in them (both are publicly available at HQ website).

Shortnose sturgeon Biological Assessment
here: http://www.nmfs.noaa.gov/pr/pdfs/species/shortnosesturgeon_biological_assessment2010.pdf

And Atlantic sturgeon status review here: http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/atlanticsturgeon.pdf

Steph

On Tue, May 20, 2014 at 9:56 AM, Fritz Rohde - NOAA Federal <fritz.rohde@noaa.gov<mailto:fritz.rohde@noaa.gov>> wrote:
Reclassifying the lower Cape Fear is a bad idea. Are any of you aware of reports that document impacts of low

DO and low pH on sturgeon?
---------- Forwarded message ----------
From: Fritz Rohde - NOAA Federal <fritz.rohde@noaa.gov<mailto:fritz.rohde@noaa.gov>>
Date: Tue, May 13, 2014 at 11:32 AM
Subject: Re: 1 of 3 re: Lower Cape Fear River
To: "Kountis, Elizabeth" <elizabeth.kountis@ncdenr.gov<mailto:elizabeth.kountis@ncdenr.gov>>
Cc: "Weaver, Adriene" <adriene.weaver@ncdenr.gov<mailto:adriene.weaver@ncdenr.gov>>

In my quick search, I could not find much info. There is Jenkins et al. 1993. Tolerance of shortnose sturgeon juveniles to different salinity and dissolved oxygen concentrations. Proc. Annual Conf. SEAFWA.

"In a 6-hr test, fish 64 days old exhibited 86% mortality when exposed to DO concnetrations of 2.5 mg/l. However, sturgeon >100 dyas old were able to tolerate concentrations of 2.5 mg/l with <20% mortality." "Chronic levels fo about 5.3 mg/l have been shown to casue mortality and reduced growth among white sturgeon (Cech et al. 1984).

Cech et al is in Estuaries 7:12-18

On Tue, May 13, 2014 at 11:08 AM, Kountis, Elizabeth
<elizabeth.kountis@ncdenr.gov<mailto:elizabeth.kountis@ncdenr.gov>> wrote:
Thanks. If you have any other info on DO levels of impact on various lifestages (adult, eggs, etc.), that would be great; I'll also take a look at the reference you provided below.

Sincerely,

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418<tel:%28919%29%20807.6418> FAX: (919) 807.6497<tel:%28919%29%20807.6497>
E-mail correspondence to and from this address may be subject to the NC Public Records Law and may be disclosed to third parties.

From: Fritz Rohde - NOAA Federal [mailto:fritz.rohde@noaa.gov<mailto:fritz.rohde@noaa.gov>]
Sent: Tuesday, May 13, 2014 9:58 AM
To: Kountis, Elizabeth

Subject: Re: 1 of 3 re: Lower Cape Fear River

In habitats with DO less than 4.7 mg/l, young of year Atlantic sturgeon experience a loss in growth. (Secor and Niklitshcek 2001). Mortality in juveniles has been observed for summer temperatures with DO levels less or equal to 3.3 mg/l. Same reference. No data on pH tolerances

Hope this helps. i will be on travel rest of the week and I don't have any staff

On Mon, May 12, 2014 at 2:41 PM, Kountis, Elizabeth
<elizabeth.kountis@ncdenr.gov<mailto:elizabeth.kountis@ncdenr.gov>> wrote:
Thanks so much for your response. If you or one of your staff could please reply back sometime this week, that would be wonderful, as this info is part of a DWR rulemaking package I'm trying to complete by this time next week.

Thanks again!

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418<tel:%28919%29%20807.6418> FAX: (919) 807.6497<tel:%28919%29%20807.6497>
E-mail correspondence to and from this address may be subject to the NC Public Records Law and may be disclosed to third parties.

From: Fritz Rohde - NOAA Federal [mailto:fritz.rohde@noaa.gov<mailto:fritz.rohde@noaa.gov>]
Sent: Friday, May 09, 2014 3:28 PM
To: Kountis, Elizabeth; Kelly Shotts - NOAA Federal
Subject: Re: 1 of 3 re: Lower Cape Fear River

We don't have voice mail at the lab so that's why it kept ringing. Plus I was on travel. As I am most of next week.
I will share this with our protected resources folks for their input also.

Fritz

On Fri, May 9, 2014 at 2:07 PM, Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov<mailto:elizabeth.kountis@ncdenr.gov>> wrote:
P.S. I tried calling you yesterday and today at the number listed at the bottom of this email (Phone: (252) 838-0828<tel:%28252%29%20838-0828>), but it just rang and rang and rang. I just wanted to let you know that of particular interest is the effect of a Sw classification, meaning DO values lower than 5.0 mg/l, and pH values as low as 4.3, on the two federally endangered fish species, shortnose sturgeon and Atlantic sturgeon, which I understand are present in the subject waters.
Thanks and have a great weekend!

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418<tel:%28919%29%20807.6418> FAX: (919) 807.6497<tel:%28919%29%20807.6497>
E-mail correspondence to and from this address may be subject to the NC Public Records Law and may be disclosed to third parties.

From: Kountis, Elizabeth
Sent: Tuesday, May 06, 2014 2:16 PM

To: fritz.rohde@noaa.gov<mailto:fritz.rohde@noaa.gov>
Cc: Weaver, Adriene
Subject: FW: 1 of 3 re: Lower Cape Fear River

Woops – forgot to attach the map of the portion of the Cape Fear River that has been requested to be reclassified. So sorry!

Here is that map!

[cid:image001.png@01CF74E0.E1C64F00]

Sincerely,

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418<tel:%28919%29%20807.6418> FAX: (919) 807.6497<tel:%28919%29%20807.6497>
E-mail correspondence to and from this address may be subject to the NC Public Records Law and may be disclosed to third parties.

From: Kountis, Elizabeth
Sent: Tuesday, May 06, 2014 2:14 PM
To: 'fritz.rohde@noaa.gov<mailto:fritz.rohde@noaa.gov>'
Cc: Weaver, Adriene
Subject: FW: 1 of 3 re: Lower Cape Fear River

Good afternoon!

Tom Augspurger and I have exchanged emails regarding a request that the NC Division of Water Resources (DWR) recently received to reclassify a portion of the lower Cape Fear River from Class SC to Class Sc Sw (Swamp) (see map below). Tom stated that you would be the appropriate contact with NOAA-National Marine Fisheries Service regarding this reclassification request.

As noted below, NC DWR is trying to assess the potential impacts of such a reclassification prior to rulemaking, and need your help in doing so for the aquatic species living in the requested waterbody.
Please feel free to forward this email to fellow staff you think could provide input on this matter. In addition, if there are any other Federal staff who could contribute information on this issue that you are aware of, I would be most grateful if you would send me their contact info.
Lastly, if at all humanly possible, please respond to this email within a week's time (by Tuesday, 5/13/2014).
Many thanks!

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418<tel:%28919%29%20807.6418> FAX: (919) 807.6497<tel:%28919%29%20807.6497>
E-mail correspondence to and from this address may be subject to the NC Public Records Law and may be disclosed to third parties.

From: Augspurger, Tom [mailto:tom_augspurger@fws.gov]
Sent: Wednesday, April 23, 2014 10:44 AM
To: Kountis, Elizabeth; Weaver, Adriene
Subject: 1 of 3 re: Lower Cape Fear River

Hello Elizabeth,

Thank you for the opportunity to suggest resources and contacts to inform NC DWR's consideration of the request to reclassify a portion of the Cape Fear River to Swamp (Sw). From the map you sent, it appears the area being considered includes the Cape Fear River between Cartwheel Branch (near Navassa) to Snow's Cut (about 17 river miles).

This is the first of three e-mails to convey information. This one provides resources and contacts to identify important aquatic species (either protected or of special management importance) in this reach, with an emphasis on the lifestages that would be present in late spring, summer and early fall when dissolved oxygen (DO) would be lowest (and therefore potentially most affected by an Sw reclassification which could lower the water quality standard for DO).

I have attached a report which is a great quick reference to species of management importance in NC estuaries. The Cape Fear River estuary is included. See the tables in the back of the report, which break out species, and life stages, by season. The references therein will also be useful.

The Fish and Wildlife Service (FWS) is particularly interested in the health and restoration of diadromous fish stocks in the area, including striped bass (Morone saxatilis), American shad (Alosa sapidissima), hickory shad (Alosa mediocris), blueback herring (Alosa aestivalis), alewife (Alosa pseudoharengus), shortnose sturgeon (Acipenser brevirostrum), Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus), and American eel (Anguilla rostrata). All diadromous species have complex life cycles entailing use of both freshwater and marine habitats and require collaborative interjurisdictional management to ensure their sustainability. All these species are managed by the states and federal agencies acting through the Atlantic States Marine Fisheries Commission (ASMFC; also the Great Lakes Fishery Commission for American eel). All of them were historically important commercially within coastal NC. All of them are the focus of significant restoration efforts by the ASMFC, the state commissions (NC Marine Fisheries Commission and NC Wildlife Resources Commission) and other management bodies such as the Mid-Atlantic and New England Fishery Management Councils (MAFMC, NEFMC). The report I attached includes life history information for these species relative to the Cape Fear River.

Additional reports and data are at this website, but I think the attached report should give you a great start: http://ccma.nos.noaa.gov/ecosystems/estuaries/elmr.aspx#products

There are no federally-protected endangered species under FWS management which occur in the area and which would be affected by the action, but the American eel is under status review (review on whether listing as threatened or endangered is warranted). The shortnose sturgeon and Atlantic sturgeon are both federally-listed endangered species known from the area and may be affected by the action under consideration; those species are under the purview of NOAA-National Marine Fisheries Service, and the appropriate contact is:

Fritz Rohde
NMFS/SER/SERO/HCD/AB

101 Pivers Island Road
F/SER47
Beaufort, NC 28516
Phone: (252) 838-0828<tel:%28252%29%20838-0828>
fritz.rohde@noaa.gov<mailto:Fritz.Rohde@noaa.gov>

Please let me know if you have any questions about this information. The next email will have information on

the DO requirements and other habitat needs for species of management concern.

Regards,

Tom

Tom Augspurger
Ecologist / Environmental Contaminants Specialist
U.S. Fish and Wildlife Service
551-F Pylon Drive
Raleigh NC 27606
919-856-4520 x21<tel:919-856-4520%20x21>
tom_augspurger@fws.gov<mailto:tom_augspurger@fws.gov>

On Tue, Apr 15, 2014 at 1:10 PM, Kountis, Elizabeth
<elizabeth.kountis@ncdenr.gov<mailto:elizabeth.kountis@ncdenr.gov>> wrote:
Thank you for talking with me today. Per our conversation, the Division of Water Resources has recently received a request to reclassify a portion of the Cape Fear River to Swamp (Sw); the portion of the river requested to be reclassified is a part of Index #18-(71), which is shown on the map below and is currently Class SC. We are trying to assess the potential impacts of such a reclassification prior to rulemaking, and need USFWS' help in doing so for the aquatic species in the requested waterbody. As a reminder, Sw waters may have DO values lower than 5.0 mg/l, and Sw waters may have a pH as low as 4.3, according to 15A NCAC 02B .0220.
Please forward this email to USFWS staff you think would be interested in it and could provide input on this matter. Please also provide the contact information for any other folks on the Federal level who could contribute information on this issue, i.e. NOAA.

Lastly, if you, and any other USFWS staff you forward this email to, could please respond to this email within a week's time (by Tuesday, 4/22/2014), I would greatly appreciate it.

Thank you very much!

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418<tel:%28919%29%20807.6418> FAX: (919) 807.6497<tel:%28919%29%20807.6497>
E-mail correspondence to and from this address may be subject to the NC Public Records Law and may be disclosed to third parties.

--
Stephania K. Bolden, Ph.D.

Petter, Lauren

From: Gordon, Lisa Perras
Sent: Friday, December 19, 2014 10:54 AM
To: Petter, Lauren
Subject: FW: 1 of 3 re: Lower Cape Fear River

Categories: Yellow Category

From: Wicker, Mike [mailto:mike_wicker@fws.gov]
Sent: Wednesday, May 21, 2014 11:42 AM
To: Gordon, Lisa Perras
Subject: Fwd: 1 of 3 re: Lower Cape Fear River

---------- Forwarded message ----------
From: **Cahoon, Larry** <cahoon@uncw.edu>
Date: Wed, May 21, 2014 at 9:29 AM
Subject: RE: 1 of 3 re: Lower Cape Fear River
To: "Wicker, Mike" <mike_wicker@fws.gov>, "Mallin, Michael A." <mallinm@uncw.edu>
Cc: Fritz Rohde - NOAA Federal <fritz.rohde@noaa.gov>, "Wynne, Bennett" <bennett.wynne@ncwildlife.org>, "Kemp M. Burdette" <kemp@cfrw.us>, "Augspurger, Tom" <Tom_Augspurger@fws.gov>, Dawn York <dyork@dialcordy.com>

I have to question whether the model adequately considers in-stream BOD driven by point source nutrient loading, which manifests particularly at times as algal blooms, but may very well also show up as enhanced microbial respiration. The point source nutrient loads in the river, notably from Smithfield Packing, are really impressive. The river's natural turbulence and turbidity limit phytoplankton growth under most circumstances, but that shifts the community to a microbially dominated situation. Give the bacteria enough nitrogen and phosphorus and they'll metabolize the organic carbon in the water. Mallin and I wrote about that situation in blackwater streams a while back. The CFR has much more N and P in it than the levels we found made a difference. Designating the river as swamp waters ignores all that dynamic.

LBC

From: Wicker, Mike [mailto:mike_wicker@fws.gov]
Sent: Tuesday, May 20, 2014 1:43 PM
To: Mallin, Michael A.
Cc: Fritz Rohde - NOAA Federal; Cahoon, Larry; Wynne, Bennett; Kemp M. Burdette; Augspurger, Tom; Dawn York
Subject: Re: 1 of 3 re: Lower Cape Fear River

model, done by UNCC, found that tightening down on point source BOD would essentially not improve river DO , non-point was not really considered

does that mean game over (sw designation will go forward - or does it mean the model is not sufficiently robust ?

On Tue, May 20, 2014 at 11:58 AM, Mallin, Michael A. <mallinm@uncw.edu> wrote:

specific information as the paper referenced below is exactly what is needed by individuals such as Dianne Reid.
Note that the model, done by UNCC, found that tightening down on point source BOD would essentially not improve river DO.
However, non-point was not really considered - this may be an opportunity to get buffer rules at least considered. The middle river has to come with a nutrient management plan over the next few years, including nutrient discharge and ambient standards, if I understood the WQ folks from DWR correctly at the habitat and WQ breakout,
Mike

From: Wicker, Mike [mike_wicker@fws.gov]
Sent: Tuesday, May 20, 2014 11:41 AM
To: Fritz Rohde - NOAA Federal
Cc: Mallin, Michael A.; Cahoon, Larry; Wynne, Bennett; Kemp M. Burdette; Augspurger, Tom; Dawn York
Subject: Re: 1 of 3 re: Lower Cape Fear River

It is the one that you do not see coming that gets you and this may be it unless somebody does something.

It is going to take some vocal opposition saying what sense could it possibly make to kill the economic engine of productive fisheries in the Cape Fear. Sending poor quality water to the coast where tourism is a major industry will hurt the coastal economy and that needs to be pointed out but in a logical way and in a way that will be heard.

If the idea is to stimulate the economy this makes no sense.

On Tue, May 20, 2014 at 9:53 AM, Fritz Rohde - NOAA Federal
<fritz.rohde@noaa.gov<mailto:fritz.rohde@noaa.gov>> wrote:
I responded to this email and also am sending it to our surgeon PRD folks. I was told at the meeting that Tom Reeder was "throwing in the towel" with lower river water quality.

---------- Forwarded message ----------
From: Fritz Rohde - NOAA Federal <fritz.rohde@noaa.gov<mailto:fritz.rohde@noaa.gov>>
Date: Tue, May 13, 2014 at 11:32 AM
Subject: Re: 1 of 3 re: Lower Cape Fear River
To: "Kountis, Elizabeth" <elizabeth.kountis@ncdenr.gov<mailto:elizabeth.kountis@ncdenr.gov>>
Cc: "Weaver, Adriene" <adriene.weaver@ncdenr.gov<mailto:adriene.weaver@ncdenr.gov>>

In my quick search, I could not find much info. There is Jenkins et al. 1993. Tolerance of shortnose sturgeon juveniles to different salinity and dissolved oxygen concentrations. Proc. Annual Conf. SEAFWA.

"In a 6-hr test, fish 64 days old exhibited 86% mortality when exposed to DO concnetrations of 2.5 mg/l. However, sturgeon >100 dyas old were able to tolerate concentrations of 2.5 mg/l with

Cech et al is in Estuaries 7:12-18

On Tue, May 13, 2014 at 11:08 AM, Kountis, Elizabeth
<elizabeth.kountis@ncdenr.gov<mailto:elizabeth.kountis@ncdenr.gov>> wrote:
Thanks. If you have any other info on DO levels of impact on various lifestages (adult, eggs, etc.), that would be great; I'll also take a look at the reference you provided below.

Sincerely,

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418<tel:%28919%29%20807.6418> FAX: (919) 807.6497<tel:%28919%29%20807.6497>
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From: Fritz Rohde - NOAA Federal [mailto:fritz.rohde@noaa.gov<mailto:fritz.rohde@noaa.gov>]
Sent: Tuesday, May 13, 2014 9:58 AM
To: Kountis, Elizabeth

Subject: Re: 1 of 3 re: Lower Cape Fear River

In habitats with DO less than 4.7 mg/l, young of year Atlantic sturgeon experience a loss in growth. (Secor and Niklitshcek 2001). Mortality in juveniles has been observed for summer temperatures with DO levels less or equal to 3.3 mg/l. Same reference. No data on pH tolerances

Hope this helps. i will be on travel rest of the week and I don't have any staff

On Mon, May 12, 2014 at 2:41 PM, Kountis, Elizabeth
<elizabeth.kountis@ncdenr.gov<mailto:elizabeth.kountis@ncdenr.gov>> wrote:
Thanks so much for your response. If you or one of your staff could please reply back sometime this week, that would be wonderful, as this info is part of a DWR rulemaking package I'm trying to complete by this time next week.

Thanks again!

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418<tel:%28919%29%20807.6418> FAX: (919) 807.6497<tel:%28919%29%20807.6497>
E-mail correspondence to and from this address may be subject to the NC Public Records Law and may be disclosed to third parties.

From: Fritz Rohde - NOAA Federal [mailto:fritz.rohde@noaa.gov<mailto:fritz.rohde@noaa.gov>]
Sent: Friday, May 09, 2014 3:28 PM
To: Kountis, Elizabeth; Kelly Shotts - NOAA Federal
Subject: Re: 1 of 3 re: Lower Cape Fear River

We don't have voice mail at the lab so that's why it kept ringing. Plus I was on travel. As I am most of next week.
I will share this with our protected resources folks for their input also.

Fritz

On Fri, May 9, 2014 at 2:07 PM, Kountis, Elizabeth
<elizabeth.kountis@ncdenr.gov<mailto:elizabeth.kountis@ncdenr.gov>> wrote:
P.S. I tried calling you yesterday and today at the number listed at the bottom of this email (Phone: (252) 838-0828<tel:%28252%29%20838-0828>), but it just rang and rang and rang. I just wanted to let you know that of particular interest is the effect of a Sw classification, meaning DO values lower than 5.0 mg/l, and pH values as low as 4.3, on the two federally endangered fish species, shortnose sturgeon and Atlantic sturgeon, which I understand are present in the subject waters.
Thanks and have a great weekend!

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418<tel:%28919%29%20807.6418> FAX: (919) 807.6497<tel:%28919%29%20807.6497>
E-mail correspondence to and from this address may be subject to the NC Public Records Law and may be disclosed to third parties.

From: Kountis, Elizabeth
Sent: Tuesday, May 06, 2014 2:16 PM

To: fritz.rohde@noaa.gov<mailto:fritz.rohde@noaa.gov>
Cc: Weaver, Adriene
Subject: FW: 1 of 3 re: Lower Cape Fear River

Woops – forgot to attach the map of the portion of the Cape Fear River that has been requested to be reclassified. So sorry!

Here is that map!

[cid:image001.png@01CF6E9B.9659AF80]

Sincerely,

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418<tel:%28919%29%20807.6418> FAX: (919) 807.6497<tel:%28919%29%20807.6497>

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From: Kountis, Elizabeth
Sent: Tuesday, May 06, 2014 2:14 PM
To: 'fritz.rohde@noaa.gov<mailto:fritz.rohde@noaa.gov>'
Cc: Weaver, Adriene
Subject: FW: 1 of 3 re: Lower Cape Fear River

Good afternoon!

Tom Augspurger and I have exchanged emails regarding a request that the NC Division of Water Resources (DWR) recently received to reclassify a portion of the lower Cape Fear River from Class SC to Class Sc Sw (Swamp) (see map below). Tom stated that you would be the appropriate contact with NOAA-National Marine Fisheries Service regarding this reclassification request.

As noted below, NC DWR is trying to assess the potential impacts of such a reclassification prior to rulemaking, and need your help in doing so for the aquatic species living in the requested waterbody.
Please feel free to forward this email to fellow staff you think could provide input on this matter. In addition, if there are any other Federal staff who could contribute information on this issue that you are aware of, I would be most grateful if you would send me their contact info.
Lastly, if at all humanly possible, please respond to this email within a week's time (by Tuesday, 5/13/2014).
Many thanks!

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418<tel:%28919%29%20807.6418> FAX: (919) 807.6497<tel:%28919%29%20807.6497>
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From: Augspurger, Tom [mailto:tom_augspurger@fws.gov]
Sent: Wednesday, April 23, 2014 10:44 AM
To: Kountis, Elizabeth; Weaver, Adriene
Subject: 1 of 3 re: Lower Cape Fear River

Hello Elizabeth,

Thank you for the opportunity to suggest resources and contacts to inform NC DWR's consideration of the request to reclassify a portion of the Cape Fear River to Swamp (Sw). From the map you sent, it appears the area being considered includes the Cape Fear River between Cartwheel Branch (near Navassa) to Snow's Cut (about 17 river miles).

This is the first of three e-mails to convey information. This one provides resources and contacts to identify important aquatic species (either protected or of special management importance) in this reach, with an emphasis on the lifestages that would be present in late spring, summer and early fall when dissolved oxygen (DO) would be lowest (and therefore potentially most affected by an Sw reclassification which could lower the water quality standard for DO).

I have attached a report which is a great quick reference to species of management importance in NC estuaries. The Cape Fear River estuary is included. See the tables in the back of the report, which break out species, and life stages, by season. The references therein will also be useful.

The Fish and Wildlife Service (FWS) is particularly interested in the health and restoration of diadromous fish stocks in the area, including striped bass (Morone saxatilis), American shad (Alosa sapidissima), hickory shad (Alosa mediocris), blueback herring (Alosa aestivalis), alewife (Alosa pseudoharengus), shortnose sturgeon (Acipenser brevirostrum), Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus), and American eel (Anguilla rostrata). All diadromous species have complex life cycles entailing use of both freshwater and marine habitats and require collaborative interjurisdictional management to ensure their sustainability. All these species are managed by the states and federal agencies acting through the Atlantic States Marine Fisheries Commission (ASMFC; also the Great Lakes Fishery Commission for American eel). All of them were historically important commercially within coastal NC. All of them are the focus of significant restoration efforts by the ASMFC, the state commissions (NC Marine Fisheries Commission and NC Wildlife Resources Commission) and other management bodies such as the Mid-Atlantic and New England Fishery Management Councils (MAFMC, NEFMC). The report I attached includes life history information for these species relative to the Cape Fear River.

Additional reports and data are at this website, but I think the attached report should give you a great start: http://ccma.nos.noaa.gov/ecosystems/estuaries/elmr.aspx#products

There are no federally-protected endangered species under FWS management which occur in the area and which would be affected by the action, but the American eel is under status review (review on whether listing as threatened or endangered is warranted). The shortnose sturgeon and Atlantic sturgeon are both federally-listed endangered species known from the area and may be affected by the action under consideration; those species are under the purview of NOAA-National Marine Fisheries Service, and the appropriate contact is:

Fritz Rohde
NMFS/SER/SERO/HCD/AB

101 Pivers Island Road
F/SER47
Beaufort, NC 28516
Phone: (252) 838-0828<tel:%28252%29%20838-0828>
fritz.rohde@noaa.gov<mailto:Fritz.Rohde@noaa.gov>

Please let me know if you have any questions about this information. The next email will have information on the DO requirements and other habitat needs for species of management concern.

Regards,

Tom

Tom Augspurger
Ecologist / Environmental Contaminants Specialist
U.S. Fish and Wildlife Service
551-F Pylon Drive
Raleigh NC 27606
919-856-4520 x21<tel:919-856-4520%20x21>
tom_augspurger@fws.gov<mailto:tom_augspurger@fws.gov>

On Tue, Apr 15, 2014 at 1:10 PM, Kountis, Elizabeth
<elizabeth.kountis@ncdenr.gov<mailto:elizabeth.kountis@ncdenr.gov>> wrote:
Thank you for talking with me today. Per our conversation, the Division of Water Resources has recently received a request to reclassify a portion of the Cape Fear River to Swamp (Sw); the portion of the river requested to be reclassified is a part of Index #18-(71), which is shown on the map below and is currently Class SC. We are trying to assess the potential impacts of such a reclassification prior to rulemaking, and need USFWS' help in doing so for the aquatic species in the requested waterbody. As a reminder, Sw waters may have DO values lower than 5.0 mg/l, and Sw waters may have a pH as low as 4.3, according to 15A NCAC 02B .0220.
Please forward this email to USFWS staff you think would be interested in it and could provide input on this matter. Please also provide the contact information for any other folks on the Federal level who could contribute information on this issue, i.e. NOAA.

Lastly, if you, and any other USFWS staff you forward this email to, could please respond to this email within a week's time (by Tuesday, 4/22/2014), I would greatly appreciate it.

Thank you very much!

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418<tel:%28919%29%20807.6418> FAX: (919) 807.6497<tel:%28919%29%20807.6497>
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Petter, Lauren

From: Petter, Lauren
Sent: Friday, February 20, 2015 2:01 PM
To: Augspurger, Tom
Cc: fritz.rohde@noaa.gov; Harper, Cecelia; rachel.sweeney@noaa.gov; Jerry_ziewitz@fws.gov; Mike Wicker; Wilson Laney
Subject: RE: use classification change in North Carolina

Tom and others,

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That being said, and knowing everyone is busy, will any of you be providing further comments during the comment period and/or have interest in seeing my comments in advance? Thought I would take a pulse to see whether I should allow time for any further coordination with you guys before sending my comments to Ms. Kountis. FYI I will be working to finalize my comments in a letter next week in order to send them prior to the close of the comment period the week after.

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Good luck in your new assignment,

Sincerely,

Tom Augspurger

Tom Augspurger
Ecologist / Environmental Contaminants Specialist
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Raleigh NC 27606
919-856-4520 x21
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Petter, Lauren

From: Augspurger, Tom <tom_augspurger@fws.gov>
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To: Petter, Lauren
Cc: fritz.rohde@noaa.gov; Harper, Cecelia; rachel.sweeney@noaa.gov; Jerry_ziewitz@fws.gov; Mike Wicker; Wilson Laney
Subject: Re: use classification change in North Carolina

Hi Lauren,

I spoke with Wilson and Mike here and would be glad to talk with you about this. I'm in until 5 today at 919-856-4520 x21.

I appreciated that your draft asks for more information on two issues: 1) whether there is a floor for DO if the swamp water designation is in place, and 2) ensuring protection for early life stages of listed fishes. The those were central issues in the four e-mails we sent to the State as technical assistance early in the process. I also think the discussion of natural vs anthropogenic influences and restoration efforts is important. Perhaps mentioning other oxygen-consuming waste sources of concern overtly would be helpful in getting feedback on the path forward post-reclassification (e.g., CAFO associated waste from the Northeast Cape Fear River; large BOD point sources upstream of the modeled reach in the Cape Fear River).

Snowy weather forecast in the normally mild Raleigh area may have our office closed tomorrow. If we don't connect today, you can call my cell at

Phone #?

Information Redacted pursuant to 5 U.S.C Section 552 (b)(6), Personal Privacy

Thanks again for coordinating with us, and I look forward to talking with you.

Tom Augspurger
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Thanks,

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All,

My draft comments are attached. I plan to discuss these more generically with Ms. Kountis before sending so please let me know as soon as possible if you see any issues or disagree with any of the comments as soon as possible (particularly where something was discussed prior to my getting involved). Also, I would prefer the letter not be distributed outside of this email group.

Did any of you attend the hearing at the beginning of February?

Thanks,

Lauren

From: Augspurger, Tom [mailto:tom_augspurger@fws.gov]
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To: Petter, Lauren
Cc: fritz.rohde@noaa.gov; Harper, Cecelia; rachel.sweeney@noaa.gov; Jerry_ziewitz@fws.gov; Mike Wicker; Wilson Laney
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Good morning Lauren,

Thanks for the follow-up note. The e-mails I sent you earlier are our only official input so far (those were from the planning stage). I'll talk with Wilson and Mike this week to see if there will be anything else from our office at this public comment stage. I'd be interested in seeing your comments in advance (thanks for the offer).

More later this week from FWS,

Sincerely,

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Thanks,

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To: Petter, Lauren
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If you are the appropriate contacts, I would appreciate the opportunity to have a call with you both (or exchange emails if that is easier) to see whether there are specific comments we (or just EPA if that is the preference) could make as part of the State's public process.

Below is the link to the EMC agenda where this was recently discussed in case you want more background. See agenda item #9 for files. http://portal.ncdenr.org/web/emc/november-13-2014

Lauren

Lauren Petter, Environmental Scientist

Water Protection Division

U.S. Environmental Protection Agency Region 4

61 Forsyth Street, SW

Atlanta, GA 30303

P: (404) 562-9272

F: (404) 562-9224

Email: petter.lauren@epa.gov

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Subject: Re: use classification change in North Carolina

Good morning Lauren,

Thanks for the follow-up note. The e-mails I sent you earlier are our only official input so far (those were from the planning stage). I'll talk with Wilson and Mike this week to see if there will be anything else from our office at this public comment stage. I'd be interested in seeing your comments in advance (thanks for the offer).

More later this week from FWS,

Sincerely,

Tom Augspurger

Tom Augspurger
Ecologist / Environmental Contaminants Specialist
U.S. Fish and Wildlife Service
551-F Pylon Drive
Raleigh NC 27606
919-856-4520 x21
tom_augspurger@fws.gov

On Fri, Feb 20, 2015 at 2:00 PM, Petter, Lauren <Petter.Lauren@epa.gov> wrote:

Tom and others,

I have nearly finished compiling possible comments to the State and wanted to check in with you as a follow up to my initial email inquiry in January. My comments are a mix of suggested revisions to address the point and nonpoint sources related to the discussion of natural sources, recommendations on where additional documentation would assist in EPA's eventual review if the reclassification is adopted, and "kudos" for early coordination with the Services and other supportive statements where appropriate.

That being said, and knowing everyone is busy, will any of you be providing further comments during the comment period and/or have interest in seeing my comments in advance? Thought I would take a pulse to see whether I should allow time for any further coordination with you guys before sending my comments to Ms. Kountis. FYI I will be

working to finalize my comments in a letter next week in order to send them prior to the close of the comment period the week after.

Thanks,

Lauren Petter

From: Augspurger, Tom [mailto:tom_augspurger@fws.gov]
Sent: Thursday, January 08, 2015 3:05 PM
To: Petter, Lauren
Cc: fritz.rohde@noaa.gov; Harper, Cecelia; rachel.sweeney@noaa.gov; Jerry_ziewitz@fws.gov; Mike Wicker; Wilson Laney
Subject: Re: Introducing myself and feedback needed on use classification change in North Carolina

Good afternoon Lauren.

Thanks for your note and for the introduction. FWS Raleigh has had a good working relationship with NCDWQ staff through the years. They asked for our input on this early, and the attached four files are feedback we provided last spring. Let me know if you want any of the attachments to those. There are three of us here at FWS who worked on portions of this. I am a contaminants specialist and responded to DWQ's initial inquiry with the help of Wilson Laney, a fisheries expert in our office. Mike Wicker is a fisheries biologist with a water quality background who followed-up with the reclassification proponents (discharges and their consultants). He is involved in a couple conservation partnerships on the Cape Fear and discussed the concerns I had (third e-mail) with the proponents and I think is OK with the proposal. After speaking with Mike, the proponents put together a fact sheet (also attached) to address concerns he raised.

The modeling seems to show that lower Cape Fear point source BOD contributors have little influence on local DO. Perhaps the action will refocus some attention on reducing loads (nonpoint and point sources) upstream of the modeled reach?

We haven't yet read the recent proposal to see how it tracks work and conversations last spring and summer, but we will do that. If you want to talk after reviewing this, I'll be glad to get our folks together on the phone with you.

Good luck in your new assignment,

Sincerely,

Tom Augspurger

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U.S. Fish and Wildlife Service

551-F Pylon Drive

Raleigh NC 27606

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On Thu, Jan 8, 2015 at 11:43 AM, Petter, Lauren <Petter.Lauren@epa.gov> wrote:

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The other reason for this email is to touch base with you on the upcoming use classification change to the Lower Cape Fear River from SC to SC Sw classification which both of you should have received an announcement about this morning from Elizabeth Kountis. During the comment period, EPA may make comments. Because this classification can allow DO and pH lower than the otherwise applicable criteria and these parameters can be of concern to certain T&E species I wanted to check in with you (or whoever else you recommend I speak with from FWS and NMFS).

Lisa provided me with email traffic from May 2014 between you both and/or Elizabeth Kountis from DENR and then more internally between NMFS and UNCW. I will send two emails separately so you don't have to go digging for them

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If you are the appropriate contacts, I would appreciate the opportunity to have a call with you both (or exchange emails if that is easier) to see whether there are specific comments we (or just EPA if that is the preference) could make as part of the State's public process.

Below is the link to the EMC agenda where this was recently discussed in case you want more background. See agenda item #9 for files. http://portal.ncdenr.org/web/emc/november-13-2014

Lauren

Lauren Petter, Environmental Scientist

Water Protection Division

U.S. Environmental Protection Agency Region 4

61 Forsyth Street, SW

Atlanta, GA 30303

P: (404) 562-9272

F: (404) 562-9224

Email: petter.lauren@epa.gov

Petter, Lauren

From: Petter, Lauren
Sent: Monday, February 23, 2015 3:28 PM
To: Augspurger, Tom
Cc: fritz.rohde@noaa.gov; Harper, Cecelia; rachel.sweeney@noaa.gov; Jerry_ziewitz@fws.gov; Mike Wicker; Wilson Laney
Subject: RE: use classification change in North Carolina
Attachments: CommentLtrLowerCapeFear 022015.docx

All,

My draft comments are attached. I plan to discuss these more generically with Ms. Kountis before sending so please let me know as soon as possible if you see any issues or disagree with any of the comments as soon as possible (particularly where something was discussed prior to my getting involved). Also, I would prefer the letter not be distributed outside of this email group.

Did any of you attend the hearing at the beginning of February?

Thanks,
Lauren

From: Augspurger, Tom [mailto:tom_augspurger@fws.gov]
Sent: Monday, February 23, 2015 11:42 AM
To: Petter, Lauren
Cc: fritz.rohde@noaa.gov; Harper, Cecelia; rachel.sweeney@noaa.gov; Jerry_ziewitz@fws.gov; Mike Wicker; Wilson Laney
Subject: Re: use classification change in North Carolina

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Lauren

Lauren Petter, Environmental Scientist

Water Protection Division

U.S. Environmental Protection Agency Region 4

61 Forsyth Street, SW

Atlanta, GA 30303

Petter, Lauren

From:	Petter, Lauren
Sent:	Monday, March 02, 2015 2:20 PM
To:	fritz.rohde@noaa.gov; rachel.sweeney@noaa.gov; Jerry_ziewitz@fws.gov; Mike Wicker; Wilson Laney; Augspurger, Tom
Subject:	FW: Comments on Proposed Swamp Reclassification with Water Quality Management Plan for Part of the Cape Fear River
Attachments:	EPACommentLetter_LowerCapeFear_2March2015.pdf

FYI...Just sharing the final copy of the EPA comment letter sent today to Ms. Kountis on the reclassification.

Lauren Petter

From: Petter, Lauren
Sent: Monday, March 02, 2015 2:17 PM
To: 'Kountis, Elizabeth'
Cc: 'Brower, Connie'; Gordon, Lisa Perras
Subject: Comments on Proposed Swamp Reclassification with Water Quality Management Plan for Part of the Cape Fear River

Ms. Kountis,

Please find attached EPA's comments on the proposed reclassification.

Sincerely,
Lauren Petter

Lauren Petter, Environmental Scientist
Water Protection Division
U.S. Environmental Protection Agency Region 4
61 Forsyth Street, SW
Atlanta, GA 30303
P: (404) 562-9272
F: (404) 562-9224
Email: petter.lauren@epa.gov

Petter, Lauren

From: Augspurger, Tom <tom_augspurger@fws.gov>
Sent: Monday, April 06, 2015 3:02 PM
To: Petter, Lauren
Subject: Fwd: Proposed reclassification of a section of the Cape Fear River from Class SC to Class SC Swamp
Attachments: 20150303_letter_Augspurger to Kountis_Lower Cape Fear River Proposed Sw Classification.pdf; 20140423_email1_Augspurger to Kountis_ Lower Cape Fear River.pdf; 20140423_email2_Augspurger to Kountis_ Lower Cape Fear River.pdf; 20140423_email3 _Augspurger to Kountis_ Lower Cape Fear River.pdf; 20140515_email_Augspurger to Kountis_ Lower Cape Fear River.pdf

Hello,

Here are the comments FWS submitted on the proposed reclassification. I also attached the scoping comments we provided last year which were referenced in our letter
just so you would have all of this in one place
.

Thanks,

Tom

Tom Augspurger
Ecologist / Environmental Contaminants Specialist
U.S. Fish and Wildlife Service
551-F Pylon Drive
Raleigh NC 27606
919-856-4520 x21
tom_augspurger@fws.gov

---------- Forwarded message ----------
From: **Augspurger, Tom** <tom_augspurger@fws.gov>
Date: Tue, Mar 3, 2015 at 3:17 PM
Subject: Proposed reclassification of a section of the Cape Fear River from Class SC to Class SC Swamp
To: "Kountis, Elizabeth" <elizabeth.kountis@ncdenr.gov>

Good afternoon Elizabeth,

Please find attached FWS's comments on the proposed Sw reclassification.

Sincerely,

Petter, Lauren

From: Gordon, Lisa Perras
Sent: Friday, November 14, 2014 1:35 PM
To: Petter, Lauren
Subject: FW: Lower Cape Fear follow-up

Categories: Yellow Category

See yellow. I'll check but I don't think they responded.

From: Gordon, Lisa Perras
Sent: Wednesday, September 03, 2014 10:19 AM
To: 'Manning, Jeff'; Kountis, Elizabeth
Cc: connie.brower@ncdenr.gov
Subject: Lower Cape Fear follow-up

Sheesh. That would have been a mess to have those reversed.

On a different note – I wanted to check in with you guys on the Lower Cape Fear reclass. We had thrown out some thoughts when we met in July and I wanted to check back in with you guys on that. Specifically, we had asked if it was possible to hone in on the limited time that the pH and DO may need to be modified in the River since it seemed as if the monitoring data showed that it could meet current standards for much of the year. I know that you guys work at a quick pace and so imagine that you've made a bunch of progress since that meeting. Wondering if there is any help we can provide or if you had an update on that one?

Lisa G.

From: Manning, Jeff [mailto:jeff.manning@ncdenr.gov]
Sent: Wednesday, September 03, 2014 8:18 AM
To: Kountis, Elizabeth; Gordon, Lisa Perras
Cc: connie.brower@ncdenr.gov
Subject: RE: NC EPA submittal for Lake Adger reclass

And, thankfully, no "declasses" from the legislature. The bill that was introduced this spring to reverse some recent water supply reclassification(s) didn't make it into law, and the legislature has adjourned.

From: Kountis, Elizabeth
Sent: Wednesday, September 03, 2014 8:09 AM
To: Gordon.Lisa-Perras@epamail.epa.gov
Cc: Manning, Jeff; Brower, Connie
Subject: NC EPA submittal for Lake Adger reclass

It appears that there will only be one reclassification that will become effective in 2014, and that is the Lake Adger reclassification. I was thinking about sending the package for it to you for EPA approval in the next few weeks, but... given that would mean a submittal with just one reclassification, perhaps it would be more prudent to wait until early next year to submit it. At that time, hopefully the triennial will have wrapped up, and Connie and I could send our respective EPA packages through the same group of required folks (AG's office, upper DWR management, etc.) at the same time, thus saving those folks from having to look at those packages at different times. Whatcha think?

Petter, Lauren

From: Gordon, Lisa Perras
Sent: Friday, November 14, 2014 1:36 PM
To: Petter, Lauren
Subject: FW: Cape Fear Follow-up

Below....

From: Gordon, Lisa Perras
Sent: Tuesday, June 24, 2014 11:34 AM
To: Kountis, Elizabeth
Subject: FW: Cape Fear Follow-up

Betsy,

Just checking in to see if you have time this week to catch up?

Lisa

From: Gordon, Lisa Perras
Sent: Tuesday, June 17, 2014 3:18 PM
To: Kountis, Elizabeth
Subject: Cape Fear Follow-up

Betsy,

Do you have time to chat this week about the Cape Fear request? I've spoken to the FWS and there are concerns that I'd like to check in with you about.

Most of Wednesday is clear or Thursday morning.

Hope your summer is going well!

Lisa

Lisa Perras Gordon
Water Quality Standards
North Carolina Coordinator
Regional CWA and Hydrologic Alteration Coordinator
U.S. Environmental Protection Agency
Atlanta, Georgia
(404) 562-9317

Petter, Lauren

From: Gordon, Lisa Perras
Sent: Friday, November 14, 2014 1:37 PM
To: Petter, Lauren
Subject: FW: Swamp

Categories: Yellow Category

Don't kill me for sending all of these...

From: Gordon, Lisa Perras
Sent: Tuesday, May 20, 2014 4:45 PM
To: Kountis, Elizabeth
Subject: Swamp

Betsy,

Thanks for the heads up today on the LCF Swamp. Turns out that by the time I got back to my desk I'd heard from NOAA and FWS. So, if you could send the request, that would be great. I'll return their call tomorrow.

Lisa Perras Gordon
Water Quality Standards
North Carolina Coordinator
Regional CWA and Hydrologic Alteration Coordinator
U.S. Environmental Protection Agency
Atlanta, Georgia
(404) 562-9317

Petter, Lauren

From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Friday, November 14, 2014 4:49 PM
To: Petter, Lauren
Cc: Gordon, Lisa Perras; Godfrey, Annie; Manning, Jeff; Weaver, Adriene
Subject: RE: Two Items: 2014 Reclassification and Cape Fear

Good afternoon! Glad you got the 2014 submittal; as you mentioned, any questions on that submittal you can send my way.

Regarding your question about my presentation at yesterday's EMC meeting, I think we may have discussed the subject waters discussed during that presentation when you visited a few months ago. At yesterday's meeting, DWR received approval to take the proposed reclassification out to public notice and hearing. The following EMC webpage for yesterday's meeting features my presentation, as well as other materials that you may find helpful, under #9 within "II. Actions"; here is that webpage: http://portal.ncdenr.org/web/emc/november-13-2014

The 60-day public comment period associated with the public notice is slated to start on January 2, 2015, and I'm in the process of setting up a hearing date, time, and location for the first week in February 2015. EPA staff is on our mailing list for public hearing announcements, which feature the details about the hearing, and that will be sent out in early January 2015.

Hope that helps. Let me know if you need further information.

Have a great weekend!

Elizabeth Kountis

From: Petter, Lauren [Petter.Lauren@epa.gov]
Sent: Friday, November 14, 2014 1:21 PM
To: Kountis, Elizabeth
Cc: Gordon, Lisa Perras; Godfrey, Annie
Subject: Two Items: 2014 Reclassification and Cape Fear

Hey Elizabeth,

Although we've already met, I just wanted to take this chance to say hey and say I'm looking forward to working with you on use changes (as I hear there are quite a lot in North Carolina).

FYI I will be taking a look at the 2014 submittal today and next week, as part of the transition from Lisa Gordon being the NC WQS coordinator to myself. If I have any questions I will follow up with you.

On another matter, Lisa was listening in to the EMC meeting yesterday and heard you present the Cape Fear DU change to the EMC. Is this the same water we discussed during our visit a couple months ago? Based on the meeting yesterday, it sounds like you guys were approved to go to public hearing. As I'm still learning your process, what does that mean as far as timing and opportunity for EPA to comment? Is your department approved to initiate rulemaking efforts or you are farther along than that in the process? Also, could you send me the presentation you gave, the date for the hearing you will have, and any other information that might be useful for EPA to review prior to an adoption of the use change?

In general, we at EPA are trying to coordinate early on in the process, given some changes in the administrative type activities we have to complete prior to taking our action, so getting as much worked out in advance helps us take timely actions and alleviate frustrations at the state level for documentation requests after the adoption has taken place. Feel free to follow up with any questions you have.

P.S. I telework on Fridays and can be reached at

Thanks,
Lauren

From: Kountis, Elizabeth [mailto:elizabeth.kountis@ncdenr.gov]
Sent: Wednesday, October 29, 2014 8:54 AM
To: Giattina, James; Benante, Joanne; Godfrey, Annie
Cc: Gordon.lisaperras@Epa.gov; Reeder, Tom; Fransen, Tom; Manning, Jeff
Subject: NC Submittal of 2014 Effective Reclassification
Importance: High

Attached is North Carolina's 2014 submittal to EPA for approval of the reclassification that became effective this year. Ms. Heather McTeer Toney has been sent her copy of the document via certified mail. If you have any questions or concerns regarding the document, please feel free to contact me.

Sincerely,

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418 FAX: (919) 807.6497
E-mail correspondence to and from this address may be subject to the NC Public Records Law and may be disclosed to third parties.

Petter, Lauren

From: Petter, Lauren
Sent: Tuesday, December 23, 2014 1:45 PM
To: 'Kountis, Elizabeth'
Cc: Gordon, Lisa Perras; connie.brower@ncdenr.gov; 'Manning, Jeff'
Subject: Lake Adger and Cape Fear

Hey Elizabeth,

I have shared a draft with folks here of my review of Lake Adger so hopefully after the new year when everyone is back from use or lose I can get some eyes on that and keep the review moving. Thanks for your timely responses to my previous questions!

As far as the proposed change for Cape Fear, I was looking through the materials from the EMC approval to move forward with the public hearing etc. and was going through some files on the subject. I wanted to check with you on the NOAA and FWS coordination it looks like you started back in the spring on the reclass. It looks like some information may have been shared on DO requirements for sturgeon but I can't tell if it was received prior to the deadline you had at the time. Also, Lisa had sent an email about the possibility of limited times for the lower DO and more generally the data that supports the change and I was wondering if you had thought about that any further. The reason I'm asking is because on January 8th I have a meeting internally to discuss with others the various activities going on in the Cape Fear Basin. So if you are available to chat or send me a quick email before January 8th to let me know where things ended with the Services coordination that would be useful for me to have.

I am flexing today until 4 (phone # and in the office 12/29 and 12/30.

Thanks,
Lauren

Lauren Petter, Environmental Scientist
Water Protection Division
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61 Forsyth Street, SW
Atlanta, GA 30303
P: (404) 562-9272
F: (404) 562-9224
Email: petter.lauren@epa.gov

Petter, Lauren

From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Thursday, January 08, 2015 11:32 AM
To: Tom_Augspurger@fws.gov; mike_wicker@fws.gov; fritz.rohde@noaa.gov; david.bernhart@noaa.gov; kelly.shotts@noaa.gov; stephania.bolden@noaa.gov; ksulak@usgs.gov; Petter, Lauren; Gordon.lisaperras@Epa.gov
Subject: Comment Period and Hearing for Lower Cape Fear River Proposed Sw Reclassification and Water Quality Management Plan
Attachments: Hearing_Announcement.pdf

Attached is an announcement for a comment period and an upcoming public hearing for a proposed surface water reclassification of a section of the Cape Fear River (Brunswick and New Hanover Counties, Cape Fear River Basin) from Class SC to Class SC Sw Swamp (Sw) with a water quality management plan. The proposed reclassification and management plan concern the portion of the Cape Fear River from the upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut, where the Intracoastal Waterway meets the river.

The public hearing and comment period are being held in accordance with the federal Water Pollution Control Act (the Clean Water Act) that requires States to conduct a Triennial Review, which includes an assessment and revision of the designated uses of waters (classifications) and associated water quality criteria (standards). This announcement will appear on a few listservs, so I apologize in advance if you receive this information more than once.

Comments on the proposed reclassification and water quality management plan may be submitted in writing, fax, or email anytime through March 3, 2015 to the following:

Elizabeth Kountis
DENR-Division of Water Resources, Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611
Fax (919) 807-6497
Elizabeth.Kountis@ncdenr.gov

If you or any of your staff would like to attend the hearing, please let me know which staff are planning to attend by January 30th, 2015, and know that I would like to introduce that staff at the hearing. The date, time, and location of the public hearing are as follows:

Thursday, February 5, 2015
6:30 p.m.
USS North Carolina Battleship
1 Battleship Road Northeast
Wilmington, NC 28401

Please reference the attached hearing announcement for further details regarding the hearing, comment period, and proposed reclassification and water quality management plan. The hearing announcement, along with the fiscal analysis and other information for this proposal, is also located on the internet at:
http://portal.ncdenr.org/web/wq/event-calendar (look under "2015-02-05").

If you should need additional information, the DWR staff contact is Elizabeth Kountis at (919) 807-6418.

The modeling seems to show that lower Cape Fear point source BOD contributors have little influence on local DO. Perhaps the action will refocus some attention on reducing loads (nonpoint and point sources) upstream of the modeled reach?

We haven't yet read the recent proposal to see how it tracks work and conversations last spring and summer, but we will do that. If you want to talk after reviewing this, I'll be glad to get our folks together on the phone with you.

Good luck in your new assignment,

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Raleigh NC 27606

919-856-4520 x21

tom_augspurger@fws.gov

On Thu, Jan 8, 2015 at 11:43 AM, Petter, Lauren <Petter.Lauren@epa.gov> wrote:

Tom and Fritz,

PROPOSED SWAMP RECLASSIFICATION WITH WATER QUALITY MANAGEMENT PLAN FOR PART OF CAPE FEAR RIVER: PUBLIC HEARING SET FOR FEBRUARY 2015

The Cape Fear River Class SC waters shown on the map below are proposed to be assigned the supplemental Swamp (Sw) classification, and would be subject to the provisions of the Sw designation as well as the provisions of a water quality management plan that is also proposed to be assigned to these waters.

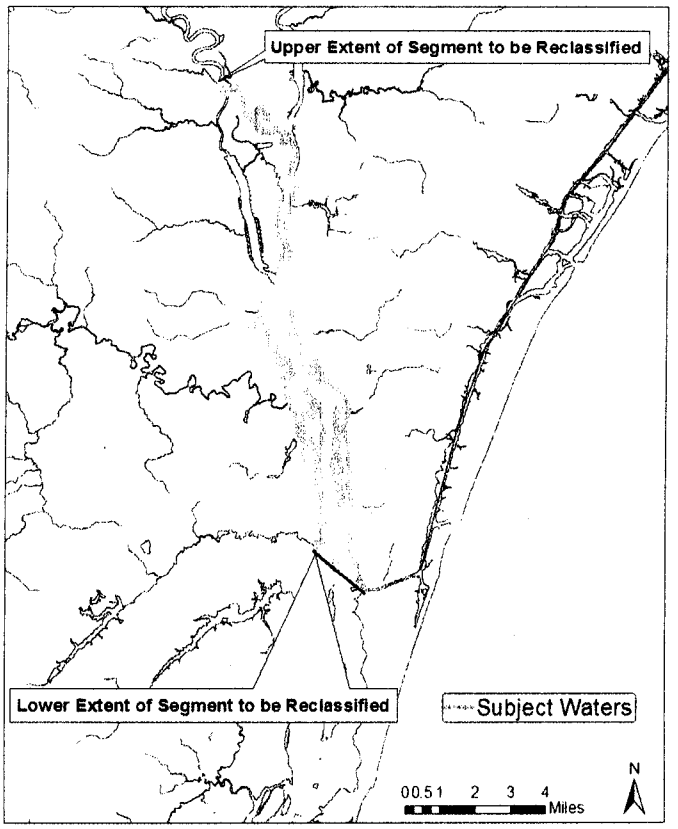
PUBLIC HEARING

Location: USS North Carolina Battleship
1 Battleship Road Northeast
Wilmington, NC 28401

Time & Date: 6:30 p.m., Thursday, February 5, 2015

Purpose: to receive public comments on a proposed reclassification and water quality management plan for a section of the Cape Fear River in Brunswick and New Hanover Counties (Cape Fear River Basin)

Proposed Swamp Reclassification and Water Quality Management Plan
Cape Fear River, Brunswick and New Hanover Counties, NC



NCDENR-Division of Water Resources
Water Planning Section
November 24, 2014

WATERS AFFECTED BY PROPOSED RECLASSIFICATION & WATER QUALITY MANAGEMENT PLAN

The proposed reclassification and water quality management plan concern the portion of the Cape Fear River from the upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut, where the Intracoastal Waterway (ICW) meets the river. No tributaries to this section of the Cape Fear River are to be affected by the proposed actions. Wetlands, developed lands, other open waters, forest lands, shrub/scrub lands, and primarily Class Sw tributaries exist directly adjacent to the subject waters. Several tidal saltwater species, including the federally endangered shortnose sturgeon and federally endangered Atlantic sturgeon, live in these waters. Within the subject waters, there are eight (8) existing NPDES wastewater discharges.

REGULATIONS INVOKED BY PROPOSED RECLASSIFICATION & WATER QUALITY MANAGEMENT PLAN

If the proposed reclassification and management plan become effective, then the pH standard applicable to these waters can be as low as 4.3 if caused by natural conditions, and the dissolved oxygen (DO) standard applicable to these waters can be lower than 5.0 mg/l if caused by natural conditions; currently the DO standard is 5 mg/l, and the pH standard is a range between 6.8-8.5, for the subject waters. In addition, new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges in the subject waters would have to meet specific effluent limits for oxygen consuming wastes. For such domestic facilities, effluent limits of 5 mg/l for BOD_5, 1 mg/l for ammonia, and 6 mg/l for DO would apply. For industrial discharges, site specific best available technology on a case by case basis would be utilized to determine the limits for BOD_5, ammonia and DO. For new individual NPDES wastewater facilities and expansions of existing individual NPDES wastewater discharges, the management plan would include consideration of seasonal effluent limits on a case by case basis, and the following stipulation: Any new or expanded permitted pollutant discharge of oxygen-consuming waste shall not cause the DO of the receiving water to drop more than 0.1 mg/l below the modeled in-stream DO at total permitted capacity.

The proposed management plan is consistent with the current permitting policy for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters. There are currently no known planned new individual NPDES wastewater discharges and one (1) planned expansion of an existing individual NPDES wastewater discharge in the subject waters, which already meets the proposal's requirements. The proposed water quality management plan in conjunction with the Sw designation provides a path forward for the subject waters' dischargers, and thus for local communities, for future planning purposes. Finally, it is unknown how the Sw standards will affect the current DO and pH impairment status of these waters.

A fiscal analysis for this proposal has been completed, and revealed no quantifiable cost or benefit to the ecosystem, humans, implementing agencies, new individual NPDES wastewater discharges, and expansions of existing individual NPDES wastewater discharges.

MEETING FEDERAL TRIENNIAL REVIEW REQUIREMENTS

The public hearing and comment period are to be held in accordance with the federal Clean Water Act that requires States, at least every three years, to review and revise water quality standards. These standards are provided in existing rules NCAC 15A 02B .0100 and .0201 through .0228. The process is in accordance with the Triennial Review and includes an assessment and revision of the designated uses of waters (classifications) and the water quality criteria (standards), which are based on the designated uses. More specifically, this public hearing and comment period are to address the potential assignment of a Sw classification and water quality management plan to a portion of the Cape Fear River. This proposal will result in additional water quality standards applicable to the subject waters.

HOW TO SUBMIT COMMENTS

You may attend the public hearing and provide verbal comments that specifically address the proposed reclassification and water quality management plan for the subject portion of the Cape Fear River. The Hearing Officer may limit the length of time that you may speak at the public hearing, if necessary, so that all those who wish to speak may have an opportunity to do so. In addition, written comments addressing the proposed reclassification and water quality management plan for the Cape Fear River segment will be accepted until March 3, 2015.

All persons interested and potentially affected by the proposal are encouraged to read this announcement and make comments on the proposal. The EMC may not adopt a rule that differs substantially from the text of the proposed rule published in the North Carolina Register unless the EMC publishes the text of the proposed different rule and accepts comments on the new text. The proposed effective date for this proposed reclassification is November 1, 2015. Written comments on the proposed reclassification and water quality management plan for the Cape Fear River segment may be submitted to Elizabeth Kountis of the Division of Water Resources Planning Section at the postal address, e-mail address, or fax number listed below.

FOR ADDITIONAL INFORMATION

This announcement and a map of the subject waters are located on the internet via http://portal.ncdenr.org/web/wq/event-calendar (look under "2015-02-5"). In the case of inclement weather on the day of the scheduled public hearing, please contact the telephone number below for a recorded message regarding any changes to the location, date, or time of the hearing. Further explanations and details on reclassifications may be obtained by writing or calling:

Elizabeth Kountis, DENR-Division of Water Resources, Planning Section
1611 Mail Service Center, Raleigh, NC 27699-1611
phone (919) 807-6418, fax (919) 807-6497, e-mail elizabeth.kountis@ncdenr.gov

To learn more about how the Division of Water Resources protects water quality in North Carolina, go to http://portal.ncdenr.org/web/wq/home/wyk.

Petter, Lauren

From: Petter, Lauren
Sent: Thursday, February 26, 2015 10:29 AM
To: 'Kountis, Elizabeth'
Subject: discuss comments on Cape Fear

Hey Elizabeth,

Just left a voicemail at your work number, but in case you are working from home due to bad weather I thought I'd send an email too. I'd like to follow up with you on the comments I mentioned last week that EPA will be sending regarding the proposed Lower Cape Fear River reclassification. Just give me a call when you have some time to chat.

Talk to you soon,
Lauren

Lauren Petter, Environmental Scientist
Water Protection Division
U.S. Environmental Protection Agency Region 4
61 Forsyth Street, SW
Atlanta, GA 30303
P: (404) 562-9272
F: (404) 562-9224
Email: petter.lauren@epa.gov

Petter, Lauren

From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Thursday, February 26, 2015 1:58 PM
To: Petter, Lauren
Subject: RE: discuss comments on Cape Fear

I'm not in the office today and it's highly likely I won't be in the office tomorrow, as we got about 6 inches of snow last night, roads are extremely slick, schools are closed, and it looks like not much will melt until Sunday. Can we chat Monday? If that's too late, can you send me an email with the contents of what you wanted to share with me?

Thanks
Elizabeth Kountis

From: Petter, Lauren [Petter.Lauren@epa.gov]
Sent: Thursday, February 26, 2015 10:29 AM
To: Kountis, Elizabeth
Subject: discuss comments on Cape Fear

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Lauren Petter, Environmental Scientist
Water Protection Division
U.S. Environmental Protection Agency Region 4
61 Forsyth Street, SW
Atlanta, GA 30303
P: (404) 562-9272
F: (404) 562-9224
Email: petter.lauren@epa.gov

Petter, Lauren

From: Petter, Lauren
Sent: Thursday, February 26, 2015 2:20 PM
To: 'Kountis, Elizabeth'
Cc: Godfrey, Annie
Subject: RE: discuss comments on Cape Fear

Yes chatting Monday sounds good. Stay warm!

Lauren

From: Kountis, Elizabeth [mailto:elizabeth.kountis@ncdenr.gov]
Sent: Thursday, February 26, 2015 1:58 PM
To: Petter, Lauren
Subject: RE: discuss comments on Cape Fear

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61 Forsyth Street, SW
Atlanta, GA 30303
P: (404) 562-9272
F: (404) 562-9224
Email: petter.lauren@epa.gov

Petter, Lauren

From:	Petter, Lauren
Sent:	Monday, March 02, 2015 2:17 PM
To:	Kountis, Elizabeth
Cc:	Brower, Connie; Gordon, Lisa Perras
Subject:	Comments on Proposed Swamp Reclassification with Water Quality Management Plan for Part of the Cape Fear River
Attachments:	EPACommentLetter_LowerCapeFear_2March2015.pdf

Ms. Kountis,

Please find attached EPA's comments on the proposed reclassification.

Sincerely,
Lauren Petter

Lauren Petter, Environmental Scientist
Water Protection Division
U.S. Environmental Protection Agency Region 4
61 Forsyth Street, SW
Atlanta, GA 30303
P: (404) 562-9272
F: (404) 562-9224
Email: petter.lauren@epa.gov

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

MAR 02 2015

Ms. Elizabeth Kountis
Division of Water Resources Planning Section
North Carolina Department of Environment
and Natural Resources
1611 Mail Service Center
Raleigh, NC 27699-1611

Dear Ms. Kountis:

Following receipt of the hearing announcement for the "Proposed Swamp Reclassification with Water Quality Management Plan for Part of the Cape Fear River," the EPA reviewed several documents prepared in support of the subject reclassification. The EPA found these documents summarized well how the reclassification came to be requested, along with summaries of the existing studies that have been completed, to better understand the cause(s) behind the dissolved oxygen (DO) levels which on occasion are below the currently applicable 5 mg/L DO criterion. These documents also discuss whether there is any longer a need for the development of a Total Maximum Daily Load (TMDL). After reading these documents, we thought it would be beneficial to make specific comments to ensure that the resulting final criteria, or more specifically the possibility for lower pH and DO values, are adequately protective of the waterbody. Additionally, EPA supports the State's continued efforts to make improvements in water quality that still may be desired, such as through decreases from anthropogenic sources, following the change in reclassification.

The EPA provides the following comments to the State, grouped by topic. These comments are also being made to ensure the State provides the necessary supporting documentation at the time of submittal as well as consider possible revisions to the proposal where indicated below.

Natural versus Anthropogenic Influences and Swamp Classification

1) The fourth technical memorandum indicates that modeling estimates 75-80% of the oxygen demand in the Lower Cape Fear River comes from wetland/marsh and SOD sources. While the analysis of the non-anthropogenic sources is useful to supporting the proposed swamp classification, when making the argument that alternative criteria are appropriate for a given waterbody, particularly on the basis of natural background, the EPA must consider whether a condition is exacerbated by other influences which are not considered natural. As indicated in the first technical memorandum, when eliminating the wastewater point source loadings the 10th percentile DO did increase. The State could consider a revision to the DO and pH language indicating that sources which are not natural will still need to be considered and addressed during activities which consider in-stream and downstream water quality, like permitting or future criteria development efforts. Additional comments on DO and pH are discussed later.

2) Within the materials, it was noted that swamp classification was removed from this segment in 1981. In the October 6, 1981 report of proceedings, a staff representative indicated the streams "had improved enough so that [the streams can] meet the C standard without being allowed the designated exception." EPA recommends the state further address this previous change which removed the swamp classification as it relates to the proposed change, reverting it back to a swamp classification.
3) As described in the definition for swamp waters, such waters "have very low velocities and other characteristics which are different from adjacent streams draining steeper topography." Since this relates to the proposed classification, the State should provide additional documentation indicating the velocities and other characteristics that make the swamp classification appropriate for the Lower Cape Fear River.

Allowance for DO less than 5 mg/L

1) As an alternative to including the type of language suggested in item one above, the State could consider some specific lower bound be selected for DO, as is the case with pH. Future assessments of the waterbody will be much more streamlined and reproducible if a specific DO criterion minimum is in place. Also, for dischargers that are not new or expanding, and therefore not covered by the management plan, it will be simpler to determine reasonable potential if a specific criterion for the waterbody is in place. As another alternative the State could consider a seasonally, or specific month(s), based lower bound for DO to more accurately represent known data from the period of record and modeling efforts.
2) Without a lower bound for DO, is there any limitation on the duration or frequency by which a measured DO level can be below the 5mg/L criterion? How will the assessment of the exceedances below 5 mg/L be determined to be based on natural conditions? EPA encourages the State to consider providing additional clarity through the adopted revisions to ensure proper implementation of the classification if adopted.

pH of 4.3

1) In general the support for the change to pH appears to have less supporting documentation than DO. The EPA recommends the State provide data documentation from the historical monitoring efforts for this segment to justify the conclusion that values as low as 4.3 are appropriate, as well as protective. Although describing upstream data, the information shown for pH provides monthly averages on page D-45. Unless monthly average was intended, it may be more useful to present data in a different way, to match the intended duration for the 4.3 value.
2) The EPA suggests that the State clarify whether the 4.3 represents an instantaneous measurement, typically referred to as a "shall not exceed" value. If something different is intended, that should also be documented and supported.

Threatened and Endangered Species

1) The EPA is aware that Ms. Kountis worked with the Services in advance of this proposal. This upfront coordination and consideration of the Service's comments is important and EPA greatly appreciates the State's effort to do this. As part of the State's final documentation, the EPA recommends the materials include a discussion on how the water quality requirements (such as DO levels) were considered and will result in a designated use, with its corresponding water quality criteria, that will be protective of the two sturgeon species that could be present in the segment.

TMDL and/or Restoration Efforts

1) Although information has been provided to describe natural sources of lower DO and pH values, it will be important to ensure that the influence from anthropogenic sources is still addressed and continues to be monitored to ensure anthropogenic sources are not contributing to lower DO or pH levels.
2) As noted on page D-3 of the materials, the petition seems to indicate that point sources will have waste load allocations developed for them. The EPA supports this conclusion.
3) The first technical memorandum mentions that further channel dredging "also showed a significant impact [on DO conditions]." Can the State provide the EPA with additional information on this analysis and how it was considered?

General Documentation

1) We encourage the State to provide specific documentation to EPA no later than the time of the State's submittal to EPA for 303(c) review to ensure a timely final review. EPA staff are also available to review any supplemental information in advance if that is the State's preference.

If you have any questions, please contact me at (404) 562-9967 or have a member of your staff contact Ms. Lauren Petter at (404) 562-9272.

Sincerely,

Annie Godfrey, Chief
Water Quality Standards Section

Petter, Lauren

From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Wednesday, April 29, 2015 4:06 PM
To: Petter, Lauren
Subject: EPA 3-2-2015 comment letter regarding LCFR proposal

Good afternoon!

Just a quick question:
In "2)" at the top of page 2 it states that "In the October 6, 1981 report of proceedings, a staff representative indicated that the streams "had improved enough so that [the streams can] meet the C standard without being allowed the designated exception."

Can you please send this documentation to me?

Thanks

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418 FAX: (919) 807.6497
E-mail correspondence to and from this address may be subject to the NC Public Records Law and may be disclosed to third parties.

Petter, Lauren

From: Petter, Lauren
Sent: Thursday, April 30, 2015 8:02 AM
To: 'Kountis, Elizabeth'
Subject: RE: EPA 3-2-2015 comment letter regarding LCFR proposal
Attachments: NC Report of Proceedings October 6 1981.pdf

The document is attached. See page 3 at the end of Mr. Tyler's response on that page.

Lauren

From: Kountis, Elizabeth [mailto:elizabeth.kountis@ncdenr.gov]
Sent: Wednesday, April 29, 2015 4:06 PM
To: Petter, Lauren
Subject: EPA 3-2-2015 comment letter regarding LCFR proposal

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STATE OF NORTH CAROLINA
DEPARTMENT OF NATURAL RESOURCES AND COMMUNITY DEVELOPMENT
DIVISION OF ENVIRONMENTAL MANAGEMENT

REPORT OF PROCEEDINGS CONCERNING THE PROPOSED RECLASSIFICATION OF TOWN DITCH IN THE LUMBER RIVER BASIN AND LAKE HUNT, LITTLE ALAMANCE CREEK, RICHLAND CREEK PENNWOOD BRANCH, CABIN CREEK IN THE CAPE FEAR RIVER BASIN AND LONGVIEW BRANCH AND WATSON BRANCH IN THE NEUSE RIVER BASIN

PUBLIC HEARING
OCTOBER 6, 1981
REIDSVILLE, NORTH CAROLINA

ENVIRONMENTAL MANAGEMENT COMMISSION
RALEIGH, NORTH CAROLINA

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SUMMARY AND RECOMMENDATIONS

Lake Hunt

The City of Reidsville requested the reclassification of Lake Hunt from Class A-II to Class A-II and B. Lake Hunt was Class A-II as a water supply for Reidsville but is no longer needed as they now have Lake Reidsville which should provide an adequate supply of water for the forseeable future. Reidsville is developing a recreational area on Lake Hunt and desires that it be protected for swimming.

On checking with the Water Supply Branch of the Division of Health Services, they suggested that instead of going to the dual classification they preferred that the A-II be dropped and the reclassification be to Class B. They do not like to have swimming in a water supply unless it is necessary and they could give a temporary permit to use the lake as a water supply should an emergency arise. This was agreeable to Reidsville so the request was changed to reclassify Lake Hunt from A-II to B.

No comments against the reclassification were made at the hearing and no written comments were received in the 30-day period following the hearing.

It is the recommendation of the Hearing Officer and the staff that Lake Hunt be reclassified to Class B.

Removal of Stream Classification Exceptions

North Carolina has a number of streams which consistently do not meet their stream classification of "C." A review of the condition of these streams was completed last year and it was found that some had improved enough so that the coliform or dissolved oxygen exception which had been granted them was no longer necessary. At this hearing seven streams that had carried exceptions were presented for removal of the exception. No oral or written comments were received concerning these streams so it is the Hearing Officer's and staff's recommendation that the exceptions on these seven streams be dropped.

Proceedings of a Public Hearing Held in
Reidsville, North Carolina
October 6, 1981

The Reidsville hearing was held to consider a request by the Reidsville City Council for the reclassification of Lake Hunt from Class "A-II" to Class "B." At the same time the Division of Environmental Management Staff asked for public consideration of the removal of the coliform and dissolved oxygen exceptions from seven streams that were previously unable to meet the Class "C" standards so that they carried the designated exceptions.

The meeting was called to order at 11:00 A.M. in the Council Room of the Reidsville City Hall.

The following persons attended the hearing:

Hearing Officer

Mr. Russell Radford, Assistant Regional Supervisor, Winston-Salem Regional Office of the Division of Environmental Management.

Staff Members

Mr. Lloyd Tyler, Staff Representative
Mr. Alridge Renn, Hearing Recorder
Mrs. Jackie Nowell, Hearing Clerk

Others

Tommy Dye, City Engineer
City of Reidsville
P.O. Box 1437
Reidsville, NC 27320

Karen L. Jacques
Intern
Reidsville City Hall
Reidsville, NC 27320

Robert G. Cox
City Manager
City of Reidsville
Box 1437
Reidsville, NC 27320

E.P. Cain
Regional Engineer
NC Division of Health Services
720 Coliseum Drive
Winston-Salem, NC 27602

Ted Nelson
Staff Writer
The Reidsville Review
P.O. Box 2157
Reidsville, NC 27302

Chuck Alston
Reporter
Greensboro Daily News
698 Linden Drive
Eden, NC 27288

Mr. Radford: The hearing will please come to order. My name is Russell Radford and I have been designated by the Director of the Division of Environmental Management to preside at this hearing. The hearing is held under the authority of North Carolina General Statutes, Chapter 143-214.1 and 143-215.3(a)(1).

In accordance with the General Statutes of North Carolina, a public notice of this hearing was published one time in each of the following papers during the week of August 30th through September 5, 1981: Randolph Guide, Montgomery Herald, Raleigh News and Observer, Reidsville Review, Greensboro Daily News, The Robesonian.

Notices were also mailed to municipal, county, and state officials as well as others thought to have an interest in this matter. Unless someone has an objection, without reading the notice I will enter a copy of it in the hearing record as Exhibit # 1. Are there any objections? There being no objections, it is ordered.

The main purpose of this hearing is to obtain public comment on a request for the reclassification of Lake Hunt from Class A-II to Class B to protect it for primary recreation for the City of Reidsville. Before we proceed further with the details of this request I would like to introduce members of the staff that are here for this hearing.

Ms. Jackie Nowell, Hearing Clerk
Mr. Alridge Renn, Hearing Recorder
Mr. Lloyd Tyler, Staff Representative

Mr. Tyler will present information relating to the request in a moment. Following the staff presentation everyone who wishes to speak will be given a chance to do so. Those that indicated on the registration form that they would like to be heard will be called upon first and then if there are others that wish to speak they will be given the opportunity.

I will now ask Mr. Tyler if he will please present the staff's findings on the Lake Hunt situation and also on the removal of the classification exceptions from seven streams which have carried dissolved oxygen or coliform exceptions in the past.

Mr. Tyler: Thank you, Mr. Radford. The reason this hearing is being held in Reidsville is that the main concern today is to get comments on the reclassification of Lake Hunt from Class A-II to Class B. The seven streams which are under consideration are scattered about the piedmont and we welcome comments on them too. As you entered the hearing room there was a handout available describing the streams under consideration. Rough maps of the area through which each stream passed were also in the handout. If you did not get one, please raise your hand and we will give you one. Mr. Radford, I would like to request that this handout be entered in the record as Exhibit # 2.

Lake Hunt which is on an unnamed tributary to Troublesome Creek was given the A-II classification on April 1, 1959 at the same time that the entire Cape Fear River Basin was classified. It covers an area of

155 acres and is said to have a holding capacity of about 750 million gallons with a depth of 30 feet at the water intake. The area surrounding the lake is both agricultural and forested and the watershed covers an area of 4.96 square miles. Now, Reidsville has Lake Reidsville as its main water supply reservoir with a storage of 2.6 billion gallons and a safe yield of 17 MGD. As the Lake Reidsville supply is very adequate for the foreseeable future, there is no need to have Lake Hunt remain Class A-II and the city considers its best usage to be for a primary recreation area, which would include swimming. By means of a resolution by the City Council on April 8, 1981 the City requested that the lake be reclassified.

A sampling program was carried out in June and July of this year at three points on the lake. Bacteriological sampling was done at the upper end of the lake, in the middle area, and at the proposed beach area not far from the dam. The results showed the lake to have very low fecal coliform counts so that it very easily meets the standards for Class B waters.

We are required in a reclassification of this kind to make a socioeconomic cost/benefit analysis of the effect of a reclassification. The analysis was made by the Office of Regulatory Relations. They say that the benefit is that the lake may be used for swimming while there are no direct economic costs if the lake is reclassified. However, the lake would not be as readily available as a water supply as it is now.

Mr. Radford, I would like to enter their full report in the record as Exhibit # 3. If anyone requests it I will be glad to read the full report.

Mr. Radford: If no one wishes it read it will be entered in the record without so-doing.

Mr. Tyler: That completes the staff's presentation on Lake Hunt.

In the handout you will note that there are seven streams in the Lumber, Cape Fear, and Neuse River Basins which are now Class C or C Sw and also have a number in parenthesis following the classification. The number one (1) indicates that at the time of classification the coliform count was consistently too high to meet the Class C standards. The four (4) indicates the stream consistently had a dissolved oxygen of below five so it could not meet the Class C standard and was required to meet a dissolved oxygen minimum of four milligrams per liter.

These streams have improved enough so that they can now be expected to meet the C standard without being allowed the designated exception so the staff is proposing that the designation be dropped from each of these streams.

Mr. Radford, that completes the staff's presentation on these streams.

Mr. Radford: No one signed up to speak at this hearing. However, we will be glad to hear comments from anyone here at this time.

PROPOSED AMENDMENT TO THE LUMBER RIVER BASIN SCHEDULE OF CLASSIFICATION AS REFERENCED IN TITLE 15 NORTH CAROLINA ADMINISTRATIVE CODE 2B .0310

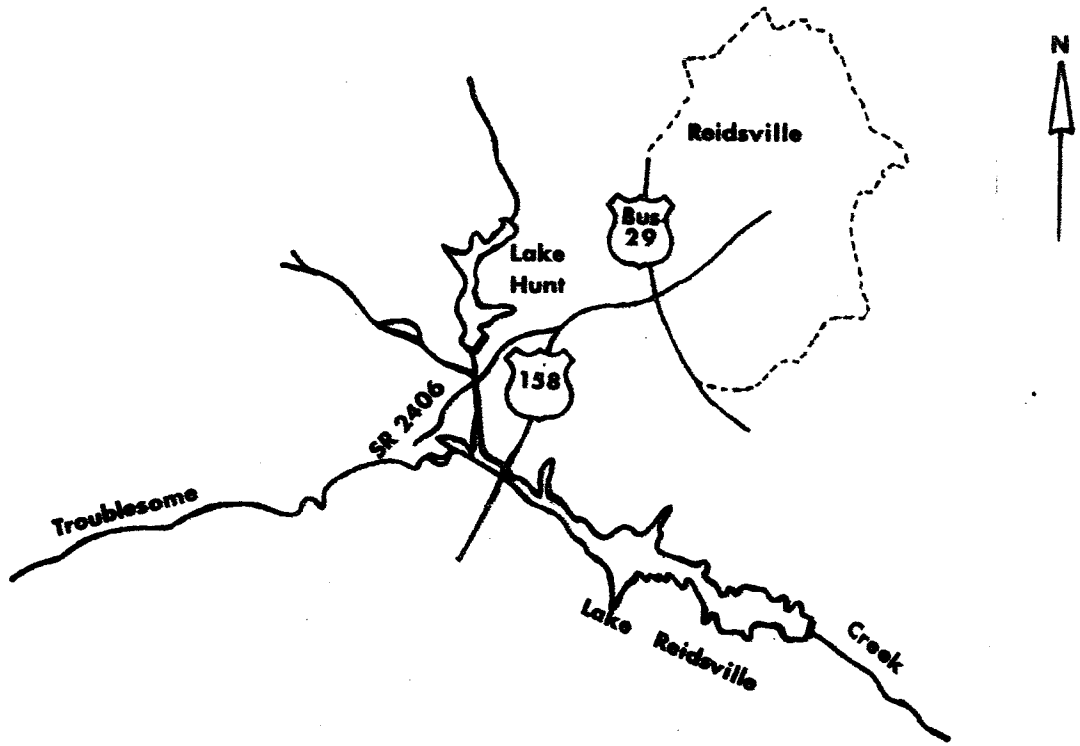
Name of Stream	Description	Existing Class	Description of Proposed Segment	Proposed Class
Town Ditch	From source to Mitchell Swamp	C Sw(1)	Same	C Sw

PROPOSED AMENDMENT TO THE CAPE FEAR RIVER BASIN SCHEDULE OF CLASSIFICATION AS REFERENCED IN TITLE 15 NORTH CAROLINA ADMINISTRATIVE CODE 2B .0311

Unnamed Tributary to Troublesome Creek (Lake Hunt)	From source to Troublesome Creek	A-II	From source to dam at Lake Hunt	B
			From dam at Lake Hunt to Troublesome Creek	A-II
Little Alamance Creek (Gant Lake, Mays Lake)	From source to Big Alamance Creek	C (1)	Same	C
Richland Creek	From source to Deep River	C (1)	Same	C
Penwood Branch	From source to Haskett Creek	C (1)	Same	C
Cabin Creek	From source to Montgomery County SR 1511	C (4)	Same	C

PROPOSED AMENDMENT TO THE NEUSE BASIN SCHEDULE OF CLASSIFICATIONS AS REFERENCED IN TITLE 15 NORTH CAROLINA ADMINISTRATIVE CODE 2B .0315

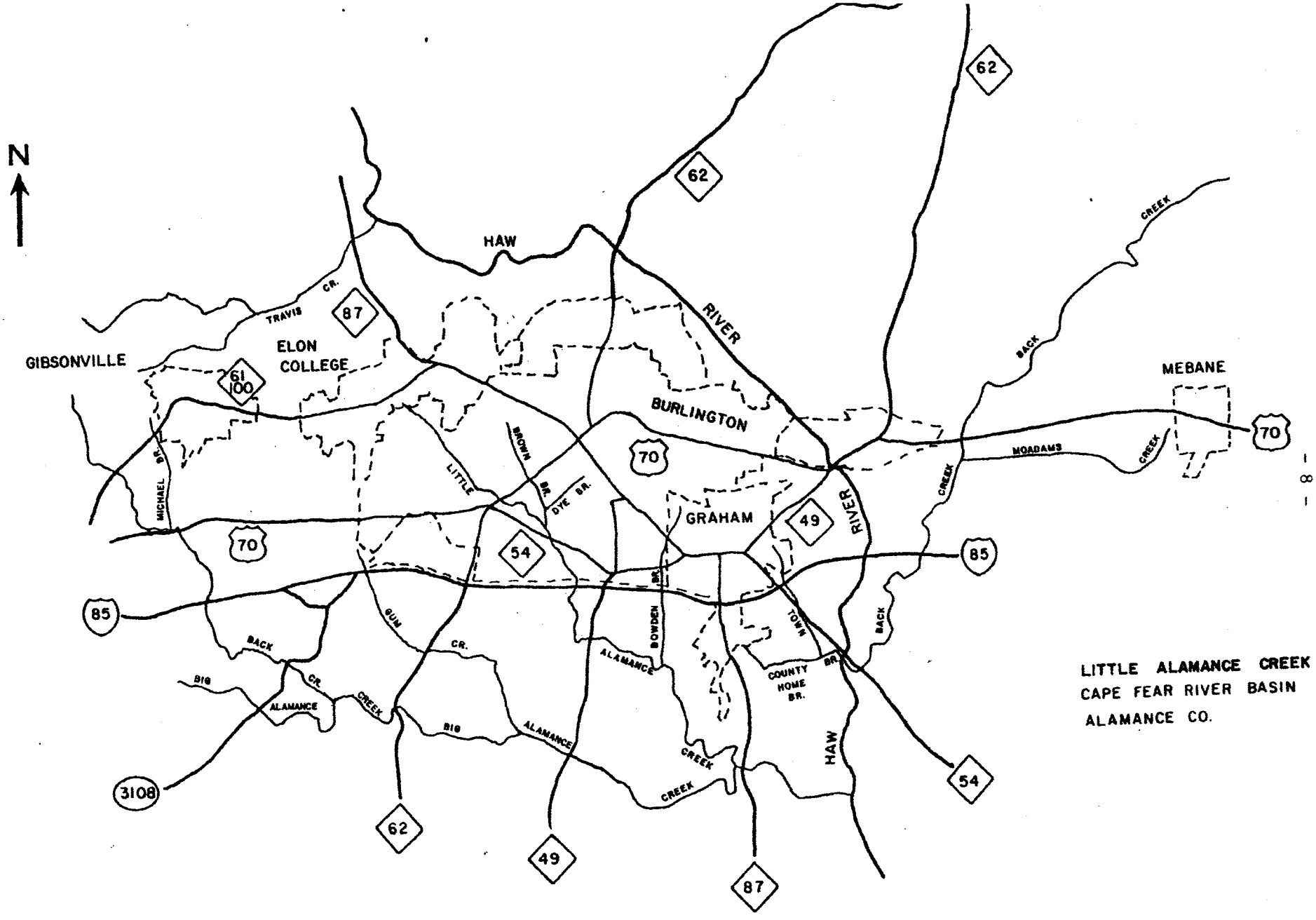
Longview Branch	From source to Crabtree Creek	C (1)	Same	C
Watson Branch	From source to Walnut Creek	C (1)	Same	C



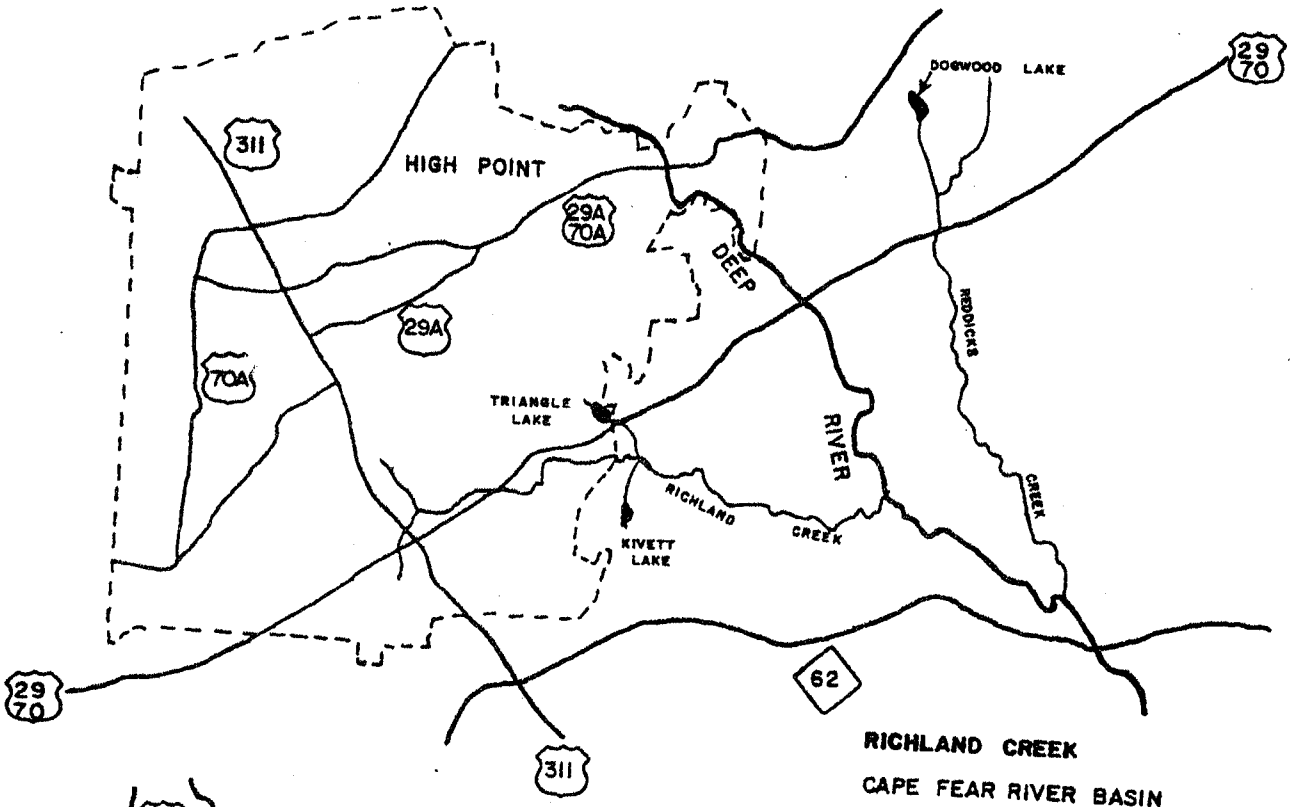
LAKE HUNT

CAPE FEAR RIVER BASIN

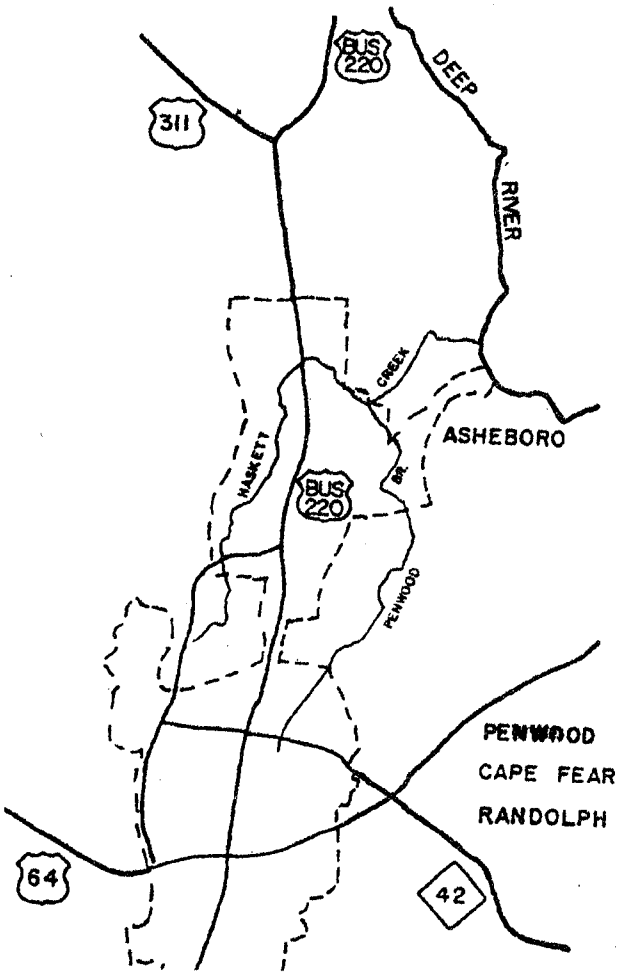
ROCKINGHAM COUNTY



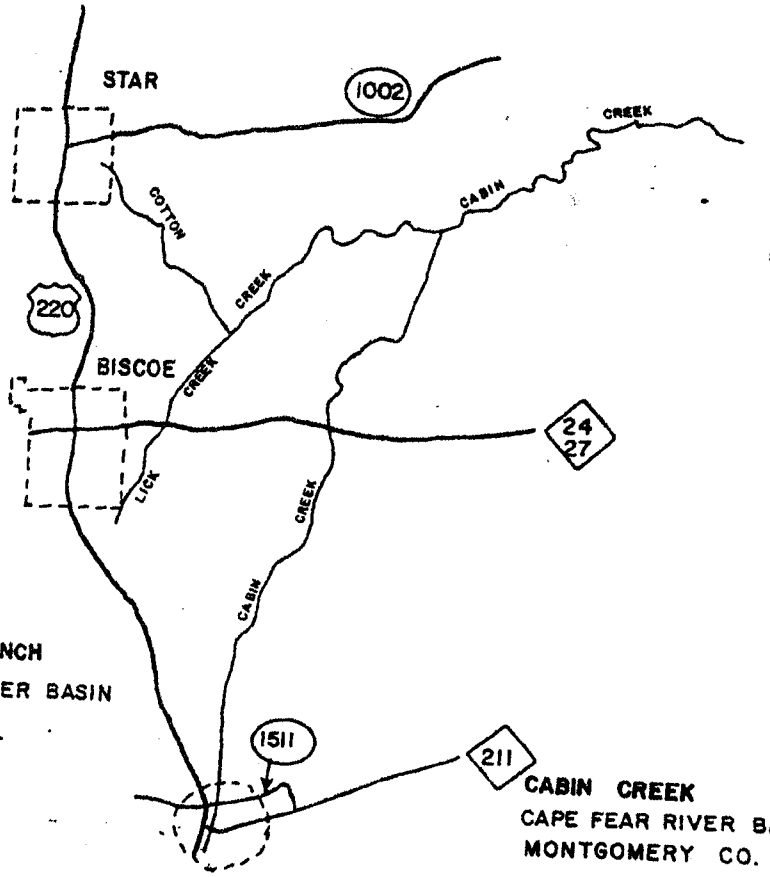
LITTLE ALAMANCE CREEK
CAPE FEAR RIVER BASIN
ALAMANCE CO.



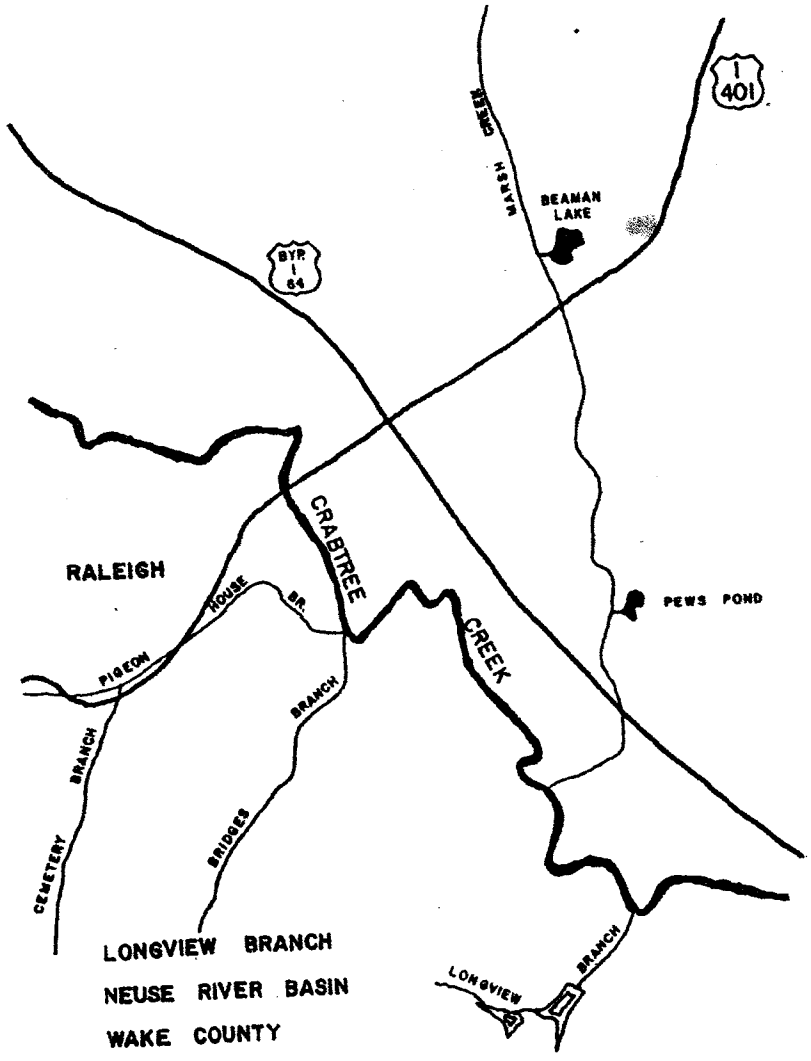
RICHLAND CREEK
CAPE FEAR RIVER BASIN
GUILFORD CO.



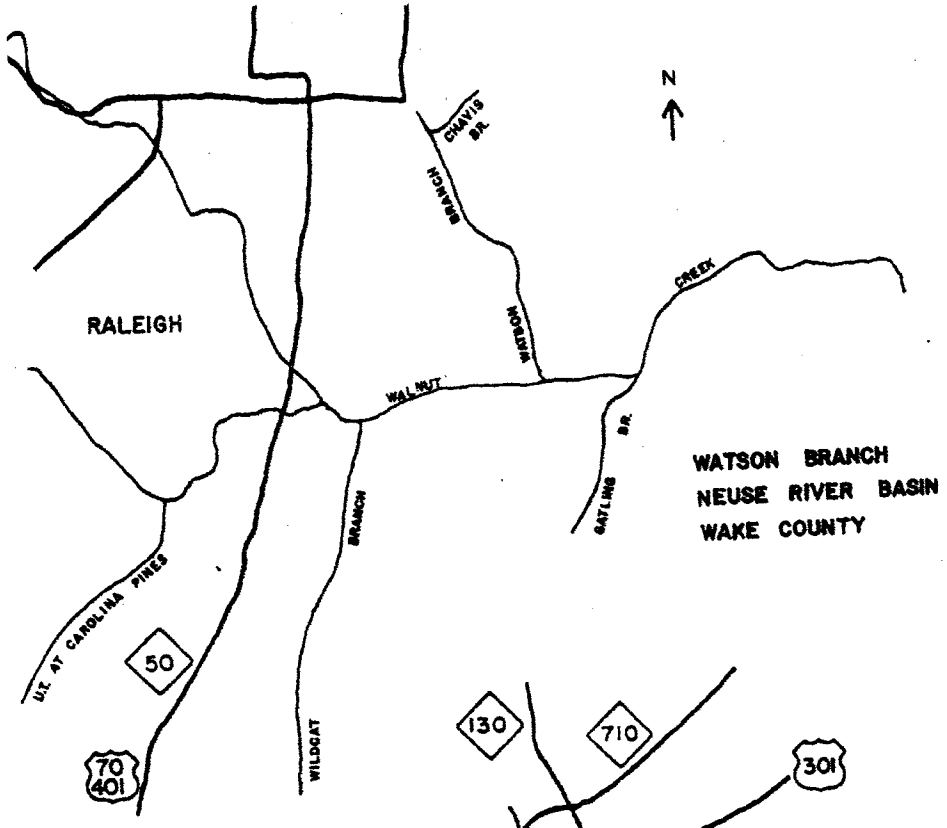
PENWOOD BRANCH
CAPE FEAR RIVER BASIN
RANDOLPH CO.



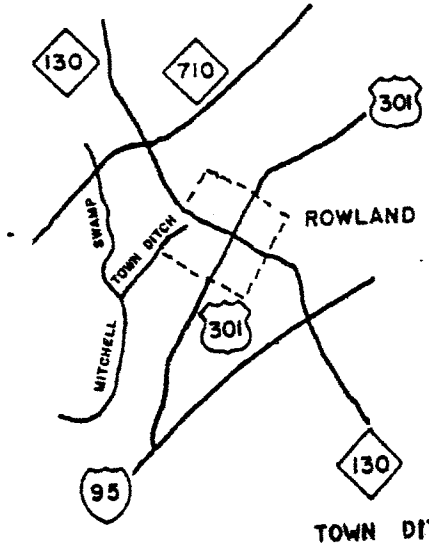
CABIN CREEK
CAPE FEAR RIVER BASIN
MONTGOMERY CO.
MOORE CO.



LONGVIEW BRANCH
NEUSE RIVER BASIN
WAKE COUNTY



WATSON BRANCH
NEUSE RIVER BASIN
WAKE COUNTY



TOWN DITCH
LUMBER RIVER BASIN
ROBESON CO.

Exhibit # 3

MEMORANDUM

To: Lloyd Tyler

From: Judy Bohan Judy
Economic Assessment Section, ORR

Re: Sociocconomic Cost/Benefit Analysis of Lake Hunt

Date: August 24, 1981

The City of Reidsville has requested a reclassification of Lake Hunt from Class A-II to Class B. The Class B water quality standards differ from the Class A-II standards in two basic ways. First, the Class B has more stringent bacterial standards that the Class A-II. Second, the Class B has less stringent chemical standards than the Class A-II. Therefore, if the request was granted, the water would be required to have a lower bacterial count than is presently required, but would be allowed a slight increase in the concentration of certain chemicals.

North Carolina General Statute 143-214.1(d)(4) requires that a socioeconomic cost/benefit analysis be made for such a request. The information for this analysis was provided by Mr. Robert G. Cox, City Manager of the City of Reidsville.

Costs

There are no direct economic costs involved in granting this request. The lake will meet the Class B water quality standards without any capital, labor, or maintenance expenses. No current users will be required to curtail their activities if the request is granted. An indirect economic cost is that the water may no longer be used for drinking, culinary, or food processing purposes. The lake has not been used for these activities since the opening of Lake Reidsville as the primary water source for the City.

Benefits

The socioeconomic benefits are that the citizens of Reidsville will be able to use the lake for primary recreation activities. These activities are not allowed under the A-II classification.

Conclusions

The social costs and benefits involved with this reclassification request need to be viewed in terms of the City's needs. If the request is granted, Lake Hunt could no longer be used as a source of drinking water. However, with the development of Lake Reidsville for that purpose, the residents of the area feel that Lake Hunt could be put to better use as a recreational facility.

JB:esp

Petter, Lauren

From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Thursday, April 30, 2015 11:03 AM
To: Petter, Lauren
Subject: RE: EPA 3-2-2015 comment letter regarding LCFR proposal

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Sent: Thursday, April 30, 2015 8:02 AM
To: Kountis, Elizabeth
Subject: RE: EPA 3-2-2015 comment letter regarding LCFR proposal

The document is attached. See page 3 at the end of Mr. Tyler's response on that page.

Lauren

From: Kountis, Elizabeth [mailto:elizabeth.kountis@ncdenr.gov]
Sent: Wednesday, April 29, 2015 4:06 PM
To: Petter, Lauren
Subject: EPA 3-2-2015 comment letter regarding LCFR proposal

Good afternoon!

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From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Wednesday, May 06, 2015 8:58 AM
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Petter, Lauren

From: Petter, Lauren
Sent: Friday, May 08, 2015 8:26 AM
To: 'Kountis, Elizabeth'
Cc: 'Manning, Jeff'
Subject: RE: EPA 3-2-2015 comment letter regarding LCFR proposal

I can look on Monday when I'm back in the office to see if there are any documents/files specific to Lower Cape Fear. Unfortunately older files are not always as easy to find.

I talked to Jeff some more generally at the SAC meeting Wednesday about my comments. Part of the reason we included the reference to the ROP was because after reading the other Cape Fear Sw to C classification change it seemed like the argument was that water quality had improved enough to be made a C classification. In describing it that way, the Sw classification came across differently (more like a "lower" designated use). The system being addressed now seems to have a lot of history and a lot of complexity that I just want to make sure we are all clear on as early in the process as possible, particularly given the level of interest from multiple stakeholders.

I'm around most of next week (not Friday) if you and Jeff would like to chat more about this. Today is a bit packed with other topics and I'd like to look over the Cape Fear specifics again in advance of us chatting.

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Sent: Monday, July 20, 2015 2:07 PM
To: Petter, Lauren
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61 Forsyth Street, SW
Atlanta, GA 30303
P: (404) 562-9272
F: (404) 562-9224
Email: petter.lauren@epa.gov

Petter, Lauren

From: Petter, Lauren
Sent: Tuesday, May 19, 2015 12:35 PM
To: 'Kountis, Elizabeth'
Cc: 'Manning, Jeff'
Subject: RE: EPA 3-2-2015 comment letter regarding LCFR proposal

Realizing I didn't follow up on this.... I'll see if there are any other files related to the subject water.

And did you and Jeff want to schedule a time anytime this month to generally chat about the reclassification? It didn't sound like there was a rush necessarily but I would like to make sure we get to the same page before getting too far along in your schedule.

Thanks,
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Good afternoon!

The language within the following response is not proposed to be incorporated into the rules, but provides information on how the dissolved oxygen impact from new or expanding discharges will most likely be assessed by the Division.

The model to be used will be the most currently available three dimensional water quality model, which at this time, is the Lower Cape Fear dissolved oxygen model, http://portal.ncdenr.org/c/document_library/get_file?uuid=a84477db-4d83-4cc0-a9b9-f7da7a6a51f9&groupId=38364. The model was finalized on October 2009 by the Division of Water Quality (now known as the Division of Water Resources). The model is calibrated to 2004 observed data and meteorological conditions. Model inputs are described in the report. The most critical season when dissolved oxygen is expected to be impacted is April-October, and this season will be the focus for model comparison.

The model will first be run with all existing discharges at full permitted capacity. This run will establish a baseline model for comparison. The baseline model will then be run with the addition of the proposed new or expanding discharge. Results from the two model runs will then be evaluated to determine the impact of a new or expanding discharge, and the entire area that is impacted by the discharge will be evaluated. If at any time there is a difference between these two model runs greater than 0.1 mg/L, the discharge will not be allowed. So, this approach will basically be a time-series comparison based on model output, and prohibition against causing DO decreases will be enforced via permit requirements stated in the proposed water quality management plan.

When modeling is conducted for a new or expanded discharge (as described directly above), the term "total permitted capacity" as stated in the proposed water quality management plan is to include all existing discharges as operating at their full permit limits plus the new or expanded discharge operating at its full permit limits. Rather than making the suggested language replacement as noted in the above fourth comment regarding point sources, DWR proposes to provide clarity to this issue by adding the following phrase to the end of the last sentence of the management plan: "for all discharges." Thus, the final sentence of the management plan would read as follows: "Any new or expanded permitted pollutant discharge of oxygen-consuming waste shall not cause the DO of the receiving water to drop more than 0.1 mg/l below the modeled in-stream DO at total permitted capacity for all discharges."

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From: Petter, Lauren [mailto:Petter.Lauren@epa.gov]
Sent: Thursday, July 16, 2015 10:19 AM
To: Kountis, Elizabeth
Cc: Brower, Connie
Subject: Reclass

Elizabeth,

Can you send me a copy of the current language which incorporates the revisions you mentioned on the call this morning?

Thanks,
Lauren

Lauren Petter, Environmental Scientist
Water Protection Division
U.S. Environmental Protection Agency Region 4
61 Forsyth Street, SW
Atlanta, GA 30303
P: (404) 562-9272
F: (404) 562-9224
Email: petter.lauren@epa.gov

Petter, Lauren

From: Petter, Lauren
Sent: Thursday, July 30, 2015 3:46 PM
To: Kountis, Elizabeth
Cc: Manning, Jeff; connie.brower@ncdenr.gov
Subject: RE: Reclass

Thanks for all the quick responses Elizabeth! I've shared the information from our previous comment letter and recent emails with our attorney to get her up to speed and she plans to get back to me by Monday. I would like to schedule a placeholder call with you guys for next week (if you are available) in case there are any specific comments we need to provide to you prior to proceeding to your next step in the rulemaking process on this provision. Wednesday through Friday currently are wide open for me.

One other thing...Have you drafted a responsiveness summary or some other prepared material which addresses/responds to our comments?

Thanks,
Lauren

From: Kountis, Elizabeth [mailto:elizabeth.kountis@ncdenr.gov]
Sent: Wednesday, July 29, 2015 3:35 PM
To: Petter, Lauren
Cc: Manning, Jeff; connie.brower@ncdenr.gov
Subject: FW: Reclass

Good afternoon!

The language within the following response is not proposed to be incorporated into the rules, but provides information on how the dissolved oxygen impact from new or expanding discharges will most likely be assessed by the Division.

The model to be used will be the most currently available three dimensional water quality model, which at this time, is the Lower Cape Fear dissolved oxygen model, http://portal.ncdenr.org/c/document_library/get_file?uuid=a84477db-4d83-4cc0-a9b9-f7da7a6a51f9&groupId=38364. The model was finalized on October 2009 by the Division of Water Quality (now known as the Division of Water Resources). The model is calibrated to 2004 observed data and

meteorological conditions. Model inputs are described in the report. The most critical season when dissolved oxygen is expected to be impacted is April-October, and this season will be the focus for model comparison.

The model will first be run with all existing discharges at full permitted capacity. This run will establish a baseline model for comparison. The baseline model will then be run with the addition of the proposed new or expanding discharge. Results from the two model runs will then be evaluated to determine the impact of a new or expanding discharge, and the entire area that is impacted by the discharge will be evaluated. If at any time there is a difference between these two model runs greater than 0.1 mg/L, the discharge will not be allowed. So, this approach will basically be a time-series comparison based on model output, and prohibition against causing DO decreases will be enforced via permit requirements stated in the proposed water quality management plan.

When modeling is conducted for a new or expanded discharge (as described directly above), the term "total permitted capacity" as stated in the proposed water quality management plan is to include all existing discharges as operating at their full permit limits plus the new or expanded discharge operating at its full permit limits. Rather than making the suggested language replacement as noted in the above fourth comment regarding point sources, DWR proposes to provide clarity to this issue by adding the following phrase to the end of the last sentence of the management plan: "for all discharges." Thus, the final sentence of the management plan would read as follows: "Any new or expanded permitted pollutant discharge of oxygen-consuming waste shall not cause the DO of the receiving water to drop more than 0.1 mg/l below the modeled in-stream DO at total permitted capacity for all discharges."

Elizabeth Kountis
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Petter, Lauren

From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Wednesday, August 05, 2015 10:41 AM
To: Petter, Lauren
Cc: Manning, Jeff
Subject: RE: Reclass

Good morning Lauren!

Sorry you didn't get a response to your email sooner than today, but I wanted to talk with fellow staff a bit before responding to it.

The "Summary of Concerns and Staff Responses" in the Report of Proceedings (ROP) responds to EPA's comments, with the exception of information that EPA's comments and discussions have mentioned were to be submitted as part of the state's final documentation, which has been interpreted as the package that NC would submit to EPA for final approval. The ROP is still being internally reviewed, and should be finalized and available on-line in late August/early September.

Lastly, today or Friday are fine for me this week if you'd like to talk.

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418 FAX: (919) 807.6497
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From: Petter, Lauren [mailto:Petter.Lauren@epa.gov]
Sent: Thursday, July 30, 2015 3:46 PM
To: Kountis, Elizabeth
Cc: Manning, Jeff; Brower, Connie
Subject: RE: Reclass

Thanks for all the quick responses Elizabeth! I've shared the information from our previous comment letter and recent emails with our attorney to get her up to speed and she plans to get back to me by Monday. I would like to schedule a placeholder call with you guys for next week (if you are available) in case there are any specific comments we need to provide to you prior to proceeding to your next step in the rulemaking process on this provision. Wednesday through Friday currently are wide open for me.

One other thing...Have you drafted a responsiveness summary or some other prepared material which addresses/responds to our comments?

Thanks,
Lauren

From: Kountis, Elizabeth [mailto:elizabeth.kountis@ncdenr.gov]
Sent: Wednesday, July 29, 2015 3:35 PM
To: Petter, Lauren
Cc: Manning, Jeff; connie.brower@ncdenr.gov
Subject: FW: Reclass

Good afternoon!

The language within the following response is not proposed to be incorporated into the rules, but provides information on how the dissolved oxygen impact from new or expanding discharges will most likely be assessed by the Division.

The model to be used will be the most currently available three dimensional water quality model, which at this time, is the Lower Cape Fear dissolved oxygen model, http://portal.ncdenr.org/c/document_library/get_file?uuid=a84477db-4d83-4cc0-a9b9-f7da7a6a51f9&groupId=38364. The model was finalized on October 2009 by the Division of Water Quality (now known as the Division of Water Resources). The model is calibrated to 2004 observed data and meteorological conditions. Model inputs are described in the report. The most critical season when dissolved oxygen is expected to be impacted is April-October, and this season will be the focus for model comparison.

The model will first be run with all existing discharges at full permitted capacity. This run will establish a baseline model for comparison. The baseline model will then be run with the addition of the proposed new or expanding discharge. Results from the two model runs will then be evaluated to determine the impact of a new or expanding discharge, and the entire area that is impacted by the discharge will be evaluated. If at any time there is a difference between these two model runs greater than 0.1 mg/L, the discharge will not be allowed. So, this approach will basically be a time-series comparison based on model output, and prohibition against causing DO decreases will be enforced via permit requirements stated in the proposed water quality management plan.

When modeling is conducted for a new or expanded discharge (as described directly above), the term "total permitted capacity" as stated in the proposed water quality management plan is to include all existing discharges as operating at their full permit limits plus the new or expanded discharge operating at its full permit

limits. Rather than making the suggested language replacement as noted in the above fourth comment regarding point sources, DWR proposes to provide clarity to this issue by adding the following phrase to the end of the last sentence of the management plan: "for all discharges." Thus, the final sentence of the management plan would read as follows: "Any new or expanded permitted pollutant discharge of oxygen-consuming waste shall not cause the DO of the receiving water to drop more than 0.1 mg/l below the modeled in-stream DO at total permitted capacity for all discharges."

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From: Petter, Lauren [mailto:Petter.Lauren@epa.gov]
Sent: Wednesday, July 29, 2015 2:31 PM
To: Kountis, Elizabeth
Cc: Brower, Connie; Manning, Jeff
Subject: RE: Reclass

One more clarifying question for now...

Is the addition of "for all dischargers" meant to imply the total reach(aka the receiving water), which is affected by existing, new, and expanding discharges potentially, receives a shared total allocation of 0.1, when reviewing future permit limits/allocations for the new or expanding discharges only?

From: Kountis, Elizabeth [mailto:elizabeth.kountis@ncdenr.gov]
Sent: Monday, July 20, 2015 2:07 PM
To: Petter, Lauren
Cc: connie.brower@ncdenr.gov; Manning, Jeff
Subject: RE: Reclass

The language is to be located in 15A NCAC 02B .0227 Water Quality Management Plans, and the reclassification proposed amendment in 15A NCAC 02B .0311 Cape Fear River Basin does reference the proposed management plan in .0227.
Fyi: the version of these two rules that went out to public notice (prior to the public comment period) are located on pages 1605 – 1609 within the 1-2-2015 version of the *NC Register* at:
http://www.ncoah.com/rules/register/Volume%2029%20Issue%2013%20January%202,%202015.pdf

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch

NC DENR Division of Water Resources
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From: Petter, Lauren [mailto:Petter.Lauren@epa.gov]
Sent: Thursday, July 16, 2015 1:43 PM
To: Kountis, Elizabeth
Cc: Manning, Jeff; Brower, Connie
Subject: RE: Reclass

And can you remind me again where this language is15 located? It sounds like a management plan. Is that a formal document? Does the WQS regulatory revision reference to the management plan? Just trying to figure out if this language would be reviewed by EPA...

Thanks,
Lauren

From: Kountis, Elizabeth [mailto:elizabeth.kountis@ncdenr.gov]
Sent: Thursday, July 16, 2015 11:26 AM
To: Petter, Lauren
Cc: Manning, Jeff; connie.brower@ncdenr.gov
Subject: RE: Reclass

Per your request below:

In response to public comments received, DWR proposes to provide, for clarity, the additional following phrase to the end of the last sentence of the management plan: "for all discharges." Thus, the final sentence of the management plan would read as follows: "Any new or expanded permitted pollutant discharge of oxygen-consuming waste shall not cause the DO of the receiving water to drop more than 0.1 mg/l below the modeled in-stream DO at total permitted capacity for all discharges."

Sincerely,

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418 FAX: (919) 807.6497
E-mail correspondence to and from this address may be subject to the NC Public Records Law and may be disclosed to third parties.

From: Petter, Lauren [mailto:Petter.Lauren@epa.gov]
Sent: Thursday, July 16, 2015 10:19 AM
To: Kountis, Elizabeth
Cc: Brower, Connie
Subject: Reclass

Petter, Lauren

From: Petter, Lauren
Sent: Friday, August 07, 2015 10:18 AM
To: Kountis, Elizabeth
Cc: Manning, Jeff; Godfrey, Annie; Augspurger, Tom; Wetherington, Michele; Gordon, Lisa Perras; Petter, Lauren
Subject: Follow up on Lower Cape Fear Swamp reclassification

Hey Elizabeth,

I appreciate your responses to date regarding clarifications on the Lower Cape Fear Reclassification revisions. However, in an effort to work out any possible issues in advance of the rulemaking going final, this email is in response to the recent discussions on the Sw classification to highlight some remaining concerns. Here is a summary:

- Based on the current wording in the regulations, the EPA anticipates we would review both 15A NCAC 02B .0227(b)(2)(C) and 15A NCAC 02B .0311(t) as part of any CWA 303(c) review, if this revision as written is finalized and adopted.
    - Given that, there is now a need to document why the amount of 0.1 mg/L was chosen as we did not previously address this point in our comment letter.
- In addition to the need to provide documentation on why the amount of 0.1 mg/L was chosen, the EPA is concerned that the provision may allow a different DO criteria expectation for a single programmatic purpose, NPDES permitting. The EPA expects that criteria should apply for all purposes.
- When other states have adopted a 0.1 mg/L type provision, it has been a provision that applies to all implementing programs and has been provided as an amount of change from background condition. And even then the background condition has to be specifically defined before the provision can be used to deviate from the natural condition.
    - As explained in your 7/29/15 email "[t]he model will first be run with all existing discharges at full permitted capacity...then [with] the addition of the proposed new or expanding discharge...If at any time there is a difference between these two model runs greater than 0.1 mg/L, the discharge will not be allowed." Given the starting point for consideration is full permitted capacity for existing dischargers, this does not appear to equate to a natural condition. Also, how will the language in .0227(b)(2)(C), which appears to allow each new or expanding discharge to lower DO by up to 0.1 mg/L, be implemented in a manner that will protect the DO criterion? Are the requirements of .0227(b)(2)(A) and (B) sufficient to protect all waters?
    - While the language in .0227(b)(2)(C) does not reference natural conditions or natural background, the Sw classification and DO criterion that is associated with Sw classification both reference natural condition/characteristics. Therefore, adoption of the Sw classification would need to be supported by natural condition type documentation as indicated in our March 2, 2015 comment letter. (Note: This would be needed to support both DO and pH levels.)
- Although the EPA's March 2, 2015 comment letter indicated certain comments should be addressed in order to support the EPA's review, the State isn't bound to wait until that point to coordinate with EPA, and in matters of discussing natural background and in this case, an atypical reclassification effort, sooner may be more advantageous to the state. That being said, we feel the questions and comments we are providing further

indicate the need for a more holistic approach to address the DO conditions in this particular reach, such as a site specific criterion. Classifying this segment as Sw may not be scientifically justifiable in this instance, recognizing we haven't seen the total documentation yet. Adopting a lower, but still protective DO criterion accomplishes the same endpoint of not utilizing the default SC DO criterion but in a different manner.

I can be reached today at if you would like to discuss. I will be back in the office at the number below on Monday.

Lauren

Lauren Petter, Environmental Scientist
Water Protection Division
U.S. Environmental Protection Agency Region 4
61 Forsyth Street, SW
Atlanta, GA 30303
P: (404) 562-9272
F: (404) 562-9224
Email: petter.lauren@epa.gov

Petter, Lauren

From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Friday, August 07, 2015 11:15 AM
To: Petter, Lauren
Subject: RE: Follow up on Lower Cape Fear Swamp reclassification

Jeff and I would like to call you at 2 pm today to discuss your concerns below. I'm hoping that time works for you...

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418 FAX: (919) 807.6497
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From: Petter, Lauren [mailto:Petter.Lauren@epa.gov]
Sent: Friday, August 07, 2015 10:18 AM
To: Kountis, Elizabeth
Cc: Manning, Jeff; Godfrey, Annie; Augspurger, Tom; Wetherington, Michele; Gordon, Lisa Perras; Petter, Lauren
Subject: Follow up on Lower Cape Fear Swamp reclassification

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- Based on the current wording in the regulations, the EPA anticipates we would review both 15A NCAC 02B .0227(b)(2)(C) and 15A NCAC 02B .0311(t) as part of any CWA 303(c) review, if this revision as written is finalized and adopted.
    - Given that, there is now a need to document why the amount of 0.1 mg/L was chosen as we did not previously address this point in our comment letter.
- In addition to the need to provide documentation on why the amount of 0.1 mg/L was chosen, the EPA is concerned that the provision may allow a different DO criteria expectation for a single programmatic purpose, NPDES permitting. The EPA expects that criteria should apply for all purposes.
- When other states have adopted a 0.1 mg/L type provision, it has been a provision that applies to all implementing programs and has been provided as an amount of change from background condition. And even then the background condition has to be specifically defined before the provision can be used to deviate from the natural condition.
    - As explained in your 7/29/15 email "[t]he model will first be run with all existing discharges at full permitted capacity...then [with] the addition of the proposed new or expanding discharge...If at any time there is a difference between these two model runs greater than 0.1 mg/L, the discharge will not be allowed." Given the starting point for consideration is full permitted capacity for existing dischargers, this does not appear to equate to a natural condition. Also, how will the language in .0227(b)(2)(C), which appears to allow each new or expanding discharge to lower DO by up to 0.1 mg/L, be

implemented in a manner that will protect the DO criterion? Are the requirements of .0227(b)(2)(A) and (B) sufficient to protect all waters?

- o While the language in .0227(b)(2)(C) does not reference natural conditions or natural background, the Sw classification and DO criterion that is associated with Sw classification both reference natural condition/characteristics. Therefore, adoption of the Sw classification would need to be supported by natural condition type documentation as indicated in our March 2, 2015 comment letter. (Note: This would be needed to support both DO and pH levels.)

- Although the EPA's March 2, 2015 comment letter indicated certain comments should be addressed in order to support the EPA's review, the State isn't bound to wait until that point to coordinate with EPA, and in matters of discussing natural background and in this case, an atypical reclassification effort, sooner may be more advantageous to the state. That being said, we feel the questions and comments we are providing further indicate the need for a more holistic approach to address the DO conditions in this particular reach, such as a site specific criterion. Classifying this segment as Sw may not be scientifically justifiable in this instance, recognizing we haven't seen the total documentation yet. Adopting a lower, but still protective DO criterion accomplishes the same endpoint of not utilizing the default SC DO criterion but in a different manner.

I can be reached today at if you would like to discuss. I will be back in the office at the number below on Monday.

Lauren

Lauren Petter, Environmental Scientist
Water Protection Division
U.S. Environmental Protection Agency Region 4
61 Forsyth Street, SW
Atlanta, GA 30303
P: (404) 562-9272
F: (404) 562-9224
Email: petter.lauren@epa.gov

Petter, Lauren

From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Thursday, August 27, 2015 4:54 PM
To: Petter, Lauren
Cc: Manning, Jeff; Weaver, Adriene
Subject: Report of Proceedings for the Cape Fear River Rulemaking

You can now go to EMC's webpage and click the "Report of Proceedings for Cape Fear River Proposal" within the 4th agenda item:

http://portal.ncdenr.org/web/emc/september-10-2015

Sincerely,

Elizabeth Kountis
Senior Environmental Specialist
Classifications & Standards/Rules Review Branch
NC DENR Division of Water Resources
Tel: (919) 807.6418 FAX: (919) 807.6497
E-mail correspondence to and from this address may be subject to the NC Public Records Law and may be disclosed to third parties.

Petter, Lauren

From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Friday, December 18, 2015 11:18 AM
To: wilson_laney@fws.gov; Tom_Augspurger@fws.gov; 'mike_wicker@fws.gov'; fritz.rohde@noaa.gov; 'david.bernhart@noaa.gov'; 'kelly.shotts@noaa.gov'; 'stephania.bolden@noaa.gov'; 'ksulak@usgs.gov'; Petter, Lauren; Gordon.lisaperras@Epa.gov
Subject: Comment Period for Revisions to 15A NCAC 2B .0227 Water Quality Management Plans
Attachments: 15A_NCAC_2B_0227_Comment_Period_Announcement.pdf

Attached is an announcement for a comment period on proposed revisions to 15A NCAC 2B .0227, Water Quality Management Plans, which were made in response to requested technical changes from legal staff with the Rules Review Commission (RRC).

The requested changes primarily addressed 2B .0227 rule language in existence prior to the most recent amendments to 2B .0227, which were approved at the September 2015 Environmental Management Commission (EMC) meeting and reflected a proposed water quality management plan for a part of the Cape Fear River in New Hanover and Brunswick Counties. At the September 2015 EMC meeting, the EMC considered comments that were received during a 1/2/2015 – 3/3/2015 comment period and addressed rule amendments concerning the proposed water quality management plan as well as a proposed Class SC Sw reclassification; EMC approved the rule amendments in conjunction with each other. The rulemaking involved proposed amendments to 15A NCAC 2B .0227 for the water quality management plan as well as to 15A NCAC 2B .0311 for the reclassification. Then the Division of Water Resources (DWR) submitted the rule amendments to the RRC, and RRC legal staff requested technical changes to 2B .0227 but not 2B .0311. DWR considered the requested changes for the purposes of clarity only. DWR responded to the requested technical changes with a revised version of 2B .0227 that EMC approved at its November 2015 meeting to go out to public notice unaccompanied by 2B .0311.

The public comment period is being held in accordance with the federal Water Pollution Control Act (the Clean Water Act) that requires States to conduct a Triennial Review, which includes an assessment and revision of the designated uses of waters (classifications) and associated water quality criteria (standards). This announcement will appear on a few listservs, so I apologize in advance if you receive this information more than once.

Comments on the proposed revisions to 2B .0227 may be submitted in writing, fax, or email anytime through February 15, 2016 to the following:

Elizabeth Kountis
DEQ/DWR Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611
Fax (919) 807-6497
Elizabeth.Kountis@ncdenr.gov

Please reference the attached announcement for further details regarding the comment period. The announcement, along with other information for this proposal, is also located on the internet at: http://portal.ncdenr.org/web/wq/event-calendar (look under "2015-12-15").

If you should need additional information, the DWR staff contact is Elizabeth Kountis at (919) 807-6418.

ANNOUNCEMENT FOR PUBLIC COMMENT PERIOD:

REVISED WATER QUALITY MANAGEMENT PLAN FOR PART OF CAPE FEAR RIVER IN NEW HANOVER AND BRUNSWICK COUNTIES

HISTORY

A Notice of Text was previously published in the 29:13 issue of the North Carolina Register for a proposed water quality management plan and Class Sc Sw reclassification for a part of the Cape Fear River, and it included notice of a public hearing, which was held on February 5, 2015, as well as a comment period.

At the September 2015 Environmental Management Commission (EMC) meeting, the EMC considered comments received concerning the rule amendments reflecting the reclassification and water quality management plan, and approved the rule amendments in conjunction with each other. The rulemaking involved proposed amendments to 15A NCAC 2B .0227 for the water quality management plan as well as to 15A NCAC 2B .0311 for the reclassification. Then the Division of Water Resources (DWR) submitted the rule amendments to the Rules Review Commission (RRC), and RRC legal staff requested technical changes to 2B .0227 but not 2B .0311. The requested changes primarily addressed 2B .0227 rule language in existence prior to the rule amendments approved at the September 2015 EMC meeting, and DWR considered the requested changes for the purposes of clarity only. DWR responded to the requested technical changes with a revised version of 2B .0227 that EMC approved at its November 2015 meeting to go out to public notice unaccompanied by 2B .0311.

REVISIONS TO 2B .0227

Revisions made to 2B .0227 in response to the requested technical changes, for which public comment is currently desired, appear underlined or ~~struck through~~ in the revised rule whereas the September 2015 EMC approved amendments to 2B .0227, for which public comment has already been received, appear in *italics* in the revised rule. The revisions due to the requested technical changes are as follows:

1. First sentence in (b): Addition of "either in Rules .0601 - .0608 of this Subchapter that address the Goose Creek watershed (Yadkin Pee-Dee River Basin)" to address requested clarification of North Carolina waters deemed by the EMC as protected by a "water quality management plan"

2. Only sentence in (b)(1)(A): Removal of brackets around "as specified in 15A NCAC 2H .1005(2)(a)" to address requested grammatical change

3. First sentence in (b)(1)(B): Removal of parentheses around "such as non-industrial process cooling or seafood processing discharges" to address requested grammatical change

4. Only sentence in (b)(1)(C): Removal of entire sentence and "(C)" to address requested clarification of "reduced loading rates" and "increased buffer zones"

   The conditions in this sentence of the rule are difficult to implement as there is no established process or criteria for determining the application rates or setbacks in this rule. In addition, DWR is not considering more restrictive application rates or setbacks for facilities located in any specific basins, or areas in the state, other than what is prescribed in the 2T rules. The 2T rules were adopted in 2006, after the 2B .0227 language regarding the Lockwoods Folly River Area (Lumber River Basin) was adopted, and were intended to provide protection to water resources by means such as setbacks and application rate restrictions. Lastly, as part of the Session Law 2013-413 process, Rule 2L .0107 Compliance Boundary will be reviewed for potential amendments to provide adequate protection to surface waters currently within the compliance boundary for a spray field.

5. Only sentence in (b)(1) new (C): Replacement of "must" with "shall" to address requested grammatical change

6. Only sentence in (b)(1) new (D): Replacement of "where significant shellfish or submerged aquatic vegetation bed resources occur," with "if those activities would result in a reduction of the beds of submerged aquatic vegetation or a reduction of shellfish producing habitat as defined in 15A NCAC 031 .0101(b)(20)(A) and (B)," to address requested deletion or clarification of "significant"

   A technical change was requested for the same existing language in 2B .0225 (c)(2) as part of a triennial review rulemaking about 15 years ago, and given the revision made to address that technical change request became effective in the North Carolina Administrative Code (NCAC), DWR recommended the same revision be made to 2B .0227.

7. Only sentence in (b)(2)(A): Addition of "utilize" and replacement of "discharges" with "discharges in accordance with Rule .0406(e) of this Subchapter" to address requested clarification of the process for a "case-by-case" determination

   DWR added the word "utilize" and a reference to 2B .0406(e) to the proposed rule to clarify the required determination process.

8. Only sentence in (b)(2)(B): Removal of "on a case-by-case basis" to address requested clarification of the process for a "case-by-case" determination

   This part of the proposed rule already references Rule 2B .0404, which states that "the staff shall also provide on a case-by-case basis for seasonal variation in the discharge of oxygen-consuming wastes" and that rule provides the criteria to do so. Because the "case-by-case" language is already provided in the referenced .0404 rule, DWR recommended removal of "on a case-by-case basis" from the proposed rule.

HOT TO SUBMIT COMMENTS

The purpose of this announcement is to provide opportunity for comments on the revisions made to 2B .0227, which were made in response to requested technical changes, to be submitted to DWR. **You may submit written comments, data or other relevant information on the proposed 2B .0227 revised rule by February 15, 2016.**

The EMC is very interested in all comments pertaining to the revisions made to 2B .0227. All persons interested and potentially affected by the revised rule are encouraged to make comments on the proposed revisions. The EMC may not adopt a rule that differs substantially from the text of the proposed rule published in the North Carolina Register unless the EMC publishes the text of the proposed different rule and accepts comments on the new text. The proposed effective date for this proposed rule is July 1, 2016. **Written comments on the proposed revisions to 2B .0227 may be submitted to Elizabeth Kountis of the DEQ/DWR Planning Section at the postal address, e-mail address, or fax number listed below.**

FOR ADDITIONAL INFORMATION

This announcement and the revised 02B .0227 rule as well as a table of the requested technical changes and resulting DWR responses for 2B .0227 are located on the internet via http://portal.ncdenr.org/web/wq/event-calendar (look under "2015-12-15") and http://portal.ncdenr.org/web/wq/rules. Further explanations and details on reclassifications may be obtained by writing or calling:

Elizabeth Kountis, DEQ/DWR Planning Section
1611 Mail Service Center, Raleigh, NC 27699-1611
phone (919) 807-6418, fax (919) 807-6497, e-mail elizabeth.kountis@ncdenr.gov

Petter, Lauren

From: Gordon, Lisa Perras
Sent: Tuesday, March 29, 2016 11:51 AM
To: Petter, Lauren
Subject: FW: Good time to chat?

From: Kountis, Elizabeth [mailto:elizabeth.kountis@ncdenr.gov]
Sent: Tuesday, March 29, 2016 10:43 AM
To: Gordon, Lisa Perras <Gordon.Lisa-Perras@epa.gov>
Subject: Re: Good time to chat?

The Cape Fear rulemaking is slated to come before the EMC at their May meeting, then the June RRC meeting, so I wouldn't expect it to come your way anytime very soon. It's hard to say when the next package would arrive; formal rulemaking for another reclassification, a WS, is slated to begin at the May WQC meeting, and if all goes well, would become effective May 2017, followed by a package to EPA most likely later that year.

I'm only busy next Tuesday morning so why don't we talk on Monday sometime? 1:30 pm?

From: Gordon, Lisa Perras <Gordon.Lisa-Perras@epa.gov>
Sent: Monday, March 28, 2016 11:51 AM
To: Kountis, Elizabeth
Subject: RE: Good time to chat?

Absolutely. My calendar is wide open next week. Name a time, and I'll put it on my calendar.

Quick question...is the Cape Fear package heading our way any time soon? Just for planning purposes...when would you guess the next package would arrive?

From: Kountis, Elizabeth [mailto:elizabeth.kountis@ncdenr.gov]
Sent: Monday, March 28, 2016 11:50 AM
To: Gordon, Lisa Perras <Gordon.Lisa-Perras@epa.gov>
Subject: Re: Good time to chat?

Good Monday morning!
This is the week of off-and-on-work being done to my house and spring break for my kids, so I won't be in the office much and working from home a lot. I don't have the ability to make long distance work calls from home, so could we perhaps discuss over the phone next week or over emails this week?

Thanks
Betsy

From: Gordon, Lisa Perras <Gordon.Lisa-Perras@epa.gov>
Sent: Friday, March 25, 2016 12:43 PM
To: Kountis, Elizabeth
Subject: Good time to chat?

Betsy, the week got away from me. Can we schedule a good time to chat about Cape Fear? I'm open all Monday afternoon – would any time that day work? I'm also open all day Wednesday next week. Let me know. Will look forward to it.

Lisa

Lisa Perras Gordon
Water Quality Standards
Hydrologic Alteration and CWA Specialist
US Environmental Protection Agency - Region 4
Atlanta, Georgia
(404) 562-9317
gordon.lisa-perras@epa.gov

Petter, Lauren

From: Petter, Lauren
Sent: Thursday, May 04, 2017 8:44 AM
To: 'Kountis, Elizabeth'
Subject: Cape Fear status

Hey Elizabeth,

I hope you are doing well! I just wanted to follow up and see if you heard any updates on the Lower Cape Fear reclassification from last week.

Thanks,
Lauren

Lauren Petter, Environmental Scientist
Water Quality Standards Section
Water Protection Division
Phone: (404) 562-9272

Petter, Lauren

From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Friday, May 05, 2017 1:26 PM
To: Petter, Lauren
Cc: Manning, Jeff
Subject: RE: Cape Fear status

All I know is that a bill was introduced in the current legislative session to defeat the proposal, but that bill did not make crossover from one side of the legislature to the other, and crossover date was last week.
There is the possibility that a future action regarding this proposal may be tagged onto a bill in the current session at any time, so it may well be prudent to wait until the end of the current session to see if anything happens regarding the proposal.

Elizabeth Kountis
Senior Environmental Specialist
Division of Water Resources
North Carolina Department of Environmental Quality

919 807-6418 office
elizabeth.kountis@ncdenr.gov

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Raleigh, NC 27699

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Subject: Cape Fear status

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Thanks,
Lauren

Lauren Petter, Environmental Scientist

Petter, Lauren

From: Petter, Lauren
Sent: Friday, May 05, 2017 1:41 PM
To: 'Kountis, Elizabeth'
Cc: 'Manning, Jeff'
Subject: RE: Cape Fear status

Thanks for the update Elizabeth!

Lauren Petter, Environmental Scientist
Water Quality Standards Section
Water Protection Division
Phone: (404) 562-9272

From: Kountis, Elizabeth [mailto:elizabeth.kountis@ncdenr.gov]
Sent: Friday, May 05, 2017 1:26 PM
To: Petter, Lauren
Cc: Manning, Jeff
Subject: RE: Cape Fear status

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Subject: Cape Fear status

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Thanks,
Lauren

Lauren Petter, Environmental Scientist
Water Quality Standards Section
Water Protection Division
Phone: (404) 562-9272

Petter, Lauren

From: Petter, Lauren
Sent: Thursday, November 30, 2017 2:25 PM
To: Manning, Jeff; Kountis, Elizabeth
Cc: Tyler, Kip
Subject: Lower Cape Fear

Hey Jeff,

I heard that Annie was able to chat with you about the Lower Cape Fear today. I was wondering if any of the following times worked for you and Elizabeth to chat with us further.

9-10am or 11am-noon on Monday, December 4th
9-10am or 11am-noon on Thursday, December 7th
Anytime 9-12 on Monday, December 11th

I can send out an invite once we find a time that works for us all.

Thanks,
Lauren

Lauren Petter, Environmental Scientist
Water Quality Standards Section
Water Protection Division
Phone: (404) 562-9272

Petter, Lauren

From: Manning, Jeff <jeff.manning@ncdenr.gov>
Sent: Thursday, November 30, 2017 2:33 PM
To: Petter, Lauren; Kountis, Elizabeth
Cc: Tyler, Kip
Subject: RE: [External] Lower Cape Fear

Hey Lauren,
Both Betsy and I are not available any of the times you listed!
Would 10-11 on Dec 7 work?

From: Petter, Lauren [mailto:Petter.Lauren@epa.gov]
Sent: Thursday, November 30, 2017 2:25 PM
To: Manning, Jeff ; Kountis, Elizabeth
Cc: Tyler, Kip
Subject: [External] Lower Cape Fear

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Hey Jeff,

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9-10am or 11am-noon on Thursday, December 7th
Anytime 9-12 on Monday, December 11th

I can send out an invite once we find a time that works for us all.

Thanks,
Lauren

Lauren Petter, Environmental Scientist
Water Quality Standards Section
Water Protection Division
Phone: (404) 562-9272

Petter, Lauren

From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Thursday, December 07, 2017 4:03 PM
To: Petter, Lauren
Cc: Manning, Jeff; Behm, Pamela; Rajbhandari, Narayan
Subject: Call to discuss Bowen model

Good afternoon!

During our call today, we talked about setting up a call with EPA and NC staff in January 2018 to further discuss the Bowen model.

The first available times for such a call for NC staff are during the 2nd week in January:
Monday January 8th – am or pm
Tuesday January 9th – pm only
Friday January 12th – am or pm

Let me know what works for you and your staff!

Thanks

Elizabeth Kountis
Senior Environmental Specialist
Division of Water Resources
North Carolina Department of Environmental Quality

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Petter, Lauren

From: Petter, Lauren
Sent: Thursday, December 07, 2017 4:10 PM
To: Kountis, Elizabeth
Cc: Manning, Jeff; Behm, Pamela; Rajbhandari, Narayan
Subject: RE: Call to discuss Bowen model

Right now...

1/8/18 Available 9-10 and 11-1.
1/9/18 Available from 2-4.

Lauren Petter, Environmental Scientist
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Phone: (404) 562-9272

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Petter, Lauren

From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Friday, December 08, 2017 11:28 AM
To: Petter, Lauren
Subject: RE: [External] RE: Call to discuss Bowen model

Can you please check on the availability of the dates I provided other EOA staff that may want to be on the call?

Thanks!

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Petter, Lauren

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To: 'Kountis, Elizabeth'
Subject: RE: [External] RE: Call to discuss Bowen model

Sorry about that. I should have said those are times that work for Kip, Annie, and myself.

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Petter, Lauren

From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Friday, December 08, 2017 11:39 AM
To: Petter, Lauren
Subject: RE: [External] RE: Call to discuss Bowen model

Let's go for 1/9 from 2-4!

Want us to call you or vice versa?

Elizabeth Kountis
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Petter, Lauren

From: Petter, Lauren
Sent: Friday, December 08, 2017 11:45 AM
To: 'Kountis, Elizabeth'
Subject: RE: [External] RE: Call to discuss Bowen model

I'll send an invite with call in information momentarily.

Lauren Petter, Environmental Scientist
Water Quality Standards Section
Water Protection Division
Phone: (404) 562-9272

From: Kountis, Elizabeth [mailto:elizabeth.kountis@ncdenr.gov]
Sent: Friday, December 08, 2017 11:39 AM
To: Petter, Lauren
Subject: RE: [External] RE: Call to discuss Bowen model

Let's go for 1/9 from 2-4!

Want us to call you or vice versa?

Elizabeth Kountis
Senior Environmental Specialist
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elizabeth.kountis@ncdenr.gov

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Raleigh, NC 27699

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Petter, Lauren

From: Manning, Jeff <jeff.manning@ncdenr.gov>
Sent: Tuesday, January 02, 2018 10:48 AM
To: Godfrey, Annie; Petter, Lauren; Tyler, Kip
Cc: connie.brower@ncdenr.gov; Ventaloro, Christopher; Kountis, Elizabeth; Weaver, Adriene
Subject: Standards and Classifications updates from NC

Hi Annie, Lauren, and Kip,

Our first Water Quality Committee of the NC Environmental Management Commission (EMC) for 2018 is next week. FYI, you are probably interested in our items #1 and #2 on the agenda. Here is a link to the agenda. There are Powerpoints for the agenda items that are linked within the agenda items, as well:
https://deq.nc.gov/node/85200

Thanks and hope you had a Happy New Year,

Jeff Manning
Chief, Classifications & Standards/Rules Review Branch (CSRRB)
Water Planning Section, Division of Water Resources, Department of Environmental Quality
1611 Mail Service Center, Raleigh, NC 27699-1611
(Archdale Building)
CSRRB online: http://deq.nc.gov/about/divisions/water-resources/planning/classification-standards
Direct: 919-807-6415
Main: 919-707-9000
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Petter, Lauren

From: Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent: Tuesday, January 30, 2018 3:18 PM
To: Petter, Lauren
Cc: Godfrey, Annie
Subject: Follow-up questions from 1-9-2018 conference call

Our understanding from the 1-9-2018 conference call between NC DWR and EPA is that EPA has additional questions regarding the Bowen model for the Lower Cape Fear River.
Can you please email those questions to me so that DWR can address them?

Thanks,

Elizabeth Kountis
Senior Environmental Specialist
Division of Water Resources
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Petter, Lauren

From: Petter, Lauren
Sent: Wednesday, January 31, 2018 7:29 AM
To: Kountis, Elizabeth
Cc: Godfrey, Annie; Tyler, Kip
Subject: RE: Follow-up questions from 1-9-2018 conference call

Hey Elizabeth,

Sorry I didn't follow up with you yet! I should have followed up to let you know we don't have any further questions at this time.

Lauren Petter, Environmental Scientist
Water Quality Standards Section
Water Protection Division
Phone: (404) 562-9272

From: Kountis, Elizabeth [mailto:elizabeth.kountis@ncdenr.gov]
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Petter, Lauren

From:	Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Sent:	Wednesday, April 11, 2018 1:16 PM
To:	Godfrey, Annie
Cc:	Culpepper, Linda; Gregson, Jim; Fransen, Tom; Manning, Jeff; Petter, Lauren
Subject:	NC Submittal of 2017 Effective Reclassification for part of Cape Fear River
Attachments:	April_2018_EPA_package_for_02B_0227_and_02B_0311.pdf

Attached is a North Carolina submittal to EPA for approval of one of two reclassifications that became effective in 2017. Last year EPA received and approved a North Carolina submittal for the *other* reclassification that became effective in 2017. Mr. Trey Glenn has been sent his copy of the attached document via certified mail. If you have any questions or concerns regarding the document, please feel free to contact me.

Sincerely,

Elizabeth Kountis
Senior Environmental Specialist
Division of Water Resources
North Carolina Department of Environmental Quality

919 807-6418 office
elizabeth.kountis@ncdenr.gov

512 North Salisbury Street
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Nothing Compares...

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Water Resources
Environmental Quality

ROY COOPER
Governor
MICHAEL S. REGAN
Secretary
LINDA CULPEPPER
Interim Director

April 9, 2018

Mr. Trey Glenn, Regional Administrator
Environmental Protection Agency, Region 4
61 Forsyth Street SW
Atlanta, GA 30303

SUBJECT: Request for Approval of Modifications to North Carolina's Surface Water Quality Classifications

Dear Mr. Glenn:

In accordance with the provisions of Section 303 of the Clean Water Act, I am submitting North Carolina's formal request for review and approval of select revisions to the Surface Water Quality Standards and Stream Classifications rules that became effective in 2017. These revisions pertain to the reclassification of a segment of the Cape Fear River, and are part of the state's Triennial Review of Classifications and Standards.

The reclassification from Class SC to Class SC Sw was based on scientific information provided by the requestor as well as information available to North Carolina's Division of Water Resources staff. This information included documents such as:

- "The Relationship of Adjacent Wetlands and Salt Marsh to Dissolved Oxygen in the Lower Cape Fear River Estuary" (Tetra Tech, 2014)
- "Analysis of Water Quality Data at Cape River Estuary Model Boundaries" and "Summary of Background Information and Previous Studies for the Lower Cape Fear River" (CH_2MHill, 2014)
- "Development and Use of a Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the Lower Cape Fear River Estuary, North Carolina" (Bowen, et al., 2009)
- "The Potential Impacts of Climate Change on Coastal North Carolina" (University of North Carolina Wilmington, 2008)

Standards applicable to Class SC waters, which include the subject waters, provide a base of protection to all North Carolina's tidal salt waters. The supplemental Sw classification recognizes natural conditions, most notably for pH and DO. Thus, additional ambient DO & pH standards apply in the subject waters under natural conditions. This proposal recognizes the inputs and effects of the majority of waters that drain into subject waters, which are also classified as Sw.

To aid the review, a water quality management plan is included for the subject waters that proceeded through rulemaking with the reclassification. The water quality management plan is consistent with and helps to implement the permitting strategy in place for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters. The management plan contains effluent limits that new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges within

the river segment must meet regarding oxygen consuming wastes as of the effective date of the rule. These limits are more stringent than the standards regarding oxygen consuming wastes for Class SC or Class Sw waters, and are very similar to the limits for one of the state's most restrictive supplemental classifications, High Quality Waters.

Discharge Effluent Limit	Before Reclassification	After Reclassification[1]
BOD_5	≥1 MGD = 5 mg/l < 1 MGD = 5 mg/l	5 mg/l
Ammonia Nitrogen	≥ 1 MGD = 1 mg/l < 1 MGD = 2 mg/l	1 mg/l
DO	5 mg/l	6 mg/l
In-stream delta DO	< 0.5 mg/l [2]	< 0.1 mg/l [3]

1. For industrial discharges, site-specific best available technology on a case-by-case basis would be utilized to determine the limits for BOD5, Ammonia and DO according to 15A NCAC 02B .0406(e).
2. HQW rules require more stringent limits if in-stream DO drops more than 0.5 mg/l.
3. The in-stream DO is not to drop more than 0.1 mg/l below the modeled in-stream DO at total permitted capacity for all discharges.

A complete listing of the enclosures submitted as part of this package is enclosed, including a map that indicates all of the upstream waters that are already supplementally classified with the Sw classification. A letter of opinion from our Attorney General certifying that the revised rule was adopted following public hearing and that the revisions are valid and enforceable in the State of North Carolina is included as Enclosure 4.

We believe the reclassification included in this package meets the requirements of the Clean Water Act. If there are any questions during the review, please feel free to contact Elizabeth Kountis at (919) 807-6418.

Sincerely,

Linda Culpepper
Interim Director, Division of Water Resources

TR:EK

Enclosures

cc: Annie Godfrey (EPA)
Tom Fransen (DWR)

List of Enclosures

Enclosure #	Title of Enclosure	Page
Enclosure 1.	*Summary of North Carolina Surface Water Quality Reclassification Effective June 30, 2017 (includes "Table 1. Surface Water Reclassification That Became Effective on June 30, 2017")*	*1*
Enclosure 2.	*Schedule of Classification as Amended on June 30, 2017*	*5*
Enclosure 3.	*Records of Rule-Making for Reclassification*	*7*
Enclosure 4.	*Attorney General's Certification*	*18*

Enclosure 1.
Summary of North Carolina Surface Water Quality Reclassification Effective on June 30, 2017

Summary of North Carolina Surface Water Quality Reclassification Effective June 30, 2017

On June 30, 2017, one surface water reclassification became effective (see Table 1).

Table 1. Surface Water Reclassification That Became Effective on June 30, 2017

Waterbody	River Basin	County	Class Change From	Class Change To	Public Hearing	EMC Final Action	Effective Date
Cape Fear River	Cape Fear	New Hanover, Brunswick	SC	SC Sw (with a water quality management plan)	02/05/15	09/10/15 (and 05/12/16)	June 30, 2017

The chemical, physical, and biological properties; character of the watershed and bordering areas; economic effects; and past, present, and future uses of the watershed were considered when determining the appropriate class for this reclassification.

The most common and basic classification for tidal salt water is Class SC. Class SC waters are protected for aquatic life propagation and maintenance of biological integrity (including fishing and fish), wildlife, secondary recreation and any other usages except for primary recreation or shellfishing. All tidal salt waters of the state are at least protected for Class SC uses.

The SC classification is a primary classification whereas the Sw classification is a supplemental classification that can accompany a primary classification. Sw waters are waters that are topographically located so as to generally have natural characteristics such as low velocity, dissolved oxygen, or pH, which are different from streams draining steeper topography.

A water quality management plan is a strategy tailored to protect existing uses or quality of waters in specific waters. "In implementing the water quality standards to protect the existing uses...of the waters of the state or the water quality which supports those uses, the Commission shall develop water quality management plans on a priority basis to attain, maintain or enhance water quality throughout the state" (15A NCAC 02B .0227).

The reclassification submitted for approval involves a portion of the lower Cape Fear River reclassified from SC to SC Sw. The main segment of the Cape Fear River directly above the reclassified river segment is classified C Sw, and the largest tributary to the subject waters, which is located immediately upstream of the subject waters, is the Northeast Cape Fear River and is classified SC Sw. The majority of the named waters flowing into the subject waters already carry the Sw designation, and this proposal recognizes the inputs and effects of all Sw waters that drain into subject waters. The highly flushed portion of the lower segment of the Cape Fear Rives is not included in this reclassification (see attached map).

Standards applicable to Class SC waters, which include the subject waters, provide a base of protection to all North Carolina's tidal salt waters. The supplemental Sw classification

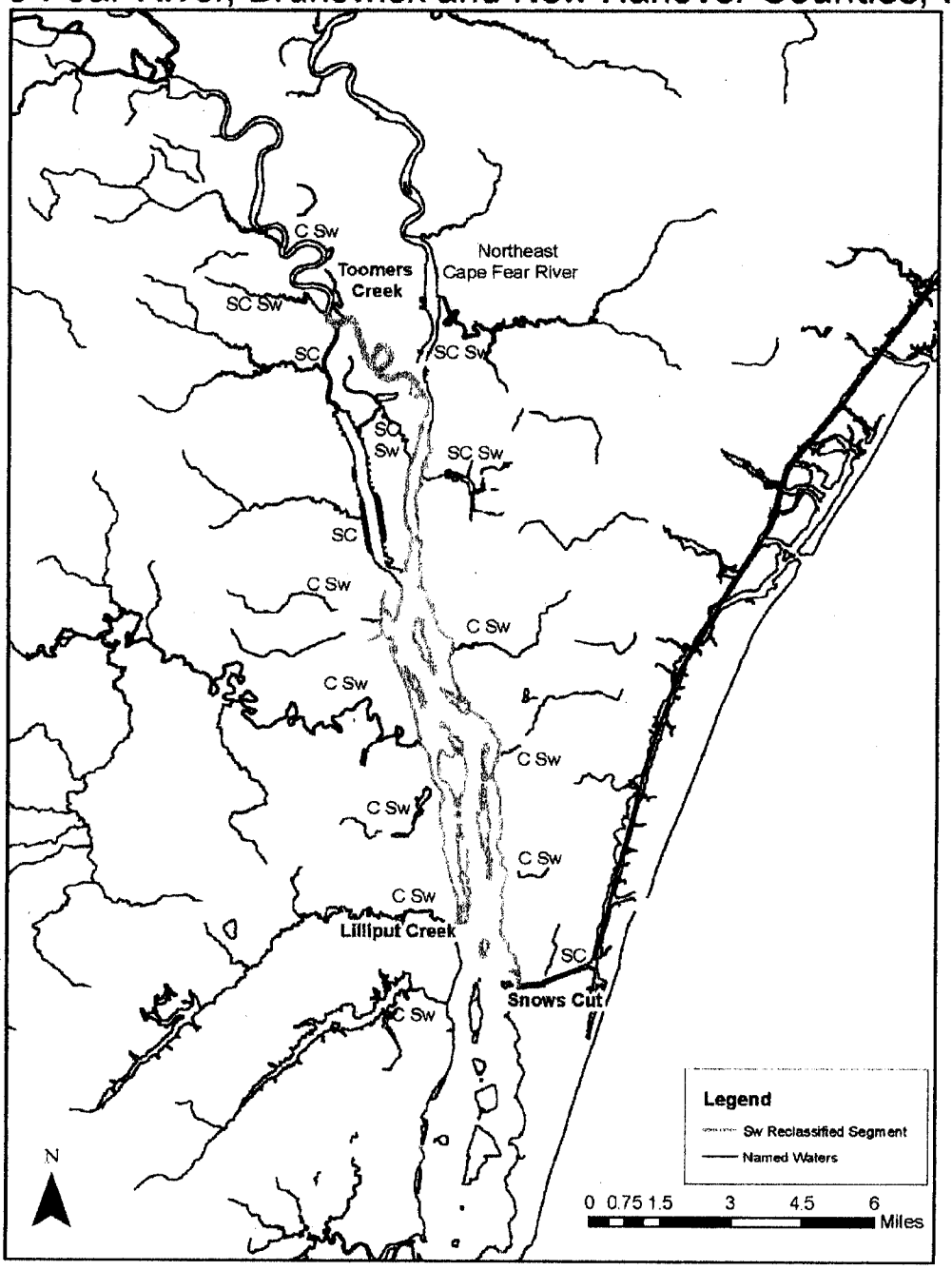
recognizes natural conditions, most notably for pH and DO. Thus, additional ambient DO & pH standards apply in the subject waters under natural conditions.

For your information, a water quality management plan is included for the subject waters that proceeded through rulemaking with the Sw reclassification. The water quality management plan is consistent with and helps to implement the current permitting strategy already in place for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters, which is designed to address water quality and existing uses of these waters. The management plan contains effluent limits that new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges within the river segment must meet regarding oxygen consuming wastes. These limits are more stringent than the standards regarding oxygen consuming wastes for Class SC or Class Sw waters.

The reclassification in conjunction with the management plan aid existing and future communities and the above-mentioned NPDES facilities in this area in preparing for the future. The management plan informs these communities and facilities about what to expect in terms of permitting, thus providing a path forward for future planning purposes.

A "Report of Proceedings" as well as an addendum to that document for the above-mentioned reclassification can be accessed at http://deq.nc.gov/about/divisions/water-resources/planning/classification-standards/current-reclassification-proposals.

Swamp Reclassification and Water Quality Management Plan
Cape Fear River, Brunswick and New Hanover Counties, NC



Enclosure 2.
Schedule of Classifications
as Amended on June 30, 2017

Reference Material to Regulation 15A 2B .0311 Cape Fear River Basin, entitled CLASSIFICATIONS AND WATER QUALITY STANDARDS ASSIGNED TO THE WATERS OF THE CAPE FEAR RIVER BASIN, has been amended 6-30-2017 as follows:

Name of Stream	*Description*	*Class*	*Stream Index #*
Cape Fear River	From upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut	SC Sw	18-(85.5)

Enclosure 3.
Records of Rule-Making for Reclassification

file
5/19/16

SUBMISSION FOR PERMANENT RULE

1. Rule-Making Agency: Environmental Management Commission (EMC)

2. Rule citation & name (name not required for repeal):
15A NCAC 02B .0227 Water Quality Management Plans

3. Action:
☐ ADOPTION ☒ AMENDMENT ☐ REPEAL ☐ READOPTION

4. Rule exempt from RRC review?
☐ Yes. Cite authority:
☒ No

5. Rule automatically subject to legislative review?
☐ Yes. Cite authority:
☒ No

FILED
2016 MAY 19 AM 9:45
OFFICE OF ADMIN HEARINGS

6. Notice for Proposed Rule:
☒ **Notice Required**
Notice of Text published on: December 15, 2015
Link to Agency notice: http://portal.ncdenr.org/web/wq/rules
Hearing on: No hearing held
Adoption by Agency on: May 12, 2016
☐ **Notice not required under G.S.:**
Adoption by Agency on:

7. Rule establishes or increases a fee? (See G.S. 12-3.1)
☐ Yes
Agency submitted request for consultation on:
Consultation not required. Cite authority:
☒ No

8. Fiscal impact (check all that apply):
☐ State funds affected
☐ Environmental permitting of DOT affected and analysis submitted to Board of Transportation
☐ Local funds affected
☐ Substantial economic impact (≥$1,000,000)
☐ Approved by OSBM
☒ No fiscal note required

9. REASON FOR ACTION

9A. What prompted this action? Check all that apply:
☒ Agency
☐ Court order / cite:
☐ Federal statute / cite:
☐ Federal regulation / cite:
☐ Legislation enacted by the General Assembly
Cite Session Law:
☐ Petition for rule-making
☐ Other:

9B. Explain:
At the September 2015 EMC meeting, the EMC approved rule amendments reflecting the reclassification of a portion of the Cape Fear River in New Hanover and Brunswick Counties to Class SC Sw with a water quality management plan. The rulemaking involved proposed amendments to 15A NCAC 2B .0227 and .0311 that had been publicly noticed in early 2015 and adopted in conjunction with each other. Then the Division of Water Resources (DWR) submitted the rule amendments to the RRC, and RRC counsel requested technical changes to 2B .0227 but not 2B .0311. DWR responded to the requested technical changes with a revised version of 2B .0227 that EMC approved at its November 2015 meeting to go out to public notice unaccompanied by 2B .0311. A 60-day public notice period was held from December 15, 2015 – February 15, 2016, and EMC adopted revisions to 2B .0227 on May 12, 2016.

10. Rule-making Coordinator: Jennifer Everett
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Phone: (919)807-6418
E-Mail: elizabeth.kountis@ncdenr.gov

11. Signature of Agency Head* or Rule-making Coordinator:
J. L. Everett
***If this function has been delegated (reassigned) pursuant to G.S. 143B-10(a), submit a copy of the delegation with this form.**
Typed Name: Jennifer Everett
Title: Rule-making Coordinator

RRC AND OAH USE ONLY

Action taken:
☐ RRC extended period of review:
☐ RRC determined substantial changes:
☐ Withdrawn by agency
☐ Subject to Legislative Review
☐ Other:

file
6/2/16

FILED

15A NCAC 02B .0227 has been amended with changes as published in 30:12 NCR 1277-1278 as follows:

2016 JUN -2 PM 12: 35

15A NCAC 02B .0227 WATER QUALITY MANAGEMENT PLANS

OFFICE OF ADMIN HEARINGS

(a) In implementing the water quality standards to protect the ~~existing uses~~ "existing uses" [as defined by Rule .0202 of this Section] of the waters of the state or the water quality ~~which~~ that supports those uses, the Commission shall develop water quality management plans on a priority basis to attain, maintain or enhance water quality throughout the state. Additional specific actions deemed necessary by the Commission to protect the water quality or the existing uses of the waters of the state shall be specified in Paragraph (b) of this Rule. These actions may include anything within the powers of the Commission. The Commission may also consider local actions ~~which~~ that have been taken to protect a waterbody in determining the appropriate protection options to be incorporated into the water quality management plan.

(b) All waters determined by the Commission to be protected by a water quality management plan are listed with specific actions either in Rules .0601- .0608 of this Subchapter that address the Goose Creek watershed (Yadkin Pee-Dee River Basin) or as follows:

(1) The Lockwoods Folly River Area (Lumber River Basin), which includes all waters of the lower Lockwoods Folly River in an area extending north from the Intracoastal Waterway to a line extending from Genoes Point to Mullet Creek, shall be protected by the specific actions described in Parts (A) through ~~(E)~~ (D) of this Subparagraph.

(A) New development activities within 575' of the mean high water line ~~which~~ that require a Sedimentation Erosion Control Plan or a CAMA major development permit ~~must~~ shall comply with the low density option of the coastal ~~Stormwater~~ stormwater ~~Runoff Disposal Rules~~ requirements ~~[as specified in 15A NCAC 2H .1005(2)(a)]~~ as specified in 15A NCAC 2H ~~.1005(2)(a)~~ .1005(3)(a).

(B) New or expanded NPDES permits shall be issued only for non-domestic, non-industrial process type discharges ~~(such as non-industrial process cooling or seafood processing discharges)~~, such as non-industrial process cooling or seafood processing discharges. A public hearing ~~is~~ shall be mandatory for any proposed (new or expanded) NPDES permit to this protected area.

~~(C) New non-discharge permits shall be required to meet reduced loading rates and increased buffer zones, to be determined on a case by case basis.~~

~~(D)~~(C) New or expanded marinas ~~must~~ shall be located in upland basin areas.

~~(E)~~(D) No dredge or fill activities shall be allowed ~~where significant shellfish or submerged aquatic vegetation bed resources occur~~, if those activities would result in a reduction of the beds of ~~submerged~~ "submerged aquatic vegetation [~~habitat~~] habitat" or [~~a reduction of shellfish~~] "shellfish producing habitat" [~~habitat as which~~] that are defined in [~~15A NCAC 03I .0101(b)(20)(A) and (B)~~,] 15A NCAC 03I .0101, except for maintenance dredging, such as that required to maintain access to existing channels and facilities located within the protected area or maintenance dredging for activities such as agriculture.

(2) A part of the Cape Fear River (Cape Fear River Basin) comprised of a section of Index No.18-(71) from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut shall be protected by the Class SC Sw standards as well as the following site-specific action: All new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges shall be required to provide treatment for oxygen consuming wastes as described in Parts (A) through (C) of this Subparagraph.

(A) Effluent limitations shall be as follows: BOD_5 = 5 mg/l, NH_3-N = 1 mg/l and DO = 6 mg/l, or utilize site-specific best available technology on a case-by-case basis for industrial ~~discharges~~.discharges in accordance with Rule .0406 (e) of this Subchapter.

(B) Seasonal effluent limits for oxygen consuming wastes [~~will~~] shall be considered ~~on a case-by-case basis~~ in accordance with Rule .0404 of this Subchapter.

(C) Any new or expanded permitted pollutant discharge of oxygen consuming waste shall not cause the dissolved oxygen of the receiving water to drop more than 0.1 mg/l below the modeled in-stream dissolved oxygen at total permitted capacity for all discharges.

History Note: *Authority G.S. 143-214.1; 143-215.8A;*
Eff. October 1, 1995;
Amended Eff. ~~November 1, 2015;~~ July 1, 2016; January 1, 1996.

file
6/14/16

SUBMISSION FOR PERMANENT RULE

1. Rule-Making Agency: Environmental Management Commission

2. Rule citation & name (name not required for repeal): 15A NCAC 02B .0311 Cape Fear River Basin

3. Action:
☐ ADOPTION ☒ AMENDMENT ☐ REPEAL

FILED
2016 JUN 14 AM 11:49
OFFICE OF ADMIN HEARINGS

4. Rule exempt from RRC review?
☐ Yes. Cite authority:
☒ No

5. Rule automatically subject to legislative review?
☐ Yes. Cite authority:
☒ No

6. Notice for Proposed Rule:

☒ Notice Required
Notice of Text published on: January 2, 2015
Link to Agency notice: http://portal.ncdenr.org/web/wq/rules
Hearing on: February 5, 2015
Adoption by agency on: September 10, 2015
☐ Notice not required under G.S.:
Adoption by agency on:

7. Rule establishes or increases a fee? (See G.S. 12-3.1)

☐ Yes
Agency submitted request for consultation on:
Consultation not required. Cite authority:

☒ No

8. Fiscal impact (check all that apply):

☐ State funds affected
☐ Environmental permitting of DOT affected and analysis submitted to Board of Transportation
☐ Local funds affected
☐ Substantial economic impact (≥$1,000,000)
☐ Approved by OSBM
☒ No fiscal note required

9. REASON FOR ACTION

9A. What prompted this action? Check all that apply:

☒ Agency
☐ Court order / cite:
☐ Federal statute / cite:
☐ Federal regulation / cite:
☐ Legislation enacted by the General Assembly
Cite Session Law:
☐ Petition for rule-making
☐ Other:

9B. Explain: Lower Cape Fear River Program staff requested that a section of the Cape Fear River in Brunswick and New Hanover Counties be reclassified. The subject waters are proposed to be reclassified from Class SC to Class SC Sw with a water quality management plan (WQMP). The proposed Sw reclassification would allow, if caused by natural conditions, the pH of the subject waters to reach as low as 4.3 (compared to the currently required 6.8-8.5 range) and the dissolved oxygen to be lower than the currently required 5 mg/l. The proposed WQMP would help implement the current permiting strategy for new individual NPDES wastewater discharges and expansions of existing individual NPDES wastewater discharges to the subject waters. The overall proposal provides a path forward for these discharges & local communities for future planning purposes.

10. Rule-making Coordinator: Jennifer Everett
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Agency Contact, if any: Elizabeth Kountis
Phone: (919)807-6418
E-Mail: elizabeth.kountis@ncdenr.gov

11. Signature of Agency Head* or Rule-making Coordinator:

Jennifer L Everett

***If this function has been delegated (reassigned) pursuant to G.S. 143B-10(a), submit a copy of the delegation with this form.**

Typed Name: Jennifer Everett
Title: Rule-making Coordinator

RRC AND OAH USE ONLY

Action taken:

☐ RRC Extended period of review:
☐ RRC determined substantial changes:
☐ Withdrawn by agency
☐ Subject to Legislative Review
☐ Other:

15A NCAC 02B .0311 has been amended <u>with changes</u> as published in 29:13 NCR 1606-1609 as follows:

15A NCAC 02B .0311 CAPE FEAR RIVER BASIN

(a) Effective February 1, 1976, the adopted classifications assigned to the waters within the Cape Fear River Basin are set forth in the Cape Fear River Basin Schedule of Classifications and Water Quality Standards, which may be inspected at the following places:

(1) the Internet at http://portal.ncdenr.org/web/wq/ps/csu/rules; and

(2) the North Carolina Department of Environment and Natural Resources:

(A) Winston-Salem Regional Office
585 Waughtown Street
Winston-Salem, North Carolina

(B) Fayetteville Regional Office
225 Green Street
Systel Building Suite 714
Fayetteville, North Carolina

(C) Raleigh Regional Office
3800 Barrett Drive
Raleigh, North Carolina

(D) Washington Regional Office
943 Washington Square Mall
Washington, North Carolina

(E) Wilmington Regional Office
127 Cardinal Drive Extension
Wilmington, North Carolina

(F) Division of Water Quality
Central Office
512 North Salisbury Street
Raleigh, North Carolina.

(b) The Cape Fear River Basin Schedule of Classification and Water Quality Standards was amended effective:

(1) March 1, 1977;

(2) December 13, 1979;

(3) December 14, 1980;

(4) August 9, 1981;

(5) April 1, 1982;

(6) December 1, 1983;

(7) January 1, 1985;

(8) August 1, 1985;

(9) December 1, 1985;

(10) February 1, 1986;

(11) July 1, 1987;

(12) October 1, 1987;

(13) March 1, 1988;

(14) August 1, 1990.

(c) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective June 1, 1988 as follows:

(1) Cane Creek [Index No. 16-21-(1)] from source to a point 0.5 mile north of N.C. Hwy. 54 (Cane Reservoir Dam) including the Cane Creek Reservoir and all tributaries has been reclassified from Class WS-III to WS-I.

(2) Morgan Creek [Index No. 16-41-1-(1)] to the University Lake dam including University Lake and all tributaries has been reclassified from Class WS-III to WS-I.

(d) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective July 1, 1988 by the reclassification of Crane Creek (Crains Creek) [Index No. 18-23-16-(1)] from source to mouth of Beaver Creek including all tributaries from C to WS-III.

(e) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective January 1, 1990 as follows:

(1) Intracoastal Waterway (Index No. 18-87) from southern edge of White Oak River Basin to western end of Permuda Island (a line from Morris Landing to Atlantic Ocean), from the eastern mouth of Old Topsail Creek to the southwestern shore of Howe Creek and from the southwest mouth of Shinn Creek to channel marker No. 153 including all tributaries except the King Creek Restricted Area, Hardison Creek, Old Topsail Creek, Mill Creek, Futch Creek and Pages Creek were reclassified from Class SA to Class SA ORW.

(2) Topsail Sound and Middle Sound ORW Area which includes all waters between the Barrier Islands and the Intracoastal Waterway located between a line running from the western most shore of Mason Inlet to the southwestern shore of Howe Creek and a line running from the western shore of New Topsail Inlet to the eastern mouth of Old Topsail Creek was reclassified from Class SA to Class SA ORW.

(3) Masonboro Sound ORW Area which includes all waters between the Barrier Islands and the mainland from a line running from the southwest mouth of Shinn Creek at the Intracoastal Waterway to the southern shore of Masonboro Inlet and a line running from the Intracoastal Waterway Channel marker No. 153 to the southside of the Carolina Beach Inlet was reclassified from Class SA to Class SA ORW.

(f) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective January 1, 1990 as follows: Big Alamance Creek [Index No. 16-19-(1)] from source to Lake Mackintosh Dam including all tributaries has been reclassified from Class WS-III NSW to Class WS-II NSW.

(g) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 3, 1992 with the reclassification of all water supply waters (waters with a primary classification of WS-I, WS-II or WS-III). These waters were reclassified to WS-I, WS-II, WS-III, WS-IV or WS-V as defined in the revised water supply protection rules, (15A NCAC 02B .0100, .0200 and .0300) which became effective on August 3, 1992. In some cases, streams with primary classifications other than WS were reclassified to a WS classification due to their proximity and linkage to water supply waters. In other cases, waters were reclassified from a WS classification to an alternate appropriate primary classification after being identified as downstream of a water supply intake or identified as not being used for water supply purposes.

(h) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective June 1, 1994 as follows:

(1) The Black River from its source to the Cape Fear River [Index Nos. 18-68-(0.5), 18-68-(3.5) and 18-65-(11.5)] was reclassified from Classes C Sw and C Sw HQW to Class C Sw ORW.

(2) The South River from Big Swamp to the Black River [Index Nos. 18-68-12-(0.5) and 18-68-12(11.5)] was reclassified from Classes C Sw and C Sw HQW to Class C Sw ORW.

(3) Six Runs Creek from Quewhiffle Swamp to the Black River [Index No. 18-68-2] was reclassified from Class C Sw to Class C Sw ORW.

(i) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective September 1, 1994 with the reclassification of the Deep River [Index No. 17-(36.5)] from the Town of Gulf-Goldston water supply intake to US highway 421 including associated tributaries from Class C to Classes C, WS-IV and WS-IV CA.

(j) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 1, 1998 with the revision to the primary classification for portions of the Deep River [Index No. 17-(28.5)] from Class WS-IV to Class WS-V, Deep River [Index No. 17-(41.5)] from Class WS-IV to Class C, and the Cape Fear River [Index 18-(10.5)] from Class WS-IV to Class WS-V.

(k) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective April 1, 1999 with the reclassification of Buckhorn Creek (Harris Lake)[Index No. 18-7-(3)] from the backwaters of Harris Lake to the Dam at Harris Lake from Class C to Class WS-V.

(l) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective April 1, 1999 with the reclassification of the Deep River [Index No. 17-(4)] from the dam at Oakdale-Cotton Mills, Inc. to the dam at Randleman Reservoir (located 1.6 mile upstream of U.S. Hwy 220 Business), and including tributaries from Class C and Class B to Class WS-IV and Class WS-IV & B. Streams within the Randleman Reservoir Critical Area have been reclassified to WS-IV CA. The Critical Area for a WS-IV reservoir is defined as 0.5 mile and draining to the normal pool elevation of the reservoir. All waters within the Randleman Reservoir Water Supply Watershed are within a designated Critical Water Supply Watershed and are subject to a special management strategy specified in 15A NCAC 02B .0248.

(m) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 1, 2002 as follows:

(1) Mill Creek [Index Nos. 18-23-11-(1), 18-23-11-(2), 18-23-11-3, 18-23-11-(5)] from its source to the Little River, including all tributaries was reclassified from Class WS-III NSW and Class WS-III B NSW to Class WS-III NSW HQW@ and Class WS-III B NSW HQW@.

(2) McDeed's Creek [Index Nos. 18-23-11-4, 18-23-11-4-1] from its source to Mill Creek, including all tributaries was reclassified from Class WS III NSW and Class WS-III B NSW to Class WS-III NSW HQW@ and Class WS-III B NSW HQW@.

The "@" symbol as used in this Paragraph means that if the governing municipality has deemed that a development is covered under a "5/70 provision" as described in Rule 15A NCAC 02B .0215(3)(b)(i)(E) (Fresh Surface Water Quality Standards for Class WS-III Waters), then that development is not subject to the stormwater requirements as described in rule 15A NCAC 02H .1006 (Stormwater Requirements: High Quality Waters).

(n) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective November 1, 2004 as follows:

(1) the portion of Rocky River [Index Number 17-43-(1)] from a point 0.3 mile upstream of Town of Siler City upper reservoir dam to a point 0.3 mile downstream of Lacy Creek from WS-III to WS-III CA.

(2) the portion of Rocky River [Index Number 17-43-(8)] from dam at lower water supply reservoir for Town of Siler City to a point 65 feet below dam (site of proposed dam) from C to WS-III CA.

(3) the portion of Mud Lick Creek (Index No. 17-43-6) from a point 0.4 mile upstream of Chatham County SR 1355 to Town of Siler City lower water supply reservoir from WS-III to WS-III CA.

(4) the portion of Lacy Creek (17-43-7) from a point 0.6 mile downstream of Chatham County SR 1362 to Town of Siler City lower water supply reservoir from WS-III to WS-III CA.

(o) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective November 1, 2007 with the reclassifications listed below, and the North Carolina Division of Water Quality maintains a Geographic Information Systems data layer of these UWLs.

(1) Military Ocean Terminal Sunny Point Pools, all on the eastern shore of the Cape Fear River [Index No. 18-(71)] were reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(2) Salters Lake Bay near Salters Lake [Index No. 18-44-4] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(3) Jones Lake Bay near Jones Lake [Index No. 18-46-7-1] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(4) Weymouth Woods Sandhill Seep near Mill Creek [18-23-11-(1)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(5) Fly Trap Savanna near Cape Fear River [Index No. 18-(71)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(6) Lily Pond near Cape Fear River [Index No. 18-(71)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(7) Grassy Pond near Cape Fear River [Index No. 18-(71)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(8) The Neck Savanna near Sandy Run Swamp [Index No. 18-74-33-2] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(9) Bower's Bog near Mill Creek [Index No. 18-23-11-(1)] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(10) Bushy Lake near Turnbull Creek [Index No. 18-46] was reclassified to Class WL UWL as defined in 15A NCAC 02B .0101.

(p) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective January 1, 2009 as follows:

(1) the portion of Cape Fear River [Index No. 18-(26)] (including tributaries) from Smithfield Packing Company's intake, located approximately 2 miles upstream of County Road 1316, to a point 0.5 miles upstream of Smithfield Packing Company's intake from Class C to Class WS-IV CA.

(2) the portion of Cape Fear River [Index No.18-(26)] (including tributaries) from a point 0.5 miles upstream of Smithfield Packing Company's intake to a point 1 mile upstream of Grays Creek from Class C to Class WS-IV.

(q) The schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective August 11, 2009 with the reclassification of all Class C NSW waters and all Class B NSW waters upstream of the dam at B. Everett Jordan Reservoir from Class C NSW and Class B NSW to Class WS-V NSW and Class WS-V & B NSW, respectively. All waters within the B. Everett Jordan Reservoir Watershed are within a designated Critical Water Supply Watershed and are subject to a special management strategy specified in 15A NCAC 02B .0262 through .0273.

(r) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective September 1, 2009 with the reclassification of a portion of the Haw River [Index No. 16-(28.5)] from the Town of Pittsboro water supply intake, which is located approximately 0.15 mile west of U.S. 15/501, to a point 0.5 mile upstream of the Town of Pittsboro water supply intake from Class WS-IV to Class WS-IV CA.

(s) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective March 1, 2012 with the reclassification of the portion of the Haw River [Index No. 16-(1)] from the City of Greensboro's intake, located approximately 650 feet upstream of Guilford County 2712, to a point 0.5 miles upstream of the intake from Class WS-V NSW to Class WS-IV CA NSW, and the portion of the Haw River [Index No. 16-(1)] from a point 0.5 miles upstream of the intake to a point 0.6 miles downstream of U.S. Route 29 from Class WS-V NSW to Class WS-IV NSW.

(t) The Schedule of Classifications and Water Quality Standards for the Cape Fear River Basin was amended effective [~~November 1, 2015~~] August 1, 2016 with the reclassification of a section of 18-(71) from upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut from Class SC to Class SC Sw. A site-specific management strategy is outlined in 15A NCAC 02B .0227.

1 *History Note:* *Authority G.S. 143-214.1; 143-215.1; 143-215.3(a)(1);*
2 *Eff. February 1, 1976;*
3 *Amended Eff. August 1, 2016; March 1, 2012; September 1, 2009; August 11, 2009; January 1,*
4 *2009; November 1, 2007; November 1, 2004; August 1, 2002; April 1, 1999; August 1, 1998;*
5 *September 1, 1994; June 1, 1994; August 3, 1992; August 1, 1990.*
6

Enclosure 4.
Attorney General's Certification

JOSH STEIN
ATTORNEY GENERAL

Reply To:
Daniel S. Hirschman
Environmental Division
Phone: (919) 716-6600
dhirschman@ncdoj.gov

March 28, 2018

Ms. Anne Heard, Acting Regional Administrator
Environmental Protection Agency, Region IV
61 Forsyth Street SW
Atlanta, GA 30303

SUBJECT: Certification of Adoption of Modifications to North Carolina's Surface Water Quality Classifications

Dear Ms. Heard:

Under the provisions of Article 21, Chapter 143 of the North Carolina General Statutes as amended, the North Carolina Environmental Management Commission is directed and empowered to adopt and assign "best use" classifications to all the surface waters of the State and to adopt water quality standards applicable to each classification.

The North Carolina Environmental Management Commission, after notice duly given, has adopted modifications to surface water classifications. The modifications to surface water classifications are shown in the enclosed *"Table 1. Surface Water Reclassification That Became Effective on June 30, 2017."*

By delegation from the Attorney General of North Carolina, I advise you that it is my opinion that the revised stream classifications listed in the enclosure have been duly adopted and promulgated in accordance with the Laws of the State of North Carolina and the Rules of the Environmental Management Commission, and that these revisions are valid and enforceable in the State of North Carolina as of the effective dates provided in the enclosure.

Very truly yours,

Daniel S. Hirschman
Senior Deputy Attorney General

Petter, Lauren

From: Gordon, Lisa Perras
Sent: Tuesday, June 19, 2018 7:26 AM
To: Wetherington, Michele; Petter, Lauren
Subject: FW: [External] Re: EPA Enforcement Meeting w/NC

Categories: Yellow Category

From: Manning, Jeff [mailto:jeff.manning@ncdenr.gov]
Sent: Monday, June 18, 2018 1:56 PM
To: Gordon, Lisa Perras
Subject: FW: [External] Re: EPA Enforcement Meeting w/NC

Hey Lisa,
I know you wanted to chat again this week about CF.
I was just made aware of a mtg tomorrow at 1:00pm. Some info below....

Jeff

From: Culpepper, Linda
Sent: Sunday, June 17, 2018 11:12 PM
To: Fransen, Tom <tom.fransen@ncdenr.gov>; Manning, Jeff <jeff.manning@ncdenr.gov>; Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>
Cc: Gregson, Jim <jim.gregson@ncdenr.gov>
Subject: FW: [External] Re: EPA Enforcement Meeting w/NC

Jeaneanne Gettle is the new Water Director at R4. As part of an all-day enforcement discussion, there's a breakout session starting at 1pm. As indicated below, Jeaneanne has to leave early and would like to discuss the Cape Fear classification. I'm not sure which conf. room we'll have our breakout session in, but plan to meet us in the Green Square Boardroom and we'll go from there.

From: Gettle, Jeaneanne [mailto:Gettle.Jeaneanne@epa.gov]
Sent: Sunday, June 17, 2018 10:39 PM
To: Culpepper, Linda <linda.culpepper@ncdenr.gov>
Subject: [External] Re: EPA Enforcement Meeting w/NC

CAUTION: External email. Do not click links or open attachments unless verified. Send all suspicious email as an attachment to

Linda

Sorry for the delay in responding. My flight leaves RDU at 3 so our time may be limited. For the time we will have, I would like to discuss the CF Swamp issue and maybe set a date for me to come back and spend more time. And of course any topic you want to cover.

Thanks
Jeaneanne

Sent from my iPhone

On Jun 13, 2018, at 9:41 AM, Culpepper, Linda <linda.culpepper@ncdenr.gov> wrote:

> Good morning – in preparation for the discussion [Tues], I was wondering if there are any specific water issues of interest for the
> general portion of the meeting or during the break out session in the afternoon? Know your time may be limited.
>
> We can talk further about the Cape Fear River reclassification, 303(d) and triennial reviews for our surface water & groundwater standards, our permit
> back log in NPDES and SFY2018-19 state funding in the breakout session. May have a few other legislative items active – our General Assembly
> seems to be headed to closure for this session by the end of June.
>
> Look forward to the discussions,
> Linda

Petter, Lauren

From: Manning, Jeff <jeff.manning@ncdenr.gov>
Sent: Tuesday, June 19, 2018 11:58 AM
To: Gordon, Lisa Perras; Petter, Lauren
Subject: FW: EPA R4 - Cape Fear Classification Discussion

just FYI...

From: Culpepper, Linda
Sent: Tuesday, June 19, 2018 11:48 AM
To: Manning, Jeff <jeff.manning@ncdenr.gov>; Behm, Pamela <pamela.behm@ncdenr.gov>; Kountis, Elizabeth <elizabeth.kountis@ncdenr.gov>; Fransen, Tom <tom.fransen@ncdenr.gov>
Subject: Re: EPA R4 - Cape Fear Classification Discussion

Jeaneanne needs to leave at 1pm so I will cancel this discussion. Will reschedule for a time when she can be back in NC.

Get Outlook for iOS

Petter, Lauren

From: Petter, Lauren
Sent: Tuesday, July 31, 2018 10:59 AM
To: 'Kountis, Elizabeth'; 'Manning, Jeff'
Subject: Lower Cape Fear
Attachments: EPA July 24 2018 Disapproval Ltr and Decision Doc for LCFR.pdf

Betsy and Jeff,

Here is a PDF of the letter signed last week.

Lauren

Lauren Petter, Environmental Scientist
Water Quality Standards Section
Water Protection Division
Phone: (404) 562-9272

Petter, Lauren

From: Augspurger, Tom <tom_augspurger@fws.gov>
Sent: Monday, April 06, 2015 5:17 PM
To: Petter, Lauren
Subject: Fwd: Thanks
Attachments: LCFR_DOModelReport_Final.zip

Hello Lauren,

Thanks for your time on the phone. If you have any feedback on the issues raised in FWS's 3/3/15 letter, please let me know. One comment is to include a plan that addresses sources of impairment (rather than stopping at a reclassification). In the attached modeling report, section 6.5 (pages 6-8 and 6-9) indicates that reduction in loadings upstream of the modeled reach could result in 95% attainment of the standard – for example a 50% reduction in upstream loads could translate into excursion below 5 mg/L DO only 5% of the time from the 33% baseline condition. Folks requesting the reclassification note current non-attainment and show with the model that local point sources (within the modeled reach) are not the driver. While it has been explained to us that a reclassification helps focus effort, perhaps this section of the model report shows the classification is OK (standard achievable, but it would take a huge effort, and outside the modeled reach).

The point of comment #3 in the FWS letter is that if the reclassification is somehow needed to focus effort on problem sources, that linkage to actions to improve upstream water quality should be made clear. As I read it again, I started thinking about the converse... that perhaps the model shows the classification is OK as is but it will take a big effort outside the modeled reach to achieve the standard.

Have a good week,

Tom

Tom Augspurger
Ecologist / Environmental Contaminants Specialist
U.S. Fish and Wildlife Service
551-F Pylon Drive
Raleigh NC 27606
919-856-4520 x21
tom_augspurger@fws.gov

DEVELOPMENT AND USE OF A THREE-DIMENSIONAL WATER QUALITY MODEL TO PREDICT DISSOLVED OXYGEN CONCENTRATIONS IN THE LOWER CAPE FEAR RIVER ESTUARY, NORTH CAROLINA

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William States Lee College of Engineering
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Charlotte, NC 28223

The research on which this report is based was supported by funds provided by the North Carolina General Assembly through the North Carolina Department of Environment and Natural Resources.

October 2009

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EXECUTIVE SUMMARY

An application of the three-dimensional water quality model EFDC (Environmental Fluid Dynamics Code) was developed for the Lower Cape Fear River Estuary, North Carolina. The model was used to investigate the effects of various organic matter and ammonia load reduction scenarios on the dissolved oxygen concentrations within the estuary. The model region included the tidally affected portions of the Cape Fear, Black, and Northeast Cape Fear Rivers near Wilmington, North Carolina, and extended southward to the mouth of the Cape Fear River near Southport, North Carolina.

The model's three-dimensional numerical grid had 1050 horizontal cells and eight vertical layers. The average horizontal grid size was approximately 600 m; individual cell sizes ranged from 100 to 1300 m. Cell water depths varied for river and estuary channel cells from 2.5 to 12.5 m. EFDC uses a "sigma" vertical grid so that the water depth within a horizontal cell was subdivided into eight layers of uniform thicknesses. The model grid included 241 "marsh" cells that were used to model the off-channel storage of wetlands adjoining the estuary. Flow boundary conditions were utilized at the upstream riverine boundaries; a radiation-separation boundary condition was used at the downstream open boundary. Model input data sets and observed data sets used for calibration and confirmation, and model scenario testing were developed using observed data gathered from various agencies. The period December 1, 2003 to December 31, 2004 was found to have sufficient data to create the necessary model data set for calibration. An additional model data set using data from January 1 to December 31, 2005 was used for model confirmation.

The model calibration period (January 1 – December 31, 2004) had streamflows that were generally below average for the first half of the year, and generally above average for the latter half of the year. After a storm in early May 2004, streamflows remained below average until August. The remainder of 2004 and 2005 until the middle of April had streamflows that were near historical average values. Flows through the summer of 2005 were generally below average. Dissolved oxygen (DO) concentrations at two stations that were in the impaired region and had continuous monitors installed in 2004 (Navassa and the Northeast Cape Fear at Wilmington) showed summertime (April 1 – October 31) dissolved oxygen concentrations that varied between 3 and 7.5 mg/L. At both of these sites the median DO concentration was below 4.5 mg/L and the 25th percentile DO concentration was below 4.1 mg/L. DO concentrations were generally lower at the Northeast Cape Fear site, and at this site were generally lower near the bottom of the water column.

Model calibration was performed separately on the hydrodynamic and water quality submodels. Hydrodynamic model calibration relied heavily on a set of continuous in-situ water level and water quality monitors that were deployed through the estuary. Hydrodynamic model calibration consisted primarily of varying the location, width, and bottom roughnesses of shallow model cells located adjacent to the river and estuary channels. The distribution of these "marsh" cells utilized information on the location and lateral extent of saltwater marshes and wetland forests adjoining the estuary. The calibrated hydrodynamic model matched well the attenuation of the tidal amplitude signal from the estuary mouth to the upstream model boundaries. The

model was also able to simulate to a reasonable extent the time histories of salinities throughout the estuary.

The twenty-one state variable water quality model available in EFDC included multiple dissolved and particulate organic carbon constituents, as well as organic and inorganic nutrients, dissolved oxygen, and three phytoplankton constituents. To adequately characterize the various organic matter decomposition rates of the riverine and wastewater inputs, both labile and refractory dissolved organic matter constituents were used. The water quality model considered inputs from the three riverine sources at the model boundaries, twenty wastewater point source inputs within the estuary, and fourteen additional point sources that simulated other freshwater inputs to the estuary from tidal creeks and wetlands. Over the three-year time period (2002-2005) for which the freshwater and point source loadings were developed, approximately 10% of the organic matter loading and 50% of the ammonia loading to the estuary came from the twenty wastewater point sources that discharged directly to the estuary.

The dissolved oxygen model utilized a user specified sediment oxygen demand (SOD) that could vary spatially and temporally. Both temporal and spatial variation in SOD was utilized for the model. The temporally variable SOD that was used in this study was based upon an analysis of the available monitoring data. Temporal variation was modeled according the observed variation in measured SOD with changes in water temperature during the SOD measurement. SOD values were then adjusted seasonally according to observed changes in water temperature in the water body. During calibration it was determined that higher SOD values should be used for the Northeast Cape Fear. The ratio between these higher SOD values and the SOD values for remaining portion of the model region was determined during calibration. Discharge and estuary monitoring data were used to quantify the loadings of organic matter, nutrients, and dissolved oxygen to the estuary. As part of calibration SOD values were varied to values above and below the average values from the monitoring program. The calibrated value was found to be nearly identical to the corresponding value from the monitoring program.

The calibrated model matched well time histories of observed dissolved oxygen concentration. Model predictions were compared to over 5200 measured dissolved oxygen concentrations collected at eighteen sites throughout the estuary. The mean model error was less than 0.01 mg/L, and the root mean square error was 0.92 mg/L, which corresponded to 13.8% of the mean value. The correlation r^2 was 84.4%. This is an excellent degree of model fit for an estuarine dissolved oxygen model. Time history comparisons were also made for other important water quality constituents, such as nitrate+nitrite, orthophosphate, total nitrogen, and chlorophyll. In each case the model acceptably simulated the spatial and temporal patterns in the observed data set. A water quality model confirmation test run using input and calibration data from 2005 showed a similar degree of fit between observed and predicted dissolved oxygen concentrations. Based upon this work, the calibrated model is considered to be suitable for conducting scenario tests on the effect of changes in organic matter and ammonia loadings on the dissolved oxygen concentrations in the estuary.

A number of scenario tests were conducted to investigate the system's sensitivity to loading changes and other possible changes in the water body. For each scenario, a model run

was used to determine the predicted dissolved oxygen concentrations during the summer period of 2004 (April 1 – October 31) within the state designated impaired region of the estuary. Twice daily dissolved oxygen snapshots were recorded from all eight vertical layers at eighteen sites within the impaired region. More than twenty separate model runs were made and compared to the base case to determine how the dissolved oxygen concentrations might vary for a particular scenario. These eight scenarios were examined:

1. Eliminating wastewater point source loadings
2. Reducing river, creek, and wetland loadings
3. Changing wastewater loadings for various values of sediment oxygen demand
4. Reducing river, creek, and wetland loadings and sediment oxygen demand
5. Eliminating ammonia inputs from wastewater point sources
6. Increasing wastewater inputs to maximum permitted values
7. Deepening of the navigation channel
8. Changing Brunswick County wastewater loadings

Four model runs were made to investigate the effect of completely turning off the discharges from the wastewater treatment plants. These scenarios were run, not because the pollutant removals used were considered achievable or advisable, but instead these scenarios were run to investigate the system's sensitivity to WWTP loads. River, creek, and wetland inputs were maintained at the base condition levels. It was assumed that organic matter and ammonia concentrations in the wastewater inputs would be decreased to 0.0 mg/L. When all WWTP loads were eliminated, the 10th percentile DO concentration increased by approximately 0.3 mg/L, from 4.3 to 4.5 mg/L. The median value DO concentration increased by about 0.10 mg/L, from 5.6 to 5.7 mg/L. Selectively turning off individual WWTP loads, as expected, had a smaller effect. Turning off the International Paper WWTP had an effect that was roughly 2/3 of that when all the plants were turned off. Turning off both Wilmington domestic wastewater treatment plants had an effect that was roughly 1/3 of that when all discharges were turned off. A fourth scenario considered eliminating the ammonia loading for all wastewater treatment plants. This scenario increased the dissolved oxygen concentration by about 0.1 mg/L at the 10th percentile level.

The impact of changing the loadings that entered the model region from rivers, creeks, and wetlands were also investigated. Loading reductions of 30%, 50%, or 70% were assumed for the three river inputs (Cape Fear, Black, and Northeast Cape Fear), and from the fourteen creeks and wetland inputs in the estuary. To reduce the loadings, flows were maintained at the observed levels, but concentrations were reduced by 30%, 50%, or 70%. Loadings for the twenty wastewater point sources were maintained at the levels in the base case scenario. These load reductions were found to have a significant impact on dissolved oxygen concentrations. At the 10th percentile level, DO concentrations for the 30%, 50%, and 70% load reduction increased by 0.20, 0.3, and 0.40 mg/L respectively, from 4.3 mg/l to either 4.5, 4.6 or 4.7 mg/L. Unlike the other scenarios investigated, this level of increase in DO concentration was maintained at the higher percentiles. In fact, the median DO concentration was increased to even a greater extent, increasing from 5.6 to 5.85 mg/L for the 30% load reduction, and from 5.6 to 6.2 mg/L for the 70% load reduction scenario.

Additional water quality model runs were conducted to investigate the sensitivity of the results to the choice of model kinetic parameters. Because of its relative importance in determining dissolved oxygen concentrations, the sensitivity analysis focused on the impact of various choices for the sediment oxygen demand. During calibration it was found that this parameter had a significant impact on dissolved oxygen concentrations in the estuary. In addition to the calibrated SOD value (0.4 $g/m^2/d$ at 20° C), runs were made at a lower value (0.3 $g/m^2/d$ at 20° C) and a higher value (0.5 $g/m^2/d$ at 20° C). Model fit to the observed data set was compared for these three cases. All three cases had similar correlation r^2 values (83.4%, 83.4%, and 84.5%), but on average the low SOD case overpredicted DO concentrations by 0.11 mg/L, while the high SOD case underpredicted DO concentrations by a similar amount (0.09 mg/L). The impact of turning off the organic matter and ammonia loadings from all wastewater treatment plants was investigated for each of these three SOD cases. Each scenario produced a very similar change in DO concentration when all point sources were turned off. Even though DO concentrations were changed with the different SOD cases, in each scenario, turning off the sources increased DO concentrations by approximately 0.25 mg/L at the 10th percentile level. It is expected that changes in other model parameters would have a similar result. Although absolute concentrations are affected by changes in parameter values, relative changes in concentration are less affected by changing parameter values.

An additional set of model runs were conducted to investigate the effect of reducing both river loading of organic matter and sediment oxygen demand. Three pairs of model runs were made that reduced river loading or river loading and SOD by 30%, 50%, and 70%, using the methods described earlier. As expected, a larger effect was seen when both river loading and SOD were reduced. A 30% reduction raised the 10th percentile DO concentration from 4.3 to 4.8 mg/L; a 50% reduction raised the 10th percentile DO concentration to 5.2 mg/L; a 70% reduction raised the 10th percentile DO concentration to 5.4 mg/L. In this final case where both river load and SOD were reduced by 70% from the base case, only about 1% of the model predicted DO concentrations in the impaired region were less than the water quality standard value of 5.0 mg/L.

The impact of increasing all wastewater treatment plant loadings to the maximum allowed by permit was also investigated. For cases where both the maximum concentration and flow were specified, both these values were used in the scenario. In permits with only a load or concentration limit, the existing flows were maintained, but concentrations were adjusted to produce the permitted limit. Using these maximum permitted loadings decreased predicted dissolved concentrations in the impaired region by approximately 0.1 mg/L. This level of decrease was fairly uniform across the range of predicted concentrations.

The impact of deepening the navigation channel on predicted dissolved oxygen concentrations in the estuary was also investigated. Model grid files were adjusted to match the channel deepening plan developed by the Wilmington district of the US Army Corps of Engineers that will deepen portions of the Cape Fear and Northeast Cape Fear Rivers. It was found that this deepening would decrease dissolved oxygen concentrations by approximately 0.1 to 0.2 mg/L. The percentage of dissolved oxygen concentrations in the summertime in the impaired region that would be below 5.0 mg/L would increase slightly with the channel deepening from 32% to 34%.

Three model scenarios considered the impact of changing the wastewater flow of a single discharger (Brunswick County wastewater treatment plant). Based on the discharge monitoring reports for the model period, the base condition had a time-averaged flow of 0.38 MGD. The three scenarios tested had time-averaged flow of 1.65, 4.65 and 15 MGD. These scenarios therefore represented the effect of changing the wastewater treatment flow by factors of 4.3, 12.1, and 39.1. Despite the relatively large changes in the assumed wastewater flow, there were only very small differences in the predicted dissolved oxygen concentrations, for summertime conditions in the impaired region. Across the entire range of dissolved oxygen concentrations, the differences between the base case and each of the three scenarios were always less than 0.05 mg/L.

An analysis was performed to attribute the observed oxygen depletion within the estuary to riverine loadings of degradable waste, wastewater discharges, and sediment oxygen demand. It was found that for three sites in the impaired region during the summer, less than 10% of the dissolved oxygen deficit was attributable to wastewater discharges. Riverine loadings and sediment oxygen demand each contributed similar amounts to the remaining 90% of the deficit.

The report concludes with some recommendations as to additional development of the model that seems justified. Both this model study and a previous effort demonstrated the importance of benthic fluxes of oxygen. As this model used a prescribed sediment oxygen demand, albeit one that varies temporally and spatially, further refinement of the sediment model seems warranted. In addition, some additional work seems justified to separately consider the effects of wetland and riverine loadings to dissolved oxygen conditions in the estuary.

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1. INTRODUCTION

1.1 Background

The Cape Fear River watershed is the largest in North Carolina with a drainage area of 9,149 square miles. The watershed is nearly 200 miles long and is completely contained within the state (NC DENR 2004). The watershed is divided into upper, middle, and lower regions. The upper region contains the Triad metropolitan area of Greensboro, High Point, and Winston-Salem. The Lower Cape Fear River Estuary occupies the southernmost 60 kilometers of the watershed, from upstream of Wilmington to the Atlantic Ocean (Figure 1). The estuary includes not only the tidally affected portion of the Cape Fear River, but also the lowermost portions of the Black and Northeast Cape Fear Rivers. The Wilmington metropolitan area is located within the estuarine portion of the Lower Cape Fear watershed.

The river and its watershed are vital resources to the state providing not only as a water supply for drinking and industrial use, but also by providing habitat for countless aquatic plants and animals. As such, reaches within the Cape Fear River watershed have been deemed by the North Carolina government to have designated uses such as water supply, primary and secondary recreation, aquatic life propagation, and agriculture depending on the desired use of the water and its quality (see classifications listing at http://h2o.enr.state.nc.us/csu/). State (NC Department of Environment and Natural Resources) and Federal (Environmental Protection Agency) agencies are charged with maintaining, protecting, and restoring the quality of surface waters. Section 303(d) of the Federal Clean Water Act (CWA) requires all states to develop a list of waters not meeting water quality standards or which are not meeting their designated use. Listed waters must be prioritized, and a management strategy or total maximum daily load (TMDL) analysis must subsequently be developed for all listed waters.

A portion of the Lower Cape Fear River Estuary occupying 5,616.7 acres is currently on the state's 303(d) list (NC Division of Water Quality 2008). This listing, having the following description:

> From upstream mouth of Toomers Cr. to a line across the river between Lilliput Creek and Snow's cut

is given in part because of violations of the state's water quality standard for dissolved oxygen (5.0 mg/L for surface waters, and 4.0 mg/L for swamp waters) (NCDEHNR 1994). Because of the history of dissolved oxygen water quality violations, and the 303(d) listing of this portion of the estuary, the NC is currently conducting a dissolved oxygen TMDL analysis of the estuary. As part of this TMDL analysis, a three-dimensional water quality model of the estuarine portion of the Cape Fear River watershed has been developed, tested, and utilized to run management scenarios. This report summarizes the development, testing, and use of this model.

1.2 Study Objectives

The overall objective of the study was to develop a water quality model of the Lower Cape Fear River estuary that would be suitable for use during the dissolved oxygen TMDL analysis performed by the NC Division of Water Quality (DWQ). During the early investigative phase of the project, it was determined that a three-dimensional numerical model would be necessary. Once the model was selected, developed and tested, the project objective was to estimate the nature and magnitude of changes in the water quality of the estuary that would result from changes in inputs of oxygen demanding wastes to the estuary. This objective was achieved by formulating, running, and analyzing several sets of model scenarios that simulated water quality conditions in the estuary for various loading levels of oxygen demanding wastes. A secondary model objective was to assess the reliability of model predictions. This objective was achieved through model confirmation and model sensitivity testing.

1.3 Organization of the Study Report

In order to achieve the model study objectives, the project was divided into the following phases:

- model selection,
- collection of model forcing and calibration data,
- creation of the model computational grid,
- creation of model input files,
- model calibration,
- model confirmation (verification and sensitivity analysis), and
- scenario testing.

The remaining chapters describe each of the phases listed above. Chapter 2 introduces the three-dimensional model and describes the process by which the computational grid was created. This section also reviews the data sources used to create model input and calibration data files. Chapter 3 provides additional details on the specifications of model inputs that were used to create the various model input files. This is followed in Chapter 4 by a description of hydrodynamic and water quality model calibration. Model evaluation, which included a model confirmation test and sensitivity testing, is described in Chapter 5. The sensitivity of the system to changes in inputs of organic matter or other changes in the system is described in chapter 6. In this chapter are described five separate scenario tests that were performed to investigate how water quality in the estuary might change with changes in organic matter loadings. Discussion of the results and some conclusions that come from the study are provided in Chapter 7. References are provided in the final chapter.

Figure 1. The Cape Fear River Basin, North Carolina

2. MODEL AND SYSTEM DESCRIPTION

2.1 Model Description

After a review of the previous monitoring and modeling work done in the Lower Cape Fear River Estuary (e.g. Cahoon et al., 1999; Lin et al. 2006, Mallin et al., 2003, Tetra Tech 2001), it was decided that a three-dimensional water quality model was needed. Because of its flexibility in water quality simulation, its frequent use for hydrodynamic simulation, and its support by EPA, the Environmental Fluid Dynamics Code (EFDC) was selected as the model to be used for this application. EFDC is a hydrodynamic and water quality model that can be used to model one, two or three-dimensional aquatic systems. EFDC uses stretched or sigma vertical coordinates and Cartesian or curvilinear-orthogonal horizontal coordinates to represent the physical characteristics of a water body. It solves the three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motion for a variable-density fluid. Dynamically coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity and temperature are also solved. The EFDC model allows for drying and wetting in shallow areas by a mass conservation scheme (Hamrick, 1992).

A water quality model with 21 state variables (Table 1) has been developed and implemented within EFDC to form a three-dimensional coupled hydrodynamic and water quality model (water quality formulation can be found in Park et al., 1995). The model simulates temporal and spatial distributions of several water quality parameters such as dissolved oxygen, suspended algae, several components of carbon, nitrogen, phosphorous, silica as well as fecal coliform bacteria. The model predicts time and space variable concentrations by coupling the fate of these constituents (Figure 2) and performing a mass balance for each constituent at each water quality model time step (Tetra Tech, Inc., 2002a, 2002b).

The complete EFDC model contains three submodels (1: Hydrodynamics and Temperature, 2: Water Quality, 3: Sediment Diagenesis). The complete model, which was originally developed by John Hamrick (Hamrick, 1992) is currently maintained by Tetra Tech, Inc.. The hydrodynamics and temperature submodel is currently supported by the Environmental Protection Agency (EPA). In this application, the hydrodynamics, temperature, and water quality submodels were utilized. The sediment diagenesis model was not used, instead fluxes between the water column and sediments were prescribed.

Table 1. EFDC Water Quality State Variables. Abbreviations refer to constituents as shown in Figure 2.

Water Quality State Variable	Abbreviation	Unit
Cyanobacteria (blue-green algae)	Bc	g/m^3
Diatoms (algae)	Bd	g/m^3
Green algae (others)	Bg	g/m^3
Refractory particulate organic carbon	RPOC	g/m^3
Labile particulate organic carbon	LPOC	g/m^3
Dissolved organic carbon	DOC	g/m^3
Refractory particulate organic phosphorus	RPOP	g/m^3
Labile particulate organic Phosphorous	LPOP	g/m^3
Dissolved organic Phosphorous	DOP	g/m^3
Total phosphate	TPO_4	g/m^3
Refractory particulate organic Nitrogen	RPON	g/m^3
Labile particulate organic Nitrogen	LPON	g/m^3
Dissolved organic Nitrogen	DON	g/m^3
Ammonium	NH_4	g/m^3
Nitrate Nitrogen	NO_3^-	g/m^3
Particulate biogenic silica	SU	g/m^3
Available silica	SA	g/m^3
Chemical Oxygen Demand	COD	g/m^3
Dissolved Oxygen	DO	g/m^3
Total active metal	TAM	g/m^3
Fecal Coliform Bacteria	FCB	Mpn/ m^3

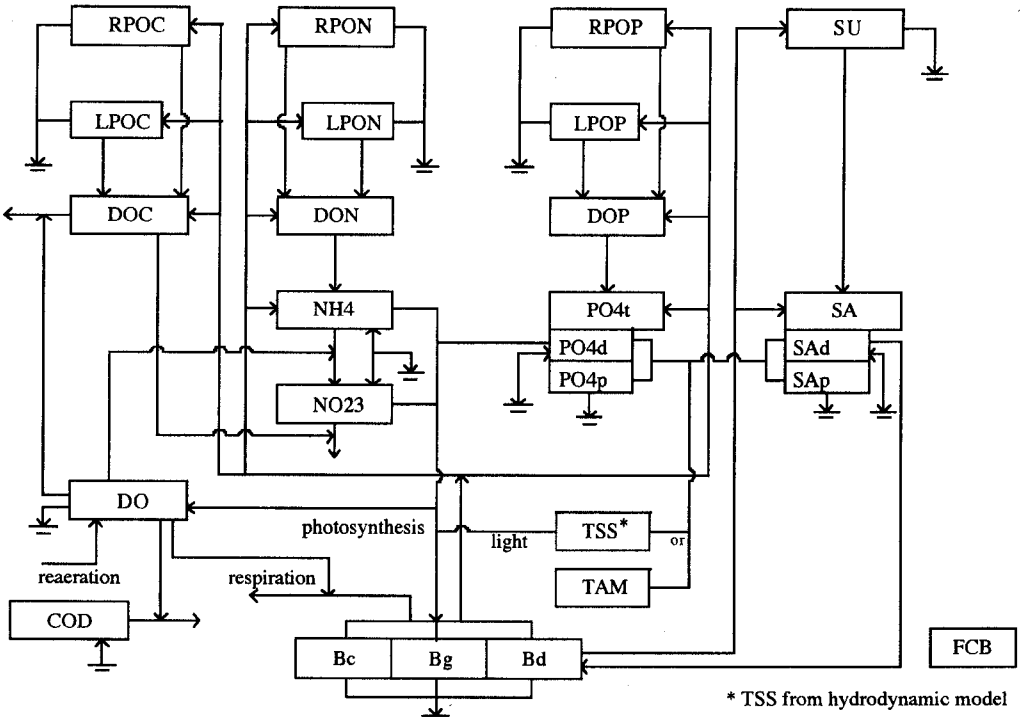


Figure 2. Schematic Description of the State Variables within the EFDC Water Quality Model.

2.2 Description of the Lower Cape Fear River Basin

The Cape Fear River flows for 200 miles through the North Carolina piedmont, crosses the coastal plain, and empties into the Atlantic Ocean near Southport, North Carolina. The river begins near Greensboro and Winston-Salem as two rivers, the Deep River and the Haw River. These two rivers converge near Moncure to form the Cape Fear River. The Black River joins the Cape Fear 15 miles above Wilmington, and the Northeast Cape Fear River enters the system at Wilmington (Figure 1).

The Lower Cape Fear River Estuary occupies the southernmost 60 kilometers of the watershed, between Wilmington and the Atlantic Ocean. The estuary includes not only the tidally affected portion of the Cape Fear River, but also the lowermost portions of the Black and Northeast Cape Fear Rivers. This area of the river basin is extremely important for saltwater animals because of its function as a nursery for juvenile fish, crabs, and shrimp. The Cape Fear River system is North Carolina's largest river system whose basin covers 9,000 square miles and encompasses streams in 29 of the state's 100 counties. It is the most industrialized of all of North Carolina's rivers (Cahoon et al., 1999; Mallin et al., 2003). The river is also an important natural resource that supports many uses including industry, transportation, recreation, drinking water and aesthetic enjoyment.

The hydrology of the Cape Fear Estuary is similar to that of most of the middle to large estuaries located along the US Atlantic Coast. During the summer and the beginning of the fall, the estuary has relatively low flows, whereas it has high flows from the end of the fall to the beginning of the spring. From a hydrodynamic perspective, the Cape Fear has approximately a two-meter tide range and strong tidal currents (> 0.5 m/s) in the navigational channel of the open estuary and in the narrow tidal river channels of the three tributaries (Ensign et al. 2004).

A region of the estuary near the junction of the Cape Fear, Black, and Northeast Cape Fear Rivers is prone to low dissolved oxygen concentrations during the warm summer and early fall seasons (Mallin et al. 2003) as a result of natural and anthropogenic (both point and nonpoint source) organic matter loadings. Dissolved oxygen concentrations are frequently below saturation concentrations, and typically exhibit an unusual vertical distribution in which surface concentrations are consistently lower than bottom concentrations (Lin et al. 2006). Previous modeling studies of the estuary have replicated this behavior, and have shown reaeration to be an important component of the dissolved oxygen budget for this region (Tetra Tech 2001).

A conceptual model of dissolved oxygen in the Lower Cape Fear River Estuary considers that the mass balance of dissolved oxygen in the water-column is simultaneously affected by several sources (Figure 3). Biologically or chemically degradable organic matter, quantified according to a biochemical oxygen demand load (BOD in kg/day), is introduced into the estuary from a variety of sources including the three major rivers (Cape Fear River, Northeast Cape Fear River, Black River), wastewater treatment plant discharges, and local inputs of non-point source loadings from the fringing wetlands and tidal creeks within the estuary. These same sources may also contribute or deplete the estuaries water column of dissolved oxygen as they either add or remove dissolved oxygen from the water. Likewise the bottom sediments of the estuary, which accepts the organic matter that settles from the water column, will also produce a water column dissolved oxygen sink as the organic matter in the bottom sediments is aerobically decomposed by benthic microbes and animals. Sources of dissolved oxygen to the estuary water column includes phytoplankton that produces oxygen as they photosynthesize new plant material, and the overlying atmosphere, which will replenish the water column with dissolved oxygen whenever surface water dissolved oxygen concentration are less than 100% saturated. Together these dissolved oxygen sources and sinks and BOD sources produces a dissolved oxygen concentration that varies both in time and space within the estuary. In general the cumulative effects result in dissolved oxygen concentrations that are lowest in the warm summer months when organic matter decomposition occurs at a maximum rate while dissolved oxygen saturation concentrations, which decrease with increasing temperature and salinity, are at their seasonal minimum values.

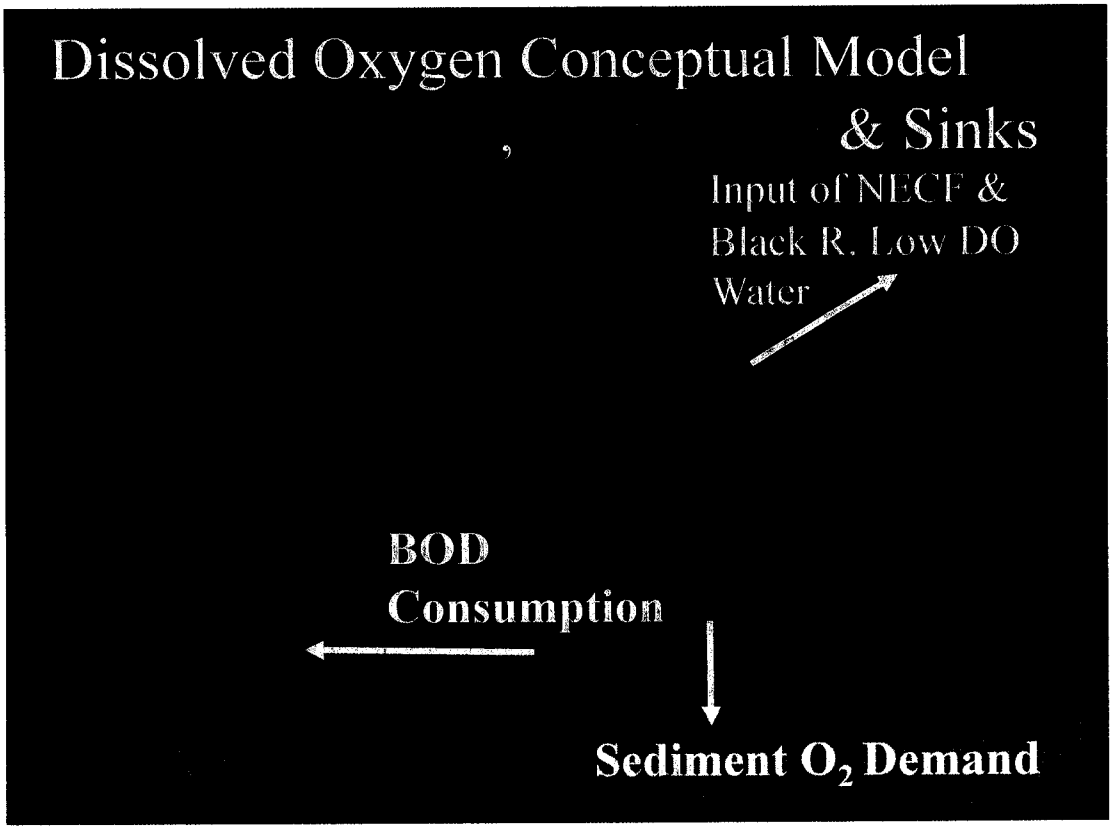


Figure 3. A Conceptual Model of the Dissolved Oxygen Mass Balance in the Lower Cape Fear River Estuary

2.3 Previous Modeling of the Lower Cape Fear River Estuary

A three-dimensional water quality model of the Lower Cape Fear River Estuary has previously been developed for the City of Wilmington and New Hanover County (Tetra Tech 2001). This work had these stated objectives:

- Simulation of the mixing and transport of the City/County existing and proposed future Northside and Southside facility effluents.
- Simulation of the impact of existing and proposed future Northside and Southside facility pollutant loads for oxygen-demanding substances.

- Evaluation of multiple sources and cumulative loads of oxygen-demanding substances to the lower Cape Fear River estuary.

- Analysis of the various processes affecting dissolved oxygen and their relative contribution to ambient dissolved oxygen deficit levels.

Included in the model analysis was a prediction of the near-field and far-field dilution of the two Wilmington wastewater treatment plants and a water quality analysis for various scenarios that considered changes to wastewater treatment plant loadings, changes to sediment oxygen demand values within the estuary, changes to river loadings of organic matter and ammonia, and changes arising from elimination of the fringing wetland areas of the estuary. The hydrodynamic model was calibrated using continuous monitoring of water surface elevation and salinity during the summer of 1993 and long-term measurements of water surface elevation at the NOAA tide gauge at Wilmington. A radiation separation boundary condition was used for the open boundary at the mouth of the Cape Fear River Estuary. The water quality model calibration utilized in-stream data from the Lower Cape Fear Program and wastewater treatment plant loading data from the NC Division of Water Quality. The water quality calibration was based upon model predicted and observed data comparisons for the entire 1998 calendar year. The scenario analysis also considered the 1998 calendar year.

The scenario analyses focused on changes to dissolved oxygen concentration that would be seen at five monitoring stations within the Cape Fear and Northeast Cape Fear Rivers (Navassa, NCF6, M61, M54, M42). The scenario analysis considered time-averaged changes in dissolved oxygen concentrations at these five stations. It was concluded based upon the results of the scenario analyses that sediment oxygen demand had the largest effect on dissolved oxygen concentrations, followed by either the point source loads or the wetland effect, depending on the station examined. Overall the tributary loadings of organic matter had the smallest effect on dissolved oxygen concentrations at the five stations examined, although there were significant differences in the relative magnitudes of the effects at the five stations. The study concluded with recommendations for additional studies and water quality modeling of the estuary aimed at better quantifying the relative magnitude of the factors causing dissolved oxygen depletion.

2.4 Model Grid and Bathymetry

The model's three-dimensional numerical grid had 1050 horizontal cells and eight vertical layers. The average horizontal grid size was approximately 600 m; individual cell side dimensions ranged from 100 to 1300 m (Figure 3). Cell water depths varied for river and estuary channel cells from 2.5 to 12.5 m. EFDC uses a "sigma" vertical grid so that the total water depth within a horizontal cell was subdivided into eight layers of uniform thicknesses.

Of the 1050 horizontal cells in the Lower Cape Fear River, the model grid included 241 "marsh" cells that were used to model the off-channel storage of wetlands adjoining the estuary. The model also has 809 channel cells that provide the majority of transport into and out of the estuary. Horizontal sizes and location of the channel cells were set to match as much as possible the estuary bathymetric information obtained from NOAA (available at

http://NOSDataExplorer.noaa.gov). The size, location, water depth, and bottom roughness of the marsh cells was determined during calibration of the hydrodynamic model. The method for specifying marsh cell characteristics will be described in more detail in the calibration section of this report (see Chapter 4).

The overall distribution of marsh cells within the estuary was initially set according to wetland delineations conducted by the North Carolina Division of Coastal Management NC Division of Coastal Management, 1999). Marsh cells were assumed to be located in regions of the estuary that had two of the wetland types identified in the NC DCM delineation: riverine swamps and saltwater marshes. Of the wetland types identified by the NC DCM, these two represented the majority of wetlands adjoining the Cape Fear River in the estuary. According to the Division of Coastal Management, within the Lower Cape Fear River estuary, saltwater marshes can be found south of Wilmington (Figure 4), while the riverine marshes are generally located farther upstream (Figure 4). The marsh cells in the calibrated EFDC model are also located both upstream and downstream of Wilmington (Figure 5).

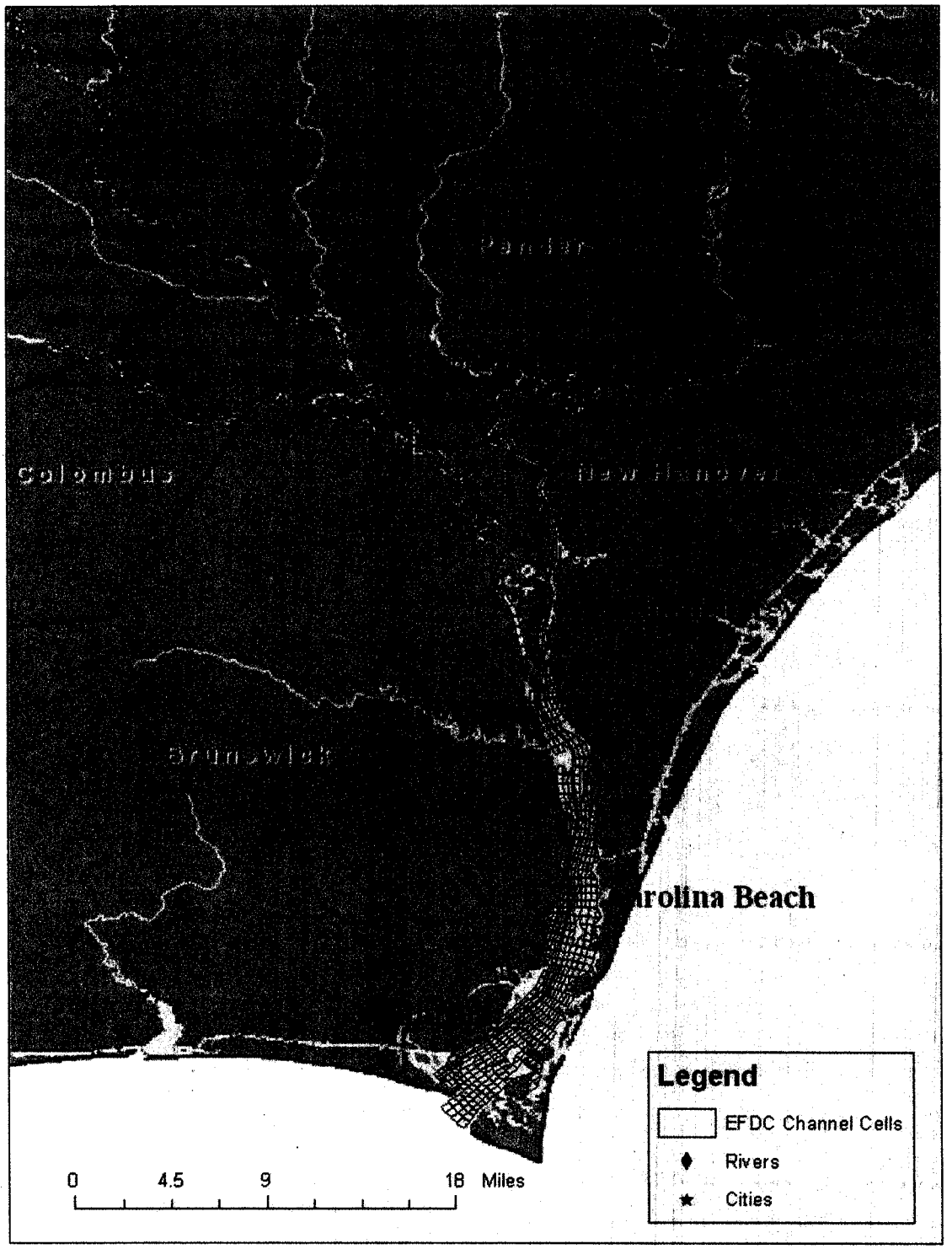


Figure 4. Channel Cells Within the Model Region

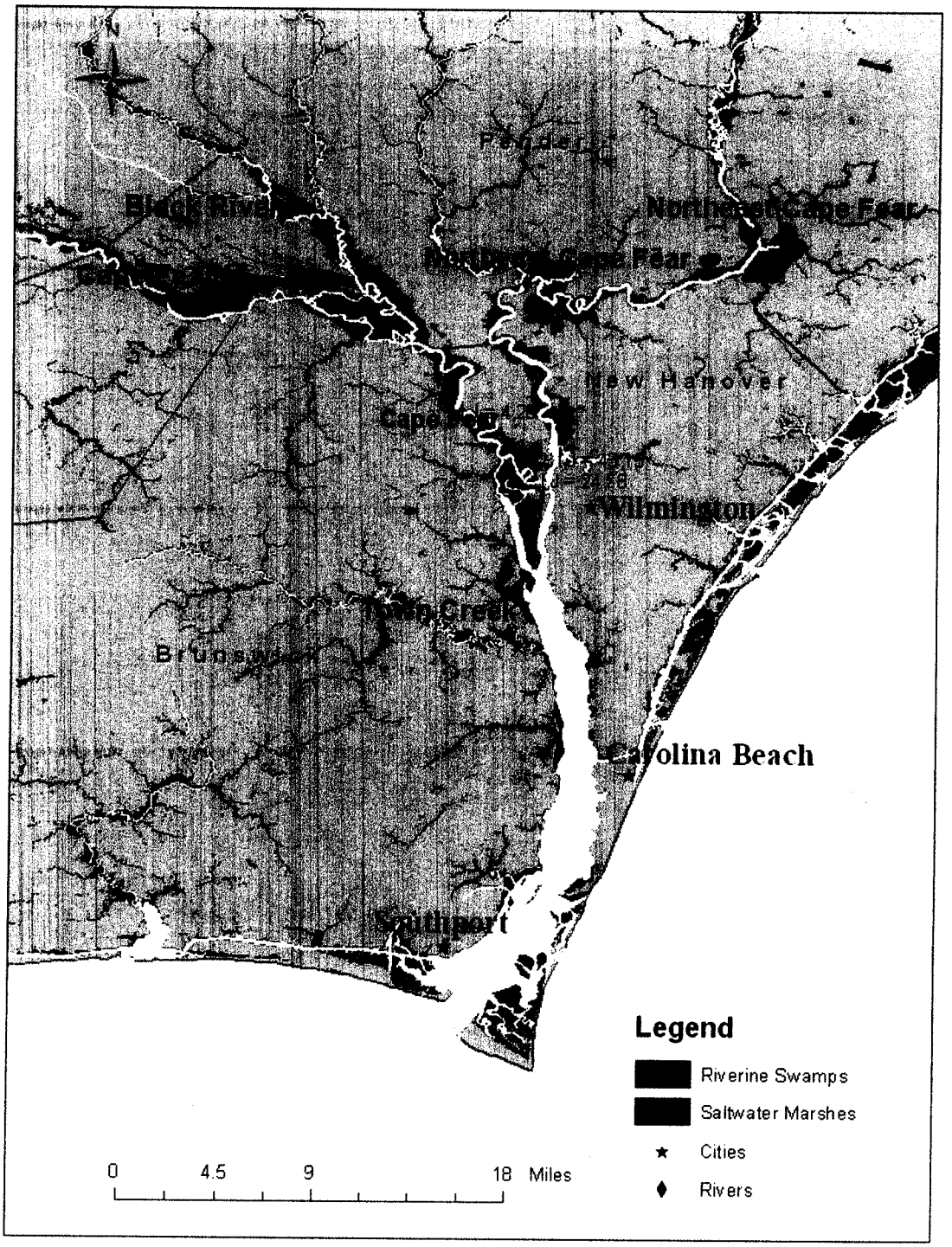


Figure 5. Riverine Swamps and Saltwater Marshes in the Lower Cape Fear River Estuary

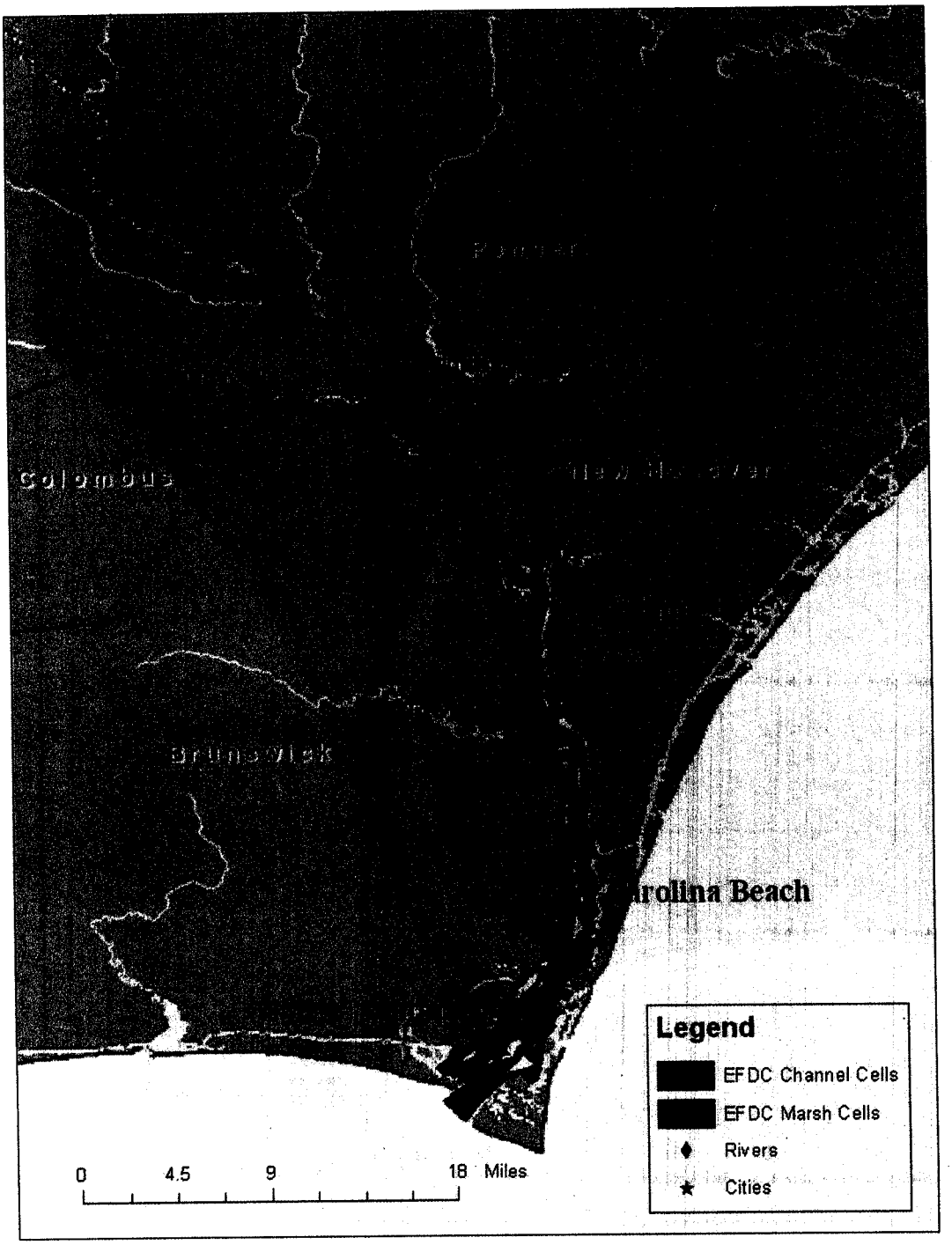


Figure 6. Model Grid Showing Location and Size of Marsh Cells

2.4 Monitoring Data Used for Model Setup and Calibration

Monitoring data is needed to define the model system characteristics and system inputs of mass, momentum, and energy. Table 2 summarizes the data types and sources used for setting up and running the Lower Cape Fear River estuary water quality model.

Table 2. EFDC Input Files and Data Sources

EFDC Input Filename	Description of Data Contained in File	Data Sources
QSER.INP	Flow time series data at flow specified model boundaries and point source locations	US Geological Survey, NC Division of Water Quality
ASER.INP	Meteorological time series data	National Weather Service
PSER.INP	Water surface elevation time series data at elevation specified model boundaries	National Oceanographic and Atmospheric Administration (NOAA)
TSER.INP	Temperature time series data at all model boundaries and point source inputs	Lower Cape Fear River Program, US Geological Survey, NC Division of Water Quality
WSER.INP	Wind time series data	National Weather Service
DXDY.INP	Horizontal cell lengths, widths, depths, bottom roughness	National Oceanographic and Atmospheric Administration (NOAA)
LXLY.INP	Horizontal cell size location, orientation relative to E-W, N-S direction	National Oceanographic and Atmospheric Administration (NOAA)
WQ3DWC.INP	Sediment oxygen demand specification	NC Division of Water Quality
SALT.INP	Initial condition for salinity for every model cell and layer	US Geological Survey, NC Division of Water Quality
TEMP.INP	Initial condition for temperature for every model cell and layer	Lower Cape Fear River Program, NC Division of Water Quality
WQPSL.INP	Time series mass load for each water quality constituent at each flow boundary or point source input	Lower Cape Fear River Program, NC Division of Water Quality
CWQSRXX.INP (XX indicates constituent number)	Time series concentration boundary condition at elevation specified boundaries	US Division of Water Quality, Lower Cape Fear River Program

Much of the water quality information for specifying initial and boundary conditions and calibration data came from the Lower Cape Fear River Program (e.g. Mallin et al. 2003). This water quality monitoring program, which is administered by the Center for Marine Science at UNC Wilmington, collects monthly data at a large number of sites throughout the estuary (Figure 6). The following monitoring data from this program were used for model specification and calibration:

Physical Parameters: temperature, salinity
Water Quality Parameters: nitrate-nitrite, ammonium, total nitrogen, orthophosphate, total phosphorus, total kjedahl nitrogen, dissolved oxygen
Biological Parameters: chlorophyll-a, biological oxygen demand

Additional water quality and physical data were collected using continuous *in-situ* monitors. This monitoring program was administered by the US Geological Survey, with financial support from the NC Division of Water Quality. The following data, which were collected every 15 minutes at each site, were used for model specification:

Physical parameters: temperature, salinity, water depth or water elevation, streamflow
Water Quality Parameters: dissolved oxygen

The continuous monitors were operated for roughly a one-year period beginning in November 2003 at six sites (Figure 7) throughout the estuary. Two of the sites (NE Cape Fear at Wilmington, Marker 12) had a near-surface and near-bottom monitor. The other stations had the monitors installed in the upper portion of the water column. The actual start and stop date of the monitoring differed somewhat for each of the sites. Two additional sites operated by the USGS that were upstream of the model region on the Black and NE Cape Fear Rivers were also used for establishing boundary conditions for flow (Figure 7).

Several other special studies administered by the NC Division of Water Quality collected important additional physical, water quality, and biological data. A short-term special study collected data from 12 sites within the estuary (Figure 7) during July and August 2004 (NC Division of Water Quality 2004). The study data were used along with the Lower Cape Fear River Program data to specify boundary conditions and calibration data for the model. The following data were collected and used in this study:

Field parameters: dissolved oxygen, temperature, salinity

Chemical parameters: 5-day biochemical oxygen demand, 30-day biochemical oxygen , total organic carbon, dissolved organic carbon, chlorophyll, ammonia nitrogen, total kjeldahl nitrogen (tkn), nitrite + nitrate nitrogen, total phosphorus, ortho-phosphorus

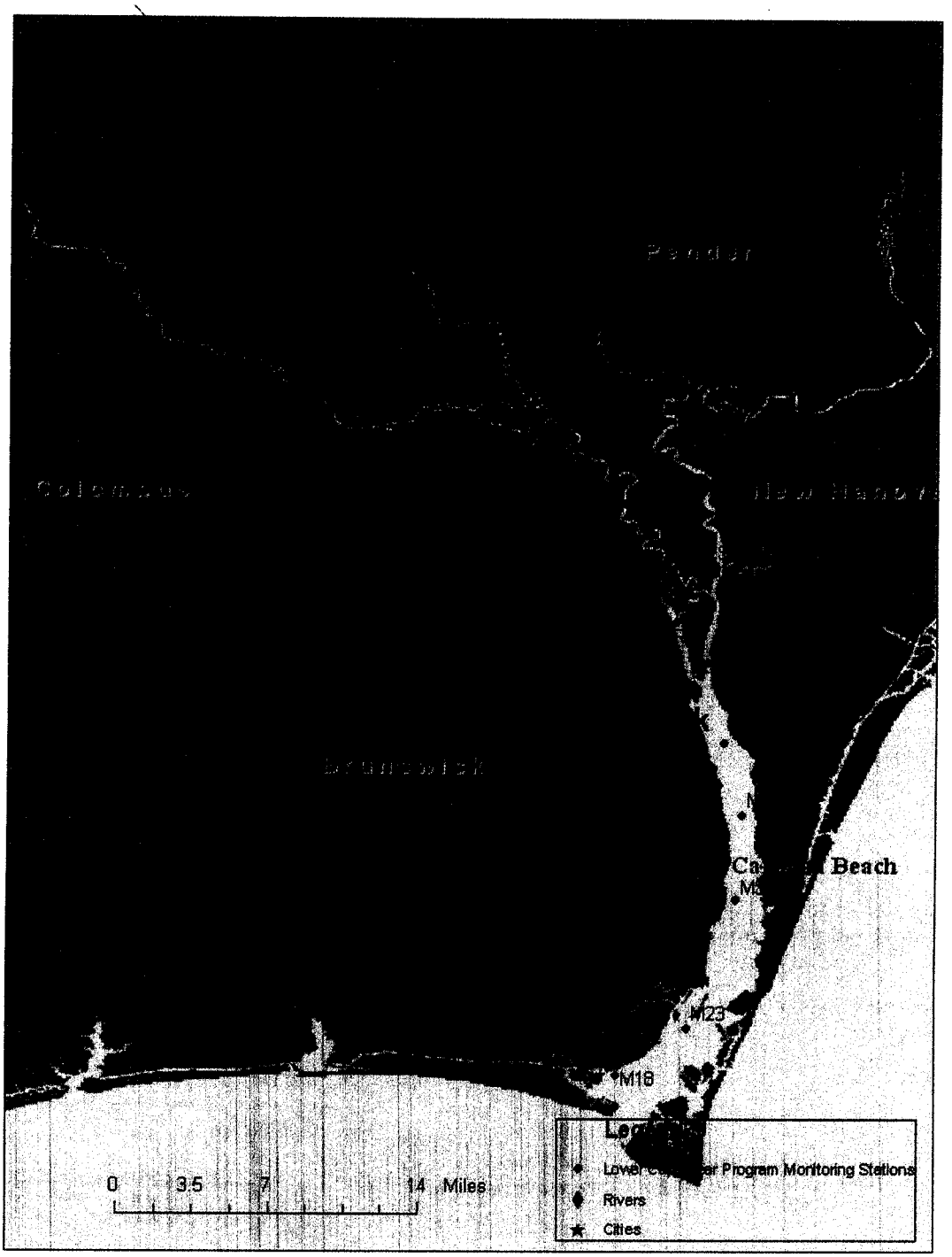


Figure 7. Lower Cape Fear River Monitoring Program Monitoring Stations

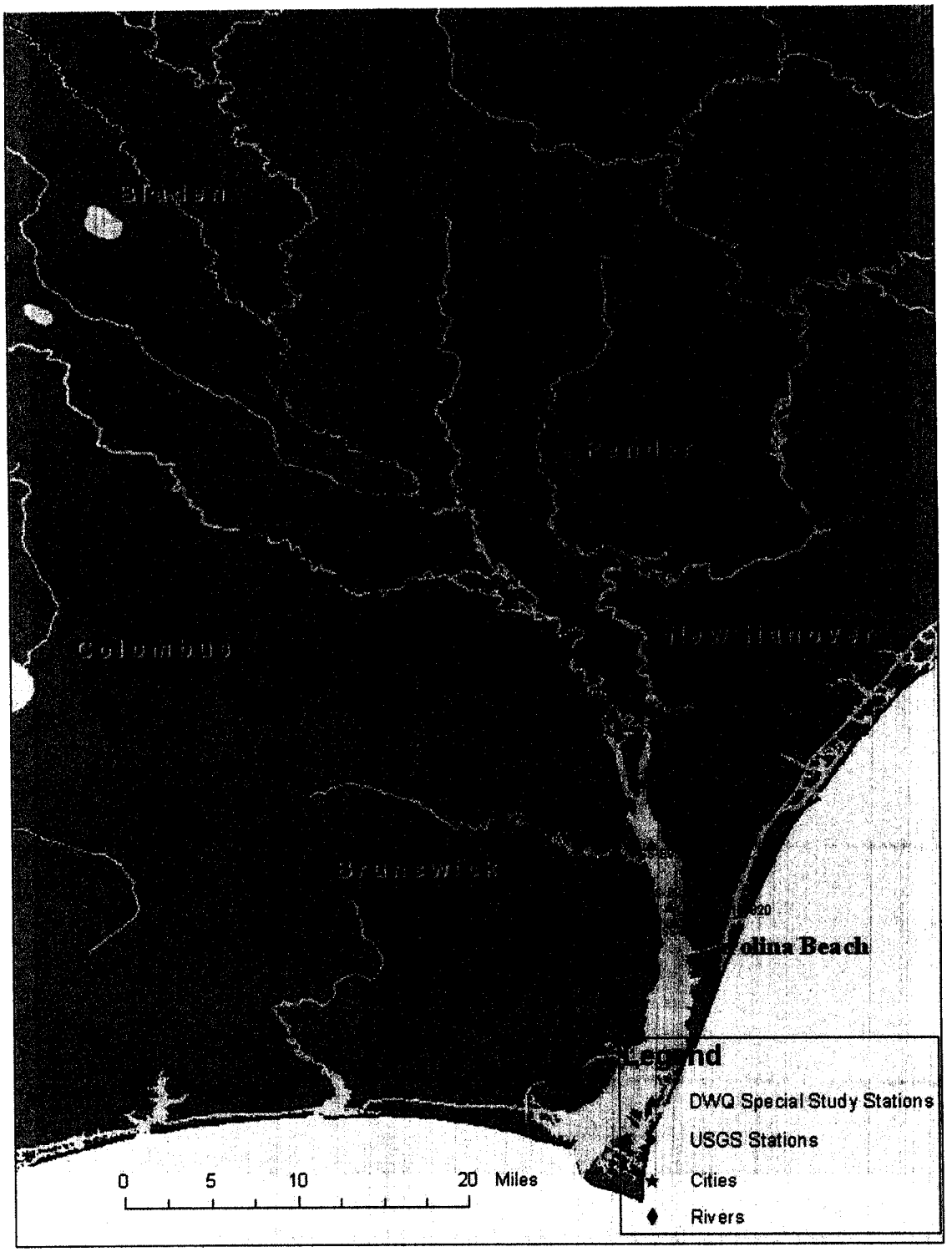


Figure 8. USGS Continuous Monitoring Stations and the Division of Water Quality Special Study Monitoring Stations

A second special study conducted by the NC Division of Water Quality surveyed river cross-sections at 21 stations throughout the estuary (Figure 8). These data were used to specify the width and depth of each channel cell. A third sampling program performed by the NC Division of Water Quality used chambers to measure *in-situ* sediment oxygen demand (SOD). Measurements were taken at five separate locations (Figure 10) on five separate days during the Summer and Fall of 2003.

Several other agencies also provided data necessary to specify model forcings or calibration data. Meteorological data (wind speed and direction, cloud cover, air and dewpoint temperature, short-wave solar radiation) were provided by the National Weather Service (NWS). The data were collected by the NWS at the Wilmington Airport. Water surface elevations at several locations (Southport, Sunset Beach, Wilmington) was provided by the National Oceanographic and Atmospheric Administration (NOAA).

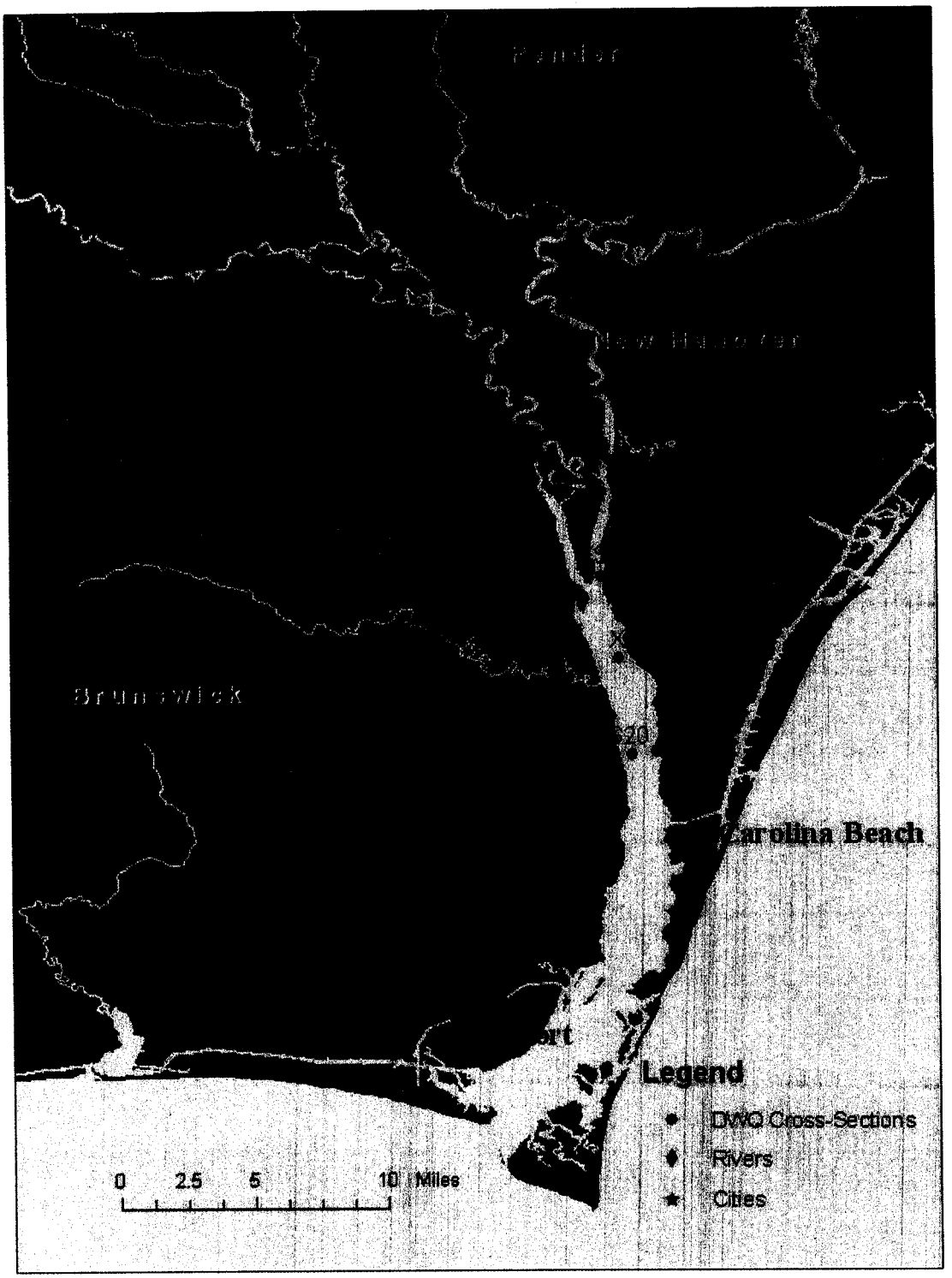


Figure 9. Cross-Sections Surveyed by the Division of Water Quality

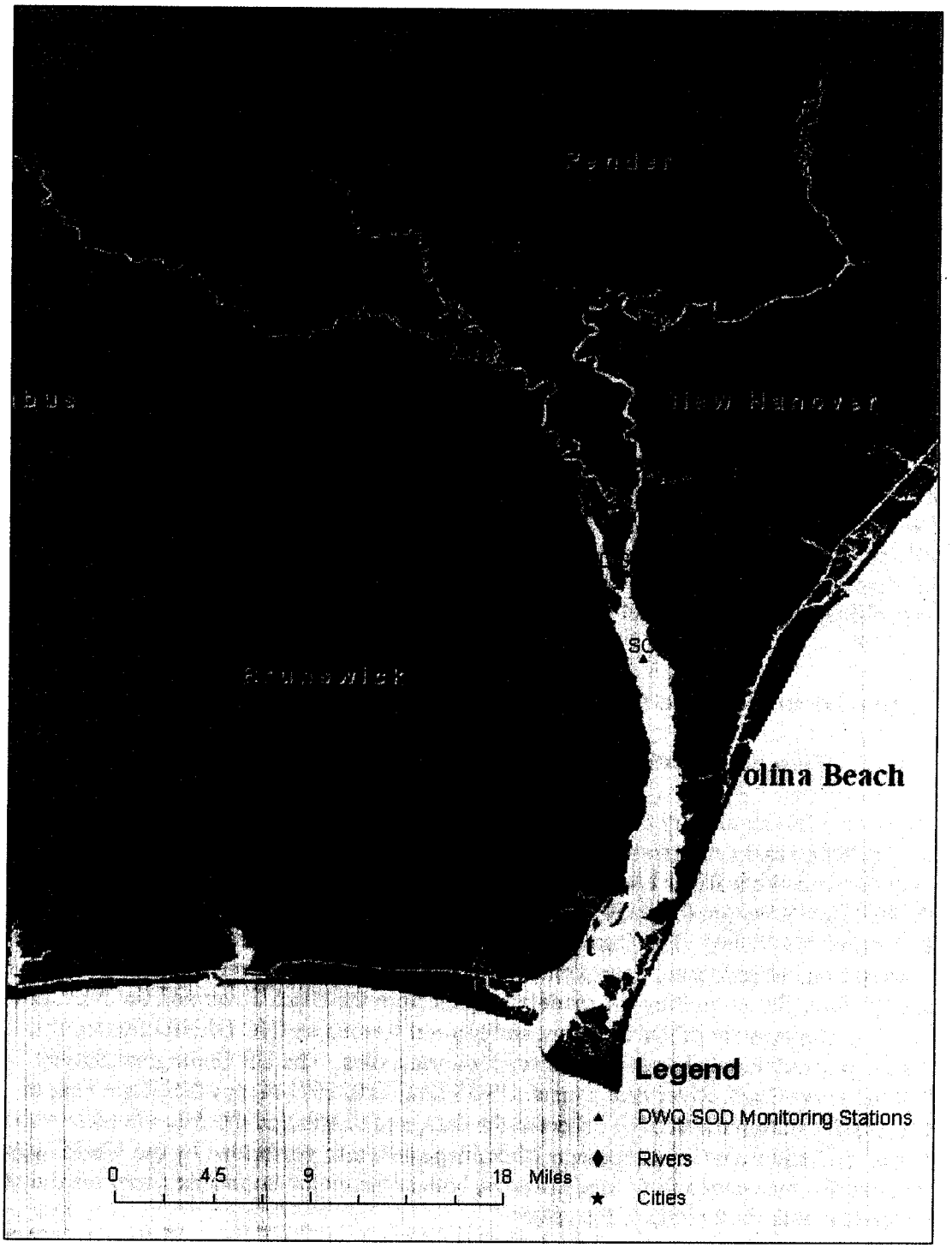


Figure 10. Division of Water Quality SOD Monitoring Stations

3. SPECIFICATION OF MODEL INPUT FILES

Using the complete set of monitoring data described in the previous section, a set of model input data files was created for a time period beginning in November 2003 and ending January 1, 2006. Flow, temperature, and water quality inputs were specified for all of the freshwater that was expected to enter the estuary. These sources included upstream inputs from the rivers (3 sources: Cape Fear, Black, and Northeast Cape Fear Rivers), wastewater loadings entering directly to the estuary (20 sources), and watershed loadings that enter directly into the estuary (14 sources). The overall approach to the specification of input loadings was to consider all loading categories (rivers, tidal creeks, wetlands, wastewater treatment plants), and to quantify these loadings according to the best information available on the particular loading to the estuary. For instance, loadings from tidal creeks downstream of Wilmington and outside of the impaired region were nonetheless estimated based upon available streamflow and/or drainage area data. In addition to this "upstream" source information, water surface elevation and water quality conditions were specified at the model's open boundary near Southport, NC. Specification of all of these model input data sets is described in Sections 3.1, 3.2, and 3.3. In addition to water inputs from point sources, flow boundaries, and elevation boundaries, the estuary's surface waters also exchange mass, momentum, and energy with the sediments below and the atmosphere above. Quantification of this transport requires another set of model input files. Specification of these model inputs is described in Sections 3.4 and 3.5.

3.1 Riverine and Wetland Inputs

3.1.1 Flow Specification

Upstream flow boundary conditions for the Cape Fear, Black, and Northeast Cape Fear Rivers were based upon continuous gauging stations operated by the United States Geological Survey at the Cape Fear River Lock & Dam #1 (USGS Station 02105769), the Black River near Tomahawk (USGS Station 02106500) and the Northeast Cape Fear River near Chinquapin (USGS Station 02108000). The Cape Fear station was located at the model boundary while the other two stations were located approximately 40 km upstream of the model boundary. To better quantify the river flows entering the modeled region from the Black River and the NE Cape Fear River the NC Department of Environment and Natural Resources (NC DENR) funded the creation of two additional shorter-term flow monitoring sites. The US Geological Survey installed the sites (Black River near Currie, USGS Station 02107544, and NE Cape Fear at Burgaw, USGS Station 02108566) collected the data, and distributed the data via their web site. These data, and additional measurements of drainage area also performed by the USGS were used to establish the needed flow time histories, both at the model boundaries, and for the creeks and wetlands that drain directly to the estuary.

With the extra data collected by the USGS, data from the two sites on the Black River and the two sites on the NE Cape Fear River were pooled to create a continuous time history at the appropriate model boundary. To model the full three-year time period modeled (November

2003 – January 2006) it was necessary to use data from both the upstream and downstream sites for each river to construct the complete flow time history at the model boundary. By examining time periods when flow data were available at both sites (e.g. Black at Tomahawk and Currie), a time lag was established for the more upstream of the two stations. This lag represented the typical travel time of flood waves from the upper to the lower station. The flows from the upstream station after lagging were then scaled according to the drainage area ratios of the two sites. This lagged and scaled upstream site data site was then combined with the downstream site to create the full time history at each of the three upstream model boundaries.

The three flow time histories data were also used to quantify the flow draining directly to the estuary from creeks and riparian wetlands. These flow estimates utilized drainage area measurements of each of the USGS monitoring sites (Table 3). Using these data, the total watershed area of the Cape Fear River was apportioned into seven groupings; three upstream rivers and four areas draining directly to the estuary (Table 4). For each of these groupings one of the flow time histories was used with a scaling constant based upon the corresponding drainage areas. For the four areas draining directly to the estuary, the closest of the three model boundary time histories was used to quantify the flow. The area draining directly to the estuary was further subdivided into a total of fourteen point sources (Figure 11), with the contribution of each source determined according to the particular drainage area of that subwatershed (Table 5).

Table 3. USGS Monitoring Station Data

Location	**USGS Station Number**	**Drainage Area (mi^2)**	**Latitude (deg, min, sec)**	**Longitude (deg, min, sec)**
Cape Fear R at Lock #1 near Kelly	02105769	5255	34, 24, 15	78, 17, 38
Black River Near Tomahawk	02106500	676	34, 45, 17	78, 17, 21
NE Cape Fear near Chinquapin	02108000	599	34, 49, 40	77, 50, 0
Hood Creek near Leland	02105900	21.6	34, 16, 43	78, 7, 34
Black River near Currie	02107544	1405	34, 24, 54	78, 08, 37
Cape Fear at Navassa	02107576	7060	34, 15, 36	77, 59, 15
NE Cape Fear near Burgaw	02108566	920	34, 35, 54	77, 52, 31
NE Cape Fear near Wilmington	02108690	1669	34, 15, 32	77, 56, 54
Cape Fear at Marker 12	02108820	9,000	34, 04, 35	77, 55, 53

Table 4. Subdivision of the Cape Fear River Watershed

Area No.	Watershed	Drainage Area (mi^2)	Flow Time History Used
1	Cape Fear River at Model Boundary	5,255	CF @ L&D 1
2	Black River at Model Boundary	1,405	Black at Currie
3	NE Cape Fear at Model Boundary	920	NE CF @ Burgaw
4	Estuary draining to Cape Fear above NE Cape Fear (upper estuary)	270	NE CF @ Burgaw
5	Estuary draining to Cape Fear below NE Cape Fear (lower estuary)	250	NE CF @ Burgaw
6	Estuary draining to Black River	120	Black @ Currie
7	Estuary draining to NE Cape Fear River	749	NE CF @ Burgaw
	Total	8,979	

Table 5. Subwatersheds Draining Directly to the Estuary

Point Source Number	Estuary Watershed Name	Drainage Area (mi^2)
21	NE Cape Fear, estuary 1	31
22	NE Cape Fear, estuary 2	6
23	NE Cape Fear, estuary 3	319
24	NE Cape Fear, estuary 4	101
25	NE Cape Fear, estuary 5	194
26	NE Cape Fear, estuary 6	109
	Total	**760**
27	Black River, estuary 1	91
28	Black River, estuary 2	30
	Total	**121**
29	Cape Fear, upper estuary 1	156
30	Cape Fear, upper estuary 2	31
31	Cape Fear, upper estuary 3	78
	Total	**265**
32	Cape Fear, lower estuary 1	61
33	Cape Fear, lower estuary 2	164
34	Cape Fear, lower estuary 3	22
	Total	**247**

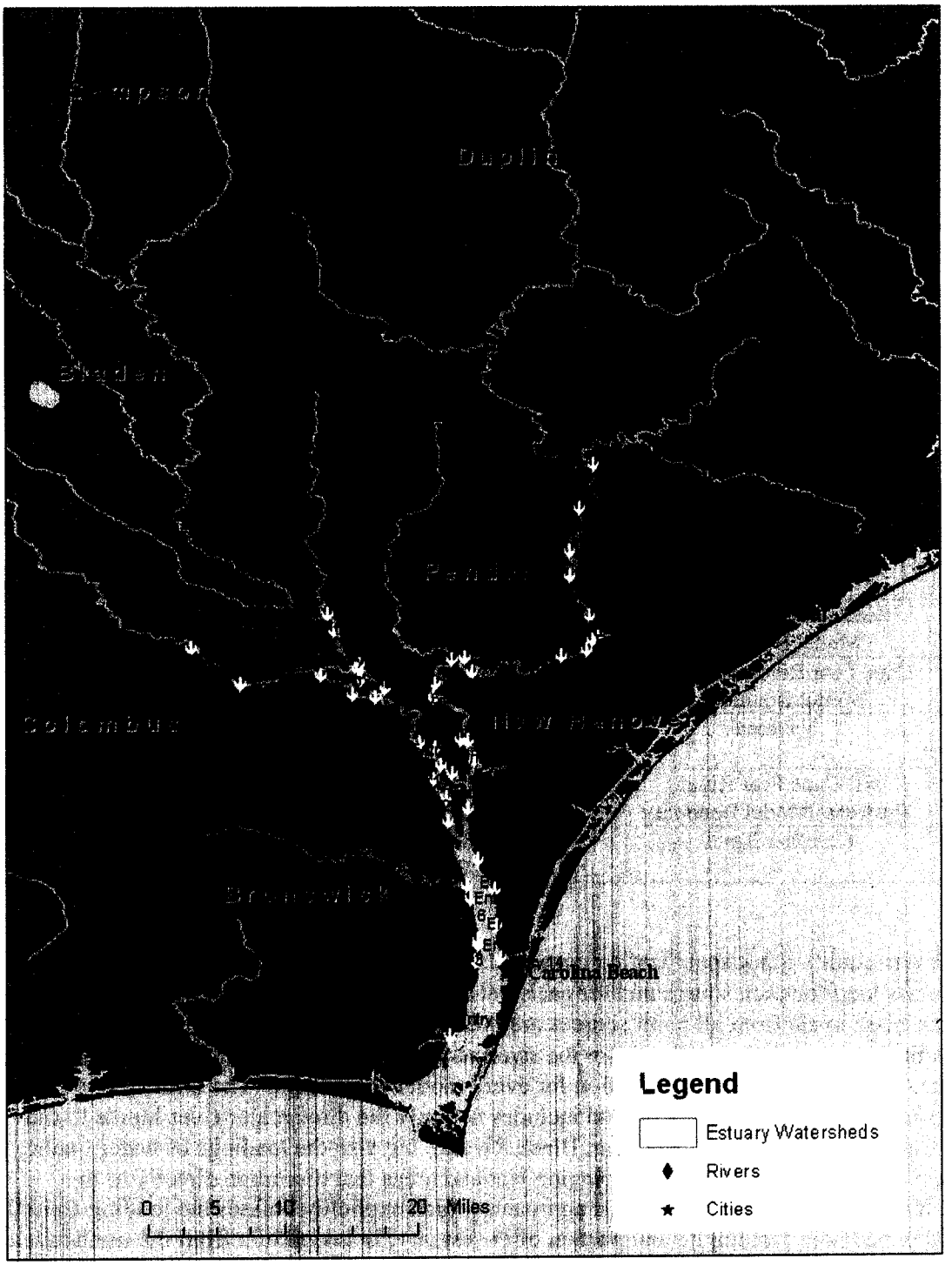


Figure 11. Watersheds Draining Directly into the Cape Fear River Estuary

3.1.2 Temperature and Concentration Specification

Specification of temperature and water quality inputs for the riverine sources utilized the monitoring programs described in the previous section. Temperature time histories were available at the Lower Cape Fear Monitoring Program sites on a monthly basis, and from the USGS continuous monitoring sites on a 15-minute basis. A total of five different monitoring locations were used to specify the temperature time histories. When available, roughly from November 2003 to November 2004, the USGS continuous monitoring data were used. After examining the temporal variability present in the 15-minute data, it was decided that daily time averaging would be sufficient for purposes of defining the temporal variation in the data. Since the model period (November 2003 – January 2006) extended beyond the period when the continuous monitoring data were available, each temperature time history also utilized data from the Lower Cape Fear River Program. All freshwater sources thus utilized two separate sources to specify temperatures and water quality concentrations (Table 6).

Table 6. Temperature Time History Specification

Time Series No.	Location	Time Period Using USGS Data and Station Number	Lower Cape Fear River Program Station Used	Point Source Numbers Using This Location
1	Black River, Upstream Model Boundary	9/8/03 – 12/3/04, 02107544	B210	19, 27-28
2	Cape Fear River, Upstream Model Boundary,	9/8/03 – 12/3/04, 02105769	NC11	6, 18
3	Navassa	9/10/03-11/24/04, 02107576	Nav	1-5, 9, 10, 13-17, 35-37
4	NE Cape Fear River, Upstream Model Boundary	9/10/03-12/2/04, 02108566	NCF117	20, 21-26, 29-34
5	Carolina Beach	11/7/03-12/2/04, 02108820	M18	7, 8, 11, 12

Water quality input specification consisted of quantifying both the flow and the time varying mass load for each source and for each water quality model constituent (Table 1). In EFDC, the mass loads from all point sources are quantified in the WQPSL.INP file. This one file gives the time varying mass loads for the riverine sources described in this section, and the point sources described in the next section for every model constituent. The term riverine sources is used rather generally here, and includes not only the three major river inputs to the estuary (Cape Fear, Northeast Cape Fear, Black Rivers), but also the loadings of water quality constituents from the tidal creeks and fringing wetland areas that discharge directly to the estuary. It should be noted here that this approach, which explicitly defines the loading from the entire watershed area draining to any portion of the estuary, is a departure from the method used in the previous modeling study of the Lower Cape Fear River estuary (Tetra Tech 2001), where the wetlands and tidal creeks did not contribute water or water quality constituents to the estuary.

For each scenario, multiple model runs were used to quantify the water quality impact of a particular change in the system (e.g. deepening the navigation channel, reducing wastewater treatment plant discharges, reducing nonpoint source loadings). Many of these scenario runs required changing the WQPSL.INP file, thus it was necessary to create many different versions (approximately 20) of this file. To simply specification of this file, an automated file generation system was created. This system used a set of Excel spreadsheets, one for each source or flow boundary, to quantify the source data time histories and the conversion of these data to mass loads for each constituent. The mass load time histories taken from each spreadsheet were then combined and reformatted to that required by EFDC using a Matlab script (make_wqpsl_capefear.m). The overall procedure for creating the WQPSL.INP is shown in Figure 12.

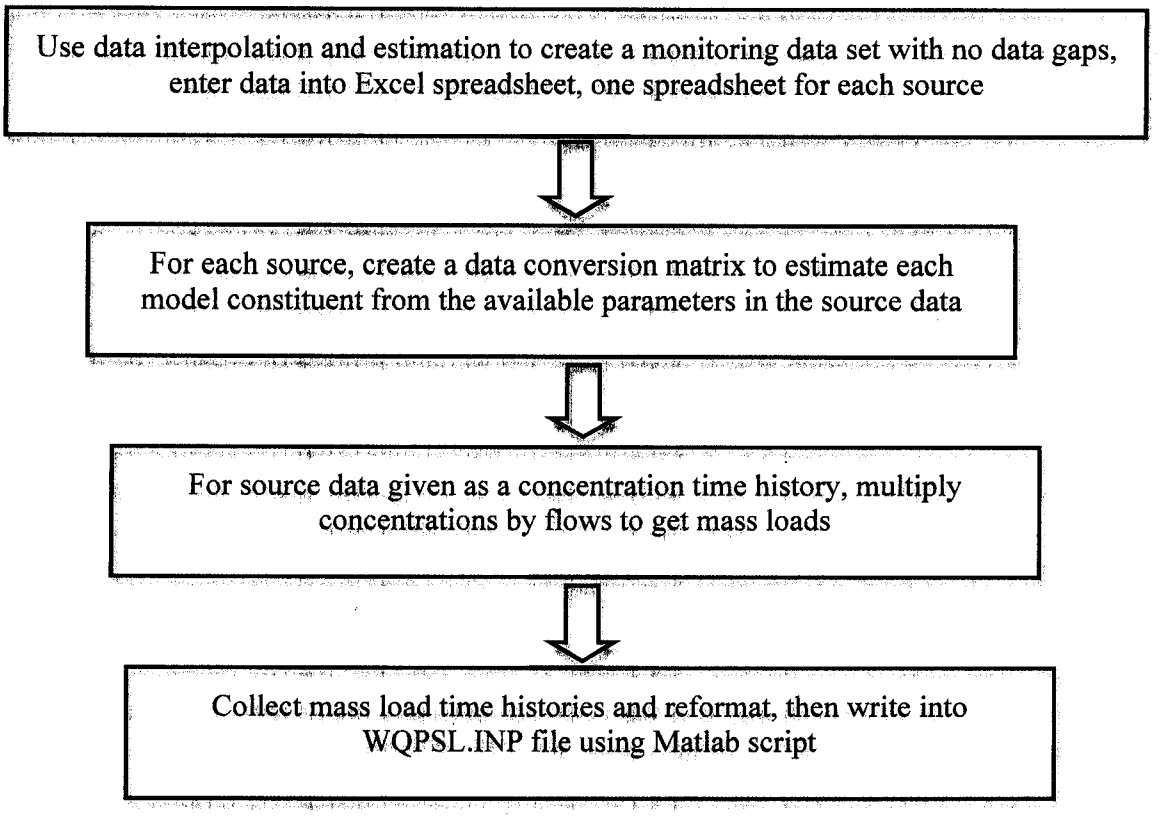


Figure 12. Procedure for creating water quality mass load file, WQPSL.INP

For the riverine and watershed sources, the mass load time history for each of the 21 model constituents was estimated from a data set that combined information from the Lower Cape Fear River Monitoring Program, the DWQ ambient monitoring program, and the USGS continuous monitoring data. The stations used were the same ones as those used for

specification of the temperature time histories (Table 6). These data were used with data interpolation to create a daily concentration time history of the following eight water quality parameters:

1. dissolved oxygen (mg/L),
2. chlorophyll-a (μg/L),
3. ammonia nitrogen (mg/L as N),
4. total nitrogen (mg/L as N),
5. nitrate+nitrite nitrogen (mg/L as N),
6. total phosphorus (mg/L as P),
7. 5-day BOD (mg/L),
8. 20-day BOD (mg/L)

Daily flows at the model boundaries were also available from the USGS data set, as described in section 3.1. Together the flow and water quality information was used to create a daily load (g/s) for seven parameters (5-day and 20-day BOD were used together to estimate ultimate BOD loading). These data served as the basis for estimating the twenty-one model constituents in the EFDC water quality model.

An important consideration in specifying the time history of water quality constituent loading was to accurately quantify the quantity and degradation rate of the various sources of organic matter to the estuary. For instance, the degradation rate of detrital algal matter could be significantly different than that of wastewater discharges, which in itself could be significantly different than the degradation rate of the riverine and wetland sources of organic matter. To provide additional flexibility in specifying organic matter inputs from different categories of sources, two different dissolved organic carbon state variables were used. To avoid changing the EFDC code to accomplish this, the refractory particulate organic matter state variables (RPOC, RPON, RPOP) were used to model refractory dissolved organic matter (RDOC, RDON, RDOP) by specifying a settling velocity of 0.0 m/d. A second set of organic matter state variables (DOC, DON, DOP) was used to model the labile dissolved organic matter fraction. Different organic matter sources were modeled by using different fractions of the two dissolved organic matter state variables.

With these considerations, the following assumptions were used to estimate the loading time histories for all 21 state variables present in the EFDC model:

- the following 8 constituents were assumed to have zero loading (labile particulate carbon, nitrogen and phosphorus, particulate biogenic silica, available silica, chemical oxygen demand, total active metal, fecal coliform bacteria),
- the carbon to chlorophyll ratio in phytoplankton was assumed to be 60:1 (mg C/mg chl),
- the phytoplankton biomass was assumed to be equally divided among the three algal constituents (diatoms, greens, blue-greens),
- the total organic nitrogen (TON) was calculated as: TON = total nitrogen – ammonia nitrogen – nitrate+nitrite nitrogen,
- total organic carbon in the EFDC model was estimated from ultimate BOD using the stoichiometric ratio for carbon oxidation (12 g carbon oxidized requires 32 g of oxygen).

From this total was subtracted the carbon associated with phytoplankton biomass, using measured chlorophyll-a concentrations and the assumed carbon:chlorophyll-a ratio.

- the Redfield ratio, 106:16:1 C:N:P molar ratios (Redfield 1934) was used to convert between dissolved organic phosphorus, nitrogen, and carbon,
- ammonia, nitrate, and dissolved oxygen loadings were estimated directly from the monitoring data,
- two separate dissolved organic matter pools (labile and refractory) were used to model various sources of organic matter (labile organic matter is shown as DOC, DON, and DOP in Figure 2), and
- the refractory **dissolved** carbon, nitrogen, and phosphorus constituents were included in the model by using corresponding refractory **particulate** (RPOC, RPON, and RPOP in Figure 2) constituents with an assumed zero settling velocity.

Using these assumptions it was possible to create a 7 x 21 parameter matrix that was used to create twenty-one loading time histories, one for each constituent, from the seven available water quality time histories. Matrix multiplication using the parameter matrix also converted each load to the proper units (kilograms per day). Matrix multiplication within Excel was used to do the conversions in an automated fashion once the monitoring time histories were created.

Different parameter matrices were used for the Cape Fear, Black, and Northeast Cape Fear, as the split between labile (first order decay rate = 0.15 day^{-1}) and refractory (first order decay rate = 0.03 day^{-1}) organic matter was different for these three water bodies. The split between labile and refractory organic carbon was determined from the average BOD20/BOD5 ratio, after correcting for the impact of nitrogenous BOD. A corrected and time-averaged BOD20/BOD5 ratio for each river was used to calculate a corresponding organic matter decay rate and the labile refractory split (Table 7). For instance, the Cape Fear River refractory/labile split was 64.5%/34.5% based on the BOD5 and BOD20 measurements. For the Cape Fear River, this gave the parameter matrix shown in Table 8.

Table 7. Organic Matter Degradation Parameters for Each Riverine Source

River	BOD20/BOD5 ratio	First Order Decay Rate (day^{-1})	Refractory/Labile Split for Organic Matter
Cape Fear	2.58	0.68	0.645/0.355
Black	2.70	0.60	0.690/0.310
Northeast Cape Fear	3.15	0.34	0.786/0.214

3.2 Point Source Inputs

A similar procedure as that described in the previous section was used to define the loading time histories from the point sources that discharge directly to estuary. After reviewing discharge records provided by the NC Division of Water Quality, it was decided that a total of

twenty point sources discharged sufficient organic matter and/or nutrients to justify including them in the model of the Lower Cape Fear River Estuary. These point sources were distributed throughout the estuary both upstream and downstream of Wilmington (Figure 13). As the owner of several of these facilities has changed over the years, the twenty sources were uniquely identified using their DWQ permit number (Table 9). The following sections describe the method for estimating the flow, temperature, and water quality load time histories for these point sources.

3.2.1 Flow Specification

Specification of the flows for the twenty wastewater point sources was taken from the discharge monitoring reports, which were provided by NC Division of Water Quality. Flows were generally provided on a monthly basis in million gallons per day. The only changes made to these flows were to convert them from this unit to that used by the model (m^3/s). Unlike the riverine sources, the wastewater data were not interpolated to a daily time step, but instead were left as monthly data.

3.2.2 Temperature and Concentration Specification

Temperature time histories were not available in the discharge monitoring reports but were required by the model. These time histories were estimated in the same way as the riverine sources. The five data sources available for the riverine inputs (Table 6) were used for the twenty wastewater sources. For each of these, the closest monitoring location was used to represent the temperature of the water for that source.

The EFDC model also requires a water quality load time history for each of the wastewater sources. This information is provided to the model along with the riverine sources in the WQPSL.INP file. The data format needed by the EFDC model for these two types of sources is identical. Because the data needs and input data were so similar, it was decided to create this information using basically the same procedure as that for the riverine sources (Figure 11).

Table 8. Parameter Matrix for Creating Cape Fear Point Source Loading Time History

Multiply by Flow to get Daily Load?	no	no	no	no	no	no	no	no	no	no	no
	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON
DO loading (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chl-a loading (g/s)	1728.00	1728.00	1728.00	-3576.96	0.00	-1607.04	-89.42	0.00	-40.18	0	-643.85
Ammonia loading as N (g/s)	0.00	0.00	0.00	0.00	0.00	0	-8.28	0.00	-3.72	12.00	-59.62
TKN loading as N (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	8.28	0.00	3.72	-12.00	59.62
NOX loading as N (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0.00
TP loading as P (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	86.40	0.00
BODU loading (g/s)	0.00	0.00	0.00	22.33	0.00	10.03	0.00	0.00	0.00	0.00	0.00

Multiply by Flow to get Daily Load?	no	no	no	no	no	no	no	no	no	no
	LPON	DON	NH4	NO3	SU	SA	COB	DO	TAM	FCB
DO loading (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	86.40	0.00	0.00
Chl-a loading (g/s)	0.00	-289.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ammonia loading as N (g/s)	0.00	-26.78	86.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TKN loading as N (g/s)	0.00	26.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOX loading as N (g/s)	0.00	0.00	0.00	86.40	0.00	0.00	0.00	0.00	0.00	0.00
TP loading as P (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BODU loading (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

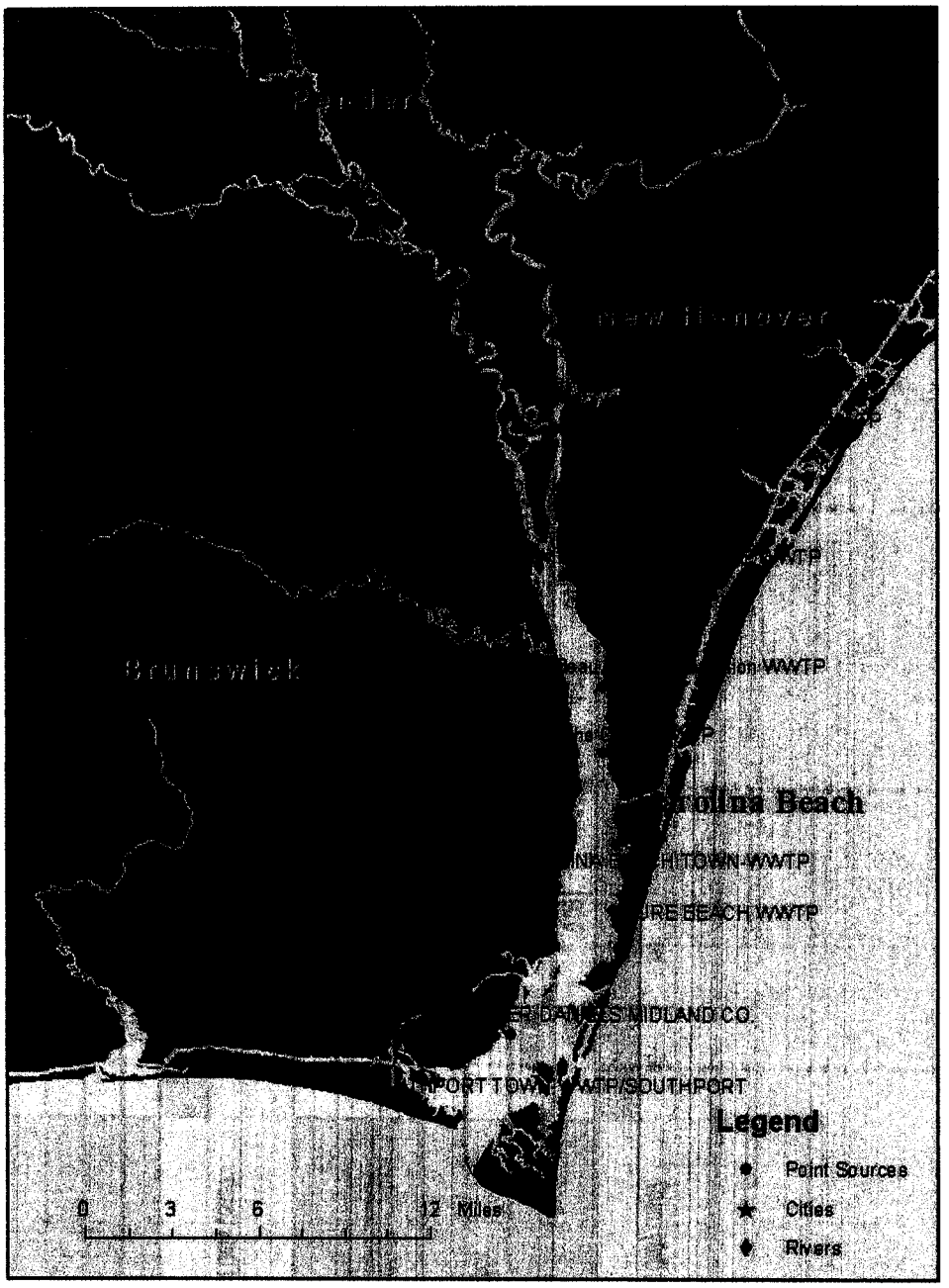


Figure 13. Wastewater Treatment Plant Source Locations

Table 9. Description of Point Sources

Source No.	NPDES Permit No.	Name of Source	Category
1	NC0000663	Dupont-Wilmington/Brunswick	WWTP
2	NC0000663	Dupont-Wilmington/Brunswick	WWTP
3	NC0000663	Dupont-Wilmington/Brunswick	WWTP
4	NC0001112	Arteva Specialties-Wilmington	WWTP
5	NC0001112	Arteva Specialties-Wilmington	WWTP
6	NC0003298	International Paper	WWTP
7	NC0021334	Southport, Town-WWTP/Southport	WWTP
8	NC0023256	Carolina Beach, Town-WWTP	WWTP
9	NC0023965	Wilmington-Northside WWTP	WWTP
10	NC0023973	Wilmington-Southside WWTP	WWTP
11	NC0025763	Kure Beach WWTP, Town Of	WWTP
12	NC0027065	Archer Daniels Midland Co.	WWTP
13	NC0059234	Takeda Chemical Products USA	WWTP
14	NC0059234	Takeda Chemical Products USA #2	WWTP
15	NC0065676	Leland Industrial Park WWTP	WWTP
16	NC0075540	Belville, Town – WWTP	WWTP
17	NC0082295	Fortron Industries	WWTP
18	NA	Cape Fear River	Upstream River
19	NA	Black River	Upstream River
20	NA	NE Cape Fear River	Upstream River
21	NA	NE Cape Fear, estuary 1	Estuarine
22	NA	NE Cape Fear, estuary 2	Estuarine
23	NA	NE Cape Fear, estuary 3	Estuarine
24	NA	NE Cape Fear, estuary 4	Estuarine
25	NA	NE Cape Fear, estuary 5	Estuarine
26	NA	NE Cape Fear, estuary 6	Estuarine
27	NA	Black River, estuary 1	Estuarine
28	NA	Black River, estuary 2	Estuarine
29	NA	Cape Fear, upper estuary 1	Estuarine
30	NA	Cape Fear, upper estuary 2	Estuarine
31	NA	Cape Fear, upper estuary 3	Estuarine
32	NA	Cape Fear, lower estuary 1	Estuarine
33	NA	Cape Fear, lower estuary 2	Estuarine
34	NA	Cape Fear, lower estuary 3	Estuarine
35	NC0086819	Brunswick Co. WWTP	WWTP
36	NC0001228	GE – Wilmington	WWTP
37	NC0003875	Occidental Chemical	WWTP

The only differences in the procedure used to create the loading time histories for the wastewater sources resulted from there being a slightly different set of water quality parameters in the discharge monitoring reports. Twenty-day BOD measurements were not available, but for three of the major sources (International Paper, Wilmington Southside WWTP, Wilmington Northside WWTP) there was a long-term BOD study undertaken. In addition, unlike the riverine water quality data set, some of the reported wastewater data were given as flow-weighted concentrations, whereas others were given as a load. For this reason, the conversion parameter matrix used to create the water quality load time histories varied from location to location, and the load calculations were done only when water quality concentrations were given. A complete set of the conversion parameter matrices is available in Appendix A along with the information showing which parameters for which sources required load calculation using the flow record.

Three of the twenty wastewater sources undertook additional monitoring to quantify the degradation rate of their organic matter. Two long-term BOD studies were done on the International Paper wastewater discharge. In addition, long-term BOD measurements were undertaken for the Wilmington Northside and Wilmington Southside municipal wastewater discharges. In all of these studies BOD was measured over approximately 100 days, while additional monitoring was done to measure changes in nitrogen compounds that might result if the waste contained an appreciable nitrogenous biochemical oxygen demand (NBOD).

These long-term BOD data were analyzed by separating the total BOD into carbonaceous and nitrogenous biochemical oxygen demands (CBOD and NBOD). The NBOD exerted was estimated by assuming that each mg/L reduction in total Kjeldahl nitrogen in the waste would result in an oxygen demand of 4.57 mg/L. The carbonaceous BOD was estimated as the total BOD exerted minus the NBOD exerted. The NBOD and CBOD were plotted as a function of time, and the following equation was used to fit a line to the CBOD vs. time data:

$$CBOD(t) = rBOD_u(1 - e^{-k_{dr}t}) + rBOD_u \frac{k_{dr}}{k_{dr} - k_{dl}}(e^{-k_{dl}t} - e^{-k_{dr}t}) + lBOD_u(1 - e^{-k_{dl}t}) \qquad (1)$$

where CBOD(t) is the carbonaceous BOD exerted at time t, $rBOD_u$ and lBODu are the ultimate BODs of the refractory and labile fractions of organic carbon, and k_{dl} and k_{dr} are the first-order decay rates of the refractory and labile organic carbon fractions. This equation assumes that the carbonaceous BOD exertion occurs as a two-step process where refractory CBOD is first degraded to labile CBOD, which then degrades while exerting an oxygen demand. This model is consistent with the organic carbon fate processes modeled in EFDC (see DOC and RPOC constituents, Figure 2).

For the International Paper waste, the two long-term BOD showed similar results. For the test done with wastewater collected on July 20, 2003 (Figure 14), the NBOD component was approximately 20%, and the CBODu was approximately 90 mg/L. In the wastewater collected on July 27, 2003 (Figure 15), the NBOD was similar to the earlier measurement, but the $CBOD_u$ was lower, at about 60 mg/L.

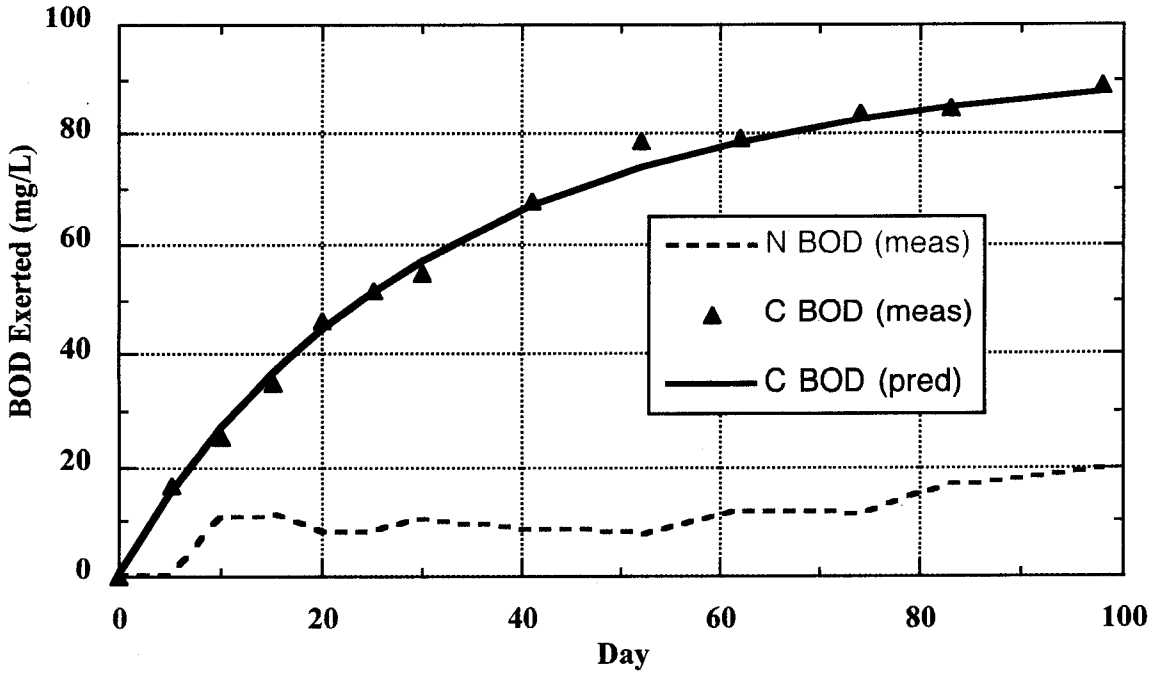


Figure 14. Long-term BOD Measurement, International Paper, July 20, 2003.

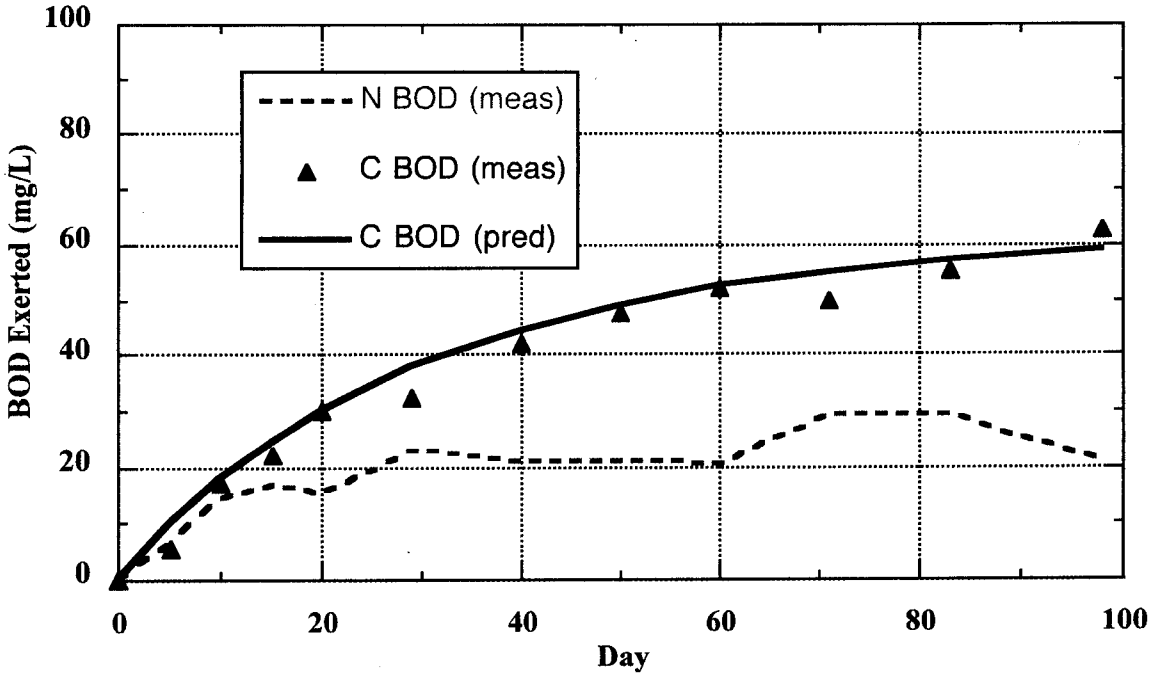


Figure 15. Long-term BOD Measurement, International Paper, July 27, 2003.

In both tests of the International Paper long-term BOD, the predicted CBOD time history matched the observed data quite well (Figure 13 and 14). From these tests, the fraction of organic carbon to be refractory was found to be approximately 75%, when using decay rates of labile and refractory organic carbon of 0.15 day^{-1} and 0.03 day^{-1} respectively (Table 10).

Table 10. Degradation Rates and Fractionation of International Paper and Wilmington Municipal Wastewaters

Location and Test	Labile First Order Decay Rate (day^{-1})	Refractory First Order Decay Rate (day^{-1})	Labile Ultimate BOD (mg/L)	Refractory Ultimate BOD (mg/L)	Fraction of Total Organic Carbon that is Refractory
IP, July 20, 2003	0.15	0.03	23	69	75%
IP, July 27, 2003	0.15	0.03	15.5	46.5	75%
Wilmington Northside	0.15	0.03	16.1	6.9	30%
Wilmington Southside	0.15	0.03	0.7	0.3	30%

The results of the long-term BOD measurements of the two Wilmington wastewater discharges looked significantly different from one another, and also different from the long-term BOD measurement of the International Paper wastewater. The test using the sample from Wilmington Northside WWTP discharge (Figure 16) had significantly more NBOD than CBOD. The NBOD exerted was approximately 30 mg/L after 100 days, but the CBOD at this time was less than 5 mg/L (Figure 16).

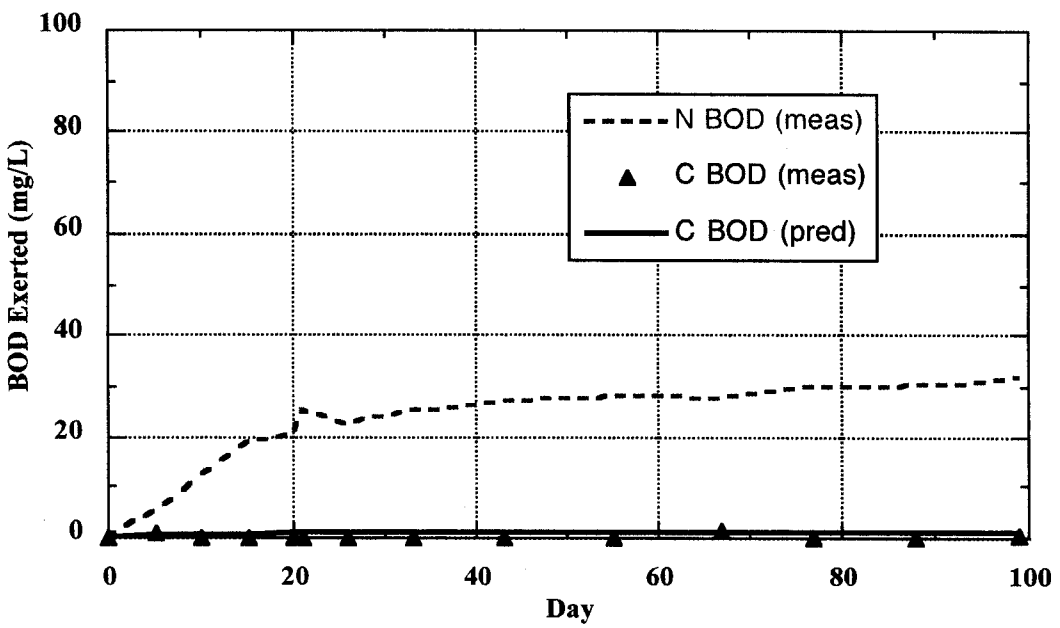


Figure 16. Long-term BOD Measurement, Wilmington Northside WWTP.

The test using a sample from the Wilmington Southside WWTP also had a significantly higher NBOD than CBOD (Figure 17), but both of these values were significantly higher than that seen for the Northside wastewater. The long-term test of the Southside WWTP sample showed an NBOD of nearly 100 mg/L, which was exerted within approximately ten days (Figure 17). The CBOD was lower, and took longer to be fully exerted. For both of these measurements, however, it was possible to model the CBOD exerted curve using the model equation (Eq. 1). Using these long-term BOD measurements, the organic matter in each of these wastewaters was fractionated into labile and refractory components (Table 10), with 30% of the Wilmington Northside and Southside wastewater assumed to be in the refractory component.

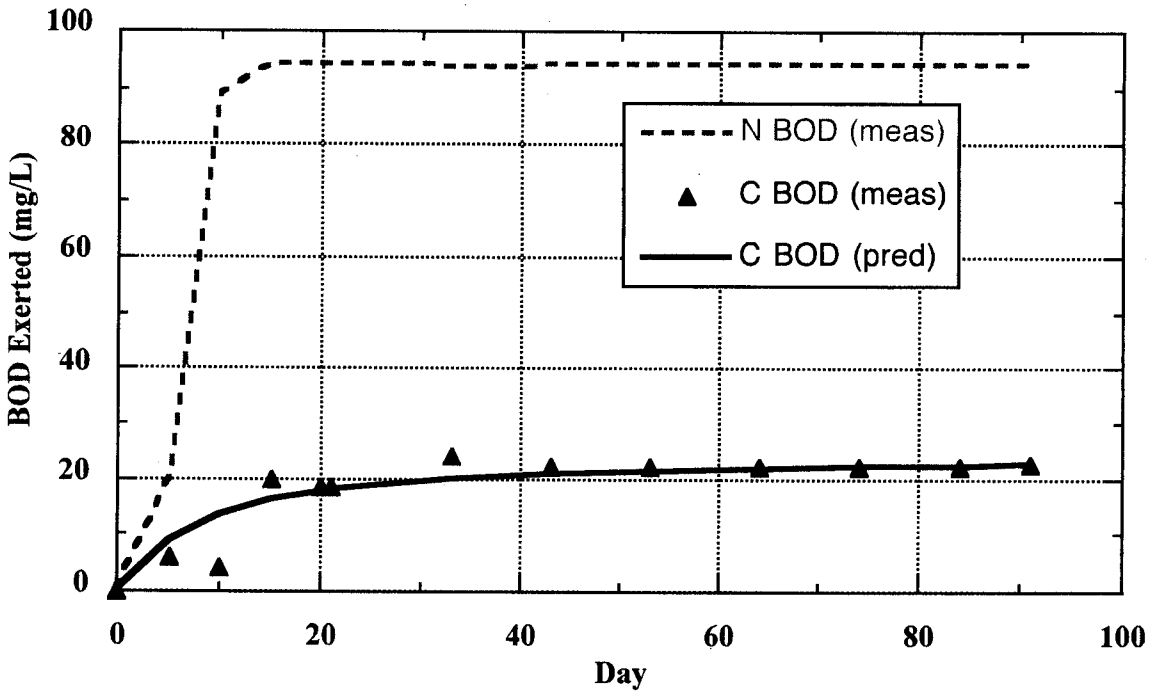


Figure 17. Long-term BOD Measurement, Wilmington Southside WWTP

3.3 Downstream Boundary Inputs

The southern boundary of the model grid, at the mouth of the Lower Cape Fear River near Southport, was specified as an elevation boundary (Figure 3). At this boundary there exist four cells (I=30:33, J=5). For these cells, information specifying the water surface elevations, salinity and temperatures, and water quality concentrations were specified for the complete time period that was modeled (November 2003 – January 2006). The following sections describe how each of these boundary conditions was specified in the model.

3.3.1 Water Surface Elevation Specification

The downstream elevation boundary condition was specified as the sum of elevation variations due to tidal motions, which were specified with tidal harmonic data, and an elevation time history that was used to represent elevation variations due to weather events. For the tidal harmonic data, a radiation separation boundary condition was used that allows for the outgoing radiation of waves generated within the model region (Bennett, 1976; Blumberg & Kantha, 1985). The tidal harmonics were determined from 6-min water surface elevation data from the NOAA station at Southport, North Carolina (Station No. 8659084) that were collected from August 1 – December 31, 2006. The data were downloaded from the NOAA's tides and current web site (tidesandcurrents.noaa.gov). The 6-min water surface elevation data were decomposed into tidal harmonic constituents using the FORTRAN program lsqhs.f that was provided with EFDC. The program produced a harmonic description of the elevation data that was dominated by the semi-diurnal (M_2, S_2, N_2) and diurnal (O_1) components (Table 11).

Table 11. Tidal Harmonic Constituent Data Used to Specify Open Boundary Elevation

Tidal Component	Period (sec)	Amplitude (m)	Phase (sec)
M2	44714	0.6431	-11019
S2	43200	0.0994	-14422
N2	45570	0.1328	-18722
O1	92950	0.0776	-43968
M4	22357	0.0023	6837.7
M6	14905	0.0045	6704.8
K2	43082	0.0296	5368.2

It was expected that a significant amount of flushing of the system might occur during periods when the water surface elevations in the estuary would either rise or fall due to episodic events such as hurricanes and other major weather events. While the effects of flooding rains would be captured with the flow data, it was believed that the effects of storm surges on the open boundary elevation would not be represented either by the flow time history or by the tidal harmonic forcing. For this reason the open boundary elevation specification also included low-pass filtered elevation data. For this specification it was necessary to have a data set near the model's open boundary at Southport during the time period to be modeled (2003-2005). While a NOAA operated tide gauge was available at Wilmington (Station No. 8658120), it was decided that these data were better used as calibration data since the station is located well within the estuary. In addition, it was felt that using Wilmington for specification of tidal amplitudes might bias the specification of wetland areas within the estuary, which was done iteratively in such a way so as to match the observed attenuation of the tidal elevation signal. Instead, elevation data at Sunset Beach (Station No. 86599897), which is on the Atlantic coast near Southport, were used to for this purpose. Hourly data from January 2003 to December 2006 were taken from the NOAA web site. The hourly data were low-pass filtered using a Butterworth filter (Roberts and Roberts 1978) having a 50-hour cutoff time period. The cutoff time period was selected to retain the majority of the elevation variations occurring over a time scale consistent with the passage of

storm events. It was found that a 50-hour cutoff time period filtered out the tidal elevations sufficiently well while allowing longer period elevation variations to remain in the filtered data.

3.3.2 Temperature and Concentration Specification

The temperature boundary condition at the southern open boundary was specified in a fashion nearly identical to that of the river boundaries described earlier. A complete time history for the model time period was developed using a combination of sources including the Lower Cape Fear River Program and the continuous monitoring data collection performed by the USGS. The southern open boundary condition for temperature used the fifth time history created for the EFDC temperature time series input file TSER.INP. This time series was also used for some of the wetland sources (Table 6). It was created by combining data from the USGS continuous monitoring station at Marker 12 (Station No. 02108820) while this station was operating (11/7/03-12/2/04), and using the Lower Cape Fear River Program data from station M18 for the other times. The USGS data were used as daily time-averaged data. The LCFRP data were collected at monthly intervals, and were interpolated linearly by EFDC to obtain the necessary temperature time history.

To run the EFDC hydrodynamic model, a salinity time series was also needed for the surface and bottom layer at the open boundary. Since the USGS data station closest to the model boundary (Station No. 02108820, Marker 12) was well removed from the actual boundary at Southport, an estimation procedure was used to create the salinity time history. Near top and near bottom salinities were available for this site, and were used to represent the upper and lower layer salinity. Creation of the boundary condition involved a combination of time-averaging of the 15-minute salinity data, and selection of a number of maximum values per day to represent the time history for that day. Time averaging and selection of the maximum value were used to as a means of estimating the salinity time history that might be expected at the mouth of the Cape Fear. Hourly time averages were calculated from the 15-minute data. From this time history were taken 1, 2, 4, or 8 maximum salinity values per day, with each value representing the maximum salinity for the appropriate fraction of the day. During model calibration each of these time histories was used and the calibration performance was assessed for each. It was found that the time history using two maximum values per day gave the best fit to the observed data and was therefore used to represent the boundary condition. Linear interpolation was used to calculate the salinities for the intermediate layers. During the time period when the USGS data were not available Lower Cape Fear River Program data from station SPD (Figure 6) was used to represent salinity for EFDC layer 5. Each layer was assumed to have a salinity that differed by 0.5 ppth from its neighbor. This layer-to-layer salinity difference was calculated by taking the difference between the mean salinity surface and bottom salinity values at the USGS Marker 12 station.

Several other water quality time histories were created for representing conditions at the model's southern boundary. Time histories were created for the following constituents:

- cyanophytes (blue-green algae)
- diatoms

- chlorophytes (green algae)
- orthophosphate phosphorus
- ammonia nitrogen
- nitrate+nitrite nitrogen
- dissolved oxygen

All of these time histories used data from the Lower Cape Fear River Program station M18. These data were available on a weekly to monthly time period, depending upon the season. All layers were assigned the same concentration. For the other constituents, a time-averaged value was set in the water quality control file WQ3DWC.INP using time-averaged or estimated values at station M18. The dissolved oxygen time history was estimated by assuming that the incoming water to the model region would be saturated with dissolved oxygen. The saturation concentration depended on water temperature and salinity (Chapra 1997). Water temperatures were taken from the temperature time series file. For this calculation only, the salinity was assumed to be 35 ppth.

3.4 Benthic Inputs

The EFDC water quality model includes a predictive sediment diagenesis model. For this study, however, a simpler prescriptive model was used in which benthic fluxes of dissolved oxygen and nutrients were specified as a time history. To better quantify the fluxes of dissolved oxygen between the water column and the benthos, the NC Division of Water Quality measured sediment oxygen demands (SODs) at five sites during the Summer and Fall of 2003 (Table 12).

Five sampling rounds were undertaken as part of the study, in which SOD was measured at one site within the estuary. The sites measured included sites in the upper and lower estuary, and in both the Northeast and Cape Fear Rivers (Figure 9). In general the modeling approach for using these data was to specify the SOD in the simplest manner possible that was sufficient for quantifying the impact of the benthos on the dissolved oxygen budget of the estuary. For this reason, these data were initially used by specifying a constant SOD rate in the water quality control file WQ3DWC.INP. During model calibration it was found that model prediction capability could be improved by varying the SOD as a function of water temperature. It was also found that model prediction of dissolved oxygen were improved by specifying a higher SOD for the Northeast Cape Fear as compared with the remainder of the estuary.

Temporal variation of SOD was considered in the following way. An SOD time history was created by developing a SOD vs. temperature curve that utilized the monitoring data to determine the reference SOD at 20° C and the rate at which SOD changes with changing temperature. Spatially averaged but temporally varying water temperatures were then estimated using the monitoring data. Together this information was used to specify the time variation in SOD, which was provided to the numerical model in the benthic flux input file . A non-zero nitrate flux to the sediments was also included, and was considered to vary according to temperature in the same way as SOD. The ratio of nitrate flux to SOD was determined during calibration by comparing model predicted and observed nitrate concentrations within the model region.

Table 12. Sediment Oxygen Demand (SOD) Measurements

Date	Measurement Location	Latitude & Longitude	Water Temp. (°C)	SOD at ambient temp (g/m2/d)	SOD corrected to 20 deg C (g/m2/d)
8/6/2003	Prince George Creek, tributary to the Northeast Cape Fear River, station located 0.5 miles upstream from its confluence with the Northeast Cape Fear River	N34° 21' 29.11" W77° 57' 7.55"	26.3	0.5189	0.3490
11/20/2003	Northeast Cape Fear River, upstream from Wilmington near channel marker 4	N34° 16' 7.67" W77° 56' 58.20"	15.9	0.1900	0.2460
10/29/2003	Cape Fear River downstream from Wilmington near channel marker 61	N34° 11' 39.30" W77° 57' 28.24"	19.3	0.4440	0.4640
7/17/2003	Cape Fear River downstream from Wilmington near channel marker 55	N34° 08' 7.8" W77° 56' 46.3"	27.6	0.4679	0.2899
10/2/2003	Town Creek, tributary to the Cape Fear River, station located 0.5 miles upstream from its confluence with the Cape Fear River.	N34° 07' 53'' W77° 57' 43''	20.7	0.6951	0.6651

3.5 Meteorological Inputs

All three EFDC sub-models (hydrodynamics, temperature, water quality) require information on meteorological conditions in the modeled region. Several options exist as to which set of data is given to the model. In the Lower Cape Fear River application, these time histories were specified in the ASER.INP and WSER.INP files:

- atmospheric pressure in millibars,
- air temperature in degrees Celsius,
- relative humidity,
- rainfall (a conversion factor is available to handle various rainfall units)
- evaporation rate (a conversion factor is available to handle various evaporation units)
- short-wave solar radiation (given as Watts/m^2, various units can be used)

- cloud cover (given as sky fraction, various units can be used)
- wind speed in m/s
- wind direction (given as the "to" direction, 0 degrees = to the north)

Data collected from the National Weather Service were used for all values except solar short-wave radiation. Data from the Wilmington International Airport were used and was assumed to represent weather conditions over the entire model region. Evaporation and precipitation were assumed to be in balance, and were therefore assumed both to be zero. Solar short-wave radiation was obtained from the National Renewable Energy Lab's National Solar Radiation Database. Hourly values of solar radiation at the Wilmington Airport (Station No. 723013) for years 2003, 2004, and 2005 were downloaded from the database's web site (www.nrel.gov/rredc/solar_data.html).

4. MODEL CALIBRATION

4.1 Description of the Calibration Time Period

A fourteen-month time period was used for model calibration (November 1, 2003 – January 1, 2005). This period of time was chosen because it offered the best set of monitoring data for establishing model forcings and for assessing model performance. A second time period (January 1, 2005 – January 1, 2006) was used for model confirmation. The model confirmation runs are described in section 5. For model calibration, the first two months of the time period (November 1, 2003 – January 1, 2004) were used for "spinning up" the model to establish initial conditions. Comparison of model predictions to data from the various monitoring programs was done for the period from January 1, 2004 to January 1, 2005.

Calibration was accomplished first using only the hydrodynamic model. Hydrodynamic calibration consisted of comparing model predicted water surface elevations, water velocities, salinities, and temperatures to corresponding values from the monitoring program. The EFDC input files describing the model grid (CELL.INP, DXDY.INP, LXLY.INP) were created as part of the hydrodynamic model calibration. These files are included in this report as Appendix B. The model time step (20 seconds), the number and location of all boundary conditions, the locations for model output, and many other parameters needed for running the model were set in the EFDC control file (EFDC.INP). This file is included in this report as Appendix C. Once the hydrodynamic model was calibrated, water quality calibration was conducted.

The model calibration period had streamflows that were generally below average for the first half of the year, and generally above average for the latter half of the year (Figure 18). After a storm in early May 2004, streamflows remained below average until August. The remainder of 2004 and 2005 until the middle of April had streamflows that were near historical average values. Flows through the summer of 2005 were generally below average (Figure 18).

Dissolved oxygen (DO) concentrations at two stations that were in the impaired region and had continuous monitors installed in 2004 (Navassa and the Northeast Cape Fear at Wilmington) showed summertime (April 1 – October 31) dissolved oxygen concentrations that varied between 3 and 7.5 mg/L (Figure 19). At both of these sites the median DO concentration was below 4.5 mg/L and the 25th percentile DO concentration was below 4.1 mg/L. DO concentrations were generally lower at the Northeast Cape Fear site, and at this site were generally lower near the bottom of the water column (Figure 19).

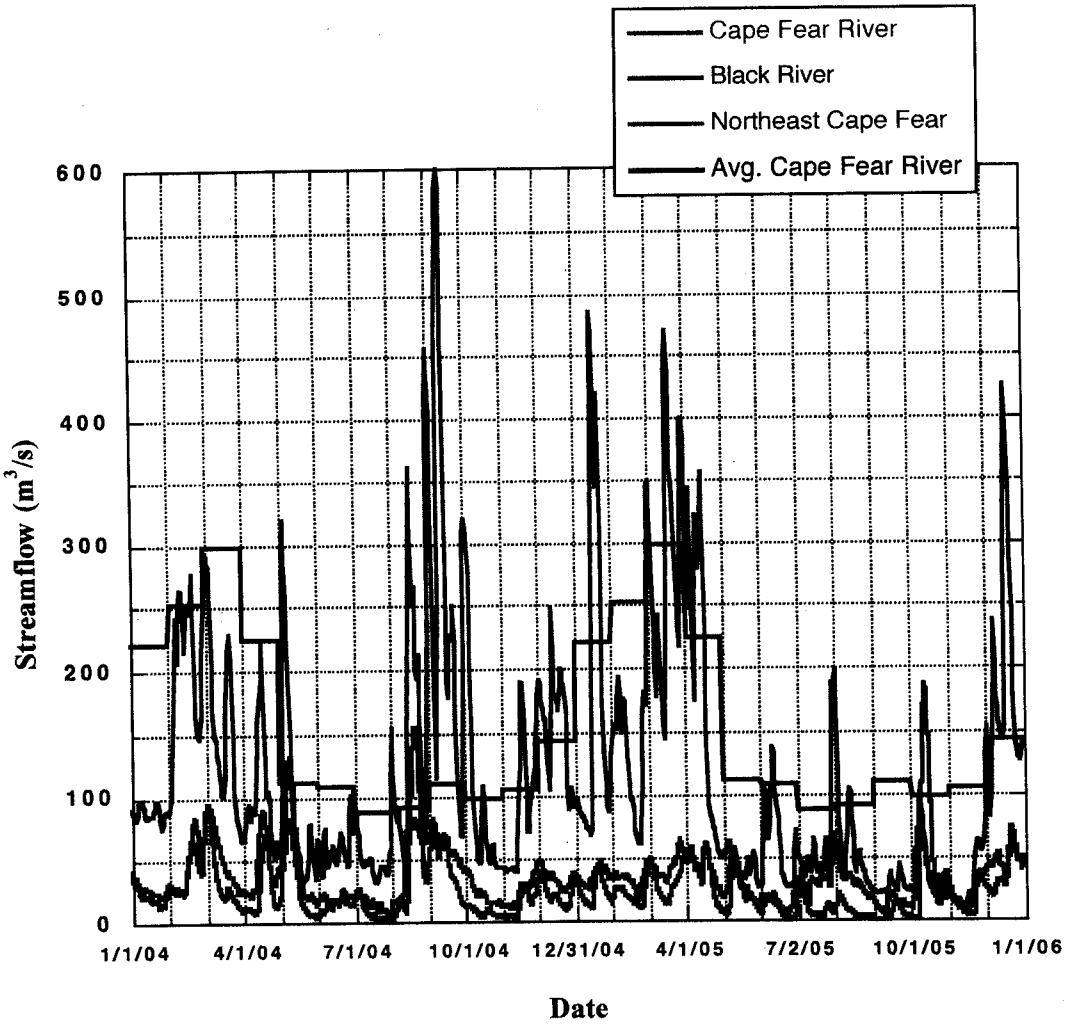


Figure 18. Streamflows at the Cape Fear River at the Lock and Dam 1 Station During the Model Time Period

4.2 Hydrodynamic Model Calibration

Hydrodynamic model calibration was performed by comparing model predictions to observations at twenty-three different locations where data had been collected by the USGS continuous monitoring program, the Lower Cape Fear River Program, or by NOAA (Table 13). These twenty-one sites span the entire model region and all three rivers that make up the Lower Cape Fear River Estuary (Figure 20). Initially hydrodynamic calibration concerned specification of the model grid. The objective of this part of the calibration task was to locate and size all the channel and wetland cells, and to establish a bottom roughness for each of these cells. Once the model grid was specified hydrodynamic calibration continued by comparing model predictions to salinity and temperature observed data. Hydrodynamic calibration is described in more detail in the following sections.

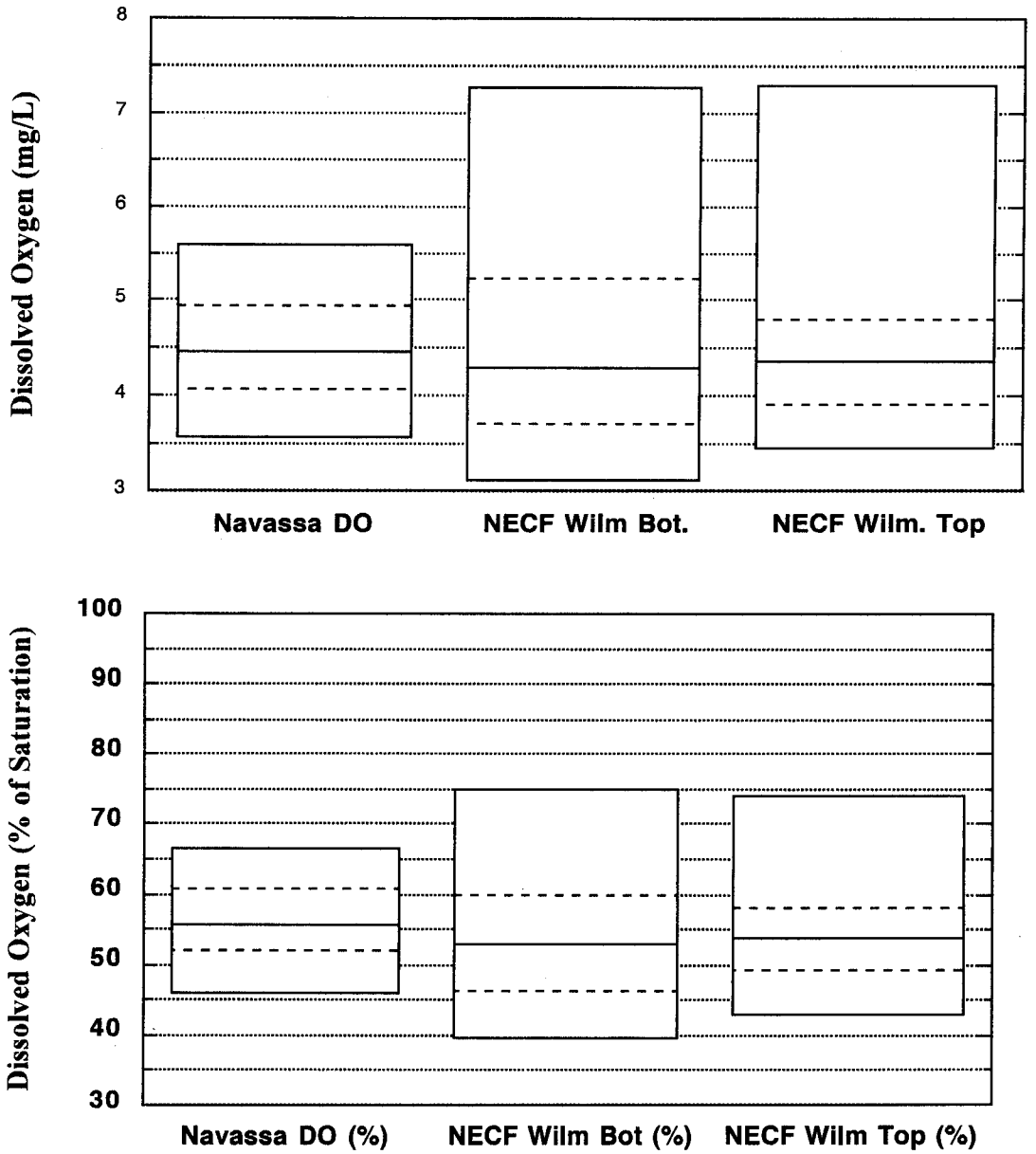


Figure 19. Dissolved Oxygen Concentrations at the Navassa and Northeast Cape Fear at Wilmington Monitoring Stations

Table 13. Locations Used for Model Calibration

EFDC Grid Cell Used (I, J)	Station Name	River	Monitoring Data Collected by
4, 84	Lock and Dam 1, 02105769	Cape Fear	USGS
4, 80	NC11	Cape Fear	LCFRP
7, 67	Black River at Currie, 02107544	Black	LCFRP
7, 66	B210	Black	LCFRP
4, 60	AC	Cape Fear	LCFRP
4, 25	IC	Cape Fear	LCFRP
43, 97	NECF at Burgaw, 02108566	Northeast Cape Fear	USGS
43, 66	NCF117	Northeast Cape Fear	LCFRP
44, 27	NCF6	Northeast Cape Fear	LCFRP
4, 11	Cape Fear at Navassa, 02107576	Cape Fear	USGS
4, 10	Nav	Cape Fear	LCFRP
22, 81	HB	Cape Fear	LCFRP
43, 15	NECF at Wilmington, 02108690	Northeast Cape Fear	USGS
18, 72	Brunswick River	Cape Fear	LCFRP
24, 68	M61	Cape Fear	LCFRP
24, 58	M54	Cape Fear	LCFRP
25, 49	M42	Cape Fear	LCFRP
25, 47	M12, 02108820	Cape Fear	USGS
26, 40	M35	Cape Fear	LCFRP
23, 21	M23	Cape Fear	LCFRP
24, 11	M18	Cape Fear	LCFRP
23,76	Wilmington Tide Gage, Station 8659084	Cape Fear	NOAA
33,5	Cape Fear at Southport, Station 8658120	Cape Fear	NOAA

4.2.1 Modeled and Observed Water Surface Elevations

Hydrodynamic model calibration began by comparing model predictions to observed water surface elevations and depths. This work took advantage of the continuous monitoring data program operated by the USGS and tide gage data available from NOAA. Model predictions of tide varying elevations were compared to observed data at these seven locations:

1. Cape Fear River at Lock and Dam 1 (USGS 02105769)
2. Black River at Currie (USGS 02107544)
3. Northeast Cape Fear River at Burgaw (USGS 02108566)
4. Cape Fear River at Navassa (USGS 02107576)

5. Northeast Cape Fear River at Wilmington (USGS 02108690)
6. Cape Fear River at Marker 12 (USGS 02108690)
7. Cape Fear River at NOAA's Wilmington Tide Gage (NOAA 8658120)

The initial model grid used the Lower Cape Fear River Estuary grid created by Tetra Tech (2001). It was recognized in Tetra Tech's earlier study that additional work needed to be done on the model grid. Specifically, two of the recommendations from the earlier modeling effort were that additional information be gathered on the bathymetry within the estuary, and that additional work be done to quantify the effect of the riparian wetlands within the estuary. Both recommended areas of additional work were undertaken during the hydrodynamic model calibration. Twenty-one river cross-sections (Figure 9) were surveyed by the Division of Water Quality as part of the data collection phase of this modeling project (go to the LCFR model website at www.coe.uncc.edu/~jdbowen/LCFR to view cross-sections). All of this new bathymetric information was incorporated into the updated specification of the model grid.

Additional work was also done to specify the location and size of "wetland" cells that adjoin the main river channel. The overall strategy in determining wetland surface area was to use the information on the attenuation of the tidal amplitude to determine the distribution and overall area of the fringing marshes. Thus the wetland area was determined to some extent as a calibrated value. The wetting/drying routines within EFDC were not used, thus water depths had to be specified to keep the cells wet during spring tides.

This work relied upon wetland delineations performed by the NC Division of Coastal Management (NC Division of Coastal Management, 1999). In the model grid these cells were assumed to be shallower (depth = approximately 1 m) and have a higher bottom roughness (z_0 = 0.04 m) than the channel cells. An initial estimate of the location and size of these cells was meant to approximate the surface area of off-channel storage available in two of the wetland types (riverine swamps and saltwater marshes) identified by the Division of Coastal Management (Figure 5). With this distribution of wetland cells as a starting point a sensitivity analysis was performed to investigate how changing the total surface area of these cells would affect the attenuation of incoming tidal waves. Multipliers of 1, 2, 5, 10 were applied to the width of each marsh cell, and the effect on the M2 component of the tide was calculated for the seven locations listed earlier that span the model region. As expected, it was found that increasing the width of the marsh cells increased the attenuation of the tidal signal (Figure 21). Width ratios of 5 and 10 seemed to over attenuate the tidal signal in the oligohaline portion of the estuary. The width ratio of 2.0 seemed to give the best overall results, but this run showed inadequate damping in the Navassa and Wilmington areas. Three additional cases were tried that used various width ratios, and distributions of wetland cells (Figure 22). In the end, the case with a uniform width ratio of 2.0, and the "v1" version of the wetland cell distribution (shown in green in Figure 22) was chosen as optimal. The final size and distribution of wetland cells has these wetland cells along each river above Wilmington, and also in the area between Wilmington and Town Creek (Figure 6).

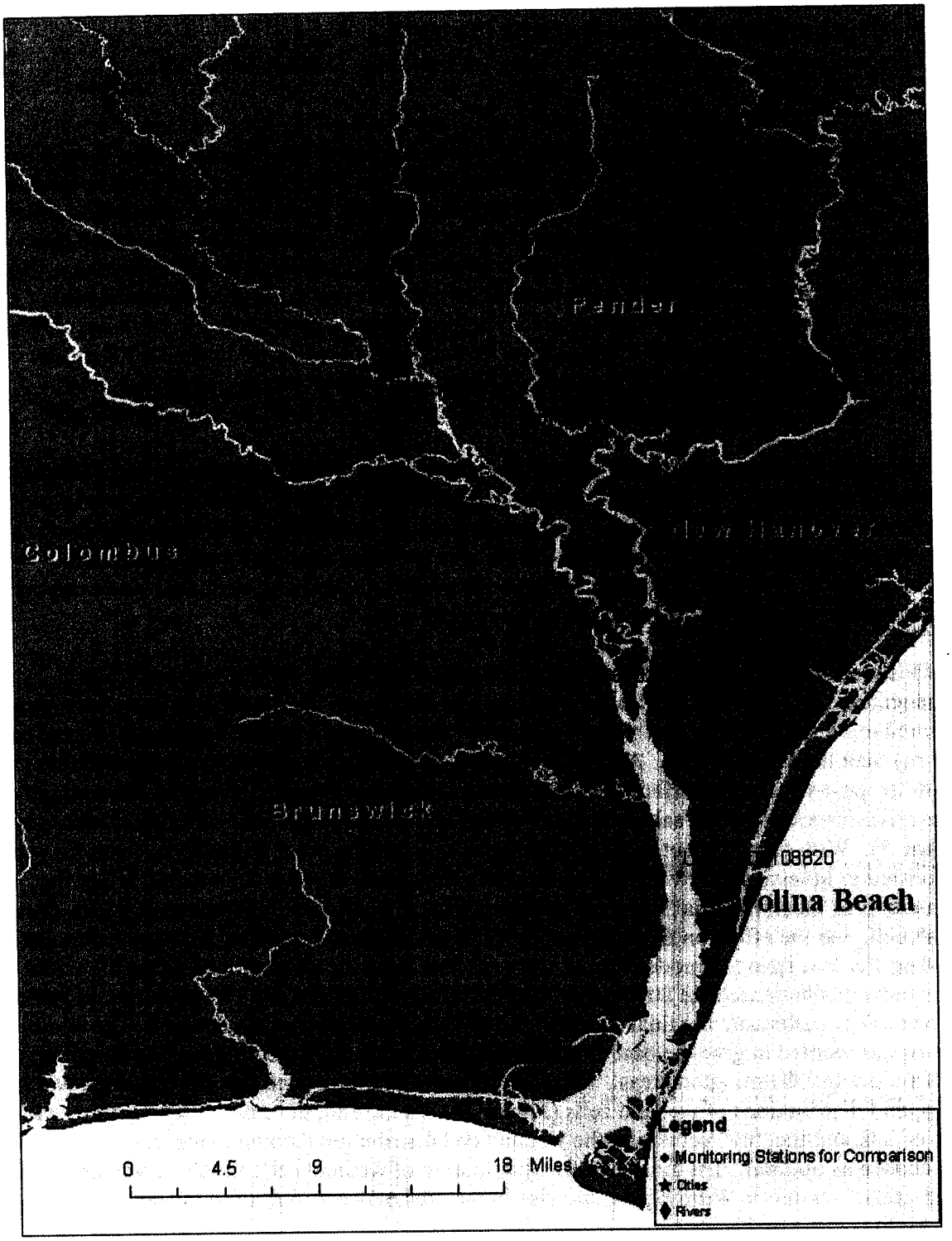


Figure 20. Monitoring Stations Used for Comparing Monitoring Data to Hydrodynamic Model Predictions.

With the specification of the model grid set model predictions of elevation were examined during the entire 2004 calibration period and at shorter time periods within the calibration period. The EFDC input files that define the model grid (CELL.INP, DXDY.INP, and LXLY.INP) are available in Appendix B. For the model/data comparison of the full 2004 calibration period, model predictions were printed twice per day and compared with observations at six stations: three near the upstream extent of the model region (Cape Fear at Lock and Dam 1, Black at Currie, NE Cape Fear at Burgaw), two in the impaired region near Wilmington (Cape Fear at Navassa, NE Cape Fear at Wilmington), and one in the lower estuary region south of Wilmington (Marker 12). Of interest was how the model responded to the longer-term changes in water surface elevation that would likely lead to episodes of flushing from the estuary. These flushing events could be seen in the flow record (Figure 18) during late August, September, and October 2004. They would also be expected in the variation of water surface elevation that would occur during the transitions between neap and spring tides. The water elevations at the three most upstream locations show increased elevations during the high flow time period in both the observations and the model predictions (Figures 23 and 24). In general, the model was found to underpredict elevation increases at the Cape Fear and Northeast Cape Fear sites during periods of high river flow. The two sites around Wilmington and the lower estuary site (Navassa, NE Cape Fear at Wilmington, Marker 12) showed elevation differences from spring to neap tide that are well represented by the model (Figures 24 and 25).

To examine elevation fluctuations within a few tide cycles it was necessary to examine shorter periods within the overall calibration time period. Hourly model predictions of elevation were compared to observations at the six sites listed earlier plus one additional site, the NOAA tide gage at Wilmington. The observations at the six sites other than the NOAA tide gage relied upon water measured and logged by the continuous water quality monitors. These pressure transducers were non-vented, thus their water depth measurement were affected by changes in atmospheric measurement. In addition, it seems likely that when the instruments were serviced, they were not always placed back in the water at exactly the depth they occupied previously, which could be seen in the data record as sudden increases or decreases in depth every few weeks. These two factors limited how the observed depth data could be used for comparison to model predictions. Because of the nature of the observed data set, we did not attempt any statistical calibration evaluations of the model's water surface elevation predictions. Rather, we examined the model predictions for evidence that the model was correctly attenuating the tidal wave at various locations within the estuary, and correctly varying tidal ranges through the neap to spring cycle. Two time periods were found to have a sufficiently a long period without disruption of any of the depth data at the six sites under study. These two time periods were January 11-21, 2004 and June 16 – 23, 2004. Tidal constituents predicted by the model at several sites within the estuary were also compared to corresponding observed data (Table 14) to assess how well the model could match the attenuation and phase lag characteristics seen in the observed data set.

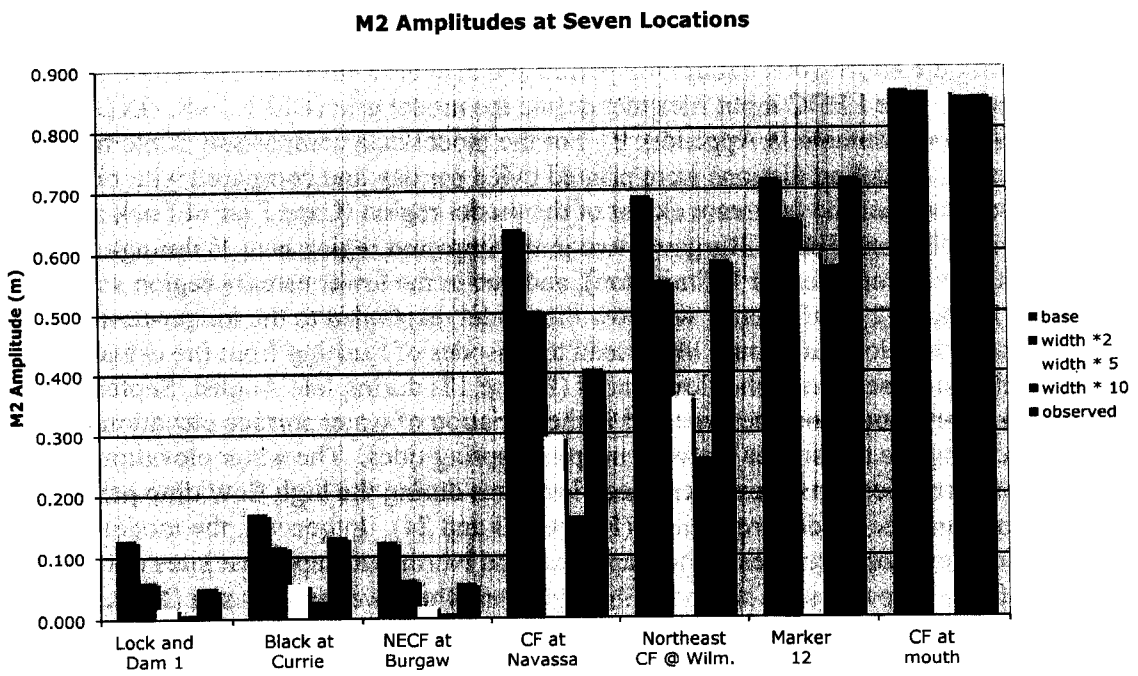


Figure 21. M2 Tidal Amplitude at Seven Stations for Various Wetland Cell Width Scenarios

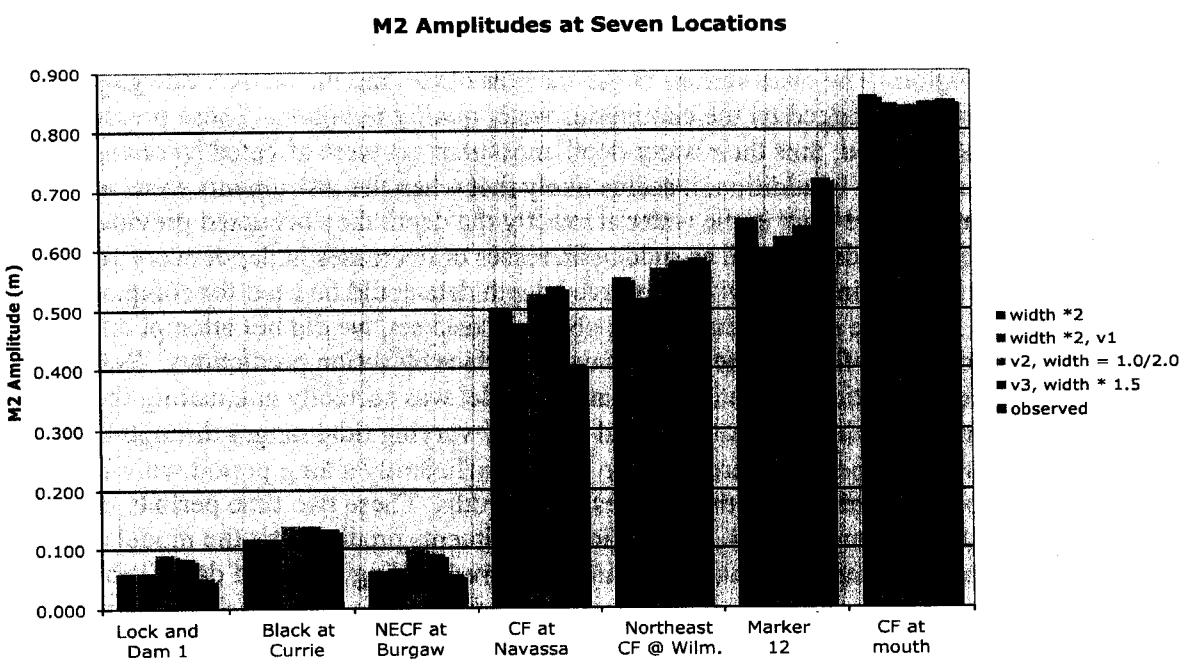


Figure 22. M2 Tidal Amplitude at Seven Stations for Various Wetland Cell Size Scenarios

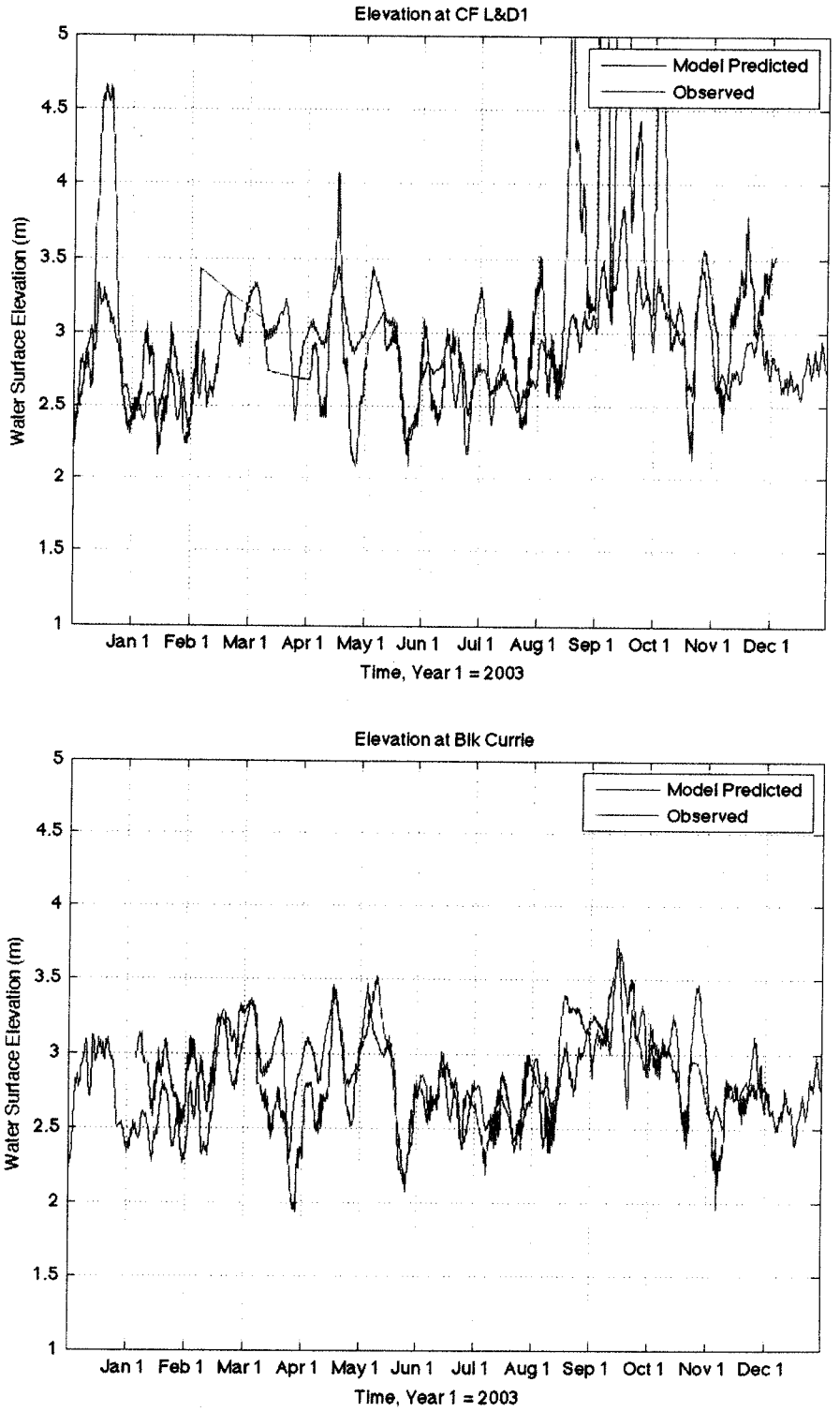


Figure 23. Model Predictions and Observed Water Surface Elevations During 2004 at Cape Fear R. Station Lock and Dam 1 and the Black R. at Currie

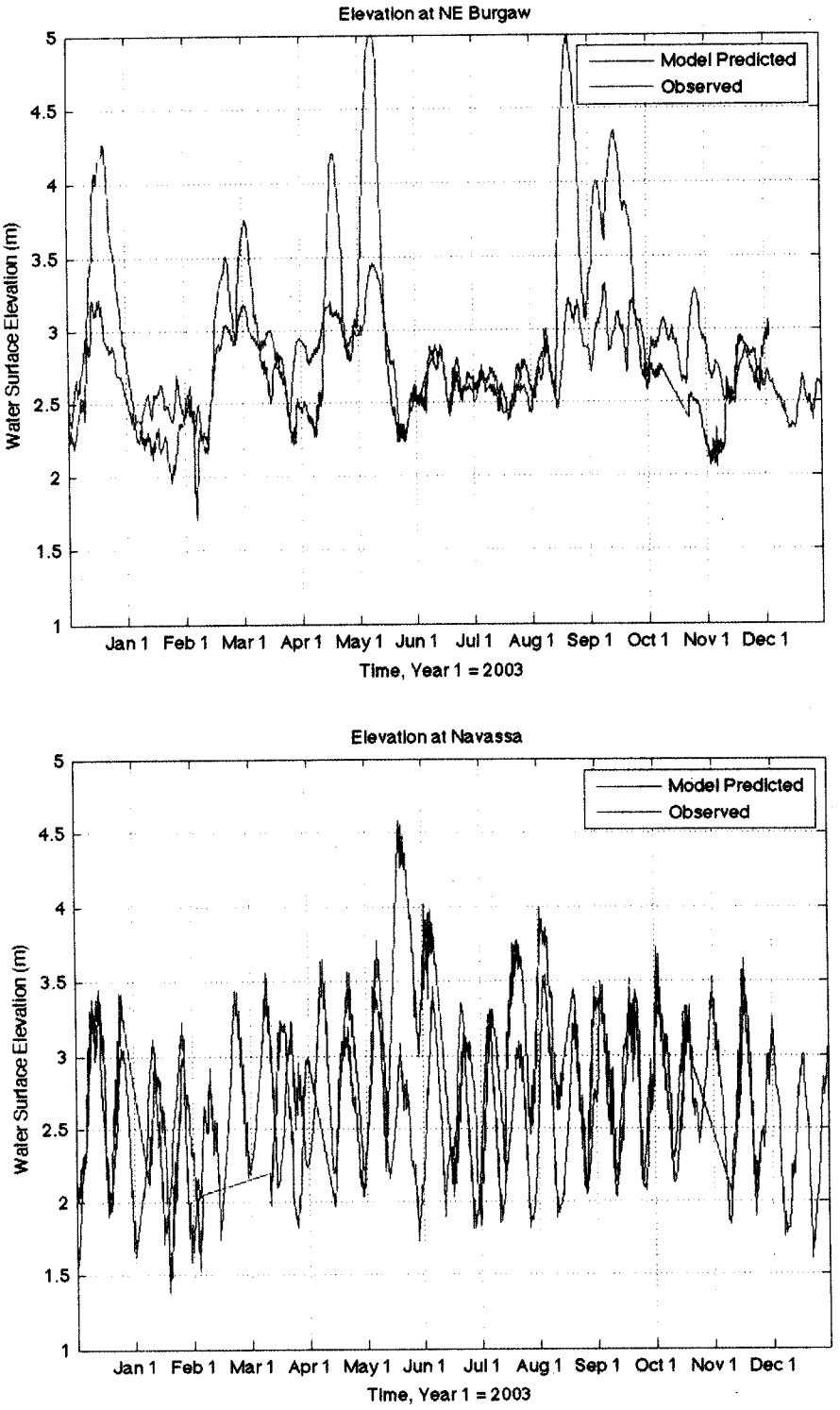


Figure 24. Model Predictions and Observed Water Surface Elevations During 2004 at NE Cape Fear at Burgaw and Cape Fear at Navassa

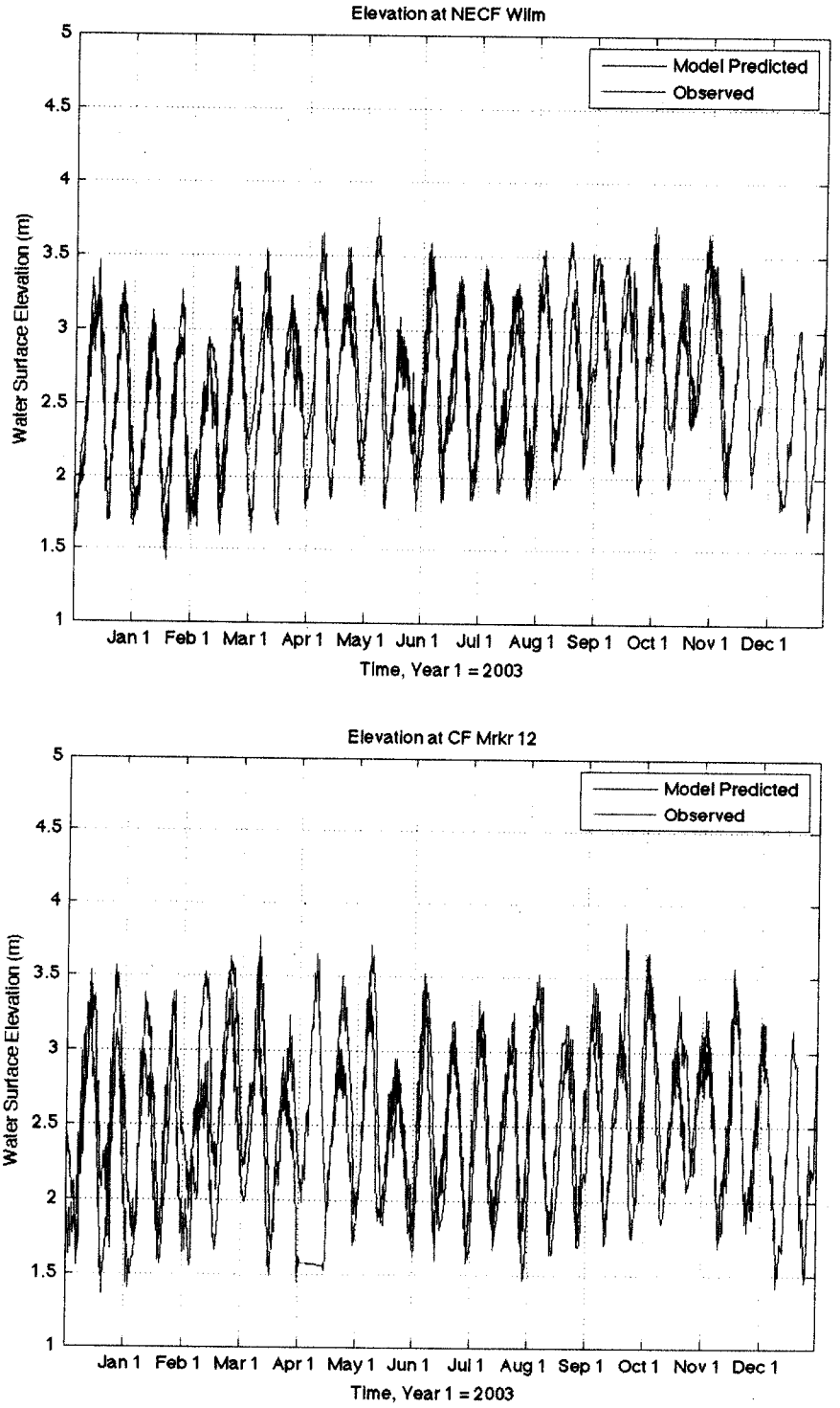


Figure 25. Model Predictions and Observed Water Surface Elevations During 2004 at NE Cape Fear at Wilmington and Cape Fear at Marker 12

Examination of the model predictions and observations during January 2004 showed that the model did a good job of simulating the attenuation of the tidal signal from lower to the upper portions of the estuary. For this comparison hourly snapshot model predictions were compared to hourly time-averaged observed data. The time-averaging of the observed data was necessary to reduce the size of the observed data files. Examination of the observed data revealed no systematic bias resulting from the averaging procedure.

The four stations in either the lower estuary (Marker 12) or the Wilmington area (Wilmington tide gage, NE Cape Fear at Wilmington, Navassa) had a close agreement between the observed and predicted tidal amplitudes (Figures 26 and 27). There does seem to be some drift in observed data at the Marker 12 station, and some disagreement in the tidal amplitude at these three stations, but overall the fit is good between model predictions and the observed data. All the stations predict well the timing of peak, although there is a consistent disagreement of about one hour between the timing of the peaks at Navassa (Figure 27). During the model calibration it was found that model predictions of the tidal phase at Navassa and farther upstream at Lock and Dam 1were relatively insensitive to changes in model parameters. Model predictions of tidal phase at this station were not as good as at the remaining three stations analyzed.

The three stations in the upper portions of the estuary (NE Cape Fear at Burgaw, Cape Fear at Lock and Dam1, Black at Currie) also show good agreement between the observed and predicted tidal amplitudes (Figures 28 and 29) during January 2004. As at the Cape Fear at Navassa, the model prediction of tidal phase at the Cape Fear at Lock and Dam1 misses the observed data by about one hour (Figure 29). Phase predictions are better at the Northeast at Burgaw (Figure 28) and the Black at Currie (Figure 29). At each location the model does a good job in simulating the attenuation of the tidal signal as it moves up into the estuary. Tidal ranges at the three upstream sites are less than 0.5 m (Figure 28 and 29), while the tidal range at Marker 12 is generally more than 1.5 m (Figure 26). In general the model slightly overpredicts attenuation in the Cape Fear and Northeast Cape Fear, and correctly simulates it in the Black River (Figures 28 and 29).

A shorter time period in June 2004 (June 16 – 23) also had an observed elevation data set that was suitable for comparison to model predictions. The same set of seven stations were analyzed by comparing hourly time histories of observed and model predicted water surface elevations. As during the other time period analyzed, the model predicted well the tidal phase at the Wilmington tide gage, at Marker 12, and at the Northeast Cape Fear at Wilmington stations, but underpredicted the tide lag at the Navassa station (Figures 30 and 31). The consistent underprediction of the time lag in the upper portion of the Cape Fear River may have something to do with the effect of the split in the river channel in the Brunswick River area. It is not expected that the relatively slight underprediction of time lag has a negative impact on the model's ability to simulate water quality conditions. As in January 2004, the model underpredicts somewhat the tidal range at Marker 12, but better represents the tidal variation at the three stations around Wilmington: the Wilmington tide gage, the Northeast Cape Fear at Wilmington, and Navassa (Figures 30 and 31).

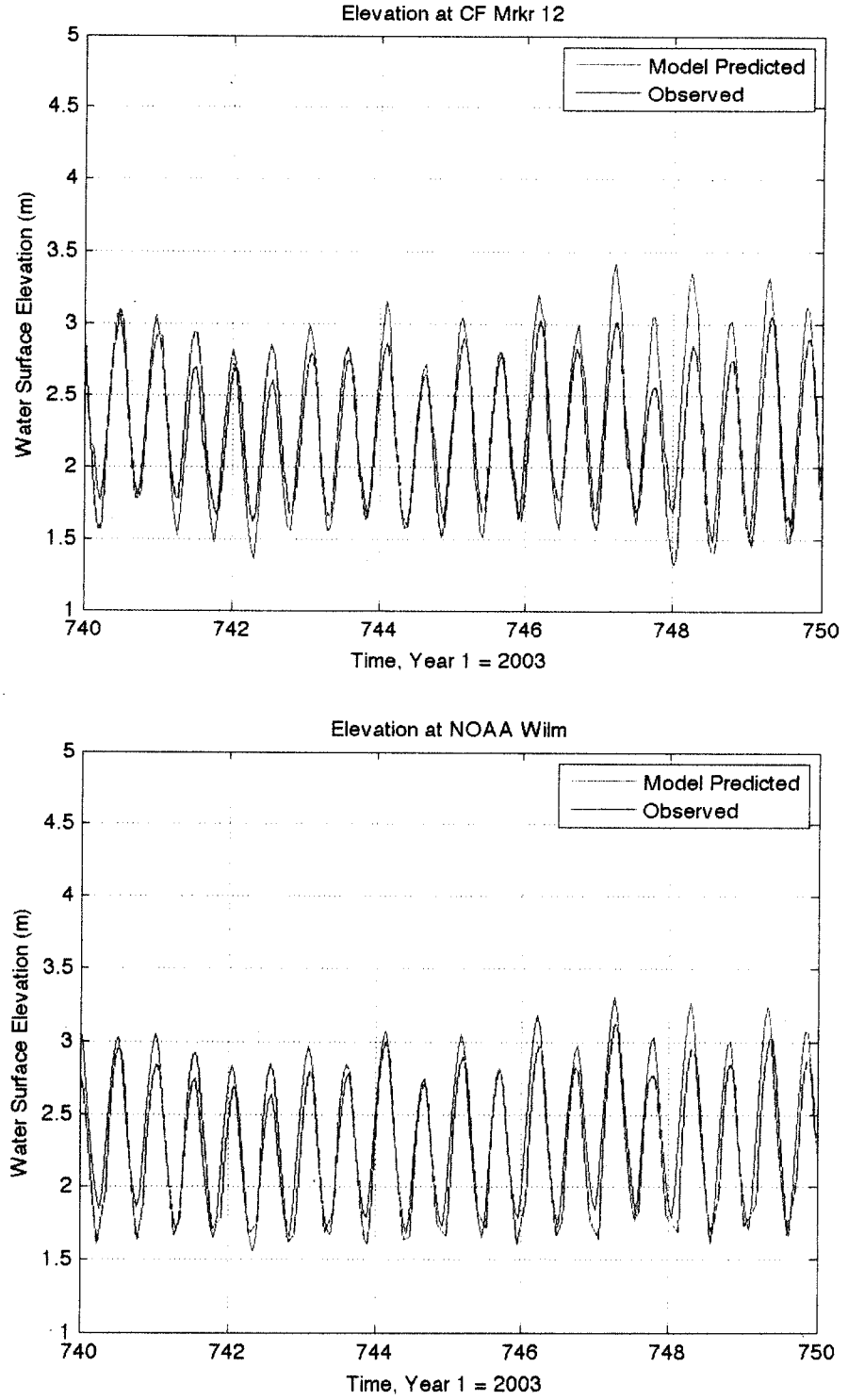


Figure 26. Model Predictions and Observed Water Surface Elevations During January 2004 (Day 740 = 1/11/2004) at Cape Fear R. Marker 12 and the Wilmington Tide Gage

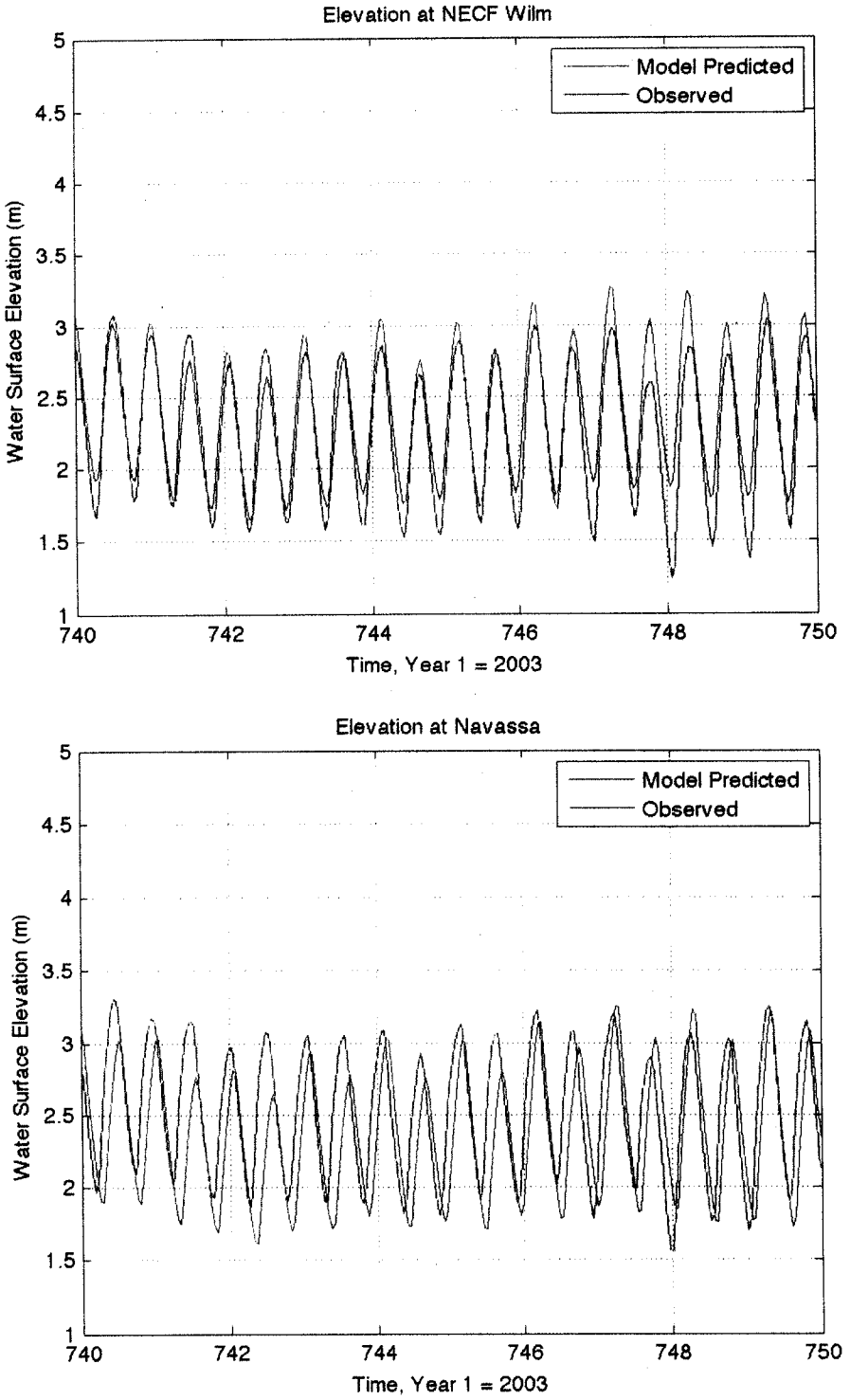


Figure 27. Model Predictions and Observed Water Surface Elevations During January 2004 (Day 740 = 1/11/2004) at NE Cape Fear at Wilmington, and the Cape Fear at Navassa.

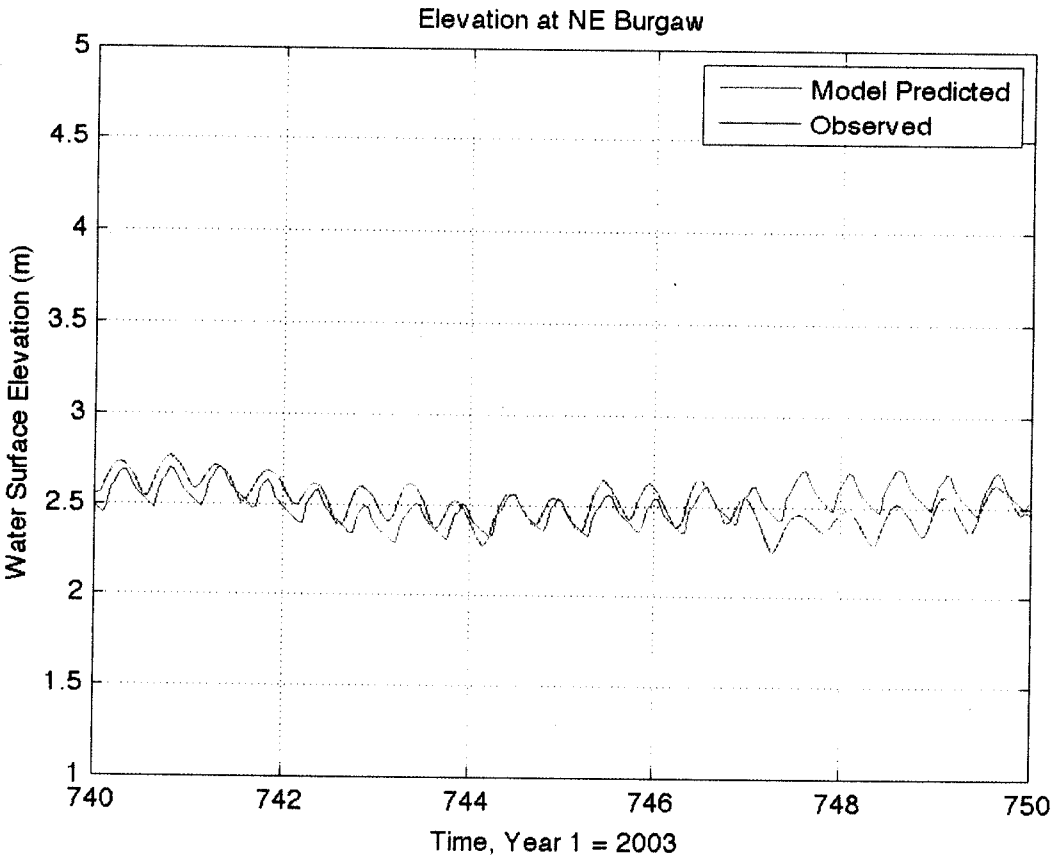


Figure 28. Model Predictions and Observed Water Surface Elevations During January 2004 (Day 740 = 1/11/2004) at NE Cape Fear at Burgaw.

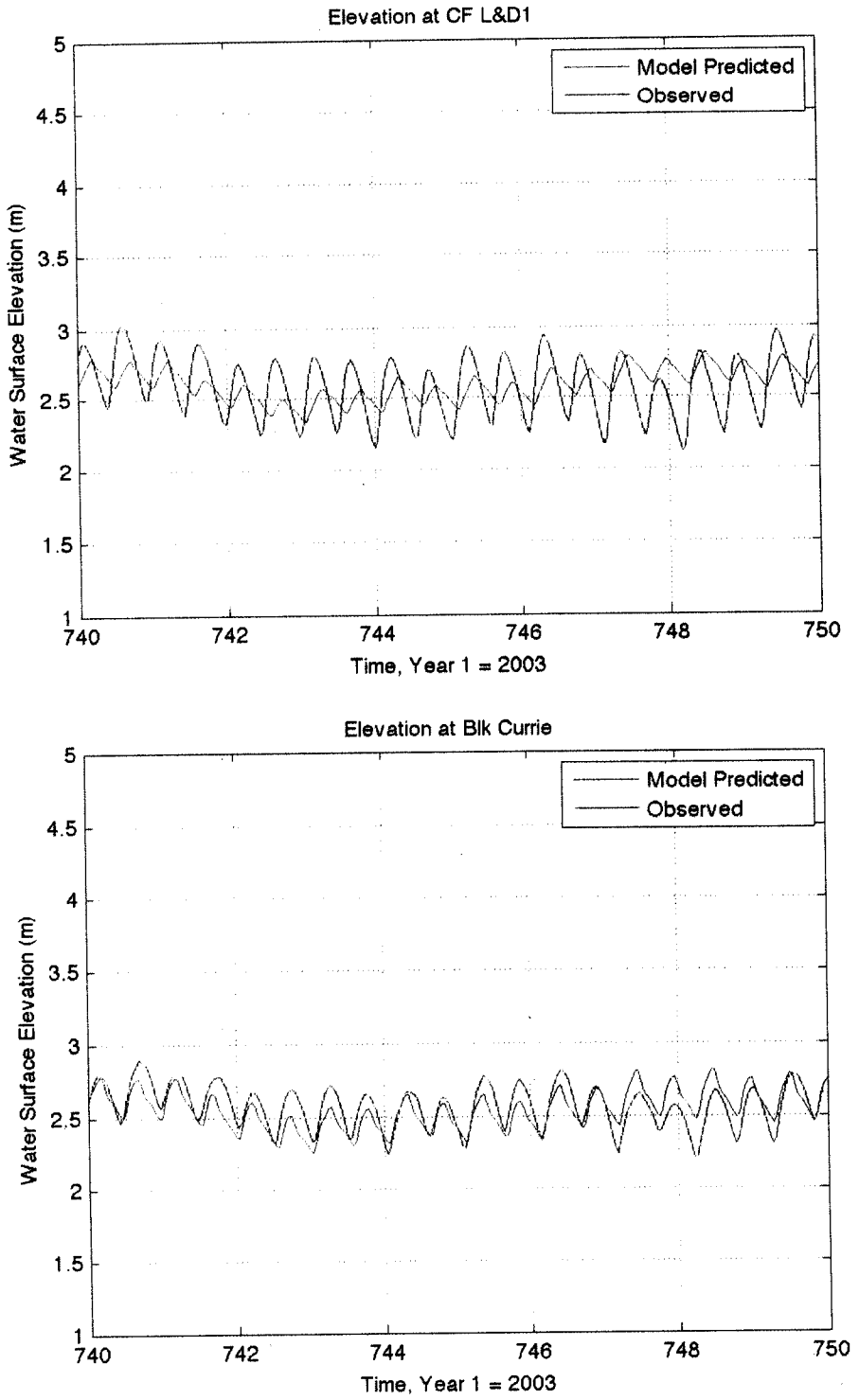


Figure 29. Model Predictions and Observed Water Surface Elevations During January 2004 (Day 740 = 1/11/2004) at the Cape Fear at Lock and Dam 1 and at the Black River at Currie.

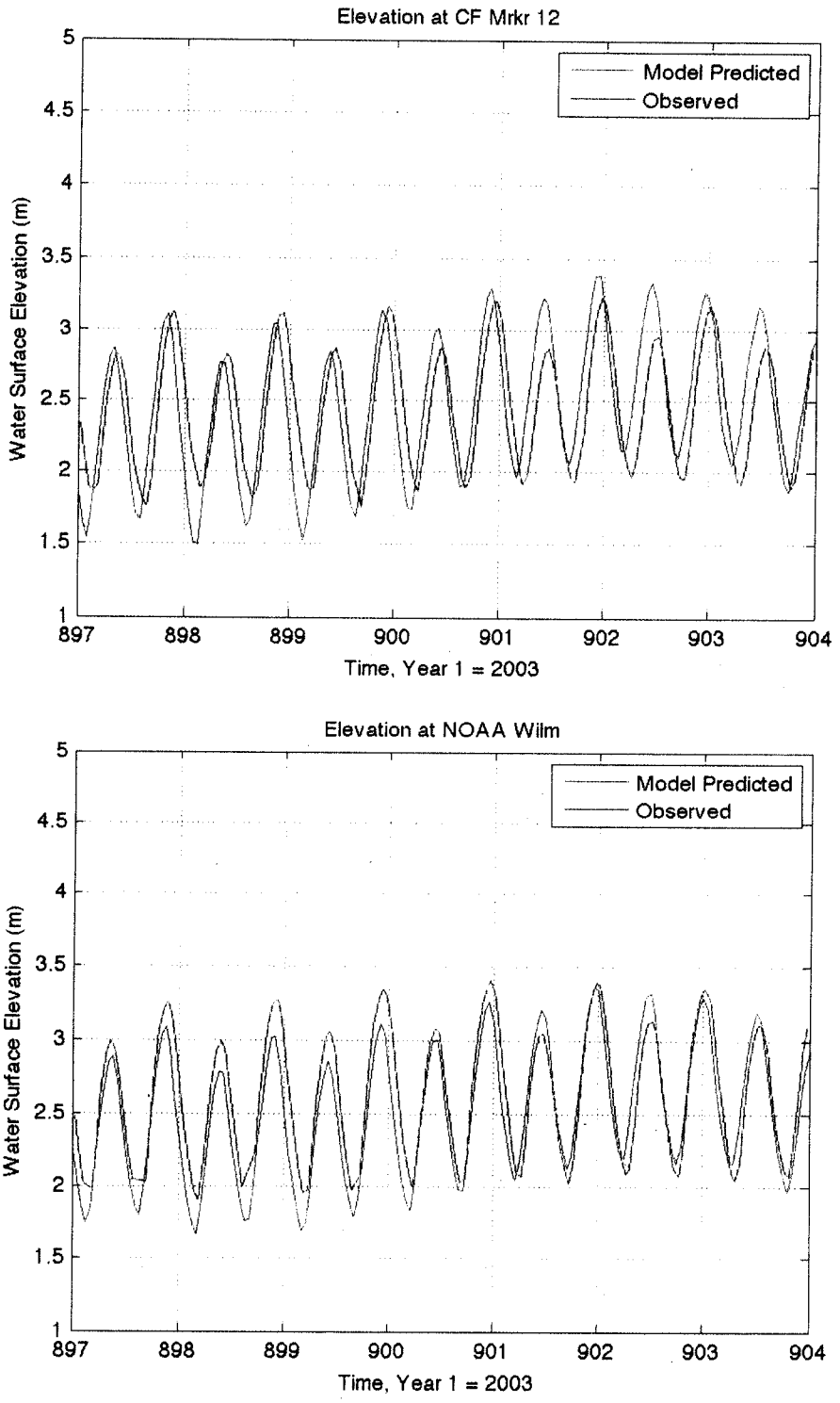


Figure 30. Model Predictions and Observed Water Surface Elevations During June 2004 (Day 900 = 6/19/2004) at the Cape Fear at Marker 12 and the Wilmington Tide Gage.

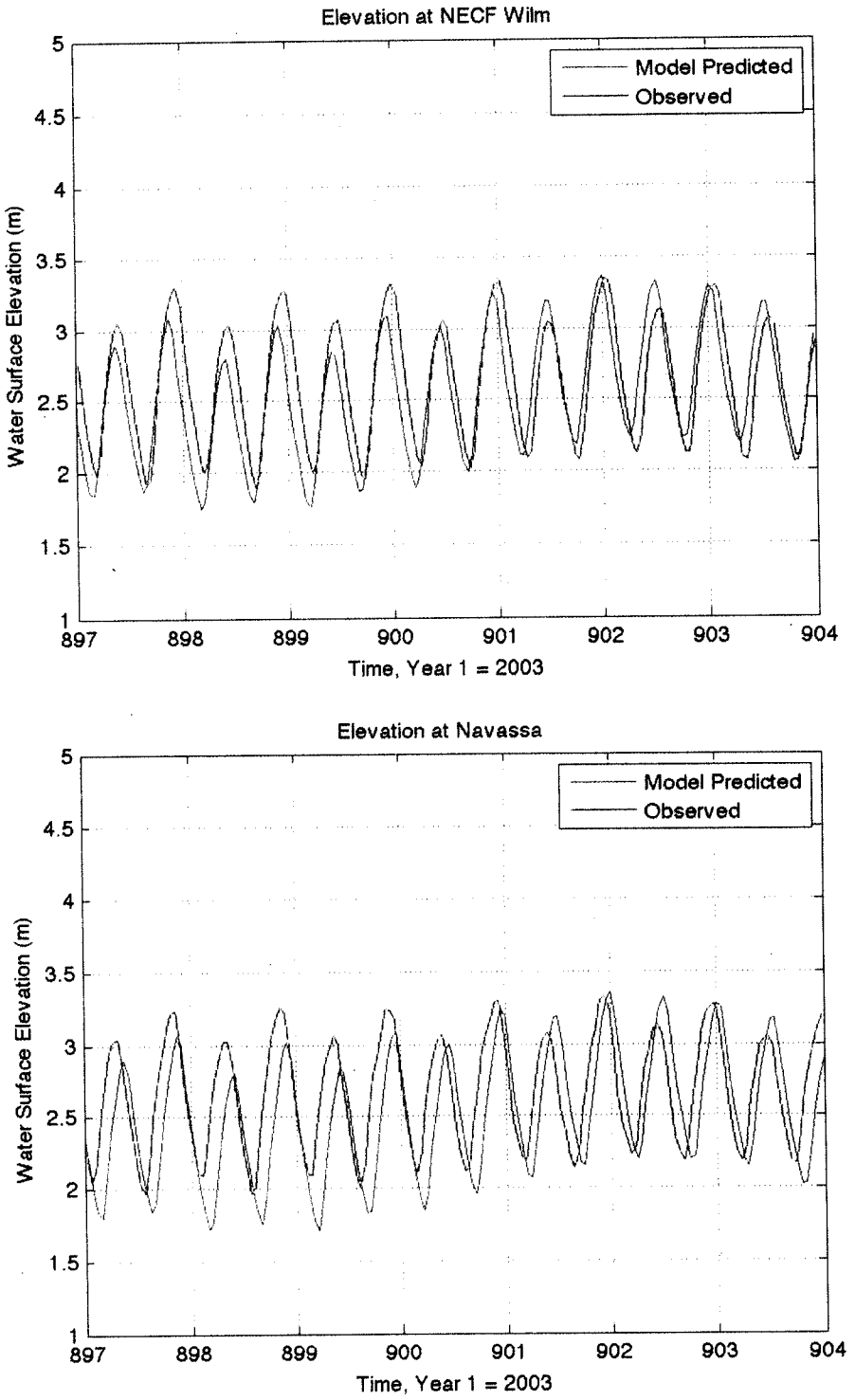


Figure 31. Model Predictions and Observed Water Surface Elevations During June 2004 (Day 900 = 6/19/2004) at the NE Cape Fear at Wilmington and the Cape Fear at Navassa.

Comparison of model predictions and observed water surface elevations at the three upstream locations (Northeast Cape Fear at Burgaw, Black at Currie, Cape Fear at Lock and Dam 1) show the model's ability to simulate the attenuation of the tidal signal as it moves through the estuary. All three locations show tidal amplitudes that are much reduced from the other more downstream stations (Figures 32 and 33). As for the January 2004 time period, the model overpredicts somewhat the attenuation at the Cape Fear station, but in this case also underpredicts slightly the tidal amplitude at the Black River site (Figure 33). Tidal phases are predicted well, although there exists again some error in the predicted phase at the Cape Fear site. Both the tidal phase and amplitude are predicted well at the Northeast Cape Fear site (Figure 32).

An additional examination of hydrodynamic model performance was performed by decomposing both observed data and model predictions into tidal frequency components. Tidal amplitudes and phases were calculated for both the model predictions and the observed data at seven stations scattered throughout the model region (Table 14). The numerical model does a good job in predicting the attenuation of the M2 tidal amplitude from the downstream location (e.g. Marker 12) to the upstream locations within the Northeast Cape Fear, Black, and Cape Fear Rivers. Errors in the predicted M2 tidal amplitude are 1 – 4 cm in the downstream locations and 1 – 8 cm in the upstream locations. Similar model performance is seen for the other tidal constituents (Table 14).

Table 14. Model Predicted and Observed Tidal Constituents at Seven Stations

Cape Fear River at Lock and Dam1							
	Tidal Amplitude (m)			Tidal Phase (sec)			
Comp-onent	Model Predicted	Observed	Difference	Model Predicted	Observed	Difference	Diff. (% per.)
M2	0.065	0.011	0.054	15790	-2907	18697	41.8%
S2	0.006	0.004	0.002	10830	31689	-20859	-48.3%
N2	0.003	0.041	-0.038	10750	21200	-10450	-22.9%
O1	0.021	0.069	-0.048	85620	88520	-2900	-3.1%
M4	0.015	0.022	-0.007	9578	11804	-2226	-10.0%
M6	0.005	0.013	-0.008	10200	14209	-4009	-26.9%
K1	0.016	0.032	-0.016	48760	87623	-38863	-45.1%

Black River at Currie							
	Tidal Amplitude (m)			Tidal Phase (sec)			
Comp-onent	Model Predicted	Observed	Difference	Model Predicted	Observed	Difference	Diff. (% per.)
M2	0.124	0.133	-0.009	11070	11315	-245	-0.5%
S2	0.012	0.009	0.003	8905	15073	-6168	-14.3%
N2	0.013	0.023	-0.010	3869	10255	-6386	-14.0%
O1	0.022	0.041	-0.019	80220	80123	97	0.1%
M4	0.033	0.019	0.014	6393	777	5616	25.1%
M6	0.005	0.007	-0.002	13300	11755	1545	10.4%
K1	0.015	0.046	-0.031	42110	57624	-15514	-18.0%

Northeast Cape Fear at Burgaw							
	Tidal Amplitude (m)			Tidal Phase (sec)			
Comp-onent	Model Predicted	Observed	Difference	Model Predicted	Observed	Difference	Diff. (% per.)
M2	0.090	0.168	-0.078	25520	20265	5255	11.8%
S2	0.013	0.036	-0.023	28190	13525	14665	33.9%
N2	0.018	0.091	-0.073	21750	4167	17583	38.6%
O1	0.008	0.114	-0.106	72480	94049	-21569	-23.2%
M4	0.031	0.020	0.011	18460	8662	9798	43.8%
M6	0.024	0.012	0.012	11550	13397	-1847	-12.4%
K1	0.026	0.117	-0.091	69710	72991	-3281	-3.8%

Cape Fear at Navassa							
	Tidal Amplitude (m)			Tidal Phase (sec)			
Comp-onent	Model Predicted	Observed	Difference	Model Predicted	Observed	Difference	Diff. (% per.)
M2	0.557	0.562	-0.005	41100	34391	6709	15.0%
S2	0.066	0.060	0.006	37580	32623	4957	11.5%
N2	0.081	0.123	-0.042	33640	28586	5054	11.1%
O1	0.072	0.095	-0.023	56840	55404	1436	1.5%
M4	0.026	0.031	-0.005	13340	2786	10554	47.2%
M6	0.033	0.044	-0.011	14210	8497	5713	38.3%
K1	0.073	0.076	-0.003	19560	41820	-22260	-25.8%

Northeast Cape Fear at Wilmington							
	Tidal Amplitude (m)			Tidal Phase (sec)			
Comp-onent	Model Predicted	Observed	Difference	Model Predicted	Observed	Difference	Diff. (% per.)
M2	0.548	0.589	-0.041	41030	40571	459	1.0%
S2	0.064	0.081	-0.017	37360	39184	-1824	-4.2%
N2	0.080	0.135	-0.055	33300	37145	-3845	-8.4%
O1	0.072	0.141	-0.069	56930	48996	7934	8.5%
M4	0.030	0.020	0.010	13650	6138	7512	33.6%
M6	0.026	0.014	0.012	14440	14044	396	2.7%
K1	0.076	0.121	-0.045	19880	42858	-22978	-26.7%

Cape Fear at Marker 12							
	Tidal Amplitude (m)			Tidal Phase (sec)			
Comp-onent	Model Predicted	Observed	Difference	Model Predicted	Observed	Difference	Diff. (% per.)
M2	0.646	0.669	-0.023	36410	36955	-545	-1.2%
S2	0.083	0.086	-0.003	31750	31720	30	0.1%
N2	0.105	0.028	0.077	28200	27412	788	1.7%
O1	0.097	0.115	-0.018	50370	83053	-32683	-35.2%
M4	0.024	0.036	-0.012	5872	23125	5872	26.3%
M6	0.024	0.017	0.007	6672	10884	-4212	-28.3%
K1	0.085	0.163	-0.078	32120	35812	-3692	-4.3%

Cape Fear at NOAA Tide Gage Wilmington							
	Tidal Amplitude (m)			Tidal Phase (sec)			
Comp-onent	Model Predicted	Observed	Difference	Model Predicted	Observed	Difference	Diff. (% per.)
M2	0.589	0.637	-0.048	40000	40207	-207	-0.5%
S2	0.068	0.084	-0.016	36270	36576	-306	-0.7%
N2	0.089	0.124	-0.035	32350	34988	-2638	-5.8%
O1	0.078	0.072	0.006	55550	55541	9	0.0%
M4	0.022	0.053	-0.031	12060	10217	1843	8.2%
M6	0.020	0.002	0.018	13240	10066	3174	21.3%
K1	0.079	0.090	-0.011	18820	34973	-16153	-18.7%

4.2.2 Modeled and Observed Salinities

To assess the model's ability to simulate the transport of a conservative substance, twice daily predictions of salinity were compared to observed data at twenty-one sites that spanned the entire model region, and included all three rivers within the estuary (Figure 20). The observed data set included information collected by both the US Geological Survey and Lower Cape Fear River Program. The USGS data came from the in-situ water quality monitors that collected salinity data every fifteen minutes. For this model/data comparison, the USGS observed data were hourly averaged, and two data points per day were taken for the calibration data set. The Lower Cape Fear River Program data was collected at more stations but less frequently. The frequency of sampling varied from season to season. The summer sampling frequency was as often as weekly at some stations. Most of the Lower Cape Fear River Program stations were sampled at a monthly interval during the winter months.

While statistical measures of model fit used all the available data, as described above, here we show time history comparison of model predictions and observations only at the USGS in the lower parts of the estuary. The three USGS sites omitted here (Cape Fear at Lock and Dam 1, Black at Currie, Northeast Cape Fear at Burgaw) all had salinities, both observed and predicted that were always near zero. Two of the sites shown here are in the impaired region (Cape Fear at Navassa, Northeast Cape Fear at Wilmington), and both sites show an excellent agreement between the model predicted and observed salinity (Figure 34). At both sites the salinities are quite dynamic, being near zero during the high flow periods late February and March and also September, and increasing to 10 to 15 ppth in the intervening time periods. Swings in salinity of approximately 5 ppth happen in about a week's time in both June and July 2004. The model predictions track the changes seen in the observed data quite nicely. While rather difficult to see with this particular data presentation, it appears that the model underpredicts somewhat the stratification seen in the observed data. At the Northeast Cape Fear station, the observed data often shows surface salinities that are approximately two ppth lower than the bottom values, but model predictions show essentially no difference between the surface and bottom values (Figure 34).

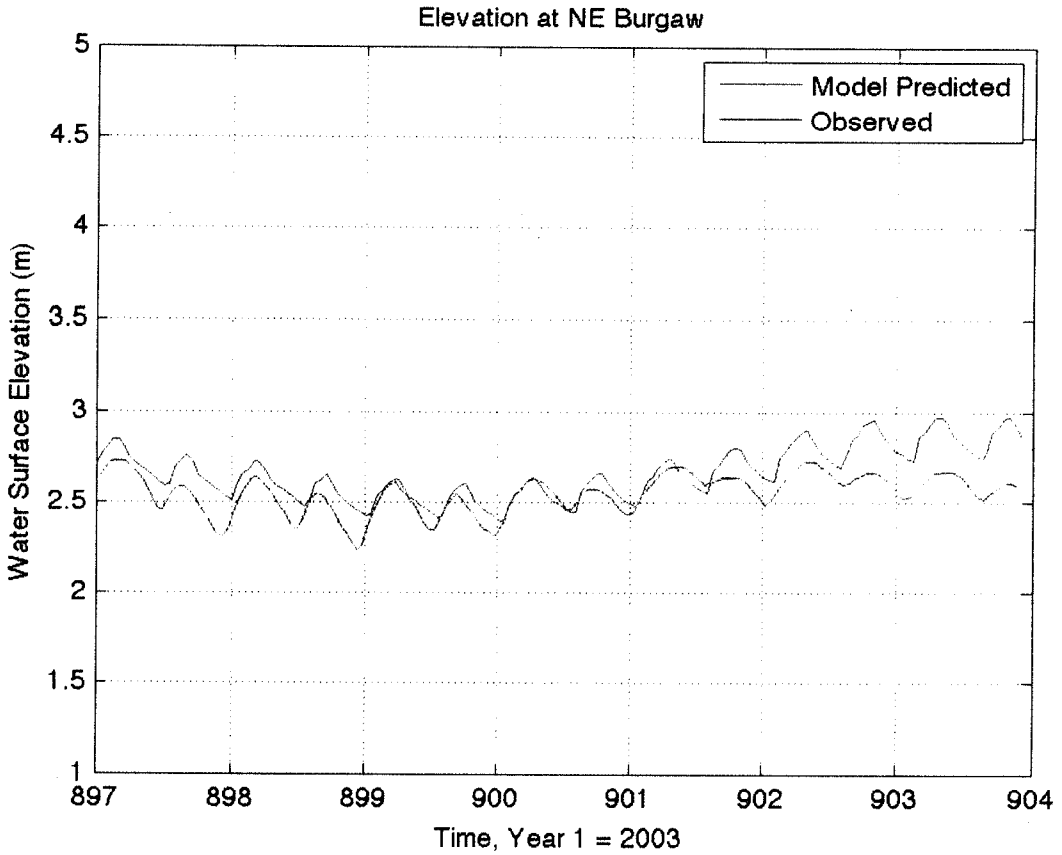


Figure 32. Model Predictions and Observed Water Surface Elevations During June 2004 (Day 900 = 6/19/2004) at the NE Cape Fear at Burgaw.

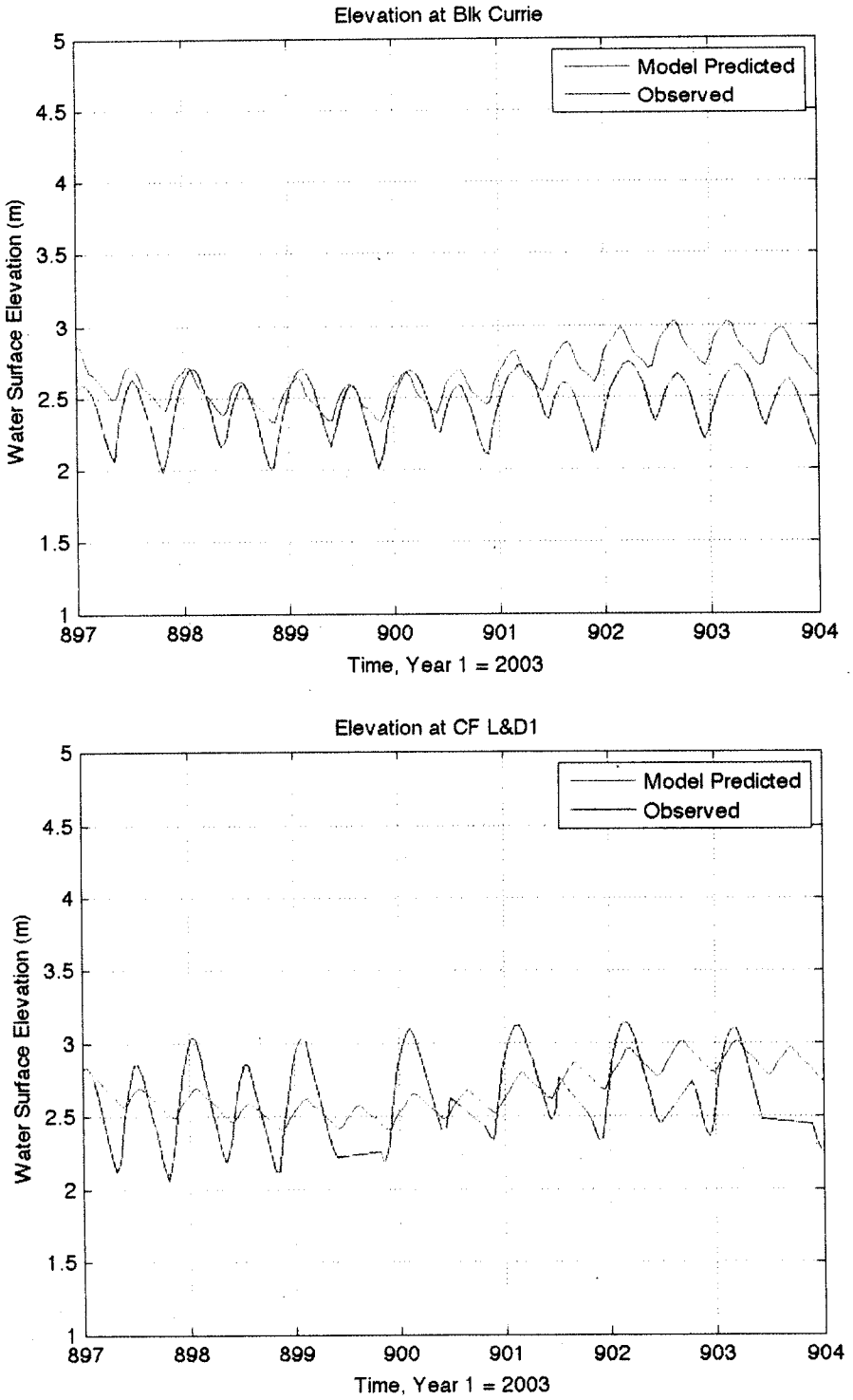


Figure 33. Model Predictions and Observed Water Surface Elevations During June 2004 (Day 897 = 6/16/2004) at the Black River at Currie and the Cape Fear R. at Lock and Dam 1.

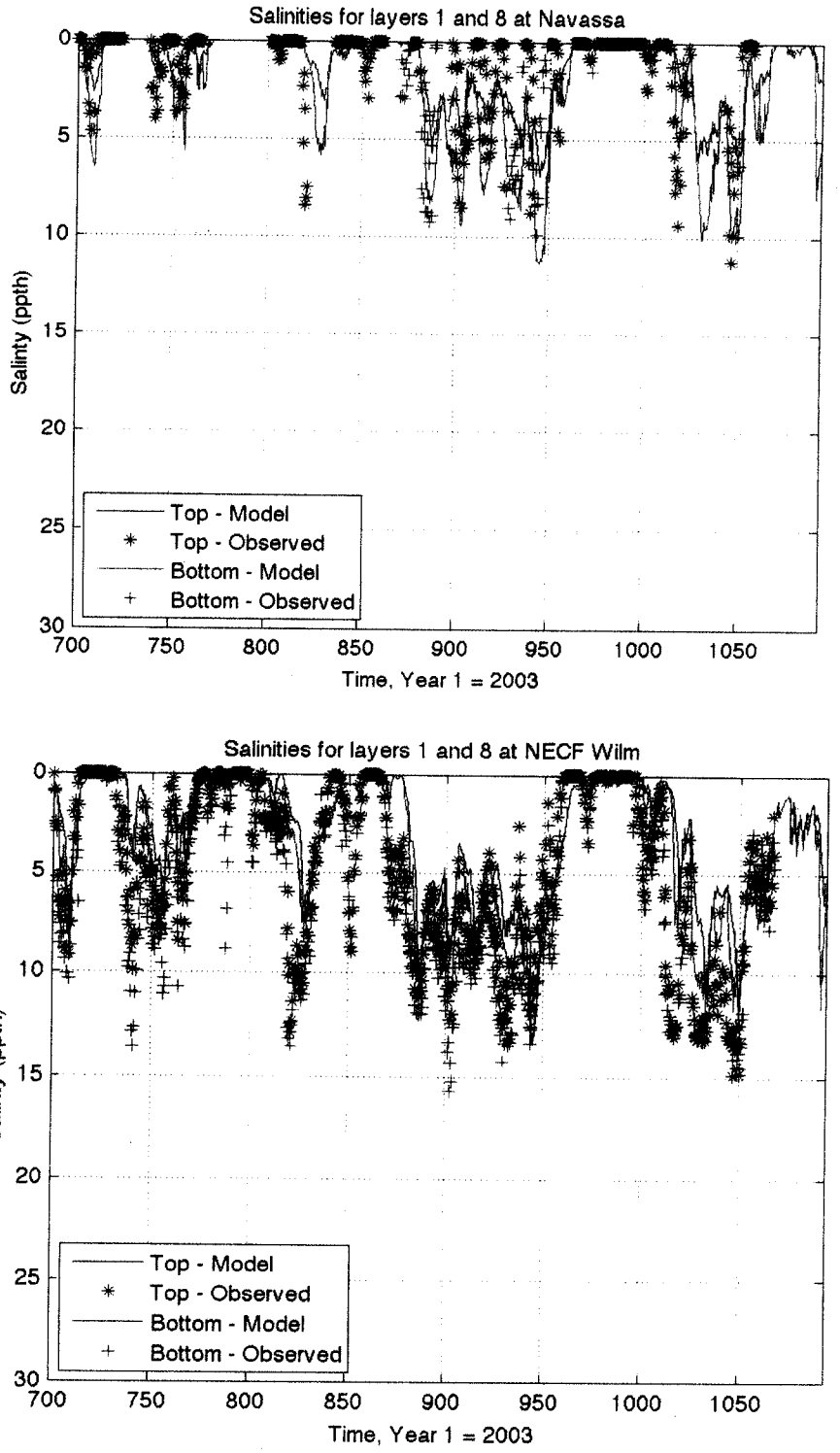


Figure 34. Model Predictions (lines) and Observed (symbols) Salinities During 2004 at the Cape River at Navassa and the NE Cape Fear River at Wilmington.

Salinities at the one station downstream of Wilmington (Cape Fear at Marker 12) are even more dynamic than the two upstream stations. As for the two other stations, salinities approach zero during the high flow periods in Spring and Fall (Figure 35). In mid-May the salinities also approach zero, which does correspond with a high flow event that is seen upstream at the Cape Fear River model boundary earlier in the month (Figure 18). During the summer, a regular variation in salinity can be seen on approximately a two-week period, which likely corresponds to the variations due the neap/spring tide cycle. As at the other two sites the model agrees with the observed data to an excellent extent, showing all of the dynamic features seen in the observed data. Once again, however, it does appear that the model underpredicts somewhat the magnitude of salinity stratification in this lower part of the estuary (Figure 35).

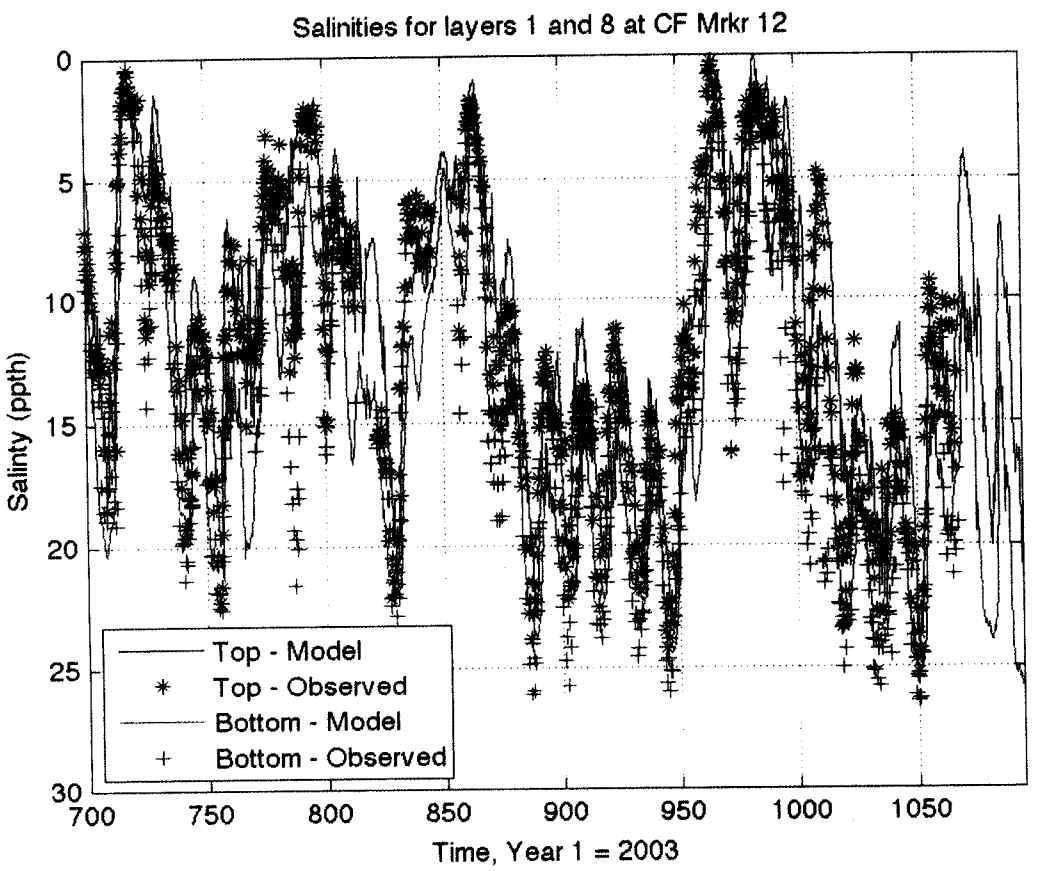


Figure 35. Model Predictions (lines) and Observed (symbols) Salinities During 2004 at the Cape River at Marker 12.

As mentioned earlier, statistical measures of the model's ability to simulate salinity distributions used all of the available salinity observations. A total of 5308 model/data comparisons were made during the 2004 calibration period, with the following statistical measures used to quantify model fit to the data (see Thomann 1982 or Tetra Tech 2001 for explanation of the measures):

- Mean error (absolute and normalized by mean of observations)
- Mean absolute error (absolute and normalized by mean of observations)
- Root mean square error (absolute and normalized by mean of observations)
- Correlation r^2
- Bias corrected r^2, also known as model efficiency

These comparisons indicated that the model slightly overpredicted salinity in the estuary by 0.112 ppth, which corresponds to a normalized mean error of 2.2% (Table 15). Two measures were used to quantify the typical magnitude of the prediction error. The root mean square error was 2.48 ppth and the mean absolute error (mean of the absolute value of each error) was 1.45 ppth (Table 15). The corresponding normalized errors for these two statistical measures of model fit were 50.1% and 29.1%. The correlation R^2 was used as an aggregate measure of model fit. For salinity the correlation R^2 was 87.6%, and the R^2 corrected for model bias was 85.7%. This level of calibration performance compares favorable with other hydrodynamic models of North Carolina estuaries (e.g. Bowen 2000).

Table 15. Calibration Statistics, Salinity

Parameter	Value	Units
Mean Error (predicted – observed)	**0.112**	**ppth**
Normalized Mean Error	**2.2**	**%**
Root Mean Square Error	**2.48**	**ppth**
Normalized Root Mean Square Error	**50.1**	**%**
Mean Absolute Error	**1.45**	**ppth**
Normalized Mean Absolute Error	**29.1**	**%**
Correlation R^2	**87.6**	**%**
Number of Model/Data Comparisons	**5308**	**-**
R^2 Corrected for Bias	**85.7**	**%**

Statistical measures of model fit were also calculated at each site where observed data were available. Each of the measures given in Table 15 were calculated at fourteen stations where salinity data were collected either by the USGS or as part of the Lower Cape Fear Program (Table 16). Mean errors were quite variable, with relatively large values in the Wilmington area, at stations such as the Northeast Cape Fear at Wilmington and Marker 54. Mean errors at sites upstream of Wilmington generally decreased. Both root-mean-square errors and mean absolute errors were generally more uniform, and were less than 2.0 ppth at most sites (Table 16).

Table 16. Model Calibration Statistics for Salinity at Monitoring Sites Within the Model Region

Station	Mean Error (ppth)	%	RMSE (ppth)	%	Mean Absolute Error (ppth)	%	R^2	No. data points
CF L&D1	-0.05	-100.0%	0.05	100.0%	0.05	101.8%	0.4%	572
Blk Currie	-0.03	-100.0%	0.03	100.0%	0.03	102.1%	9.6%	653
NE Burgaw	-0.05	-100.0%	0.05	100.0%	0.05	102.2%	20.5%	689
NCF6, NECF	0.13	5.9%	2.51	116.6%	3.55	165.0%	0.0%	12
USGS, Navassa	0.72	44.7%	1.42	88.4%	2.35	146.4%	47.4%	510
CF @ Nav	1.77	128.3%	2.15	155.7%	2.81	202.9%	27.9%	12
USGS, NECF Wilm	-1.46	-29.4%	1.94	39.1%	2.80	56.3%	68.9%	1439
Brnswk Riv	0.25	7.5%	1.74	52.2%	2.54	76.2%	30.3%	12
CF,Mrkr 61	-0.04	-0.6%	1.92	28.2%	2.52	37.0%	71.4%	13
M54, CFM54	2.34	27.6%	2.61	30.7%	3.60	42.4%	79.7%	13
M42, CFM42	2.43	22.8%	2.76	25.8%	3.35	31.4%	81.5%	13
USGS, CF Mrkr 12	1.76	13.6%	2.84	21.9%	3.61	27.9%	76.8%	1344
M35, CFM35	0.55	3.8%	2.12	14.3%	2.73	18.5%	75.9%	13
M23, CFM23	-3.92	-18.1%	4.80	22.1%	5.60	25.8%	43.9%	13

Scatter plots of observed vs. predicted salinity also give an indication of the relatively good fit of the model to the observed data. Little bias is seen in the predictions overall, with the points shown to be evenly distributed around the 45-degree line indicating observation = prediction (Figure 36). Model error seems not to vary with the magnitude of model prediction, as the magnitude of the error is similar for relatively low and high salinities. At the low salinity

values, there are many points where zero salinity is predicted but not observed or vice-versa, but there doesn't exist more of one type of error as opposed to the other. The magnitude of the residuals is significant, however, which may be due to the model's relatively poor ability at matching the temporal variations in the extent of salinity intrusion at certain times (see for example Figure 35).

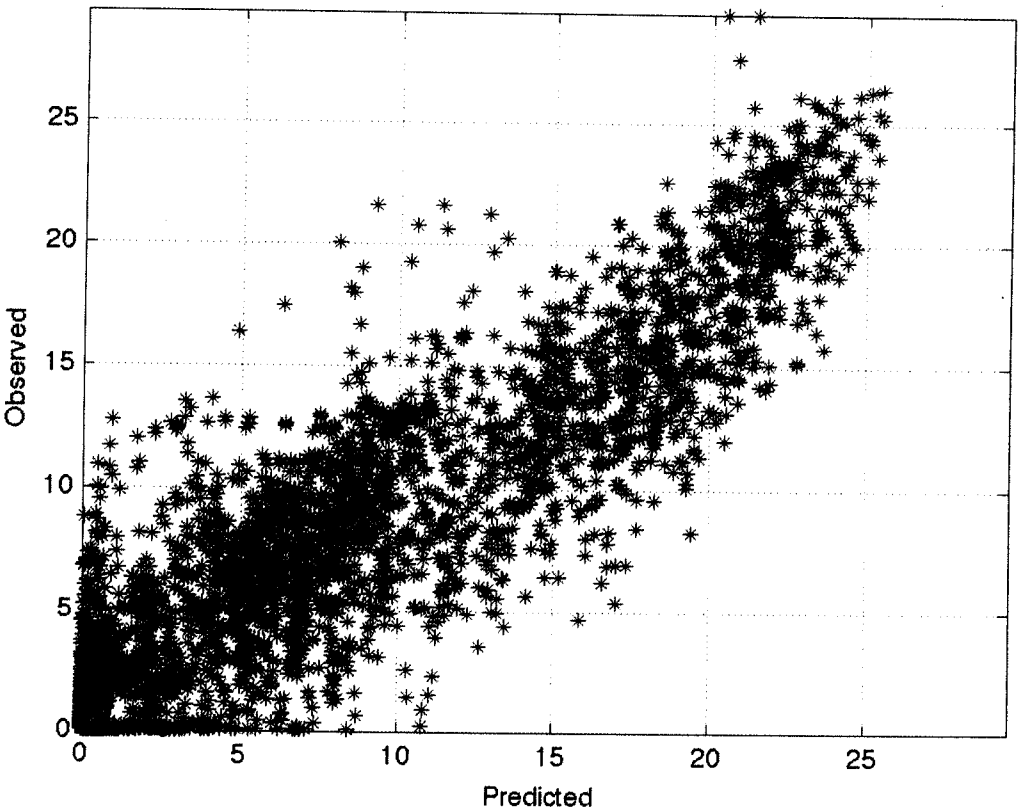


Figure 36. Scatter Plot of Predicted Salinity (ppth, x-axis) vs. Corresponding Observed Salinity (ppth, y-axis).

Percentile plots of observed data and model predictions were also created for the salinity values in the estuary. These percentile plots are useful in assessing how the model predictions values and the corresponding observations are distributed relative to one another. Both model predictions and observed data have approximately 50% of the salinities at zero (Figure 37). At the higher salinity values the model both slightly under and over predicts salinity and the frequency of a particular salinity value. For instance, at the 90th percentile value the observed salinity is 15 ppth. This same salinity value is seen in about only 85% of the model predictions. The lower percentile values, where the salinities are lower also show some error, but in this case the model predictions for a particular salinity value are slightly more frequent than seen in the observations. Over the entire range of salinities, however, there is not a very large difference between the observed and predicted salinities (Figure 37).

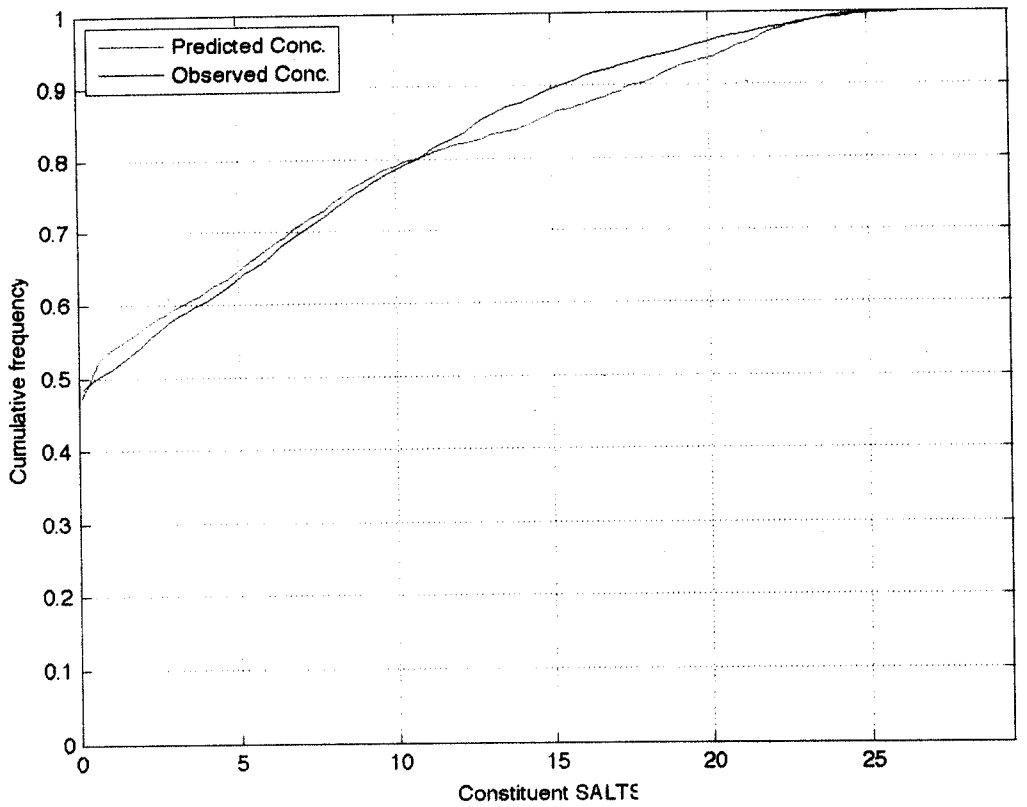


Figure 37. Percentile Plot of Observed and Model Predicted Salinities During the Calibration Period. The y-axis indicates the fraction of values below the corresponding salinity (ppth) indicated on the x-axis.

4.3 Temperature Model Calibration

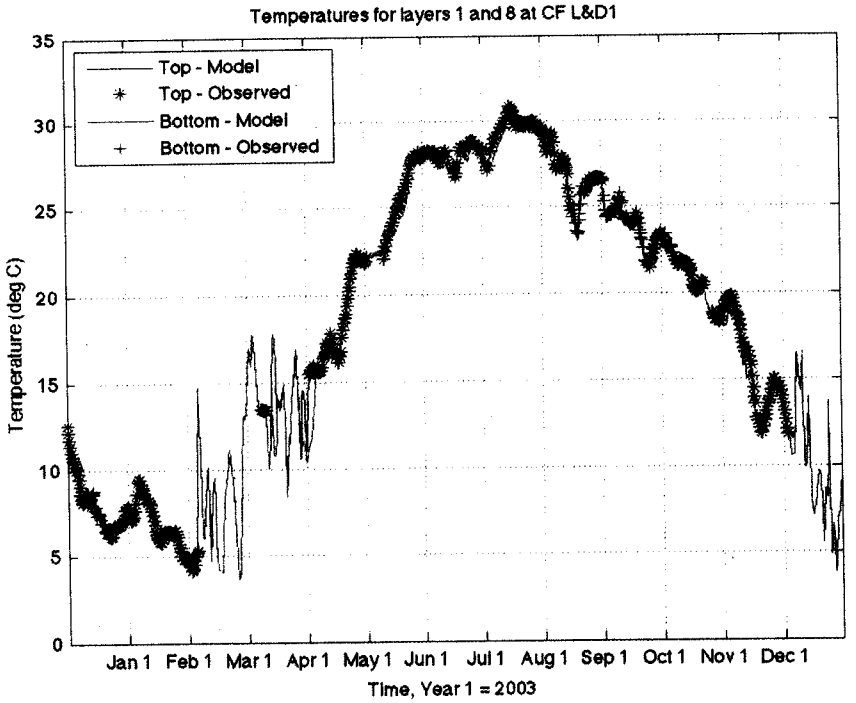
The procedure for assessing the temperature model's calibration performance was very similar to the procedure for salinity. Observations from the twenty-one Lower Cape Fear River Program and USGS stations in the model region (Table 13) were compared. The USGS data were synthesized to produced two hourly-averaged temperatures per day. The Lower Cape Fear River program data were used without any data synthesis. While time histories comparisons were produced at all twenty-one stations, only six representative sites are shown here. Five of the six are the USGS sites where twice daily data are available. Three of the sites are near the upstream model boundary (Cape Fear at Lock and Dam 1, Black River at Currie, Northeast Cape

Fear at Burgaw), and two are in the mesohaline region of the estuary (Navassa, NE Cape Fear at Wilmington, Marker 12). One Lower Cape Fear River Program station from the Northeast Cape Fear River (NCF 117) is shown as well.

The model vs. data time history comparison at the Cape Fear station at Lock and Dam1 is typical of all of the temperature time histories. Model predictions follow the observed data to an excellent extent, with very little difference between model predictions and observed data (Figure 38). In the summertime, the model slightly overpredicts temperatures in the surface layer, but not so in the lower layers at this site. The seasonal variation in temperature from summer to winter is represented very well.

The two stations along the Northeast Cape Fear (Figure 39) and in the mesohaline portion of the estuary (Figure 40) also show an excellent fit between model predictions and observed data. Seasonal variations in temperature are nearly identical between model predictions and observations, and at only one site (Northeast Cape Fear at Wilmington) is there any observable difference between these temperatures. At this one site the model overpredicts summertime temperature by a few degrees.

This excellent degree of model fit is also seen in the other measures of model calibration. The normalized mean error in the model is less than 1%, and the normalized root mean square error is only 5.8% (Table 17). The correlation R^2 is 97.9%, indicating an excellent fit of the model to the observed data. Statistical measures of model fit were also calculated at individual stations (Table 18). All stations had calibration R^2 values above 97% and root mean square errors of less than 9% (Table 18). The scatter plot of observed data vs. corresponding model predictions (Figure 41) and the percentile plot (Figure 42) also indicate the excellent ability of the temperature model to match the observed temperatures.



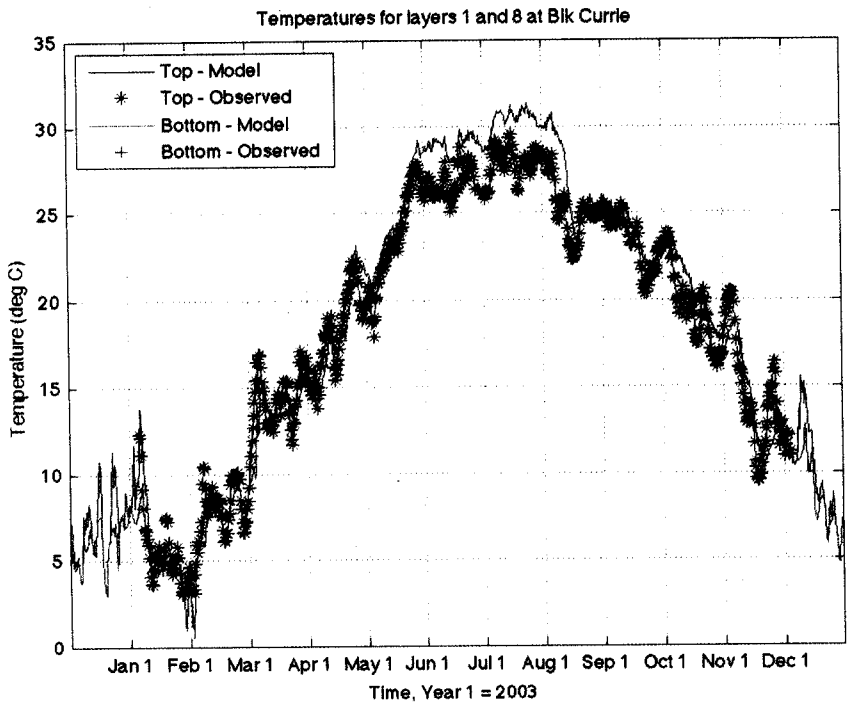


Figure 38. Model Predicted and Observed Temperatures During 2004 at the Cape Fear River at Lock and Dam 1 and the Black River at Currie.

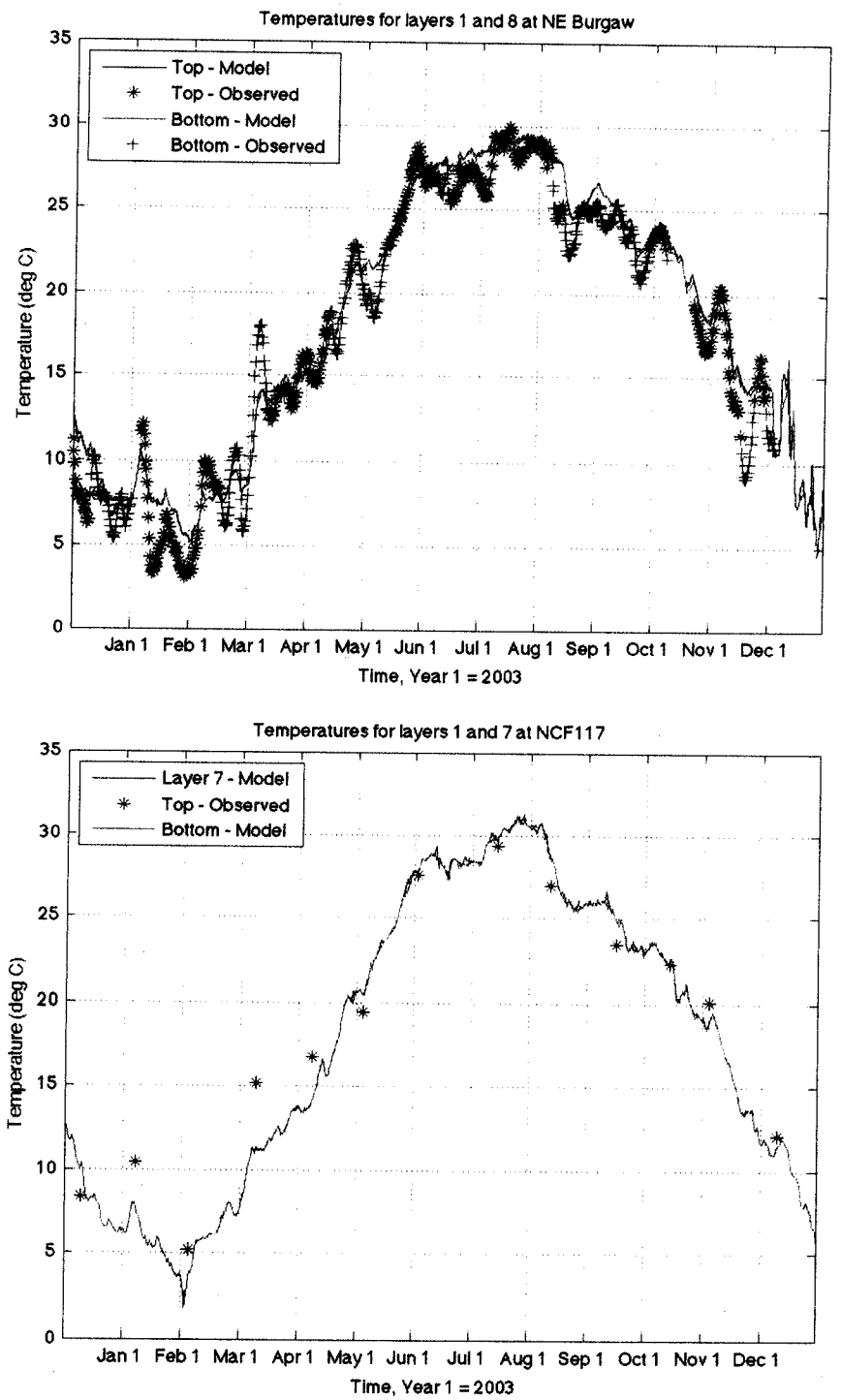


Figure 39. Model Predicted and Observed Temperatures During 2004 at the NE Cape Fear River at Burgaw and at Station NCF 117.

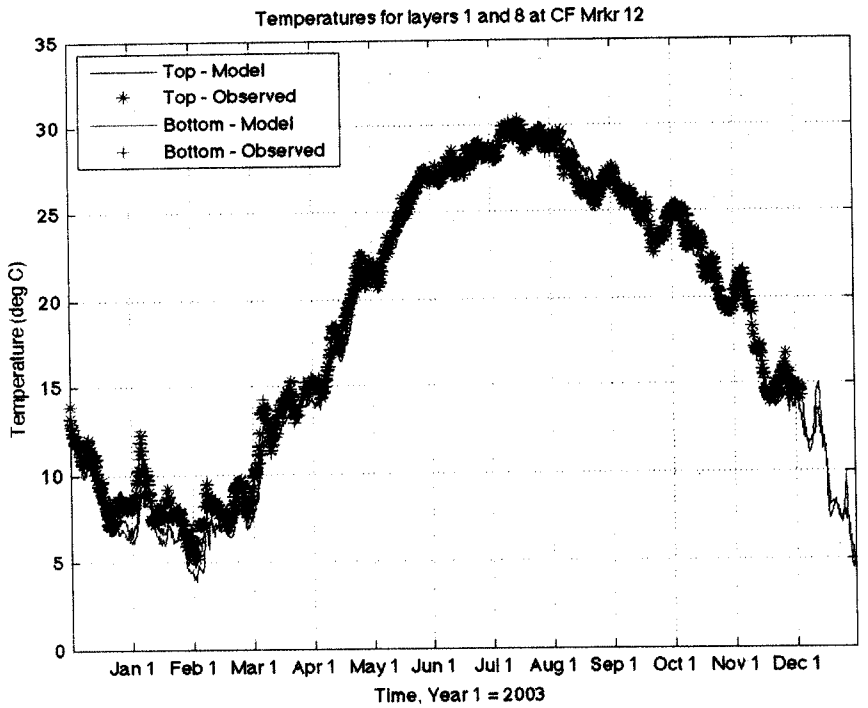


Figure 40. Model Predicted and Observed Temperatures During 2004 at the NE Cape Fear River at Wilmington and the Cape Fear River at Marker 12.

Table 17. Calibration Statistics, Temperature

Parameter	Value	Units
Mean Error (predicted – observed)	**-0.12**	**Deg C**
Normalized Mean Error	**-0.61**	**%**
Root Mean Square Error	**1.12**	**Deg C**
Normalized Root Mean Square Error	**5.8**	**%**
Mean Absolute Error	**0.81**	**Deg C**
Normalized Mean Absolute Error	**4.2**	**%**
Correlation R^2	**98.4**	**%**
Number of Model/Data Comparisons	**6040**	**-**
R^2 Corrected for Bias	**97.9**	**%**

Table 18. Model Calibration Statistics for Temperature at Monitoring Sites Within the Model Region.

Station	Mean Error (ppth)	%	RMS (ppth)	%	MAE (ppth)	%	R^2	No. data points
CF L&D1	-0.21	-1.1%	0.30	1.5%	0.58	3.0%	99.6%	573
NC11, CF	-0.17	-0.7%	0.59	2.7%	0.99	4.4%	98.3%	75
Blk Currie	-0.31	-1.7%	0.63	3.4%	1.01	5.4%	98.4%	653
B210, Blk	-0.66	-3.8%	0.93	5.3%	1.26	7.2%	97.9%	13
AC-CF@Acme	-0.44	-2.0%	0.65	2.9%	0.88	3.9%	98.9%	75
IC, Cape Fear	0.26	1.1%	0.87	3.9%	1.07	4.7%	99.1%	75
NE Burgaw	0.73	4.1%	1.23	6.8%	1.59	8.8%	96.9%	690
NCF117	-0.50	-2.7%	1.49	8.2%	1.84	10.1%	96.3%	13
NCF6, NECF	0.09	0.4%	1.78	8.8%	2.07	10.3%	98.6%	47
Navassa	0.13	0.6%	0.76	3.8%	0.92	4.5%	99.4%	510
CF @ Nav	0.26	1.2%	0.87	3.8%	1.04	4.6%	99.4%	75
HB, CF@HSB	0.14	0.6%	1.06	4.7%	1.36	6.0%	98.6%	74
NECF Wilm	-0.30	-1.6%	1.16	6.1%	1.39	7.3%	99.2%	1462
Brnswk Riv	-0.56	-3.0%	0.92	4.9%	1.29	6.9%	98.9%	39
CF,Mrkr 61	-0.73	-3.6%	1.24	6.1%	1.46	7.2%	99.0%	48
M54, CFM54	-0.63	-3.1%	0.87	4.3%	1.10	5.4%	99.4%	48
M42, CFM42	-0.58	-2.8%	0.85	4.1%	1.15	5.7%	99.0%	48
CF Mrkr 12	-0.25	-1.3%	0.50	2.6%	0.66	3.4%	99.5%	1429
M35, CFM35	-0.58	-2.8%	0.82	4.0%	1.15	5.6%	98.7%	48
M23, CFM23	-0.40	-2.0%	0.96	4.8%	1.22	6.1%	97.7%	45

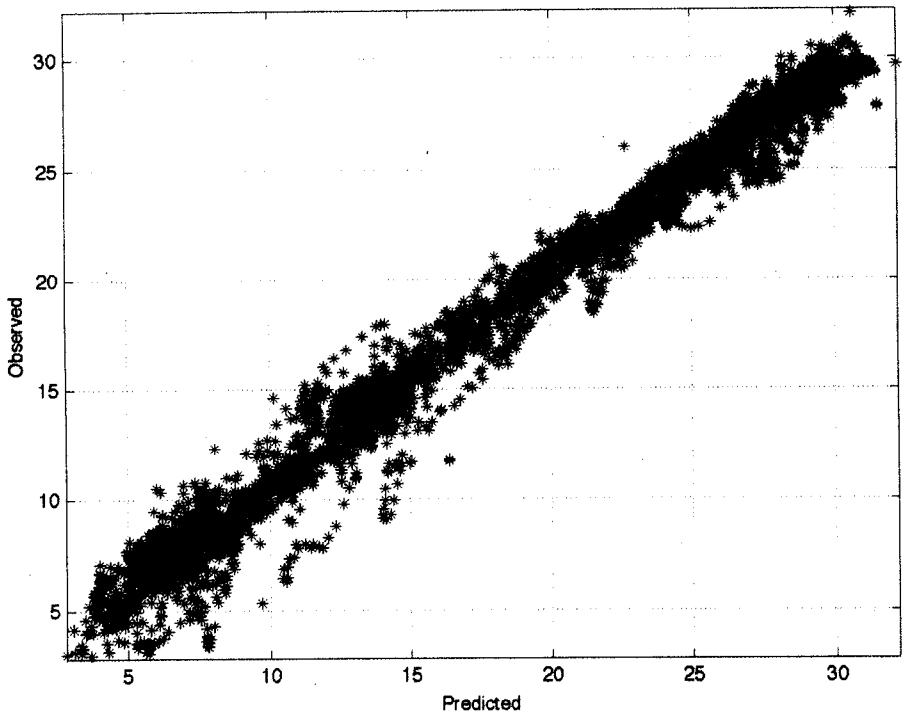


Figure 41. Scatter Plot of Predicted Temperature (°C, x-axis) vs. Corresponding Observed Temperature (°C, y-axis) During the 2004 Calibration Run.

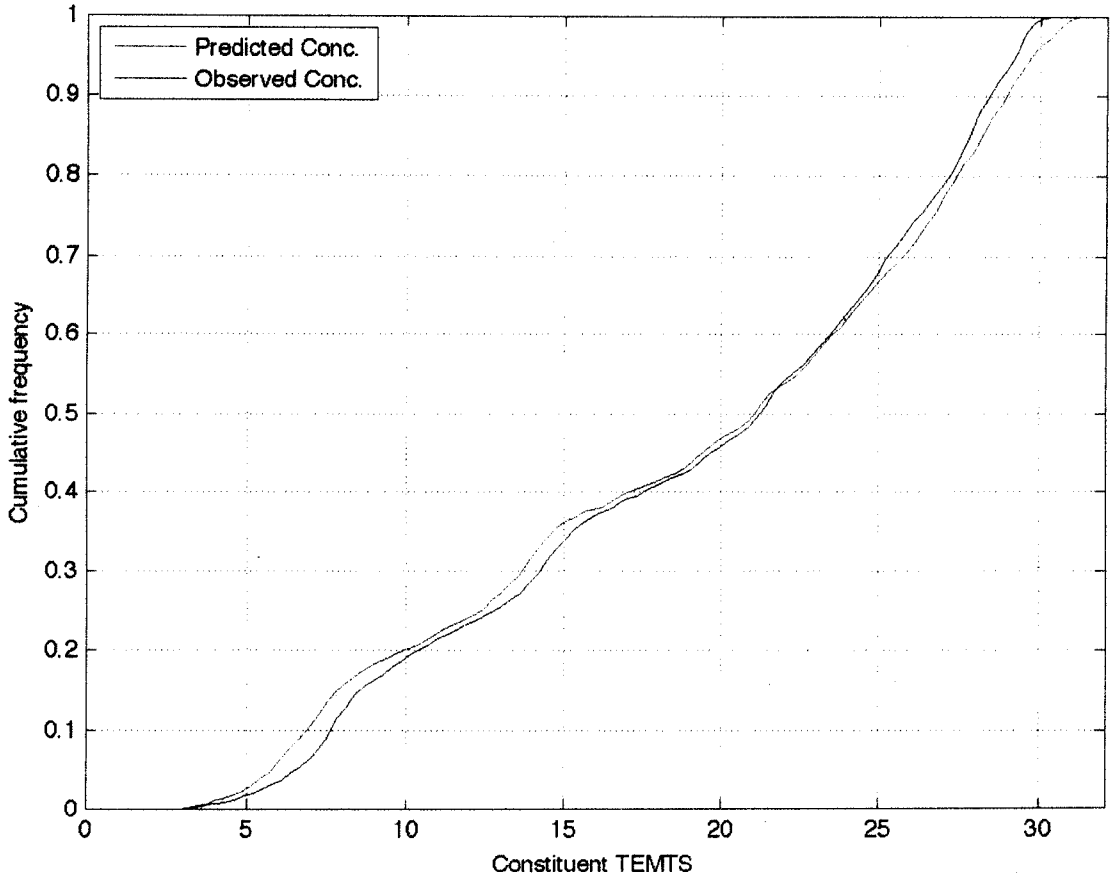


Figure 42. Percentile Plot of Observed and Model Predicted Temperatures During the 2004 Calibration Period. The y-axis indicates the fraction of values below the corresponding temperature (°C) indicated on the x-axis.

Overall the hydrodynamic model's level of calibration performance is as good, or even better than other hydrodynamic models of North Carolina estuaries (e.g. Bowen 2000). Each component of the hydrodynamic model (hydrodynamics, temperature, conservative transport) fits well the seasonal and event-related dynamics within the system. Examination of time histories in the impaired region indicate the hydrodynamic model is capable of simulating conditions in this part of the estuary. Based upon this evaluation, the hydrodynamic model seems suitable for use as part of the water quality evaluation.

4.4 Water Quality Model Calibration

Following the procedures described in section 2, the input files necessary to run the water quality model were quantified. Specifically, the loadings of all constituents from all water sources where flows were specified in the QSER.INP file were quantified in the WQPSL.INP file. A total of 37 sources of water were quantified this way (Table 9), which required quantifying loads for all 21 constituents (Table 1). These loads were calculated with a procedure that utilized conversion matrix tables that quantified how constituent loading was calculated from the available monitoring data. Twenty-three such conversion tables (Appendix A) were needed to quantify these sources. At the model southern open boundary, concentrations were specified either as a time history or in the water quality control file WQ3DWC.INP (see Appendix D).

During calibration, predicted dissolved oxygen concentrations were compared to observed data at the same twenty-one stations used for hydrodynamic model calibration (Table 14, Figure 19). The USGS continuous monitoring data were synthesized to give two hourly averaged dissolved oxygen values per day. The Lower Cape Fear River Program data were generally collected monthly during the non-summer months, and bi-weekly during the summer. These twice-daily data were combined with the LCFRP data to create an extensive calibration data set that had frequent measurements of DO at stations throughout the estuary and somewhat less frequent measures of other water quality constituents. During calibration, kinetic values in the water quality model were adjusted to improve the fit between model predicted water quality concentrations and observed data. Model/data comparisons were made of the following water quality measures:

- Dissolved oxygen (mg/L)
- Total chlorophyll-a (μg/L)
- Total phosphorus (mg/L as P)
- Ammonia (mg/L as N)
- Nitrite/nitrate (mg/L as N)

Multiple measures were used to quantify the model's fit to the observed data, just as was done during hydrodynamic calibration. As described earlier the following measures were analyzed for each model run during calibration, (see Thomann 1982 or Tetra Tech 2001 for explanation of the measures):

- Mean error (absolute and normalized by mean of observations)
- Mean absolute error (absolute and normalized by mean of observations)
- Root mean square error (absolute and normalized by mean of observations)
- Correlation r^2
- Bias corrected r^2, also known as model efficiency

The calibration had the following multiple objectives

- Use water quality kinetics parameter values that fall within the expected range of values for temperature estuaries (Bowie et al. 1985),

- Produce predicted water quality concentrations that qualitatively agree with the expected seasonal and spatial variations for temperature estuaries,
- Produce predicted water quality concentrations that simultaneously minimized mean error, mean absolute error, and root mean square error
- Produce predicted water quality concentrations that maximum correlation r^2 and bias corrected r^2,
- Produce predicted water quality concentrations with a cumulative frequency distribution that was a close approximation of the observed distribution over the full range of percentiles.

A phased approach to water quality calibration was undertaken. The calibration phasing was done in such a way that recognized the expected relative importance of processes in the estuary's dissolved oxygen budget, and the inherent dependencies between water quality constituents. Thus, special importance was given to maximizing the model's fit to observed dissolved oxygen concentrations. Calibration phasing was done as follows:

- Calibrate first the sediment oxygen demand to give a reasonably low mean error for dissolved oxygen concentrations,
- Calibrate the nitrification rate to give an acceptable value for the mean error for ammonia concentrations within the estuary,
- Calibrate the phytoplankton group specific maximum growth rates, temperature optima, and half-saturation constants for nutrient concentrations to give a reasonable seasonal pattern of total chlorophyll-a concentrations,
- Calibrate the phytoplankton stoichiometric ratios (C/Chl, C/N, C/P) to give acceptable mean errors for total P and total N concentrations
- Calibrate the benthic flux rates for nitrate/nitrite to give an acceptable value for the mean error of nitrite/nitrate concentrations in the water column,
- Calibrate again the sediment oxygen demand to give acceptable error statistics and cumulative frequency distributions for dissolved oxygen,
- Check the statistical measures of model fit for the remaining water quality constituents, and repeat the calibration procedure if warranted.

At the conclusion of this calibration procedure, a complete set of calibrated water quality kinetic parameters was produced for the base case calibration run. These water quality kinetic parameters were then used for all subsequent model confirmation and scenario testing model runs. All of these parameters except SOD are specified in EFDC's water quality control file (see file WQ3DWC.INP, Appendix D). Benthic fluxes are specified in a separate file (benflux_tser.inp, Appendix E).

Of particular interest in the water quality modeling was the point source loadings of oxygen demanding wastes. In the EFDC water quality model as applied here, three EFDC constituents present in the point source loadings accounted for the water-column oxygen demand, refractory dissolved organic carbon (RDOC – in table 1 RDOC is shown as RPOC), dissolved organic carbon (DOC), and ammonia. The RDOC load was found to come primarily from the Cape Fear River inflow, and to a lesser extent the estuary inflows (Figure 43). The

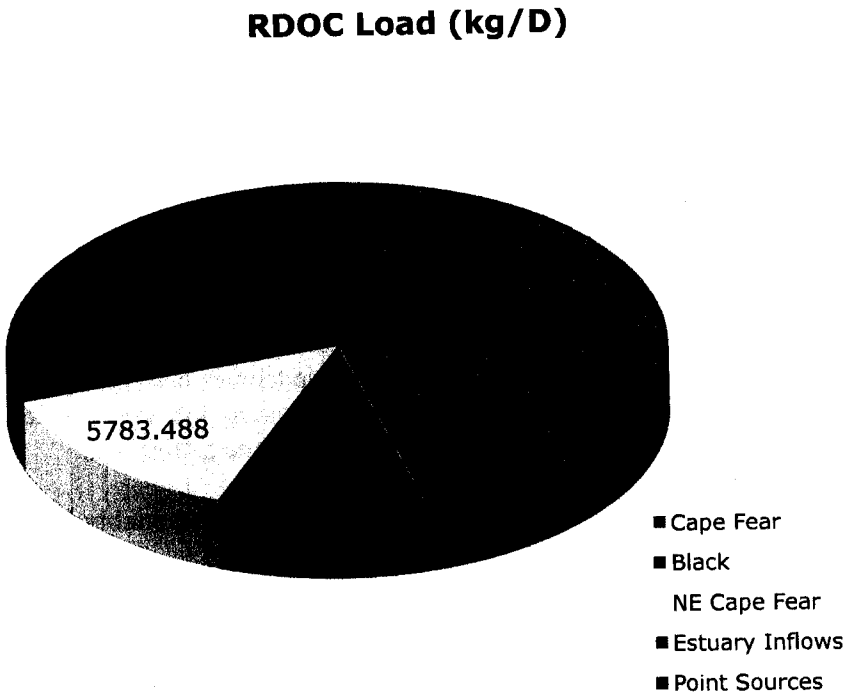


Figure 43. Average Daily Load of Refractory Dissolved Organic Carbon to the Model Region from Various Sources

source contribution to the RDOC loading was relatively small (Figure 43). Likewise, more than half of the DOC load came from the Cape Fear River inflow, while the other four categories of sources (Black River, NE Cape Fear River, estuary inflows, and point sources) were of roughly equal magnitude (Figure 44). The ammonia loading distribution was quite different, with point sources contributing more than half of the total loading, and only small contributions from the Black and Northeast Cape Fear rivers and the estuary inflows (Figure 45).

An additional sink of dissolved oxygen results from the transport of water-column oxygen to satisfy the sediment oxygen demand (SOD). As described in previous sections, an SOD measurement program conducted by the NC Division of Water Quality collected SOD measurements at five locations (Figure 9) during the Summer and Fall of 2003 (Table 13). Initially these data were used to quantify a time-averaged SOD rate that was applied over the entire model grid. During calibration it was found that this strategy resulted in overpredictions of dissolved oxygen concentration in the summer and underprediction during the winter. For this reason, it was decided to introduce a temperature dependence to the SOD specification. The SOD data were fit with the following temperature dependent model:

$$SOD(t) = SOD(20) \times \Theta^{T-20} \qquad (2)$$

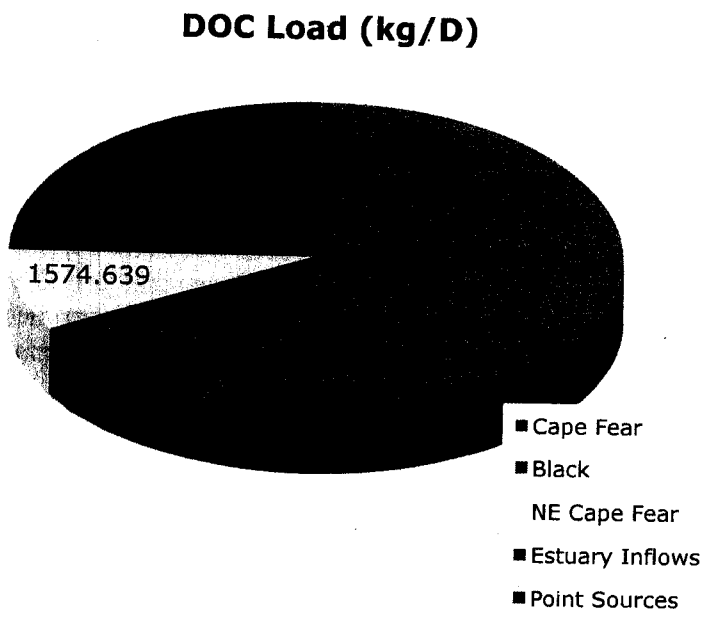


Figure 44. Average Daily Load of Dissolved Organic Carbon to the Model Region from Various Sources

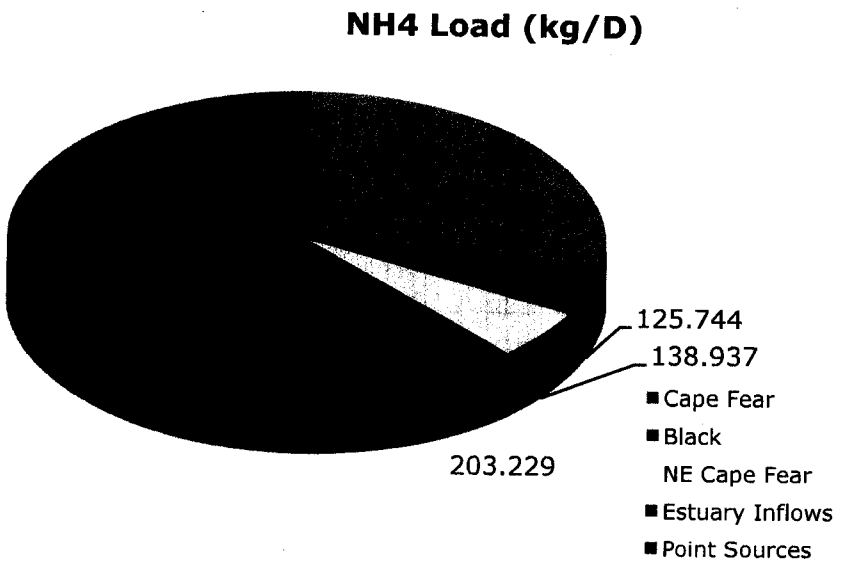


Figure 45. Average Daily Load of Ammonia to the Model Region from Various Sources.

where SOD(t) and SOD(20) is the sediment oxygen demands at the desired temperature and at 20° C, and Θ is an empirical temperature multiplier. When fit to this model (Figure 46), the SOD data produced a SOD(20) of 0.4 $g/m^2/d$ and a temperature multiplier of 1.058. Using this SOD model and spatially averaged observed temperatures, an SOD time history file was created for input to the model. Using this approach it was found during calibration that the model consistently overpredicted dissolved oxygen concentrations in all three of the Northeast Cape Fear stations. This overprediction was confined to these stations, which indicated that SOD values for these stations should be increased for the cells within the Northeast Cape Fear river basin. During calibration an additional factor was introduced that gave the ratio of SOD in the NE Cape Fear and the rest of the model region. This factor was determined during calibration to give the best fit with a value of 1.5. In this way SODs were given temperature and spatial variation during the model

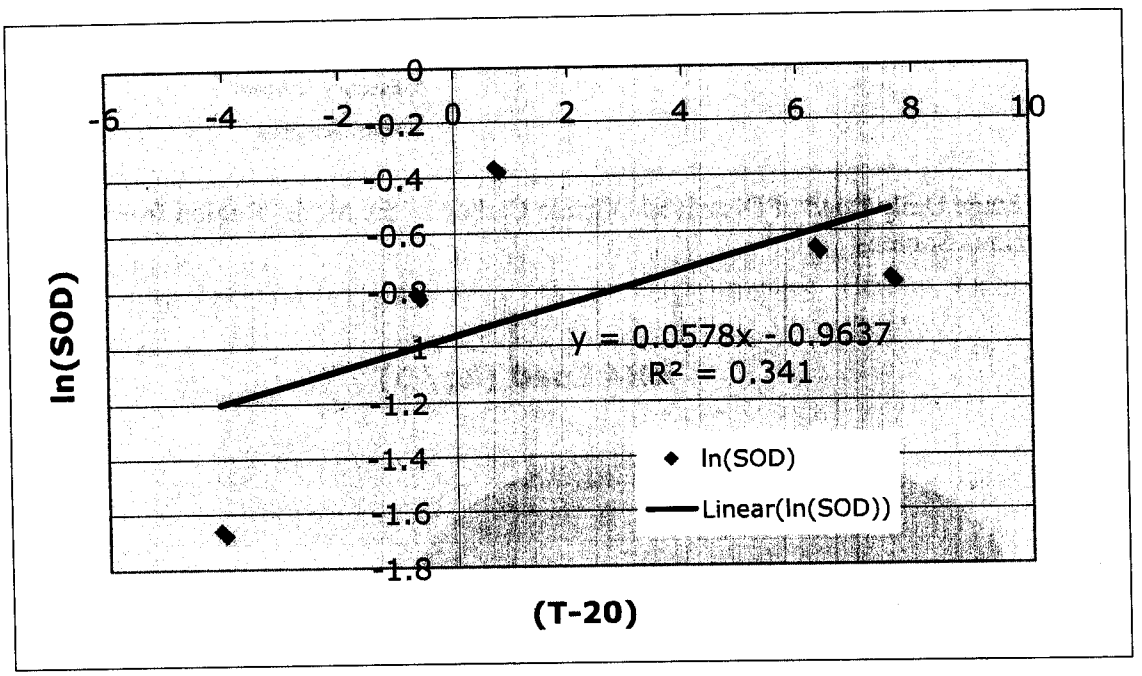


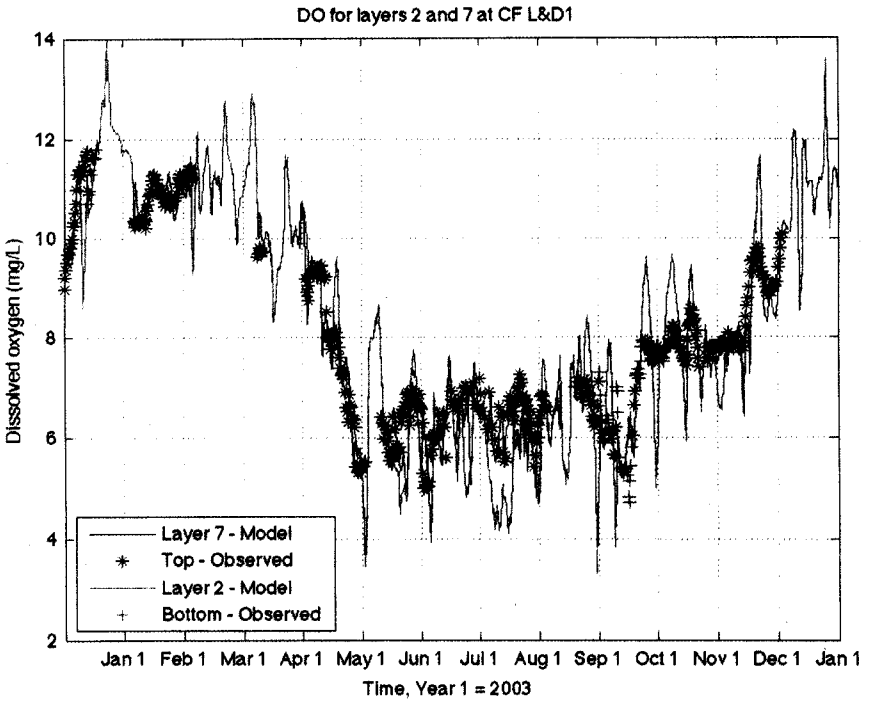
Figure 46. Natural Logarithm of Measured Sediment Oxygen Demand (y-axis) vs. Deviation from 20 Degree °C Measured Temperature (x-axis).

Time history comparisons of observed vs. predicted dissolved oxygen concentrations were used to assess water quality model calibration performance. Here we show these time histories at seven stations, the six USGS stations used previously, and one LCFRP station in the Northeast Cape Fear River (NCF117) that was presented earlier when showing temperature time

histories. In general the time history comparisons show an excellent calibration performance for dissolved oxygen. At the two of the USGS sites in the oligohaline sites (Cape Fear at Lock and Dam 1, Black at Currie), the model closely tracks the seasonal variation in dissolved oxygen, whereby the summertime DO concentrations are low and the wintertime DO concentrations are relatively high (Figure 47). As seen in the temperature time history, some density stratification seems to be present at the Black River site, which seems to produce a relatively low DO concentration in the bottom waters (Figure 47). The surface DO concentration value, however, follows the observed data closely throughout the 2004 calibration period (Figure 47).

The two oligohaline stations along the Northeast Cape Fear produced interesting model results. The upper site (NE Cape Fear at Burgaw) had model predictions and observations that agreed well with one another, but at the more downstream site (NCF 117), the model generally overpredicted the DO concentration (Figure 48). During the summer months at this station the observed DO concentrations were approximately four mg/L while the model predictions were approximately six mg/L. A similar discrepancy was seen further downstream along the NE Cape Fear at the Wilmington site (Figure 49). Once again the observed data, this time from a USGS continuous water quality monitor showed DO concentration through the summer of approximately 4.0 mg/L. The model predictions are higher, but are closer to the observed data than at station NCF 117. The overprediction of DO concentration here is approximately 1 mg/L (Figure 49).

At the other station in the impaired area (Cape Fear at Navassa), the model fits the observed DO concentration very well (Figure 49). Both summertime and wintertime conditions are predicted well, as are more short-term changes during the summer months. The observed concentrations at the station south of Wilmington (Marker 12), showed significantly more variation in dissolved oxygen (Figure 50) than the other two sites in the mesohaline portion of the estuary. Nonetheless, the model did a good job of simulating the dynamic changes in the DO concentrations that occurred throughout the 2004 calibration period (Figure 50). In general the model predictions are somewhat less variable than the observed data, but the model does do a particularly good job of simulating the temporal changes in the minimum dissolved oxygen concentrations that occur through the summer months (Figure 50).



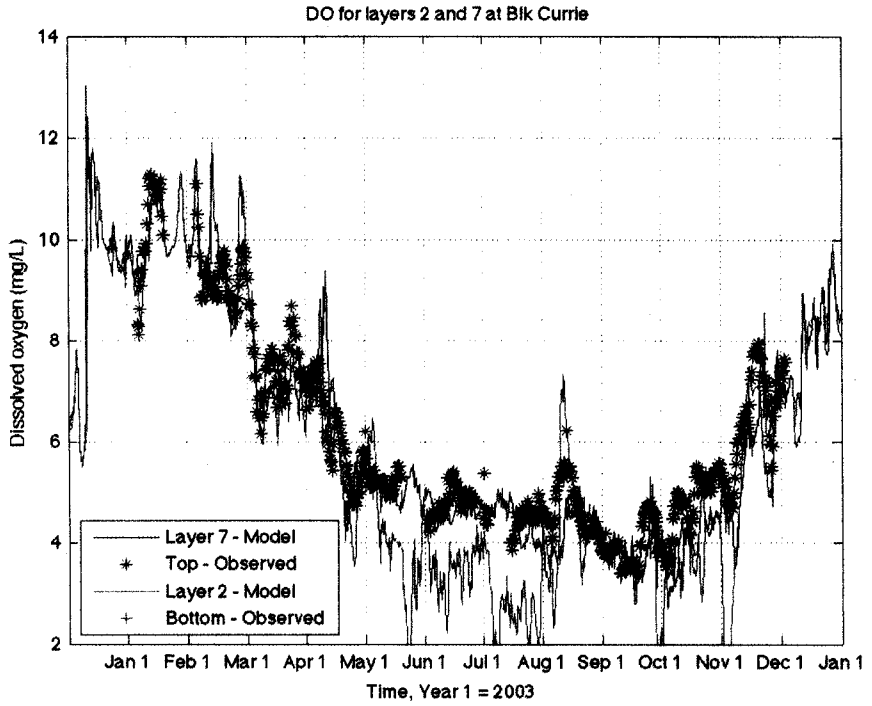


Figure 47. Model Predicted (lines) and Observed (symbols) Dissolved Oxygen Concentrations During 2004 at the Cape Fear River at Lock and Dam1 and the Black River at Currie.

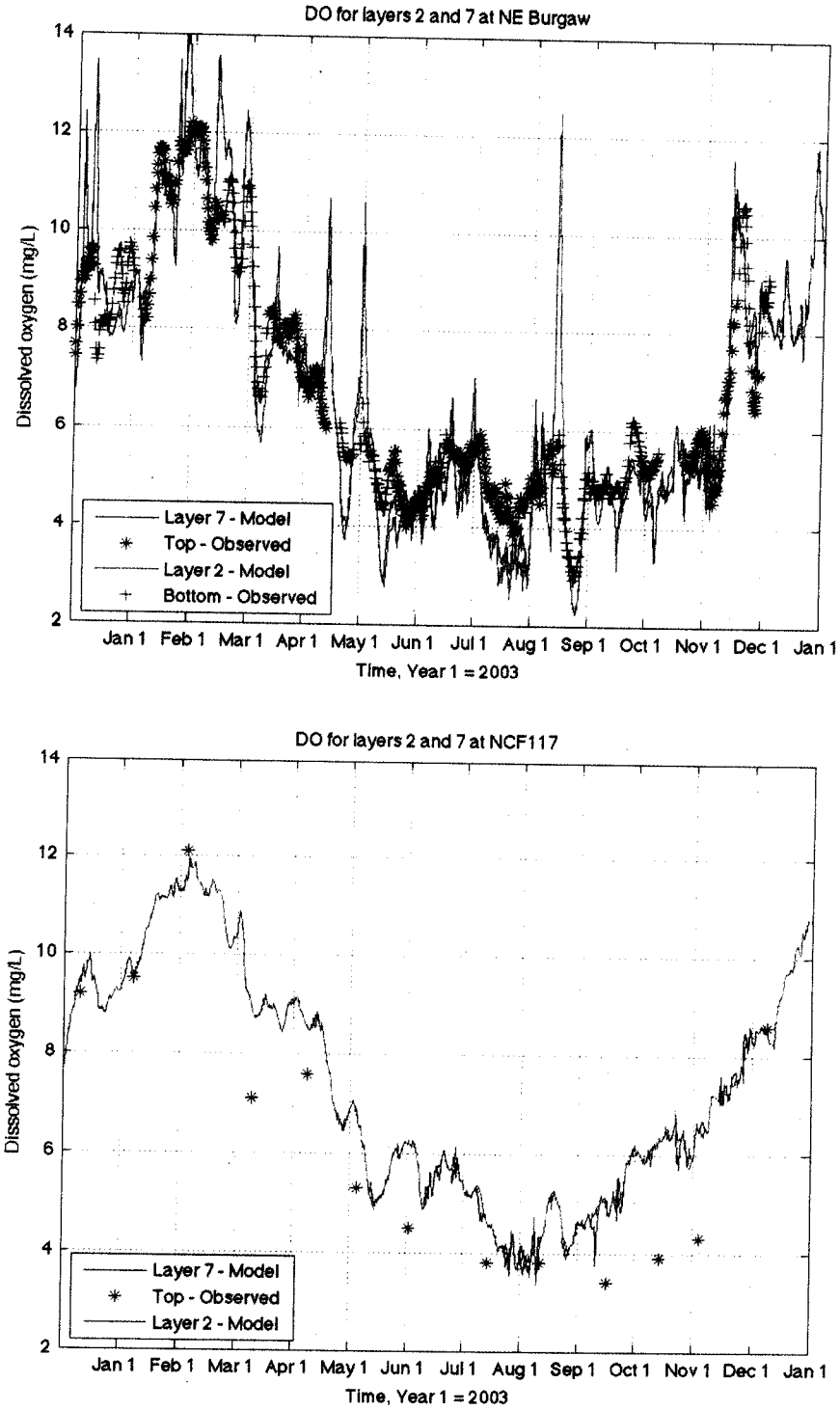
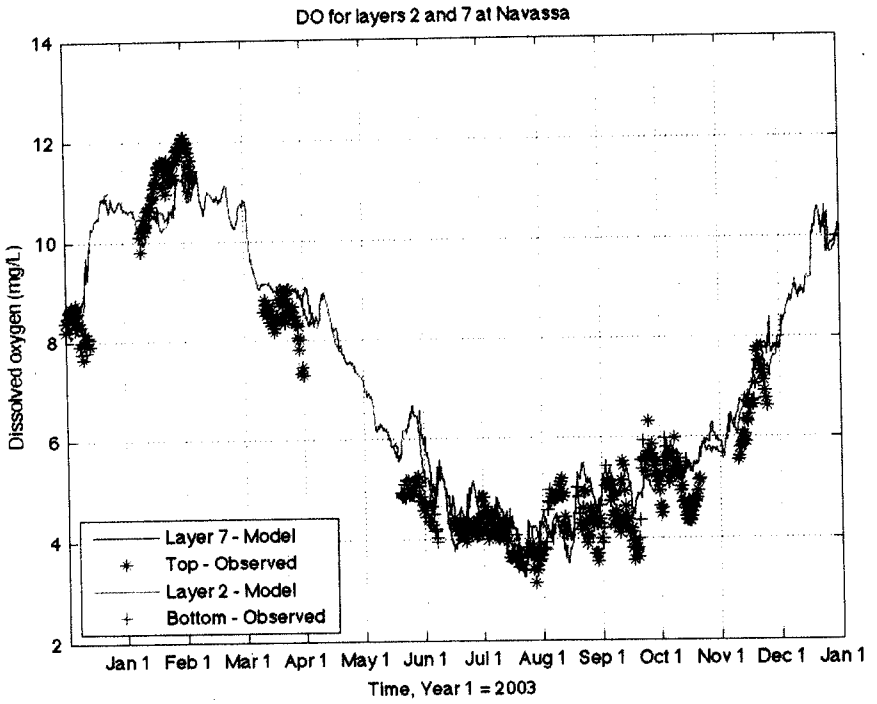


Figure 48. Model Predicted (lines) and Observed (symbols) Dissolved Oxygen Concentrations During 2004 at the NE Cape Fear River at Burgaw and Station NCF 117.



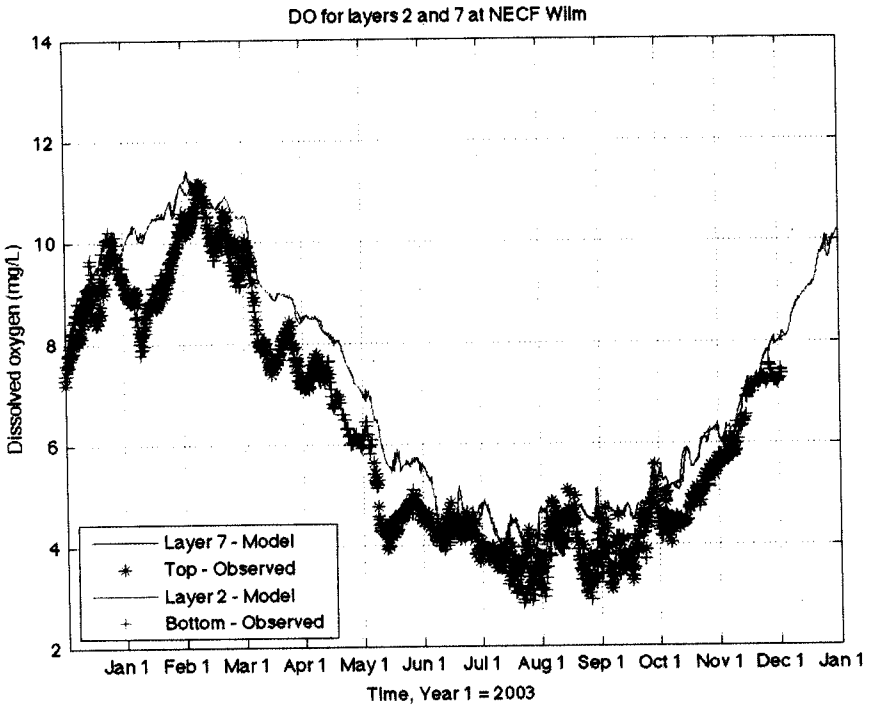


Figure 49. Model Predicted (lines) and Observed (symbols) Dissolved Oxygen Concentrations During 2004 at the Cape Fear River at Navassa and the NE Cape Fear River at Wilmington.

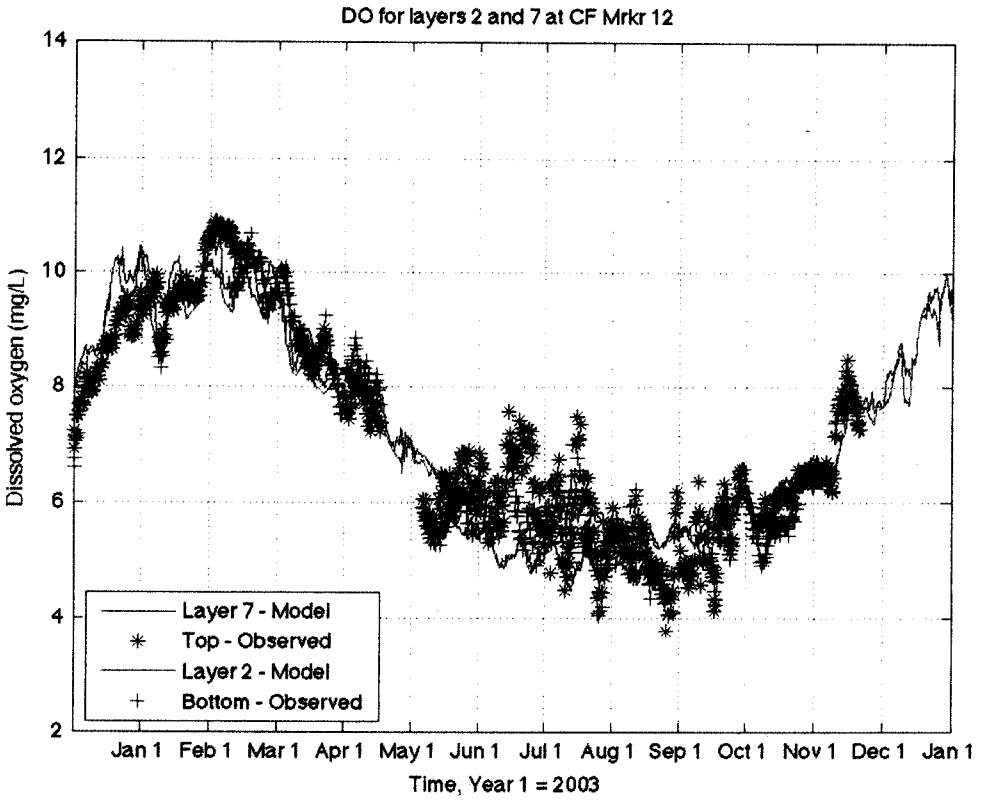


Figure 50. Model Predicted (lines) and Observed (symbols) Dissolved Oxygen Concentrations During 2004 at the Cape Fear River at Marker 12.

Statistical measures of model fit demonstrate the model's ability to simulate the temporal and spatial differences in DO concentration. As for the hydrodynamic model calibration, the calibration statistics are based on model/data comparisons at all twenty-one sites. The USGS sites use hourly average values that have been sampled at two times per day, at twelve hour intervals. The Lower Cape Fear River Program data comes from boat-based sampling that occurred at a variable frequency – as often as weekly during the summer months and stretching to monthly during the winter months. A total of 5,274 model/data comparisons were used to assess model calibration performance for dissolved oxygen. The mean error for dissolved oxygen concentration (predicted – observed) was -0.06 mg/L, which represented a mean error of 0.86% (Table 19). Root mean square errors and mean absolute errors were 0.90 mg/L and 0.69 mg/L respectively, which gives normalized errors of 13.4% and 10.3% respectively. The correlation R^2 for dissolved oxygen model predictions relative to the observed data was 85.4%, or 83.5% when the correlation coefficient is corrected for model bias (Table 19). In general this is excellent calibration performance for an estuary dissolved oxygen model.

Table 19. Calibration Statistics, Dissolved Oxygen

Parameter	Value	Units
Mean Error (predicted – observed)	**0.005**	**g/m^3**
Normalized Mean Error	**0.06**	**%**
Root Mean Square Error	**0.92**	**g/m^3**
Normalized Root Mean Square Error	**13.8**	**%**
Mean Absolute Error	**0.73**	**g/m^3**
Normalized Mean Absolute Error	**13.8**	**%**
Correlation R^2	**84.4**	**%**
Number of Model/Data Comparisons	**5274**	**-**
R^2 Corrected for Bias	**82.7**	**%**

Statistical measures of model fit were also calculated at individual stations (Table 20). The mean error statistics show that the majority of the stations in the Black and Cape Fear Rivers had predicted dissolved oxygen concentrations that were generally under predicted with respect to observed values, while the predictions in the Northeast Cape Fear were slightly above the observed values. Most stations had a mean error of less than 0.5 mg/L. Root mean square errors were similar to that seen for the cumulative data (13.4%, Table 19). Correlation r^2 values ranged from a low of 67.3% at station B210 to a high of 96.3% at Marker 61 in the Cape Fear. Correlation r2 in the impaired region of the estuary near Wilmington were generally near or above 90% (Table 20).

The scatter plots of observed vs. predicted dissolved oxygen concentration also indicate the excellent agreement between model prediction and observation. There is little or no bias in the model predictions, and the residuals appear to be of uniform magnitude across the range of predicted dissolved oxygen concentrations (Figure 51). There are a few values in which the model badly overpredicts DO concentration, but compared to the more than 5,000 model/data comparisons, the number of badly predicted DO concentrations is very small (Figure 51).

Equally impressive is the close agreement between model predictions and observations as seen in the percentile plot. The distribution of DO concentrations in the model predictions matches almost exactly that seen in the observations (Figure 52). Of special interest is the fact the number of relatively low DO concentrations, say for example the percentage of values below 4.0 mg/L is near identical (10%) for both the model predictions and the observed data. Only at the very lowest DO concentrations is there any discrepancy between the two distributions. At these lowest DO concentrations, it appears the observed data have slightly higher percentiles, although the magnitude of the differences (e.g. 0% vs. 3% at 3.0 mg/L) is relatively small (Figure 52).

Table 20. Model Calibration Statistics for Dissolved Oxygen at Monitoring Sites Within the Model Region.

Station	Mean Error (ppth)	%	RMS (ppth)	%	MAE (ppth)	%	R^2	No. data points
CF @ L&D1	-0.18	-2.3%	0.66	8.3%	0.89	11.2%	81.8%	509
NC11, CF	-0.87	-11.1%	1.11	14.1%	1.31	16.6%	79.8%	75
Blk. @ Currie	-0.62	-10.4%	0.88	14.7%	1.13	18.8%	85.8%	571
B210, Blk	-1.43	-19.9%	1.59	22.2%	2.02	28.2%	66.9%	13
CF @ Acme	-0.76	-10.2%	0.96	12.8%	1.22	16.4%	81.7%	75
IC, CF	-0.05	-0.7%	0.61	9.8%	0.76	12.1%	90.4%	75
NE Burgaw	-0.18	-2.7%	0.82	12.1%	1.09	16.1%	85.3%	671
NCF117	1.01	15.7%	1.05	16.4%	1.32	20.6%	92.7%	13
NCF6, NECF	-0.71	-11.1%	1.03	16.0%	1.30	20.3%	82.5%	47
Navassa	0.23	3.7%	0.57	9.3%	0.68	11.1%	93.7%	433
CF @ Nav	-0.43	-6.8%	0.68	10.9%	0.82	13.0%	92.3%	75
CF @ HSB	-0.15	-2.6%	0.61	10.1%	0.76	12.5%	91.5%	74
NECF Wilm	0.74	11.7%	0.78	12.2%	0.90	14.1%	95.6%	1297
Brnswk Riv	-0.45	-6.0%	0.73	9.7%	0.99	13.1%	89.3%	39
CF @ M61	0.11	1.6%	0.46	6.8%	0.58	8.6%	95.7%	48
CF @ M54	-0.24	-3.4%	0.62	8.9%	0.74	10.6%	90.0%	48
CF @ M42	-0.53	-7.3%	0.80	11.0%	0.92	12.7%	86.0%	48
CF Mrkr 12	-0.16	-2.3%	0.59	8.5%	0.74	10.8%	82.4%	1070
CF @ M35	-0.54	-7.3%	0.79	10.7%	0.93	12.6%	83.4%	48
CF @ M23	-0.40	-5.3%	0.62	8.2%	0.75	10.0%	84.5%	45

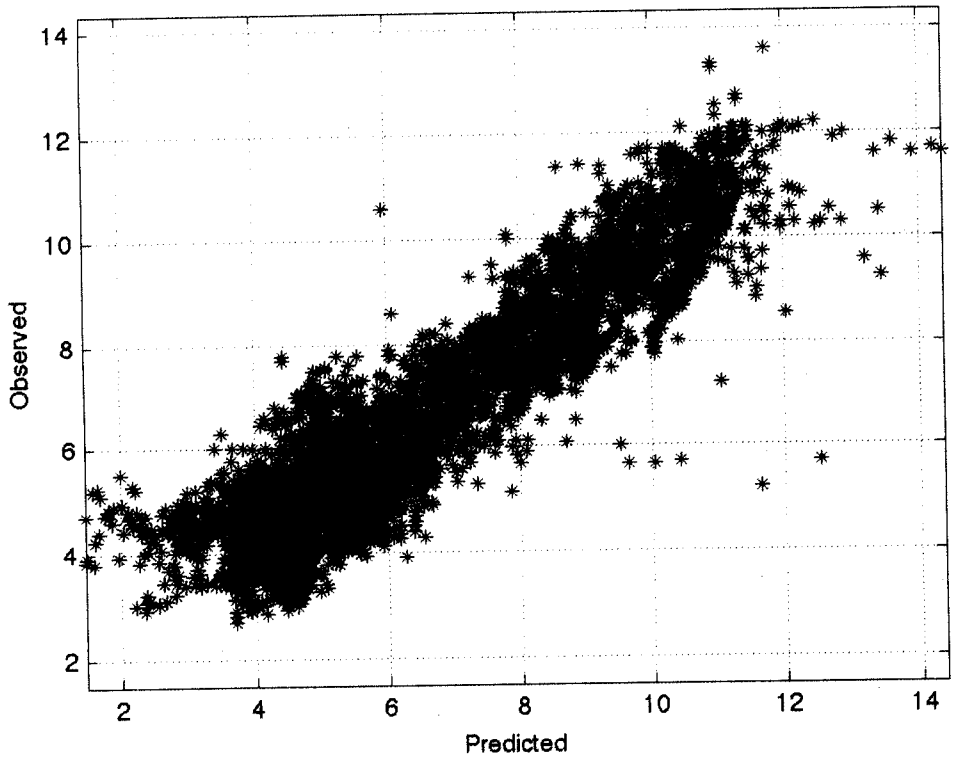


Figure 51. Scatter Plot of Predicted Dissolved Oxygen Concentrations (mg/L, x-axis) vs. Corresponding Observed Dissolved Oxygen Concentrations (mg/L, y-axis) for the 2004 Calibration Period.

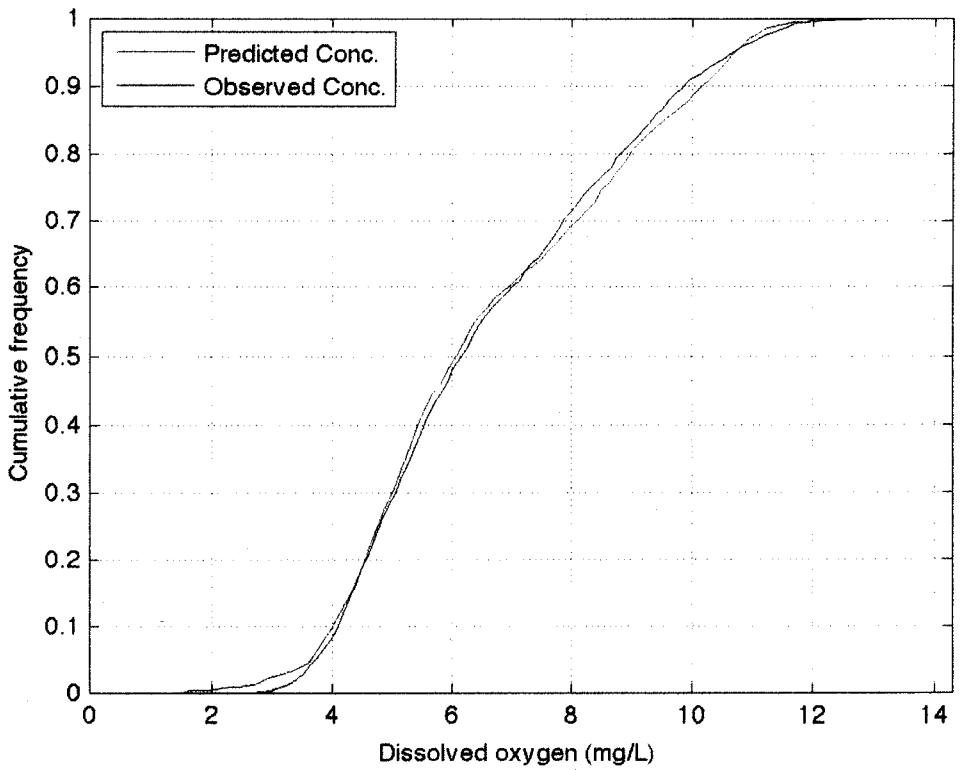


Figure 52. Percentile Plot of Observed and Model Predicted Dissolved Oxygen Concentrations During the Calibration Period. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

On the following pages time histories comparisons are shown for several other key constituents in EFDC's water quality model:

- Ammonia nitrogen
- Nitrate+nitrite nitrogen
- Total phosphorus
- Total chlorophyll-a

These constituents were chosen for presentation because they represent key information on how organic matter is cycling between organic and inorganic pools within the estuary. Time histories are shown for each of these constituents at the following six sites:

1. Cape Fear River at NC 11
2. Black River at B210
3. Northeast Cape Fear at NCF6
4. Cape Fear River at IC
5. Cape Fear River at Navassa
6. Cape Fear River at Marker 23

These six sites, all monitored by the Lower Cape Fear River Program span the entire model region. Each set of model predicted vs. observed data time histories shows the water quality model's capability to simulate water quality dynamics within the system.

Ammonia concentrations at the six sites (Figures 53-55) are generally less than 0.5 mg/L but are occasionally higher in the summertime. The monitoring data at certain sites (e.g. Black River site B210, and Northeast Cape Fear site NCF6) shows a relatively large amount of sample-to-sample variability. In general the monitoring data are more variable in time than the model predictions. There are no significant spatial or temporal trends in either the monitoring data or model predictions. For instance, the lowest concentrations were seen upstream in the Black River and downstream at Marker 23 (Figures 53 and 55).

Nitrate+nitrate (NOx) concentrations (Figures 56-58) are generally higher in the oligohaline portion of the estuary and are always higher than total phosphorus concentrations (Figure 59-61). The lowest NOx concentrations are at station M23 (Figure 58). The model does a good job of representing these spatial trends. There are no detectable temporal trends in the monitoring data for nitrate+nitrite. Total phosphorus (TP) concentrations show a similar spatial trend, with the highest total phosphorus concentrations in the oligohaline portion of the estuary and the lowest concentrations near the estuary mouth. As for ammonia, the monitoring data shows a large amount of sample variability in total phosphorus concentration. There is no detectable temporal trend either in the monitoring data or the model predictions, although there do seem to be episodic increases in TP concentrations. As for ammonia, the model predictions are less variable in time than the observed data (Figures 59-61).

Total chl-a concentrations are always than 10 μg/L, but do show some significant increases during summertime events (Figures 62-64). Model predictions also show temporal variability, with two distinct peaks occurring at each station, although interestingly, the timing of the peak differs from station to station. For instance at station M23 the peaks occur in the March and July (Figure 64), whereas in the Northeast Cape Fear the peaks occur in May and October. These differences in the timing of the chlorophyll peaks are probably related to differences in timing of nutrient supply between these two areas of the estuary. The overall level of variability in the observations and in the model predictions are similar to one another (Figures 62-64).

Overall the water quality model's calibration performance was considered acceptable for its use as part of a dissolved oxygen TMDL. Calibration performance for the DO model was excellent, with statistical measures of calibration performance indicating that the model does an excellent job of capturing the observed spatial and temporal variability in dissolved oxygen concentrations. Correlation r^2 values at individual sites and overall are comparable, if not better, than those expected for estuarine water quality models. The model's predictions of other water quality constituents are also good. While for these constituents, the model's capability to match observed spatial and temporal patterns is not as good as for dissolved oxygen, the model is able to match the overall concentration level seen across the estuary during the calibration period. Together this information provides confidence that the model is suitable for its intended use, to estimate the system's dissolved oxygen response to changes in the discharge of oxygen demanding waste.

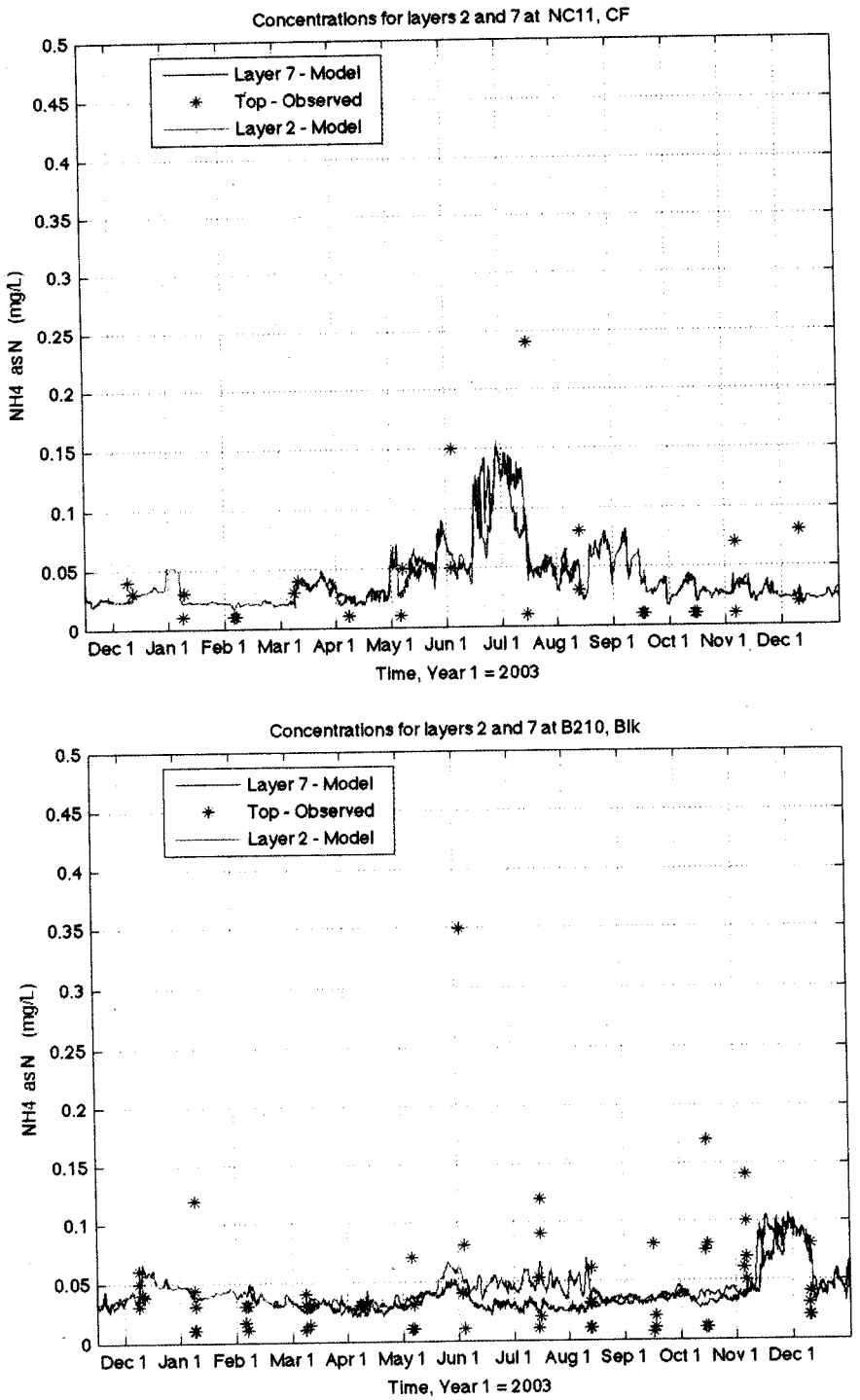
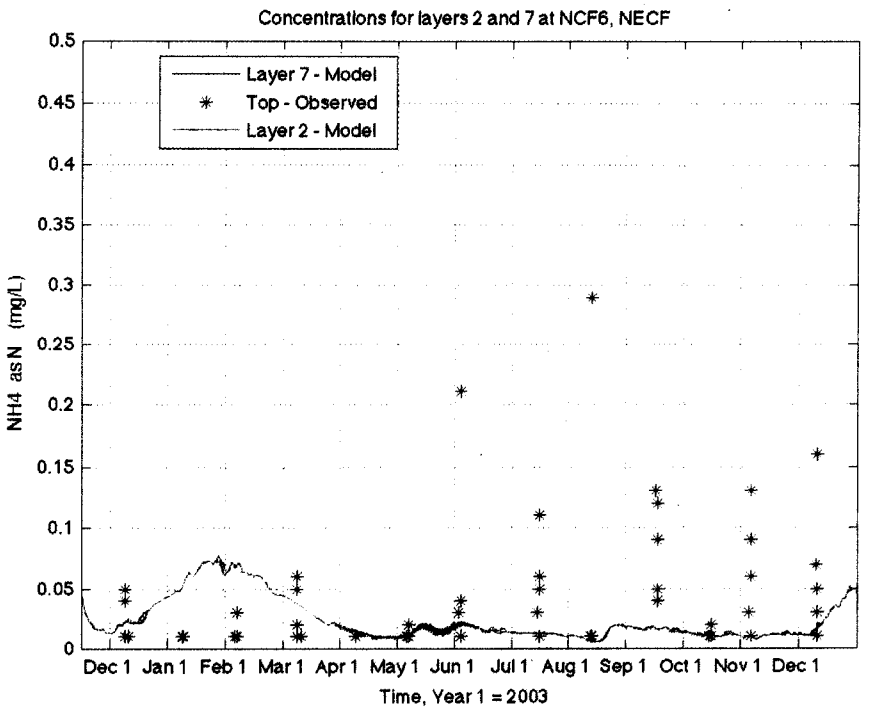


Figure 53. Model Predicted (lines) and Observed (symbols) Ammonia Concentrations During 2004 at the Cape Fear River at Station NC 11 and the Black River at Station B210.



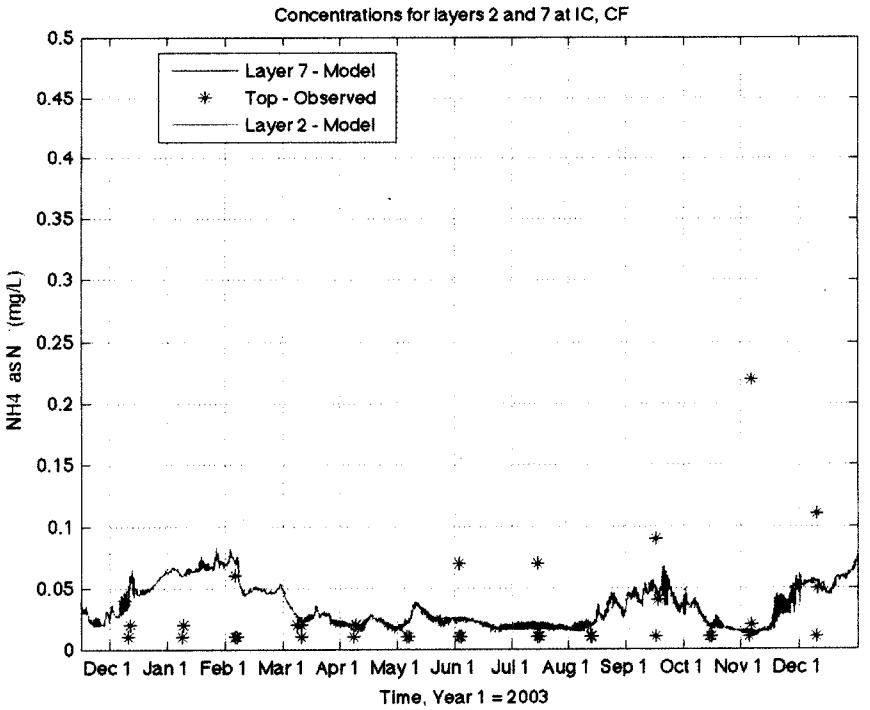


Figure 54. Model Predicted (lines) and Observed (symbols) Ammonia Concentrations During 2004 at the NE Cape Fear River at Station NCF6 and the Cape Fear River at Station IC.

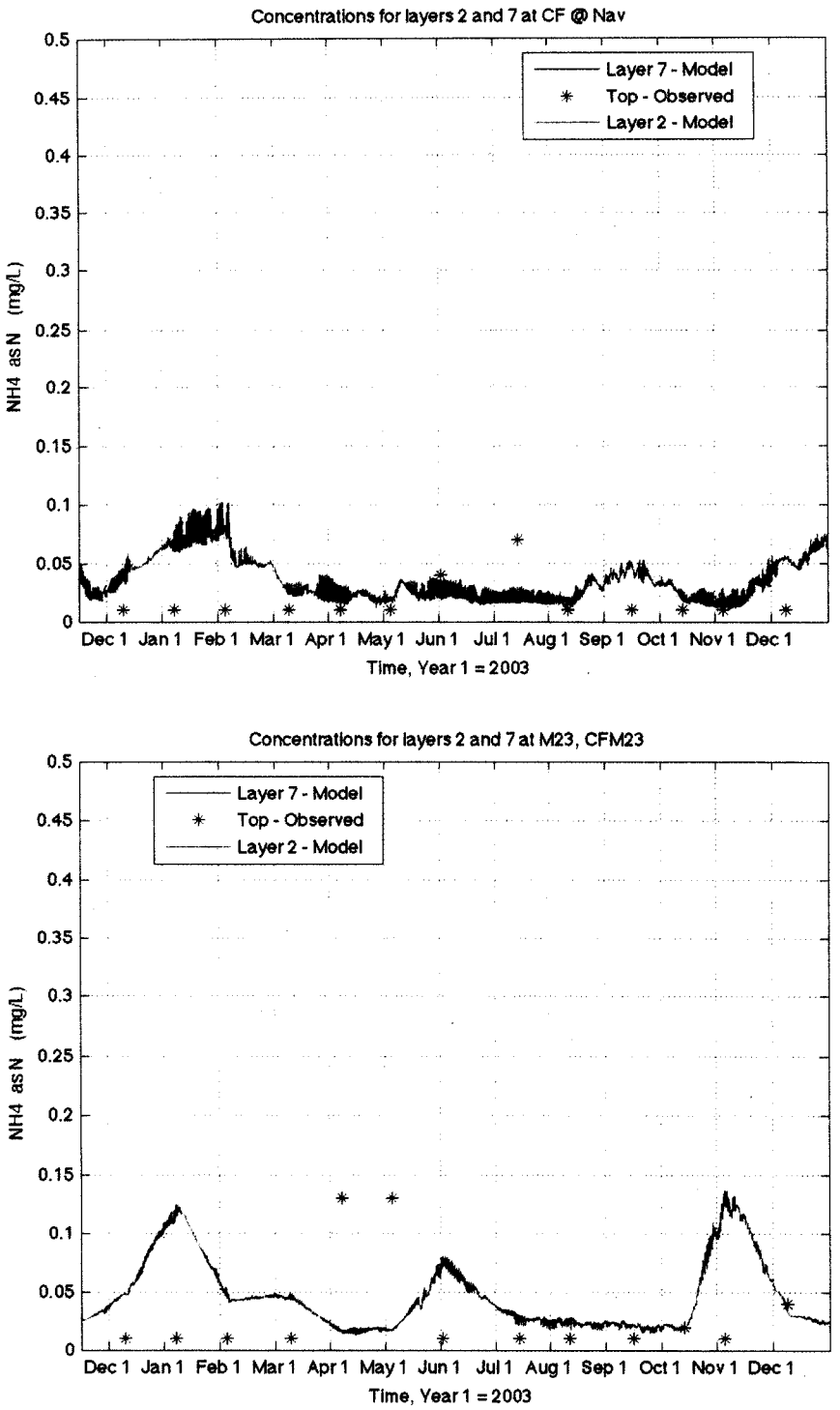
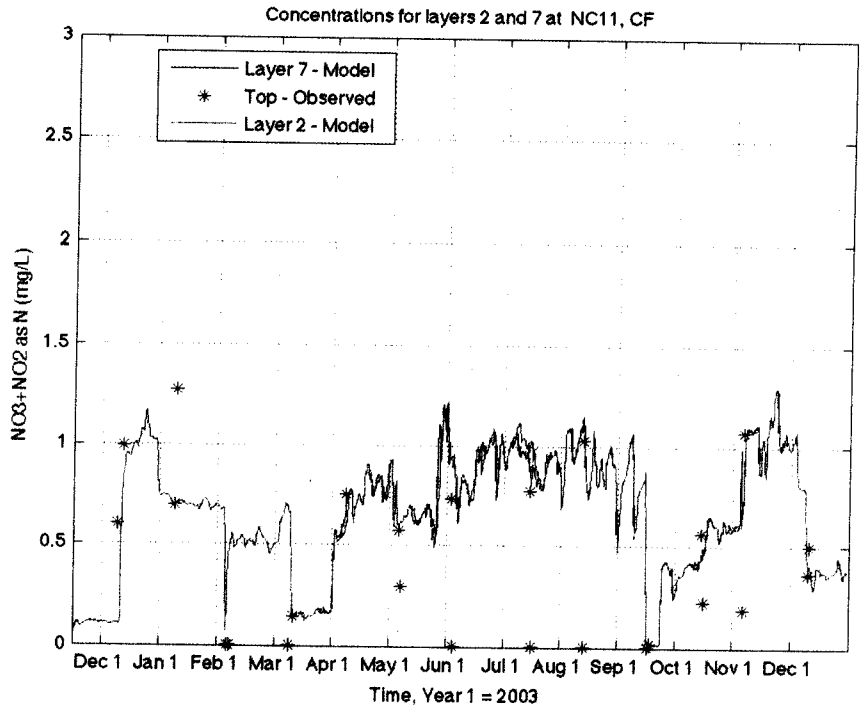


Figure 55. Model Predicted (lines) and Observed (symbols) Ammonia Concentrations During 2004 at the Cape Fear River at Navassa and at Station M23.



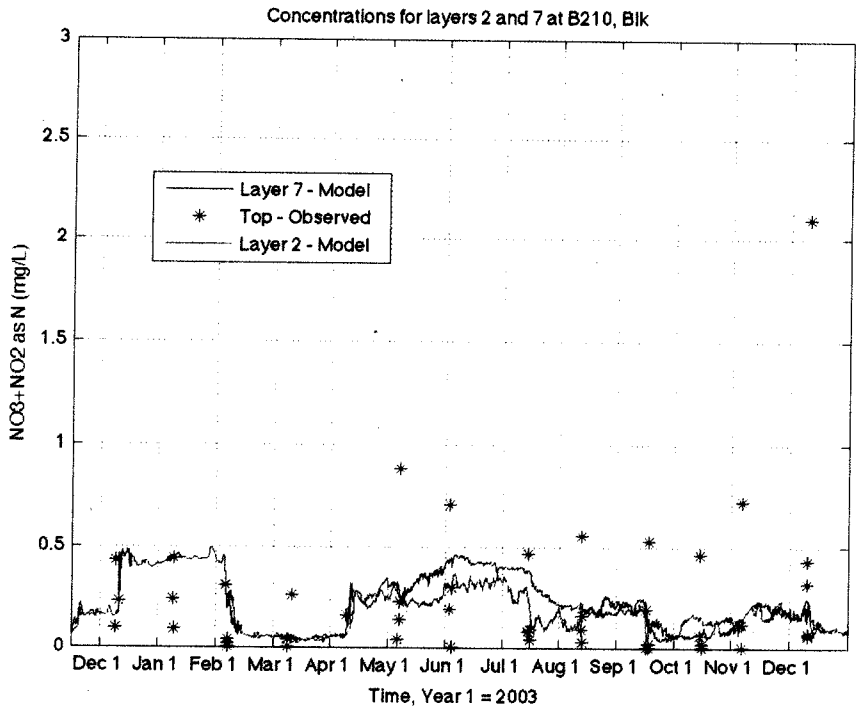


Figure 56. Model Predicted (lines) and Observed (symbols) Nitrate + Nitrite Concentrations During 2004 at the Cape Fear River at Station NC 11 and the Black River at Station B210.

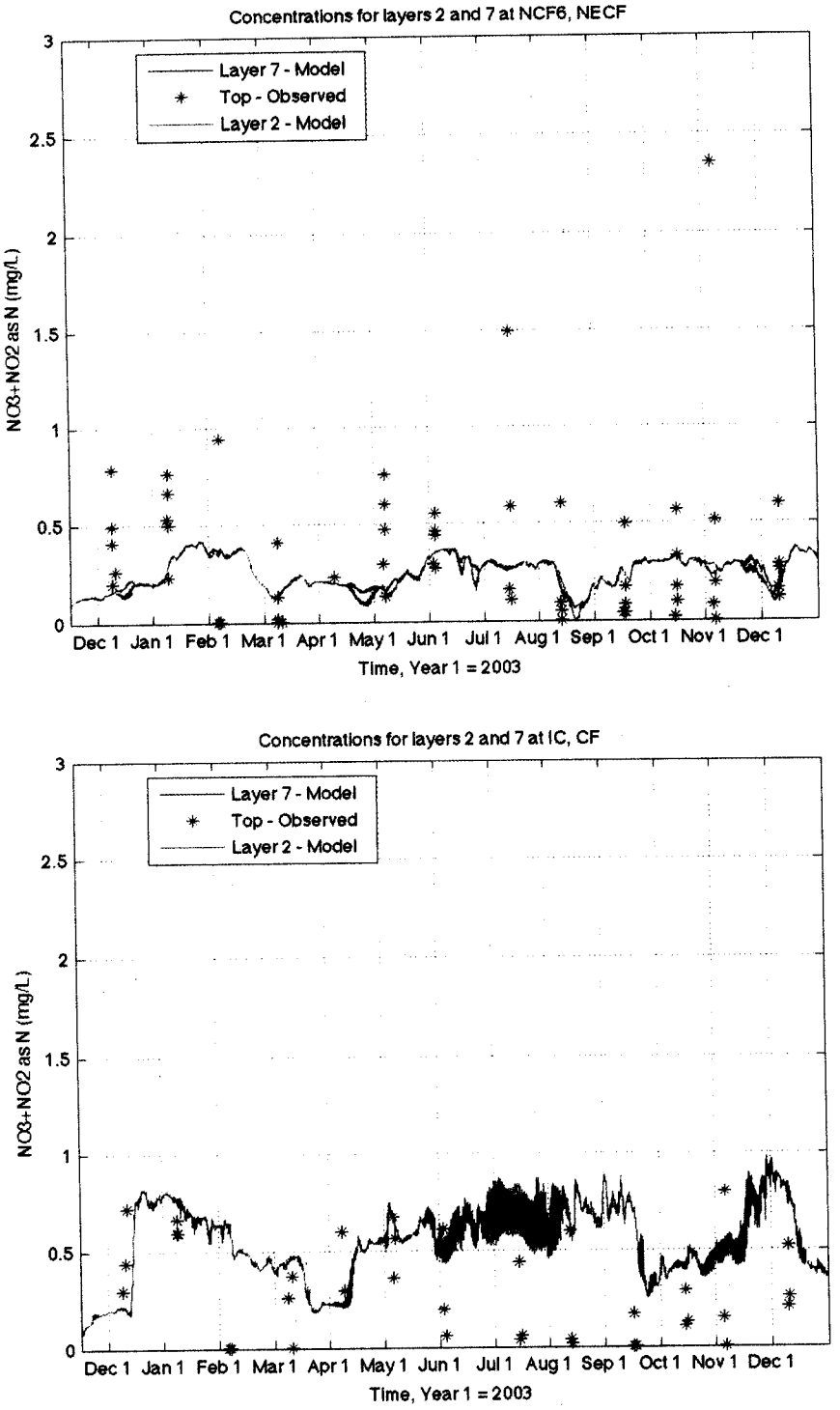
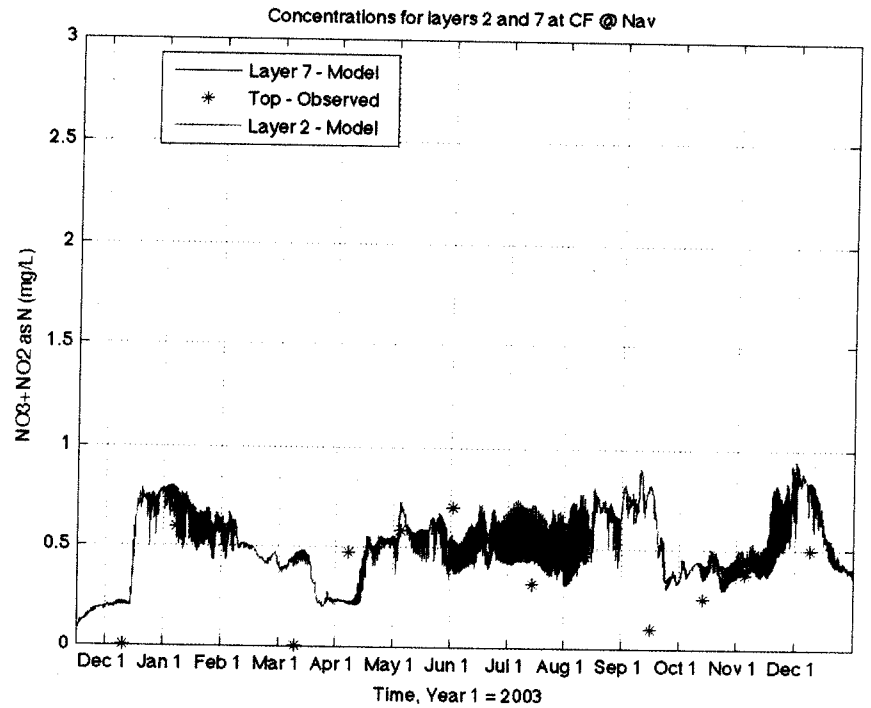


Figure 57. Model Predicted (lines) and Observed (symbols) Nitrate + Nitrite Concentrations During 2004 at the NE Cape Fear River at Station NCF6 and the Cape Fear River at Station IC.



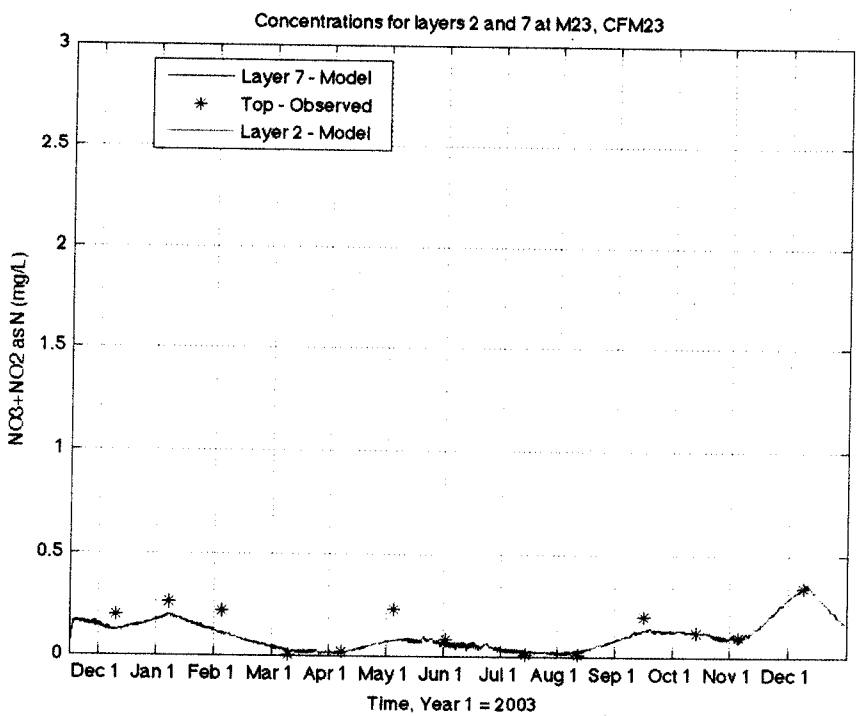
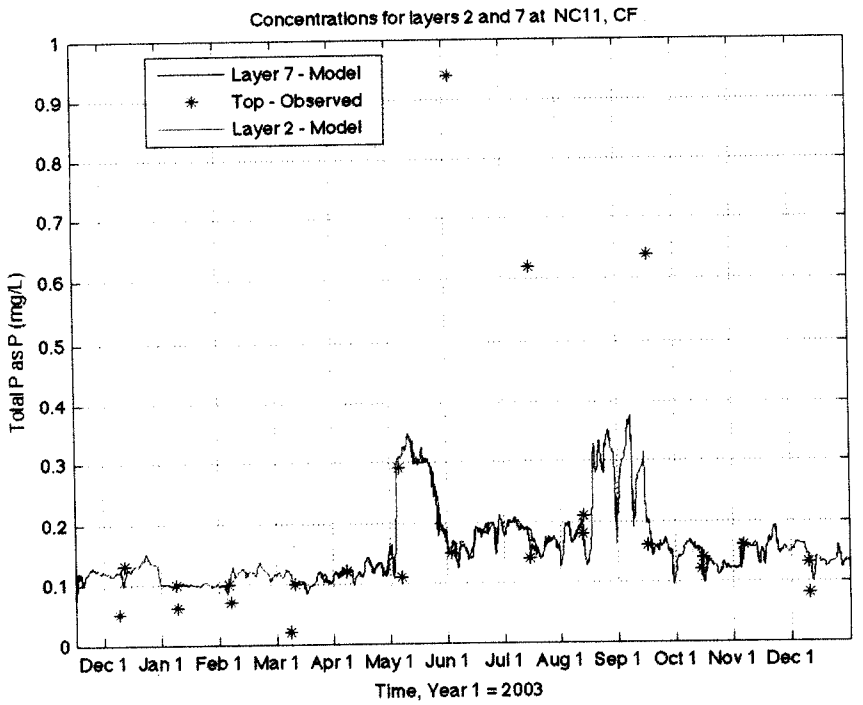


Figure 58. Model Predicted (lines) and Observed (symbols) Nitrate + Nitrite Concentrations During 2004 at the Cape Fear River at Navassa and at Station M23.



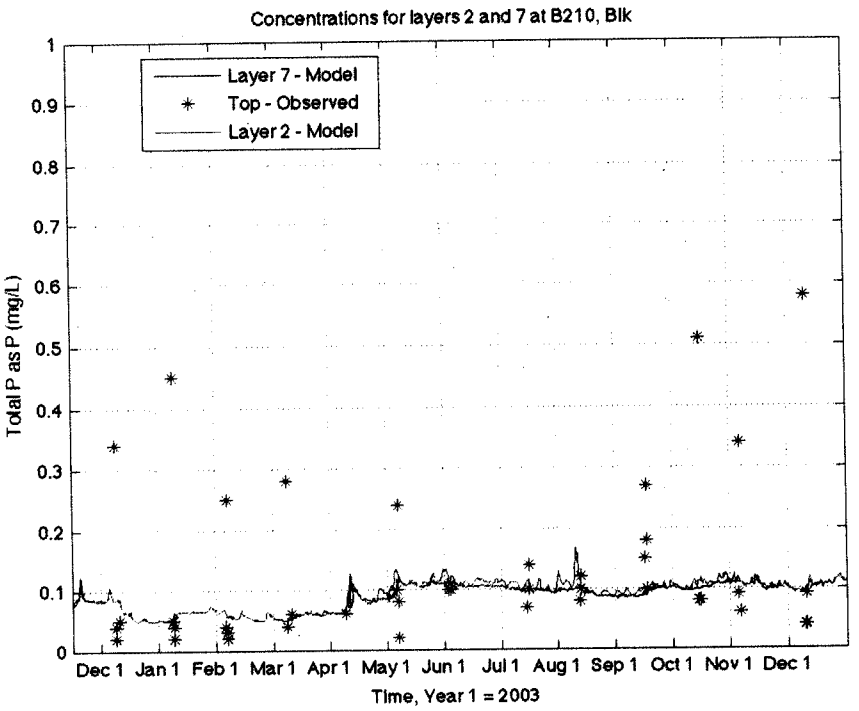
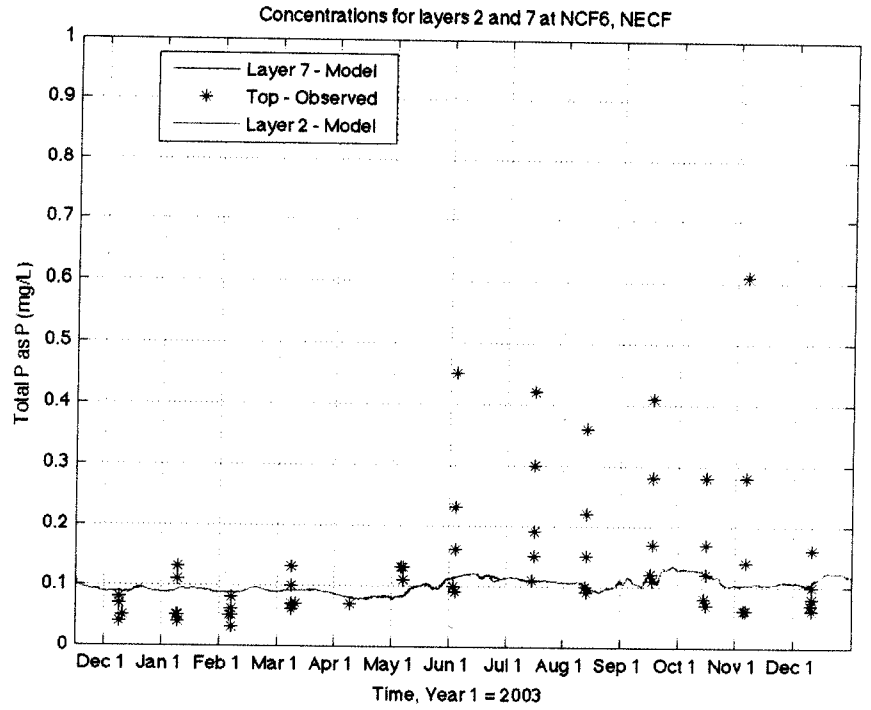


Figure 59. Model Predicted (lines) and Observed (symbols) Total Phosphorus Concentrations During 2004 at the Cape Fear River at Station NC 11 and the Black River at Station B210.



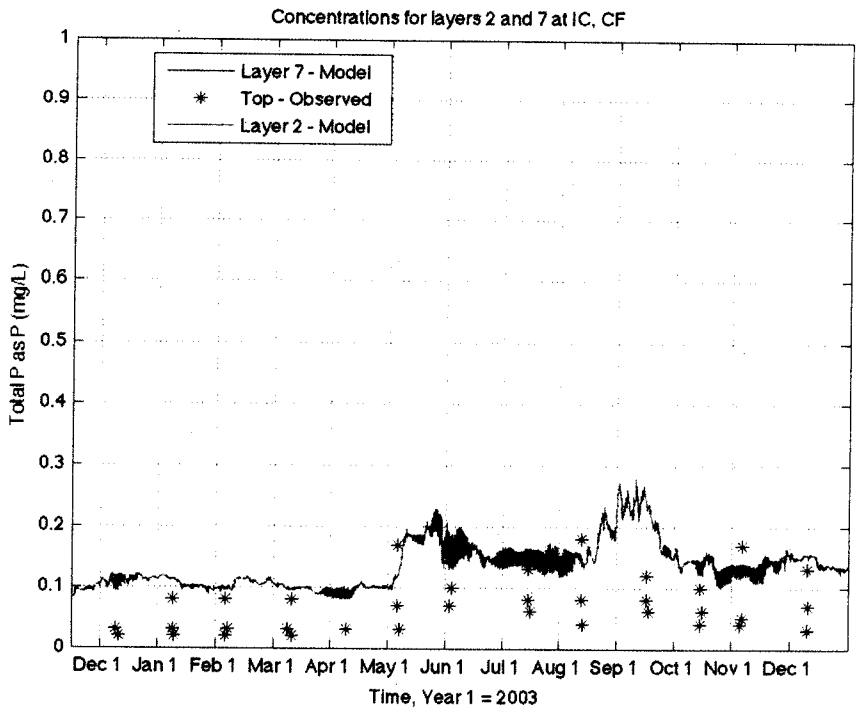


Figure 60. Model Predicted (lines) and Observed (symbols) Total Phosphorus Concentrations During 2004 at the NE Cape Fear River at Station NCF6 and the Cape Fear River at Station IC.

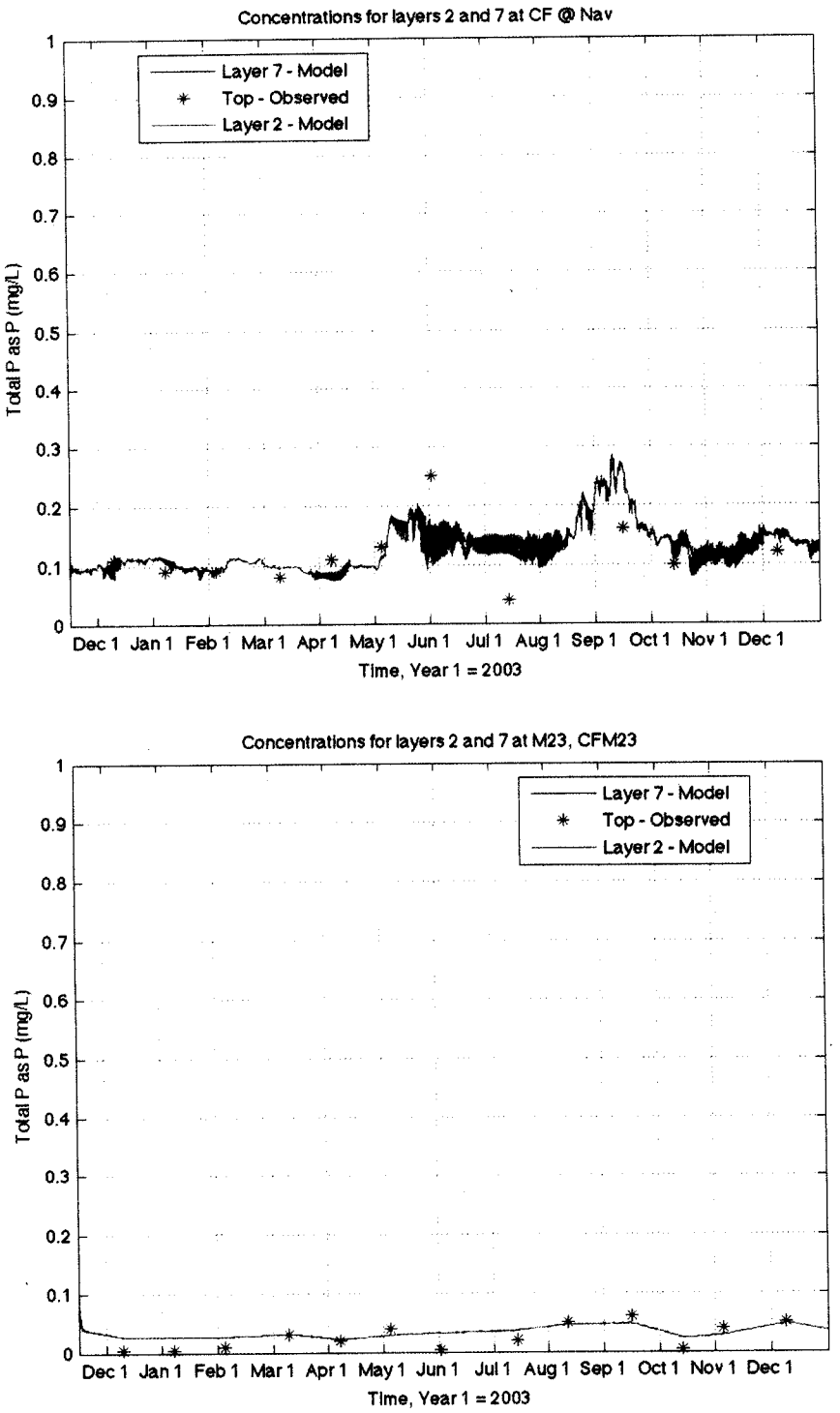
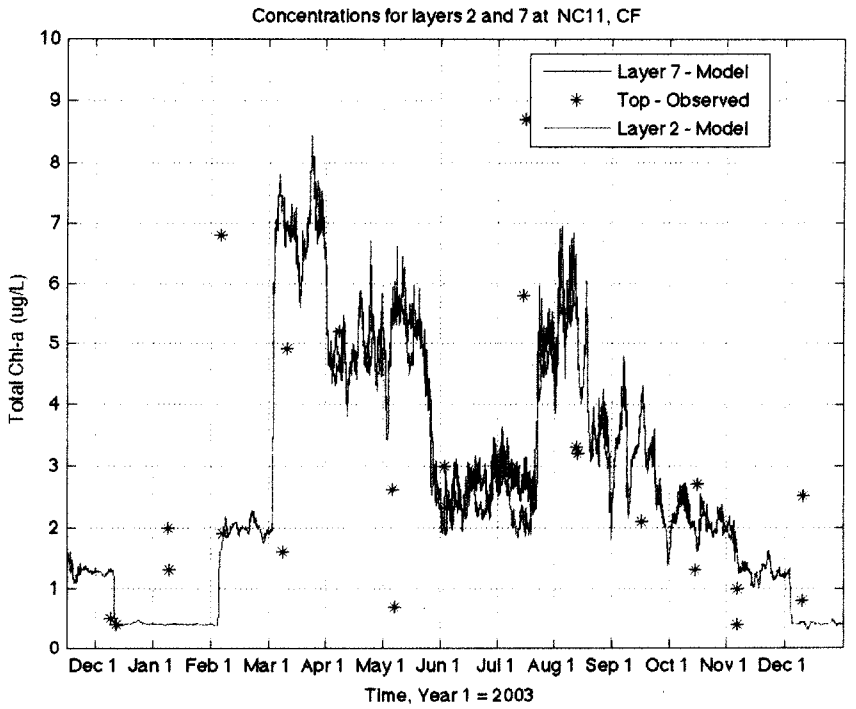


Figure 61. Model Predicted (lines) and Observed (symbols) Total Phosphorus Concentrations During 2004 at the Cape Fear River at Navassa and at Station M23.



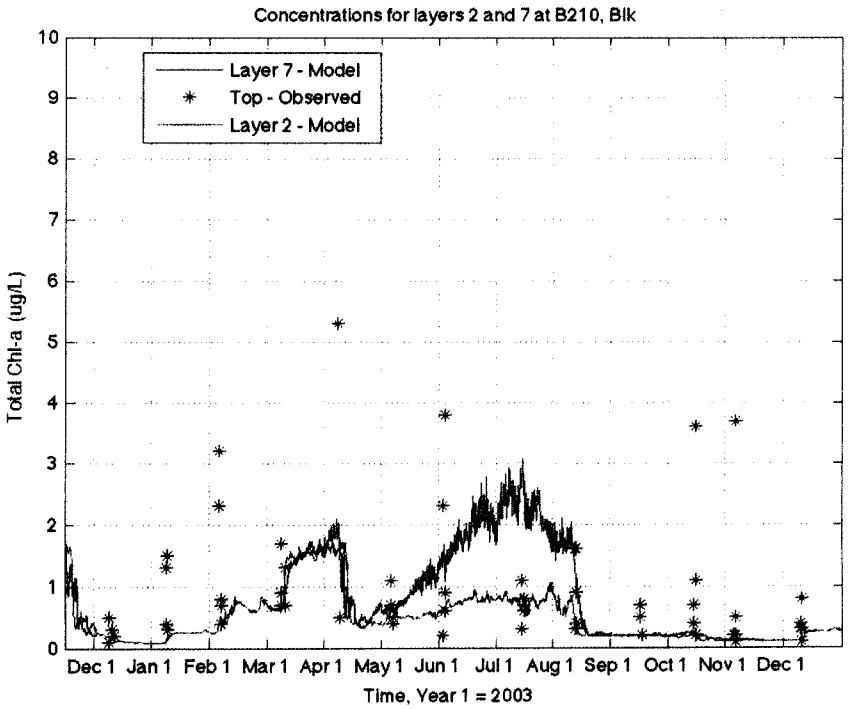
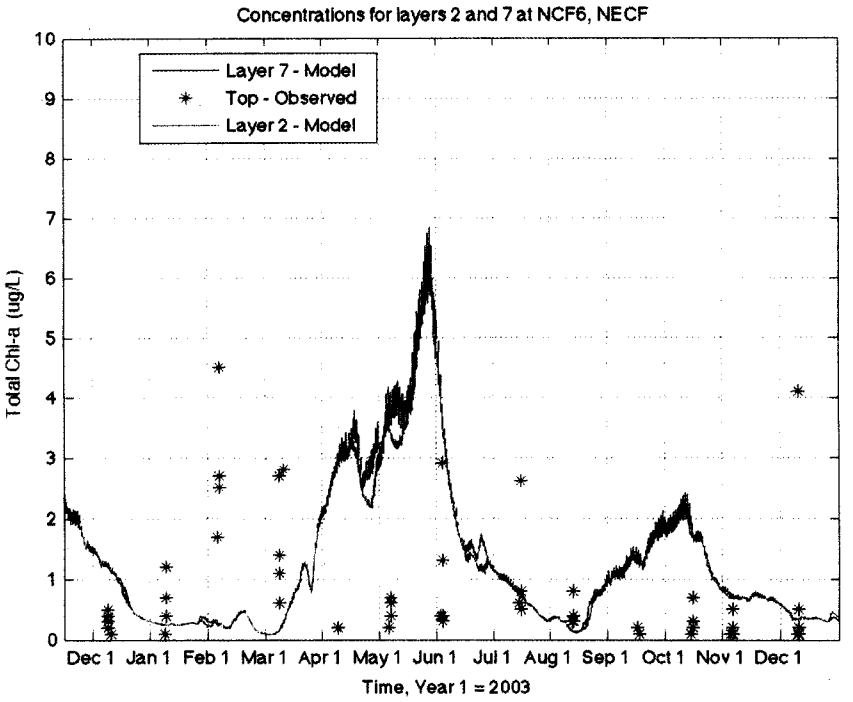


Figure 62. Model Predicted (lines) and Observed (symbols) Chl-a Concentrations During 2004 at the Cape Fear River at Station NC 11 and the Black River at Station B210.



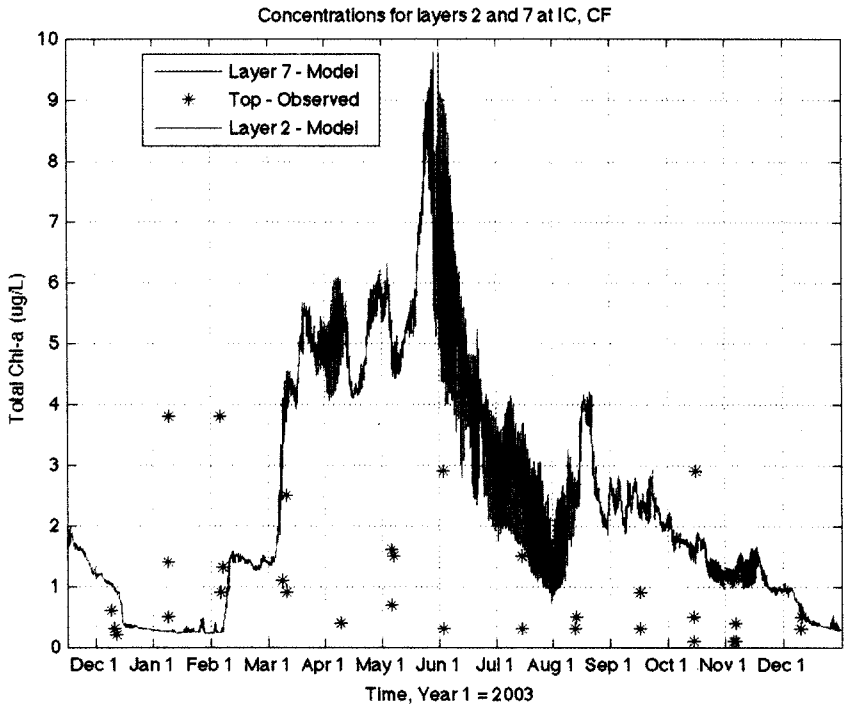
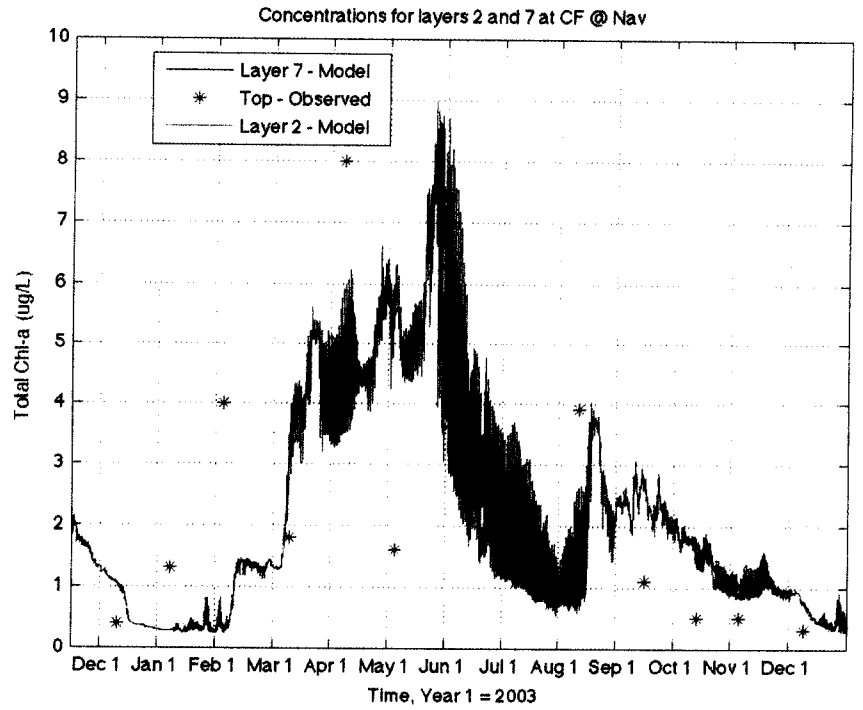


Figure 63. Model Predicted (lines) and Observed (symbols) Chl-a Concentrations During 2004 at the NE Cape Fear River at Station NCF6 and the Cape Fear River at Station IC.



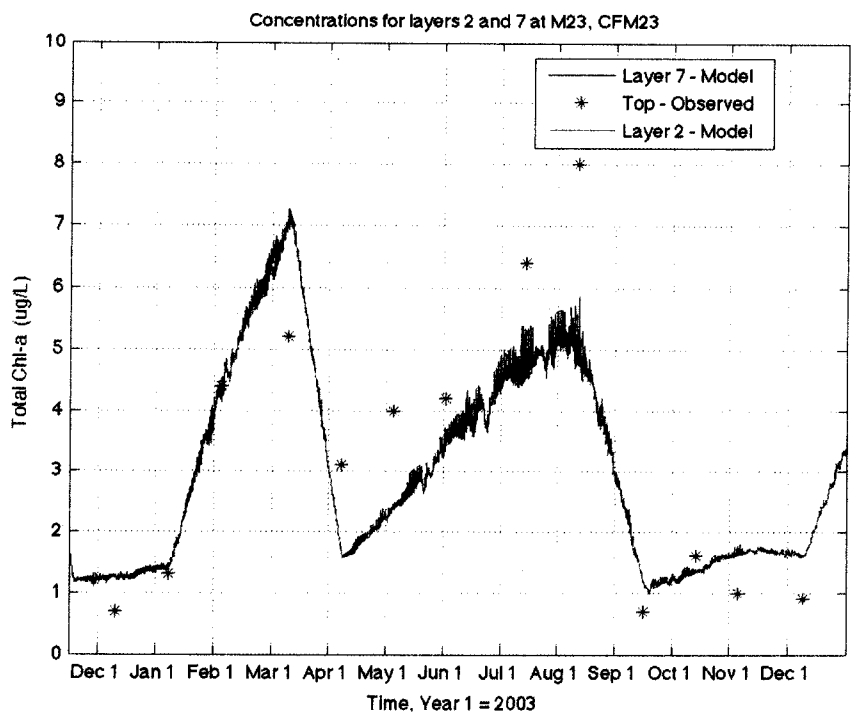


Figure 64. Model Predicted (lines) and Observed (symbols) Chl-a Concentrations During 2004 at the Cape Fear River at Navassa and at Station M23.

5. MODEL EVALUATION

5.1 Model Confirmation

A model confirmation run was conducted to test the calibrated model's ability to simulate water quality conditions during a time period that was not used for model calibration. The 2005 calendar year was used for a model confirmation run. The 2005 calendar year had several high flow events in January and April, but had a dry summer (Figure 18). A short period in early August had streamflows above long-term average values, but otherwise had flows that were consistently below average from mid-April until the end of the year. The Northeast Cape Fear did have one high flow event in October 2004 that was not seen in the larger watershed (Figure 18). This high flow event was the result of heavy rains from tropical storm Jeanne that hit the coastal area but not farther upstream in the watershed.

A significant challenge of the confirmation run was collecting the necessary data to run the model. For the hydrodynamic model, the water surface elevation data was not a problem as both the Sunset Beach and Southport elevation data were sufficient for creating the necessary model forcings. The flow time histories at the upstream boundary on the Cape Fear River used the same location (Lock and Dam 1) as for the calibration run. For the Black and Northeast Cape Fear Rivers, however, data from the two USGS gaging stations nearest the upstream boundary (Black at Currie, Northeast Cape Fear at Burgaw) were no longer available. Instead data from the stations farther upstream (Black at Tomahawk, Northeast Cape Fear at Chinqapin, see Table 3 and Figure 7 for location information) were used instead. The USGS continuous station at Marker 12 was also not available for establishing the downstream boundary condition during 2005. Instead, the monthly salinities at one of the Lower Cape Fear River Stations (M18) was used instead. There was also much less data that could be used for calibration. For instance, over 5000 model/data comparisons were made when calibrating salinity, but for the 2005 confirmation run, only 96 monitored salinities were available. Because of the small amount of monitoring data available only two stations (Navassa, Marker 23) are shown here as time history plots.

Time histories of model predicted salinities and observed salinities during 2005 demonstrate that the model can simulate estuarine dynamics in the system during periods other than the calibration period. Model predicted salinities at two stations in the impaired region (Navassa and Marker 61) and at two other stations in the Northeast Cape Fear and the lower estuary (NCF6 and M35) generally follow the patterns seen in the observed data (Figures 65 and 66). In general the model predicts a somewhat higher salinity than what is observed, but the magnitude of the overprediction is not severe. In addition the model does seem capable of modeling the overall seasonal trends in salinity, and does seem to correctly freshen the estuary during high flow events. For instance early and late 2005 had relatively high flows, and the model correctly simulates the freshening of the estuary that occurs during these times (Figure 65 and Figure 66).

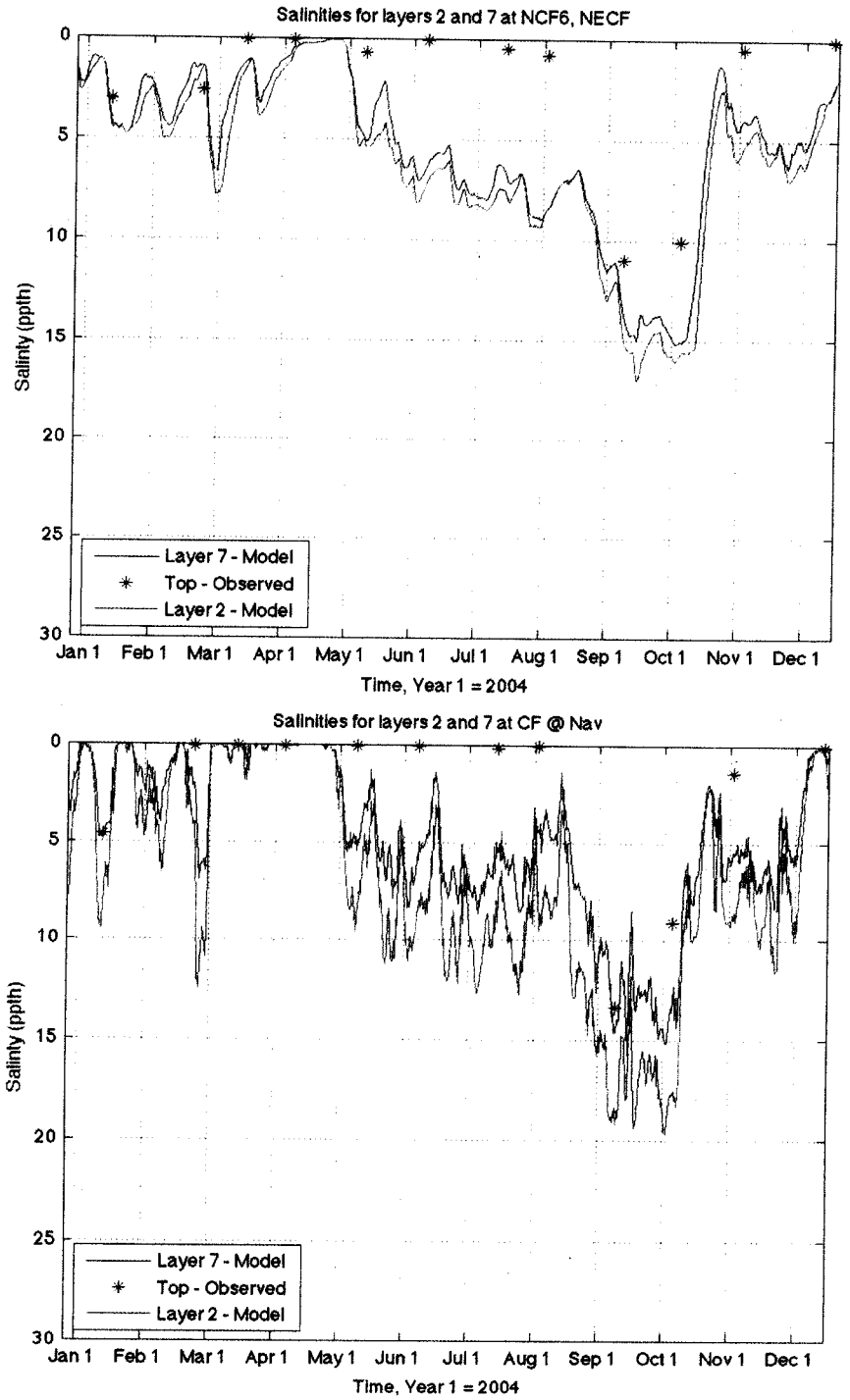


Figure 65. Model Predicted (lines) and Observed (symbols) Salinities During the 2005 Confirmation Run in the NE Cape Fear River at Station NCF6 and in the Cape Fear River at Navassa.

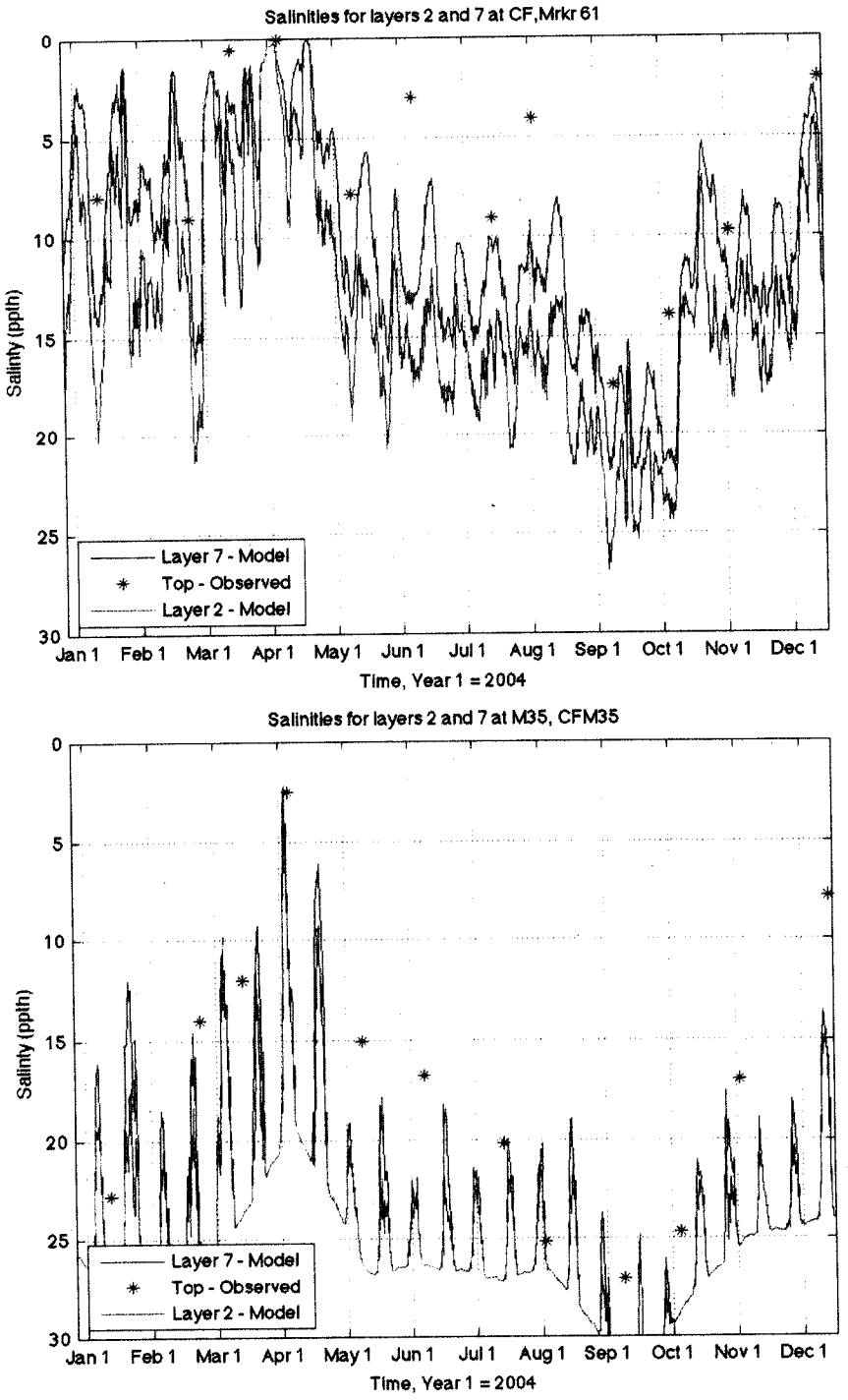


Figure 66. Model Predicted (lines) and Observed (symbols) Salinities During the 2005 Confirmation Run at the Cape Fear River at Marker 61 and at Station M35.

Compared to salinity observations, significantly more observed data were available for assessing the performance of the temperature submodel during the confirmation run. The input data files needed to run the temperature submodel (e.g. meteorological data) were also available for the full 2005 confirmation run. Here we show time history comparisons of model predicted vs. observed temperatures at four sites within the estuary; two sites near Wilmington (Navassa, NCF117), and two sites downstream of Wilmington (Marker 61) and near the mouth of the estuary (Marker 35). Overall, all sixteen of the Lower Cape Fear River Monitoring Program sites used during calibration (Table 12, Figure 20) also had temperature data that could be used for performing a model confirmation run.

At all of the sites examined, the model did a good job predicting temperature time histories. At the two sites near Wilmington, the temperature reaches its maximum value near 30° C during August and drops to approximately 10° C by December 1 (Figure 67). A similar seasonal pattern is seen at the other sites (Figure 68), although it seems that the peak temperature arrives just a little later (mid-August) at these two sites. The model follows the observed seasonal trend very well. At the most downstream site shown here (M35, Figure 68), the peak temperature arrives even a little later than at the other sites. Just as at the other three sites, the peak temperature is approximately 30° C, and occurs sometime during August. At this site temperatures fall slightly less rapidly than at the other three sites. By the end of the year, model predicted temperatures were just above 10° C (Figure 68).

The same procedure used to assess model fit to an observed data set is used for the confirmation run. A total of 780 model/data comparisons were made for the 2005 confirmation run. Predicted temperatures had a mean value that was 0.52° C below that observed. The normalized mean error was only -2.3%, which attests to the model's overall ability to predict temperatures (Table 20). Likewise other measures of calibration performance (e.g. root mean square error, correlation R^2, Table 20) are all similar to corresponding values for the calibration run (Table 16). Likewise the scatter plot (Figure 69) and the percentile plot (Figure 70) for the confirmation run look very similar to that for the calibration run (Figures 41 and 42).

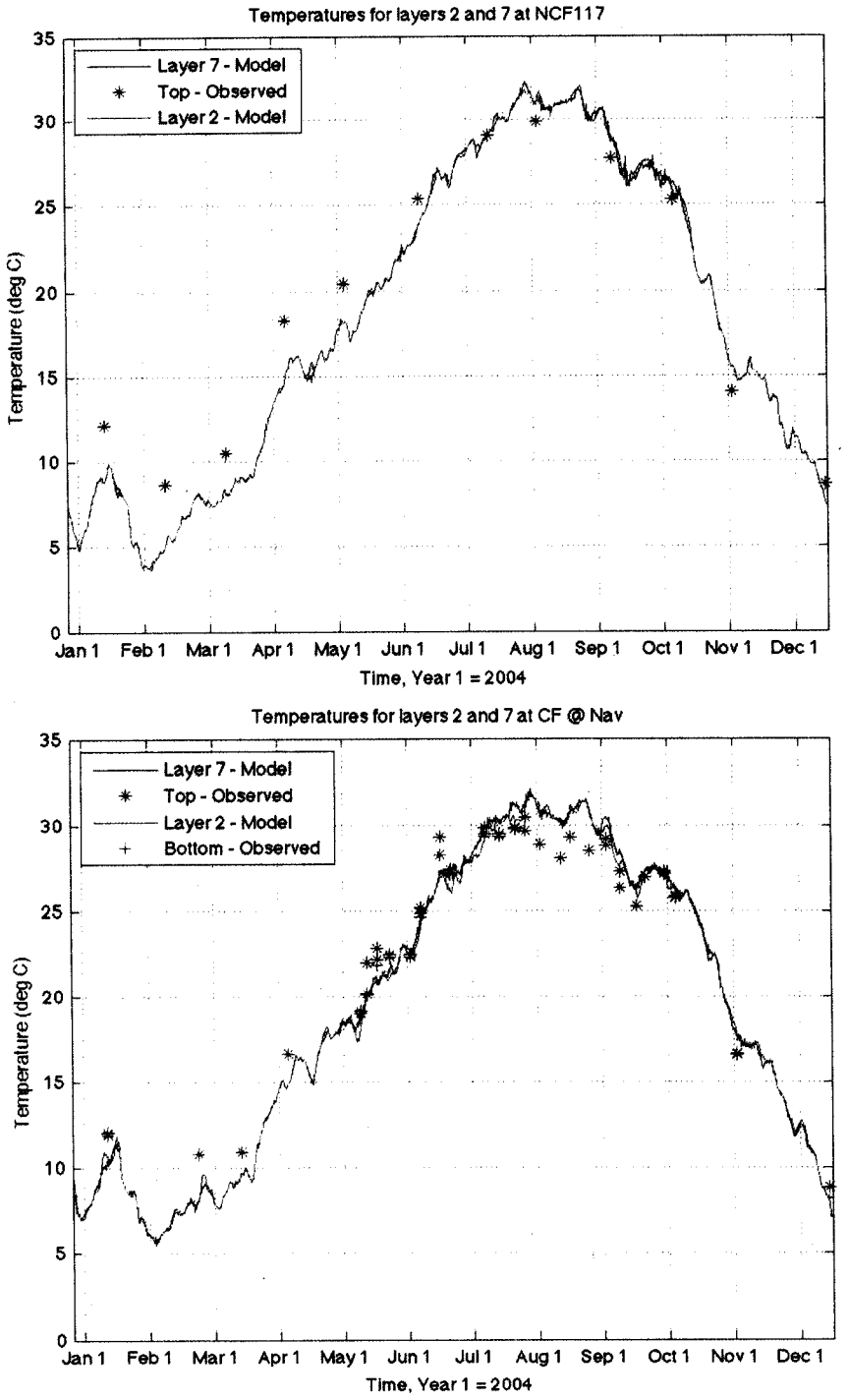


Figure 67. Model Predicted (lines) and Observed (symbols) Temperatures During the 2005 Confirmation Run for the NE Cape Fear River at Station NCF117 and the Cape Fear River at Navasssa.

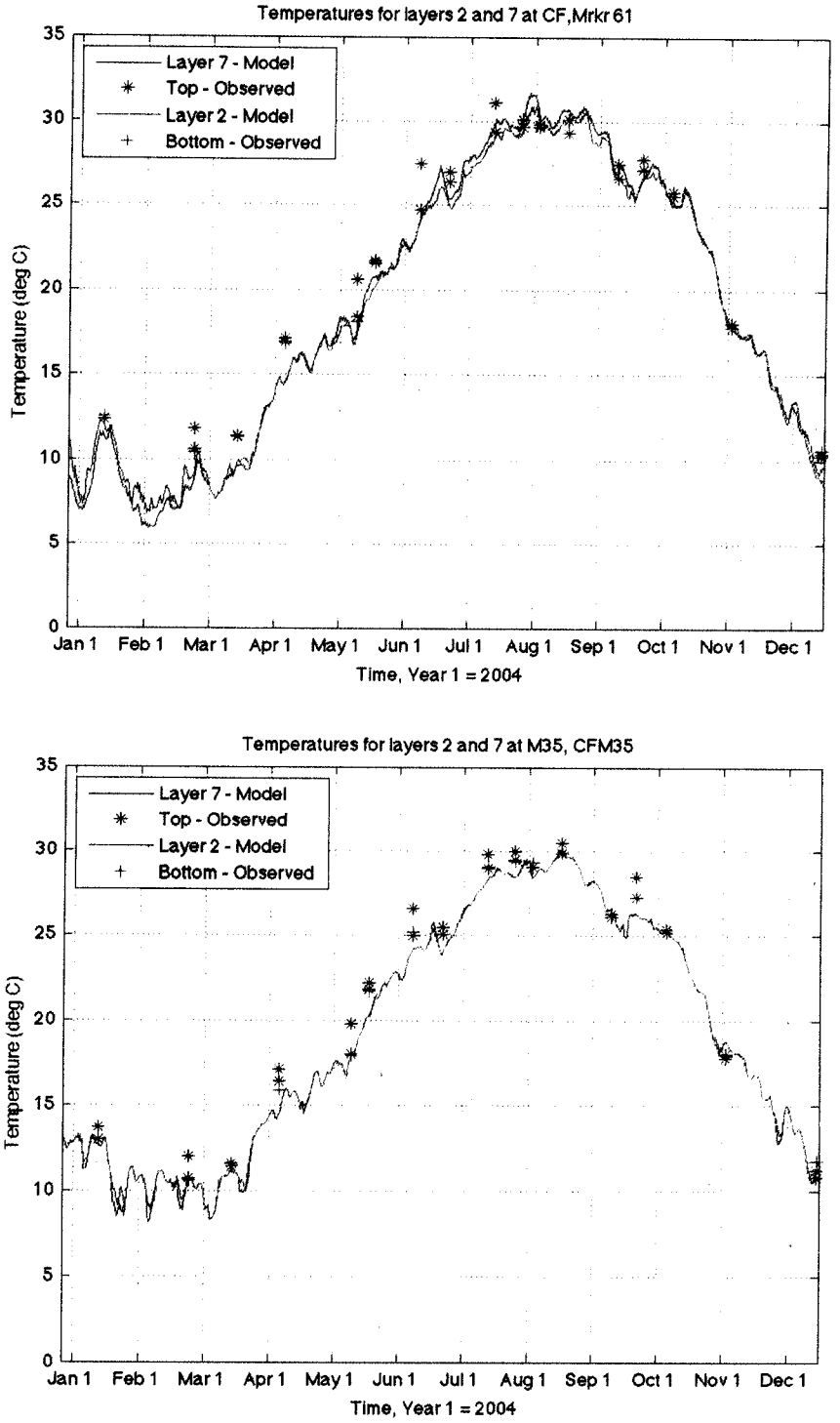


Figure 68. Model Predicted (lines) and Observed (symbols) Temperatures During the 2005 Confirmation Run for the Cape Fear River at Marker 61 and at Station M35.

Table 20. Model Fit Statistics, Temperature, 2005 Confirmation Run

Parameter	Value	Units
Mean Error (predicted – observed)	-0.52	°C
Normalized Mean Error	-2.3	%
Root Mean Square Error	1.51	°C
Normalized Root Mean Square Error	6.7	%
Mean Absolute Error	1.08	°C
Normalized Mean Absolute Error	4.8	%
Correlation R^2	96.4	%
Number of Model/Data Comparisons	780	-
R^2 Corrected for Bias	96.0	%

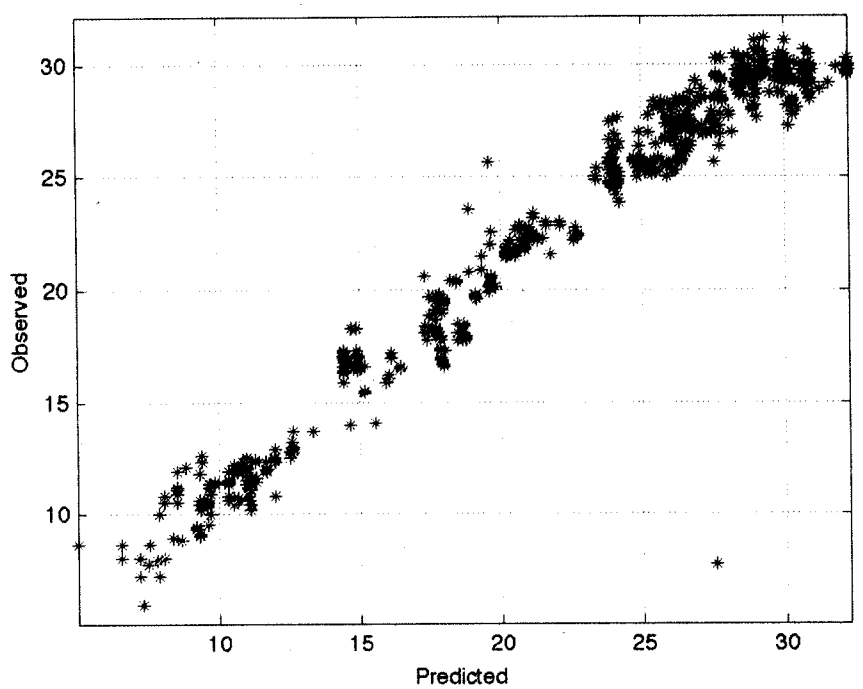


Figure 69. Scatter Plot of Predicted Temperature (°C, x-axis) vs. Corresponding Observed Temperature (°C, y-axis) during the 2005 Confirmation Run.

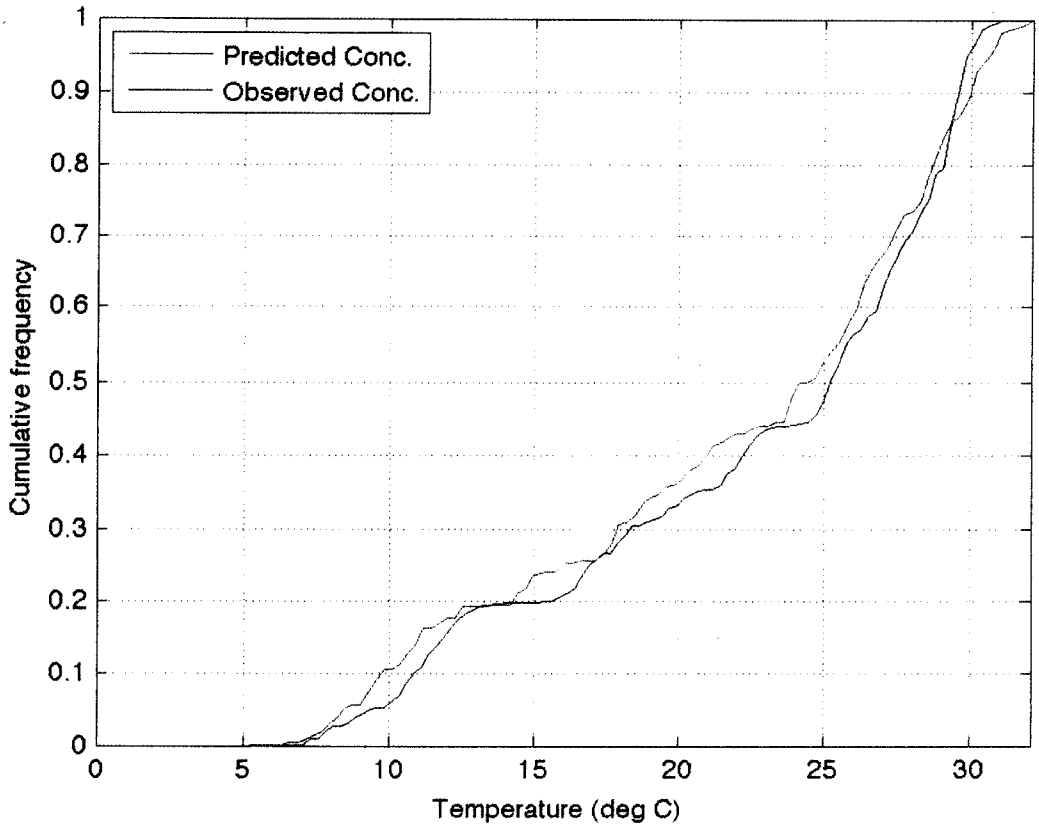


Figure 70. Percentile Plot of Observed and Model Predicted Temperatures During the 2005 Confirmation Period. The y-axis indicates the fraction of values below the corresponding temperature (°C) indicated on the x-axis.

The model also did an excellent job of simulating DO concentrations during the confirmation run. The two upstream stations examined using time history plots (NC11, B210) had minimum dissolved oxygen concentrations that occurred near early September. The model simulates well the timing and magnitude of the minimum DO concentration (Figure 71). Likewise the recovery that occurs in the subsequent months as the water cools is simulated well by the model. At both upstream sites the model predicts a rise to a DO concentration of about 10 mg/L by December 2005. Observed DO concentrations at the upstream sites in late 2005 closely match the model predictions (Figure 71).

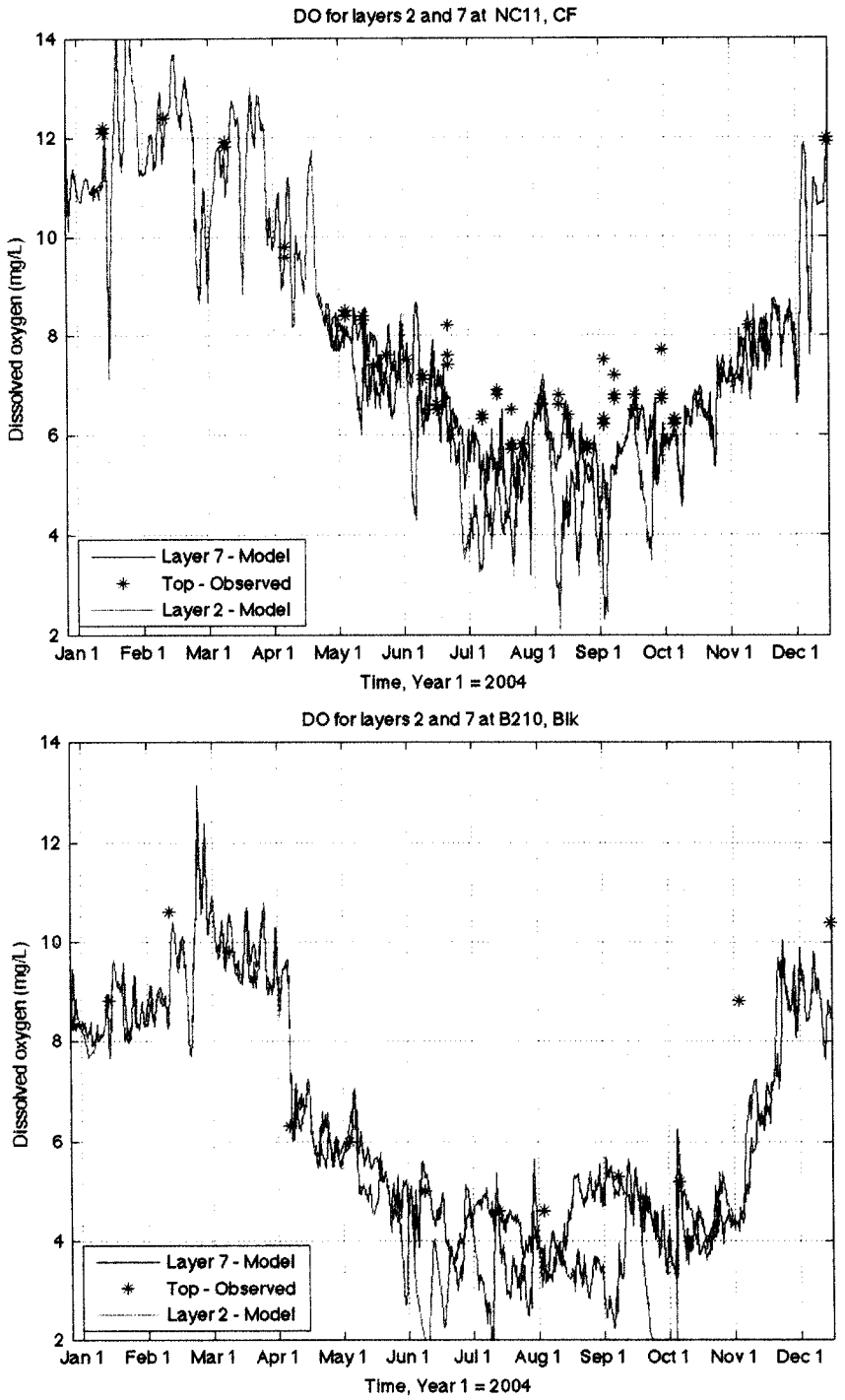


Figure 71. Model Predicted (lines) and Observed (symbols) Dissolved Oxygen Concentrations During the 2005 Confirmation Run for the Cape Fear River at Station NC11 and the Black River at Station B210.

Like the calibration run, the model overpredicts somewhat the DO concentrations in the Northeast Cape Fear during the early summer months. The model does a good job, however, at predicting the minimum dissolved oxygen concentration of approximately 3 mg/L (Figure 72). The duration of low dissolved oxygen (< 4 mg/L) at this site is somewhat underpredicted by the model. The model does a better job predicting DO concentration at this site during late Fall, when the water is cooler and DO concentrations are higher. The model does a better job predicting DO concentrations at Navassa, as both the observed and model predicted minimum DO concentrations are below 4 mg/L (Figure 72). The model does an equally good job matching the observed data at the Brunswick River station and at station M35 (Figure 73). At station M35, the model nicely predicts the timing of the DO minimum concentration, but overpredicts slightly the DO concentration at this time. Both the descent to the minimum DO concentration and the recovery later in the Fall are nicely represented by the model (Figure 73).

Model performance statistics for dissolved oxygen are very similar to those for the calibration run. Again, a total of 780 monitored DO concentrations were compared to the corresponding model prediction at that time and place (Table 21). The normalized mean error was slightly higher as compared with the calibration run (-2.0% vs. 0.06%, see Table 18), but the normalized root mean square error and normalized mean absolute error are both in the range of 10-15%, which is quite good for an estuary DO model.

The excellent fit to observed DO data during the 2005 model confirmation run can also been seen in the scatter and percentile plots. The scatter plot has a fairly tight distribution (Figure 74) and little bias is evident. Likewise the percentile plot for the confirmation run (Figure 75) looks very similar to the corresponding plot for the calibration run (Figure 52).

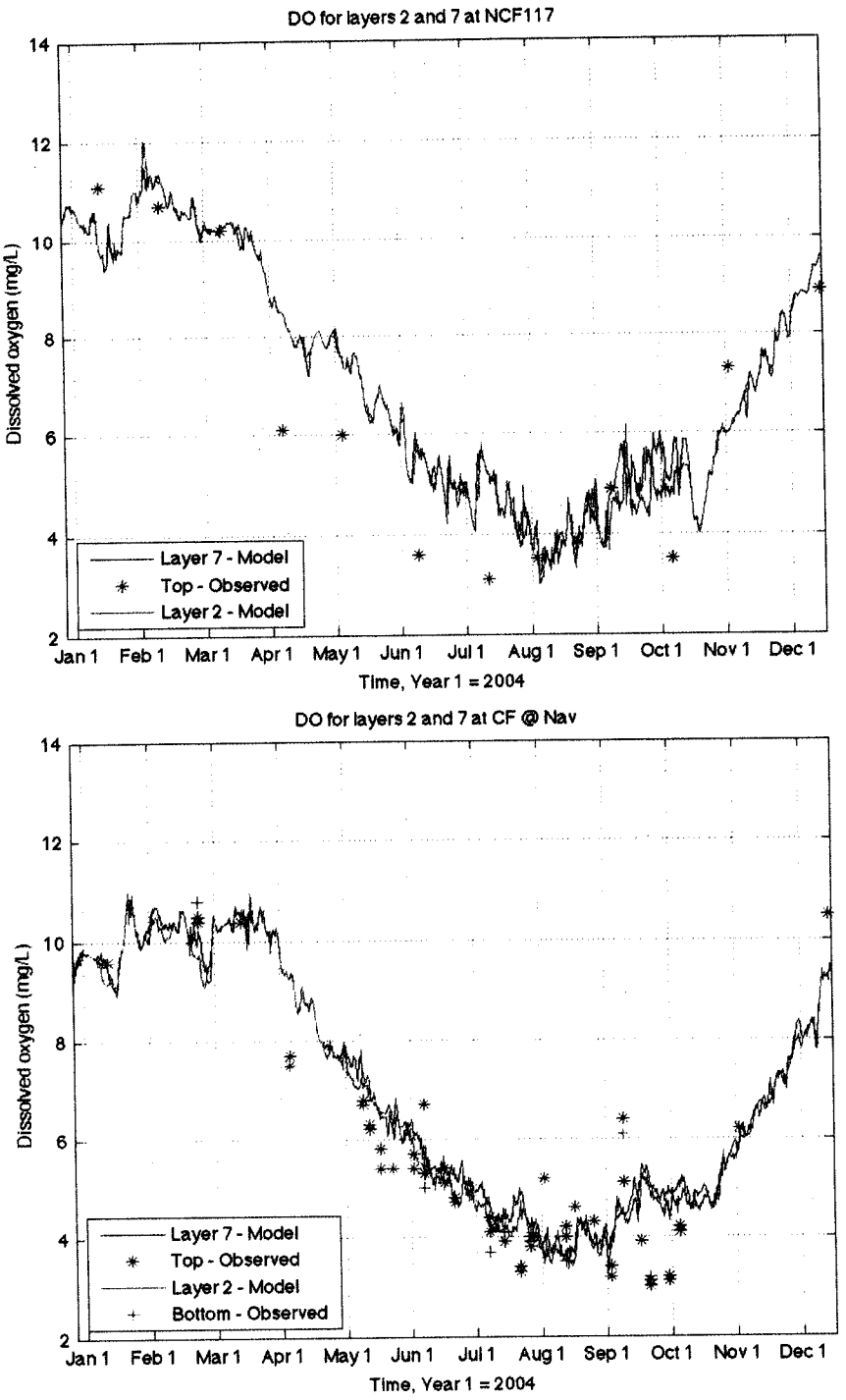


Figure 72. Model Predicted (lines) and Observed (symbols) Dissolved Oxygen Concentrations During the 2005 Confirmation Run for the NE Cape Fear River at Station NCF117 and the Cape Fear River at Navasssa.

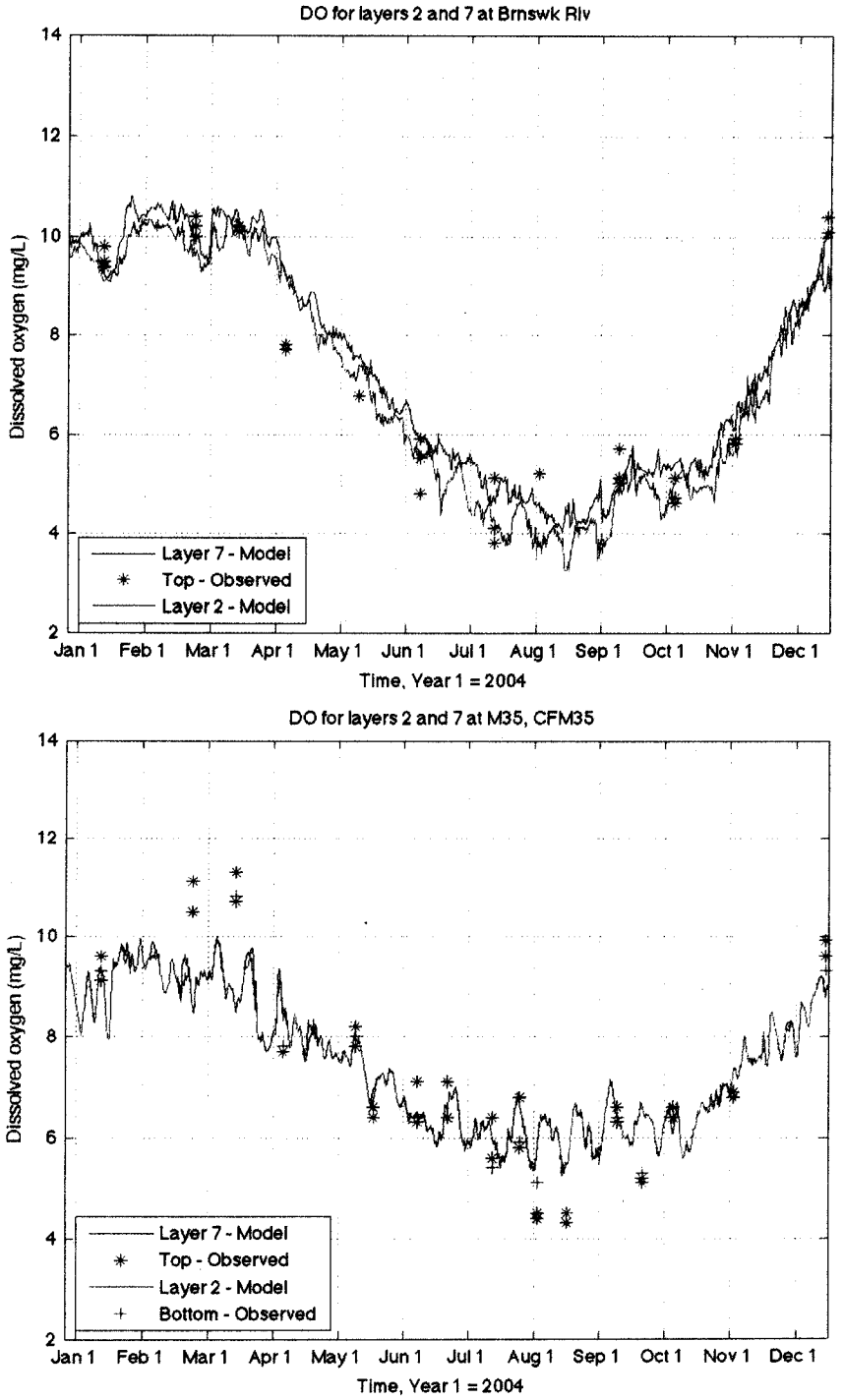


Figure 73. Model Predicted (lines) and Observed (symbols) Dissolved Oxygen Concentrations During the 2005 Confirmation Run for the Cape Fear River at the Brunswick River Station and at Station M35.

Table 21. Model Fit Statistics, Dissolved Oxygen, 2005 Confirmation Run

Parameter	Value	Units
Mean Error (predicted – observed)	**-0.13**	**mg/L**
Normalized Mean Error	**-2.0**	**%**
Root Mean Square Error	**1.20**	**mg/L**
Normalized Root Mean Square Error	**18.2**	**%**
Mean Absolute Error	**0.92**	**mg/L**
Normalized Mean Absolute Error	**14.1**	**%**
Correlation R^2	**73.8**	**%**
Number of Model/Data Comparisons	**780**	**-**
R^2 Corrected for Bias	**73.0**	**%**

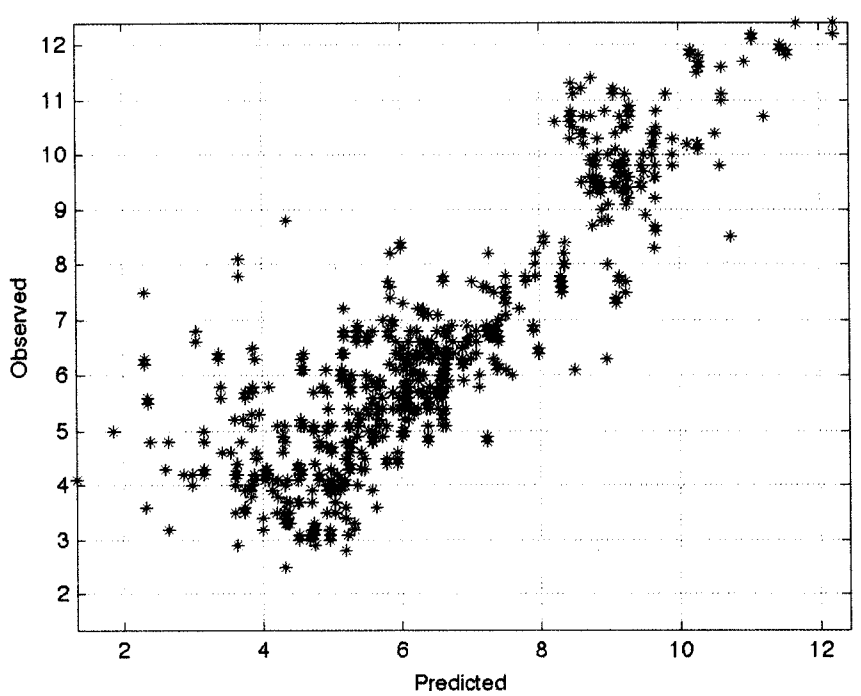


Figure 74. Scatter Plot of Predicted Dissolved Oxygen Concentrations (mg/L, x-axis) vs. Corresponding Observed Dissolved Oxygen Concentrations (mg/L, y-axis) for the 2005 Confirmation Period.

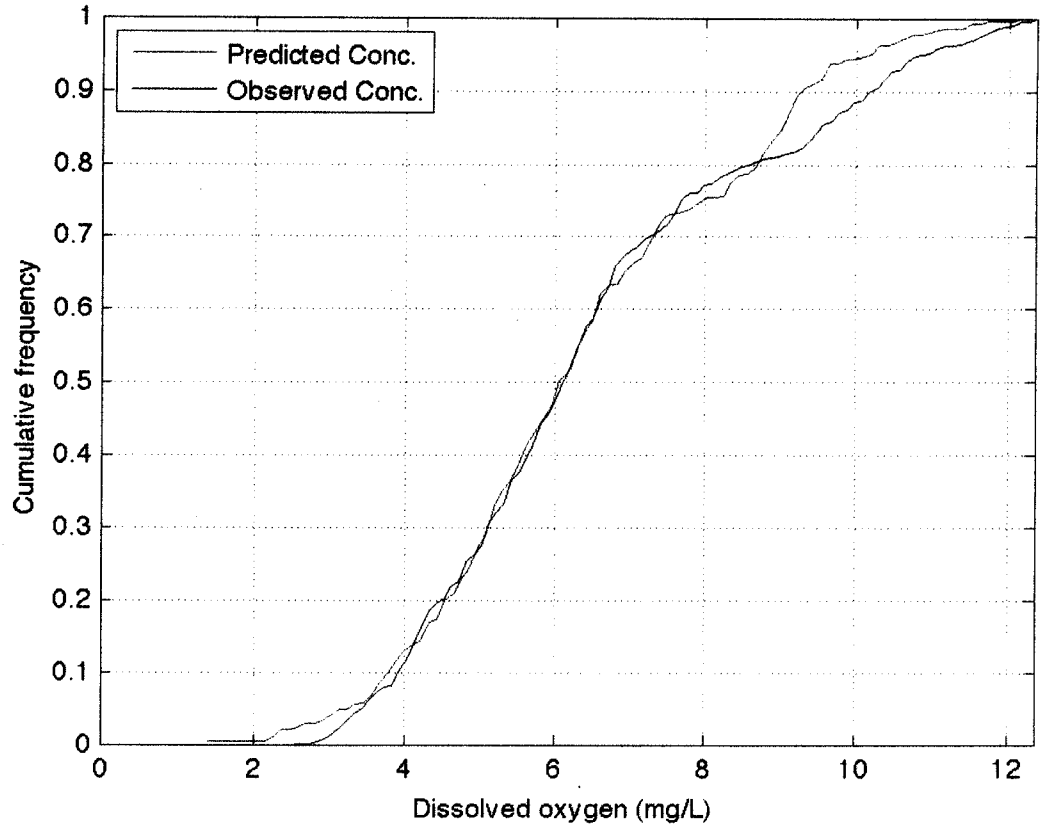


Figure 75. Percentile Plot of Observed and Model Predicted Dissolved Oxygen Concentrations During the 2005 Confirmation Period. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

5.2 Sensitivity Testing

Model evaluation also included sensitivity testing. During calibration it was realized that the DO results were quite sensitive to the choice of the sediment oxygen demand. The SOD rate was determined during calibration to give a percentile plot that matched the observed data while giving good values for the numerical measures of calibration performance. Here we show how changing the SOD rate at 20° C from the calibrated value of 0.4 $g/m^2/d$ to a value 25% higher (0.5 $g/m^2/d$) and a value 25% lower (0.3 $g/m^2/d$). While we examined the model results several different ways (e.g. time history plots, statistical measures of model fit), here we show only the percentile plot and the scatter plot for the high SOD and low SOD cases. These figures can be

compared to the corresponding scatter (Figure 51) and percentile plots (Figure 52) for DO using the calibrated SOD value of 0.4 $g/m^2/d$.

The most noticeable difference between the three runs is in the percentage of low DO concentrations. The scatter plots show more subtle differences. The three scatter plots for low, medium, and high SOD rate (Figures 51, 76, 77) are very similar in overall shape. The higher SOD seems to simply raise predicted DO concentrations without affecting the overall distribution, such that the predicted DO's are moved to the left on the figure (lower predicted DO) without changing the shape or tightness of the distribution. The percentile plots are also very similar, but there is a marked increase in the number of low DO value as the SOD rate is increased (Figures 52, 76, 77). For instance, with the SOD of 0.3 $g/m^2/d$ the percentage of values below 4 mg/L is approximately 7%, while at an SOD rate of 0.5 $g/m^2/d$ the percentage of DO concentrations below is approximately 12%. For this higher SOD rate, there is noticeable difference between the observed and model predicted distribution of data. This offset, where the model predicted frequency exceeds the observed data by approximately 5% exists in the lower range of the distribution, up to a percentile of approximately 65%.

The sensitivity testing did show that the model results are sensitive to the calibrated SOD value. Additional runs were made to determine how changing the SOD rate might change the estuary's sensitivity to changes in organic matter loading. This set of runs, which examined if scenario results were sensitive to the SOD rate used is presented in the following section with the other scenario tests.

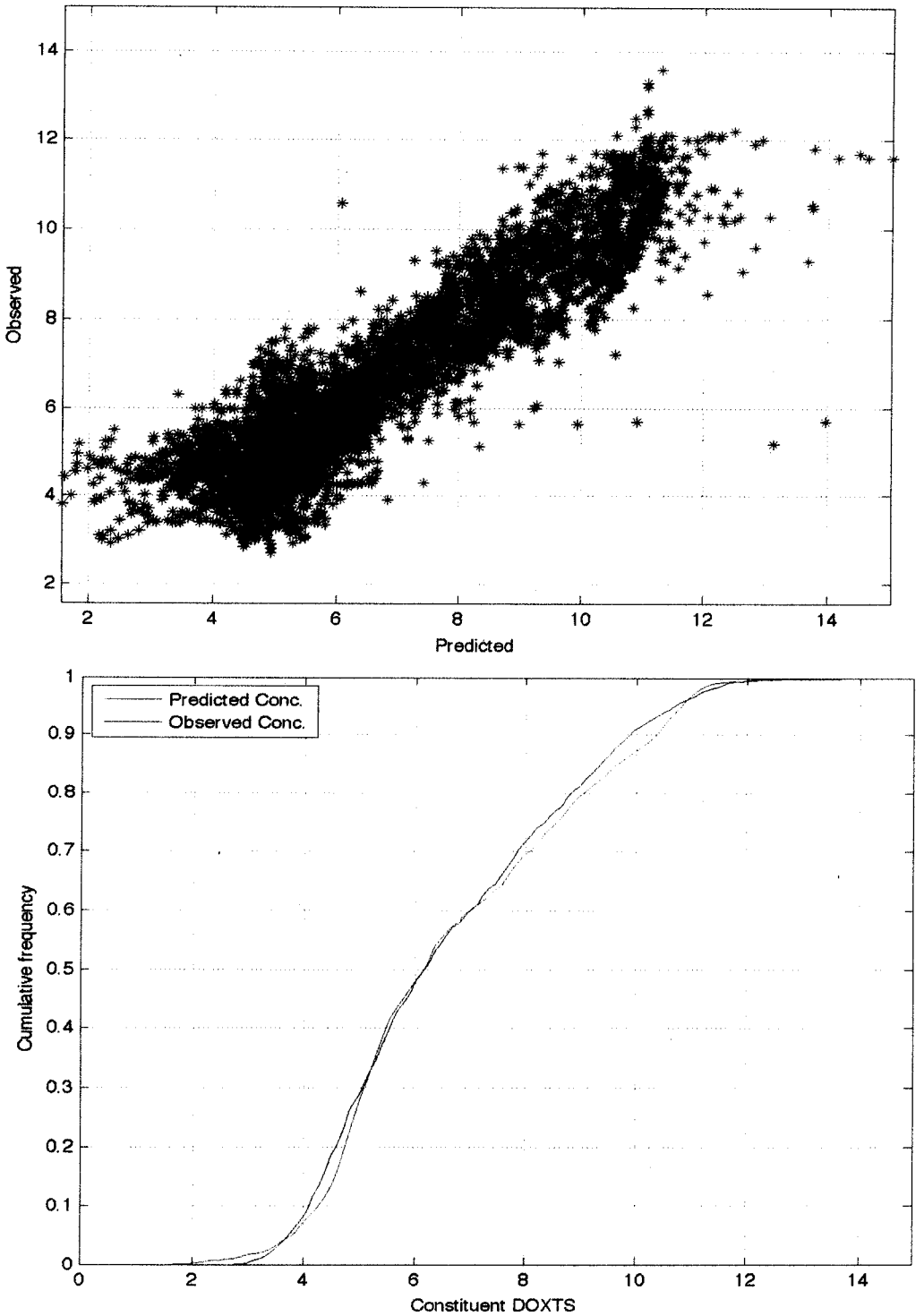


Figure 76. Scatter Plot and Percentile Plot, DO, SOD = 0.3

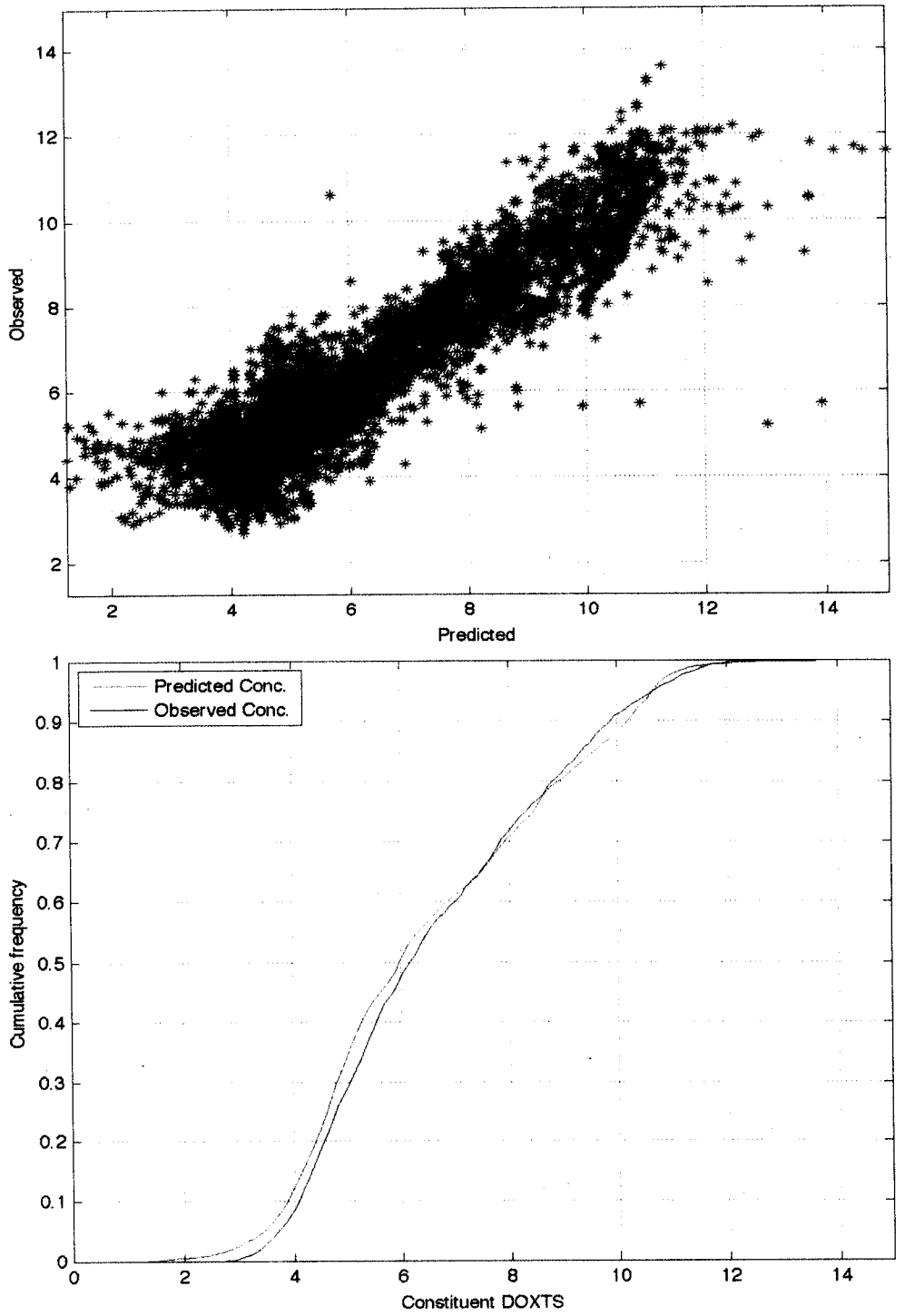


Figure 77. Scatter Plot and Percentile Plot, DO, SOD = 0.5

6. SCENARIO TESTING

6.1 Description of Base and Scenario Cases

A number of scenario tests were conducted to investigate the system's sensitivity to loading changes or to other possible changes in the system. For each scenario, model runs were conducted to estimate the time varying dissolved oxygen concentrations during the summer period of 2004 (April 1 – October 31) within the state designated impaired region of the estuary. For the base case run and each of the various scenario cases, twice-daily dissolved oxygen snapshots were recorded from all eight vertical layers at eighteen sites within the impaired region (Figure 78). This data collection method gave a total of 61,920 DO concentration values for a particular model run (215 days x 18 stations x 8 layers per station x 2 snapshots per day). The distribution of these DO concentration values was then compared between the base case and the various scenario cases by making percentile plots. In the following sections, the following eight different scenarios are examined:

1. Eliminating wastewater point source loadings
2. Reducing river, creek, and wetland loadings
3. Changing wastewater loadings for various values of sediment oxygen demand
4. Reducing river, creek, and wetland loadings and sediment oxygen demand
5. Eliminating ammonia inputs from wastewater point sources
6. Increasing wastewater inputs to maximum permitted values
7. Deepening of the navigation channel
8. Changing Brunswick County wastewater loadings

The final section provides an analysis of the relative magnitudes of the processes that produce a dissolved oxygen deficit in the impaired region of the Lower Cape Fear River Estuary during the summer months.

6.2 Effect of Eliminating Wastewater Point Source Loadings

Three model runs were made to investigate the effect of completely turning off the discharges from the twenty wastewater treatment plants that discharge directly to the Lower Cape Fear River Estuary (see Table 9 for a list of wastewater point sources). These scenarios were run, not because completely eliminating pollutant discharges was considered achievable or advisable, but instead to investigate the system's sensitivity to WWTP loads. For this analysis, the river loads arriving at the model boundary, plus the creek and wetland inputs within the estuary were maintained at the base condition levels. To model the elimination of wastewater loads it was assumed that organic matter (refractory particulate carbon, nitrogen, and phosphorus; dissolved carbon, nitrogen, and phosphorus) and ammonia concentrations in the wastewater inputs would be decreased to 0.0 mg/L.

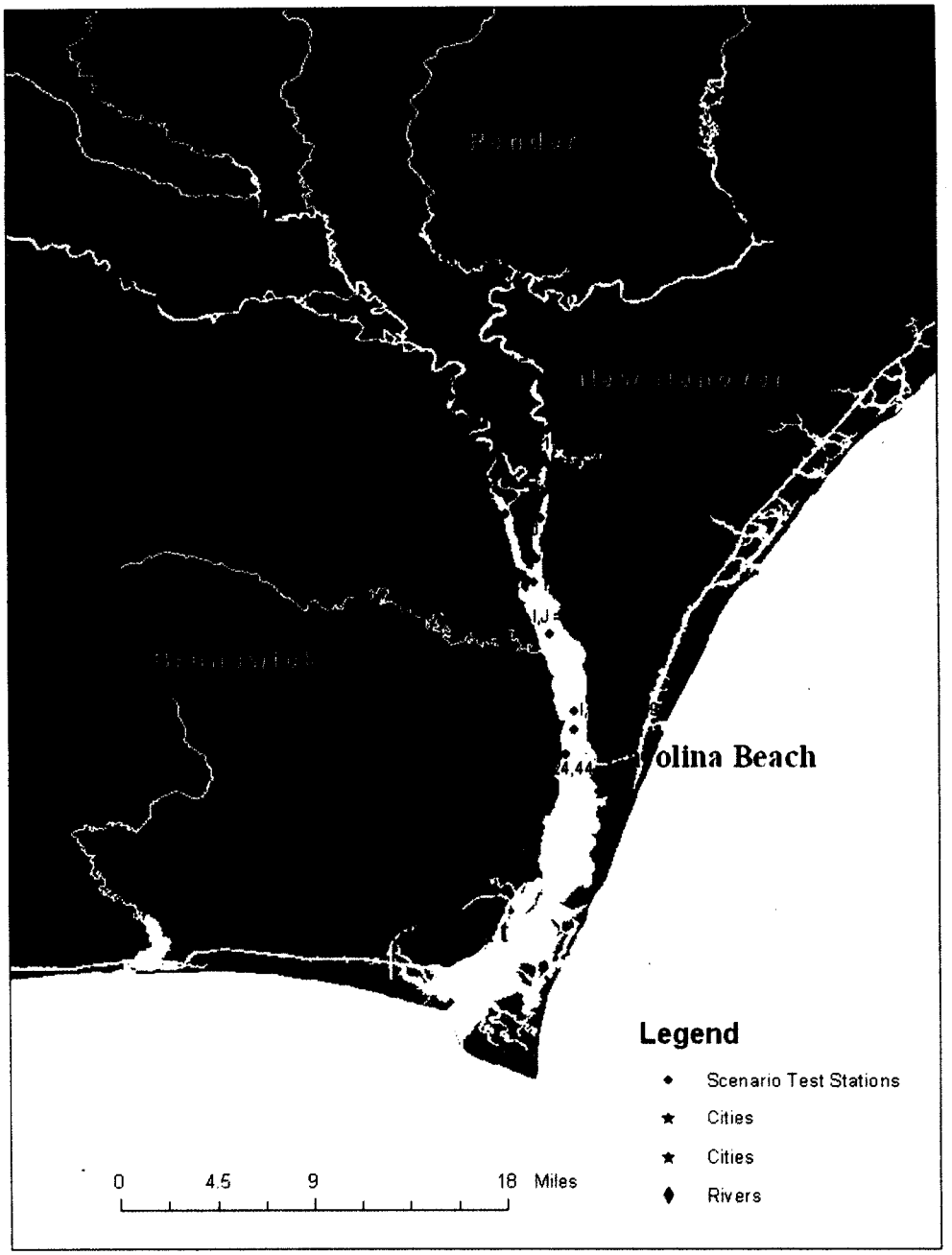


Figure 78. Eighteen Locations Used to Determine Model Predicted Dissolved Oxygen Concentrations for the Scenario Tests

When all WWTP loads were eliminated, the 10th percentile DO concentration increased by approximately 0.3 mg/L, from 4.3 to 4.6 mg/L (Figure 79). In general the effect of eliminating the wastewater input had a larger impact on the lower dissolved oxygen concentrations than it did on the higher DO concentrations. Whereas the 10th percentile DO

concentration increased by 0.3 mg/L, the median value DO concentration increased by about 0.10 mg/L, from 5.6 to 5.7 mg/L when all point source discharges were removed. The distribution of dissolved oxygen concentrations above 6.0 mg/L was only slightly changed (< 0.1 mg/L) by eliminating wastewater inputs of organic matter and ammonia (Figure 79). Selectively turning off individual WWTP loads, as expected, had a smaller effect. Turning off the International Paper WWTP had an effect that was roughly 2/3 of that when all the plants were turned off. Turning off both Wilmington domestic wastewater treatment plants had an effect that was roughly 1/3 of that when all discharges were turned off (Figure 79). It was also found that eliminating the wastewater point sources results in only a small decrease in the percentage of DO concentrations below 5.0 mg/L. For the base case, with discharges from all twenty wastewater

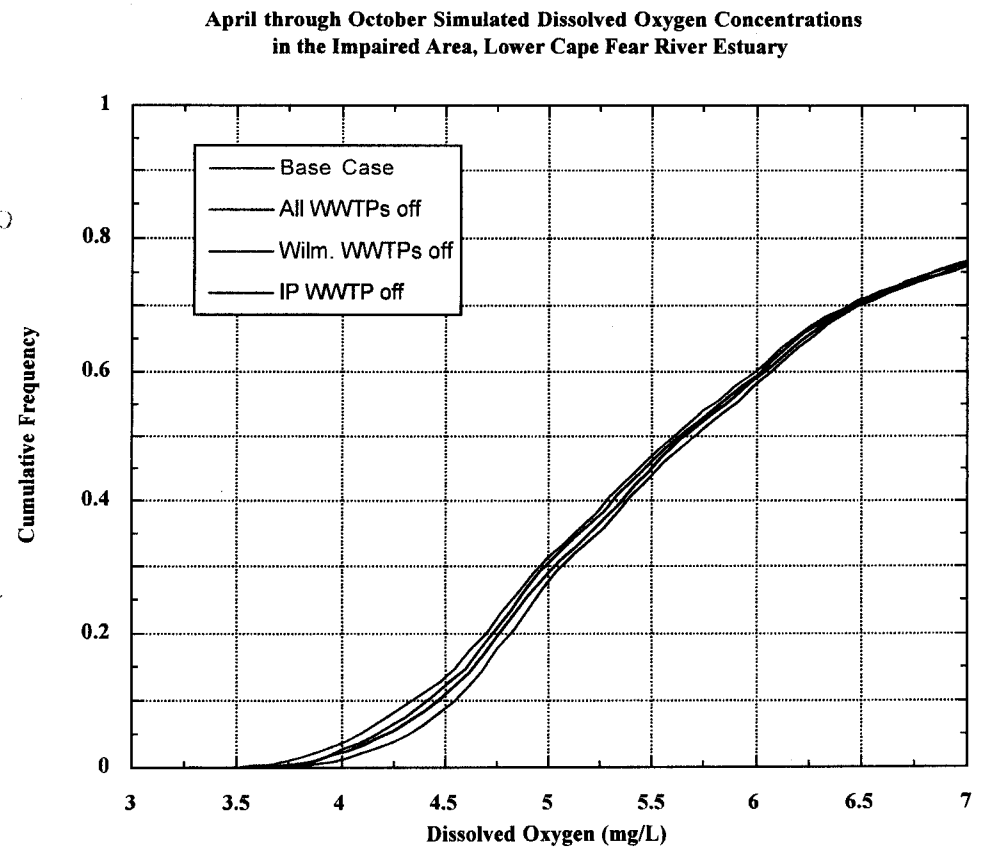


Figure 79. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and Three Wastewater Treatment Plant Load Reduction Scenarios. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

treatment plants, approximately 32% of the estimated DO concentrations in the impaired region during the summer months are below 5.0 mg/L. When the oxygen demanding wastes from these point sources are completely eliminated, approximately 27% of summertime DO concentrations are below 5.0 mg/L (Figure 79).

6.3 Effect of Reducing River, Creek, and Wetland Loadings

The impact of changing the loadings that entered the model region from rivers, creeks, and wetlands was also investigated. Loading reductions of either 30%, 50%, or 70% were assumed for the three river inputs (Cape Fear, Black, and Northeast Cape Fear), and from the fourteen creek and wetland inputs into the estuary. To reduce the loadings, flows were maintained at the base case levels, but concentrations were reduced by 30%, 50%, or 70% from the base case values. Identical reduction percentages were assumed for the organic matter (refractory particulate carbon, nitrogen, and phosphorus; dissolved carbon, nitrogen, and phosphorus) and ammonia constituents. Loadings for the twenty wastewater point sources were maintained at the levels in the base case scenario. As with all scenarios, twice-daily DO concentration snapshots were analyzed for all eight model layers, at eighteen sites within the impaired region for 215 days during 2004 (April 1, 2004 – October 31, 2004).

The load reductions of riverine, creek, and wetland inputs were found to have a significant impact on the estimated dissolved oxygen concentrations during the summer months in the impaired region of the Lower Cape Fear River Estuary. At the 10th percentile level, DO concentrations for the three load reduction scenarios increased by 0.2, 0.3, and 0.4 mg/L respectively, from 4.3 mg/l to either 4.5, 4.6, or 4.7 mg/L (Figure 80). Unlike the scenarios described in the previous section in which wastewater loading decreases were investigated, the level of increase in DO concentration was maintained at the higher percentiles when reductions in the river, creek, and wetland loadings were made. In fact, for this "clean river" scenario, the median DO concentration increased to even a greater extent than the 10th percentile value, increasing from 5.6 to 5.85 mg/L for the 30% reduction (an increase of 0.25 mg/L), and from 5.6 to 6.2 mg/L (an increase of 0.6 mg/L) for the 70% reduction scenario (Figure 80). Nonetheless, even at this largest assumed loading reduction amount of 70%, a significant fraction (approximately 19%) of DO concentrations are below 5.0 mg/L. For the base case, approximately 32% of DO concentrations during the summer months are below 5.0 mg/L (Figure 80).

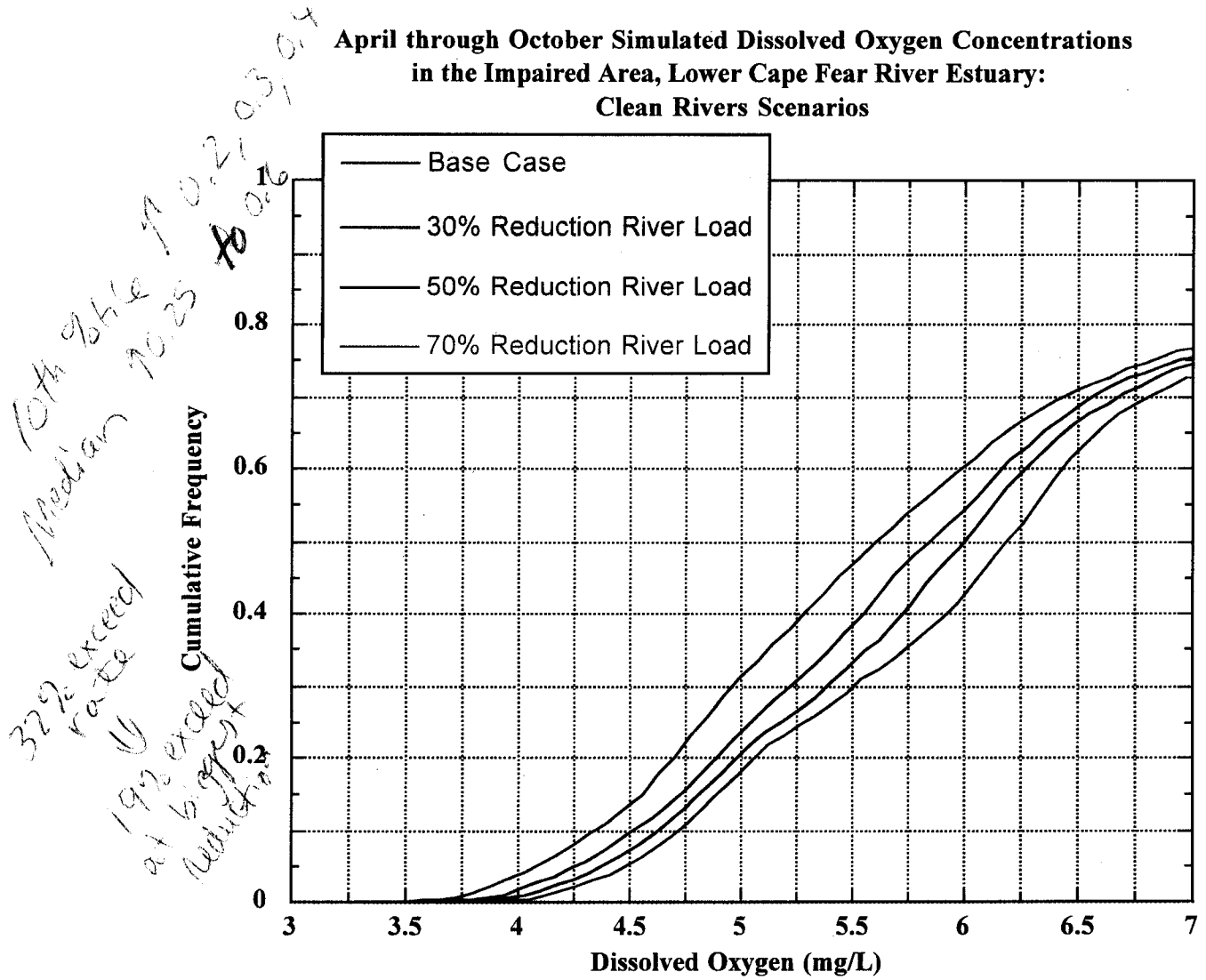


Figure 80. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and two Scenarios that Reduce Loading from Rivers and Creeks by 30%, 50%, and 70%. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.4 Effect of Changing Sediment Oxygen Demand

Additional water quality model runs were conducted to investigate the sensitivity of the results to the choice of model kinetic parameters. Because of its relative importance in determining dissolved oxygen concentrations, the sensitivity analysis focused on the impact of various choices for the sediment oxygen demand. During calibration it was found that this parameter had a significant impact on dissolved oxygen concentrations in the estuary. In addition to the calibrated SOD value (0.4 $g/m^2/d$ at 20° C), runs were made at a lower value (0.3 $g/m^2/d$ at 20° C) and a higher value (0.5 $g/m^2/d$ at 20° C). Model fit to the observed data set was compared for these three cases. All three cases (SOD @ 20 deg C = 0.3, 0.4, 0.5) had similar correlation r^2 values (83.4%, and 84.5%, and 83.4%), but on average the low SOD case overpredicted DO concentrations by 0.11 mg/L, while the high SOD case underpredicted DO concentrations by a similar amount (0.09 mg/L).

The impact of turning off the organic matter and ammonia loadings from all wastewater treatment plants was investigated for each of these three SOD cases. Each scenario produced a very similar change in DO concentration when all point sources were turned off (Figure 81). Even though DO concentrations were changed with the different SOD cases, in each scenario, turning off the sources increased DO concentrations by approximately 0.25 mg/L at the 10th percentile level (Figure 81). Likewise the percentage of DO values below 5.0 mg/L decreased by a similar amount using the three different sediment oxygen demand values. For the base case SOD value (0.4 $g/m^2/d$ at 20° C) turning off the wastewater sources decreased the percentage of DO values below 5.0 mg/L from 45% to 40%. For the lower SOD value (0.3 $g/m^2/d$ at 20° C), removing the wastewater sources decreased the percentage of values below 5.0 mg/L from 37% to 29%. Using the higher SOD value (0.5 $g/m^2/d$ at 20° C) removing the wastewater sources decreased the percentage of values below 5.0 mg/L from 54% to 49% (Figure 81). The magnitude of change in the percentage of values below 5.0 mg/L changes only slightly for these three SOD values. It is expected that changes in other model parameters would have a qualitatively similar result. Although absolute concentrations are affected by changes in parameter values, relative changes in concentration are less affected by changing parameter values.

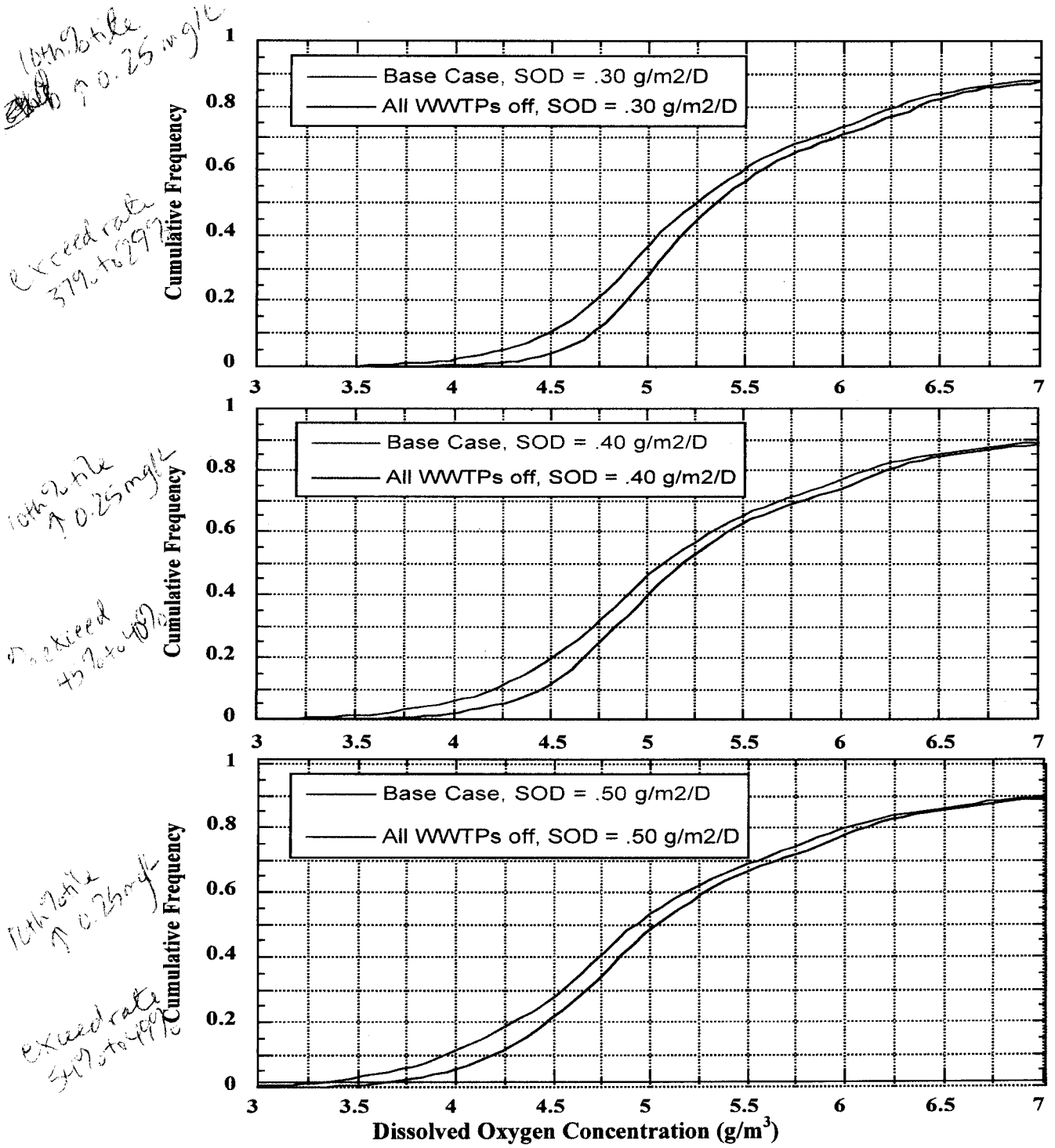


Figure 81. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and a No WWTP Loading Scenario for Three Different Values of Sediment Oxygen Demand. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.5 Cumulative Effect of Lower Sediment Oxygen Demand and Reduced Loadings from Rivers, Creeks, and Wetlands

It has been shown (section 6.3) that even a 70% loading reduction in the organic matter inputs from rivers, creeks, and wetlands sources is not enough to completely eliminate violations of the state water quality standard of 5.0 mg/L (see Figure 80), even though these sources constitute the majority of inputs of oxygen demanding wastes into the Lower Cape Fear Estuary (see Figures 42 and 43). In this scenario we examine what conditions would be necessary to produce summertime DO concentrations above 5.0 mg/L. In addition, one limitation of the analysis done previously is that it ignores possible changes that might occur in the benthos if organic matter loadings were reduced. For instance, it is likely that a reduction of 30% or 50% or 70% in organic matter loading would in the long-term also result in lower sediment oxygen demands. The cumulative effect of decreasing both organic matter loading and sediment oxygen demand are examined in this scenario.

In this scenario a total of six additional runs were made and compared to the base case. As done previously, three runs assumed that the oxygen demanding wastes (organic matter and ammonia) from the three rivers (Cape Fear, Black, Northeast Cape Fear) and from the fourteen creek and wetland inputs to the estuary were reduced by 30%, 50%, or 70%. These reductions were made by holding steady the freshwater inflows while reducing the concentrations by the appropriate amount. For these three runs, wastewater inputs and the sediment oxygen demand were held at the values used in the base case. Three additional runs were made that assumed 30%, 50%, or 70% reductions both in the oxygen demanding waste input and the sediment oxygen demands. These reductions in sediment oxygen demand were made by assuming a constant percentage reduction in sediment oxygen demand while retaining the assumed time variations in these values. As described in the calibration section of the report, sediment oxygen demand was assumed to vary seasonally, with higher values in the summer when the benthic layer is warmer and the biota more active as compared with the winter months.

As expected reducing the sediment oxygen demand along with the waste inputs had a larger effect than when only the waste inputs were reduced. For the case with a 30% reduction in SOD and loadings from rivers, creeks, and wetlands, the percentage of summertime DO concentrations below 5.0 mg/L was reduced to 22%, as compared to 45% for the base case and 33% when only the oxygen demanding wastes are decreased (Figure 82). The 50% reduction case had an even lower rate of water quality violations, but these were not completely eliminated. With both SOD and oxygen demanding wastes decreased, approximately 7% of summertime DO concentrations in the impaired region are below 5.0 mg/L, as compared to 27% when only the oxygen demanding wastes are decreased (Figure 82). There is also a large increase in the minimum predicted DO concentration for this case. The base case had a minimum predicted DO concentration of approximately 3.2 mg/L, whereas the minimum when SOD and oxygen demanding wastes are reduced by 50% is approximately 4.6 mg/L (Figure 82). A decrease in SOD of 70% and a reduction in river load of 70%, however, does almost completely eliminate dissolved oxygen concentrations below 5.0 mg/L (Figure 82). For this case, only about 1% of the predicted dissolved oxygen concentrations are below the water quality standard value.

April through October Simulated Dissolved Oxygen Concentrations in the Impaired Area, Lower Cape Fear River Estuary: Clean Rivers Scenarios

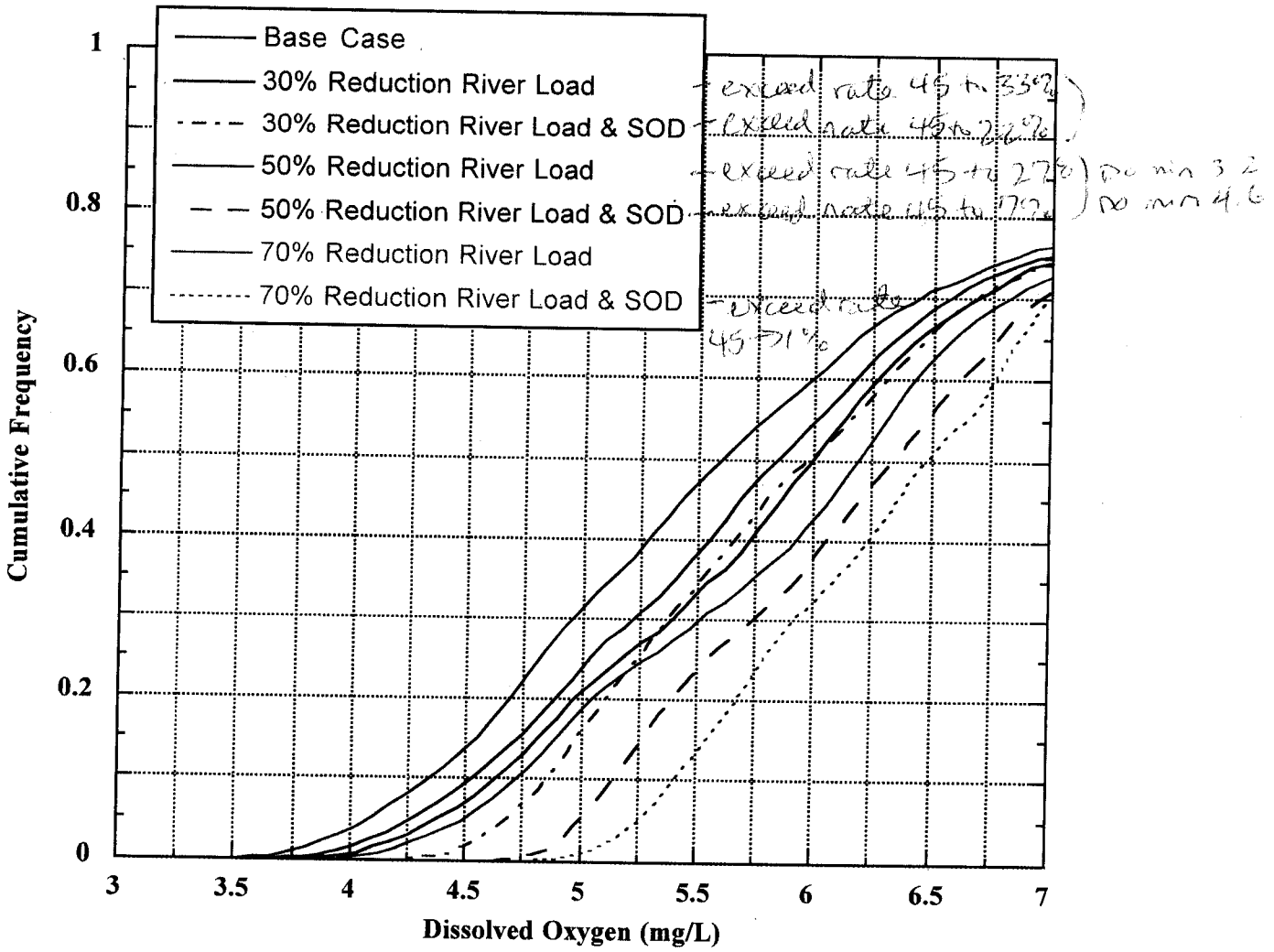


Figure 82. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and two Scenarios that Reduce Loading from Rivers and Creeks by 30% and 50%. The dashed lines show the corresponding changes in dissolved oxygen when SOD is also reduced by 30% or 50%. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.6 Effect of Eliminating Ammonia Inputs from Wastewater Point Sources

A fifth scenario considered eliminating the ammonia loading for all wastewater treatment plants. As for the other scenarios, loading reductions were achieved by decreasing the effluent concentrations, while keep the discharges at that specified in the base case. For this scenario the ammonia concentration in all twenty wastewater point sources was set to zero. The wastewater loadings from all other constituents was held constant, as was the loading from the seventeen other point sources that provided contributions from the rivers, creeks, and wetlands that discharge directly to the estuary.

This scenario produced an increase in dissolved oxygen concentrations that was detectable but not dramatic. As expected, the magnitude of the increase was less than when both the organic matter and ammonia loadings were eliminated from wastewater sources. At the 10th percentile level, dissolved oxygen concentrations increased by about 0.1 mg/L, from about 4.3 mg/L for the base case to about 4.4 mg/L when the ammonia loading was eliminated (Figure 83). The magnitude of the increase generally decreased for higher percentile values. For instance, the median dissolved oxygen concentration in the base case (5.6 mg/L) increased by only about 0.05 mg/L, with concentrations in the upper part of the distribution (> 6.0 mg/L) increasing by an even lesser amount. A small, but detectable drop in percentage of DO concentrations less than 5.0 mg/L was seen when ammonia discharges from wastewater treatment plants was eliminated. In the base case approximately 32% of summertime DO concentrations in the impaired region are below the water quality standard of 5.0 mg/L, whereas approximately 30% are below 5.0 mg/L when ammonia discharges are eliminated (Figure 83).

10th ctile 0.1 mg/L
median 0.05 mg/L
exceed rate
32% → 30%

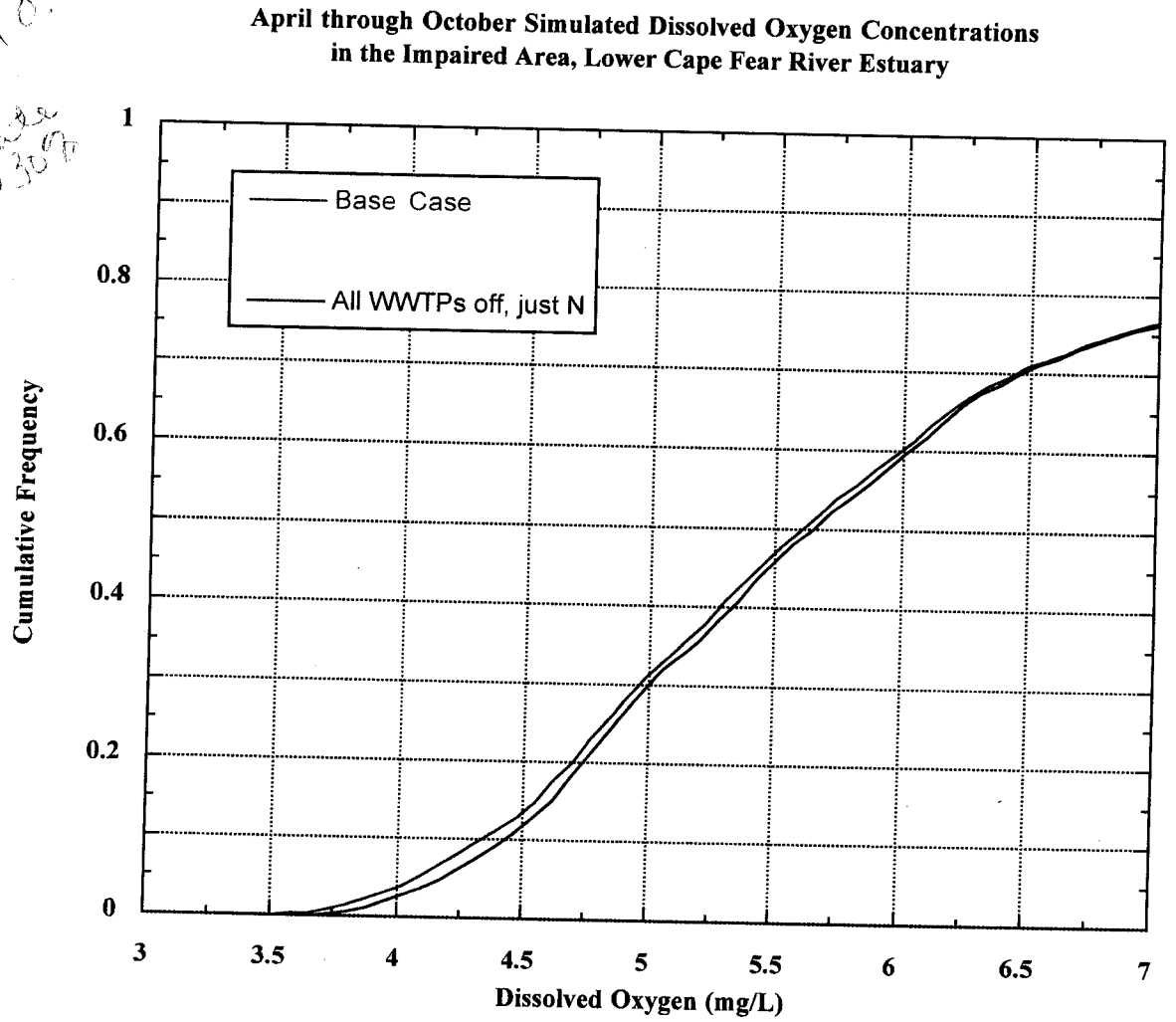


Figure 83. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and a no Ammonia Loading Scenario. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.7 Effect of Increasing Wastewater Inputs to Maximum Permitted Values

The base case scenario used facility discharge monitoring records to establish the loadings of oxygen demanding wastes from each of the twenty wastewater point sources that discharge directly to the Lower Cape Fear Estuary. In several instances, the actual loadings were considerably below permitted maximum values. Of interest is how increasing all 20 wastewater inputs to the permitted maximum values would affect the dissolved oxygen conditions in the estuary. In this scenario, those permitted maximum discharges are assumed for each of the sources where that information is available.

Of the twenty wastewater point sources in the model, thirteen had maximum permitted discharges for either BOD, flow, or ammonia that exceeded the loadings in the base case (Table 23). For each of these sources, modifications were made to the EFDC water quality point source input file (WQPSL.INP) to simulate a continuous discharge at the maximum permitted value. The permit limits for these thirteen sources (Table 24) were provided by the NC Division of Water Quality (DWQ). In keeping with the DWQ's rules for these permits, winter limits were used for five months (January, February, March, November, December) and summer limits for the remaining seven months. In creating the scenario all other sources and parameters were held at the base case levels..

Table 23. Model Point Sources That Were Adjusted to Maximum Permitted Values

Source No.	NPDES Permit No.	Name of Source
1	NC0000663	Dupont-Wilmington/Brunswick, Outfall 1
5	NC0001112	Arteva Specialties-Wilmington, Outfall 2
6	NC0003298	International Paper
7	NC0021334	Southport, Town-WWTP/Southport
8	NC0023256	Carolina Beach, Town-WWTP
9	NC0023965	Wilmington-Northside WWTP
10	NC0023973	Wilmington-Southside WWTP
11	NC0025763	Kure Beach WWTP, Town Of
12	NC0027065	Archer Daniels Midland Co.
13	NC0059234	Takeda Chemical Products USA
16	NC0075540	Belville, Town – WWTP
17	NC0082295	Fortron Industries
35	NC0086819	Brunswick Co. WWTP

The scenario with the thirteen wastewater sources at their permitted maximum values produced dissolved oxygen concentrations that were slightly lower than the corresponding base values by approximately 0.1 mg/L (Figure 84). This decrease of approximately 0.1 mg/L was seen throughout the distributions, with both the 10th percentile DO concentration value and the

median value decrease by a similar amount. More low DO concentrations were predicted for the maximum permit case as opposed to the base case. The percentage of DO concentration below the water quality permit value of 5.0 mg/L increased from 32% to approximately 34% for the maximum permit case (Figure 84). Approximately 4% of the base case DO concentrations in the impaired region during the Summer were expected to be below 4.0 mg/L, while the maximum permit case had approximately 7% below 4.0 mg/L (Figure 84).

Table 24. Total Maximum Monthly Permitted Values for the Point Sources in the Lower Cape Fear Estuary.

Permit #	Constituents	[redacted]
NC0000663	Flow	
1	BOD, 5-Day (20 Deg. C)	
	Solids, Total Suspended	
NC0001112	Flow	
5 (2)	BOD, 5-Day (20 Deg. C) Summer	
	Solids, Total Suspended	
NC0003298	Flow	
6	BOD, 5-Day (20 Deg. C) Winter	
	BOD, 5-Day (20 Deg. C) Summer	
	Solids, Total Suspended	
NC0021334	Flow	
7	BOD, 5-Day (20 Deg. C)	
	Solids, Total Suspended	
NC0023256	Flow	
8	BOD, 5-Day (20 Deg. C) Winter	
	BOD, 5-Day (20 Deg. C) Summer	
	Nitrogen, Ammonia Total (as N) winter	
	Nitrogen, Ammonia Total (as N) summer	
NC0023965	Flow	
9	BOD, 5-Day (20 Deg. C)	
	Solids, Total Suspended	
	Nitrogen, Ammonia Total (as N) winter	
	Nitrogen, Ammonia Total (as N) summer	

NC0023973	Flow	[redacted]
10	BOD, Carbonaceous 05 Day, 20 deg C	
	Solids, Total Suspended	
NC0025763	Flow	
11	BOD, 5-Day (20 Deg. C) All Yr	
	Solids, Total Suspended	
NC0027065	Flow	
12	BOD, 5-Day (20 Deg. C)	
	COD, Oxygen Demand, Chem. (High Level)	
	Solids, Total Suspended	
	Nitrogen, Total (as N)	
NC0059234	Flow	
13	BOD, 5-Day (20 Deg. C)	
	COD, Oxygen Demand, Chem. (High Level)	
	Solids, Total Suspended	
NC0075540	Flow	
16	BOD, 5-Day (20 Deg. C) Winter	
	BOD, 5-Day (20 Deg. C) Summer	
	Solids, Total Suspended	
	Nitrogen, Ammonia Total (as N) winter	
	Nitrogen, Ammonia Total (as N) summer	
NC0082295	Flow	
17	BOD, 5-Day (20 Deg. C)	
	Solids, Total Suspended	
NC0086619	Flow	
35	BOD, 5-Day (20 Deg. C) All Yr	
	BOD, 5-Day (20 Deg. C) Winter	
	BOD, 5-Day (20 Deg. C) Summer	
	COD, Oxygen Demand, Chem. (High Level)	
	Solids, Total Suspended	
	Nitrogen, Ammonia Total (as N)	
	Nitrogen, Ammonia Total (as N) winter	
	Nitrogen, Ammonia Total (as N) summer	

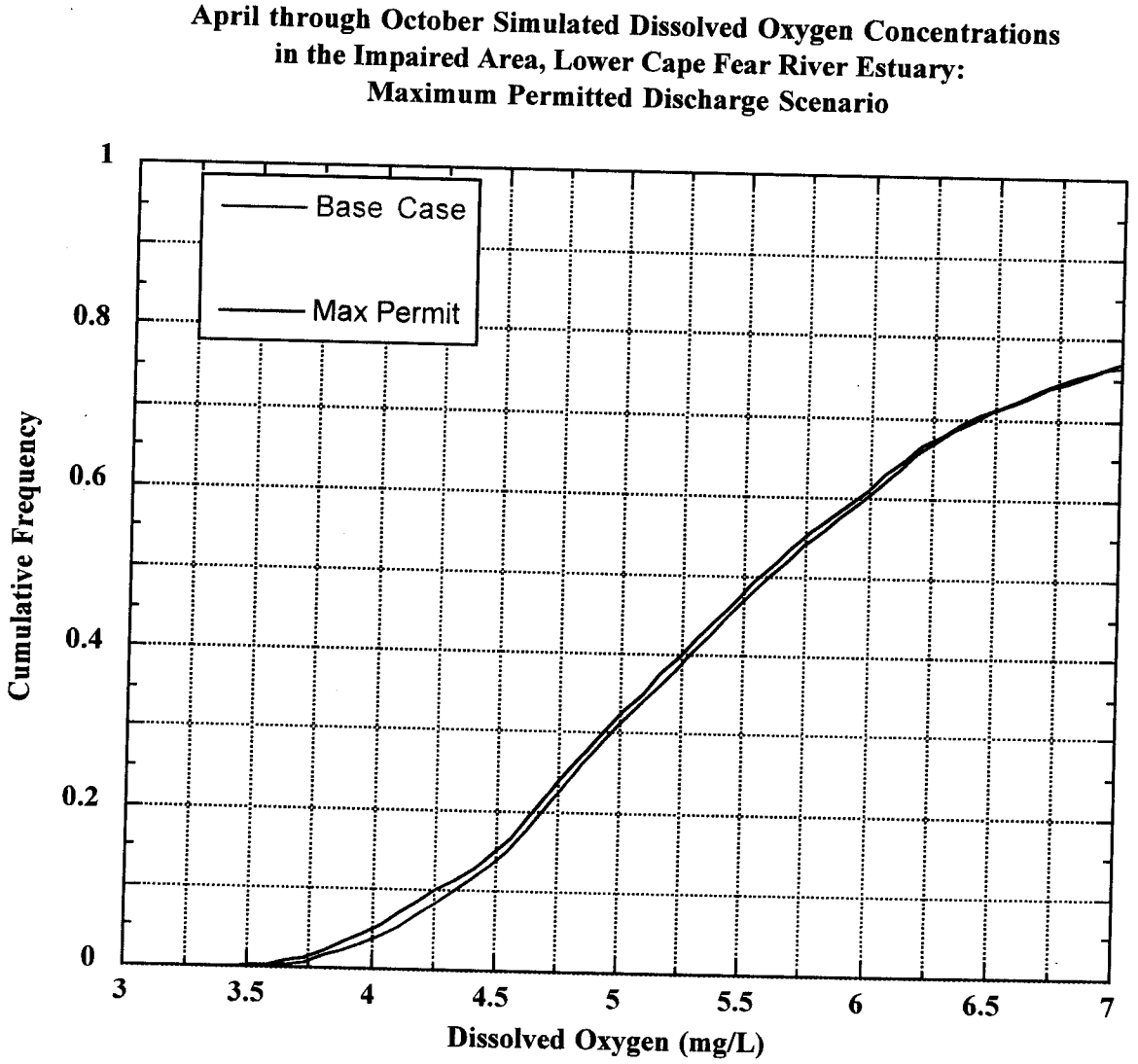


Figure 84. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and a Scenario Where all WWTP's are Set to the Their Maximum Permitted Discharge. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.8 Effect of Deepening of the Navigation Channel

An ongoing navigation channel deepening project is underway in the Lower Cape Fear River Estuary. This project is being conducted by the Wilmington district of the US Army Corps of Engineers. The Wilmington Harbor Project will deepen 37 miles of channel by 4 feet in the Cape Fear River up to the State Port of Wilmington, and into the Northeast Cape Fear River. Project information is available www.saw.usace.army.mil/wilmington-harbor/main.htm. Information from this site was used to modify the water depths given in the EFDC grid file DXDY.INP. Each grid cell in the navigation channel was deepened according to the plan described by the Army Corps of Engineers. No other changes were made from the base case values in defining the various input files needed to run the model.

The channel deepening had a noticeable, and slightly negative effect on dissolved oxygen concentrations during the summertime in the Lower Cape Fear River Estuary. Deepening of the channel slightly decreased dissolved oxygen concentrations. The reduction in dissolved oxygen concentrations was similar across the distribution of dissolved oxygen values. At the 10th percentile value, the dissolved oxygen was decreased by about 0.2 mg/L, from 4.3 mg/L to 4.1 mg/L. Near the median dissolved oxygen concentration, the dissolved oxygen decreased by about 0.1 mg/L, from 5.6 mg/L to 5.5 mg/L (Figure 85). The effect of deepening the channel is also seen when comparing the frequency of DO concentrations below 5.0 mg/L. For the base case the percentage below 5.0 mg/L was 32%, for the deepened channel the percentage was approximately 34%. Thus there is an effect with the channel deepening, which slightly lowers dissolved oxygen concentrations, but the magnitude of the effect is small (< 0.2 mg/L difference, > 5% difference in DO concentrations below a particular value).

April through October Simulated Dissolved Oxygen Concentrations in the Impaired Area, Lower Cape Fear River Estuary: Dredged Channel Scenario

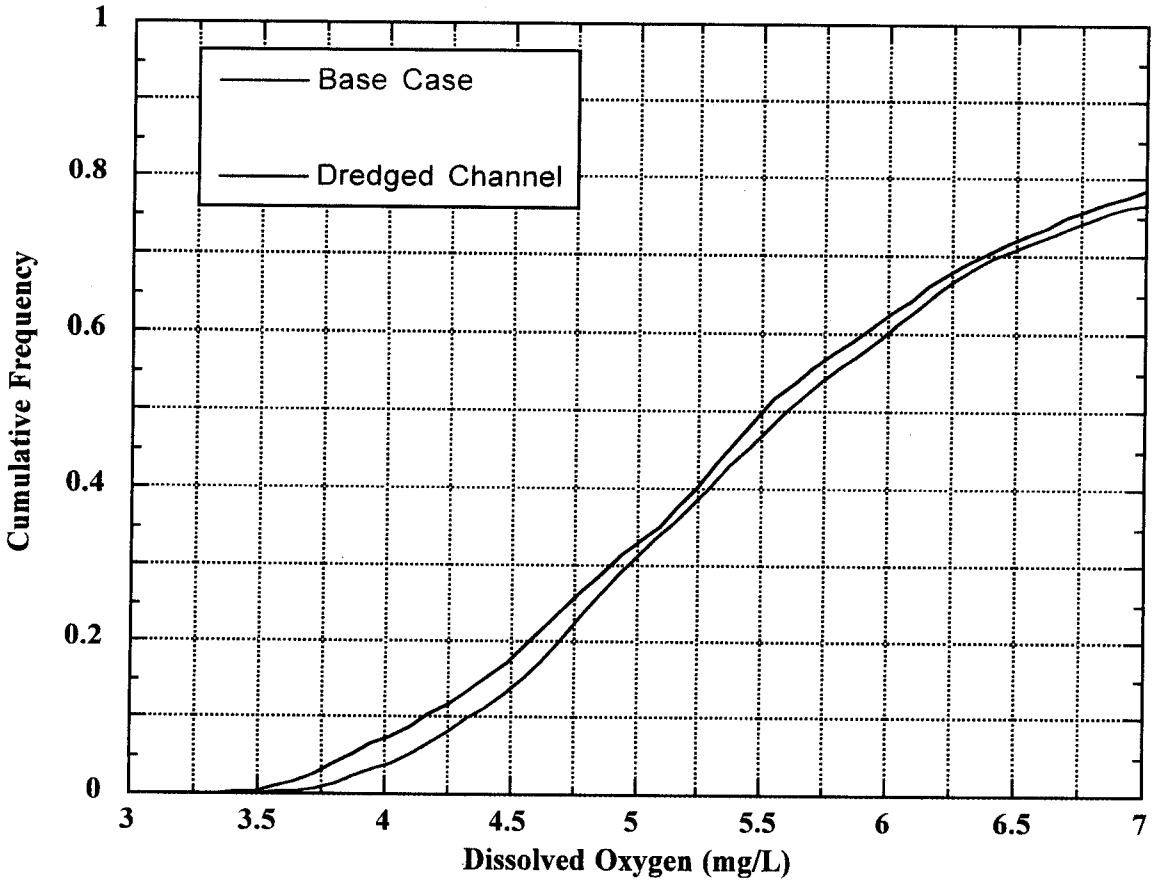


Figure 85. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and a Scenario Where the Navigation Channel is Deepened by Dredging. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.9 Effect of Changing Brunswick County Wastewater Loadings

Three model scenarios considered the impact of changing the wastewater flow of a single discharger (Brunswick County wastewater treatment plant). Based on the discharge monitoring reports for the model period (2003-2005), the base condition had a time-averaged flow of 0.38 MGD. The three alternate scenarios tested had time-averaged flows of 1.65, 4.65 and 15 MGD. These scenarios therefore represented the effect of changing the wastewater treatment flow by factors of 4.3, 12.1, and 39.1. In these alternate loading scenarios, each discharge flow was increased by a constant factor. All concentrations were assumed to be constant. Thus the wastewater loadings had identical patterns of time variation, but had time-averaged flows that equaled the values given above. As for the other scenarios, twice daily dissolved oxygen concentrations were collected and compared to the base case at eighteen sites within the impaired region, from all eight layers of the model and from every day within the summertime period (April 1 – October 31, 2004).

Despite the relatively large changes in the assumed wastewater flow, there were only very small differences in the predicted dissolved oxygen concentrations, for summertime conditions in the impaired region. Across the entire range of dissolved oxygen concentrations, the differences between the base case and each of the three scenarios was always less than 0.05 mg/L (Figure 86). Thus there was essentially no effect of changing the wastewater flow. One limitation of this analysis is the assumption that loading would increase solely by increasing the flow. Since the organic matter concentrations were only slightly higher than the receiving waters, it is not surprising that changing the loading by holding effluent concentrations constant while increasing the flows had a very small effect on dissolved oxygen concentrations.

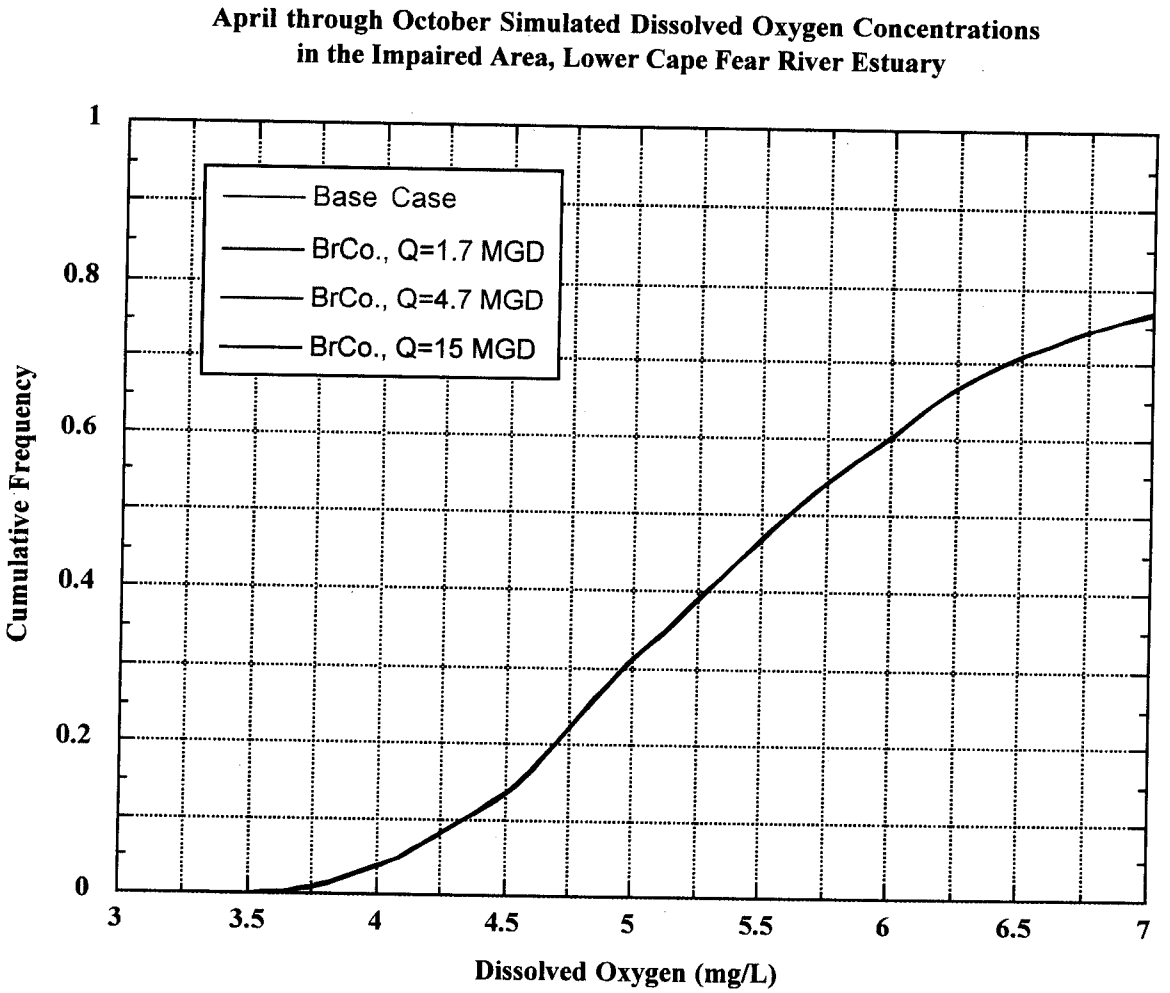


Figure 86. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and Three Brunswick County WWTP Loading Scenarios. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.10 Analysis of the Summer Dissolved Oxygen Deficit in the Impaired Region

One conclusion that results from the previous scenarios is that depressed summertime dissolved oxygen concentrations in the Lower Cape Fear River Estuary can possibly be the result from one or more processes. Sediment oxygen demand, water-column decomposition of organic matter, or oxidation of ammonia can all result in dissolved oxygen depletion. Furthermore, there are several sources of organic matter in the water column (e.g. wastewater point sources, riverine inputs, inputs from creeks and rivers). An important consideration in the analysis of water quality in the Lower Cape Fear River Estuary is the relative importance of these various sources and processes to the dissolved oxygen concentrations in the impaired region of the Estuary.

To investigate the relative importance of these sources and processes, an analysis was performed to quantitatively compare the rates of oxygen consumption in the water-column due to riverine, estuarine, and wastewater sources, and to compare this consumption to sediment oxygen demand. The analysis focused on three sites within the impaired region where monitoring data were available: Cape Fear at Navassa (see Figure 6, Station NAV), Northeast Cape Fear River at Wilmington (see Figure 7, USGS Station 02108690), and Cape Fear River at Horseshoe Bend (see Figure 6, Station HB). Twice daily model predicted dissolved oxygen concentration, temperature, and salinity values were recorded near the surface (layer 7 of 8) at these three stations. Temperature and salinity values were used to calculate dissolved oxygen saturation concentration (Chapra 1997), and then the DO concentrations were plotted as a fraction of the DO saturation concentration (Figure 87) for a fourteen-month period beginning December 1, 2003. At all three stations, the DO saturation fraction is highest during the winter months and lowest during the summer months, probably as a result of temperature related differences in the consumption rate of water-column dissolved oxygen. At all three stations DO saturation percentages peak at about 90% in early March but then decline steady until August, when DO saturation percentages are less than 60% at all three stations. Beginning in early April, DO saturation values go below 70% at all stations, and do go back above 70% until late October (Figure 87).

Clearly oxygen consumption and under-saturated DO concentrations are a persistent feature during the summer at these three stations within the impaired region of the Lower Cape Fear Estuary, but what is the relative importance of the processes that produce this under saturation of dissolved oxygen in the water-column? To investigate this question, a first-order sensitivity analysis was performed to determine the relative importance of these three processes:

1. Discharge of oxygen demanding wastes by the 20 wastewater treatment plants that discharge directly to the estuary,
2. Discharge of oxygen demanding wastes by the three rivers in the basin (Cape Fear, Black, Northeast Cape Fear) as well as the creek and wetlands areas that discharge directly to the estuary, and
3. Sediment oxygen demand.

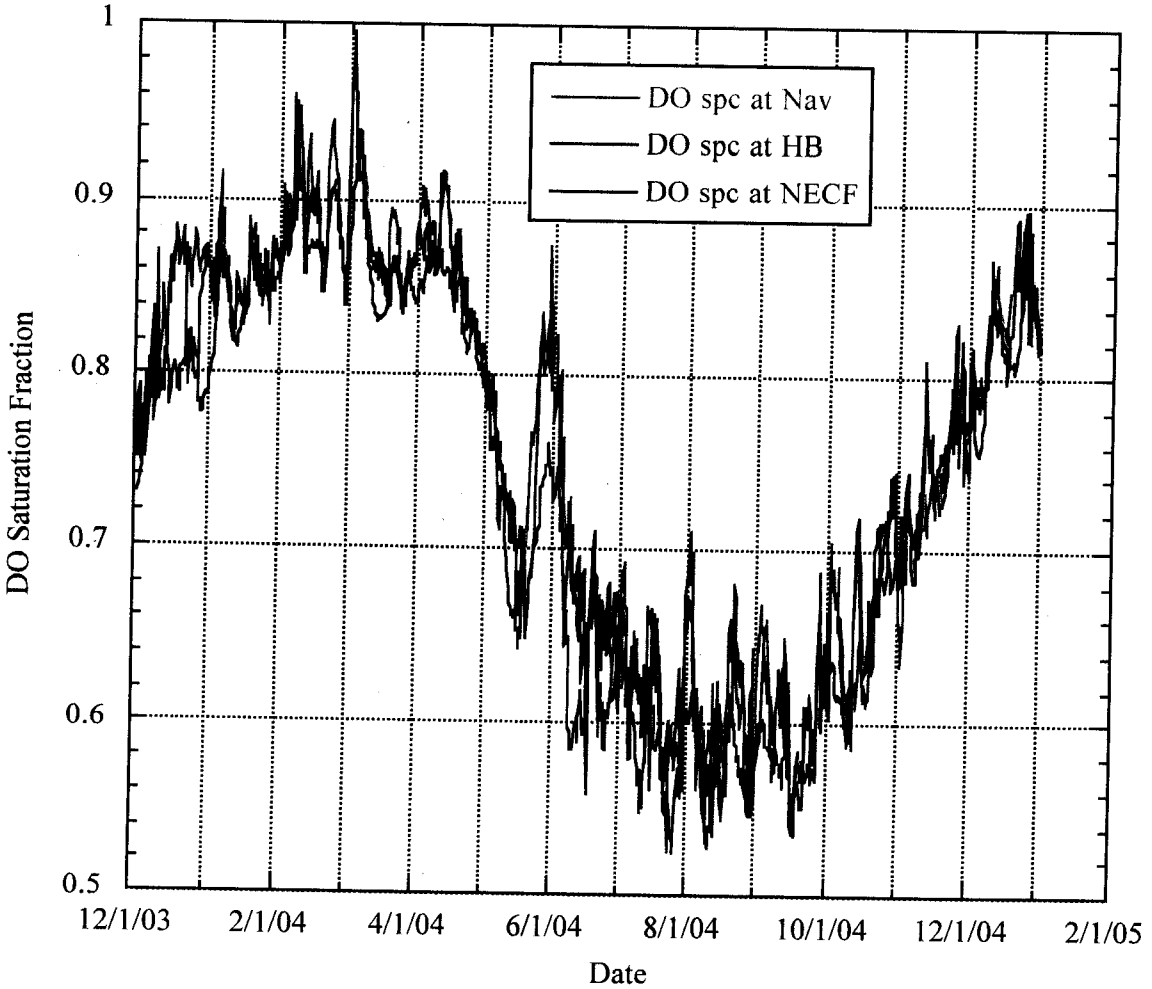


Figure 87. Model Predicted Dissolved Oxygen Concentrations in the Surface Waters as a Percentage of Saturation Concentration at Two Cape Fear Locations (Navassa and Horseshoe Bend) and one NE Cape Fear Station (Wilmington).

Three separate runs were made to determine the sensitivity of the time-averaged DO concentration at the three test sites to changes in one of the processes listed above. In each run, a prescribed relative change (e.g. 10% of the base case) in one of the loadings or the sediment oxygen demand rate was made, while holding all other rates and parameters at the values set in the base case. These three runs were then compared to the base case and the relatively sensitivity of each process was determined by comparing the change in dissolved oxygen

concentration between the cases. The time-averaged mean oxygen depletion at each site was then apportioned based upon the relative sensitivity of the three processes.

There were slight differences in the magnitudes of the oxygen depletion attributable to the three different factors at the three different sites (Figure 88). In general, however, the dissolved oxygen deficit caused by SOD and the river loadings of organic matter were significantly greater than that caused by the WWTP loadings. Time averaged dissolved oxygen concentrations were slightly different at the three sites, ranging from 5.65 mg/L at Navassa to 5.45 mg/L at the Northeast Cape Fear at Wilmington site. At each site the time-averaged dissolved oxygen saturation concentration was approximately 8.2 mg/L, thus each site had a time-averaged dissolved oxygen depletion of approximately 2.7 mg/L. Of the three processes compared, the wastewater treatment plant discharges had by far the smallest dissolved oxygen depletion effect. At each wastewater treatment plants accounted for approximately 0.2 mg/L of the total dissolved oxygen depletion. This amount of depletion represents approximately 7 to 9% of the total depletion. Of the remaining DO depletion (approximately 2.5 mg/L, which is more than 90% of the total), roughly similar amounts could be attributable to SOD or riverine loadings of organic matter. The exception to this was the Northeast Cape Fear at Wilmington site, where more of the depletion (56% vs. 37%) was due to the SOD. These findings are consistent with earlier estimates of organic matter loading that show that rivers, creeks, and wetlands are the dominant sources of oxygen demanding wastes to the estuary (e.g. see Figures 43, 44, and 45).

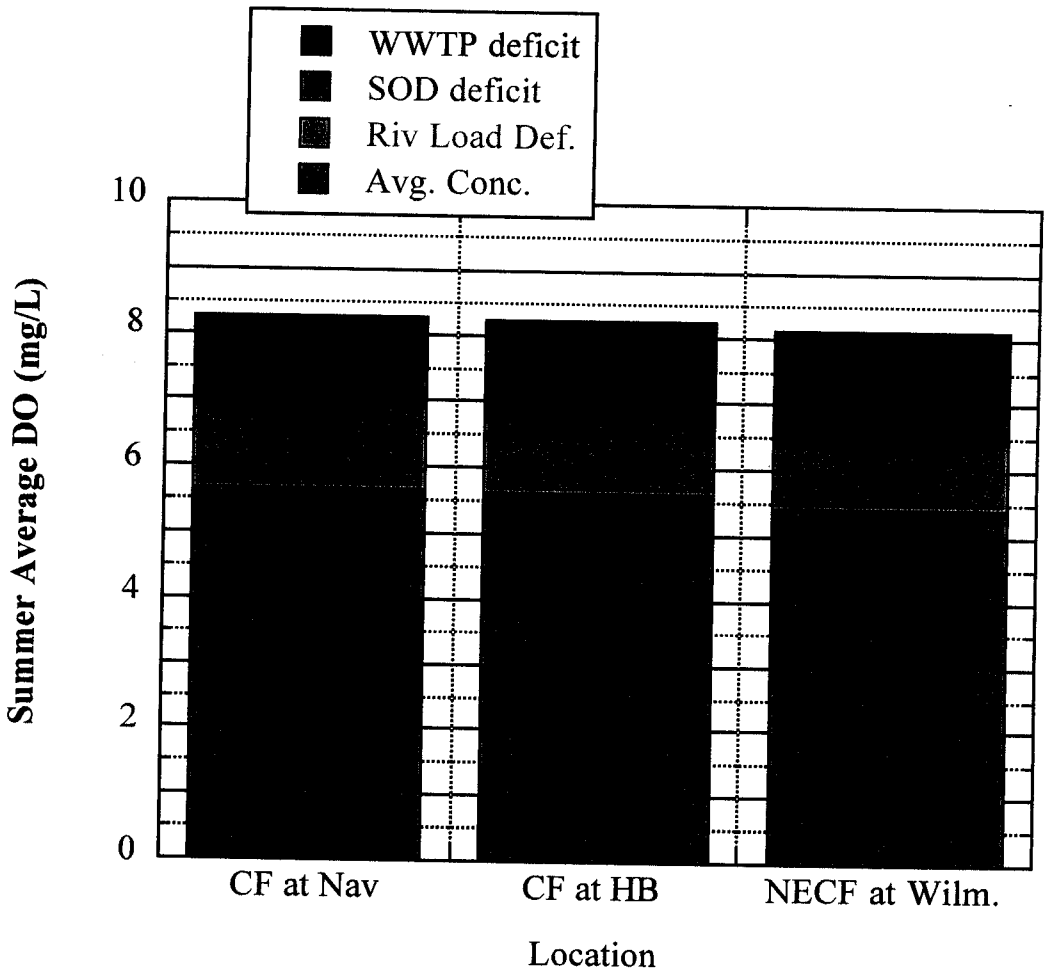


Figure 88. Bar Graphs of Summer Season (April through October) Time-Averaged Model Predicted Dissolved Oxygen Concentrations (green) and the Dissolved Oxygen Deficit Caused by Wastewater Treatment Plants (black) Riverine Discharges (blue), and Sediment Oxygen Demand (pink) at Two Cape Fear Locations (Navassa and Horseshoe Bend) and one NE Cape Fear Station (Wilmington).

7. SUMMARY, DISCUSSION, AND CONCLUSIONS

The three-dimensional water quality model EFDC (Environmental Fluid Dynamics Code) was applied to simulate hydrodynamic and water conditions for the Lower Cape Fear River Estuary, North Carolina. The model region included the tidally affected portions of the Cape Fear, Black, and Northeast Cape Fear Rivers near Wilmington, North Carolina, and extended southward to the mouth of the Cape Fear River near Southport, North Carolina. A multi-agency monitoring program was used to gather the necessary data to run and calibrate the model. A fourteen-month period from November 2003 until January 2005 was used for model calibration. The model was created in such a way so that it separately accounted for the oxygen demanding loadings to the estuary from the three major rivers, tidal creeks and fringing wetlands within the estuary, wastewater treatment plant discharges, and sediment oxygen demand within the estuary. A phased multi-objective calibration procedure was implemented that sought to maximize the model's fit to multiple water quality constituents. The calibration phasing was accomplished in such a way that recognized the primary importance of dissolved oxygen prediction. The calibrated model simulated well the temporal and spatial patterns of dissolved oxygen concentration within the estuary. Model confirmation testing was performed for a twelve-month period from January 2005 to January 2006. The model's ability to simulate dissolved oxygen during the confirmation run was similar to that for the calibration period.

The model was used to investigate the effects of various organic matter and ammonia load reduction scenarios on the dissolved oxygen concentrations within the estuary. Various scenarios investigated the system response to reductions in wastewater and watershed loadings. Of the three primary constituents that contribute to oxygen depletion, only ammonia had a load that was contributed primarily from the wastewater sources. For organic matter loadings, the majority of the load was contributed by the incoming rivers and local tidal creeks and wetlands discharging directly to the estuary. Reducing these watershed loads had a significant impact on the dissolved concentrations within the estuary. Despite the sensitivity of the system to changes in these loadings, elimination of violations of the water quality standard for dissolved oxygen (5 mg/L) would require a 70% reduction both in riverine loadings but also a similar reduction in sediment oxygen demand.

Reducing wastewater loads generally had a smaller, but still noticeable impact on dissolved oxygen concentrations. Generally the magnitude of the increase in dissolved oxygen concentration followed the relative importance of the discharge to the overall loading to the estuary. An additional scenario tested the degree to which parameter variation, in this case sediment oxygen demand, could change the system's sensitivity to load reductions. This case demonstrated that the change in DO concentrations for a particular load reduction did not vary appreciably as the SOD used by the model was changed. Other scenarios investigated the system's sensitivity, with regard to dissolved oxygen concentrations to changes in the estuary that might result from dredging of the navigation channel or increases in wastewater treatment plant loadings up to the maximum permitted values. These two scenarios had a relatively minor effect on dissolved oxygen concentrations.

The model was designed to allow for relatively simple specification of additional scenarios. The results of the scenario tests, strategic choices made in creating the model, and results from previous modeling work on the estuary (e.g. Tetra Tech 2001), indicate that further refinement of the benthic flux model is justified. Both this study and the previous modeling effort demonstrate the significance of benthic fluxes to the overall dissolved oxygen budget. While special efforts were undertaken to rationally specify the temporal and spatial variation in SOD, the method by which benthic fluxes are prescribed rather than predicted from a sediment diagenesis model does limit the predictive ability of this model. For instance, it was recognized that reductions in river loading would probably also reduce sediment oxygen demand in the long-term, but with the prescribed SOD there was no way to predict the magnitude of the changes in SOD, or the time scale of those changes. Also, the monitoring data indicated that spatial differences in SOD probably exist within the estuary, but the DO monitoring data alone don't provide sufficient information to rationally prescribe the spatial variation in sediment quality.

The results of the analysis are qualitatively similar to that of the previous modeling study (Tetra Tech 2001), despite the conceptual differences in the two models. Both models indicate the importance of the wetland areas within the estuary, even though conceptualization of this portion of the water body differs between the two models. The previous model only considered the wetlands to be a sink of dissolved oxygen; consideration of organic matter loadings from these areas was not considered. In the model described here, the tidal creeks and wetlands were considered sinks of dissolved oxygen as well as a source of organic matter and freshwater. In the previous modeling work the "marsh effect" was estimated by completely removing these cells from the model, which had both water quality and circulation effects. In the modeling work described here, the effects of the wetlands were lumped together with that of the major rivers that drain to the estuary. These effects were quantified by varying the loadings from the all of the riverine and non-point sources, and then observing the resulting effects on dissolved oxygen concentrations within the estuary. With the analysis done this way, it is not possible to distinguish between the effect caused by the riverine sources and that from the wetlands and tidal creeks. One good aspect of this model, however, is that a scenario that looks separately at the effects of the rivers and the wetlands could be easily formulated and may be warranted in the future.

It is hoped that the model will be used as a tool for the rational water quality management of the system. The model was created with the objective of considering all sources of oxygen demanding waste to the estuary. A second objective was to quantify these sources in such way so that additional scenario testing would not be overly burdensome. Considering the complexity of the system, the importance of the natural resource, and the importance of the economy supported by the estuary's resources, further analysis in the future using this model seems warranted.

8. REFERENCES

Banks, R. B., and Herrera, F. F. (1977). "Effect of wind and rain on surface reaeration." *J. Environ. Engr. Div. ASCE*, 103(EE3): 489-504.

Bennett, A. F., and P. C. McIntosh. (1982). Open ocean modeling as an inverse problem: tidal theory. *J. Physical Oceanography*, 12, 1004-1018.

Blumberg, A. F., and L. H. Kantha. (1985). Open boundary condition for circulation models. *J. Hydraulic Engineering.*, 111, 237-255.

Bowen, James D. (2000). Calibration Performance of a Two-Dimensional, Laterally-Averaged Eutrophication Model of a Partially Mixed Estuary. In *Estuarine and Coastal Modeling: Proceedings of the 6th International Conference*, Spaulding, Malcolm L., and Butler, H. Lee (ed.), pp. 1244-1258. American Society of Civil Engineers, New York, NY.

Bowie, G. L., Mills, W. B., Porcella, D. B., Campbell, C. L., Pagenkopf, J. R., Rupp, G. L., Johnson, K. M., Chan, P. W. H., Gherini, S. A. & Chamberlin, C. E. (1985). *Rates, constants, and kinetic formulations in surface water quality modeling (Second Edition).* U.S. Environmental Protection Agency, ORD, Athens, GA, ERL, EPA/600/3-85/040. 455 pp.

Cahoon, L.B., J.A. Mickucki and M.A. Mallin. (1999). Nutrient imports to the Cape Fear and Neuse River basins to support animal production. *Environmental Science and Technology* 33:410-415.

Chapra, S. C. (1997). "*Surface Water Quality Modeling.*" WCB McGraw-Hill, Boston, MA, 844 pp.

Cole, T., and Buchack, E. (1995). "*CE-QUAL-W2: A two-dimensional, laterally averaged, hydrodynamic and water quality model, version 2.0.*" Technical Report E1-95-1. U.S. Army Engineer Waterways Experiment Station. Vicksburg, MS.

Duclaud, B. R. (2007). "*Improved reaeration prediction for the Lower Cape Fear River Estuary, North Carolina.*" MS Thesis, University of North Carolina at Charlotte, Charlotte, NC.

Ensign, S. H., Halls, J. N., and Mallin, M. A. (2004). "Application of digital bathymetry data in an analysis of flushing times of two large estuaries." *Computers & Geosciences,* 30, 501-511.

Hamrick, J. M. (1992). "A three-dimensional environmental fluid dynamics computer code: Theoretical and computational aspects." The College of William and Mary, Virginia Institute of Marine Science, Special Report 317, 63 pp.

Hamrick, J. M. (1996). "*Users manual for the Environmental Fluid Dynamic Code*." The College of William and Mary, Virginia Institute of Marine Science, Special Report 328, 224 pp.

Lin, J., Xie, L., Pietrafesa, L. J., Shen, J., Mallin, M. A, and Durako M. J. (2006). "Dissolved oxygen stratification in two micro-tidal partially-mixed estuaries." *Estuarine, Coastal and Shelf Science*, 70, 423-437.

Mallin, M. A., McIver, M. R., Wells, H. A., Williams, M. S., Lankford, T. E., and Merrit, J.F. (2003). "Environmental assessment of the lower Cape Fear River system, 2002-2003." CMS Report Number 03, Center for Marine Science, University of North Carolina at Wilmington, Wilmington, NC.

Mellor, G. L., and Yamada, T. (1982) "Development of a turbulence closure model for geophysical fluid problems." *Rev. Geophys. Space Phys.*, 20, 851-875.

NC Division of Coastal Management. (1999). DCM Wetland Mapping in Coastal North Carolina. Published online at http://www.nccoastalmanagement.net/Wetlands/WTYPEMAPDOC.pdf.

NC Division of Water Quality. (2008). North Carolina 303(d) List, Draft for Public Review, January 10, 2008, http://h2o.enr.state.nc.us/tmdl/General_303d.htm

NCDEHNR. (1994). Water Quality Progress in North Carolina, 1992-1993. 305(b) Report. Report No. 94-07, North Carolina Department of Environment, Health, and Natural Resources, Division of Environmental Management, Water Quality Section, Raleigh, NC.

O'Connor, D. J., and Dobbins, W.E. (1958). "Mechanism of Reaeration in Natural Streams." *Transactions of the American Society of Civil Engineers*, 123, 641-666.

Park, K., Kuo, A.Y, Shen, J., and Hamrick, J.M. (1995). "*A three-dimensional hydrodynamic-eutrophication model (HEM3D): description of water quality and sediment processes submodels*." The College of William and Mary, Virginia Institute of Marine Science. Special Report 327, 113 pp.

Redfield, A. C. (1934). On the proportions of organic derivative in sea water and their relation to the composition of plankton. *In Daniel, R. J. [Ed.] James Johnstone Memorial Volume*. University Press of Liverpool, pp. 177-192.

Roberts, J., and Roberts, T. D. (1978). Use of the butterworth low-pass filter for oceanographic data. *Journal of Geophysical Research*, 83(C11), 5510-5514.

Streeter, H. W., and Phelps. E. B. (1925). "A study of the pollution and natural purification of the Ohio River." Public Health Bulletin No. 146. Public Health Service. Washington, D.C.

Tennekes H., and Lumley J. L. (1972). "*A First Course in Turbulence*." The MIT Press. Cambridge, MA. 300pp.

Tetra Tech. (2001). *3-Dimensional EFDC Water Quality Model of the Lower Cape Fear River and its Estuary*. Prepared for the City of Wilmington and New Hanover County. 174 pp.

Tetra Tech, Inc. (2002a). Theoretical and computational aspects of sediment and contaminant transport in EFDC. A report to the U. S. Environmental Protection Agency, Fairfax, VA.

Tetra Tech, Inc. (2002b). Hydrodynamic and transport extension to the EFDC model. A report to the U. S. Environmental Protection Agency, Fairfax, VA.

Thomann R. V., and Fitzpatrick JF. (1982). "*Calibration and verification of a mathematical model of the eutrophication of the Potomac Estuary*." Report by Hydroqual, Inc. Mahwah, NJ, to DES, Dist. Col.

Thomann, R. V. (1982). Verification of water quality models. *J. Environ. Engrg. Div., ASCE.* 108, 923-940.

Parameters Used to Calculate Loads

	Value	Units	Notes
Name	37257	days	Day 0 = 1/1/2002
Starting Day	15.5	days	Noon on the 15th of the month
Sample Day			

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent value is linearly related to the following 7 measurements, which are given either as loads, concentrations, or flow. Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 D-C), g/m3	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00625 - Nitrogen, Total, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0157	-0.0157	0.00	0.00	0.1134	0.00	0.3402	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00671 - Phosphorus, Total, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.0157	0.0157	0.00	0.00	-0.1134	0.45	-0.3402	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00630 - Nitrogen, Nitrate (NO3), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
50050 - Flow, in conduit, cu ft/sec, treatment plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio					0.4536	0.4536			0.4536	0.4536			0.4536	0.4536	0.4536							
BOD5 to BODU scaleup					1.9	1.9																
C to O2 molecular weight ratio (12/32)					0.3745	0.3745													0.001			
kilograms per gram																			3786.2			
m3 per million gallon									0.25	0.25			0.25									
fraction of non-ammonia nitrogen that is DON															0.75							
fraction of non-ammonia nitrogen that is NOX									0.1389	0.1389												
P to N mass ratio					0.0%	100.0%													100%			
LPOC/DOC split (see jdb_1485)					100%	100%			100%	100%			100%	100%	100%							
Fraction Remaining																						
Resulting Unit in Computed Data						kg/d			kg/d	kg/d			kg/d	kg/d	kg/d				kg/MG			

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	BC	BQ	BQ	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PO4T	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB
	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no
[redacted]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0157	-0.0157	0.00	0.00	0.11	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.0157	0.0157	0.00	0.00	-0.11	0.45	-0.34	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

	BOD	DOP	PO4T	DON	NH4	NO3	DO
Kg to lb ratio	0.4536	0.4536	0.4536	0.4536	0.4536	0.4536	
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram							0.001
m3 per million gallon							3786.2
fraction of non-ammonia nitrogen that is DON		0.25	0.25	0.25			
fraction of non-ammonia nitrogen that is NOX						0.75	
P to N mass ratio		0.1389	0.1389				
Fraction Remaining	100%			100%	100%		

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bq	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB
	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no
00300 - DO, Oxygen, Dissolved	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00310 - BOD, 5-day (20 Deg. C)	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Total (as N)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0157	-0.0157	0.00	0.00	0.11	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00
00630 - Nitrogen, Nitrate (NO3 + NO2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.0157	0.0157	0.00	0.00	-0.11	0.45	-0.34	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00940 - Chloride (as Cl)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00
80082 - Coliform, Fecal (MF, NA-FC)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio						0.4536			0.4536	0.4536				0.4536	0.4536	0.4536					
BOD5 to BODU scaleup						1.9															
C to O2 molecular weight ratio (12/32)						0.3745													0.001		
kilograms per gram																			3786.2		
m3 per million gallon									0.25	0.25			0.25								
fraction of non-ammonia nitrogen that is DON															0.75						
fraction of non-ammonia nitrogen that is NOX									0.1389	0.1389											
P to N mass ratio						100%							100%	100%							
Fraction Remaining																					

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1315	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.1315	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio						0.4536																
BOD5 to BODU scaleup						1.9																
C to O2 molecular weight ratio (12/32)						0.3745																
kilograms per gram									0.001	0.001			0.001	0.001	0.001				0.001			
m3 per million gallon									3786.2	3786.2			3786.2	3786.2	3786.2				3786.2			
fraction of non-ammonia nitrogen that is DON									0.25	0.25			0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio									0.1389	0.1389												
Fraction Remaining						100%							100%	100%								

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

0 0.3228

Parameters Used to Calculate Loads

	Value	Units	Notes
Name			
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg. C), lb/day	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, lb/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1315	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.1315	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, Inflow, of the treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio	0.4536																					
BOD5 to BODU scaleup	1.9																					
C to O2 molecular weight ratio (12/32)	0.3745																					
kilograms per gram									0.001	0.001			0.001	0.001	0.001				0.001			
m3 per million gallon									3786.2	3786.2			3786.2	3786.2	3786.2				3786.2			
fraction of non-ammonia nitrogen that is DON									0.25	0.25			0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio									0.1389	0.1389												
Fraction Remaining	100%												100%	100%								

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

0 0.3228

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
	Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent																					
	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.78	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.03	-0.13	0.71	0.00	0.24	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	-0.10	0.00	-0.03	0.13	-0.71	0.00	-0.24	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio			0.4536		0.4536																	
BOD5 to BODU scaleup			6.11		6.11																	
C to O2 molecular weight ratio (12/32)			0.3745		0.3745																	
kilograms per gram						0.001		0.001	0.001	0.001		0.001	0.001	0.001					0.001			
m3 per million gallon						3786.2		3786.2	3786.2	3786.2		3786.2	3786.2	3786.2					3786.2			
fraction of non-ammonia nitrogen that is ON						0.25		0.25	0.25	0.25		0.25										
fraction of non-ammonia nitrogen that is NOX														0.75								
P to N mass ratio						0.1389		0.1389	0.1389													
LPOC/DOC split (see jdb_1485)			75.0%		[illegible]	[illegible]		[illegible]		[illegible]		[illegible]										
Fraction Remaining			100%		100%	100%		100%	100%	100%		100%	100%	100%					100%			

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

0 1.038

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	ECB	Flow
	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, [illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5 Day (20 Deg. C), [illegible]	0.00	0.00	0.00	0.00	0.00	2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, total suspended, [illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1315	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.1315	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio																						
BOD5 to BODU scaleup	1.9																					
C to O2 molecular weight ratio (12/32)	0.3745																					
kilograms per gram	0.001			0.001	0.001								0.001	0.001	0.001				0.001			
m3 per million gallon	3786.2			3786.2	3786.2								3786.2	3786.2	3786.2				3786.2			
fraction of non-ammonia nitrogen that is DON				0.25	0.25								0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio				0.1389	0.1389																	
Fraction Remaining	100%												100%	100%								

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1315	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.1315	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio																						
BOD5 to BODU scaleup						1.9																
C to O2 molecular weight ratio (12/32)						0.3745																
kilograms per gram						0.001			0.001	0.001			0.001	0.001	0.001				0.001			
m3 per million gallon						3786.2			3786.2	3786.2			3786.2	3786.2	3786.2				3786.2			
fraction of non-ammonia nitrogen that is DON									0.25	0.25			0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio									0.1389	0.1389												
Fraction Remaining						100%							100%	100%								

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
	no	no	no	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day, 20 Deg. C, mg/L	0.00	0.00	0.00	0.00	0.00	4.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, g/mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total Kjeldahl, g/mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia, Total (as N), g/mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.13	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio													
BOD5 to BODU scaleup	3.51	3.51											
C to O2 molecular weight ratio (12/32)	0.3745	0.3745											
kilograms per gram	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		0.001	
m3 per million gallon	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2		3786.2	
fraction of non-ammonia nitrogen that is DON			0.25	0.25	0.25	0.25	0.25						
fraction of non-ammonia nitrogen that is NOX									0.75				
P to N mass ratio			0.1389	0.1389	0.1389								
RPOC/DOC split (see jdb_1485)	0.0%	100.0%	0.0%	100.0%		0.0%	100.0%						
Fraction Remaining	100%	100%	100%	100%	100%	100%	100%	100%	100%			100%	

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	Sd	SA	COD	DO	TAM	FCB	Flow
[illegible]	no	no	no	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	-0.13	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.13	0.13	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio																		
BOD5 to BODU scaleup	1.9	1.9																
C to O2 molecular weight ratio (12/32)	0.3745	0.3745																
kilograms per gram	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001						0.001		
m3 per million gallon	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2						3786.2		
fraction of non-ammonia nitrogen that is DON			0.25	0.25	0.25	0.25	0.25	0.25										
fraction of non-ammonia nitrogen that is NOX										0.75								
P to N mass ratio			0.1389	0.1389	0.1389	0.1389												
RPOC/DOC split (see jdb_1615)	0.0%	100.0%	100.0%		100.0%		0.0%	100.0%										
Fraction Remaining	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%						100%		

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	ECB	Flow
Multiply by Flow to get Daily Load?	no	no	no	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, Biochemical Oxygen Dem, mg/L	0.00	0.00	0.00	0.00	0.00	2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total, mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1315	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia, mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.1315	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total, mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PO4T - Ortho P, Dissolved (Reactive)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio																						
BOD5 to BODU scaleup			1.9		1.9																	
C to O2 molecular weight ratio (12/32)			0.3745		0.3745														0.001			
kilograms per gram			0.001		0.001				0.001	0.001			0.001	0.001	0.001				3786.2			
m3 per million gallon			3786.2		3786.2				3786.2	3786.2			3786.2	3786.2	3786.2							
fraction of non-ammonia nitrogen that is DON									0.25	0.25			0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio									0.1389	0.1389												
LPOC/DOC split (see jdb_1485)			0.0%		100.0%														100%			
Fraction Remaining			100%		100%				100%	100%			100%	100%	100%							

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Br	Bd	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SS	SA	COD	DO	TAM	RCB	Flow
	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no	no
[redacted]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
[redacted]	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[redacted]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[redacted]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[redacted]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.11	0.45	-0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[redacted]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.89	1.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[redacted]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio						0.4536							0.4536	0.4536	0.4536							
BOD5 to BODU scaleup						1.9																
C to O2 molecular weight ratio (12/32)						0.3745																
kilograms per gram									0.001	0.001									0.001			
m3 per million gallon									3786.2	3786.2									3786.2			
fraction of non-ammonia nitrogen that is DON													0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
fraction of TP that is PO4 or DOP									0.5	0.5												
Fraction Remaining						100%							100%	100%								

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = 1/2 TP
PO4 = 1/2 TP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, [illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1315	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.1315	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio	0.4536																					
BOD5 to BODU scaleup	1.9																					
C to O2 molecular weight ratio (12/32)	0.3745																					
kilograms per gram									0.001	0.001			0.001	0.001	0.001				0.001			
m3 per million gallon									3786.2	3786.2			3786.2	3786.2	3786.2				3786.2			
fraction of non-ammonia nitrogen that is DON									0.25	0.25			0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio									0.1389	0.1389												
Fraction Remaining	100%												100%	100%								

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	BC	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
[redacted]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
[redacted]	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[redacted]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[redacted]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1315	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[redacted]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.1315	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[redacted]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[redacted]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio						0.4536																
BOD5 to BODU scaleup						1.9																
C to O2 molecular weight ratio (12/32)						0.3745																
kilograms per gram									0.001	0.001			0.001	0.001	0.001				0.001			
m3 per million gallon									3786.2	3786.2			3786.2	3786.2	3786.2				3786.2			
fraction of non-ammonia nitrogen that is DON									0.25	0.25			0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio									0.1389	0.1389												
Fraction Remaining						100%							100%	100%								

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, mg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1315	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.1315	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio																						
BOD5 to BODU scaleup						1.9																
C to O2 molecular weight ratio (12/32)						0.3745																
kilograms per gram						0.001			0.001	0.001			0.001	0.001	0.001				0.001			
m3 per million gallon						3786.2			3786.2	3786.2			3786.2	3786.2	3786.2				3786.2			
fraction of non-ammonia nitrogen that is DON									0.25	0.25			0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio									0.1389	0.1389												
Fraction Remaining						100%							100%	100%								

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
[illegible]	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1315	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.1315	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio																						
BOD5 to BODU scaleup						1.9																
C to O2 molecular weight ratio (12/32)						0.3745																
kilograms per gram						0.001			0.001	0.001			0.001	0.001	0.001				0.001			
m3 per million gallon						3786.2			3786.2	3786.2			3786.2	3786.2	3786.2				3786.2			
fraction of non-ammonia nitrogen that is DON									0.25	0.25			0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio									0.1389	0.1389												
Fraction Remaining						100%							100%	100%								

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, [illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1315	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.1315	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio						0.4536																
BOD5 to BODU scaleup						1.9																
C to O2 molecular weight ratio (12/32)						0.3745																
kilograms per gram									0.001	0.001			0.001	0.001	0.001				0.001			
m3 per million gallon									3786.2	3786.2			3786.2	3786.2	3786.2				3786.2			
fraction of non-ammonia nitrogen that is DON									0.25	0.25			0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio									0.1389	0.1389												
Fraction Remaining						100%							100%	100%								

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

1

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Br	Bd	Bf	RBOC	RBOC	DBOC	RPOC	DPOC	DOC	PPOC	RPON	DPON	DON	NH4	NO3	SU	SA	COLI	DO	TAM	ECB	Flow
	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+00	0.0E+00	0.0E+00	0.0E+00
	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.7E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-01	-1.3E-01	0.0E+00	0.0E+00	9.5E-01	0.0E+00	2.8E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	-1.3E-01	1.3E-01	0.0E+00	0.0E+00	-9.5E-01	3.8E+00	-2.8E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio																						
BOD5 to BODU scaleup						1.9																
C to O2 molecular weight ratio (12/32)						0.3745																
kilograms per gram						0.001			0.001	0.001			0.001	0.001	0.001				0.001			
m3 per million gallon						3786.2			3786.2	3786.2			3786.2	3786.2	3786.18				3786.2			
fraction of non-ammonia nitrogen that is DON									0.25	0.25			0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio									0.1389	0.1389												
Fraction Remaining						100%							100%	100%								

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

	Value	Units	Notes
Name			
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

1

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	no	no	no	no	no	no	yes	no	no	no
00300: DO, Oxygen, Dissolved, Bottle	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+00	0.0E+00	0.0E+00	0.0E+00
00310: BOD, Biochem. Oxygen Dem. (20 Deg. C) 5 Day	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.7E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00625: Nitrogen, Total (as N) Bottle	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00630: Nitrogen, Nitrate (NO3-N) Bottle	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-01	-1.3E-01	0.0E+00	0.0E+00	1.1E-01	0.0E+00	3.4E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00671: Phosphorus, Orthophosphate (as P) Bottle	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	-1.3E-01	1.3E-01	0.0E+00	0.0E+00	-1.1E-01	4.5E-01	-3.4E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00665: Phosphorus, Total (as P) Bottle	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
00940: Chloride (Cl-) Bottle	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio													0.4536	0.4536	0.4536							
BOD5 to BODU scaleup						1.9																
C to O2 molecular weight ratio (12/32)						0.3745													0.001			
kilograms per gram						0.001			0.001	0.001									3786.2			
m3 per million gallon						3786.2			3786.2	3786.2												
fraction of non-ammonia nitrogen that is DON									0.25	0.25			0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio									0.1389	0.1389												
Fraction Remaining						100%			100%	100%			100%	100%	100%				100%			

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

1

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	BC	BU	BU	RPOC	LPOC	DOC	RPOP	LPOP	DOP	RTOP	RNON	LNON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
[illegible]	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+00	0.0E+00	0.0E+00	0.0E+00
[illegible]	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.7E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
[illegible]	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
[illegible]	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-01	-1.3E-01	0.0E+00	0.0E+00	9.5E-01	0.0E+00	2.8E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
[illegible]	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	-1.3E-01	1.3E-01	0.0E+00	0.0E+00	-9.5E-01	3.8E+00	-2.8E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
[illegible]	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
[illegible]	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio																						
BOD5 to BODU scaleup						1.9																
C to O2 molecular weight ratio (12/32)						0.3745																
kilograms per gram						0.001			0.001	0.001			0.001	0.001	0.001				0.001			
m3 per million gallon						3786.2			3786.2	3786.2			3786.2	3786.2	3786.18				3786.2			
fraction of non-ammonia nitrogen that is DON									0.25	0.25			0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio									0.1389	0.1389												
Fraction Remaining						100%							100%	100%								

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

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C cell.inp file, i columns and j rows, for Cape Fear River
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C dxdy.inp file, in free format across columns
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      30     5    528.85    580.93      4.50      -4.20       0.015
      31     5    498.24    594.57      7.50      -7.20       0.015
      32     5    518.20    604.75     10.50     -10.20       0.015
      33     5    592.94    615.96     13.30     -13.00       0.015
      30     6    492.08    506.28      4.50      -4.20       0.015
      31     6    478.97    511.64      7.50      -7.20       0.015
      32     6    482.89    517.41     13.30     -13.00       0.015
      33     6    503.19    529.03     13.30     -13.00       0.015
       4     7    150.00    688.47      7.00      -6.70       0.015
       5     7   1000.00    688.47      0.30       0.00       0.035
      24     7    343.40    343.39      2.50      -2.20       0.015
      25     7    301.41    355.30      2.50      -2.20       0.015
      26     7    377.25    350.60      2.50      -2.20       0.015
      30     7    471.21    457.79      7.50      -7.20       0.015
      31     7    456.40    451.89     10.50     -10.20       0.015
      32     7    448.45    447.44     13.30     -13.00       0.015
      33     7    455.71    423.62     13.30     -13.00       0.015
       4     8    150.00    706.12      7.00      -6.70       0.015
       5     8   1000.00    706.12      0.30       0.00       0.035
      24     8    315.90    376.14      2.50      -2.20       0.015
      25     8    316.12    358.25      2.50      -2.20       0.015
      26     8    361.08    363.58      2.50      -2.20       0.015
      27     8    403.12    381.77      2.50      -2.20       0.015
      30     8    471.40    379.09     10.50     -10.20       0.015
      31     8    440.39    409.90     10.50     -10.20       0.015
      32     8    420.66    423.09     13.50     -13.20       0.015
      33     8    387.87    430.16     10.50     -10.20       0.015
       4     9    150.00    637.80      7.00      -6.70       0.015
       5     9   1000.00    637.80      0.30       0.00       0.035
      24     9    301.27    332.29      2.50      -2.20       0.015
      25     9    299.34    347.79      2.96      -2.66       0.015
      26     9    367.67    354.97     11.50     -11.20       0.015
      27     9    416.54    350.16     11.85     -11.55       0.015
      28     9    426.36    362.20     12.04     -11.74       0.015
      29     9    415.95    376.67     12.31     -12.01       0.015
      30     9    458.98    378.65     12.50     -12.20       0.015
      31     9    425.34    389.37     13.50     -13.20       0.015
      32     9    405.59    400.23     13.50     -13.20       0.015
      33     9    384.84    399.03     10.50     -10.20       0.015
       4    10    150.00    481.44      7.00      -6.70       0.015
       5    10    514.08    481.44      0.30       0.00       0.035
      23    10    308.45    383.19      7.50      -7.20       0.015
      24    10    272.89    400.25     11.50     -11.20       0.015
      25    10    232.70    381.49     12.76     -12.46       0.015
      26    10    402.96    339.18     11.50     -11.20       0.015
      27    10    424.18    320.70      6.44      -6.14       0.015
      28    10    406.80    333.02      6.81      -6.51       0.015
      29    10    450.81    336.48      7.10      -6.80       0.015
      30    10    435.38    358.01      8.71      -8.41       0.015
      31    10    404.65    369.54      6.38      -6.08       0.015
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32	10	396.96	388.02	4.83	-4.53	0.015
33	10	401.39	402.40	4.00	-3.70	0.015
3	11	102.96	519.71	4.00	-3.70	0.015
4	11	102.96	519.71	6.50	-6.20	0.015
5	11	952.46	519.71	0.30	0.00	0.035
23	11	308.45	565.33	6.65	-6.35	0.015
24	11	224.53	549.10	12.62	-12.32	0.015
25	11	231.61	553.22	7.84	-7.54	0.015
26	11	389.53	547.83	3.08	-2.78	0.015
27	11	406.39	518.22	3.50	-3.20	0.015
28	11	425.67	506.80	3.50	-3.20	0.015
29	11	444.94	495.38	3.50	-3.20	0.015
30	11	422.60	496.68	3.50	-3.20	0.015
31	11	397.62	507.27	3.04	-2.74	0.015
32	11	395.98	499.86	3.00	-2.70	0.015
33	11	396.09	488.63	3.00	-2.70	0.015
4	12	150.75	524.62	6.50	-6.20	0.015
5	12	943.54	524.62	0.30	0.00	0.035
23	12	273.34	598.81	9.55	-9.25	0.015
24	12	189.10	603.06	12.50	-12.20	0.015
25	12	293.87	594.69	4.29	-3.99	0.015
27	12	371.39	591.58	3.00	-2.70	0.015
28	12	390.67	580.90	3.00	-2.70	0.015
29	12	409.95	570.22	3.00	-2.70	0.015
30	12	408.75	562.23	3.00	-2.70	0.015
31	12	400.95	556.47	2.67	-2.37	0.015
32	12	400.20	556.03	2.50	-2.20	0.015
33	12	402.23	563.44	2.50	-2.20	0.015
4	13	141.42	672.68	6.50	-6.20	0.015
5	13	735.86	672.68	0.30	0.00	0.035
23	13	252.41	613.21	6.29	-5.99	0.015
24	13	189.10	623.44	12.50	-12.20	0.015
25	13	304.58	623.26	5.18	-4.88	0.015
26	13	345.10	606.82	2.50	-2.20	0.015
27	13	345.10	606.82	2.50	-2.20	0.015
28	13	365.60	605.64	2.50	-2.20	0.015
29	13	351.93	606.43	2.50	-2.20	0.015
30	13	358.77	606.03	2.50	-2.20	0.015
31	13	393.13	597.25	2.50	-2.20	0.015
32	13	395.63	597.47	2.74	-2.44	0.015
33	13	397.70	603.03	2.00	-1.70	0.015
4	14	185.00	600.19	6.98	-6.68	0.015
5	14	824.74	600.19	0.30	0.00	0.035
23	14	252.41	585.68	3.63	-3.33	0.015
24	14	189.10	575.05	12.54	-12.24	0.015
25	14	292.16	568.85	6.93	-6.63	0.015
26	14	305.24	580.07	2.00	-1.70	0.015
27	14	323.03	593.24	2.00	-1.70	0.015
28	14	341.53	604.50	2.00	-1.70	0.015
29	14	357.97	612.25	1.90	-1.60	0.015
30	14	370.67	616.44	1.82	-1.52	0.015
31	14	379.72	618.02	2.00	-1.70	0.015
32	14	386.09	617.78	2.11	-1.81	0.015
33	14	389.81	613.75	1.50	-1.20	0.015
34	14	398.29	590.09	1.71	-1.41	0.015

4	15	70.71	514.78	6.98	-6.68	0.015
5	15	961.58	514.78	0.30	0.00	0.035
23	15	232.72	518.62	3.48	-3.18	0.015
24	15	203.73	519.01	12.50	-12.20	0.015
25	15	267.28	527.85	7.38	-7.08	0.015
26	15	287.84	567.41	1.74	-1.44	0.015
27	15	307.36	591.25	1.70	-1.40	0.015
28	15	325.26	606.47	1.70	-1.40	0.015
29	15	341.16	616.62	3.00	-2.70	0.015
30	15	354.76	623.64	2.00	-1.70	0.015
31	15	366.10	628.97	1.50	-1.20	0.015
32	15	375.52	633.99	1.50	-1.20	0.015
34	15	391.31	651.94	1.50	-1.20	0.015
35	15	362.71	665.69	1.50	-1.20	0.015
36	15	345.64	649.55	1.50	-1.20	0.015
37	15	410.70	617.62	1.50	-1.20	0.015
43	15	175.40	625.58	9.50	-9.20	0.015
4	16	111.80	585.23	7.31	-7.01	0.015
5	16	845.82	585.23	0.30	0.00	0.035
23	16	213.90	573.56	4.69	-4.39	0.015
24	16	181.95	606.08	12.50	-12.20	0.015
25	16	265.58	631.76	7.57	-7.27	0.015
26	16	285.37	618.71	2.33	-2.03	0.015
27	16	301.78	614.69	1.70	-1.40	0.015
28	16	316.24	615.38	1.74	-1.44	0.015
29	16	316.24	615.38	1.74	-1.44	0.015
31	16	352.89	627.91	1.50	-1.20	0.015
32	16	363.04	634.16	1.50	-1.20	0.015
35	16	373.09	661.76	1.50	-1.20	0.015
36	16	372.83	678.98	1.50	-1.20	0.015
37	16	409.99	701.91	1.50	-1.20	0.015
42	16	173.30	664.97	2.47	-2.17	0.015
43	16	178.85	690.47	8.50	-8.20	0.015
44	16	1200.00	690.47	0.30	0.00	0.035
4	17	152.40	619.05	6.00	-5.70	0.015
5	17	1200.00	619.05	0.30	0.00	0.035
22	17	277.60	558.33	1.50	-1.20	0.015
23	17	208.15	576.02	5.38	-5.08	0.015
24	17	142.13	569.94	12.71	-12.41	0.015
25	17	283.37	576.10	7.21	-6.91	0.015
26	17	290.40	586.29	2.20	-1.90	0.015
27	17	299.13	593.15	2.20	-1.90	0.015
28	17	308.69	598.64	1.50	-1.20	0.015
29	17	318.78	603.66	1.50	-1.20	0.015
31	17	340.33	613.76	1.50	-1.20	0.015
32	17	351.86	619.24	1.93	-1.63	0.015
33	17	363.60	625.06	1.72	-1.42	0.015
34	17	374.06	631.04	1.50	-1.20	0.015
35	17	379.64	639.75	1.50	-1.20	0.015
36	17	357.64	645.77	1.50	-1.20	0.015
42	17	163.91	628.06	6.45	-6.15	0.015
43	17	175.85	615.84	8.50	-8.20	0.015
44	17	1200.00	615.84	0.30	0.00	0.035
4	18	103.08	689.66	5.00	-4.70	0.015
5	18	1200.00	689.66	0.30	0.00	0.035

22	18	256.33	572.13	1.50	-1.20	0.015
23	18	208.47	572.13	6.95	-6.65	0.015
24	18	142.13	569.94	12.50	-12.20	0.015
25	18	294.34	571.37	6.83	-6.53	0.015
26	18	292.72	574.87	3.07	-2.77	0.015
27	18	295.64	579.22	2.87	-2.57	0.015
28	18	301.17	583.82	1.99	-1.69	0.015
29	18	308.49	588.38	1.50	-1.20	0.015
30	18	317.43	592.80	1.50	-1.20	0.015
31	18	328.33	597.05	1.50	-1.20	0.015
32	18	342.06	600.95	1.50	-1.20	0.015
34	18	382.56	595.98	1.50	-1.20	0.015
35	18	369.92	536.08	1.50	-1.20	0.015
42	18	147.00	548.72	4.15	-3.85	0.015
43	18	181.02	574.22	8.50	-8.20	0.015
44	18	1100.00	574.22	0.30	0.00	0.035
4	19	143.96	561.89	4.00	-3.70	0.015
5	19	1100.00	561.89	0.30	0.00	0.035
20	19	1200.00	606.11	0.30	0.00	0.035
21	19	268.74	591.33	1.50	-1.20	0.015
22	19	242.74	575.98	1.50	-1.20	0.015
23	19	214.36	572.58	7.41	-7.11	0.015
24	19	160.70	587.76	13.03	-12.73	0.015
25	19	290.92	595.87	5.56	-5.26	0.015
26	19	288.52	582.50	1.69	-1.39	0.015
27	19	289.64	578.92	3.44	-3.14	0.015
28	19	292.95	579.41	2.73	-2.43	0.015
29	19	298.09	581.74	1.74	-1.44	0.015
30	19	305.21	585.07	1.55	-1.25	0.015
31	19	315.05	589.42	1.60	-1.30	0.015
32	19	329.66	596.24	1.50	-1.20	0.015
33	19	355.08	611.71	1.50	-1.20	0.015
34	19	391.49	599.21	2.27	-1.97	0.015
42	19	160.82	683.53	2.49	-2.19	0.015
43	19	187.33	706.38	8.50	-8.20	0.015
44	19	700.76	706.38	0.30	0.00	0.035
4	20	125.00	497.02	4.00	-3.70	0.015
5	20	497.97	497.02	0.30	0.00	0.035
19	20	522.22	544.85	0.30	0.00	0.035
20	20	520.46	563.13	0.30	0.00	0.035
21	20	247.16	578.30	1.50	-1.20	0.015
22	20	232.22	589.15	1.50	-1.20	0.015
23	20	217.55	599.84	6.54	-6.24	0.015
24	20	177.84	570.44	12.50	-12.20	0.015
25	20	272.68	548.08	5.51	-5.21	0.015
26	20	278.30	566.47	1.50	-1.20	0.015
27	20	280.92	573.68	1.97	-1.67	0.015
28	20	283.23	577.77	3.64	-3.34	0.015
29	20	286.59	581.73	2.37	-2.07	0.015
30	20	291.66	586.42	1.73	-1.43	0.015
31	20	298.83	591.48	1.52	-1.22	0.015
32	20	308.33	594.99	1.50	-1.20	0.015
33	20	321.25	592.33	1.50	-1.20	0.015
43	20	179.96	493.03	7.50	-7.20	0.015
44	20	980.00	493.03	0.30	0.00	0.035

4	21	163.48	636.97	4.00	-3.70	0.015
5	21	777.12	636.97	0.30	0.00	0.035
18	21	543.88	559.19	0.30	0.00	0.035
19	21	924.48	545.94	0.30	0.00	0.035
21	21	238.38	558.01	1.50	-1.20	0.015
22	21	226.86	564.47	1.50	-1.20	0.015
23	21	214.85	568.55	5.19	-4.89	0.015
24	21	161.25	588.38	12.50	-12.20	0.015
25	21	279.99	595.49	6.85	-6.55	0.015
26	21	274.83	580.73	3.94	-3.64	0.015
27	21	272.02	577.38	2.00	-1.70	0.015
28	21	270.92	579.52	2.75	-2.45	0.015
29	21	271.63	585.15	2.84	-2.54	0.015
30	21	274.38	594.03	1.50	-1.20	0.015
31	21	279.21	607.06	1.50	-1.20	0.015
32	21	285.25	625.55	1.50	-1.20	0.015
33	21	307.14	640.88	1.50	-1.20	0.015
43	21	159.14	686.53	6.50	-6.20	0.015
44	21	1200.00	686.53	0.30	0.00	0.035
4	22	125.00	548.29	4.00	-3.70	0.015
5	22	902.80	548.29	0.30	0.00	0.035
17	22	482.46	505.75	0.30	0.00	0.035
18	22	482.46	505.75	0.30	0.00	0.035
20	22	482.54	516.75	0.30	0.00	0.035
21	22	235.11	523.47	2.04	-1.74	0.015
22	22	227.95	530.67	1.50	-1.20	0.015
23	22	218.67	534.34	3.13	-2.83	0.015
24	22	142.84	534.77	12.50	-12.20	0.015
25	22	287.61	540.45	9.28	-8.98	0.015
26	22	268.32	552.92	5.09	-4.79	0.015
27	22	259.86	565.91	2.45	-2.15	0.015
28	22	255.71	577.68	2.46	-2.16	0.015
29	22	253.83	587.67	2.34	-2.04	0.015
30	22	254.30	596.42	1.56	-1.26	0.015
31	22	259.21	606.91	1.50	-1.20	0.015
32	22	267.68	615.01	1.50	-1.20	0.015
43	22	133.14	474.05	5.50	-5.20	0.015
44	22	900.00	474.05	0.30	0.00	0.035
4	23	145.77	637.38	4.00	-3.70	0.015
5	23	776.62	637.38	0.30	0.00	0.035
17	23	485.30	419.43	0.30	0.00	0.035
21	23	333.07	467.21	1.50	-1.20	0.015
22	23	236.64	486.00	1.50	-1.20	0.015
23	23	250.57	515.23	1.96	-1.66	0.015
24	23	142.84	534.77	12.50	-12.20	0.015
25	23	254.17	543.71	10.15	-9.85	0.015
26	23	248.18	565.59	5.56	-5.26	0.015
27	23	245.71	589.65	2.42	-2.12	0.015
28	23	243.18	611.71	2.46	-2.16	0.015
29	23	238.70	629.28	1.90	-1.60	0.015
30	23	228.74	627.96	1.50	-1.20	0.015
31	23	236.34	639.74	1.50	-1.20	0.015
32	23	290.26	652.64	1.50	-1.20	0.015
43	23	160.08	656.22	4.50	-4.20	0.015
44	23	1300.00	656.22	0.30	0.00	0.035

4	24	175.00	654.31	4.00	-3.70	0.015
5	24	1000.00	654.31	0.30	0.00	0.035
17	24	552.30	324.88	0.30	0.00	0.035
21	24	329.94	434.94	1.50	-1.20	0.015
23	24	255.88	468.59	1.56	-1.26	0.015
24	24	160.70	490.37	12.50	-12.20	0.015
25	24	216.28	532.57	11.08	-10.78	0.015
26	24	229.52	582.31	5.39	-5.09	0.015
27	24	238.30	621.92	3.02	-2.72	0.015
28	24	243.31	654.04	2.01	-1.71	0.015
29	24	244.31	677.03	1.50	-1.20	0.015
43	24	201.56	638.85	4.00	-3.70	0.015
44	24	1200.00	638.85	0.30	0.00	0.035
4	25	206.16	667.08	4.00	-3.70	0.015
5	25	1200.00	667.08	0.30	0.00	0.035
17	25	546.10	363.99	0.30	0.00	0.035
21	25	228.08	481.03	1.50	-1.20	0.015
23	25	220.85	548.87	2.20	-1.90	0.015
24	25	146.29	578.54	12.50	-12.20	0.015
25	25	218.41	602.23	10.98	-10.68	0.015
26	25	229.55	626.21	5.65	-5.35	0.015
27	25	241.98	657.39	2.68	-2.38	0.015
28	25	253.89	694.36	1.65	-1.35	0.015
29	25	267.85	730.59	1.74	-1.44	0.015
30	25	237.07	769.45	1.89	-1.59	0.015
31	25	280.18	793.17	1.50	-1.20	0.015
43	25	237.17	617.45	4.00	-3.70	0.015
44	25	801.68	617.45	0.30	0.00	0.035
4	26	201.56	627.00	4.00	-3.70	0.015
5	26	1200.00	627.00	0.30	0.00	0.035
17	26	800.00	442.85	0.30	0.00	0.035
21	26	231.49	534.05	1.50	-1.20	0.015
23	26	211.17	596.25	4.28	-3.98	0.015
24	26	112.25	611.44	12.50	-12.20	0.015
25	26	214.55	618.01	12.58	-12.28	0.015
26	26	229.21	631.30	3.87	-3.57	0.015
27	26	249.96	640.47	1.90	-1.60	0.015
28	26	278.35	639.12	1.50	-1.20	0.015
43	26	227.71	613.88	4.00	-3.70	0.015
44	26	1200.00	613.88	0.30	0.00	0.035
4	27	180.28	631.59	4.00	-3.70	0.015
5	27	1200.00	631.59	0.30	0.00	0.035
18	27	907.14	457.00	0.30	0.00	0.035
19	27	504.02	485.41	0.30	0.00	0.035
20	27	497.56	513.00	0.30	0.00	0.035
21	27	244.65	543.95	1.50	-1.20	0.015
22	27	221.05	564.90	1.77	-1.47	0.015
23	27	210.12	573.31	7.07	-6.77	0.015
24	27	127.57	608.89	12.50	-12.20	0.015
25	27	196.57	649.51	10.84	-10.54	0.015
26	27	227.48	664.59	2.33	-2.03	0.015
27	27	260.00	677.77	1.66	-1.36	0.015
28	27	300.82	699.04	1.50	-1.20	0.015
29	27	369.52	732.80	1.50	-1.20	0.015
43	27	196.47	693.18	4.00	-3.70	0.015

44	27	1200.00	693.18	0.30	0.00	0.035
4	28	180.28	758.22	4.00	-3.70	0.015
5	28	1300.00	758.22	0.30	0.00	0.035
22	28	220.33	556.60	2.87	-2.57	0.015
23	28	201.66	595.76	9.07	-8.77	0.015
24	28	139.75	587.33	12.50	-12.20	0.015
25	28	236.87	573.35	9.32	-9.02	0.015
26	28	258.18	598.68	1.50	-1.20	0.015
27	28	287.31	619.34	1.50	-1.20	0.015
28	28	326.60	638.21	1.50	-1.20	0.015
29	28	382.93	655.65	1.50	-1.20	0.015
30	28	537.69	682.65	1.50	-1.20	0.015
43	28	222.99	690.015	4.00	-3.70	0.015
44	28	1200.00	690.015	0.30	0.00	0.035
4	29	125.00	703.58	4.00	-3.70	0.015
5	29	1300.00	703.58	0.30	0.00	0.035
21	29	237.07	616.81	2.51	-2.21	0.015
22	29	222.71	584.61	6.02	-5.72	0.015
23	29	212.54	566.87	8.25	-7.95	0.015
24	29	134.63	560.24	12.50	-12.20	0.015
25	29	300.91	558.19	7.62	-7.32	0.015
26	29	301.39	561.70	1.50	-1.20	0.015
27	29	320.51	573.01	1.50	-1.20	0.015
28	29	355.82	585.93	1.50	-1.20	0.015
29	29	412.04	596.97	1.50	-1.20	0.015
30	29	495.77	597.43	1.50	-1.20	0.015
31	29	364.42	592.89	1.50	-1.20	0.015
43	29	276.09	789.45	4.00	-3.70	0.015
44	29	1300.00	789.45	0.30	0.00	0.035
4	30	191.64	580.28	4.00	-3.70	0.015
5	30	1100.00	580.28	0.30	0.00	0.035
20	30	227.49	531.80	5.20	-4.90	0.015
21	30	225.31	519.01	7.46	-7.16	0.015
22	30	221.45	535.00	2.64	-2.34	0.015
23	30	217.91	522.32	3.81	-3.51	0.015
24	30	152.07	538.11	12.50	-12.20	0.015
25	30	322.64	570.13	6.90	-6.60	0.015
26	30	325.67	572.98	1.50	-1.20	0.015
27	30	340.06	571.48	1.50	-1.20	0.015
28	30	366.83	569.34	1.50	-1.20	0.015
29	30	412.52	563.71	1.50	-1.20	0.015
30	30	499.28	538.03	1.50	-1.20	0.015
43	30	302.08	575.54	4.00	-3.70	0.015
44	30	1100.00	575.54	0.30	0.00	0.035
4	31	176.71	666.13	4.00	-3.70	0.015
5	31	1300.00	666.13	0.30	0.00	0.035
20	31	235.34	770.17	8.26	-7.96	0.015
21	31	231.35	726.78	7.02	-6.72	0.015
22	31	225.06	711.81	1.75	-1.45	0.015
23	31	215.77	720.88	2.87	-2.57	0.015
24	31	162.50	728.36	12.50	-12.20	0.015
25	31	325.08	685.99	5.92	-5.62	0.015
26	31	335.30	625.33	1.50	-1.20	0.015
27	31	335.30	625.33	1.50	-1.20	0.015
28	31	366.85	584.47	1.50	-1.20	0.015

29	31	397.56	590.72	1.50	-1.20	0.015
30	31	510.41	612.57	1.50	-1.20	0.015
43	31	214.71	733.55	4.00	-3.70	0.015
44	31	1400.00	733.55	0.30	0.00	0.035
4	32	90.14	548.29	4.00	-3.70	0.015
5	32	1080.00	548.29	0.30	0.00	0.035
20	32	235.44	611.75	6.75	-6.45	0.015
21	32	228.95	601.48	6.05	-5.75	0.015
22	32	223.75	592.29	4.71	-4.41	0.015
23	32	219.85	583.35	5.29	-4.99	0.015
24	32	152.15	554.19	12.50	-12.20	0.015
25	32	331.01	536.81	5.62	-5.32	0.015
26	32	334.64	550.15	1.50	-1.20	0.015
28	32	434.64	600.15	1.50	-1.20	0.015
29	32	399.67	618.24	1.50	-1.20	0.015
30	32	399.67	618.24	1.50	-1.20	0.015
43	32	131.24	627.00	4.00	-3.70	0.015
44	32	1200.00	627.00	0.30	0.00	0.035
4	33	176.78	637.38	4.00	-3.70	0.015
5	33	1200.00	637.38	0.30	0.00	0.035
19	33	249.63	512.48	3.93	-3.63	0.015
20	33	226.63	497.43	8.50	-8.20	0.015
21	33	220.16	496.84	3.39	-3.09	0.015
22	33	217.70	490.62	1.50	-1.20	0.015
23	33	222.09	479.36	2.31	-2.01	0.015
24	33	134.82	467.11	12.50	-12.20	0.015
25	33	327.40	478.91	6.58	-6.28	0.015
26	33	322.66	511.83	1.50	-1.20	0.015
28	33	399.13	544.22	1.50	-1.20	0.015
29	33	399.13	544.22	1.50	-1.20	0.015
30	33	338.54	550.21	1.50	-1.20	0.015
43	33	143.96	508.94	4.00	-3.70	0.015
44	33	1000.00	508.94	0.30	0.00	0.035
4	34	106.07	686.04	4.00	-3.70	0.015
5	34	1300.00	686.04	0.30	0.00	0.035
19	34	255.29	434.56	8.39	-8.09	0.015
20	34	232.33	468.82	6.01	-5.71	0.015
21	34	218.89	489.13	1.50	-1.20	0.015
22	34	211.57	502.76	1.50	-1.20	0.015
23	34	210.35	512.93	2.55	-2.25	0.015
24	34	123.31	519.82	12.50	-12.20	0.015
25	34	279.83	533.34	7.64	-7.34	0.015
26	34	296.11	568.27	1.50	-1.20	0.015
28	34	459.92	646.01	1.50	-1.20	0.015
29	34	401.90	617.07	1.50	-1.20	0.015
30	34	404.01	618.20	1.50	-1.20	0.015
43	34	200.06	752.08	4.00	-3.70	0.015
44	34	1400.00	752.08	0.30	0.00	0.035
4	35	158.11	707.74	4.00	-3.70	0.015
5	35	1400.00	707.74	0.30	0.00	0.035
19	35	280.38	507.76	6.02	-5.72	0.015
20	35	237.79	518.99	2.58	-2.28	0.015
21	35	214.96	549.70	1.50	-1.20	0.015
22	35	198.12	589.87	1.50	-1.20	0.015
23	35	182.35	636.76	3.34	-3.04	0.015

24	35	134.54	661.85	12.50	-12.20	0.015
25	35	186.65	662.57	12.50	-12.20	0.015
26	35	244.99	662.91	3.73	-3.43	0.015
27	35	403.62	643.10	1.50	-1.20	0.015
28	35	459.92	646.01	1.50	-1.20	0.015
29	35	434.88	689.59	1.50	-1.20	0.015
30	35	405.87	741.94	1.50	-1.20	0.015
43	35	154.03	642.83	4.00	-3.70	0.015
44	35	1200.00	642.83	0.30	0.00	0.035
4	36	182.00	594.24	4.00	-3.70	0.015
19	36	271.75	432.19	3.24	-2.94	0.015
20	36	233.35	466.32	4.99	-4.69	0.015
21	36	211.96	484.98	1.50	-1.20	0.015
22	36	198.55	493.62	1.79	-1.49	0.015
23	36	191.37	490.80	4.34	-4.04	0.015
24	36	127.57	512.62	12.50	-12.20	0.015
25	36	158.41	553.88	9.76	-9.46	0.015
26	36	200.015	580.32	4.10	-3.80	0.015
27	36	476.04	637.67	1.50	-1.20	0.015
28	36	486.04	637.67	1.50	-1.20	0.015
29	36	478.18	665.86	1.50	-1.20	0.015
30	36	398.21	716.00	1.50	-1.20	0.015
43	36	164.92	626.26	4.00	-3.70	0.015
44	36	1200.00	626.26	0.30	0.00	0.035
4	37	150.00	500.00	4.00	-3.70	0.015
5	37	750.42	375.00	4.00	-3.70	0.015
6	37	627.00	201.56	4.00	-3.70	0.015
7	37	400.00	200.00	4.00	-3.70	0.015
20	37	227.35	480.86	10.46	-10.16	0.015
21	37	214.29	487.70	8.12	-7.82	0.015
22	37	207.59	495.04	4.70	-4.40	0.015
23	37	209.05	500.69	5.79	-5.49	0.015
24	37	126.00	504.00	12.50	-12.20	0.015
25	37	194.49	505.31	6.39	-6.09	0.015
26	37	177.01	506.07	3.08	-2.78	0.015
27	37	151.51	520.49	1.50	-1.20	0.015
28	37	269.56	510.51	1.50	-1.20	0.015
30	37	287.10	513.43	1.50	-1.20	0.015
31	37	458.65	517.80	1.50	-1.20	0.015
43	37	217.83	647.65	4.00	-3.70	0.015
44	37	1200.00	647.65	0.30	0.00	0.035
4	38	152.07	682.37	4.00	-3.70	0.015
7	38	254.95	471.70	4.00	-3.70	0.015
8	38	1399.20	471.70	0.30	0.00	0.035
21	38	209.45	602.09	2.96	-2.66	0.015
22	38	205.82	591.46	4.32	-4.02	0.015
23	38	203.09	582.59	5.79	-5.49	0.015
24	38	126.00	581.00	12.50	-12.20	0.015
25	38	199.45	582.66	6.18	-5.88	0.015
26	38	178.19	587.13	2.68	-2.38	0.015
27	38	151.51	590.49	1.50	-1.20	0.015
28	38	269.56	587.51	1.50	-1.20	0.015
29	38	262.32	582.20	1.50	-1.20	0.015
30	38	334.06	587.41	1.50	-1.20	0.015
31	38	396.13	598.20	1.50	-1.20	0.015

32	38	328.00	605.56	1.50	-1.20	0.015
43	38	195.26	811.25	4.00	-3.70	0.015
44	38	1400.00	811.25	0.30	0.00	0.035
4	39	155.24	869.60	4.00	-3.70	0.015
5	39	999.00	869.60	0.30	0.00	0.035
7	39	151.33	615.55	4.00	-3.70	0.015
8	39	1072.22	615.55	0.30	0.00	0.035
22	39	202.11	562.70	1.50	-1.20	0.015
23	39	201.60	575.19	3.88	-3.58	0.015
24	39	126.00	580.00	12.50	-12.20	0.015
25	39	184.55	578.93	7.32	-7.02	0.015
26	39	192.10	577.31	3.26	-2.96	0.015
27	39	205.95	579.39	1.50	-1.20	0.015
28	39	234.43	585.48	1.50	-1.20	0.015
29	39	268.40	588.73	1.50	-1.20	0.015
30	39	317.31	584.27	1.50	-1.20	0.015
31	39	388.41	567.45	1.50	-1.20	0.015
32	39	328.00	605.56	1.50	-1.20	0.015
43	39	145.77	617.45	4.00	-3.70	0.015
44	39	1068.92	617.45	0.30	0.00	0.035
4	40	91.24	723.30	4.00	-3.70	0.015
5	40	999.00	723.30	0.30	0.00	0.035
7	40	202.24	637.89	4.00	-3.70	0.015
8	40	1200.00	637.89	0.30	0.00	0.035
23	40	201.50	605.00	4.29	-3.99	0.015
24	40	126.50	605.00	12.50	-12.20	0.015
25	40	179.16	608.68	6.49	-6.19	0.015
26	40	194.24	612.52	1.61	-1.31	0.015
27	40	211.95	610.54	1.59	-1.29	0.015
28	40	234.60	604.35	2.32	-2.02	0.015
29	40	265.08	593.56	1.71	-1.41	0.015
30	40	311.23	575.37	1.50	-1.20	0.015
31	40	396.48	534.45	1.50	-1.20	0.015
43	40	168.00	592.22	4.00	-3.70	0.015
44	40	1114.46	592.22	0.30	0.00	0.035
4	41	102.96	652.76	4.00	-3.70	0.015
5	41	900.00	652.76	0.30	0.00	0.035
7	41	125.00	450.69	4.00	-3.70	0.015
8	41	732.21	450.69	0.30	0.00	0.035
23	41	201.50	707.00	7.60	-7.30	0.015
24	41	114.00	707.12	12.50	-12.20	0.015
25	41	192.42	694.87	4.82	-4.52	0.015
26	41	206.01	670.20	1.50	-1.20	0.015
28	41	239.39	622.55	1.50	-1.20	0.015
29	41	264.90	601.93	2.61	-2.31	0.015
30	41	310.28	591.34	1.50	-1.20	0.015
31	41	430.95	576.15	1.66	-1.36	0.015
43	41	168.00	733.64	4.00	-3.70	0.015
44	41	899.62	733.64	0.30	0.00	0.035
4	42	127.48	571.18	4.00	-3.70	0.015
5	42	750.00	571.18	0.30	0.00	0.035
7	42	134.63	536.77	4.00	-3.70	0.015
8	42	614.79	536.77	0.30	0.00	0.035
22	42	278.08	735.33	2.40	-2.10	0.015
23	42	189.50	707.00	7.26	-6.96	0.015

24	42	116.22	682.03	12.52	-12.22	0.015
25	42	224.51	647.62	3.31	-3.01	0.015
26	42	228.81	627.93	1.50	-1.20	0.015
28	42	248.37	588.73	1.50	-1.20	0.015
29	42	266.94	566.00	2.54	-2.24	0.015
30	42	300.32	534.15	1.50	-1.20	0.015
43	42	134.63	770.15	4.00	-3.70	0.015
44	42	856.98	770.15	0.30	0.00	0.035
4	43	130.00	715.89	4.00	-3.70	0.015
5	43	999.00	715.89	0.30	0.00	0.035
7	43	125.00	419.08	4.00	-3.70	0.015
8	43	787.44	419.08	0.30	0.00	0.035
23	43	189.50	616.05	5.46	-5.16	0.015
24	43	124.23	616.05	12.50	-12.20	0.015
25	43	248.72	606.75	6.05	-5.75	0.015
26	43	245.29	595.90	1.50	-1.20	0.015
27	43	247.72	588.13	1.50	-1.20	0.015
28	43	255.01	581.60	1.89	-1.59	0.015
29	43	267.24	575.40	2.11	-1.81	0.015
30	43	284.14	568.12	1.50	-1.20	0.015
31	43	295.31	569.01	2.05	-1.75	0.015
43	43	150.33	741.69	4.00	-3.70	0.015
44	43	889.86	741.69	0.30	0.00	0.035
4	44	183.44	649.04	4.00	-3.70	0.015
5	44	900.00	649.04	0.30	0.00	0.035
7	44	201.56	340.035	4.00	-3.70	0.015
8	44	970.47	340.035	0.30	0.00	0.035
23	44	183.45	569.01	2.93	-2.63	0.015
24	44	126.62	556.71	12.50	-12.20	0.015
25	44	251.81	600.98	5.83	-5.53	0.015
26	44	251.29	602.14	1.50	-1.20	0.015
27	44	253.29	602.81	1.50	-1.20	0.015
28	44	258.96	604.81	2.69	-2.39	0.015
29	44	269.61	609.51	2.04	-1.74	0.015
30	44	269.33	606.01	1.98	-1.68	0.015
31	44	269.33	606.01	1.98	-1.68	0.015
33	44	300.00	300.00	4.20	-3.90	0.015
34	44	1300.00	100.00	4.20	-3.90	0.015
35	44	1300.00	100.00	4.20	-3.90	0.015
43	44	176.14	660.015	4.00	-3.70	0.015
44	44	999.96	660.015	0.30	0.00	0.035
4	45	161.25	657.65	4.00	-3.70	0.015
5	45	900.00	657.65	0.30	0.00	0.035
7	45	160.08	347.31	4.00	-3.70	0.015
8	45	950.16	347.31	0.30	0.00	0.035
22	45	326.01	645.54	1.50	-1.20	0.015
23	45	193.07	682.91	4.29	-3.99	0.015
24	45	126.62	680.27	12.50	-12.20	0.015
25	45	261.68	637.43	6.38	-6.08	0.015
26	45	255.11	639.18	1.50	-1.20	0.015
27	45	252.40	644.54	2.00	-1.70	0.015
28	45	253.08	652.54	2.39	-2.09	0.015
29	45	266.07	660.45	1.50	-1.20	0.015
30	45	266.07	660.45	1.50	-1.20	0.015
43	45	237.12	661.23	4.00	-3.70	0.015

44	45	998.14	661.23	0.30	0.00	0.035
4	46	131.53	634.11	4.00	-3.70	0.015
5	46	900.00	634.11	0.30	0.00	0.035
7	46	145.77	382.43	4.00	-3.70	0.015
8	46	862.90	382.43	0.30	0.00	0.035
22	46	290.60	624.83	1.50	-1.20	0.015
23	46	250.88	591.85	3.24	-2.94	0.015
24	46	101.83	611.92	12.50	-12.20	0.015
25	46	268.16	659.53	7.89	-7.59	0.015
26	46	255.09	683.69	2.72	-2.42	0.015
27	46	248.08	710.82	3.29	-2.99	0.015
28	46	225.96	719.10	1.50	-1.20	0.015
43	46	201.56	665.68	4.00	-3.70	0.015
44	46	991.46	665.68	0.30	0.00	0.035
4	47	122.58	677.66	4.00	-3.70	0.015
5	47	900.00	677.66	0.30	0.00	0.035
7	47	230.49	654.31	4.00	-3.70	0.015
8	47	1008.70	654.31	0.30	0.00	0.035
22	47	286.12	586.77	1.50	-1.20	0.015
23	47	275.88	649.52	2.20	-1.90	0.015
24	47	116.22	683.86	12.50	-12.20	0.015
25	47	236.80	697.98	9.06	-8.76	0.015
26	47	240.86	723.27	3.57	-3.27	0.015
27	47	241.82	746.05	2.00	-1.70	0.015
43	47	111.80	538.52	4.00	-3.70	0.015
44	47	612.79	538.52	0.30	0.00	0.035
4	48	133.14	719.81	4.00	-3.70	0.015
5	48	900.00	719.81	0.30	0.00	0.035
7	48	195.26	529.74	4.00	-3.70	0.015
8	48	622.95	529.74	0.30	0.00	0.035
21	48	303.16	601.49	1.50	-1.20	0.015
22	48	287.20	642.65	1.50	-1.20	0.015
23	48	267.57	687.69	1.81	-1.51	0.015
24	48	114.19	698.39	12.50	-12.20	0.015
25	48	238.08	691.62	8.72	-8.42	0.015
26	48	239.88	701.04	2.10	-1.80	0.015
27	48	241.58	710.49	1.80	-1.50	0.015
28	48	251.32	724.31	1.50	-1.20	0.015
43	48	175.00	760.35	4.00	-3.70	0.015
44	48	1200.00	760.35	0.30	0.00	0.035
4	49	166.51	691.47	4.00	-3.70	0.015
5	49	900.00	691.47	0.30	0.00	0.035
7	49	103.08	477.62	4.00	-3.70	0.015
8	49	690.93	477.62	0.30	0.00	0.035
21	49	303.24	669.34	1.50	-1.20	0.015
22	49	291.88	671.42	1.50	-1.20	0.015
23	49	280.39	667.05	2.40	-2.10	0.015
24	49	113.50	662.55	12.50	-12.20	0.015
25	49	266.06	666.79	7.37	-7.07	0.015
26	49	250.68	674.29	1.50	-1.20	0.015
27	49	241.30	678.15	1.97	-1.67	0.015
28	49	228.74	698.43	1.50	-1.20	0.015
43	49	160.08	691.47	4.00	-3.70	0.015
44	49	1300.00	691.47	0.30	0.00	0.035
4	50	183.98	678.12	4.00	-3.70	0.015

5	50	900.00	678.12	0.30	0.00	0.035
7	50	160.08	427.93	4.00	-3.70	0.015
8	50	771.15	427.93	0.30	0.00	0.035
21	50	321.20	721.48	1.50	-1.20	0.015
22	50	302.75	713.41	1.50	-1.20	0.015
23	50	289.30	714.29	1.70	-1.40	0.015
24	50	126.00	717.64	12.50	-12.20	0.015
25	50	285.19	713.74	6.35	-6.05	0.015
26	50	250.09	712.00	1.50	-1.20	0.015
27	50	222.49	715.63	1.50	-1.20	0.015
28	50	222.49	715.63	1.50	-1.20	0.015
43	50	127.48	480.88	4.00	-3.70	0.015
44	50	686.24	500.00	0.30	0.00	0.035
4	51	167.63	659.24	4.00	-3.70	0.015
5	51	900.00	678.12	0.30	0.00	0.035
7	51	127.48	395.28	4.00	-3.70	0.015
8	51	834.85	395.28	0.30	0.00	0.035
21	51	340.15	764.48	1.50	-1.20	0.015
22	51	304.35	721.37	1.50	-1.20	0.015
23	51	276.82	683.32	2.45	-2.15	0.015
24	51	138.50	663.05	12.50	-12.20	0.015
25	51	300.43	656.66	5.25	-4.95	0.015
27	51	242.78	620.65	1.50	-1.20	0.015
28	51	242.78	620.65	1.50	-1.20	0.015
43	51	141.42	509.90	4.00	-3.70	0.015
44	51	970.78	509.90	0.30	0.00	0.035
4	52	175.00	550.015	4.00	-3.70	0.015
5	52	600.00	550.015	0.30	0.00	0.035
7	52	167.71	648.56	4.00	-3.70	0.015
8	52	1017.64	648.56	0.30	0.00	0.035
21	52	344.26	732.63	1.50	-1.20	0.015
22	52	300.63	725.85	1.50	-1.20	0.015
23	52	263.39	716.70	2.88	-2.58	0.015
24	52	151.00	711.00	12.50	-12.20	0.015
25	52	313.52	689.92	3.01	-2.71	0.015
27	52	264.23	622.67	1.50	-1.20	0.015
28	52	264.23	622.67	1.50	-1.20	0.015
43	52	115.00	601.02	4.00	-3.70	0.015
44	52	1100.00	601.02	0.30	0.00	0.035
4	53	191.64	659.34	4.00	-3.70	0.015
5	53	900.00	659.34	0.30	0.00	0.035
7	53	145.77	728.87	4.00	-3.70	0.015
8	53	905.52	728.87	0.30	0.00	0.035
20	53	737.40	618.99	0.30	0.00	0.035
21	53	339.51	639.88	2.65	-2.35	0.015
22	53	304.13	665.46	1.50	-1.20	0.015
23	53	275.04	696.38	1.78	-1.48	0.015
24	53	151.56	699.79	12.50	-12.20	0.015
25	53	324.27	693.28	4.56	-4.26	0.015
26	53	282.14	712.66	1.50	-1.20	0.015
27	53	252.88	744.61	1.50	-1.20	0.015
28	53	252.88	744.61	1.50	-1.20	0.015
43	53	99.25	578.66	4.00	-3.70	0.015
44	53	1100.00	578.66	0.30	0.00	0.035
4	54	140.00	542.31	4.00	-3.70	0.015

5	54	750.00	542.31	0.30	0.00	0.035
7	54	160.08	585.77	4.00	-3.70	0.015
8	54	1126.72	585.77	0.30	0.00	0.035
20	54	742.66	409.16	0.30	0.00	0.035
21	54	742.66	409.16	0.30	0.00	0.035
24	54	126.00	584.53	12.50	-12.20	0.015
25	54	316.45	637.57	3.83	-3.53	0.015
26	54	290.22	674.67	1.50	-1.20	0.015
27	54	275.62	672.76	1.50	-1.20	0.015
43	54	111.80	570.09	4.00	-3.70	0.015
44	54	1100.00	570.09	0.30	0.00	0.035
4	55	100.00	602.08	4.00	-3.70	0.015
5	55	800.00	602.08	0.30	0.00	0.035
7	55	176.78	807.00	4.00	-3.70	0.015
8	55	613.38	807.00	0.30	0.00	0.035
20	55	702.32	439.24	0.30	0.00	0.035
21	55	702.32	439.24	0.30	0.00	0.035
24	55	107.62	739.19	12.50	-12.20	0.015
25	55	301.07	803.61	8.09	-7.79	0.015
26	55	296.45	926.21	1.50	-1.20	0.015
27	55	292.41	1095.30	1.50	-1.20	0.015
43	55	100.00	471.70	4.00	-3.70	0.015
44	55	524.70	500.00	0.30	0.00	0.035
4	56	87.46	728.87	4.00	-3.70	0.015
5	56	900.00	728.87	0.30	0.00	0.035
7	56	167.71	627.00	4.00	-3.70	0.015
8	56	789.48	627.00	0.30	0.00	0.035
20	56	2600.00	507.24	0.30	0.00	0.035
21	56	322.59	545.33	1.69	-1.39	0.015
22	56	334.89	591.26	1.50	-1.20	0.015
23	56	368.54	648.71	1.50	-1.20	0.015
24	56	118.73	692.69	12.50	-12.20	0.015
25	56	314.73	720.21	7.40	-7.10	0.015
26	56	317.38	748.33	1.50	-1.20	0.015
27	56	286.57	765.79	1.50	-1.20	0.015
43	56	111.80	602.08	4.00	-3.70	0.015
44	56	1100.00	602.08	0.30	0.00	0.035
4	57	77.62	499.52	4.00	-3.70	0.015
5	57	700.00	499.52	0.30	0.00	0.035
7	57	134.63	783.02	4.00	-3.70	0.015
8	57	632.16	783.02	0.30	0.00	0.035
20	57	2600.00	596.43	0.30	0.00	0.035
21	57	304.70	620.97	1.50	-1.20	0.015
22	57	300.81	660.73	1.53	-1.23	0.015
23	57	300.55	706.79	1.58	-1.28	0.015
24	57	154.55	725.96	12.50	-12.20	0.015
25	57	313.78	735.26	6.06	-5.76	0.015
26	57	274.30	777.83	1.50	-1.20	0.015
43	57	70.71	626.50	4.00	-3.70	0.015
44	57	790.10	626.50	0.30	0.00	0.035
4	58	100.00	670.30	4.00	-3.70	0.015
5	58	900.00	670.30	0.30	0.00	0.035
7	58	145.77	649.04	4.00	-3.70	0.015
8	58	762.66	649.04	0.30	0.00	0.035
20	58	2600.00	728.30	0.30	0.00	0.035

21	58	263.49	728.27	1.50	-1.20	0.015
22	58	263.96	690.15	1.50	-1.20	0.015
23	58	257.00	644.65	2.32	-2.02	0.015
24	58	171.71	625.42	12.50	-12.20	0.015
25	58	272.94	617.26	3.98	-3.68	0.015
26	58	245.19	571.37	1.50	-1.20	0.015
43	58	125.00	760.35	4.00	-3.70	0.015
44	58	1200.00	760.35	0.30	0.00	0.035
4	59	90.00	606.71	4.00	-3.70	0.015
5	59	800.00	606.71	0.30	0.00	0.035
7	59	145.77	571.18	4.00	-3.70	0.015
8	59	866.62	571.18	0.30	0.00	0.035
20	59	2400.00	640.74	0.30	0.00	0.035
21	59	241.35	640.74	1.50	-1.20	0.015
22	59	253.27	629.91	1.50	-1.20	0.015
23	59	152.32	630.25	1.50	-1.20	0.015
24	59	157.54	606.79	12.50	-12.20	0.015
25	59	260.57	570.62	4.56	-4.26	0.015
26	59	282.40	557.67	1.84	-1.54	0.015
27	59	349.95	531.00	1.50	-1.20	0.015
43	59	125.00	548.29	4.00	-3.70	0.015
44	59	1000.00	548.29	0.30	0.00	0.035
4	60	90.00	629.36	4.00	-3.70	0.015
5	60	900.00	629.36	0.30	0.00	0.035
7	60	106.07	617.45	4.00	-3.70	0.015
8	60	801.68	617.45	0.30	0.00	0.035
21	60	1000.00	520.78	0.30	0.00	0.035
22	60	233.22	520.78	1.50	-1.20	0.015
23	60	152.32	509.49	1.50	-1.20	0.015
24	60	147.15	532.78	12.50	-12.20	0.015
25	60	276.16	553.69	5.14	-4.84	0.015
26	60	293.30	534.01	1.50	-1.20	0.015
27	60	317.05	518.21	1.97	-1.67	0.015
28	60	287.74	494.07	1.50	-1.20	0.015
43	60	167.71	742.04	4.00	-3.70	0.015
44	60	667.08	742.04	0.30	0.00	0.035
4	61	100.00	618.47	4.00	-3.70	0.015
5	61	900.00	618.47	0.30	0.00	0.035
7	61	103.08	682.37	4.00	-3.70	0.015
8	61	725.42	682.37	0.30	0.00	0.035
21	61	1100.00	556.15	0.30	0.00	0.035
22	61	219.82	556.16	1.50	-1.20	0.015
23	61	276.79	533.25	1.50	-1.20	0.015
24	61	153.97	499.11	12.50	-12.20	0.015
25	61	285.54	478.25	3.83	-3.53	0.015
27	61	292.58	472.78	1.50	-1.20	0.015
28	61	291.38	485.85	1.73	-1.43	0.015
29	61	291.38	485.85	1.73	-1.43	0.015
43	61	145.77	637.38	4.00	-3.70	0.015
44	61	517.74	637.38	0.30	0.00	0.035
4	62	100.00	701.78	4.00	-3.70	0.015
5	62	1000.00	701.78	0.30	0.00	0.035
7	62	103.08	581.49	4.00	-3.70	0.015
8	62	851.26	581.49	0.30	0.00	0.035
21	62	1200.00	618.07	0.30	0.00	0.035

22	62	243.07	618.06	1.50	-1.20	0.015
23	62	227.88	569.34	2.05	-1.75	0.015
24	62	135.47	532.57	12.50	-12.20	0.015
25	62	329.32	490.13	4.66	-4.36	0.015
27	62	284.02	390.73	1.50	-1.20	0.015
28	62	301.69	313.49	1.88	-1.58	0.015
29	62	301.69	313.49	1.88	-1.58	0.015
43	62	175.00	654.31	4.00	-3.70	0.015
44	62	504.34	654.31	0.30	0.00	0.035
4	63	87.32	754.80	4.00	-3.70	0.015
5	63	900.00	754.80	0.30	0.00	0.035
7	63	103.08	682.37	4.00	-3.70	0.015
8	63	725.42	682.37	0.30	0.00	0.035
21	63	1600.00	814.38	0.30	0.00	0.035
22	63	228.48	814.38	1.50	-1.20	0.015
23	63	213.04	738.12	1.88	-1.58	0.015
24	63	113.19	673.54	12.50	-12.20	0.015
25	63	319.79	579.71	3.70	-3.40	0.015
26	63	288.26	494.28	1.50	-1.20	0.015
27	63	285.07	428.07	1.50	-1.20	0.015
28	63	309.26	350.09	1.57	-1.27	0.015
43	63	150.00	626.50	4.00	-3.70	0.015
44	63	526.74	626.50	0.30	0.00	0.035
4	64	120.42	596.41	4.00	-3.70	0.015
5	64	800.00	596.41	0.30	0.00	0.035
7	64	100.00	694.62	4.00	-3.70	0.015
8	64	712.62	694.62	0.30	0.00	0.035
22	64	1200.00	622.28	0.30	0.00	0.035
23	64	203.11	622.29	2.19	-1.89	0.015
24	64	158.75	622.29	12.50	-12.20	0.015
25	64	234.32	619.28	5.12	-4.82	0.015
26	64	271.12	595.81	1.50	-1.20	0.015
27	64	297.73	556.52	1.63	-1.33	0.015
28	64	310.33	522.29	1.50	-1.20	0.015
43	64	106.07	664.27	4.00	-3.70	0.015
44	64	496.78	664.27	0.30	0.00	0.035
4	65	122.98	659.34	4.00	-3.70	0.015
5	65	900.00	659.34	0.30	0.00	0.035
7	65	103.08	673.15	4.00	-3.70	0.015
8	65	735.34	673.15	0.30	0.00	0.035
22	65	1200.00	625.13	0.30	0.00	0.035
23	65	192.29	625.13	1.99	-1.69	0.015
24	65	165.40	638.07	12.50	-12.20	0.015
25	65	198.69	660.10	7.73	-7.43	0.015
26	65	283.05	662.64	1.83	-1.53	0.015
27	65	200.00	520.00	1.83	-1.53	0.015
43	65	145.77	675.46	4.00	-3.70	0.015
44	65	488.56	675.46	0.30	0.00	0.035
4	66	147.14	686.48	4.00	-3.70	0.015
5	66	900.00	686.48	0.30	0.00	0.035
7	66	125.00	800.39	4.00	-3.70	0.015
8	66	618.44	800.39	0.30	0.00	0.035
19	66	1000.00	536.71	0.30	0.00	0.035
20	66	215.46	536.71	6.00	-5.70	0.015
21	66	303.07	538.75	6.00	-5.70	0.015

22	66	252.31	551.62	6.00	-5.70	0.015
23	66	195.15	561.99	6.00	-5.70	0.015
24	66	152.01	547.83	6.00	-5.70	0.015
25	66	189.45	547.32	6.00	-5.70	0.015
43	66	111.80	626.50	4.00	-3.70	0.015
44	66	526.74	626.50	0.30	0.00	0.035
4	67	150.08	678.40	4.00	-3.70	0.015
5	67	900.00	678.40	0.30	0.00	0.035
7	67	111.80	570.09	4.00	-3.70	0.015
8	67	868.28	570.09	0.30	0.00	0.035
18	67	1400.00	742.71	0.30	0.00	0.035
19	67	210.42	755.70	6.00	-5.70	0.015
20	67	239.33	774.61	6.00	-5.70	0.015
23	67	600.00	495.63	0.30	0.00	0.035
24	67	164.97	521.85	12.50	-12.20	0.015
25	67	163.50	534.32	6.54	-6.24	0.015
43	67	140.00	551.45	4.00	-3.70	0.015
44	67	598.42	551.45	0.30	0.00	0.035
4	68	108.17	617.41	4.00	-3.70	0.015
5	68	900.00	617.41	0.30	0.00	0.035
7	68	100.00	715.89	4.00	-3.70	0.015
8	68	691.44	715.89	0.30	0.00	0.035
18	68	1500.00	798.26	0.30	0.00	0.035
19	68	400.00	798.26	6.00	-5.70	0.015
24	68	177.00	762.64	12.50	-12.20	0.015
43	68	166.88	590.64	4.00	-3.70	0.015
44	68	558.72	590.64	0.30	0.00	0.035
4	69	95.53	584.23	4.00	-3.70	0.015
5	69	800.00	584.23	0.30	0.00	0.035
7	69	134.63	800.39	4.00	-3.70	0.015
8	69	618.44	800.39	0.30	0.00	0.035
17	69	653.04	757.99	0.30	0.00	0.035
18	69	1500.00	757.99	0.30	0.00	0.035
19	69	400.00	757.99	6.00	-5.70	0.015
23	69	386.50	486.34	0.30	0.00	0.035
24	69	185.63	510.73	12.50	-12.20	0.015
43	69	167.71	583.63	4.00	-3.70	0.015
44	69	565.42	583.63	0.30	0.00	0.035
4	70	97.08	301.04	4.00	-3.70	0.015
5	70	400.00	301.04	0.30	0.00	0.035
7	70	160.08	687.84	4.00	-3.70	0.015
8	70	719.64	687.84	0.30	0.00	0.035
17	70	650.92	760.46	0.30	0.00	0.035
18	70	1500.00	760.46	0.30	0.00	0.035
19	70	400.00	760.46	6.00	-5.70	0.015
23	70	214.62	555.64	2.26	-1.96	0.015
24	70	175.41	556.18	12.50	-12.20	0.015
43	70	180.28	756.90	4.00	-3.70	0.015
44	70	435.98	756.90	0.30	0.00	0.035
4	71	99.25	472.07	4.00	-3.70	0.015
5	71	700.00	472.07	0.30	0.00	0.035
7	71	111.80	750.00	4.00	-3.70	0.015
8	71	660.00	750.00	0.30	0.00	0.035
17	71	626.62	789.96	0.30	0.00	0.035
18	71	1500.00	789.96	0.30	0.00	0.035

19	71	400.00	789.96	6.00	-5.70	0.015
23	71	223.32	539.75	2.97	-2.67	0.015
24	71	169.02	503.35	12.50	-12.20	0.015
43	71	167.71	706.77	4.00	-3.70	0.015
44	71	700.36	706.77	0.30	0.00	0.035
4	72	129.03	637.38	4.00	-3.70	0.015
5	72	800.00	637.38	0.30	0.00	0.035
7	72	103.08	608.79	4.00	-3.70	0.015
18	72	1400.00	768.70	0.30	0.00	0.035
19	72	400.00	768.70	6.00	-5.70	0.015
23	72	212.06	465.57	5.72	-5.42	0.015
24	72	188.46	450.09	12.50	-12.20	0.015
43	72	158.11	583.10	4.00	-3.70	0.015
44	72	848.92	583.10	0.30	0.00	0.035
4	73	138.29	593.49	4.00	-3.70	0.015
5	73	750.00	593.49	0.30	0.00	0.035
18	73	1500.00	920.98	0.30	0.00	0.035
19	73	350.00	939.24	6.00	-5.70	0.015
23	73	192.25	446.72	6.42	-6.12	0.015
24	73	183.46	456.84	12.50	-12.20	0.015
43	73	142.21	730.56	4.00	-3.70	0.015
44	73	677.56	730.56	0.30	0.00	0.035
4	74	86.02	539.07	4.00	-3.70	0.015
5	74	750.00	539.07	0.30	0.00	0.035
19	74	150.00	550.00	6.00	-5.70	0.015
23	74	162.53	456.30	5.62	-5.32	0.015
24	74	158.40	459.66	12.50	-12.20	0.015
43	74	142.21	733.30	4.00	-3.70	0.015
44	74	675.04	733.30	0.30	0.00	0.035
4	75	129.03	675.02	4.00	-3.70	0.015
5	75	900.00	675.02	0.30	0.00	0.035
18	75	1200.00	659.62	0.30	0.00	0.035
19	75	150.00	659.62	5.50	-5.20	0.015
23	75	132.19	420.70	3.03	-2.73	0.015
24	75	137.18	418.01	12.50	-12.20	0.015
43	75	190.39	617.45	4.00	-3.70	0.015
44	75	801.68	617.45	0.30	0.00	0.035
4	76	180.28	570.09	4.00	-3.70	0.015
5	76	800.00	570.09	0.30	0.00	0.035
18	76	898.26	551.06	0.30	0.00	0.035
19	76	150.00	551.06	5.50	-5.20	0.015
23	76	262.26	513.46	0.30	0.00	0.035
24	76	153.09	506.97	11.50	-11.20	0.015
43	76	201.56	665.68	4.00	-3.70	0.015
44	76	743.60	665.68	0.30	0.00	0.035
4	77	145.77	664.27	4.00	-3.70	0.015
5	77	800.00	664.27	0.30	0.00	0.035
18	77	704.64	702.49	0.30	0.00	0.035
19	77	150.00	702.49	5.00	-4.70	0.015
23	77	282.80	489.27	0.30	0.00	0.035
24	77	164.28	527.01	10.50	-10.20	0.015
43	77	176.78	649.04	4.00	-3.70	0.015
44	77	762.66	649.04	0.30	0.00	0.035
4	78	117.05	530.75	4.00	-3.70	0.015
5	78	700.00	530.75	0.30	0.00	0.035

19	78	150.00	649.44	4.50	-4.20	0.015
24	78	139.11	489.98	10.50	-10.20	0.015
43	78	180.28	721.11	4.00	-3.70	0.015
44	78	686.44	721.11	0.30	0.00	0.035
4	79	120.42	701.78	4.00	-3.70	0.015
5	79	900.00	701.78	0.30	0.00	0.035
22	79	113.15	522.62	6.00	-5.70	0.015
23	79	151.91	529.39	8.00	-7.70	0.015
24	79	140.83	508.50	8.00	-7.70	0.015
43	79	223.61	610.33	4.00	-3.70	0.015
44	79	847.22	610.33	0.30	0.00	0.035
4	80	107.35	634.05	4.00	-3.70	0.015
5	80	800.00	634.05	0.30	0.00	0.035
21	80	914.48	541.29	0.30	0.00	0.035
22	80	150.00	541.29	6.50	-6.20	0.015
24	80	140.83	587.83	10.50	-10.20	0.015
43	80	201.56	638.85	4.00	-3.70	0.015
44	80	501.56	638.85	4.00	-3.70	0.015
4	81	120.21	607.82	4.00	-3.70	0.015
5	81	800.00	607.82	0.30	0.00	0.035
21	81	1000.00	589.82	0.30	0.00	0.035
22	81	150.00	589.82	7.00	-6.70	0.015
24	81	157.98	583.93	10.50	-10.20	0.015
43	81	201.56	1038.85	4.00	-3.70	0.015
44	81	1003.12	1038.85	0.30	0.00	0.035
4	82	105.95	685.00	4.00	-3.70	0.015
5	82	675.00	685.00	0.30	0.00	0.035
43	82	201.56	2300.00	4.00	-3.70	0.015
44	82	1003.12	2300.00	0.30	0.00	0.035
4	83	105.95	603.92	4.00	-3.70	0.015
5	83	600.00	603.92	0.30	0.00	0.035
43	83	201.56	700.00	4.00	-3.70	0.015
44	83	1003.12	700.00	0.30	0.00	0.035
4	84	103.08	589.94	4.00	-3.70	0.015
5	84	600.00	589.94	0.30	0.00	0.035
43	84	201.56	1650.00	4.00	-3.70	0.015
44	84	1003.12	1650.00	0.30	0.00	0.035
4	85	134.54	628.01	4.00	-3.70	0.015
5	85	525.00	628.01	0.30	0.00	0.035
43	85	201.56	2140.00	4.00	-3.70	0.015
44	85	800.00	2140.00	0.30	0.00	0.035
43	86	201.56	1820.00	4.00	-3.70	0.015
44	86	1000.00	1820.00	0.30	0.00	0.035
43	87	201.56	2570.00	4.00	-3.70	0.015
44	87	1400.00	2570.00	0.30	0.00	0.035
43	88	201.56	2160.00	4.00	-3.70	0.015
44	88	1600.00	2160.00	0.30	0.00	0.035
43	89	101.56	2500.00	4.00	-3.70	0.015
44	89	903.12	2500.00	0.30	0.00	0.035
43	90	101.56	2100.00	4.00	-3.70	0.015
44	90	603.12	2100.00	0.30	0.00	0.035
43	91	101.56	1900.00	4.00	-3.70	0.015
44	91	903.12	1900.00	0.30	0.00	0.035
43	92	101.56	2360.00	4.00	-3.70	0.015
44	92	1403.12	2360.00	0.30	0.00	0.035

43	93	101.56	2000.00	4.00	-3.70	0.015
44	93	803.12	2000.00	0.30	0.00	0.035
43	94	71.56	1350.00	4.00	-3.70	0.015
44	94	603.12	1350.00	0.30	0.00	0.035
43	95	71.56	1220.00	4.00	-3.70	0.015
44	95	603.12	1220.00	0.30	0.00	0.035
43	96	71.56	1550.00	4.00	-3.70	0.015
44	96	603.12	1550.00	0.30	0.00	0.035
43	97	71.56	710.00	4.00	-3.70	0.015
44	97	603.12	710.00	0.30	0.00	0.035

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I	J	XLNUTME	YLTUTMN	CCUE		CCVE	CCUN	CCVN
30	5	28.6640	5.1879	0.6001682	0.7998738	-0.7998738	0.6001682	-1.0000000
31	5	28.9620	4.7698	0.6388829	0.7693040	-0.7693040	0.6388829	-1.0000000
32	5	29.2820	4.3761	0.6796822	0.7335067	-0.7335067	0.6796822	-1.0000000
33	5	29.6730	3.9819	0.7768199	0.6297228	-0.6297228	0.7768199	-1.0000000
30	6	29.0820	5.5352	0.6028011	0.7978915	-0.7978915	0.6028011	-1.0000000
31	6	29.3690	5.1438	0.6482844	0.7613983	-0.7613983	0.6482844	-1.0000000
32	6	29.6770	4.7749	0.6946676	0.7193308	-0.7193308	0.6946676	-1.0000000
33	6	30.0280	4.4300	0.7529863	0.6580362	-0.6580362	0.7529863	-1.0000000
4	7	33.5230	45.5200	0.7695577	-0.6385772	0.6385772	0.7695577	-1.0000000
5	7	33.5230	45.5200	0.7695577	-0.6385772	0.6385772	0.7695577	-0.0100000
24	7	28.0190	7.6812	0.6344351	0.7729761	-0.7729761	0.6344351	-1.0000000
25	7	28.2230	7.4320	0.6772386	0.7357635	-0.7357635	0.6772386	-1.0000000
26	7	28.4460	7.1765	0.6609870	0.7503973	-0.7503973	0.6609870	-1.0000000
30	7	29.4490	5.8471	0.6120957	0.7907837	-0.7907837	0.6120957	-1.0000000
31	7	29.7220	5.4720	0.6479908	0.7616482	-0.7616482	0.6479908	-1.0000000
32	7	30.0100	5.1238	0.6942729	0.7197118	-0.7197118	0.6942729	-1.0000000
33	7	30.3260	4.8009	0.7750288	0.6319259	-0.6319259	0.7750288	-1.0000000
4	8	33.1580	46.0970	0.9412231	-0.3377853	0.3377853	0.9412231	-1.0000000
5	8	33.1580	46.0970	0.9412231	-0.3377853	0.3377853	0.9412231	-0.0100000
24	8	28.2870	7.9212	0.6309558	0.7758188	-0.7758188	0.6309558	-1.0000000
25	8	28.4840	7.6746	0.6651604	0.7467005	-0.7467005	0.6651604	-1.0000000
26	8	28.7070	7.4198	0.6756155	0.7372542	-0.7372542	0.6756155	-1.0000000
27	8	28.9600	7.1332	0.6596907	0.7515372	-0.7515372	0.6596907	-1.0000000
30	8	29.7570	6.1308	0.6470400	0.7624561	-0.7624561	0.6470400	-1.0000000
31	8	30.0340	5.7690	0.6630404	0.7485836	-0.7485836	0.6630404	-1.0000000
32	8	30.3100	5.4391	0.6918504	0.7220409	-0.7220409	0.6918504	-1.0000000
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4	9	32.9380	46.7320	0.9547390	-0.2974447	0.2974447	0.9547390	-1.0000000
5	9	32.9380	46.7320	0.9547390	-0.2974447	0.2974447	0.9547390	-0.0100000
24	9	28.5550	8.1530	0.6153132	0.7882828	-0.7882828	0.6153132	-1.0000000
25	9	28.7400	7.9174	0.6749297	0.7378821	-0.7378821	0.6749297	-1.0000000
26	9	28.9640	7.6705	0.6988578	0.7152606	-0.7152606	0.6988578	-1.0000000
27	9	29.2290	7.3811	0.6789733	0.7341629	-0.7341629	0.6789733	-1.0000000
28	9	29.4970	7.0564	0.6529557	0.7573961	-0.7573961	0.6529557	-1.0000000
29	9	29.7580	6.7258	0.6482436	0.7614330	-0.7614330	0.6482436	-1.0000000
30	9	30.0350	6.3874	0.6454550	0.7637983	-0.7637983	0.6454550	-1.0000000
31	9	30.3190	6.0487	0.6757985	0.7370864	-0.7370864	0.6757985	-1.0000000
32	9	30.5940	5.7372	0.6998252	0.7143142	-0.7143142	0.6998252	-1.0000000
33	9	30.8620	5.4467	0.6859388	0.7276593	-0.7276593	0.6859388	-1.0000000
4	10	32.6210	47.1310	0.5318148	-0.8468607	0.8468607	0.5318148	-1.0000000
5	10	32.6210	47.1310	0.5318148	-0.8468607	0.8468607	0.5318148	-0.0100000
23	10	28.6800	8.6055	0.5486947	0.8360228	-0.8360228	0.5486947	-1.0000000
24	10	28.8490	8.3695	0.5735527	0.8191687	-0.8191687	0.5735527	-1.0000000
25	10	29.0040	8.1696	0.6566030	0.7542363	-0.7542363	0.6566030	-1.0000000
26	10	29.2030	7.9222	0.6866325	0.7270048	-0.7270048	0.6866325	-1.0000000
27	10	29.4740	7.6099	0.6745856	0.7381966	-0.7381966	0.6745856	-1.0000000
28	10	29.7480	7.2974	0.6649767	0.7468641	-0.7468641	0.6649767	-1.0000000
29	10	30.0210	6.9668	0.6622297	0.7493010	-0.7493010	0.6622297	-1.0000000
30	10	30.3110	6.6319	0.6732972	0.7393720	-0.7393720	0.6732972	-1.0000000
31	10	30.5880	6.3166	0.6797018	0.7334886	-0.7334886	0.6797018	-1.0000000
32	10	30.8630	6.0256	0.7320566	0.6812438	-0.6812438	0.7320566	-1.0000000
33	10	31.1380	5.7369	0.7078733	0.7063394	-0.7063394	0.7078733	-1.0000000
3	11	32.1750	47.2450	0.4929779	-0.8700418	0.8700418	0.4929779	-1.0000000
4	11	32.1750	47.3550	0.4929779	-0.8700418	0.8700418	0.4929779	-1.0000000
5	11	32.1750	47.3550	0.4929779	-0.8700418	0.8700418	0.4929779	-0.0100000
23	11	29.0800	8.8595	0.5535087	0.8328434	-0.8328434	0.5535087	-1.0000000
24	11	29.2360	8.6438	0.6071576	0.7945815	-0.7945815	0.6071576	-1.0000000
25	11	29.3690	8.4587	0.5625369	0.8267722	-0.8267722	0.5625369	-1.0000000
26	11	29.5440	8.2018	0.5647510	0.8252614	-0.8252614	0.5647510	-1.0000000
27	11	29.7880	7.8883	0.6587110	0.7523960	-0.7523960	0.6587110	-1.0000000
28	11	30.0535	7.5724	0.6678548	0.7441901	-0.7441901	0.6678548	-1.0000000
29	11	30.3190	7.2564	0.6769987	0.7359842	-0.7359842	0.6769987	-1.0000000
30	11	30.6110	6.9355	0.7159277	0.6981744	-0.6981744	0.7159277	-1.0000000
31	11	30.8900	6.6348	0.7010635	0.7130989	-0.7130989	0.7010635	-1.0000000
32	11	31.1660	6.3502	0.7262066	0.6874765	-0.6874765	0.7262066	-1.0000000
33	11	31.4390	6.0647	0.6865529	0.7270799	-0.7270799	0.6865529	-1.0000000
4	12	32.0000	47.7430	0.9989396	0.0460408	-0.0460408	0.9989396	-1.0000000

5	12	32.0000	47.7430	0.9989396	0.0460408	-0.0460408	0.9989396	-0.0100000
23	12	29.5680	9.1768	0.5495203	0.8354804	-0.8354804	0.5495203	-1.0000000
24	12	29.6990	8.9865	0.5917935	0.8060896	-0.8060896	0.5917935	-1.0000000
25	12	29.8380	8.7892	0.5730659	0.8195093	-0.8195093	0.5730659	-1.0000000
27	12	30.2180	8.2379	0.5987160	0.8009614	-0.8009614	0.5987160	-1.0000000
28	12	30.4615	7.9312	0.6319295	0.7738387	-0.7738387	0.6319295	-1.0000000
29	12	30.7050	7.6244	0.6651430	0.7467161	-0.7467161	0.6651430	-1.0000000
30	12	30.9760	7.3184	0.6952052	0.7188114	-0.7188114	0.6952052	-1.0000000
31	12	31.2530	7.0230	0.7065539	0.7076592	-0.7076592	0.7065539	-1.0000000
32	12	31.5290	6.7329	0.7077067	0.7065063	-0.7065063	0.7077067	-1.0000000
33	12	31.8060	6.4421	0.7027650	0.7114220	-0.7114220	0.7027650	-1.0000000
4	13	31.8250	48.2500	0.7254514	-0.6882734	0.6882734	0.7254514	-1.0000000
5	13	31.8250	48.2500	0.7254514	-0.6882734	0.6882734	0.7254514	-0.0100000
23	13	30.0680	9.5190	0.5866270	0.8098572	-0.8098572	0.5866270	-1.0000000
24	13	30.1990	9.3415	0.5822363	0.8130196	-0.8130196	0.5822363	-1.0000000
25	13	30.3380	9.1375	0.5522318	0.8336906	-0.8336906	0.5522318	-1.0000000
26	13	30.5175	8.8680	0.5866877	0.8098133	-0.8098133	0.5866877	-1.0000000
27	13	30.6970	8.5984	0.5866877	0.8098133	-0.8098133	0.5866877	-1.0000000
28	13	30.9070	8.3116	0.6182861	0.7859532	-0.7859532	0.6182861	-1.0000000
29	13	31.1560	8.0202	0.6450496	0.7624805	-0.7624805	0.6450496	-1.0000000
30	13	31.4050	7.7289	0.6718131	0.7390079	-0.7390079	0.6718131	-1.0000000
31	13	31.6540	7.4375	0.6985766	0.7155352	-0.7155352	0.6985766	-1.0000000
32	13	31.9260	7.1516	0.7109920	0.7032000	-0.7032000	0.7109920	-1.0000000
33	13	32.2040	6.8684	0.7247499	0.6890120	-0.6890120	0.7247499	-1.0000000
4	14	31.3000	48.4930	-0.0124970	-0.9999219	0.9999219	-0.0124970	-1.0000000
5	14	31.3000	48.4930	-0.0124970	-0.9999219	0.9999219	-0.0124970	-0.0100000
23	14	30.5680	9.8490	0.5580681	0.8297951	-0.8297951	0.5580681	-1.0000000
24	14	30.6990	9.6715	0.5630806	0.8264019	-0.8264019	0.5630806	-1.0000000
25	14	30.8320	9.4710	0.5399109	0.8417222	-0.8417222	0.5399109	-1.0000000
26	14	30.9940	9.2200	0.5727640	0.8197203	-0.8197203	0.5727640	-1.0000000
27	14	31.1740	8.9626	0.6011724	0.7991194	-0.7991194	0.6011724	-1.0000000
28	14	31.3730	8.6969	0.6280314	0.7781880	-0.7781880	0.6280314	-1.0000000
29	14	31.5920	8.4243	0.6537747	0.7566892	-0.7566892	0.6537747	-1.0000000
30	14	31.8290	8.1477	0.6768548	0.7361166	-0.7361166	0.6768548	-1.0000000
31	14	32.0810	7.8698	0.6953431	0.7186779	-0.7186779	0.6953431	-1.0000000
32	14	32.3450	7.5919	0.7085580	0.7056525	-0.7056525	0.7085580	-1.0000000
33	14	32.6170	7.3151	0.7161195	0.6979777	-0.6979777	0.7161195	-1.0000000
34	14	32.9000	7.0411	0.7244834	0.6892922	-0.6892922	0.7244834	-1.0000000
4	15	30.8750	48.7100	0.7983498	-0.6021940	0.6021940	0.7983498	-1.0000000
5	15	30.8750	48.7100	0.7983498	-0.6021940	0.6021940	0.7983498	-0.0100000
23	15	31.0180	10.1660	0.6410422	0.7675056	-0.7675056	0.6410422	-1.0000000
24	15	31.1430	9.9888	0.5650052	0.8250874	-0.8250874	0.5650052	-1.0000000
25	15	31.2750	9.7938	0.6155017	0.7881356	-0.7881356	0.6155017	-1.0000000
26	15	31.4440	9.5743	0.6325455	0.7745232	-0.7745232	0.6325455	-1.0000000
27	15	31.6290	9.3409	0.6436657	0.7653068	-0.7653068	0.6436657	-1.0000000
28	15	31.8290	9.0956	0.6558726	0.7548716	-0.7548716	0.6558726	-1.0000000
29	15	32.0440	8.8410	0.6704367	0.7419667	-0.7419667	0.6704367	-1.0000000
30	15	32.2740	8.5800	0.6862755	0.7273417	-0.7273417	0.6862755	-1.0000000
31	15	32.5180	8.3148	0.7016494	0.7125223	-0.7125223	0.7016494	-1.0000000
32	15	32.7740	8.0470	0.7152123	0.6989073	-0.6989073	0.7152123	-1.0000000
34	15	33.3150	7.5026	0.7367963	0.6761148	-0.6761148	0.7367963	-1.0000000
35	15	33.5830	7.2376	0.7430266	0.6692619	-0.6692619	0.7430266	-1.0000000
36	15	33.8390	6.9933	0.7355433	0.6774777	-0.6774777	0.7355433	-1.0000000
37	15	34.1060	6.7256	0.7077494	0.7064636	-0.7064636	0.7077494	-1.0000000
43	15	35.4910	46.6510	0.9433333	0.3318467	-0.3318467	0.9433333	-1.0000000
4	16	31.0250	49.0350	0.3951271	0.9186265	-0.9186265	0.3951271	-1.0000000
5	16	31.0250	49.0350	0.3951271	0.9186265	-0.9186265	0.3951271	-0.0100000
23	16	31.4440	10.5090	0.6623239	0.7492176	-0.7492176	0.6623239	-1.0000000
24	16	31.5690	10.3560	0.6115171	0.7912312	-0.7912312	0.6115171	-1.0000000
25	16	31.7060	10.1800	0.6786932	0.7344219	-0.7344219	0.6786932	-1.0000000
26	16	31.8850	9.9709	0.6667828	0.7452521	-0.7452521	0.6667828	-1.0000000
27	16	32.0750	9.7469	0.6655040	0.7463943	-0.7463943	0.6655040	-1.0000000
28	16	32.2760	9.5120	0.6715572	0.7409527	-0.7409527	0.6715572	-1.0000000
29	16	32.4545	9.2503	0.6715572	0.7409527	-0.7409527	0.6715572	-1.0000000
31	16	32.9530	8.7686	0.7104025	0.7037957	-0.7037957	0.7104025	-1.0000000
32	16	33.2040	8.5135	0.7240213	0.6897777	-0.6897777	0.7240213	-1.0000000
35	16	34.0120	7.7439	0.7465540	0.6653248	-0.6653248	0.7465540	-1.0000000
36	16	34.2830	7.4877	0.7335630	0.6796215	-0.6796215	0.7335630	-1.0000000
37	16	34.5560	7.2078	0.7065688	0.7076443	-0.7076443	0.7065688	-1.0000000
42	16	35.4080	47.2940	0.9998655	-0.0164028	0.0164028	0.9998655	-1.0000000
43	16	35.5840	47.2940	0.9999119	0.0132733	-0.0132733	0.9999119	-1.0000000

44	16	35.5840	47.2940	0.9999119	0.0132733	-0.0132733	0.9999119	-0.0100000
4	17	31.5500	49.3180	0.6234583	0.7818566	-0.7818566	0.6234583	-1.0000000
5	17	31.5500	49.3180	0.6234583	0.7818566	-0.7818566	0.6234583	-0.0100000
22	17	31.7230	11.0800	0.6277183	0.7784406	-0.7784406	0.6277183	-1.0000000
23	17	31.8730	10.8890	0.6934327	0.7205215	-0.7205215	0.6934327	-1.0000000
24	17	31.9940	10.7620	0.7079788	0.7062337	-0.7062337	0.7079788	-1.0000000
25	17	32.1360	10.6040	0.6761965	0.7367213	-0.7367213	0.6761965	-1.0000000
26	17	32.3220	10.3860	0.6693958	0.7429060	-0.7429060	0.6693958	-1.0000000
27	17	32.5140	10.1620	0.6715772	0.7409346	-0.7409346	0.6715772	-1.0000000
28	17	32.7130	9.9327	0.6794583	0.7337142	-0.7337142	0.6794583	-1.0000000
29	17	32.9230	9.6993	0.6910695	0.7227883	-0.7227883	0.6910695	-1.0000000
31	17	33.3770	9.2219	0.7194868	0.6945061	-0.6945061	0.7194868	-1.0000000
32	17	33.6230	8.9790	0.7332160	0.6799958	-0.6799958	0.7332160	-1.0000000
33	17	33.8830	8.7333	0.7442197	0.6679350	-0.6679350	0.7442197	-1.0000000
34	17	34.1560	8.4847	0.7507761	0.6605567	-0.6605567	0.7507761	-1.0000000
35	17	34.4380	8.2353	0.7543160	0.6565115	-0.6565115	0.7543160	-1.0000000
36	17	34.7140	7.9904	0.7539246	0.6569610	-0.6569610	0.7539246	-1.0000000
42	17	35.4020	47.9410	0.9998367	-0.0180733	0.0180733	0.9998367	-1.0000000
43	17	35.5720	47.9470	0.9991729	-0.0406649	0.0406649	0.9991729	-1.0000000
44	17	35.5720	47.9470	0.9991729	-0.0406649	0.0406649	0.9991729	-0.0100000
4	18	31.5500	49.7370	0.8638121	-0.5038141	0.5038141	0.8638121	-1.0000000
5	18	31.5500	49.7370	0.8638121	-0.5038141	0.5038141	0.8638121	-0.0100000
22	18	32.1260	11.4760	0.6805899	0.7326646	-0.7326646	0.6805899	-1.0000000
23	18	32.2760	11.2980	0.6860554	0.7275493	-0.7275493	0.6860554	-1.0000000
24	18	32.3940	11.1680	0.7079788	0.7062337	-0.7062337	0.7079788	-1.0000000
25	18	32.5430	11.0090	0.6895712	0.7242179	-0.7242179	0.6895712	-1.0000000
26	18	32.7380	10.7900	0.6833805	0.7300624	-0.7300624	0.6833805	-1.0000000
27	18	32.9340	10.5700	0.6846561	0.7288663	-0.7288663	0.6846561	-1.0000000
28	18	33.1340	10.3490	0.6913524	0.7225177	-0.7225177	0.6913524	-1.0000000
29	18	33.3400	10.1250	0.7019037	0.7122719	-0.7122719	0.7019037	-1.0000000
30	18	33.5570	9.8983	0.7149797	0.6991452	-0.6991452	0.7149797	-1.0000000
31	18	33.7840	9.6696	0.7291431	0.6843613	-0.6843613	0.7291431	-1.0000000
32	18	34.0260	9.4373	0.7423468	0.6700159	-0.6700159	0.7423468	-1.0000000
34	18	34.5580	8.9483	0.7450547	0.6670034	-0.6670034	0.7450547	-1.0000000
35	18	34.8220	8.6810	0.7163877	0.6977025	-0.6977025	0.7163877	-1.0000000
42	18	35.3930	48.5290	0.9984258	-0.0560881	0.0560881	0.9984258	-1.0000000
43	18	35.5570	48.5420	0.9990983	-0.0424564	0.0424564	0.9990983	-1.0000000
44	18	35.5570	48.5420	0.9990983	-0.0424564	0.0424564	0.9990983	-0.0100000
4	19	31.0250	49.9170	-0.2767535	-0.9609410	0.9609410	-0.2767535	-1.0000000
5	19	31.0250	49.9170	-0.2767535	-0.9609410	0.9609410	-0.2767535	-0.0100000
20	19	32.1960	12.2820	0.6305340	0.7761616	-0.7761616	0.6305340	-1.0000000
21	19	32.3630	12.0770	0.6679710	0.7441873	-0.7441873	0.6679710	-1.0000000
22	19	32.5300	11.8840	0.6722420	0.7403315	-0.7403315	0.6722420	-1.0000000
23	19	32.6760	11.7080	0.6752896	0.7375527	-0.7375527	0.6752896	-1.0000000
24	19	32.8060	11.5750	0.7358146	0.6771830	-0.6771830	0.7358146	-1.0000000
25	19	32.9630	11.4130	0.6635685	0.7481155	-0.7481155	0.6635685	-1.0000000
26	19	33.1530	11.1940	0.6770118	0.7359721	-0.7359721	0.6770118	-1.0000000
27	19	33.3450	10.9780	0.6874166	0.7262633	-0.7262633	0.6874166	-1.0000000
28	19	33.5420	10.7630	0.6979731	0.7161240	-0.7161240	0.6979731	-1.0000000
29	19	33.7440	10.5480	0.7100492	0.7041521	-0.7041521	0.7100492	-1.0000000
30	19	33.9550	10.3320	0.7239887	0.6898119	-0.6898119	0.7239887	-1.0000000
31	19	34.1760	10.1150	0.7396690	0.6729708	-0.6729708	0.7396690	-1.0000000
32	19	34.4120	9.8950	0.7566243	0.6538498	-0.6538498	0.7566243	-1.0000000
33	19	34.6690	9.6687	0.7727824	0.6346710	-0.6346710	0.7727824	-1.0000000
34	19	34.9370	9.4099	0.7383686	0.6743974	-0.6743974	0.7383686	-1.0000000
42	19	35.3220	49.1390	0.9754158	-0.2203725	0.2203725	0.9754158	-1.0000000
43	19	35.4920	49.1770	0.9835003	-0.1809066	0.1809066	0.9835003	-1.0000000
44	19	35.4920	49.1770	0.9835003	-0.1809066	0.1809066	0.9835003	-0.0100000
4	20	30.5500	49.7130	-0.3124077	-0.9499481	0.9499481	-0.3124077	-1.0000000
5	20	30.5500	49.7130	-0.3124077	-0.9499481	0.9499481	-0.3124077	-0.0100000
19	20	32.4750	12.8680	0.6385090	0.7696144	-0.7696144	0.6385090	-1.0000000
20	20	32.6380	12.6650	0.6371729	0.7707209	-0.7707209	0.6371729	-1.0000000
21	20	32.7980	12.4680	0.6510249	0.7590564	-0.7590564	0.6510249	-1.0000000
22	20	32.9520	12.2850	0.6624232	0.7491298	-0.7491298	0.6624232	-1.0000000
23	20	33.0980	12.1140	0.6617146	0.7497558	-0.7497558	0.6617146	-1.0000000
24	20	33.2310	11.9680	0.6851623	0.7283905	-0.7283905	0.6851623	-1.0000000
25	20	33.3830	11.8020	0.6672414	0.7448416	-0.7448416	0.6672414	-1.0000000
26	20	33.5650	11.5940	0.6818820	0.7314622	-0.7314622	0.6818820	-1.0000000
27	20	33.7520	11.3860	0.6925446	0.7213750	-0.7213750	0.6925446	-1.0000000
28	20	33.9430	11.1790	0.7040743	0.7101264	-0.7101264	0.7040743	-1.0000000
29	20	34.1400	10.9740	0.7174609	0.6965988	-0.6965988	0.7174609	-1.0000000

30	20	34.3450	10.7690	0.7325891	0.6806712	-0.6806712	0.7325891	-1.0000000
31	20	34.5580	10.5650	0.7494920	0.6620134	-0.6620134	0.7494920	-1.0000000
32	20	34.7830	10.3610	0.7699677	0.6380828	-0.6380828	0.7699677	-1.0000000
33	20	35.0220	10.1560	0.8023614	0.5968385	-0.5968385	0.8023614	-1.0000000
43	20	35.3170	49.7430	0.8284003	-0.5601366	0.5601366	0.8284003	-1.0000000
44	20	35.3170	49.7430	0.8284003	-0.5601366	0.5601366	0.8284003	-0.0100000
4	21	30.3750	49.8820	0.9863912	-0.1644152	0.1644152	0.9863912	-1.0000000
5	21	30.3750	49.8820	0.9863912	-0.1644152	0.1644152	0.9863912	-0.0100000
18	21	32.7090	13.4270	0.6519520	0.7582602	-0.7582602	0.6519520	-1.0000000
19	21	32.9520	13.1570	0.6593421	0.7518431	-0.7518431	0.6593421	-1.0000000
21	21	33.2170	12.8520	0.6780766	0.7349913	-0.7349913	0.6780766	-1.0000000
22	21	33.3730	12.6790	0.6838822	0.7295924	-0.7295924	0.6838822	-1.0000000
23	21	33.5210	12.5160	0.6903108	0.7235130	-0.7235130	0.6903108	-1.0000000
24	21	33.6440	12.3740	0.6787784	0.7343432	-0.7343432	0.6787784	-1.0000000
25	21	33.7870	12.2060	0.6995152	0.7146177	-0.7146177	0.6995152	-1.0000000
26	21	33.9720	11.9990	0.6889566	0.7248026	-0.7248026	0.6889566	-1.0000000
27	21	34.1560	11.7970	0.6961728	0.7178743	-0.7178743	0.6961728	-1.0000000
28	21	34.3420	11.5990	0.7108852	0.7033080	-0.7033080	0.7108852	-1.0000000
29	21	34.5320	11.4060	0.7291807	0.6843212	-0.6843212	0.7291807	-1.0000000
30	21	34.7290	11.2170	0.7495099	0.6619932	-0.6619932	0.7495099	-1.0000000
31	21	34.9350	11.0310	0.7704629	0.6374848	-0.6374848	0.7704629	-1.0000000
32	21	35.1500	10.8490	0.7892618	0.6140569	-0.6140569	0.7892618	-1.0000000
33	21	35.3770	10.6590	0.7836223	0.6212376	-0.6212376	0.7836223	-1.0000000
43	21	34.8950	50.1180	0.5809758	-0.8139208	0.8139208	0.5809758	-1.0000000
44	21	34.8950	50.1180	0.5809758	-0.8139208	0.8139208	0.5809758	-0.0100000
4	22	30.2000	50.3880	0.7447912	-0.6672976	0.6672976	0.7447912	-1.0000000
5	22	30.2000	50.3880	0.7447912	-0.6672976	0.6672976	0.7447912	-0.0100000
17	22	32.8900	13.8500	0.6364682	0.7713029	-0.7713029	0.6364682	-1.0000000
18	22	33.1200	13.7650	0.6364682	0.7713029	-0.7713029	0.6364682	-1.0000000
20	22	33.4420	13.4010	0.6886922	0.7250539	-0.7250539	0.6886922	-1.0000000
21	22	33.6060	13.2280	0.6969191	0.7171497	-0.7171497	0.6969191	-1.0000000
22	22	33.7660	13.0610	0.6951142	0.7188994	-0.7188994	0.6951142	-1.0000000
23	22	33.9190	12.8980	0.6794225	0.7337473	-0.7337473	0.6794225	-1.0000000
24	22	34.0440	12.7670	0.6844263	0.7290820	-0.7290820	0.6844263	-1.0000000
25	22	34.1880	12.6080	0.6661321	0.7458338	-0.7458338	0.6661321	-1.0000000
26	22	34.3720	12.4000	0.6896967	0.7240984	-0.7240984	0.6896967	-1.0000000
27	22	34.5530	12.2070	0.7088799	0.7053292	-0.7053292	0.7088799	-1.0000000
28	22	34.7340	12.0240	0.7266873	0.6869684	-0.6869684	0.7266873	-1.0000000
29	22	34.9180	11.8470	0.7453201	0.6667067	-0.6667067	0.7453201	-1.0000000
30	22	35.1070	11.6770	0.7664203	0.6423393	-0.6423393	0.7664203	-1.0000000
31	22	35.3040	11.5130	0.7911461	0.6116272	-0.6116272	0.7911461	-1.0000000
32	22	35.5120	11.3520	0.8066753	0.5909949	-0.5909949	0.8066753	-1.0000000
43	22	34.6950	50.4870	0.8634763	0.5043895	-0.5043895	0.8634763	-1.0000000
44	22	34.6950	50.4870	0.8634763	0.5043895	-0.5043895	0.8634763	-0.0100000
4	23	29.6880	50.6380	0.3606009	-0.9327202	0.9327202	0.3606009	-1.0000000
5	23	29.6880	50.6380	0.3606009	-0.9327202	0.9327202	0.3606009	-0.0100000
17	23	33.2247	14.1757	0.7236159	0.6902029	-0.6902029	0.7236159	-1.0000000
21	23	33.9500	13.5840	0.7322029	0.6810866	-0.6810866	0.7322029	-1.0000000
22	23	34.1220	13.4230	0.7334517	0.6797416	-0.6797416	0.7334517	-1.0000000
23	23	34.3010	13.2580	0.7152382	0.6988808	-0.6988808	0.7152382	-1.0000000
24	23	34.4430	13.1230	0.6844263	0.7290820	-0.7290820	0.6844263	-1.0000000
25	23	34.5820	12.9800	0.6942698	0.7197148	-0.7197148	0.6942698	-1.0000000
26	23	34.7590	12.8030	0.7317309	0.6815936	-0.6815936	0.7317309	-1.0000000
27	23	34.9410	12.6350	0.7507888	0.6605423	-0.6605423	0.7507888	-1.0000000
28	23	35.1240	12.4730	0.7616604	0.6479764	-0.6479764	0.7616604	-1.0000000
29	23	35.3060	12.3160	0.7709812	0.6368579	-0.6368579	0.7709812	-1.0000000
30	23	35.4810	12.1610	0.7696230	0.6384986	-0.6384986	0.7696230	-1.0000000
31	23	35.6650	12.0210	0.8373985	0.5465928	-0.5465928	0.8373985	-1.0000000
32	23	35.8800	11.8680	0.8015182	0.5979704	-0.5979704	0.8015182	-1.0000000
43	23	35.0130	50.9500	0.7714882	0.6362436	-0.6362436	0.7714882	-1.0000000
44	23	35.0130	50.9500	0.7714882	0.6362436	-0.6362436	0.7714882	-0.0100000
4	24	29.4130	51.0250	0.9983510	0.0574046	-0.0574046	0.9983510	-1.0000000
5	24	29.4130	51.0250	0.9983510	0.0574046	-0.0574046	0.9983510	-0.0100000
17	24	33.4497	14.4707	0.8075448	0.5898062	-0.5898062	0.8075448	-1.0000000
21	24	34.2400	13.9280	0.7868346	0.6171640	-0.6171640	0.7868346	-1.0000000
23	24	34.6170	13.6320	0.8127608	0.5825975	-0.5825975	0.8127608	-1.0000000
24	24	34.7800	13.5030	0.8036001	0.5951697	-0.5951697	0.8036001	-1.0000000
25	24	34.9290	13.3880	0.8087633	0.5881342	-0.5881342	0.8087633	-1.0000000
26	24	35.1090	13.2560	0.8265285	0.5628948	-0.5628948	0.8265285	-1.0000000
27	24	35.3000	13.1210	0.8316516	0.5552979	-0.5552979	0.8316516	-1.0000000
28	24	35.4970	12.9830	0.8277945	0.5610314	-0.5610314	0.8277945	-1.0000000

29	24	35.6950	12.8400	0.8147732	0.5797799	-0.5797799	0.8147732	-1.0000000
43	24	35.0620	51.4750	0.8646075	-0.5024480	0.5024480	0.8646075	-1.0000000
44	24	35.0620	51.4750	0.8646075	-0.5024480	0.5024480	0.8646075	-0.0100000
4	25	29.5250	51.6750	0.9723064	0.2337099	-0.2337099	0.9723064	-1.0000000
5	25	29.5250	51.6750	0.9723064	0.2337099	-0.2337099	0.9723064	-0.0100000
17	25	33.6377	14.7597	0.8662348	0.4996371	-0.4996371	0.8662348	-1.0000000
21	25	34.4940	14.3080	0.8562559	0.5165517	-0.5165517	0.8562559	-1.0000000
23	25	34.8740	14.0700	0.8670021	0.4983045	-0.4983045	0.8670021	-1.0000000
24	25	35.0300	13.9730	0.8902680	0.4554370	-0.4554370	0.8902680	-1.0000000
25	25	35.1910	13.8870	0.9153073	0.4027561	-0.4027561	0.9153073	-1.0000000
26	25	35.3920	13.7880	0.9077492	0.4195133	-0.4195133	0.9077492	-1.0000000
27	25	35.6030	13.6830	0.9032380	0.4291400	-0.4291400	0.9032380	-1.0000000
28	25	35.8240	13.5710	0.8965612	0.4429198	-0.4429198	0.8965612	-1.0000000
29	25	36.0530	13.4450	0.8772830	0.4799734	-0.4799734	0.8772830	-1.0000000
30	25	36.2680	13.3140	0.8692204	0.4944249	-0.4944249	0.8692204	-1.0000000
31	25	36.4930	13.1870	0.8786447	0.4774762	-0.4774762	0.8786447	-1.0000000
43	25	34.7870	52.0370	0.9402708	-0.3404275	0.3404275	0.9402708	-1.0000000
44	25	34.7870	52.0370	0.9402708	-0.3404275	0.3404275	0.9402708	-0.0100000
4	26	29.5750	52.3120	0.9997522	0.0222634	-0.0222634	0.9997522	-1.0000000
5	26	29.5750	52.3120	0.9997522	0.0222634	-0.0222634	0.9997522	-0.0100000
17	26	33.8107	15.1217	0.9381382	0.3462611	-0.3462611	0.9381382	-1.0000000
21	26	34.7160	14.7630	0.9232709	0.3841495	-0.3841495	0.9232709	-1.0000000
23	26	35.1210	14.5860	0.9174718	0.3978008	-0.3978008	0.9174718	-1.0000000
24	26	35.2680	14.5190	0.9019989	0.4317383	-0.4317383	0.9019989	-1.0000000
25	26	35.4180	14.4530	0.9265593	0.3761488	-0.3761488	0.9265593	-1.0000000
26	26	35.6240	14.3720	0.9356194	0.3530105	-0.3530105	0.9356194	-1.0000000
27	26	35.8470	14.2840	0.9350733	0.3544543	-0.3544543	0.9350733	-1.0000000
28	26	36.0900	14.1820	0.9233244	0.3840209	-0.3840209	0.9233244	-1.0000000
43	26	34.7830	52.6120	0.9404899	0.3398216	-0.3398216	0.9404899	-1.0000000
44	26	34.7830	52.6120	0.9404899	0.3398216	-0.3398216	0.9404899	-0.0100000
4	27	29.6750	52.9150	0.8787842	0.4772194	-0.4772194	0.8787842	-1.0000000
5	27	29.6750	52.9150	0.8787842	0.4772194	-0.4772194	0.8787842	-0.0100000
18	27	34.0660	15.4620	0.9706644	0.2404383	-0.2404383	0.9706644	-1.0000000
19	27	34.4100	15.3990	0.9702239	0.2422097	-0.2422097	0.9702239	-1.0000000
20	27	34.6530	15.3360	0.9679702	0.2510650	-0.2510650	0.9679702	-1.0000000
21	27	34.8910	15.2720	0.9626060	0.2709052	-0.2709052	0.9626060	-1.0000000
22	27	35.1140	15.2040	0.9514159	0.3079087	-0.3079087	0.9514159	-1.0000000
23	27	35.3180	15.1350	0.9560024	0.2933590	-0.2933590	0.9560024	-1.0000000
24	27	35.4800	15.0890	0.9700117	0.2430585	-0.2430585	0.9700117	-1.0000000
25	27	35.6360	15.0470	0.9527801	0.3036612	-0.3036612	0.9527801	-1.0000000
26	27	35.8380	14.9830	0.9488931	0.3155977	-0.3155977	0.9488931	-1.0000000
27	27	36.0690	14.9040	0.9422109	0.3350203	-0.3350203	0.9422109	-1.0000000
28	27	36.3320	14.8060	0.9331436	0.3595040	-0.3595040	0.9331436	-1.0000000
29	27	36.6450	14.6860	0.9374290	0.3481765	-0.3481765	0.9374290	-1.0000000
43	27	35.0450	53.2100	0.9357268	0.3527257	-0.3527257	0.9357268	-1.0000000
44	27	35.0450	53.2100	0.9357268	0.3527257	-0.3527257	0.9357268	-0.0100000
4	28	30.0500	53.4900	0.7936341	0.6083954	-0.6083954	0.7936341	-1.0000000
5	28	30.0500	53.4900	0.7936341	0.6083954	-0.6083954	0.7936341	-0.0100000
22	28	35.2250	15.7510	0.9874628	0.1578516	-0.1578516	0.9874628	-1.0000000
23	28	35.4310	15.7070	0.9862506	0.1652567	-0.1652567	0.9862506	-1.0000000
24	28	35.5980	15.6730	0.9897601	0.1427409	-0.1427409	0.9897601	-1.0000000
25	28	35.7840	15.6390	0.9853291	0.1706653	-0.1706653	0.9853291	-1.0000000
26	28	36.0250	15.5860	0.9666363	0.2561528	-0.2561528	0.9666363	-1.0000000
27	28	36.2880	15.5140	0.9506565	0.3102454	-0.3102454	0.9506565	-1.0000000
28	28	36.5820	15.4250	0.9371049	0.3490480	-0.3490480	0.9371049	-1.0000000
29	28	36.9210	15.3210	0.9268980	0.3753133	-0.3753133	0.9268980	-1.0000000
30	28	37.3610	15.1850	0.9321541	0.3620618	-0.3620618	0.9321541	-1.0000000
43	28	34.9950	53.7980	0.8825015	-0.4703096	0.4703096	0.8825015	-1.0000000
44	28	34.9950	53.7980	0.8825015	-0.4703096	0.4703096	0.8825015	-0.0100000
4	29	30.0500	54.0220	0.7538046	-0.6570987	0.6570987	0.7538046	-1.0000000
5	29	30.0500	54.0220	0.7538046	-0.6570987	0.6570987	0.7538046	-0.0100000
21	29	35.0460	16.3610	0.9899104	0.1416951	-0.1416951	0.9899104	-1.0000000
22	29	35.2720	16.3200	0.9935336	0.1135388	-0.1135388	0.9935336	-1.0000000
23	29	35.4870	16.2850	0.9935947	0.1130023	-0.1130023	0.9935947	-1.0000000
24	29	35.6540	16.2440	0.9725293	0.2327804	-0.2327804	0.9725293	-1.0000000
25	29	35.8660	16.1990	0.9910555	0.1334501	-0.1334501	0.9910555	-1.0000000
26	29	36.1630	16.1490	0.9801720	0.1981484	-0.1981484	0.9801720	-1.0000000
27	29	36.4670	16.0830	0.9695137	0.2450373	-0.2450373	0.9695137	-1.0000000
28	29	36.7940	15.9980	0.9611259	0.2761104	-0.2761104	0.9611259	-1.0000000
29	29	37.1640	15.8960	0.9567010	0.2910723	-0.2910723	0.9567010	-1.0000000
30	29	37.6020	15.7760	0.9561771	0.2927890	-0.2927890	0.9561771	-1.0000000

31	29	38.0160	15.6620	0.9516390	0.3072185	-0.3072185	0.9516390	-1.0000000
43	29	34.4200	54.2130	0.4679558	-0.8837519	0.8837519	0.4679558	-1.0000000
44	29	34.4200	54.2130	0.4679558	-0.8837519	0.8837519	0.4679558	-0.0100000
4	30	29.5250	54.1780	-0.2899929	-0.9570288	0.9570288	-0.2899929	-1.0000000
5	30	29.5250	54.1780	-0.2899929	-0.9570288	0.9570288	-0.2899929	-0.0100000
20	30	34.8800	16.9390	0.9999987	0.0016130	-0.0016130	0.9999987	-1.0000000
21	30	35.1040	16.9260	0.9865689	0.1633455	-0.1633455	0.9865689	-1.0000000
22	30	35.3220	16.8770	0.9859585	0.1669906	-0.1669906	0.9859585	-1.0000000
23	30	35.5360	16.8280	0.9851987	0.1714165	-0.1714165	0.9851987	-1.0000000
24	30	35.7160	16.7890	0.9885377	0.1509742	-0.1509742	0.9885377	-1.0000000
25	30	35.9510	16.7560	0.9887211	0.1497684	-0.1497684	0.9887211	-1.0000000
26	30	36.2720	16.7060	0.9837881	0.1793347	-0.1793347	0.9837881	-1.0000000
27	30	36.5980	16.6400	0.9774381	0.2112221	-0.2112221	0.9774381	-1.0000000
28	30	36.9410	16.5570	0.9724447	0.2331337	-0.2331337	0.9724447	-1.0000000
29	30	37.3180	16.4550	0.9701402	0.2425450	-0.2425450	0.9701402	-1.0000000
30	30	37.7540	16.3220	0.9670946	0.2544171	-0.2544171	0.9670946	-1.0000000
43	30	33.8120	54.5130	0.4910846	-0.8711119	0.8711119	0.4910846	-1.0000000
44	30	33.8120	54.5130	0.4910846	-0.8711119	0.8711119	0.4910846	-0.0100000
4	31	28.9870	53.8800	-0.5232630	-0.8521712	0.8521712	-0.5232630	-1.0000000
5	31	28.9870	53.8800	-0.5232630	-0.8521712	0.8521712	-0.5232630	-0.0100000
20	31	34.9820	17.5810	0.9830278	0.1834570	-0.1834570	0.9830278	-1.0000000
21	31	35.2120	17.5380	0.9775684	0.2106183	-0.2106183	0.9775684	-1.0000000
22	31	35.4350	17.4890	0.9737473	0.2276317	-0.2276317	0.9737473	-1.0000000
23	31	35.6490	17.4380	0.9705318	0.2409729	-0.2409729	0.9705318	-1.0000000
24	31	35.8350	17.4110	0.9936789	0.1122602	-0.1122602	0.9936789	-1.0000000
25	31	36.0740	17.3720	0.9738554	0.2271687	-0.2271687	0.9738554	-1.0000000
26	31	36.3940	17.2920	0.9718764	0.2354914	-0.2354914	0.9718764	-1.0000000
27	31	36.7325	17.2055	0.9718764	0.2354914	-0.2354914	0.9718764	-1.0000000
28	31	37.0710	17.1190	0.9698592	0.2436661	-0.2436661	0.9698592	-1.0000000
29	31	37.4400	17.0190	0.9711381	0.2385179	-0.2385179	0.9711381	-1.0000000
30	31	37.8740	16.8850	0.9633242	0.2683400	-0.2683400	0.9633242	-1.0000000
43	31	33.2500	54.8450	0.4646240	-0.8855081	0.8855081	0.4646240	-1.0000000
44	31	33.2500	54.8450	0.4646240	-0.8855081	0.8855081	0.4646240	-0.0100000
4	32	28.5380	53.8750	0.7834641	-0.6214371	0.6214371	0.7834641	-1.0000000
5	32	28.5380	53.8750	0.7834641	-0.6214371	0.6214371	0.7834641	-0.0100000
20	32	35.1530	18.2500	0.9514315	0.3078605	-0.3078605	0.9514315	-1.0000000
21	32	35.3750	18.1810	0.9604740	0.2783697	-0.2783697	0.9604740	-1.0000000
22	32	35.5930	18.1220	0.9672033	0.2540035	-0.2540035	0.9672033	-1.0000000
23	32	35.8090	18.0700	0.9713605	0.2376105	-0.2376105	0.9713605	-1.0000000
24	32	35.9910	18.0330	0.9756268	0.2194364	-0.2194364	0.9756268	-1.0000000
25	32	36.2220	17.9650	0.9522054	0.3054585	-0.3054585	0.9522054	-1.0000000
26	32	36.5390	17.8620	0.9614001	0.2751543	-0.2751543	0.9614001	-1.0000000
28	32	37.2300	17.7025	0.9695262	0.2449876	-0.2449876	0.9695262	-1.0000000
29	32	37.5940	17.6030	0.9695262	0.2449876	-0.2449876	0.9695262	-1.0000000
30	32	38.0000	17.4900	0.9695262	0.2449876	-0.2449876	0.9695262	-1.0000000
43	32	32.8530	55.3200	0.9633588	-0.2682160	0.2682160	0.9633588	-1.0000000
44	32	32.8530	55.3200	0.9633588	-0.2682160	0.2682160	0.9633588	-0.0100000
4	33	28.4130	54.3880	0.9856443	0.1688350	-0.1688350	0.9856443	-1.0000000
5	33	28.4130	54.3880	0.9856443	0.1688350	-0.1688350	0.9856443	-0.0100000
19	33	35.0860	18.8500	0.9633446	0.2682669	-0.2682669	0.9633446	-1.0000000
20	33	35.3140	18.7800	0.9545438	0.2980707	-0.2980707	0.9545438	-1.0000000
21	33	35.5260	18.7090	0.9571682	0.2895324	-0.2895324	0.9571682	-1.0000000
22	33	35.7350	18.6440	0.9609579	0.2766946	-0.2766946	0.9609579	-1.0000000
23	33	35.9460	18.5830	0.9640154	0.2658465	-0.2658465	0.9640154	-1.0000000
24	33	36.1160	18.5280	0.9557030	0.2943330	-0.2943330	0.9557030	-1.0000000
25	33	36.3360	18.4590	0.9766065	0.2150341	-0.2150341	0.9766065	-1.0000000
26	33	36.6510	18.3800	0.9823801	0.1868940	-0.1868940	0.9823801	-1.0000000
28	33	37.3100	18.2750	0.9908106	0.1352568	-0.1352568	0.9908106	-1.0000000
29	33	37.7090	18.1700	0.9908106	0.1352568	-0.1352568	0.9908106	-1.0000000
30	33	38.0600	18.0650	0.9583178	0.2857045	-0.2857045	0.9583178	-1.0000000
43	33	32.7320	55.8750	0.9634417	-0.2679183	0.2679183	0.9634417	-1.0000000
44	33	32.7320	55.8750	0.9634417	-0.2679183	0.2679183	0.9634417	-0.0100000
4	34	28.2370	54.9470	0.7143571	-0.6997814	0.6997814	0.7143571	-1.0000000
5	34	28.2370	54.9470	0.7143571	-0.6997814	0.6997814	0.7143571	-0.0100000
19	34	35.2020	19.3090	0.9746724	0.2236374	-0.2236374	0.9746724	-1.0000000
20	34	35.4380	19.2470	0.9665051	0.2566476	-0.2566476	0.9665051	-1.0000000
21	34	35.6550	19.1850	0.9637472	0.2668169	-0.2668169	0.9637472	-1.0000000
22	34	35.8620	19.1240	0.9642811	0.2648811	-0.2648811	0.9642811	-1.0000000
23	34	36.0640	19.0650	0.9684821	0.2490834	-0.2490834	0.9684821	-1.0000000
24	34	36.2210	19.0100	0.9492237	0.3146019	-0.3146019	0.9492237	-1.0000000
25	34	36.4150	18.9590	0.9859970	0.1667632	-0.1667632	0.9859970	-1.0000000

26	34	36.7000	18.9170	0.9974847	0.0708827	-0.0708827	0.9974847	-1.0000000
28	34	37.3405	18.8320	0.9842117	0.1769952	-0.1769952	0.9842117	-1.0000000
29	34	37.7710	18.7470	0.9842117	0.1769952	-0.1769952	0.9842117	-1.0000000
30	34	38.1590	18.6400	0.9710875	0.2387238	-0.2387238	0.9710875	-1.0000000
43	34	32.3220	56.0250	-0.1465520	-0.9892030	0.9892030	-0.1465520	-1.0000000
44	34	32.3220	56.0250	-0.1465520	-0.9892030	0.9892030	-0.1465520	-0.0100000
4	35	27.6750	55.3350	0.3562477	-0.9343916	0.9343916	0.3562477	-1.0000000
5	35	27.6750	55.3350	0.3562477	-0.9343916	0.9343916	0.3562477	-0.0100000
19	35	35.2790	19.7730	0.9900692	0.1405811	-0.1405811	0.9900692	-1.0000000
20	35	35.5350	19.7310	0.9873909	0.1583007	-0.1583007	0.9873909	-1.0000000
21	35	35.7580	19.6940	0.9878280	0.1555502	-0.1555502	0.9878280	-1.0000000
22	35	35.9620	19.6610	0.9898052	0.1424280	-0.1424280	0.9898052	-1.0000000
23	35	36.1500	19.6320	0.9928368	0.1194780	-0.1194780	0.9928368	-1.0000000
24	35	36.3020	19.5940	0.9732487	0.2297542	-0.2297542	0.9732487	-1.0000000
25	35	36.4570	19.5540	0.9968849	0.0788707	-0.0788707	0.9968849	-1.0000000
26	35	36.6710	19.5300	0.9998183	-0.0190645	0.0190645	0.9998183	-1.0000000
27	35	36.9940	19.5020	0.9999999	0.0004214	-0.0004214	0.9999999	-1.0000000
28	35	37.4240	19.4570	0.9961948	0.0871549	-0.0871549	0.9961948	-1.0000000
29	35	37.8660	19.3930	0.9851460	0.1717187	-0.1717187	0.9851460	-1.0000000
30	35	38.2780	19.3100	0.9802942	0.1975432	-0.1975432	0.9802942	-1.0000000
43	35	31.6420	55.9750	0.1915226	-0.9814882	0.9814882	0.1915226	-1.0000000
44	35	31.6420	55.9750	0.1915226	-0.9814882	0.9814882	0.1915226	-0.0100000
4	36	27.0750	55.5880	0.3271701	-0.9449654	0.9449654	0.3271701	-1.0000000
19	36	35.3340	20.2400	0.9949861	0.1000137	-0.1000137	0.9949861	-1.0000000
20	36	35.5860	20.2200	0.9981602	0.0606322	-0.0606322	0.9981602	-1.0000000
21	36	35.8080	20.2080	0.9990488	0.0436072	-0.0436072	0.9990488	-1.0000000
22	36	36.0140	20.1990	0.9989846	0.0450535	-0.0450535	0.9989846	-1.0000000
23	36	36.2080	20.1930	0.9972126	0.0746120	-0.0746120	0.9972126	-1.0000000
24	36	36.3670	20.1770	0.9842031	0.1770432	-0.1770432	0.9842031	-1.0000000
25	36	36.5080	20.1570	0.9914514	0.1304767	-0.1304767	0.9914514	-1.0000000
26	36	36.6870	20.1450	0.9923452	0.1234950	-0.1234950	0.9923452	-1.0000000
27	36	37.0000	20.1205	0.9961115	0.0881021	-0.0881021	0.9961115	-1.0000000
28	36	37.4850	20.0960	0.9961115	0.0881021	-0.0881021	0.9961115	-1.0000000
29	36	37.9660	20.0630	0.9942500	0.1070836	-0.1070836	0.9942500	-1.0000000
30	36	38.4020	20.0280	0.9928061	0.1197332	-0.1197332	0.9928061	-1.0000000
43	36	31.4300	56.3200	0.9572459	0.2892753	-0.2892753	0.9572459	-1.0000000
44	36	31.4300	56.3200	0.9572459	0.2892753	-0.2892753	0.9572459	-0.0100000
4	37	26.5500	55.7000	0.0000000	-1.0000000	1.0000000	0.0000000	-1.0000000
5	37	26.4870	56.1500	0.0166598	-0.9998612	0.9998612	0.0166598	-1.0000000
6	37	26.5250	56.8380	0.1019175	-0.9947929	0.9947929	0.1019175	-1.0000000
7	37	26.5500	57.3500	0.0000000	-1.0000000	1.0000000	0.0000000	-1.0000000
20	37	35.5990	20.6940	0.9999930	0.0037393	-0.0037393	0.9999930	-1.0000000
21	37	35.8190	20.6940	0.9999934	-0.0036145	0.0036145	0.9999934	-1.0000000
22	37	36.0300	20.6930	0.9999002	0.0141315	-0.0141315	0.9999002	-1.0000000
23	37	36.2390	20.6870	0.9996251	0.0273795	-0.0273795	0.9996251	-1.0000000
24	37	36.4060	20.6820	1.0000000	0.0000000	0.0000000	1.0000000	-1.0000000
25	37	36.5660	20.6830	0.9998916	0.0147209	-0.0147209	0.9998916	-1.0000000
26	37	36.7520	20.6830	0.9996842	0.0251325	-0.0251325	0.9996842	-1.0000000
27	37	36.9220	20.6830	0.9996842	0.0251325	-0.0251325	0.9996842	-1.0000000
28	37	37.1320	20.6830	0.9996842	0.0251325	-0.0251325	0.9996842	-1.0000000
30	37	37.6580	20.6780	0.9998260	0.0186575	-0.0186575	0.9998260	-1.0000000
31	37	38.0310	20.6760	0.9984464	0.0557206	-0.0557206	0.9984464	-1.0000000
43	37	31.7180	56.8820	0.8378644	0.5458784	-0.5458784	0.8378644	-1.0000000
44	37	31.7180	56.8820	0.8378644	0.5458784	-0.5458784	0.8378644	-0.0100000
4	38	25.9620	55.7500	0.1554819	-0.9878387	0.9878387	0.1554819	-1.0000000
7	38	26.2500	57.4750	0.3690618	-0.9294049	0.9294049	0.3690618	-1.0000000
8	38	26.2500	57.4750	0.3690618	-0.9294049	0.9294049	0.3690618	-0.0100000
21	38	35.8290	21.2390	0.9999892	0.0046539	-0.0046539	0.9999892	-1.0000000
22	38	36.0370	21.2370	0.9996812	0.0252500	-0.0252500	0.9996812	-1.0000000
23	38	36.2410	21.2290	0.9997902	0.0204827	-0.0204827	0.9997902	-1.0000000
24	38	36.4050	21.2250	0.9999996	-0.0008606	0.0008606	0.9999996	-1.0000000
25	38	36.5680	21.2260	0.9997911	-0.0204365	0.0204365	0.9997911	-1.0000000
26	38	36.7570	21.2290	0.9998496	-0.0173443	0.0173443	0.9998496	-1.0000000
27	38	36.9220	21.2290	0.9989399	0.0460324	-0.0460324	0.9989399	-1.0000000
28	38	37.1320	21.2270	0.9980754	0.0620122	-0.0620122	0.9980754	-1.0000000
29	38	37.3980	21.2250	0.9993327	0.0365269	-0.0365269	0.9993327	-1.0000000
30	38	37.6960	21.2270	0.9994706	0.0325357	-0.0325357	0.9994706	-1.0000000
31	38	38.0620	21.2330	0.9999999	0.0002705	-0.0002705	0.9999999	-1.0000000
32	38	38.4240	21.2390	0.9997694	-0.0214729	0.0214729	0.9997694	-1.0000000
43	38	32.1250	57.4870	0.8012773	0.5982931	-0.5982931	0.8012773	-1.0000000
44	38	32.1250	57.4870	0.8012773	0.5982931	-0.5982931	0.8012773	-0.0100000

4	39	25.2700	55.8500	0.1554819	-0.9878387	0.9878387	0.1554819	-1.0000000
5	39	25.2700	55.8500	0.1554819	-0.9878387	0.9878387	0.1554819	-1.0000000
7	39	25.8400	57.8250	0.4584127	-0.8887394	0.8887394	0.4584127	-1.0000000
8	39	25.8400	57.8250	0.4584127	-0.8887394	0.8887394	0.4584127	-0.0100000
22	39	36.0400	21.8140	0.9998346	0.0181869	-0.0181869	0.9998346	-1.0000000
23	39	36.2410	21.8070	0.9999337	0.0115199	-0.0115199	0.9999337	-1.0000000
24	39	36.4050	21.8050	1.0000000	0.0000000	0.0000000	1.0000000	-1.0000000
25	39	36.5600	21.8070	0.9999191	-0.0127214	0.0127214	0.9999191	-1.0000000
26	39	36.7490	21.8110	0.9999030	-0.0139281	0.0139281	0.9999030	-1.0000000
27	39	36.9470	21.8130	0.9999957	0.0029346	-0.0029346	0.9999957	-1.0000000
28	39	37.1680	21.8120	0.9999439	0.0105946	-0.0105946	0.9999439	-1.0000000
29	39	37.4190	21.8100	0.9999998	-0.0006578	0.0006578	0.9999998	-1.0000000
30	39	37.7120	21.8120	0.9998754	-0.0157842	0.0157842	0.9998754	-1.0000000
31	39	38.0650	21.8160	0.9998900	-0.0148300	0.0148300	0.9998900	-1.0000000
32	39	38.4240	21.8160	0.9998900	-0.0148300	0.0148300	0.9998900	-1.0000000
43	39	32.6380	57.9380	0.6455021	0.7637585	-0.7637585	0.6455021	-1.0000000
44	39	32.6380	57.9380	0.6455021	0.7637585	-0.7637585	0.6455021	-0.0100000
4	40	24.6080	55.9900	0.1554819	-0.9878387	0.9878387	0.1554819	-1.0000000
5	40	24.6080	55.9900	0.1554819	-0.9878387	0.9878387	0.1554819	-1.0000000
7	40	25.3150	58.0000	-0.1525558	-0.9882948	0.9882948	-0.1525558	-1.0000000
8	40	25.3150	58.0000	-0.1525558	-0.9882948	0.9882948	-0.1525558	-0.0100000
23	40	36.2410	22.3970	0.9999999	-0.0004132	0.0004132	0.9999999	-1.0000000
24	40	36.4050	22.3970	0.9999999	-0.0004132	0.0004132	0.9999999	-1.0000000
25	40	36.5570	22.4010	0.9997835	-0.0208103	0.0208103	0.9997835	-1.0000000
26	40	36.7440	22.4060	0.9998882	-0.0149534	0.0149534	0.9998882	-1.0000000
27	40	36.9470	22.4080	0.9999945	-0.0033126	0.0033126	0.9999945	-1.0000000
28	40	37.1710	22.4060	0.9999669	0.0081378	-0.0081378	0.9999669	-1.0000000
29	40	37.4200	22.4010	0.9998735	0.0159050	-0.0159050	0.9998735	-1.0000000
30	40	37.7080	22.3920	0.9997147	0.0238873	-0.0238873	0.9997147	-1.0000000
31	40	38.0610	22.3670	0.9988315	0.0483286	-0.0483286	0.9988315	-1.0000000
43	40	32.7320	58.2750	0.7821845	-0.6230469	0.6230469	0.7821845	-1.0000000
44	40	32.7320	58.2750	0.7821845	-0.6230469	0.6230469	0.7821845	-0.0100000
4	41	23.9750	55.9700	0.0000000	-1.0000000	1.0000000	0.0000000	-1.0000000
5	41	23.9750	55.9700	0.0000000	-1.0000000	1.0000000	0.0000000	-0.0100000
7	41	24.7880	58.0250	0.4718579	-0.8816746	0.8816746	0.4718579	-1.0000000
8	41	24.7880	58.0250	0.4718579	-0.8816746	0.8816746	0.4718579	-0.0100000
23	41	36.2400	23.0530	0.9999999	-0.0003536	0.0003536	0.9999999	-1.0000000
24	41	36.3980	23.0530	0.9999577	-0.0091924	0.0091924	0.9999577	-1.0000000
25	41	36.5510	23.0520	0.9999986	-0.0016686	0.0016686	0.9999986	-1.0000000
26	41	36.7500	23.0470	0.9994124	0.0342764	-0.0342764	0.9994124	-1.0000000
28	41	37.1930	23.0190	0.9971045	0.0760432	-0.0760432	0.9971045	-1.0000000
29	41	37.4440	22.9980	0.9967363	0.0807263	-0.0807263	0.9967363	-1.0000000
30	41	37.7310	22.9740	0.9971915	0.0748933	-0.0748933	0.9971915	-1.0000000
31	41	38.0970	22.9200	0.9875750	0.1571484	-0.1571484	0.9875750	-1.0000000
43	41	32.2320	58.7000	0.6852555	-0.7283028	0.7283028	0.6852555	-1.0000000
44	41	32.2320	58.7000	0.6852555	-0.7283028	0.7283028	0.6852555	-0.0100000
4	42	23.7630	56.2630	0.9549969	0.2966157	-0.2966157	0.9549969	-1.0000000
5	42	23.7630	56.2630	0.9549969	0.2966157	-0.2966157	0.9549969	-0.0100000
7	42	24.8120	58.2250	0.7428958	0.6694070	-0.6694070	0.7428958	-1.0000000
8	42	24.8120	58.2250	0.7428958	0.6694070	-0.6694070	0.7428958	-0.0100000
22	42	36.0260	23.7720	0.9954726	0.0950491	-0.0950491	0.9954726	-1.0000000
23	42	36.2590	23.7600	0.9996480	0.0265299	-0.0265299	0.9996480	-1.0000000
24	42	36.4100	23.7470	0.9907788	0.1354895	-0.1354895	0.9907788	-1.0000000
25	42	36.5780	23.7220	0.9942727	0.1068730	-0.1068730	0.9942727	-1.0000000
26	42	36.8030	23.6930	0.9900991	0.1403699	-0.1403699	0.9900991	-1.0000000
28	42	37.2720	23.6180	0.9834660	0.1810931	-0.1810931	0.9834660	-1.0000000
29	42	37.5260	23.5750	0.9819075	0.1893611	-0.1893611	0.9819075	-1.0000000
30	42	37.8060	23.5300	0.9843979	0.1759569	-0.1759569	0.9843979	-1.0000000
43	42	32.0130	59.2750	0.9538864	0.3001678	-0.3001678	0.9538864	-1.0000000
44	42	32.0130	59.2750	0.9538864	0.3001678	-0.3001678	0.9538864	-0.0100000
4	43	23.8000	56.8750	0.9944351	-0.1053515	0.1053515	0.9944351	-1.0000000
5	43	23.8000	56.8750	0.9944351	-0.1053515	0.1053515	0.9944351	-0.0100000
7	43	25.1120	58.5500	0.9885548	0.1508618	-0.1508618	0.9885548	-1.0000000
8	43	25.1120	58.5500	0.9885548	0.1508618	-0.1508618	0.9885548	-0.0100000
23	43	36.3340	24.4160	0.9958323	0.0912032	-0.0912032	0.9958323	-1.0000000
24	43	36.4860	24.3910	0.9547542	0.2973960	-0.2973960	0.9547542	-1.0000000
25	43	36.6650	24.3430	0.9835840	0.1804507	-0.1804507	0.9835840	-1.0000000
26	43	36.9070	24.2960	0.9797590	0.2001808	-0.2001808	0.9797590	-1.0000000
27	43	37.1480	24.2450	0.9768392	0.2139748	-0.2139748	0.9768392	-1.0000000
28	43	37.3940	24.1910	0.9750853	0.2218301	-0.2218301	0.9750853	-1.0000000
29	43	37.6480	24.1320	0.9750735	0.2218819	-0.2218819	0.9750735	-1.0000000

30	43	37.9170	24.0700	0.9777054	0.2099816	-0.2099816	0.9777054	-1.0000000
31	43	38.1940	23.9880	0.9594585	0.2818498	-0.2818498	0.9594585	-1.0000000
43	43	32.4700	59.6750	0.0669665	0.9977552	-0.9977552	0.0669665	-1.0000000
44	43	32.4700	59.6750	0.0669665	0.9977552	-0.9977552	0.0669665	-0.0100000
4	44	23.4130	57.3120	0.2847662	-0.9585970	0.9585970	0.2847662	-1.0000000
5	44	23.4130	57.3120	0.2847662	-0.9585970	0.9585970	0.2847662	-0.0100000
7	44	25.0380	58.8500	0.7447901	-0.6672989	0.6672989	0.7447901	-1.0000000
8	44	25.0380	58.8500	0.7447901	-0.6672989	0.6672989	0.7447901	-0.0100000
23	44	36.4540	24.9960	0.9691049	0.2466490	-0.2466490	0.9691049	-1.0000000
24	44	36.6050	24.9650	0.9867981	0.1619553	-0.1619553	0.9867981	-1.0000000
25	44	36.7910	24.9330	0.9751245	0.2216581	-0.2216581	0.9751245	-1.0000000
26	44	37.0370	24.8810	0.9746800	0.2236042	-0.2236042	0.9746800	-1.0000000
27	44	37.2830	24.8250	0.9731268	0.2302702	-0.2302702	0.9731268	-1.0000000
28	44	37.5330	24.7670	0.9715608	0.2367900	-0.2367900	0.9715608	-1.0000000
29	44	37.7900	24.7070	0.9699782	0.2431921	-0.2431921	0.9699782	-1.0000000
30	44	38.0520	24.6410	0.9651112	0.2618403	-0.2618403	0.9651112	-1.0000000
31	44	38.3340	24.5910	0.9651112	0.2618403	-0.2618403	0.9651112	-1.0000000
33	44	0.0000	0.0000	1.0000000	0.0000000	0.0000000	1.0000000	-1.0000000
34	44	0.0000	0.0000	1.0000000	0.0000000	0.0000000	1.0000000	-1.0000000
35	44	0.0000	0.0000	1.0000000	0.0000000	0.0000000	1.0000000	-1.0000000
43	44	33.1400	59.8380	0.2684468	0.9632945	-0.9632945	0.2684468	-1.0000000
44	44	33.1400	59.8380	0.2684468	0.9632945	-0.9632945	0.2684468	-0.0100000
4	45	22.7750	57.4500	0.1380637	-0.9904233	0.9904233	0.1380637	-1.0000000
5	45	22.7750	57.4500	0.1380637	-0.9904233	0.9904233	0.1380637	-0.0100000
7	45	24.7500	59.0370	0.5658044	-0.8245395	0.8245395	0.5658044	-1.0000000
8	45	24.7500	59.0370	0.5658044	-0.8245395	0.8245395	0.5658044	-0.0100000
22	45	36.3250	25.6660	0.9862451	0.1652894	-0.1652894	0.9862451	-1.0000000
23	45	36.5770	25.6100	0.9654331	0.2606511	-0.2606511	0.9654331	-1.0000000
24	45	36.7300	25.5700	0.9898514	0.1421067	-0.1421067	0.9898514	-1.0000000
25	45	36.9220	25.5380	0.9816907	0.1904819	-0.1904819	0.9816907	-1.0000000
26	45	37.1750	25.4860	0.9779080	0.2090356	-0.2090356	0.9779080	-1.0000000
27	45	37.4230	25.4330	0.9776682	0.2101546	-0.2101546	0.9776682	-1.0000000
28	45	37.6700	25.3810	0.9800057	0.1989692	-0.1989692	0.9800057	-1.0000000
29	45	37.9240	25.3270	0.9826248	0.1856028	-0.1856028	0.9826248	-1.0000000
30	45	38.1720	25.2770	0.9826248	0.1856028	-0.1856028	0.9826248	-1.0000000
43	45	33.6700	60.2130	0.6968868	0.7171811	-0.7171811	0.6968868	-1.0000000
44	45	33.6700	60.2130	0.6968868	0.7171811	-0.7171811	0.6968868	-0.0100000
4	46	22.2000	57.6950	0.3963514	-0.9180989	0.9180989	0.3963514	-1.0000000
5	46	22.2000	57.6950	0.3963514	-0.9180989	0.9180989	0.3963514	-0.0100000
7	46	24.4130	59.0880	0.1706729	-0.9853277	0.9853277	0.1706729	-1.0000000
8	46	24.4130	59.0880	0.1706729	-0.9853277	0.9853277	0.1706729	-0.0100000
22	46	36.4310	26.2920	0.9851137	0.1719037	-0.1719037	0.9851137	-1.0000000
23	46	36.6960	26.2360	0.9772605	0.2120425	-0.2120425	0.9772605	-1.0000000
24	46	36.8690	26.2010	0.9822542	0.1875545	-0.1875545	0.9822542	-1.0000000
25	46	37.0520	26.1730	0.9820345	0.1887013	-0.1887013	0.9820345	-1.0000000
26	46	37.3100	26.1330	0.9848358	0.1734891	-0.1734891	0.9848358	-1.0000000
27	46	37.5590	26.0970	0.9860556	0.1664166	-0.1664166	0.9860556	-1.0000000
28	46	37.7930	26.0550	0.9820862	0.1884321	-0.1884321	0.9820862	-1.0000000
43	46	34.1750	60.6380	0.5301558	0.8479002	-0.8479002	0.5301558	-1.0000000
44	46	34.1750	60.6380	0.5301558	0.8479002	-0.8479002	0.5301558	-0.0100000
4	47	21.6120	57.9200	0.1464948	-0.9892114	0.9892114	0.1464948	-1.0000000
5	47	21.6120	57.9200	0.1464948	-0.9892114	0.9892114	0.1464948	-0.0100000
7	47	24.2630	59.3750	0.9562553	-0.2925336	0.2925336	0.9562553	-1.0000000
8	47	24.2630	59.3750	0.9562553	-0.2925336	0.2925336	0.9562553	-0.0100000
22	47	36.5060	26.8930	0.9929683	0.1183803	-0.1183803	0.9929683	-1.0000000
23	47	36.7830	26.8490	0.9917006	0.1285683	-0.1285683	0.9917006	-1.0000000
24	47	36.9760	26.8380	0.9980386	-0.0626007	0.0626007	0.9980386	-1.0000000
25	47	37.1510	26.8430	0.9975356	0.0701625	-0.0701625	0.9975356	-1.0000000
26	47	37.3890	26.8300	0.9992295	0.0392482	-0.0392482	0.9992295	-1.0000000
27	47	37.6300	26.8190	0.9997009	0.0244566	-0.0244566	0.9997009	-1.0000000
43	47	34.5500	60.5750	-0.9122413	0.4096533	-0.4096533	-0.9122413	-1.0000000
44	47	34.5500	60.5750	-0.9122413	0.4096533	-0.4096533	-0.9122413	-0.0100000
4	48	20.9380	58.0750	0.4587257	-0.8885779	0.8885779	0.4587257	-1.0000000
5	48	20.9380	58.0750	0.4587257	-0.8885779	0.8885779	0.4587257	-0.0100000
7	48	24.2120	59.9500	0.8217237	-0.5698861	0.5698861	0.8217237	-1.0000000
8	48	24.2120	59.9500	0.8217237	-0.5698861	0.5698861	0.8217237	-0.0100000
21	48	36.2130	27.4910	0.9973906	-0.0721946	0.0721946	0.9973906	-1.0000000
22	48	36.5080	27.5060	0.9982136	-0.0597467	0.0597467	0.9982136	-1.0000000
23	48	36.7850	27.5160	0.9985209	-0.0543693	0.0543693	0.9985209	-1.0000000
24	48	36.9750	27.5260	0.9949672	-0.1002008	0.1002008	0.9949672	-1.0000000
25	48	37.1510	27.5360	0.9986563	-0.0518219	0.0518219	0.9986563	-1.0000000

26	48	37.3900	27.5410	0.9997076	-0.0241826	0.0241826	0.9997076	-1.0000000
27	48	37.6310	27.5470	0.9998791	-0.0155474	0.0155474	0.9998791	-1.0000000
28	48	37.8770	27.5540	0.9998484	-0.0174091	0.0174091	0.9998484	-1.0000000
43	48	34.5880	59.9500	-0.9965926	-0.0824812	0.0824812	-0.9965926	-1.0000000
44	48	34.5880	59.9500	-0.9965926	-0.0824812	0.0824812	-0.9965926	-0.0100000
4	49	20.3370	58.4250	0.7024830	-0.7117006	0.7117006	0.7024830	-1.0000000
5	49	20.3370	58.4250	0.7024830	-0.7117006	0.7117006	0.7024830	-0.0100000
7	49	23.8880	60.1750	-0.1740423	-0.9847382	0.9847382	-0.1740423	-1.0000000
8	49	23.8880	60.1750	-0.1740423	-0.9847382	0.9847382	-0.1740423	-0.0100000
21	49	36.1360	28.1210	0.9899129	-0.1416776	0.1416776	0.9899129	-1.0000000
22	49	36.4310	28.1580	0.9909456	-0.1342640	0.1342640	0.9909456	-1.0000000
23	49	36.7150	28.1890	0.9932561	-0.1159412	0.1159412	0.9932561	-1.0000000
24	49	36.9120	28.2040	0.9987404	-0.0501760	0.0501760	0.9987404	-1.0000000
25	49	37.1010	28.2130	0.9976012	-0.0692236	0.0692236	0.9976012	-1.0000000
26	49	37.3590	28.2280	0.9984771	-0.0551680	0.0551680	0.9984771	-1.0000000
27	49	37.6050	28.2400	0.9982271	-0.0595206	0.0595206	0.9982271	-1.0000000
28	49	37.8380	28.2630	0.9915454	-0.1297605	0.1297605	0.9915454	-1.0000000
43	49	34.7870	59.3500	-0.7189829	0.6950278	-0.6950278	-0.7189829	-1.0000000
44	49	34.7870	59.3500	-0.7189829	0.6950278	-0.6950278	-0.7189829	-0.0100000
4	50	19.8880	58.9320	0.7616763	-0.6479577	0.6479577	0.7616763	-1.0000000
5	50	19.8880	58.9320	0.7616763	-0.6479577	0.6479577	0.7616763	-0.0100000
7	50	23.6250	59.9380	-0.8744090	-0.4851896	0.4851896	-0.8744090	-1.0000000
8	50	23.6250	59.9380	-0.8744090	-0.4851896	0.4851896	-0.8744090	-0.0100000
21	50	36.0180	28.8060	0.9882227	-0.1530227	0.1530227	0.9882227	-1.0000000
22	50	36.3280	28.8420	0.9919519	-0.1266151	0.1266151	0.9919519	-1.0000000
23	50	36.6230	28.8740	0.9926128	-0.1213249	0.1213249	0.9926128	-1.0000000
24	50	36.8290	28.8890	0.9973666	-0.0725246	0.0725246	0.9973666	-1.0000000
25	50	37.0350	28.9000	0.9950978	-0.0988962	0.0988962	0.9950978	-1.0000000
26	50	37.3020	28.9190	0.9965158	-0.0834041	0.0834041	0.9965158	-1.0000000
27	50	37.5370	28.9340	0.9957656	-0.0919290	0.0919290	0.9957656	-1.0000000
28	50	37.7570	28.9340	0.9957656	-0.0919290	0.0919290	0.9957656	-1.0000000
43	50	35.2870	59.0880	0.0203985	0.9997919	-0.9997919	0.0203985	-1.0000000
44	50	35.2870	59.0880	0.0203985	0.9997919	-0.9997919	0.0203985	-0.0100000
4	51	19.3750	59.1600	0.0675665	-0.9977148	0.9977148	0.0675665	-1.0000000
5	51	19.3750	59.1600	0.0675665	-0.9977148	0.9977148	0.0675665	-1.0000000
7	51	23.4380	59.8380	0.3907743	-0.9204865	0.9204865	0.3907743	-1.0000000
8	51	23.4380	59.8380	0.3907743	-0.9204865	0.9204865	0.3907743	-0.0100000
21	51	35.9270	29.5420	0.9985710	-0.0534405	0.0534405	0.9985710	-1.0000000
22	51	36.2490	29.5550	0.9984819	-0.0550818	0.0550818	0.9984819	-1.0000000
23	51	36.5400	29.5670	0.9973355	-0.0729517	0.0729517	0.9973355	-1.0000000
24	51	36.7470	29.5740	0.9988502	-0.0479403	0.0479403	0.9988502	-1.0000000
25	51	36.9660	29.5820	0.9980040	-0.0631503	0.0631503	0.9980040	-1.0000000
27	51	37.5020	29.5990	0.9999764	0.0068682	-0.0068682	0.9999764	-1.0000000
28	51	37.7220	29.5990	0.9999764	0.0068682	-0.0068682	0.9999764	-1.0000000
43	51	35.5750	59.3000	0.8816737	0.4718597	-0.4718597	0.8816737	-1.0000000
44	51	35.5750	59.3000	0.8816737	0.4718597	-0.4718597	0.8816737	-0.0100000
4	52	18.7750	59.1030	-0.0045454	-0.9999897	0.9999897	-0.0045454	-1.0000000
5	52	18.7750	59.1030	-0.0045454	-0.9999897	0.9999897	-0.0045454	-1.0000000
7	52	23.1250	60.2370	0.8905388	-0.4549073	0.4549073	0.8905388	-1.0000000
8	52	23.1250	60.2370	0.8905388	-0.4549073	0.4549073	0.8905388	-0.0100000
21	52	35.9040	30.2900	0.9997537	0.0221955	-0.0221955	0.9997537	-1.0000000
22	52	36.2260	30.2780	0.9997140	0.0239155	-0.0239155	0.9997140	-1.0000000
23	52	36.5080	30.2660	0.9996815	0.0252368	-0.0252368	0.9996815	-1.0000000
24	52	36.7150	30.2600	0.9999998	-0.0007032	0.0007032	0.9999998	-1.0000000
25	52	36.9470	30.2540	0.9996598	0.0260798	-0.0260798	0.9996598	-1.0000000
27	52	37.5160	30.2210	0.9986607	0.0517387	-0.0517387	0.9986607	-1.0000000
28	52	37.7360	30.2210	0.9986607	0.0517387	-0.0517387	0.9986607	-1.0000000
43	52	35.9250	59.5330	-0.0291295	0.9995757	-0.9995757	-0.0291295	-1.0000000
44	52	35.9250	59.5330	-0.0291295	0.9995757	-0.9995757	-0.0291295	-0.0100000
4	53	18.1880	58.9950	-0.2255335	-0.9742354	0.9742354	-0.2255335	-1.0000000
5	53	18.1880	58.9950	-0.2255335	-0.9742354	0.9742354	-0.2255335	-1.0000000
7	53	22.8370	60.8620	0.8944252	-0.4472176	0.4472176	0.8944252	-1.0000000
8	53	22.8370	60.8620	0.8944252	-0.4472176	0.4472176	0.8944252	-0.0100000
20	53	35.5620	31.0000	0.9977726	0.0667063	-0.0667063	0.9977726	-1.0000000
21	53	35.9150	30.9760	0.9997212	0.0236134	-0.0236134	0.9997212	-1.0000000
22	53	36.2370	30.9730	0.9999347	0.0114232	-0.0114232	0.9999347	-1.0000000
23	53	36.5270	30.9720	0.9995725	0.0292360	-0.0292360	0.9995725	-1.0000000
24	53	36.7390	30.9640	0.9969051	0.0786149	-0.0786149	0.9969051	-1.0000000
25	53	36.9770	30.9450	0.9972379	0.0742743	-0.0742743	0.9972379	-1.0000000
26	53	37.2790	30.9220	0.9977372	0.0672345	-0.0672345	0.9977372	-1.0000000
27	53	37.5460	30.9030	0.9978903	0.0649225	-0.0649225	0.9978903	-1.0000000

28	53	37.7660	30.9030	0.9978903	0.0649225	-0.0649225	0.9978903	-1.0000000
43	53	36.2870	59.2320	-0.8934140	0.4492344	-0.4492344	-0.8934140	-1.0000000
44	53	36.2870	59.2320	-0.8934140	0.4492344	-0.4492344	-0.8934140	-0.0100000
4	54	17.6250	58.9950	0.1975061	-0.9803017	0.9803017	0.1975061	-1.0000000
5	54	17.6250	58.9950	0.1975061	-0.9803017	0.9803017	0.1975061	-1.0000000
7	54	22.4750	61.3880	0.6324716	-0.7745836	0.7745836	0.6324716	-1.0000000
8	54	22.4750	61.3880	0.6324716	-0.7745836	0.7745836	0.6324716	-0.0100000
20	54	35.5520	31.5130	0.9975114	-0.0705053	0.0705053	0.9975114	-1.0000000
21	54	36.2370	31.5130	0.9975114	-0.0705053	0.0705053	0.9975114	-1.0000000
24	54	36.7770	31.6050	0.9997712	0.0213893	-0.0213893	0.9997712	-1.0000000
25	54	36.9980	31.6090	0.9998575	-0.0168831	0.0168831	0.9998575	-1.0000000
26	54	37.3010	31.6150	0.9999893	-0.0046180	0.0046180	0.9999893	-1.0000000
27	54	37.5840	31.6110	0.9992100	0.0397417	-0.0397417	0.9992100	-1.0000000
43	54	36.4250	58.6750	-0.9341418	0.3569020	-0.3569020	-0.9341418	-1.0000000
44	54	36.4250	58.6750	-0.9341418	0.3569020	-0.3569020	-0.9341418	-0.0100000
4	55	17.0750	59.0750	-0.0415583	-0.9991361	0.9991361	-0.0415583	-1.0000000
5	55	17.0750	59.0750	-0.0415583	-0.9991361	0.9991361	-0.0415583	-1.0000000
7	55	22.1380	61.9630	0.8607903	-0.5089598	0.5089598	0.8607903	-1.0000000
8	55	22.1380	61.9630	0.8607903	-0.5089598	0.5089598	0.8607903	-0.0100000
20	55	35.4850	31.9310	0.9681812	-0.2502502	0.2502502	0.9681812	-1.0000000
21	55	36.2370	31.9310	0.9681812	-0.2502502	0.2502502	0.9681812	-1.0000000
24	55	36.7140	32.2590	0.9593446	-0.2822373	0.2822373	0.9593446	-1.0000000
25	55	36.9090	32.3200	0.9685498	-0.2488196	0.2488196	0.9685498	-1.0000000
26	55	37.1960	32.4030	0.9680122	-0.2509030	0.2509030	0.9680122	-1.0000000
27	55	37.4790	32.4810	0.9709209	-0.2394007	0.2394007	0.9709209	-1.0000000
43	55	36.7000	58.2750	-0.2756825	0.9612488	-0.9612488	-0.2756825	-1.0000000
44	55	36.7000	58.2750	-0.2756825	0.9612488	-0.9612488	-0.2756825	-0.0100000
4	56	16.5870	58.7370	-0.7071068	-0.7071068	0.7071068	-0.7071068	-1.0000000
5	56	16.5870	58.7370	-0.7071068	-0.7071068	0.7071068	-0.7071068	-1.0000000
7	56	22.0500	62.6620	0.9816423	-0.1907311	0.1907311	0.9816423	-1.0000000
8	56	22.0500	62.6620	0.9816423	-0.1907311	0.1907311	0.9816423	-0.0100000
20	56	35.3380	32.3790	0.9203100	-0.3911899	0.3911899	0.9203100	-1.0000000
21	56	35.6330	32.5100	0.9101977	-0.4141740	0.4141740	0.9101977	-1.0000000
22	56	35.9310	32.6480	0.9006951	-0.4344518	0.4344518	0.9006951	-1.0000000
23	56	36.2470	32.8030	0.8816995	-0.4718114	0.4718114	0.8816995	-1.0000000
24	56	36.4610	32.9180	0.8514692	-0.5244046	0.5244046	0.8514692	-1.0000000
25	56	36.6480	33.0280	0.8733473	-0.4870980	0.4870980	0.8733473	-1.0000000
26	56	36.9210	33.1880	0.8755207	-0.4831806	0.4831806	0.8755207	-1.0000000
27	56	37.1750	33.3510	0.8494966	-0.5275940	0.5275940	0.8494966	-1.0000000
43	56	36.8750	58.4500	0.9819567	0.1891057	-0.1891057	0.9819567	-1.0000000
44	56	36.8750	58.4500	0.9819567	0.1891057	-0.1891057	0.9819567	-0.0100000
4	57	16.2350	58.2370	-0.5268322	-0.8499693	0.8499693	-0.5268322	-1.0000000
5	57	16.2350	58.2370	-0.5268322	-0.8499693	0.8499693	-0.5268322	-1.0000000
7	57	21.9620	63.3500	0.9440873	-0.3296956	0.3296956	0.9440873	-1.0000000
8	57	21.9620	63.3500	0.9440873	-0.3296956	0.3296956	0.9440873	-0.0100000
20	57	35.0890	32.8700	0.8733296	-0.4871298	0.4871298	0.8733296	-1.0000000
21	57	35.3580	33.0230	0.8524539	-0.5228024	0.5228024	0.8524539	-1.0000000
22	57	35.6130	33.1860	0.8306066	-0.5568597	0.5568597	0.8306066	-1.0000000
23	57	35.8610	33.3560	0.7877274	-0.6160241	0.6160241	0.7877274	-1.0000000
24	57	36.0460	33.4890	0.7843815	-0.6202787	0.6202787	0.7843815	-1.0000000
25	57	36.2370	33.6240	0.7910602	-0.6117383	0.6117383	0.7910602	-1.0000000
26	57	36.4760	33.7950	0.7568150	-0.6536292	0.6536292	0.7568150	-1.0000000
43	57	37.0000	59.0250	0.8006779	0.5990951	-0.5990951	0.8006779	-1.0000000
44	57	37.0000	59.0250	0.8006779	0.5990951	-0.5990951	0.8006779	-0.0100000
4	58	15.7350	58.0400	-0.0149208	-0.9998887	0.9998887	-0.0149208	-1.0000000
5	58	15.7350	58.0400	-0.0149208	-0.9998887	0.9998887	-0.0149208	-1.0000000
7	58	21.9380	64.0370	0.9910745	-0.1333093	0.1333093	0.9910745	-1.0000000
8	58	21.9380	64.0370	0.9910745	-0.1333093	0.1333093	0.9910745	-0.0100000
20	58	34.7000	33.4320	0.8567287	-0.5157673	0.5157673	0.8567287	-1.0000000
21	58	35.0120	33.6020	0.8567287	-0.5157673	0.5157673	0.8567287	-1.0000000
22	58	35.2340	33.7440	0.8318910	-0.5549390	0.5549390	0.8318910	-1.0000000
23	58	35.4490	33.8910	0.8186513	-0.5742909	0.5742909	0.8186513	-1.0000000
24	58	35.6230	34.0160	0.8090318	-0.5877649	0.5877649	0.8090318	-1.0000000
25	58	35.8050	34.1440	0.8011975	-0.5984000	0.5984000	0.8011975	-1.0000000
26	58	36.0190	34.2900	0.8027360	-0.5963345	0.5963345	0.8027360	-1.0000000
43	58	37.3250	58.9630	-0.5194607	0.8544943	-0.8544943	-0.5194607	-1.0000000
44	58	37.3250	58.9630	-0.5194607	0.8544943	-0.8544943	-0.5194607	-0.0100000
4	59	15.1000	57.9850	-0.0743757	-0.9972303	0.9972303	-0.0743757	-1.0000000
5	59	15.1000	57.9850	-0.0743757	-0.9972303	0.9972303	-0.0743757	-1.0000000
7	59	21.9130	64.6130	0.8903607	-0.4552558	0.4552558	0.8903607	-1.0000000
8	59	21.9130	64.6130	0.8903607	-0.4552558	0.4552558	0.8903607	-0.0100000

20	59	34.4180	34.1500	0.8854092	-0.4648124	0.4648124	0.8854092	-1.0000000
21	59	34.6680	34.1940	0.8854092	-0.4648124	0.4648124	0.8854092	-1.0000000
22	59	34.8880	34.3060	0.8782620	-0.4781798	0.4781798	0.8782620	-1.0000000
23	59	35.1630	34.4620	0.8703567	-0.4924219	0.4924219	0.8703567	-1.0000000
24	59	35.2960	34.5360	0.8771753	-0.4801702	0.4801702	0.8771753	-1.0000000
25	59	35.4790	34.6370	0.8807117	-0.4736528	0.4736528	0.8807117	-1.0000000
26	59	35.7190	34.7630	0.8987764	-0.4384074	0.4384074	0.8987764	-1.0000000
27	59	35.9950	34.9160	0.8831446	-0.4691010	0.4691010	0.8831446	-1.0000000
43	59	37.6880	58.8250	0.6672976	0.7447912	-0.7447912	0.6672976	-1.0000000
44	59	37.6880	58.8250	0.6672976	0.7447912	-0.7447912	0.6672976	-0.0100000
4	60	14.5000	57.8450	-0.1527375	-0.9882668	0.9882668	-0.1527375	-1.0000000
5	60	14.5000	57.8450	-0.1527375	-0.9882668	0.9882668	-0.1527375	-1.0000000
7	60	21.6380	65.1370	0.7839124	-0.6208714	0.6208714	0.7839124	-1.0000000
8	60	21.6380	65.1370	0.7839124	-0.6208714	0.6208714	0.7839124	-0.0100000
21	60	34.3250	34.8170	0.8981718	-0.4396447	0.4396447	0.8981718	-1.0000000
22	60	34.6250	34.8170	0.8981718	-0.4396447	0.4396447	0.8981718	-1.0000000
23	60	34.9010	34.9680	0.8881603	-0.4595336	0.4595336	0.8881603	-1.0000000
24	60	35.0370	35.0430	0.8816512	-0.4719016	0.4719016	0.8816512	-1.0000000
25	60	35.2260	35.1390	0.9049813	-0.4254515	0.4254515	0.9049813	-1.0000000
26	60	35.4850	35.2570	0.9074348	-0.4201930	0.4201930	0.9074348	-1.0000000
27	60	35.7610	35.3860	0.8922241	-0.4515930	0.4515930	0.8922241	-1.0000000
28	60	36.0310	35.5220	0.8705022	-0.4921645	0.4921645	0.8705022	-1.0000000
43	60	38.0750	59.3380	0.8695643	0.4938197	-0.4938197	0.8695643	-1.0000000
44	60	38.0750	59.3380	0.8695643	0.4938197	-0.4938197	0.8695643	-0.0100000
4	61	13.9000	57.6750	-0.1221857	-0.9925073	0.9925073	-0.1221857	-1.0000000
5	61	13.9000	57.6750	-0.1221857	-0.9925073	0.9925073	-0.1221857	-1.0000000
7	61	21.1380	65.3500	0.0489322	-0.9988021	0.9988021	0.0489322	-1.0000000
8	61	21.1380	65.3500	0.0489322	-0.9988021	0.9988021	0.0489322	-0.0100000
21	61	34.1650	35.3040	0.9083694	-0.4181688	0.4181688	0.9083694	-1.0000000
22	61	34.3950	35.3040	0.9083694	-0.4181688	0.4181688	0.9083694	-1.0000000
23	61	34.6210	35.4050	0.9023107	-0.4310863	0.4310863	0.9023107	-1.0000000
24	61	34.8100	35.5070	0.8565553	-0.5160553	0.5160553	0.8565553	-1.0000000
25	61	35.0050	35.6050	0.9167880	-0.3993741	0.3993741	0.9167880	-1.0000000
27	61	35.5390	35.8280	0.9083964	-0.4181101	0.4181101	0.9083964	-1.0000000
28	61	35.8020	35.9550	0.8976976	-0.4406120	0.4406120	0.8976976	-1.0000000
29	61	36.0810	36.0500	0.8976976	-0.4406120	0.4406120	0.8976976	-1.0000000
43	61	38.4870	59.8880	0.6370447	0.7708268	-0.7708268	0.6370447	-1.0000000
44	61	38.4870	59.8880	0.6370447	0.7708268	-0.7708268	0.6370447	-0.0100000
4	62	13.2500	57.5750	-0.0356462	-0.9993645	0.9993645	-0.0356462	-1.0000000
5	62	13.2500	57.5750	-0.0356462	-0.9993645	0.9993645	-0.0356462	-1.0000000
7	62	20.5380	65.4250	0.0995512	-0.9950324	0.9950324	0.0995512	-1.0000000
8	62	20.5380	65.4250	0.0995512	-0.9950324	0.9950324	0.0995512	-0.0100000
21	62	33.9500	35.8500	0.9598657	-0.2804601	0.2804601	0.9598657	-1.0000000
22	62	34.1840	35.8500	0.9598657	-0.2804601	0.2804601	0.9598657	-1.0000000
23	62	34.4110	35.9140	0.9555624	-0.2947889	0.2947889	0.9555624	-1.0000000
24	62	34.5830	35.9700	0.9160641	-0.4010320	0.4010320	0.9160641	-1.0000000
25	62	34.8030	36.0450	0.9329047	-0.3601233	0.3601233	0.9329047	-1.0000000
27	62	35.3740	36.2270	0.9485602	-0.3165967	0.3165967	0.9485602	-1.0000000
28	62	35.6510	36.3240	0.9442009	-0.3293700	0.3293700	0.9442009	-1.0000000
29	62	35.9310	36.3940	0.9442009	-0.3293700	0.3293700	0.9442009	-1.0000000
43	62	39.0250	60.0880	-0.0574046	0.9983510	-0.9983510	-0.0574046	-1.0000000
44	62	39.0250	60.0880	-0.0574046	0.9983510	-0.9983510	-0.0574046	-0.0100000
4	63	12.5250	57.5920	0.1711236	-0.9852496	0.9852496	0.1711236	-1.0000000
5	63	12.5250	57.5920	0.1711236	-0.9852496	0.9852496	0.1711236	-1.0000000
7	63	19.9380	65.5000	-0.1947787	-0.9808472	0.9808472	-0.1947787	-1.0000000
8	63	19.9380	65.5000	-0.1947787	-0.9808472	0.9808472	-0.1947787	-0.0100000
21	63	33.8800	36.5530	0.9998210	0.0189193	-0.0189193	0.9998210	-1.0000000
22	63	34.1050	36.5530	0.9998210	0.0189193	-0.0189193	0.9998210	-1.0000000
23	63	34.3260	36.5530	0.9999964	0.0026806	-0.0026806	0.9999964	-1.0000000
24	63	34.4890	36.5470	0.9965425	0.0830845	-0.0830845	0.9965425	-1.0000000
25	63	34.7040	36.5580	0.9988645	-0.0476422	0.0476422	0.9988645	-1.0000000
26	63	35.0060	36.5930	0.9943762	-0.1059052	0.1059052	0.9943762	-1.0000000
27	63	35.2910	36.6250	0.9950503	-0.0993730	0.0993730	0.9950503	-1.0000000
28	63	35.5870	36.6470	0.9975940	-0.0693269	0.0693269	0.9975940	-1.0000000
43	63	39.6250	60.2000	0.2470855	0.9689937	-0.9689937	0.2470855	-1.0000000
44	63	39.6250	60.2000	0.2470855	0.9689937	-0.9689937	0.2470855	-0.0100000
4	64	11.9050	57.8050	0.6183338	-0.7859156	0.7859156	0.6183338	-1.0000000
5	64	11.9050	57.8050	0.6183338	-0.7859156	0.7859156	0.6183338	-1.0000000
7	64	19.3000	65.2750	-0.2609794	-0.9653444	0.9653444	-0.2609794	-1.0000000
8	64	19.3000	65.2750	-0.2609794	-0.9653444	0.9653444	-0.2609794	-0.0100000
22	64	34.1140	37.2260	0.9865040	0.1637369	-0.1637369	0.9865040	-1.0000000

23	64	34.3940	37.2260	0.9865040	0.1637369	-0.1637369	0.9865040	-1.0000000
24	64	34.5700	37.1880	0.9655078	0.2603740	-0.2603740	0.9655078	-1.0000000
25	64	34.7620	37.1530	0.9909816	0.1339979	-0.1339979	0.9909816	-1.0000000
26	64	35.0140	37.1350	0.9971902	0.0749107	-0.0749107	0.9971902	-1.0000000
27	64	35.2980	37.1150	0.9952444	0.0974089	-0.0974089	0.9952444	-1.0000000
28	64	35.6000	37.0810	0.9932615	0.1158948	-0.1158948	0.9932615	-1.0000000
43	64	40.0130	60.0370	-0.8443334	0.5358183	-0.5358183	-0.8443334	-1.0000000
44	64	40.0130	60.0370	-0.8443334	0.5358183	-0.5358183	-0.8443334	-0.0100000
4	65	11.5550	58.2870	0.9234211	-0.3837884	0.3837884	0.9234211	-1.0000000
5	65	11.5550	58.2870	0.9234211	-0.3837884	0.3837884	0.9234211	-1.0000000
7	65	18.6880	65.2250	0.3076707	-0.9514929	0.9514929	0.3076707	-1.0000000
8	65	18.6880	65.2250	0.3076707	-0.9514929	0.9514929	0.3076707	-0.0100000
22	65	34.3080	37.8420	0.9888400	0.1489810	-0.1489810	0.9888400	-1.0000000
23	65	34.4880	37.8420	0.9888400	0.1489810	-0.1489810	0.9888400	-1.0000000
24	65	34.6640	37.8110	0.9922076	0.1245959	-0.1245959	0.9922076	-1.0000000
25	65	34.8450	37.7860	0.9948414	0.1014425	-0.1014425	0.9948414	-1.0000000
26	65	35.0840	37.7610	0.9941316	0.1081773	-0.1081773	0.9941316	-1.0000000
27	65	35.3040	37.6610	0.9941316	0.1081773	-0.1081773	0.9941316	-1.0000000
43	65	40.1120	59.3880	0.9684899	-0.2490529	0.2490529	0.9684899	-1.0000000
44	65	40.1120	59.3880	0.9684899	-0.2490529	0.2490529	0.9684899	-0.0100000
4	66	11.5120	58.9380	0.9999809	0.0061868	-0.0061868	0.9999809	-1.0000000
5	66	11.5120	58.9380	0.9999809	0.0061868	-0.0061868	0.9999809	-1.0000000
7	66	18.0620	65.6000	0.6124235	-0.7905298	0.7905298	0.6124235	-1.0000000
8	66	18.0620	65.6000	0.6124235	-0.7905298	0.7905298	0.6124235	-0.0100000
19	66	33.5460	38.5080	0.9931667	0.1167046	-0.1167046	0.9931667	-1.0000000
20	66	33.7960	38.5080	0.9931667	0.1167046	-0.1167046	0.9931667	-1.0000000
21	66	34.0540	38.4830	0.9937400	0.1117173	-0.1117173	0.9937400	-1.0000000
22	66	34.3310	38.4640	0.9956812	0.0928388	-0.0928388	0.9956812	-1.0000000
23	66	34.5510	38.4320	0.9826409	0.1855181	-0.1855181	0.9826409	-1.0000000
24	66	34.7210	38.4010	0.9961902	0.0872063	-0.0872063	0.9961902	-1.0000000
25	66	34.8910	38.3880	0.9976149	0.0690250	-0.0690250	0.9976149	-1.0000000
43	66	40.3750	58.9000	-0.4631031	0.8863044	-0.8863044	-0.4631031	-1.0000000
44	66	40.3750	58.9000	-0.4631031	0.8863044	-0.8863044	-0.4631031	-0.0100000
4	67	11.2550	59.3880	0.6386882	-0.7694656	0.7694656	0.6386882	-1.0000000
5	67	11.2550	59.3880	0.6386882	-0.7694656	0.7694656	0.6386882	-1.0000000
7	67	17.6750	66.1250	0.9341418	-0.3569020	0.3569020	0.9341418	-1.0000000
8	67	17.6750	66.1250	0.9341418	-0.3569020	0.3569020	0.9341418	-0.0100000
18	67	33.3940	39.1580	0.9992611	-0.0384342	0.0384342	0.9992611	-1.0000000
19	67	33.5960	39.1650	0.9992186	-0.0395252	0.0395252	0.9992186	-1.0000000
20	67	33.8200	39.1620	0.9998428	0.0177342	-0.0177342	0.9998428	-1.0000000
23	67	34.5950	38.9590	0.9913591	0.1311760	-0.1311760	0.9913591	-1.0000000
24	67	34.7650	38.9340	0.9972720	0.0738143	-0.0738143	0.9972720	-1.0000000
25	67	34.9290	38.9280	0.9993833	0.0351133	-0.0351133	0.9993833	-1.0000000
43	67	40.9250	58.7700	0.0362918	0.9993412	-0.9993412	0.0362918	-1.0000000
44	67	40.9250	58.7700	0.0362918	0.9993412	-0.9993412	0.0362918	-0.0100000
4	68	10.6550	59.6300	0.4893424	-0.8720917	0.8720917	0.4893424	-1.0000000
5	68	10.6550	59.6300	0.4893424	-0.8720917	0.8720917	0.4893424	-1.0000000
7	68	17.5250	66.7500	0.9944351	-0.1053515	0.1053515	0.9944351	-1.0000000
8	68	17.5250	66.7500	0.9944351	-0.1053515	0.1053515	0.9944351	-0.0100000
18	68	33.3260	39.9250	0.9940071	-0.1093160	0.1093160	0.9940071	-1.0000000
19	68	33.5270	39.9440	0.9935773	-0.1131556	0.1131556	0.9935773	-1.0000000
24	68	34.8080	39.5750	0.9994620	0.0327986	-0.0327986	0.9994620	-1.0000000
43	68	41.4870	58.8570	0.1893369	0.9819122	-0.9819122	0.1893369	-1.0000000
44	68	41.4870	58.8570	0.1893369	0.9819122	-0.9819122	0.1893369	-0.0100000
4	69	10.1580	59.9550	0.6740256	-0.7387080	0.7387080	0.6740256	-1.0000000
5	69	10.1580	59.9550	0.6740256	-0.7387080	0.7387080	0.6740256	-1.0000000
7	69	17.4620	67.5000	0.9847905	-0.1737459	0.1737459	0.9847905	-1.0000000
8	69	17.4620	67.5000	0.9847905	-0.1737459	0.1737459	0.9847905	-0.0100000
17	69	33.1970	40.6920	0.9840309	-0.1779976	0.1779976	0.9840309	-0.0100000
18	69	33.1970	40.6920	0.9840309	-0.1779976	0.1779976	0.9840309	-1.0000000
19	69	33.3990	40.7230	0.9837608	-0.1794844	0.1794844	0.9837608	-1.0000000
23	69	34.6400	40.2230	0.9997077	0.0241757	-0.0241757	0.9997077	-1.0000000
24	69	34.8290	40.2100	0.9999974	-0.0022844	0.0022844	0.9999974	-1.0000000
43	69	41.9870	59.1250	0.5723556	0.8200055	-0.8200055	0.5723556	-1.0000000
44	69	41.9870	59.1250	0.5723556	0.8200055	-0.8200055	0.5723556	-0.0100000
4	70	9.7900	60.1620	0.5019256	-0.8649108	0.8649108	0.5019256	-1.0000000
5	70	9.7900	60.1620	0.5019256	-0.8649108	0.8649108	0.5019256	-1.0000000
7	70	17.3620	68.2250	0.8756611	-0.4829261	0.4829261	0.8756611	-1.0000000
8	70	17.3620	68.2250	0.8756611	-0.4829261	0.4829261	0.8756611	-0.0100000
17	70	33.0230	41.4300	0.9785854	-0.2058412	0.2058412	0.9785854	-0.0100000
18	70	33.0230	41.4300	0.9785854	-0.2058412	0.2058412	0.9785854	-1.0000000

19	70	33.2310	41.4620	0.9806373	-0.1958329	0.1958329	0.9806373	-1.0000000
23	70	34.6130	40.7430	0.9997286	-0.0232990	0.0232990	0.9997286	-1.0000000
24	70	34.8080	40.7430	0.9997869	-0.0206469	0.0206469	0.9997869	-1.0000000
43	70	42.4750	59.5850	0.6230873	0.7821523	-0.7821523	0.6230873	-1.0000000
44	70	42.4750	59.5850	0.6230873	0.7821523	-0.7821523	0.6230873	-0.0100000
4	71	9.4325	60.0620	0.1084285	-0.9941043	0.9941043	0.1084285	-1.0000000
5	71	9.4325	60.0620	0.1084285	-0.9941043	0.9941043	0.1084285	-1.0000000
7	71	17.0250	68.8500	0.6407458	-0.7677531	0.7677531	0.6407458	-1.0000000
8	71	17.0250	68.8500	0.6407458	-0.7677531	0.7677531	0.6407458	-0.0100000
17	71	32.8710	42.1890	0.9917078	-0.1285131	0.1285131	0.9917078	-0.0100000
18	71	32.8710	42.1890	0.9917078	-0.1285131	0.1285131	0.9917078	-1.0000000
19	71	33.0910	42.2150	0.9929819	-0.1182664	0.1182664	0.9929819	-1.0000000
23	71	34.6290	41.2900	0.9954019	0.0957862	-0.0957862	0.9954019	-1.0000000
24	71	34.8240	41.2710	0.9938225	0.1109816	-0.1109816	0.9938225	-1.0000000
43	71	43.0620	60.0100	0.4570889	0.8894210	-0.8894210	0.4570889	-1.0000000
44	71	43.0620	60.0100	0.4570889	0.8894210	-0.8894210	0.4570889	-0.0100000
4	72	9.1625	60.2630	0.8397512	-0.5429713	0.5429713	0.8397512	-1.0000000
5	72	9.1625	60.2630	0.8397512	-0.5429713	0.5429713	0.8397512	-1.0000000
7	72	16.5130	69.2500	0.2858175	-0.9582841	0.9582841	0.2858175	-1.0000000
18	72	32.6880	42.9430	0.9531692	-0.3024376	0.3024376	0.9531692	-1.0000000
19	72	32.8960	43.0000	0.9531636	-0.3024552	0.3024552	0.9531636	-1.0000000
23	72	34.7090	41.7850	0.9730717	0.2305028	-0.2305028	0.9730717	-1.0000000
24	72	34.9040	41.7400	0.9762105	0.2168251	-0.2168251	0.9762105	-1.0000000
43	72	43.6250	60.3250	0.4178606	0.9085112	-0.9085112	0.4178606	-1.0000000
44	72	43.6250	60.3250	0.4178606	0.9085112	-0.9085112	0.4178606	-0.0100000
4	73	8.8700	60.7630	0.6413739	-0.7672285	0.7672285	0.6413739	-1.0000000
5	73	8.8700	60.7630	0.6413739	-0.7672285	0.7672285	0.6413739	-1.0000000
18	73	32.3440	43.7110	0.8784728	-0.4777924	0.4777924	0.8784728	-1.0000000
19	73	32.5130	43.8000	0.8829616	-0.4694452	0.4694452	0.8829616	-1.0000000
23	73	34.8130	42.2290	0.9726977	0.2320757	-0.2320757	0.9726977	-1.0000000
24	73	34.9950	42.1840	0.9786102	0.2057235	-0.2057235	0.9786102	-1.0000000
43	73	44.2370	60.5200	0.1495430	0.9887552	-0.9887552	0.1495430	-1.0000000
44	73	44.2370	60.5200	0.1495430	0.9887552	-0.9887552	0.1495430	-0.0100000
4	74	8.4350	61.1250	0.7369719	-0.6759234	0.6759234	0.7369719	-1.0000000
5	74	8.4350	61.1250	0.7369719	-0.6759234	0.6759234	0.7369719	-1.0000000
19	74	32.0570	44.4290	0.8754952	-0.4832268	0.4832268	0.8754952	-1.0000000
23	74	34.9240	42.6660	0.9686953	0.2482525	-0.2482525	0.9686953	-1.0000000
24	74	35.0820	42.6340	0.9829894	0.1836624	-0.1836624	0.9829894	-1.0000000
43	74	44.9630	60.6200	0.1629133	0.9866404	-0.9866404	0.1629133	-1.0000000
44	74	44.9630	60.6200	0.1629133	0.9866404	-0.9866404	0.1629133	-0.0100000
4	75	8.2275	61.6380	0.9511582	-0.3087040	0.3087040	0.9511582	-1.0000000
5	75	8.2275	61.6380	0.9511582	-0.3087040	0.3087040	0.9511582	-1.0000000
18	75	31.8430	44.9810	0.9966757	-0.0814712	0.0814712	0.9966757	-0.0100000
19	75	31.8430	44.9810	0.9966757	-0.0814712	0.0814712	0.9966757	-1.0000000
23	75	35.0350	43.0900	0.9773861	0.2114628	-0.2114628	0.9773861	-1.0000000
24	75	35.1680	43.0650	0.9813164	0.1924011	-0.1924011	0.9813164	-1.0000000
43	75	45.6120	60.7870	0.3792095	0.9253109	-0.9253109	0.3792095	-1.0000000
44	75	45.6120	60.7870	0.3792095	0.9253109	-0.9253109	0.3792095	-0.0100000
4	76	7.9500	61.9000	0.1601805	-0.9870877	0.9870877	0.1601805	-1.0000000
5	76	7.9500	61.9000	0.1601805	-0.9870877	0.9870877	0.1601805	-1.0000000
18	76	31.7810	45.5770	0.9644126	-0.2644018	0.2644018	0.9644126	-0.0100000
19	76	31.7810	45.5770	0.9644126	-0.2644018	0.2644018	0.9644126	-1.0000000
23	76	35.1350	43.5460	0.9788923	0.2043765	-0.2043765	0.9788923	-1.0000000
24	76	35.2740	43.5150	0.9694539	0.2452736	-0.2452736	0.9694539	-1.0000000
43	76	46.1750	61.0880	0.5301558	0.8479002	-0.8479002	0.5301558	-1.0000000
44	76	46.1750	61.0880	0.5301558	0.8479002	-0.8479002	0.5301558	-0.0100000
4	77	7.5625	62.1380	0.7725407	-0.6349652	0.6349652	0.7725407	-1.0000000
5	77	7.5625	62.1380	0.7725407	-0.6349652	0.6349652	0.7725407	-1.0000000
18	77	31.8620	46.1610	0.9407222	0.3391779	-0.3391779	0.9407222	-0.0100000
19	77	31.8620	46.1610	0.9407222	0.3391779	-0.3391779	0.9407222	-1.0000000
23	77	35.2170	44.0410	0.9972686	0.0738612	-0.0738612	0.9972686	-1.0000000
24	77	35.3680	44.0220	0.9868888	0.1614020	-0.1614020	0.9868888	-1.0000000
43	77	46.7630	61.3620	0.5048463	0.8632092	-0.8632092	0.5048463	-1.0000000
44	77	46.7630	61.3620	0.5048463	0.8632092	-0.8632092	0.5048463	-0.0100000
4	78	7.2700	62.6450	0.5539256	-0.8325662	0.8325662	0.5539256	-1.0000000
5	78	7.2700	62.6450	0.5539256	-0.8325662	0.8325662	0.5539256	-1.0000000
19	78	32.0820	46.7960	0.9803649	0.1971922	-0.1971922	0.9803649	-1.0000000
24	78	35.3280	44.5190	0.9819896	-0.1889350	0.1889350	0.9819896	-1.0000000
43	78	47.2750	61.7500	0.8320503	0.5547002	-0.5547002	0.8320503	-1.0000000
44	78	47.2750	61.7500	0.8320503	0.5547002	-0.5547002	0.8320503	-0.0100000
4	79	6.7950	62.6500	-0.3218375	-0.9467949	0.9467949	-0.3218375	-1.0000000

5	79	6.7950	62.6500	-0.3218375	-0.9467949	0.9467949	-0.3218375	-1.0000000
22	79	34.9190	44.8930	0.9080355	-0.4188932	0.4188932	0.9080355	-1.0000000
23	79	35.0390	44.9500	0.9217742	-0.3877271	0.3877271	0.9217742	-1.0000000
24	79	35.1770	44.9940	0.9677365	-0.2519643	0.2519643	0.9677365	-1.0000000
43	79	47.6500	62.3000	0.8591530	0.5117188	-0.5117188	0.8591530	-1.0000000
44	79	47.6500	62.3000	0.8591530	0.5117188	-0.5117188	0.8591530	-1.0000000
4	80	6.2000	62.5620	0.3957258	-0.9183687	0.9183687	0.3957258	-1.0000000
5	80	6.2000	62.5620	0.3957258	-0.9183687	0.9183687	0.3957258	-1.0000000
21	80	34.5790	45.2610	0.3922861	-0.9198433	0.9198433	0.3922861	-0.0100000
22	80	34.5790	45.2610	0.3922861	-0.9198433	0.9198433	0.3922861	-1.0000000
24	80	35.1270	45.5270	0.9896071	0.1437977	-0.1437977	0.9896071	-1.0000000
43	80	47.9870	62.8250	0.8646075	0.5024480	-0.5024480	0.8646075	-1.0000000
44	80	47.9870	62.8250	0.8646075	0.5024480	-0.5024480	0.8646075	-1.0000000
4	81	5.8175	62.9580	0.8627293	-0.5056661	0.5056661	0.8627293	-1.0000000
5	81	5.8175	62.9580	0.8627293	-0.5056661	0.5056661	0.8627293	-1.0000000
21	81	34.0510	45.3300	0.0077300	-0.9999701	0.9999701	0.0077300	-1.0000000
22	81	34.0510	45.3300	0.0077300	-0.9999701	0.9999701	0.0077300	-1.0000000
24	81	35.2770	46.0860	0.8954697	0.4451226	-0.4451226	0.8954697	-1.0000000
43	81	48.1570	63.6050	1.0000000	0.0000000	-0.0000000	1.0000000	-1.0000000
44	81	48.1570	63.6050	1.0000000	0.0000000	-0.0000000	1.0000000	-1.0000000
4	82	5.3925	63.2500	0.1675430	-0.9858648	0.9858648	0.1675430	-1.0000000
5	82	5.3925	63.2500	0.1675430	-0.9858648	0.9858648	0.1675430	-1.0000000
43	82	47.5570	65.0350	-0.8443334	0.5358183	-0.5358183	-0.8443334	-1.0000000
44	82	47.5570	65.0350	-0.8443334	0.5358183	-0.5358183	-0.8443334	-1.0000000
4	83	4.7575	63.1750	-0.2896261	-0.9571398	0.9571398	-0.2896261	-1.0000000
5	83	4.7575	63.1750	-0.2896261	-0.9571398	0.9571398	-0.2896261	-1.0000000
43	83	46.9900	66.4000	1.0000000	0.0000000	-0.0000000	1.0000000	-1.0000000
44	83	46.9900	66.4000	1.0000000	0.0000000	-0.0000000	1.0000000	-1.0000000
4	84	4.1875	63.2000	0.2911504	-0.9566773	0.9566773	0.2911504	-1.0000000
5	84	4.1875	63.2000	0.2911504	-0.9566773	0.9566773	0.2911504	-1.0000000
43	84	46.4300	67.2800	-0.7189829	0.6950278	-0.6950278	-0.7189829	-1.0000000
44	84	46.4300	67.2800	-0.7189829	0.6950278	-0.6950278	-0.7189829	-1.0000000
4	85	3.7200	63.5500	0.7358159	-0.6771816	0.6771816	0.7358159	-1.0000000
5	85	3.7200	63.5500	0.7358159	-0.6771816	0.6771816	0.7358159	-1.0000000
43	85	45.7200	68.9000	0.9884899	-0.1512869	0.1512869	0.9884899	-1.0000000
44	85	45.7200	68.9000	0.9884899	-0.1512869	0.1512869	0.9884899	-1.0000000
43	86	45.5500	70.8500	1.0000000	0.0000000	-0.0000000	1.0000000	-1.0000000
44	86	45.4500	70.8500	1.0000000	0.0000000	-0.0000000	1.0000000	-1.0000000
43	87	45.3000	72.9700	0.9684899	-0.2490529	0.2490529	0.9684899	-1.0000000
44	87	45.4500	72.9700	1.0000000	0.0000000	-0.0000000	1.0000000	-1.0000000
43	88	45.6700	75.0500	0.7587842	0.6513421	-0.6513421	0.7587842	-1.0000000
44	88	45.6700	75.0500	0.7587842	0.6513421	-0.6513421	0.7587842	-1.0000000
43	89	46.4100	77.1600	1.0000000	0.0000000	-0.0000000	1.0000000	-1.0000000
44	89	46.4100	77.1600	1.0000000	0.0000000	-0.0000000	1.0000000	-1.0000000
43	90	47.2800	79.0800	0.6587842	0.7523320	-0.7523320	0.6587842	-1.0000000
44	90	47.2800	79.0800	0.6587842	0.7523320	-0.7523320	0.6587842	-1.0000000
43	91	47.5800	80.5800	-0.8443334	0.5358183	-0.5358183	-0.8443334	-1.0000000
44	91	47.5800	80.5800	-0.8443334	0.5358183	-0.5358183	-0.8443334	-1.0000000
43	92	47.5700	82.4800	0.9219567	0.3872930	-0.3872930	0.9219567	-1.0000000
44	92	47.5500	82.4800	0.9219567	0.3872930	-0.3872930	0.9219567	-1.0000000
43	93	46.9700	83.5300	0.0669665	0.9977552	-0.9977552	0.0669665	-1.0000000
44	93	46.9700	83.6300	0.0669665	0.9977552	-0.9977552	0.0669665	-1.0000000
43	94	45.5100	83.9000	-0.6443334	0.7647447	-0.7647447	-0.6443334	-1.0000000
44	94	45.5100	83.9000	-0.6443334	0.7647447	-0.7647447	-0.6443334	-1.0000000
43	95	44.4500	84.6000	-0.4443334	0.8958615	-0.8958615	-0.4443334	-1.0000000
44	95	44.4500	84.6000	-0.4443334	0.8958615	-0.8958615	-0.4443334	-1.0000000
43	96	43.1300	84.8000	0.0669665	0.9977552	-0.9977552	0.0669665	-1.0000000
44	96	43.1300	84.8000	0.0669665	0.9977552	-0.9977552	0.0669665	-1.0000000
43	97	42.1100	84.9700	-0.6443334	0.7647447	-0.7647447	-0.6443334	-1.0000000
44	97	42.1100	84.9700	-0.6443334	0.7647447	-0.7647447	-0.6443334	-1.0000000

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 ---------------------------------------------------------------------------
C71B FOOD CHAIN MODEL OUTPUT CONTROL
C
     ISFDCH: 1 TO WRITE OUTPUT FOR HOUSATONIC RIVER FOOD CHAIN MODEL
     NFDCHZ: NUMBER OF SPATIAL ZONES
     HBFDCH: AVERAGING DEPTH FOR TOP PORTION OF BED (METERS)
     TFCAVG: TIME AVERAGING INTERVAL FOR FOOD CHAIN OUTPUT (SECONDS)
C
C71B ISFDCH   NFDCHZ   HBFDCH    TFCAVG
     0         5       0.1524    86400.
---------------------------------------------------------------------------C72
CONTROLS FOR HORIZONTAL SURFACE ELEVATION OR PRESSURE CONTOURING          |
C72 CONTROLS FOR HORIZONTAL SURFACE ELEVATION OR PRESSURE CONTOURING          |
 C                                                                            |
       ISPPH:  1 TO WRITE FILE FOR SURF ELEVATION CONTOURING                  |
|
               2 WRITE ONLY DURING LAST REFERENCE TIME PERIOD                 |
|
       NPPPH:    NUMBER OF WRITES PER REFERENCE TIME PERIOD                   |
       ISRPPH: 1 TO WRITE FILE FOR RESIDUAL SURFACE ELEVATION  CONTOURNG IN   |
                 HORIZONTAL PLANE                                             |
       IPPHXY: 0 DOES NOT WRITE I,J,X,Y IN surfplt.out and rsurfplt.out FILES |
               1 WRITES I,J ONLY IN surfplt.out and rsurfplt.out FILES        |
               2 WRITES I,J,X,Y  IN surfplt.out and rsurfplt.out FILES        |
               3 WRITES EFDC EXPLORER BINARY FORMAT FILES                     |
 C                                                                             |
 C72 ISPPH   NPPPH   ISRPPH     IPPHXY                                        |
     0       4       0          0
 ---------------------------------------------------------------------------
 C73 CONTROLS FOR HORIZONTAL PLANE VELOCITY VECTOR PLOTTING                   |
 C                                                                            |
       ISVPH:  1 TO WRITE FILE FOR VELOCITY PLOTTING IN HORIZONTAL PLANE      |
               2 WRITE ONLY DURING LAST REFERENCE TIME PERIOD                 |
       NPVPH:    NUMBER OF WRITES PER REFERENCE TIME PERIOD                   |
       ISRVPH: 1 TO WRITE FILE FOR RESIDUAL VELOCITY PLOTTIN IN               |
                 HORIZONTAL PLANE                                             |
       IVPHXY: 0 DOES NOT WRITE I,J,X,Y IN velplth.out and rvelplth.out FILES |
               1 WRITES I,J ONLY IN velplth.out and rvelplth.out FILES        |
               2 WRITES I,J,X,Y  IN velplth.out and rvelplth.out FILES        |
               3 WRITES EFDC EXPLORER BINARY FORMAT FILES                     |
 C                                                                            |
 C73 ISVPH   NPVPH   ISRVPH  IVPHXY                                           |
     0       24      0       3
 ---------------------------------------------------------------------------
 C74 CONTROLS FOR VERTICAL PLANE SCALAR FIELD CONTOURING                      |
 C                                                                            |
       ISECSPV:  N AN INTEGER NUMBER OF VERTICAL SECTIONS (N.LE.9) TO WRITE   |
                   N FILES FOR SCALAR  FIELD CONTOURING                       |
       NPSPV:      NUMBER OF WRITES PER REFERENCE TIME PERIOD                 |
       ISSPV:    1 TO ACTIVATE INSTANTANEOUS SCALAR FIELDS                    |
                 2 TO WRITE ONLY DURING LAST REFERENCE TIME PERIOD
       ISRSPV:   1 TO ACTIVATE FOR RESIDUAL SCALAR FIELDS                     |
       ISHPLTV:  1 FOR VERTICAL PLANE PLOTTING FOR MSL DATUMS, ZERO OTHERWISE |
       DATA LINE REPEATS 7 TIMES FOR SAL,TEM,DYE,SFL,TOX,SED,SND              |
       ISECSPV IS DETERMINED FOR ALL 7 VARIABLES BY VALUE ON FIRST DATA LINE  |
 C                                                                            |
 C74 ISECSPV   NPSPV  ISSPV  ISRSPV  ISHPLTV                                  |
     1          6      0      0       1          !SAL
     0          6      0      0       1          !TEM
     0          6      0      0       1          !DYE
     0          6      0      0       1          !SFL
     0          6      0      0       1          !TOX
     0          6      0      0       1          !SED
```

```
   0          6      0      0      1          !SND
-------------------------------------------------------------------------------
C75 MORE CONTROLS FOR VERTICAL PLANE SCALAR FIELD CONTOURING                   |
C                                                                              |
      ISECSPV:  SECTION NUMBER                                                 |
      NIJSPV:   NUMBER OF CELLS OR I,J PAIRS IN SECTION                        |
      SEC ID:   CHARACTER FORMAT SECTION TITLE                                 |
C
C75 ISECSPV NIJSPV  SEC ID
   1        10      'test n-s printout'
-------------------------------------------------------------------------------
C76 I,J LOCATIONS FOR VERTICAL PLANE SCALAR FIELD CONTOURING                   |
C                                                                              |
      ISECSPV: SECTION NUMBER                                                  |
      ISPV:    I CELL                                                          |
      JSPV:    J CELL                                                          |
C
C76 ISECSPV ISPV    JSPV
   1        32      5
   1        32      6
   1        32      7
   1        32      8
   1        32      9
   1        32      10
   1        32      11
   1        32      12
   1        32      13
   1        32      14
-------------------------------------------------------------------------------
C77 CONTROLS FOR VERTICAL PLANE VELOCITY VECTOR PLOTTING                       |
C                                                                              |
      ISECVPV:  N AN INTEGER NUMBER (N.LE.9) OF VERTICAL SECTIONS              |
                  TO WRITE N FILES FOR VELOCITY PLOTTING                       |
      NPVPV:      NUMBER OF WRITES PER REFERENCE TIME PERIOD                   |
      ISVPV:    1 TO ACTIVATE INSTANTANEOUS VELOCITY                           |
                2 TO WRITE ONLY DURING LAST REFERENCE TIME PERIOD              |
      ISRSPV:   1 TO ACTIVATE FOR RESIDUAL VELOCITY                            |
C                                                                              |
C77 ISECVPV   NPVPV  ISVPV  ISRSPV                                             |
   0          6      0      0
-------------------------------------------------------------------------------
C78 MORE CONTROLS FOR VERTICAL PLANE VELOCITY VECTOR PLOTTING                  |
C                                                                              |
      ISCEVPV:  SECTION NUMBER                                                 |
      NIJVPV:   NUMBER IS CELLS OR I,J PAIRS IN SECTION                        |
      ANGVPV:   CCW POSITIVE ANGLE FROM EAST TO SECTION NORMAL                 |
      SEC ID:   CHARACTER FORMAT SECTION TITLE                                 |
C                                                                              |
C78 ISECVPV   NIJVPV  ANGVPV  SEC ID                                           |
-------------------------------------------------------------------------------
C79 CONTROLS FOR VERTICAL PLANE VELOCITY PLOTTING                              |
C                                                                              |
      ISECVPV:  SECTION NUMBER (REFERENCE USE HERE)                            |
      IVPV:     I CELL INDEX                                                   |
      JVPV:     J CELL INDEX                                                   |
C                                                                              |
C79 ISECVPV IVPV    JVPV                                                       |
-------------------------------------------------------------------------------
C80 CONTROLS FOR 3D FIELD OUTPUT                                               |
C                                                                              |
      IS3DO:  1 TO WRITE TO 3D ASCI INTEGER FORMAT FILES, JS3Dvar.LE.2      SEE|
              1 TO WRITE TO 3D ASCI FLOAT POINT FORMAT FILES, JS3Dvar.EQ.3 C57|
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                2 TO WRITE TO 3D CHARACTER ARRAY FORMAT FILES (NOT ACTIVE)
                3 TO WRITE TO 3D HDF IMAGE FORMAT FILES (NOT ACTIVE)
                4 TO WRITE TO 3D HDF FLOATING POINT FORMAT FILES (NOT ACTIVE)
        ISR3DO:   SAME AS IS3DO EXCEPT FOR RESIDUAL VARIABLES
        NP3DO:    NUMBER OF WRITES PER LAST REF TIME PERIOD FOR INST VARIABLES
        KPC:      NUMBER OF UNSTRETCHED PHYSICAL VERTICAL LAYERS
        NWGG:     IF NWGG IS GREATER THAN ZERO, NWGG DEFINES THE NUMBER OF !2877
                  WATER CELLS IN CARTESIAN 3D GRAPHICS GRID OVERLAY OF THE
                  CURVILINEAR GRID. FOR NWGG>0 AND EFDC RUNS ON A CURVILINEAR
                  GRID, I3DMI,I3DMA,J3DMI,J3DMA REFER TO CELL INDICES ON THE
                  ON THE CARTESIAN GRAPHICS GRID OVERLAY DEFINED BY FILE
                  gcell.inp.  THE FILE gcell.inp IS NOT USED BY EFDC, BUT BY
                  THE COMPANION GRID GENERATION CODE GEFDC.F.  INFORMATION
                  DEFINING THE OVERLAY IS READ BY EFDC.F FROM THE FILE
                  gcellmp.inp. IF NWGG EQUALS 0, I3DMI,I3DMA,J3DMI,J3DMA REFER
                  TO INDICES ON THE EFDC GRID DEFINED BY cell.inp.
                  ACTIVATION OF THE REWRITE OPTION I3DRW=1 WRITES TO THE FULL
                  GRID DEFINED BY cell.inp AS IF cell.inp DEFINES A CARTESIAN
                  GRID.  IF NWGG EQ 0 AND THE EFDC COMP GRID IS CO, THE REWRITE
                  OPTION IS NOT RECOMMENDED AND A POST PROCESSOR SHOULD BE USED
                  TO TRANSFER THE SHORT FORM, I3DRW=0, OUTPUT TO AN APPROPRIATE
                  FORMAT FOR VISUALIZATION. CONTACT DEVELOPER FOR MORE DETAILS
        I3DMI:    MINIMUM OR BEGINNING I INDEX FOR 3D ARRAY OUTPUT
        I3DMA:    MAXIMUM OR ENDING I INDEX FOR 3D ARRAY OUTPUT
        J3DMI:    MINIMUM OR BEGINNING J INDEX FOR 3D ARRAY OUTPUT
        J3DMA:    MAXIMUM OR ENDING J INDEX FOR 3D ARRAY OUTPUT
        I3DRW:  0 FILES WRITTEN FOR ACTIVE CO WATER CELLS ONLY
                1 REWRITE FILES TO CORRECT ORIENTATION DEFINED BY gcell.inp
                  AND gcellmp.inp FOR CO WITH NWGG.GT.0 OR BY cell.inp IF THE
                  COMPUTATIONAL GRID IS CARTESIAN AND NWGG.EQ.0
        SELVMAX:  MAXIMUM SURFACE ELEVATION FOR UNSTRETCHING (ABOVE MAX SELV )
        BELVMIN:  MINIMUM BOTTOM ELEVATION FOR UNSTRETCHING (BELOW MIN BELV)
C
C80 IS3DO ISR3DO NP3DO KPC NWGG I3DMI I3DMA J3DMI J3DMA I3DRW SELVMAX BELVMIN
    0     0      0     1   0    1     42    1     118   0     15.0     -315.
-----------------------------------------------------------------------------
C81 OUTPUT ACTIVATION AND SCALES FOR 3D FIELD OUTPUT
C
      VARIABLE:       DUMMY VARIBLE ID (DO NOT CHANGE ORDER)
      IS3(VARID):   1 TO ACTIVATE THIS VARIBLES
      JS3(VARID):   0 FOR NO SCALING OF THIS VARIABLE
                    1 FOR AUTO SCALING OF THIS VARIABLE OVER RANGE 0<VAL<255
                      AUTO SCALES FOR EACH FRAME OUTPUT IN FILES out3d.dia AND
                      rout3d.dia  OUTPUT IN I4 FORMAT
                    2 FOR SCALING SPECIFIED IN NEXT TWO COLUMNS WITH OUTPUT
                      DEFINED OVER RANGE  0<VAL<255 AND WRITTEN IN I4 FORMAT
                    3 FOR MULTIPLIER SCALING BY MAX SCALE VALUE WITH OUTPUT
                      WRITTEN IN F7.1 FORMAT (IS3DO AND ISR3DO MUST BE 1)
C
C81 VARIABLE     IS3D(VARID)  JS3D(VARID)   MAX SCALE VALUE  MIN SCALE VALUE
    'U VEL'      1            3              100.0            -1.0
    'V VEL'      1            3              100.0            -1.0
    'W VEL'      0            0             1000.0         -1.0E-3
    'SALINITY'   1            3                1.0             0.0
    'TEMP'       1            3                1.0            10.0
    'DYE'        0            0             1000.0             0.0
    'COH SED'    1            3             1000.0             0.0
    'NCH SED'    1            3             1000.0             0.0
    'TOX CON'    1            3             1000.0             0.0
-----------------------------------------------------------------------------
C82 INPLACE HARMONIC ANALYSIS PARAMETERS
C
      ISLSHA:  1 FOR IN PLACE LEAST SQUARES HARMONIC ANALYSIS
```

```
      MLLSHA:  NUMBER OF LOCATIONS FOR LSHA
      NTCLSHA: LENGTH OF LSHA IN INTEGER NUMBER OF REFERENCE TIME PERIODS
      ISLSTR:  1 FOR TREND REMOVAL
      ISHTA :  1 FOR SINGLE TREF PERIOD SURFACE ELEV ANALYSIS
C                    90
C82 ISLSHA  MLLSHA   NTCLSHA  ISLSTR  ISHTA
    1       7        29       0       0
-------------------------------------------------------------------------------
C83 HARMONIC ANALYSIS LOCATIONS AND SWITCHES
C
      ILLSHA:   I CELL INDEX
      JLLSHA:   J CELL INDEX
      LSHAP:  1 FOR ANALYSIS OF SURFACE ELEVATION
      LSHAB:  1 FOR ANALYSIS OF SALINITY
      LSHAUE: 1 FOR ANALYSIS OF EXTERNAL MODE HORIZONTAL VELOCITY
      LSHAU:  1 FOR ANALYSIS OF HORIZONTAL VELOCITY IN EVERY LAYER
      CLSL:     LOCATION AS A CHARACTER VARIALBLE
C
C83 ILLSHA   JLLSHA   LSHAP  LSHAB  LSHAUE LSHAU  CLSL
      4      84       1      1      0      0     'Lock and Dam 1'
      7      67       1      1      0      0     'Black at Currie'
      43     97       1      1      0      0     'NECF at Burgaw'
      4      11       1      1      0      0     '02107576, CF @ Nav'          |1
      43     15       1      1      0      0     '02108692, NECF @ Wilm'       |2
      25     47       1      1      0      0     '02108820  M12'               |3
      33     5        1      1      0      0     '02108894  Cape Fear at mouth'
-------------------------------------------------------------------------------
C84 CONTROLS FOR WRITING TO TIME SERIES FILES
C
      ISTMSR:  1 OR 2 TO WRITE TIME SERIES OF SURF ELEV, VELOCITY, NET
               INTERNAL AND EXTERNAL MODE VOLUME SOURCE-SINKS, AND
               CONCENTRATION VARIABLES,  2 APPENDS EXISTING TIME SERIES FILES
      MLTMSR:  NUMBER HORIZONTAL LOCATIONS TO WRITE TIME SERIES OF SURF ELEV,
               VELOCITY, AND CONCENTRATION VARIABLES,  MAXIMUM LOCATIONS = 9
      NBTMSR:  TIME STEP TO BEGIN WRITING TO TIME SERIES FILES
      NSTMSR:  TIME STEP TO STOP WRITING TO TIME SERIES FILES
      NWTSER:  WRITE INTERVAL FOR WRITING TO TIME SERIES FILES
     NTSSTSP:  NUMBER OF TIME SERIES START-STOP SCENARIOS,  1 OR GREATER
      TCTMSR:  UNIT CONVERSION FOR TIME SERIES TIME.  FOR SECONDS, MINUTES,
               HOURS,DAYS USE 1.0, 60.0, 3600.0, 86400.0 RESPECTIVELY
        IDUM:  2 DUMMY INTEGER VARIABLES REQUIRED, BOTH = 0
C          13                      1728
C84 ISTMSR  MLTMSR  NBTMSR  NSTMSR  NWTMSR  NTSSTSP  TCTMSR   IDUM  IDUM
    1       21      1       2000000 2160    1        86400.    0     0
-------------------------------------------------------------------------------
C85 CONTROLS FOR WRITING TO TIME SERIES FILES
C
     ITSSS:    START-STOP SCENARIO NUMBER 1.GE.ISSS.LE.NTSSTSP
   MTSSTSP:    NUMBER OF STOP-START PAIRS FOR SCENARIO ISSS
C
C85 ITSSS  MTSSTSP
      1      1    !FULL SAVE
-------------------------------------------------------------------------------
C86 CONTROLS FOR WRITING TO TIME SERIES FILES
C
     ITSSS:    START-STOP SCENARIO NUMBER 1.GE.ISSS.LE.NTSSTSP
     MTSSS:    NUMBER OF STOP-START PAIRS FOR SCENARIO ISSS
    TSSTRT:    STARTING TIME FOR SCENARIO ITSSS, SAVE INTERVAL MTSSS
    TSSTOP:    STOPING TIME FOR SCENARIO ITSSS, SAVE INTERVAL MTSSS
C                  -1000.
C86 ISSS   MTSSS   TSSTRT    TSSTOP     USER COMMENT
      1      1     700       10000.     ! FULL SAVE
-------------------------------------------------------------------------------
```

```
C87 CONTROLS FOR WRITING TO TIME SERIES FILES                                  |
C                                                                              |
      ILTS:     I CELL INDEX                                                   |
      JLTS:     J CELL INDEX                                                   |
    NTSSSS:     WRITE SCENARIO FOR THIS LOCATION                               |
      MTSP:  1 FOR TIME SERIES OF SURFACE ELEVATION                            |
      MTSC:  1 FOR TIME SERIES OF TRANSPORTED CONCENTRATION VARIABLES          |
      MTSA:  1 FOR TIME SERIES OF EDDY VISCOSITY AND DIFFUSIVITY               |
      MTSUE: 1 FOR TIME SERIES OF EXTERNAL MODE HORIZONTAL VELOCITY            |
      MTSUT: 1 FOR TIME SERIES OF EXTERNAL MODE HORIZONTAL TRANSPORT           |
      MTSU:  1 FOR TIME SERIES OF HORIZONTAL VELOCITY IN EVERY LAYER           |
      MTSQE: 1 FOR TIME SERIES OF NET EXTERNAL MODE VOLUME SOURCE/SINK         |
      MTSQ:  1 FOR TIME SERIES OF NET EXTERNAL MODE VOLUME SOURCE/SINK         |
      CLTS:     LOCATION AS A CHARACTER VARIALBLE                              |
C                                                                              |
C87 ILTS JLTS NTSSSS MTSP MTSC MTSA MTSUE MTSUT MTSU MTSQE MTSQ  CLTS          |
      4  84    1     1    1    0     0     0    0    0     0    'USGS, L&D1'  1
      4  80    1     0    1    0     0     0    0    0     0    'NC11'        2
      7  67    1     1    1    0     0     0    0    0     0    '02107544'    3
      7  66    1     0    1    0     0     0    0    0     0    ' B210'       4
      4  60    1     0    1    0     0     0    0    0     0    'AC, CF'      5
      4  25    1     0    1    0     0     0    0    0     0    'IC, CF'      6
     43  97    1     1    1    0     0     0    0    0     0    'NE Burhaw'   7
     43  66    1     0    1    0     0     0    0    0     0    'NCF117'      8
     44  27    1     0    1    0     0     0    0    0     0    'NCF6'        9
      4  11    1     1    1    0     0     0    0    0     0    '02107576 '  10
      4  10    1     0    1    0     0     0    0    0     0    'Nav, CF@Nav'11
     22  81    1     0    1    0     0     0    0    0     0    'HB, CF'     12
     43  15    1     1    1    0     0     0    0    0     0    'NECF Wilm'  13
     18  72    1     0    1    0     0     0    0    0     0    'Brnsk R.'   14
     24  68    1     0    1    0     0     0    0    0     0    'CF, M61'    15
     24  58    1     0    1    0     0     0    0    0     0    'CF, M54'    16
     25  49    1     0    1    0     0     0    0    0     0    'CF, M42'    17
     25  47    1     1    1    0     0     0    0    0     0    'CF, M12'    18
     26  40    1     0    1    0     0     0    0    0     0    'CF, M35'    19
     23  21    1     0    1    0     0     0    0    0     0    'CF, M23'    20
     24  11    1     1    1    0     0     0    0    0     0    'CF, M18'    21
-------------------------------------------------------------------------------
C88 CONTROLS FOR EXTRACTING INSTANTANEOUS VERTICAL SCALAR FIELD PROFILES       |
C                                                                              |
      ISVSFP: 1 FOR EXTRACTING INSTANTANEOUS VERTICAL FIELD PROFILES           |
      MDVSFP:   MAXIMUM NUMBER OF DEPTHS FOR SAMPLING VALUES                   |
      MLVSFP:   NUMBER OF HORIZONTAL SPACE-TIME LOCATION PAIRS TO BE SAMPLED   |
      TMVSFP:   MULTIPLIER TO CONVERT SAMPLING TIMES TO SECONDS                |
      TAVSFP:   ADDITIVE ADJUSTMENT TO SAMPLING TIME BEFORE CONVERSION TO SEC  |
C          200max   1600max                                                    |
C88 ISVSFP  MDVSFP  MLVSFP  TMVSFP  TAVSFP                                     |
      0       0     0       86400.  0.0                                        |
-------------------------------------------------------------------------------
C89 SAMPLING DEPTHS FOR EXTRACTING INST VERTICAL SCALAR FIELD PROFILES         |
C                                                                              |
      MMDVSFP:  Mth SAMPLING DEPTH                                             |
      DMSFP:    SAMPLING DEPTH BELOW SURFACE, IN METERS                        |
C                                                                              |
C89 MMDVSFP  DMVSFP                                                            |
-------------------------------------------------------------------------------
C90 HORIZONTAL SPACE-TIME LOCATIONS FOR SAMPLING                               |
C                                                                              |
      MMLVSFP:  Mth SPACE TIME SAMPLING LOCATION                               I
      TIMVSFP:  SAMPLING TIME                                                  |
      IVSFP:    I HORIZONTAL LOCATON INDEX                                     |
      JVSFP:    J HORIZONTAL LOCATON INDEX                                     |
C                                                                              |
```

```
# <-- set first character to "#" to use extended annotation in this file
C-------------------------------------------------------------------------------
C01  MAIN TITLE CARDS
C
C  TITLE(M), M=1,3
C
C01 THREE TITLE CARDS FOLLOW:
': Cape Fear River Water Quality Model'
': Variable stream flow and variable NPDES discharges'
': using tetratech input files'
C-------------------------------------------------------------------------------
C02 I/O CONTROL VARIABLE CARD
C
C02 ONE TITLE CARD FOLLOWS:
$$ C02 I/O control variables $$
C02
C  IWQLVL = kinetic complexity level
C           1  WASP5 LEVEL KINETICS (SINGLE ORGANIC CARBON, PHOSPHOROUS, AND
C              NITROGEN CLASSES + REACTIVE DOC/CBOD VARIABLE)
C           2  INTERMEDIATE LEVEL KINETICS (TOTAL REFRACTORY AND TOTAL LABILE
C              ORGANIC CARBON, PHOSPHOROUS, AND NITROGEN CLASSES
C              + REACTIVE DOC/CBOD)
C           3  CE-QUAL-ICM (ORIGINAL CHES BAY VARIABLES)
C           4  EXTENDED CE-QUAL-ICM (4 ORGANIC CARBON, PHOSPHOROUS, AND
C              NITROGEN CLASSES + REACTIVE DOC/CBOD VARIABLE)
C    NWQV = number of water quality water column variables
C    NWQZ = max. number of spatial zones having varying water quality parameters
C   NWQPS = max. number of water quality point source locations
C   NWQTD = number of data points in the temperature lookup table
C   NWQTS = max. number of water quality time-series output locations
C  NTSWQV = max. number of water quality time-series output variables
C    NSMG = number of sediment model groups (= 3)
C    NSMZ = max. number of sediment model spatial variation zones
C  NTSSMV = max. number of sediment model time-series output variables
C   NSMTS = not used
C NWQKDPT = number of kinetic updates per transport update
C
C02 IWQLVL NWQV NWQZ NWQPS NWQTD NWQTS NTSWQV NSMG NSMZ NTSSMV NSMTS NWQKDPT
      3    21   1    38    551   22     21     1    1    3      30    1
C-------------------------------------------------------------------------------
C02A TRANSPORT BYPASS FLAGS
C   B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
C   c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A  C
C            O  O  C  O  O  P  4  O  O  N  4  3        D     M
C            C  C     P  P     t  N  N
    1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0
C-------------------------------------------------------------------------------
C03
C  IWQDT   = number of water quality time steps per hydrodynamic time step
C            =1 for 2 time level hydrodynamic and =2 for three time level
C  IWQM    = full or reduced model switch (1=full model; 2=reduced model)
C  IWQBEN  = benthic flux model switch (0=specified flux; 1=predictive flux, 2
predictive flux w/ time and space variation)
C  IWQSI   = switch to activate silica state variables (0=off; 1=activated)
C  IWQFCB  = switch to activate fecal coliform bacteria (0=off; 1=activated)
C  IWQSRP  = switch for sediment sorption (1=TAM sorption; 2=sediment sorption)
C  IWQSTOX = cyanobacteria salinity toxicity switch (0=no toxicity; 1=toxicity)
C  IWQKA   = reaeration option
C          = 0, constant reaeration (WQKRO), no wind reaeration
C          = 1, constant reaeration (WQKRO) plus wind reaeration
C          = 2, use O'Connor-Dobbins (1958) formula
C          = 3, use Owens & Gibbs (1964) formula
C          = 4, modified Owens & Gibbs (1964) formula (for Christina River)
```

```
C  IWQVLIM = option for velocity limitation of macroalgae growth
C          = 0, macroalgae growth is not limited by stream velocity
C          = 1, macroalgae growth limited using Michaelis-Menton formula
C          = 2, macroalgae growth limited using 5-parameter Logistic Function
C
C03 IWQDT   IWQM    IWQBEN  IWQSI   IWQFCB  IWQSRP  IWQSTOX  IWQKA IWQVLIM
     1       1       2       0       0       0       1        2     0
C-----------------------------------------------------------------------------
C04
C     IWQZ = number of zones for spatially varying WQ parameters
C    IWQNC = switch to save negative concentrations to WQ3DNC.LOG (0=OFF; 1=ON)
C   IWQRST = switch to save WQ restart data to WQWCRST.OUT (0=OFF; 1=ON)
C    NDMWQ = number of horizontal spatial domains for decomposition calc. (=1)
C    LDMWQ = number of horizontal cells in the WQ computational domain (=LC-2)
C  NDDOAVG = no longer used
C  NDLTAVG = no longer used
C IDNOTRVA = ID number of macroalgae water quality variable
C
C04 IWQZ    IWQNC   IWQRST  NDMWQ   LDMWQ   NDDOAVG  NDLTAVG IDNOTRVA
    1       0       1       1       1050    0        0       0
C-----------------------------------------------------------------------------
C05
C   IWQICI = initial condition switch
C            0=spatially constant initial conditions (card C44)
C            1=read initial condition file ICIFN (see card C51)
C            2=read initial conditions from restart file WQWCRST.INP
C   IWQAGR = algae growth kinetics switch
C            0=use constant kinetics on card C45
C            1=read spatial/time-varying kinetics from file AGRFN (card C51)
C   IWQSTL = settling velocity switch
C            0=use spatially/temporally constant settling velocities (card C46)
C            1=use spatial/time-varying settling vel. from STLFN (card C51)
C   IWQSUN = solar radiation switch
C            0=use constant solar radiation (I0) and FD from card C10
C            1=use daily average solar rad. and FD from file SUNDAY.INP
C            2=use hourly solar rad. from ASER.INP file
C   IWQPSL = point source load switch
C            0=use constant point source loads
C            1=use time-variable point source loads from file WQPSL.INP
C   IWQNPL = not used
C isDIURDO = switch for saving diurnal D.O. data
C            0=do not save diurnal D.O. data to file
C            1=save diurnal D.O. data to binary file WQDIURDO.BIN
C              if WQDIURDO.BIN already exists, delete it
C            2=save diurnal D.O. data to binary file WQDIURDO.BIN
C              if WQDIURDO.BIN already exists, append to it
C  WQDIUDT = time interval for writing to diurnal D.O. file (hours)
C   IWQKIN = switch for using spatially-varying kinetic rate constants
C            0=do not use spatially-varying kinetics
C            1=use spatially-varying kinetics in file KINETICS.INP
C              Only applies to IWQKA, KRO, KTR, REAC, KDC, KDCALGm, KHRm
C              DOPTm, KCD, and KHCOD.
C
C05 IWQICI  IWQAGR  IWQSTL  IWQSUN  IWQPSL  IWQNPL  isDIURDO WQDIUDT IWQKIN
     0       0       0       2       1       0       0        24.0     0
C-----------------------------------------------------------------------------
C06
C    IWQTS = number of time-series locations to output to ASCII file WQWCTS.OUT
C   TWQTSB = beginning time for recording time-series data (Julian Day)
C   TWQTSE = ending    time for recording time-series data (Julian Day)
C   WQTSDT = write interval (hours), also averaging interval for binary files
C            use 24.0 hours for daily averages (solar day)
C            use 24.8412 hours to average over the M2 tide period (lunar day)
```

```
C  isWQAVG = switch to save WQ averages to binary file WQWCAVG.BIN
C            0=OFF; 1=ON, overwrite existing file; 2=ON, append to existing file
C  isWQMIN = switch to save WQ minimums to binary file WQWCMIN.BIN
C            0=OFF; 1=ON, overwrite existing file; 2=ON, append to existing file
C  isWQMAX = switch to save WQ minimums to binary file WQWCMAX.BIN
C            0=OFF; 1=ON, overwrite existing file; 2=ON, append to existing file
C   isCOMP = switch to save DO components to file WQDOCOMP.BIN
C            0=OFF; 1=ON, overwrite existing file; 2=ON, append to existing file
C   17
C06 IWQTS   TWQTSB  TWQTSE  WQTSDT  isWQAVG isWQMIN isWQMAX  isCOMP
     14      0000.0  10000.0 12.4206     0       0       0       0
C-----------------------------------------------------------------------------
C07  TIME-SERIES WRITE CONTROLS
C     CHL = total chlorophyll
C     TOC = total organic carbon
C     DOC = dissolved organic carbon
C      TP = total phosphorus
C     DOP = dissolved organic phosphorus
C    PO4t = total orthophosphate
C    PO4d = dissolved orthophosphate
C     APC = algae phosphorus-to-carbon ratio
C      TN = total nitrogen
C     DON = dissolved organic nitrogen
C     NH4 = ammonia nitrogen
C     NO3 = nitrite + nitrate nitrogen
C     TSI = total silica
C      SU = unavailable dissolved silica
C      SA = total available biogenic dissolved silica
C     SAd = dissolved available biogenic dissolved silica
C     COD = chemical oxygen demand
C     TAM = total active metal
C    TAMp = total active metal
C     FCB = fecal coliform bacteria
C      Fm = macroalgae
C
C    ICWQTS(NW,M), NW=1,NTSWQV, M=1,IWQTS
C
C07  Two title cards follow:
$I   J     CHL  TOC  DOC  TP   DOP  PO4t PO4d APC  TN   DON  NH4  NO3  TSI
$          SU   SA   SAd  COD  O2   TAM  TAMp FCB  Fm
 4  80     1    1    1    1    1    1    1    1    1    1    1    1    1
           1    1    1    1    1    0    0    0    0                                  ! NC11
  7 66     1    1    1    1    1    1    1    1    1    1    1    1    1
           1    1    1    1    1    0    0    0    0                                  ! B210
 4  60     1    1    1    1    1    1    1    1    1    1    1    1    1
           1    1    1    1    1    0    0    0    0                                  ! AC
 4 25      1    1    1    1    1    1    1    1    1    1    1    1    1
           1    1    1    1    1    0    0    0    0                                  ! IC
 44 27     1    1    1    1    1    1    1    1    1    1    1    1    1
           1    1    1    1    1    0    0    0    0                                  ! NCf6
  4 10     1    1    1    1    1    1    1    1    1    1    1    1    1
           1    1    1    1    1    0    0    0    0                                  ! Nav
 22 81     1    1    1    1    1    1    1    1    1    1    1    1    1
           1    1    1    1    1    0    0    0    0                                  ! HB
 18 72     1    1    1    1    1    1    1    1    1    1    1    1    1
           1    1    1    1    1    0    0    0    0                                  ! Bruns.
River
 24 68     1    1    1    1    1    1    1    1    1    1    1    1    1
           1    1    1    1    1    0    0    0    0                                  ! M61
 24 58     1    1    1    1    1    1    1    1    1    1    1    1    1
           1    1    1    1    1    0    0    0    0                                  ! M54
 25 49     1    1    1    1    1    1    1    1    1    1    1    1    1
           1    1    1    1    1    0    0    0    0                                  ! M42
```

```
26 40     1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                                   ! M35
23 21     1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                                   ! M23
24 11     1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                                   ! M18
C-----------------------------------------------------------------------------
C08 ONE TITLE CARD FOLLOWS:
$$ C08 constant parameters for ALGAE (see Table 3-1) $$
C08
C     KHNc = nitrogen half-saturation for cyanobacteria (mg/L)
C     KHNd = nitrogen half-saturation for algae diatoms (mg/L)
C     KHNg = nitrogen half-saturation for algae greens algae (mg/L)
C     KHNm = nitrogen half-saturation for macroalgae (mg/L)
C     KHPc = phosphorus half-saturation for cyanobacteria (mg/L)
C     KHPd = phosphorus half-saturation for algae diatoms (mg/L)
C     KHPg = phosphorus half-saturation for algae greens algae (mg/L)
C     KHPm = phosphorus half-saturation for macroalgae (mg/L)
C      KHS = silica half-saturation for algae diatoms (mg/L)
C     STOX = salinity at which microsystis growth is halved for cyanobacteria
C   0.030  0.030  0.030  0.030  0.003  0.003  0.003  0.003  0.035 1.0
C08 KHNc   KHNd   KHNg   KHNm   KHPc   KHPd   KHPg   KHPm   KHS   STOX
    0.010  0.010  0.010  0.010  0.001  0.001  0.001  0.001  0.035 2.0
C-----------------------------------------------------------------------------
C09 constant parameters for ALGAE (see Table 3-1)
C   KeTSS = light extinction for total suspended solids (1/m per g/m3)
C   KeCHL = light extinction for total suspended chlorophyll (1/m per g/m3)
C     Note: if KeCHL is negative, the Riley (1956) formula is used to
C           compute the extinction coefficient due to chlorophyll:
C             KeCHL = 0.054*CHL^0.6667 + 0.0088*CHL
C             where CHL = total chloryphyll concentration (ug/L)
C   CChlc = carbon-to-chlorophyll ratio for cyanobacteria (mg C / ug Chl)
C   CChld = carbon-to-chlorophyll ratio for algae diatoms (mg C / ug Chl)
C   CChlg = carbon-to-chlorophyll ratio for algae greens (mg C / ug Chl)
C   CChlm = carbon-to-chlorophyll ratio for macroalgae (mg C / ug Chl)
C   DOPTc = optimal depth (m) for cyanobacteria growth
C   DOPTd = optimal depth (m) for algae diatoms growth
C   DOPTg = optimal depth (m) for algae greens growth
C   DOPTm = optimal depth (m) for macroalgae growth
C          0.041  0.060  0.060  0.060
C09 KeTSS  KeChl  CChlc  CChld  CChlg  CChlm  DOPTc  DOPTd DOPTg DOPTm
    0.015  0.017  0.060  0.060  0.060  0.060  1.0    1.0   1.0   0.10
C-----------------------------------------------------------------------------
C10 constant parameters for ALGAE (see Table 3-1)
C      I0 = initial solar radiation (Langley/day) at water surface
C   IsMIN = minimum optimum solar radiation (Langley/day)
C      FD = fraction of day that is daylight
C     CIa = weighting factor for solar radiation at current day
C     CIb = weighting factor for solar radiation at (-1) days
C     CIc = weighting factor for solar radiation at (-2) days
C     CIm = not used
C     Rea = global reaeration adjustment factor
C  PARadj = solar radiation multiplied by this factor to get the
C           photoactive available radiation (PAR) for algae growth
C           4.6
C10  I0    IsMIN  FD    CIa    CIb    CIc    CIm    Rea    PARadj
     28.0  40.0   0.5   0.7    0.2    0.1    0.7    1.00   0.43
C-----------------------------------------------------------------------------
C11 constant parameters for ALGAE (see Table 3-1)
C    TMc1 = lower optimal temperature for cyanobacteria growth (degC)
C    TMc2 = upper optimal temperature for cyanobacteria growth (degC)
C    TMd1 = lower optimal temperature for algae diatoms growth (degC)
C    TMd2 = upper optimal temperature for algae diatoms growth (degC)
```

```
C     TMg1 = lower optimal temperature for algae greens growth (degC)
C     TMg2 = upper optimal temperature for algae greens growth (degC)
C     TMm1 = lower optimal temperature for macroalgae growth (degC)
C     TMm2 = upper optimal temperature for macroalgae growth (degC)
C     TMp1 = lower optimal temperature for diatom predation (degC)
C     TMp2 = upper optimal temperature for diatom predation (degC)
C
C11 TMc1  TMc2   TMd1   TMd2   TMg1   TMg2   TMm1   TMm2   TMp1   TMp2
    27.5  32.5   17.0   20.0   20.0   30.0    1.0    1.0    2.0   29.0
C-----------------------------------------------------------------------------
C12 constant parameters for ALGAE (see Table 3-1)
C   KTG1c = suboptimal   temperature effect coef. for cyanobacteria growth
C   KTG2c = superoptimal temperature effect coef. for cyanobacteria growth
C   KTG1d = suboptimal   temperature effect coef. for algae diatoms growth
C   KTG2d = superoptimal temperature effect coef. for algae diatoms growth
C   KTG1g = suboptimal   temperature effect coef. for algae greens growth
C   KTG2g = superoptimal temperature effect coef. for algae greens growth
C   KTG1m = suboptimal   temperature effect coef. for macroalgae growth
C   KTG2m = superoptimal temperature effect coef. for macroalgae growth
C   KTG1p = suboptimal   temperature effect coef. for diatom predation growth
C   KTG2p = superoptimal temperature effect coef. for diatom predation growth
C  0.0080 0.0100 0.0040 0.0060 0.0080 0.0200 0.001  0.001 0.0001 0.0001
0.0100
C12 KTG1c KTG2c  KTG1d  KTG2d  KTG1g  KTG2g  KTG1m  KTG2m  KTG1p  KTG2p
   0.0080 0.0100 0.0040 0.0060 0.0080 0.0200 0.001  0.001 0.0001 0.0001
C-----------------------------------------------------------------------------
C13 constant parameters for ALGAE (see Table 3-1)
C     TRc = reference temperature for cyanobacteria metabolism (degC)
C     TRd = reference temperature for algae diatoms metabolism (degC)
C     TRg = reference temperature for algae greens metabolism (degC)
C     TRm = reference temperature for macroalgae metabolism (degC)
C    KTBc = temperature effect coef. for cyanobacteria metabolism
C    KTBd = temperature effect coef. for algae diatoms metabolism
C    KTBg = temperature effect coef. for algae greens metabolism
C    KTBm = temperature effect coef. for macroalgae metabolism
C
C13 TRc   TRd   TRg   TRm   KTBc   KTBd   KTBg   KTBm
    20.0  20.0  20.0  20.0  0.069  0.069  0.069  0.069
C-----------------------------------------------------------------------------
C14 ONE TITLE CARD FOLLOWS:
$$ C14 constant parameters for CARBON (see Table 3-2) $$
C14
C    FCRP = carbon distribution coef. for algae predation: refractory POC
C    FCLP = carbon distribution coef. for algae predation: labile POC
C    FCDP = carbon distribution coef. for algae predation: DOC
C    FCDc = carbon distribution coef. for cyanobacteria metabolism
C    FCDd = carbon distribution coef. for algae diatoms metabolism
C    FCDg = carbon distribution coef. for algae greens metabolism
C    KHRc = half-sat. constant (gO2/m3) for cyanobacteria DOC excretion
C    KHRd = half-sat. constant (gO2/m3) for algae diatoms DOC excretion
C    KHRg = half-sat. constant (gO2/m3) for algae greens  DOC excretion
C Note:  FCRP + FCLP + FCDP = 1.0
C
C14 FCRP   FCLP   FCDP   FCDc  FCDd   FCDg   KHRc  KHRd  KHRg
    0.35   0.55   0.10   0.0   0.0    0.0    0.5   0.5   0.5
C-----------------------------------------------------------------------------
C15 ONE TITLE CARD FOLLOWS:
$$ C15 constant parameters for CARBON (macroalgae)
C15
C   FCRPm = carbon distribution coef. for macroalgae predation: refractory POC
C   FCRPm = carbon distribution coef. for macroalgae predation: labile POC
C   FCRPm = carbon distribution coef. for macroalgae predation: DOC
C    FCDm = carbon distribution coef. for macroalgae metabolism
```

```
C     KHRm = half-sat. constant (gO2/m3) for macroalgae DOC excretion
C Note:  FCRPm + FCLPm + FCDPm = 1.0
C
C15 FCRPm  FCLPm  FCDPm  FCDm  KHRm
    0.25   0.25   0.50   0.0   0.5
C-----------------------------------------------------------------------------
C16 constant parameters for CARBON (see Table 3-2)
C      KRC = minimum dissolution rate (1/day) of refractory POC
C      KLC = minimum dissolution rate (1/day) of labile POC
C      KDC = minimum dissolution rate (1/day) of DOC
C   KRCalg = constant relating refractory POC dissolution rate to total chla
C   KLCalg = constant relating labile POC dissolution rate to total chla
C   KDCalg = constant relating DOC dissolution rate to total chla
C  KDCalgm = constant relating DOC dissolution rate to macroalgae
C   0.020    0.150    0.300
C16 KRC      KLC      KDC      KRCalg  KLCalg  KDCalg KDCalgm
    0.03    0.075    0.150    0.0     0.0     0.2    0.000
C-----------------------------------------------------------------------------
C17 constant parameters for CARBON (see Table 3-2)
C    TRHDR = reference temperature for hydrolysis (degC)
C    TRMNL = reference temperature for mineralization (degC)
C    KTHDR = temperature effect constant for hydrolysis
C    KTMNL = temperature effect constant for mineralization
C   KHORDO = oxic respiration half-sat. constant for D.O. (gO2/m3)
C    KHDNN = half-sat. constant for denitrification (gN/m3)
C    AANOX = ratio of denitrification rate to oxic DOC respiration rate
C                                    0.1
C17 TRHDR    TRMNL    KTHDR    KTMNL    KHORDO   KHDNN    AANOX
    20.0     20.0     0.069    0.069    0.5      0.1      0.7
C-----------------------------------------------------------------------------
C18 ONE TITLE CARD FOLLOWS:
$$ C18 constant parameters for PHOSPHORUS (see Table 3-3) $$
C18
C     FPRP = phos. distribution coef. for algae predation: refractory POP
C     FPLP = phos. distribution coef. for algae predation: labile POP
C     FPDP = phos. distribution coef. for algae predation: DOP
C     FPIP = phos. distribution coef. for algae predation: Inorganic P
C     FPRc = phos. distribution coef. of RPOP for cyanobacteria metabolism
C     FPRd = phos. distribution coef. of RPOP for algae diatoms metabolism
C     FPRg = phos. distribution coef. of RPOP for algae greens metabolism
C     FPLc = phos. distribution coef. of LPOP for cyanobacteria metabolism
C     FPLd = phos. distribution coef. of LPOP for algae diatoms metabolism
C     FPLg = phos. distribution coef. of LPOP for algae greens metabolism
C Note, the following must sum to 1.0:
C          FPRP + FPLP + FPDP + FPIP = 1.0
C          FPRc + FPLc + FPDc + FPIc = 1.0
C          FPRd + FPLd + FPDd + FPId = 1.0
C          FPRg + FPLg + FPDg + FPIg = 1.0
C   0.30 0.30  0.20  0.20             0.3             0.2
C18 FPRP FPLP  FPDP  FPIP  FPRc  FPRd FPRg FPLc FPLd FPLg
    0.10 0.20  0.50  0.20  0.0   0.0  0.0  0.0  0.0  0.0
C-----------------------------------------------------------------------------
C19 ONE TITLE CARD FOLLOWS:
$$ C19 constant parameters for PHOSPHORUS (macroalgae)
C19
C    FPRPM = phos. distribution coef. for macroalgae predation: RPOP
C    FPLPM = phos. distribution coef. for macroalgae predation: LPOP
C    FPDPM = phos. distribution coef. for macroalgae predation: DOP
C    FPIPM = phos. distribution coef. for macroalgae predation: Inorganic P
C     FPRm = phos. distribution coef. of RPOP for macroalgae metabolism
C     FPLm = phos. distribution coef. of LPOP for macroalgae metabolism
C     APCM = factor to modify APC for macroalgae
C Note, the following must sum to 1.0:
```

```
C          FPRPM + FPLPM + FPDPM + FPIPM = 1.0
C          FPRm + FPLm + FPDm + FPIm = 1.0
C
C19 FPRPM  FPLPM  FPDPM  FPIPM   FPRm   FPLm   APCM
    0.40   0.40   0.1    0.1     0.2    0.3    0.50
C-----------------------------------------------------------------------------
C20 constant parameters for PHOSPHORUS (see Table 3-3)
C     FPDc = phosphorus distribution coef. of DOP for cyanobacteria metabolism
C     FPDd = phosphorus distribution coef. of DOP for algae diatoms metabolism
C     FPDg = phosphorus distribution coef. of DOP for algae greens metabolism
C     FPDm = phosphorus distribution coef. of DOP for macroalgae metabolism
C     FPIc = phosphorus distribution coef. of P4T for cyanobacteria metabolism
C     FPId = phosphorus distribution coef. of P4T for algae diatoms metabolism
C     FPIg = phosphorus distribution coef. of P4T for algae greens metabolism
C     FPIm = phosphorus distribution coef. of P4T for macroalgae metabolism
C    KPO4p = partition coefficient for sorbed/dissolved PO4
C
C Notes, the following must sum to 1.0:
C          FPRc + FPLc + FPDc + FPIc = 1.0
C          FPRd + FPLd + FPDd + FPId = 1.0
C          FPRg + FPLg + FPDg + FPIg = 1.0
C                 0.4                          0.1
C20 FPDc   FPDd   FPDg   FPDm   FPIc   FPId   FPIg   FPIm   KPO4p
    1.0    1.0    1.0    1.0    0.0    0.0    0.0    0.0    1.00
C-----------------------------------------------------------------------------
C21 constant parameters for PHOSPHORUS (see Table 3-3)
C      KRP = minimum hydrolysis rate (1/day) of RPOP
C      KLP = minimum hydrolysis rate (1/day) of LPOP
C      KDP = minimum hydrolysis rate (1/day) of DOP
C   KRPalg = constant relating hydrolysis rate of RPOP to algae
C   KLPalg = constant relating hydrolysis rate of LPOP to algae
C   KDPalg = constant relating hydrolysis rate of DOP to algae
C   CPprm1 = constant used in determining algae Phos-to-Carbon ratio
C   CPprm2 = constant used in determining algae Phos-to-Carbon ratio
C   CPprm3 = constant used in determining algae Phos-to-Carbon ratio
C                 0.100                  0.2
C21 KRP    KLP    KDP    KRPalg KLPalg KDPalg CPprm1 CPprm2 CPprm3
    0.03   0.075  0.150  0.0    0.0    0.5    15.0   35.0   350.0
C-----------------------------------------------------------------------------
C22 ONE TITLE CARD FOLLOWS:
$$ C22 constant parameters for NITROGEN (see Table 3-4) $$
C22
C     FNRP = nitrogen distribution coef. for algae predation: RPON
C     FNLP = nitrogen distribution coef. for algae predation: LPON
C     FNDP = nitrogen distribution coef. for algae predation: DON
C     FNIP = nitrogen distribution coef. for algae predation: Inorganic N
C     FNRc = nitrogen distribution coef. of RPON for cyanobacteria metabolism
C     FNRd = nitrogen distribution coef. of RPON for algae diatoms metabolism
C     FNRg = nitrogen distribution coef. of RPON for algae greens  metabolism
C     FNLc = nitrogen distribution coef. of LPON for cyanobacteria metabolism
C     FNLd = nitrogen distribution coef. of LPON for algae diatoms metabolism
C     FNLg = nitrogen distribution coef. of LPON for algae greens  metabolism
C   0.3    0.5    0.1    0.1                0.2                0.4
C22 FNRP   FNLP   FNDP   FNIP   FNRc   FNRd   FNRg   FNLc   FNLd   FNLg
    0.35   0.55   0.1    0.0    0.0    0.0    0.0    0.0    0.0    0.0
C-----------------------------------------------------------------------------
C23 ONE TITLE CARD FOLLOWS:
$$ C23  constant parameters for NITROGEN (MACROALGAE)
C23
C    FNRPM = nitrogen distribution coef. for marcoalgae predation: RPON
C    FNLPM = nitrogen distribution coef. for marcoalgae predation: LPON
C    FNDPM = nitrogen distribution coef. for marcoalgae predation: DON
C    FNIPM = nitrogen distribution coef. for marcoalgae predation: Inorganic N
```

```
C     FNRm = nitrogen distribution coef. of RPON for macroalgae metabolism
C     FNLm = nitrogen distribution coef. of LPON for macroalgae metabolism
C
C23 FNRPM FNLPM  FNDPM  FNIPM  FNRm  FNLm
    0.4   0.5    0.1    0.0    0.2   0.4
C-----------------------------------------------------------------------------
C24 constant parameters for NITROGEN (see Table 3-4)
C     FNDc = nitrogen distribution coef. of DON for cyanobacteria metabolism
C     FNDd = nitrogen distribution coef. of DON for algae diatoms metabolism
C     FNDg = nitrogen distribution coef. of DON for algae greens  metabolism
C     FNDm = nitrogen distribution coef. of DON for macroalgae    metabolism
C     FNIc = nitrogen distribution coef. of DIN for cyanobacteria metabolism
C     FNId = nitrogen distribution coef. of DIN for algae diatoms metabolism
C     FNIg = nitrogen distribution coef. of DIN for algae greens  metabolism
C     FNIm = nitrogen distribution coef. of DIN for macroalgae    metabolism
C     ANCc = nitrogen-to-carbon ratio for cyanobacteria
C     ANCd = nitrogen-to-carbon ratio for algae diatoms
C     ANCg = nitrogen-to-carbon ratio for algae greens
C     ANCm = nitrogen-to-carbon ratio for macroalgae
C Note: FNRx + FNLx + FNDx + FNIx = 1.0
C   1.0   1.0   1.0   1.0   0.0   0.0   0.0   0.0   0.100 0.100 0.100 0.100
C24 FNDc  FNDd  FNDg  FNDm  FNIc  FNId  FNIg  FNIm  ANCc  ANCd  ANCg  ANCm
    1.0   1.0   1.0   1.0   0.0   0.0   0.0   0.0   0.17 0.17 0.17 0.050
C-----------------------------------------------------------------------------
C25 constant parameters for NITROGEN (see Table 3-4)
C     ANDC = mass NO3 reduces per DOC oxidized (gN/gC)
C    rNitM = maximum nitrification rate (gN/m3/day)
C KHNitDO = nitrification half-sat. constant for D.O.
C  KHNitN = nitrification half-sat. constant for NH4
C     TNit = reference temperature for nitrification (degC)
C    KNit1 = suboptimal temperature effect constant for nitrification
C    Knit2 = superoptimal temperature effect constant for nitrification
C
C            0.25    0.1     0.1     20.0
C25 ANDC     rNitM   KHNitDO KHNitN  TNit    KNit1   KNit2 changed rNitM from 0.99
baker
    0.933    0.11    0.1     0.1     27.0    0.0045  0.0045
C-----------------------------------------------------------------------------
C26 constant parameters for NITROGEN (see Table 3-4)
C      KRN = minimum hydrolysis rate (1/day) of RPON
C      KLN = minimum hydrolysis rate (1/day) of LPON
C      KDN = minimum hydrolysis rate (1/day) of DON
C   KRNalg = constant relating hydrolysis rate of RPON to algae
C   KLNalg = constant relating hydrolysis rate of LPON to algae
C   KDNalg = constant relating hydrolysis rate of DON to algae
C   0.005   0.075   0.600   0.0     0.0     0.0
C26 KRN     KLN     KDN     KRNalg  KLNalg  KDNalg
    0.03    0.075   0.150   0.0     0.0     0.0
C-----------------------------------------------------------------------------
C27 ONE TITLE CARD FOLLOWS:
$$ C27 constant parameters for SILICA (see Table 3-5) $$
C27
C     FSPP = silica distribution coef. for diatom predation
C     FSIP = silica distribution coef. for diatom predation
C     FSPd = silica distribution coef. for diatom metabolism
C     FSId = silica distribution coef. for diatom metabolism
C     ASCd = silica-to-carbon ratio for algae diatoms
C     KSAp = partition coef. for sorbed/dissolved SA
C      KSU = dissolution rate (1/day) of particulate silica (PSi)
C    TRSUA = reference temperature (degC) for PSi dissolution
C    KTSUA = temperature effect on PSi dissolution
C
C27 FSPP    FSIP    FSPd    FSId    ASCd    KSAp    KSU     TRSUA   KTSUA
```

```
    1.0      0.0      1.0      0.0      0.36     0.16     0.05     20.0     0.092
C-------------------------------------------------------------------------------
C28 ONE TITLE CARD FOLLOWS:
$$ C28 constant parameters for COD & DO (see Table 3-6) $$
C28
C     AOCR = stoichiometric algae oxygen-to-carbon ratio (gO2/gC)
C     AONT = stoichiometric algae oxygen-to-nitrate ratio (gO2/gN)
C      KRO = reaeration constant (3.933 for OConnor-Dobbins; 5.32 for Owen-Gibbs)
C      KTR = temperature rate constant for reaeration
C    KHCOD = oxygen half-saturation constant for COD decay (mg/L O2)
C      KCD = COD decay rate (per day)
C    TRCOD = reference temperature for COD decay (degC)
C    KTCOD = temperature rate constant for COD decay
C   AOCRpm = macroalgae photosynthesis oxygen-to-carbon ratio
C   AOCRrm = macroalgae respiration oxygen-to-carbon ratio
C                        1.25
C28 AOCR     AONT     KRO      KTR      KHCOD    KCD      TRCOD    KTCOD AOCRpm AOCRrm
    2.67     4.33     3.933    1.024    1.5      1.00     20.0     0.041 0.041   0.041
C-------------------------------------------------------------------------------
C29 ONE TITLE CARD FOLLOWS:
$$ C29 constant parameters for TAM & FCB (see Table 3-7) $$
C29
C    KHbmf = D.O. concentration where TAM release is half the anoxic rate
C    BFTAM = anoxic release rate of TAM (mol/m2/day)
C     Ttam = reference temperature for TAM release (degC)
C     Ktam = temperature effect constant for TAM release
C   TAMdmx = TAM solubility at anoxic conditions (mol/m3)
C   Kdotam = constant relating TAM solubility to D.O.
C     KFCB = first-order fecal coliform bacteria decay rate (1/day)
C     TFCB = temperature effect constant for KFCB decay rate
C
C29 KHbmf    BFTAM    Ttam     Ktam     TAMdmx   Kdotam   KFCB     TFCB
    0.5      0.1      20.0     0.2      0.015    1.0      0.5      1.07
C-------------------------------------------------------------------------------
C30 SIX TITLE CARDS FOLLOW:
$$ C30 CONCENTRATION TIME SERIES DATA $$
$$ NUMBER OF TIME SERIES FOR EACH STATE VARIABLE
$  B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
$  c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A  C
$           O  O  C  O  O  P  4  O  O  N  4  3        D     M
$           C  C     P  P     t  N  N
   1  1  1  0  0  0  0  0  0  1  0  0  0  1  1  0  0  0  1  0  0
C-------------------------------------------------------------------------------
C31 ONE TITLE CARD FOLLOWS:
$$ C31 parameters for OPEN BDRY CONDITIONS $$
C31
C  NWQOBS = number of WQ open boundary cells on SOUTH boundary
C  NWQOBW = number of WQ open boundary cells on WEST boundary
C  NWQOBE = number of WQ open boundary cells on EAST boundary
C  NWQOBN = number of WQ open boundary cells on NORTH boundary
C
C31 NWQOBS   NWQOBW   NWQOBE   NWQOBN
    4        0        1        0
C-------------------------------------------------------------------------------
C32 SIX TITLE CARDS FOLLOW:
$$ C32 SOUTH OPEN BOUNDARY $$
$$ TIME SERIES ID'S FOR EACH STATE VARIABLE
$  I   J   B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
$          c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A  C
$                   O  O  C  O  O  P  4  O  O  N  4  3        D     M
$                   C  C     P  P     t  N  N
  30   5   1  1  1  0  0  0  0  0  0  1  0  0  0  1  1  0  0  0  1  0  0
  31   5   1  1  1  0  0  0  0  0  0  1  0  0  0  1  1  0  0  0  1  0  0
```

```
 32   5   1  1  1  0  0  0  0  0  0  1  0  0  0  1  1  0  0  0  1  0  0
 33   5   1  1  1  0  0  0  0  0  0  1  0  0  0  1  1  0  0  0  1  0  0
C-----------------------------------------------------------------------
C33 FIVE TITLE CARDS FOLLOW:
$$ C33 SOUTH OPEN BOUNDARY $$
$$ CONSTANT BOTTOM CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$           RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$           NH4     NO3     SU      SA      COD     DO      TAM     FCB
     30       5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
                0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
                0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
     31       5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
                0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
                0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
     32       5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
                0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
                0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
     33       5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
                0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
                0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
C-----------------------------------------------------------------------
C34 FIVE TITLE CARDS FOLLOW:
$$ C34 SOUTH OPEN BOUNDARY $$
$$ CONSTANT SURFACE CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$           RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$           NH4     NO3     SU      SA      COD     DO      TAM     FCB
     30       5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
                0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
                0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
     31       5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
                0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
                0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
     32       5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
                0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
                0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
     33       5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
                0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
                0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
C-----------------------------------------------------------------------
C35 SIX TITLE CARDS FOLLOW:
$$ C35 WEST OPEN BOUNDARY $$
$$ TIME SERIES ID'S FOR EACH STATE VARIABLE
$  I   J   B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
$           c  d  g  P  P  O  P  P  O  O  P  P  O  N  H  O  U  A  O  O  A  C
$                    O  O  C  O  O  P  4  O  O  N  4  3        D     M
$                    C  C     P  P     t  N  N
$
C-----------------------------------------------------------------------
C36 FIVE TITLE CARDS FOLLOW:
$$ C36 WEST OPEN BOUNDARY $$
$$ CONSTANT BOTTOM CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$           RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$           NH4     NO3     SU      SA      COD     DO      TAM     FCB
C-----------------------------------------------------------------------
C37 FIVE TITLE CARDS FOLLOW:
$$ C37 WEST OPEN BOUNDARY $$
$$ CONSTANT SURFACE CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$           RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$           NH4     NO3     SU      SA      COD     DO      TAM     FCB
C-----------------------------------------------------------------------
```

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C38 SIX TITLE CARDS FOLLOW:
$$ C38 EAST OPEN BOUNDARY $$
$$ TIME SERIES ID'S FOR EACH STATE VARIABLE
$  I   J   B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
$           c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A  C
$                    O  O  C  O  O  P  4  O  O  N  4  3        D     M
$                    C  C     P  P     t  N  N
  35  44   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  1  0  0
C-----------------------------------------------------------------------
C39 FIVE TITLE CARDS FOLLOW:
$$ C39 EAST OPEN BOUNDARY $$
$$ CONSTANT BOTTOM CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$           RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$           NH4     NO3     SU      SA      COD     DO      TAM     FCB
  35  44   0.0     0.0     0.3     0.1     0.0     0.1
           0.05    0.0     0.05    0.1     0.2     0.0     0.2
           0.04    0.08    0.0     0.0     0.0     0.0     0.0     0.0
C-----------------------------------------------------------------------
C40 FIVE TITLE CARDS FOLLOW:
$$ C40 EAST OPEN BOUNDARY $$
$$ CONSTANT SURFACE CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$           RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$           NH4     NO3     SU      SA      COD     DO      TAM     FCB
  35  44   0.0     0.0     0.3     0.1     0.0     0.1
           0.05    0.0     0.05    0.1     0.2     0.0     0.2
           0.04    0.08    0.0     0.0     0.0     0.0     0.0     0.0
C-----------------------------------------------------------------------
C41 SIX TITLE CARDS FOLLOW:
$$ C41 NORTH OPEN BOUNDARY $$
$$ TIME SERIES ID'S FOR EACH STATE VARIABLE
$  I   J   B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
$           c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A  C
$                    O  O  C  O  O  P  4  O  O  N  4  3        D     M
$                    C  C     P  P     t  N  N
C-----------------------------------------------------------------------
C42 FIVE TITLE CARDS FOLLOW:
$$ C42 NORTH OPEN BOUNDARY $$
$$ CONSTANT BOTTOM CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$           RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$           NH4     NO3     SU      SA      COD     DO      TAM     FCB
C-----------------------------------------------------------------------
C43 FIVE TITLE CARDS FOLLOW:
$$ C43 NORTH OPEN BOUNDARY $$
$$ CONSTANT SURFACE CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$           RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$           NH4     NO3     SU      SA      COD     DO      TAM     FCB
C-----------------------------------------------------------------------
C44 ONE TITLE CARD FOLLOWS:
$$ C44 constant ICs (g/m^3): TAM(mol/m^3), FCB(MPN/100mL) $$
C44
C Definitions:
C   Bc = cyanobacteria
C   Bd = algae diatoms
C   Bg = algae greens
C RPOC = refractory particulate carbon
C LPOC = labile particulate carbon
C  DOC = dissolved organic carbon
C RPOP = refractory particulate organic phosphorus
C LPOP = labile particulate organic phosphorus
```

```
C  DOP = dissolved organic phosphorus
C PO4t = total orthophosphate
C RPON = refractory particulate organic nitrogen
C LPON = labile particulate organic nitrogen
C  DON = dissolved organic nitrogen
C  NH4 = ammonia nitrogen
C  NO3 = nitrite + nitrate nitrogen
C   SU = unavailable silica
C   SA = available biogenic silica
C  COD = chemical oxygen demand
C   DO = dissolved oxygen
C  TAM = total active metal
C  FCB = fecal coliform bacteria
C   Bm = macroalgae
C Bmin = minimum macroalgae biomass
C
C  Bc      Bd      Bg      RPOC    LPOC    DOC
C  RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
C  NH4     NO3     SU      SA      COD     DO      TAM     FCB     Bm   Bmin
   0.05    0.05    0.05    1.0     0.1     1.0
   0.025   0.01    0.025   0.05    0.14    0.07    0.14
   0.05    0.10    0.0     0.0     0.0     10.0    0.0     0.0     0.0  0.0
C-----------------------------------------------------------------------------
C45 ONE TITLE CARD FOLLOWS:
$$ C45 spatially/temporally constant ALGAL PARAMETERS (/d except Keb in /m) $$
C45
C     PMc = max. growth rate for cyanobacteria (1/day)
C     PMd = max. growth rate for algae diatoms (1/day)
C     PMg = max. growth rate for algae greens  (1/day)
C     PMm = max. growth rate for macroalgae    (1/day)
C    BMRc = basal metabolism rate for cyanobacteria (1/day)
C    BMRd = basal metabolism rate for algae diatoms (1/day)
C    BMRg = basal metabolism rate for algae greens  (1/day)
C    BMRm = basal metabolism rate for macroalgae    (1/day)
C    PRRc = predation rate on cyanobacteria (1/day)
C    PRRd = predation rate on algae diatoms (1/day)
C    PRRg = predation rate on algae greens  (1/day)
C    PRRm = predation rate on macroalgae    (1/day)
C     Keb = background light extinction coefficient (1/m)
C     0.0  0.0  3.0  2.0  0.05  0.01  0.02  0.10 0.28  0.10  0.10  0.33 0.475
C45   PMc  PMd  PMg  PMm  BMRc  BMRd  BMRg  BMRm PRRc  PRRd  PRRg  PRRm Keb
      1.1  0.7  0.9  0.0  0.01  0.01  0.02  0.10  0.10  0.10  0.10  0.0  0.475
C-----------------------------------------------------------------------------
C46 ONE TITLE CARD FOLLOWS:
$$ C46 spatially/temporally constant SETTLING VELOCITIES (m/d) $$
C46
C     WSc = settling velocity for cyanobacteria (m/day)
C     WSd = settling velocity for algae diatoms (m/day)
C     WSg = settling velocity for algae greens  (m/day)
C    WSrp = settling velocity for refractory POM (m/day)
C    WSlp = settling velocity for labile POM (m/day)
C     WSs = settling velocity for particles sorbed to TAM (m/day)
C     WSM = settling velocity for macroalgae (m/day = 0.0)
C    REAC = reaeration adjustment factor
C   0.0      0.10     0.10     0.12     0.12     0.10     1.0    1.00
C46 WSc      WSd      WSg      WSrp     WSlp     WSs      WSM    REAC
    0.05     0.10     0.10     0.00     0.10     0.10     1.0    1.00
C-----------------------------------------------------------------------------
C47 ONE TITLE CARD FOLLOWS:
$$ C47 constant benthic flux rates (g/m^2/d) $$
C47
C    FPO4 = benthic flux rate of phosphate
C    FNH4 = benthic flux rate of ammonia nitrogen
```

```
C    FNO3 = benthic flux rate of nitrite+nitrite nitrogen
C    FSAD = benthic flux rate of silica
C    FCOD = benthic flux rate of chemical oxygen demand
C     SOD = sediment oxygen demand rate
C
C47  FPO4     FNH4     FNO3     FSAD     FCOD     SOD
     0.000    0.000    -0.05    0.000    0.000    -0.50
C-----------------------------------------------------------------------------
C48 ONE TITLE CARD FOLLOWS:
$$ C48 const PS (kg/d): PSQ(m^3/s),DO(g/m^3),TAM(kmol/d),FCB(MPN/100mL)
C48
C    IWQPS = number of point sources
C NPSTMSR = number of point source time series
C
C48 const PS (kg/d): PSQ(m^3/s),DO(g/m^3),TAM(kmol/d),FCB(MPN/100mL)
C IWQPS    NPSTMSR
C IWQPS    NPSTMSR
  38      38
C  I    J    K    N    PSQ      Bc       Bd       Bg       RPOC     LPOC     DOC
C                  S    RPOP     LPOP     DOP      PO4t     RPON     LPON     DON
C                  R    NH4      NO3      SU       SA       COD      DO       TAM      FCB
   4    32   0    1    0.0      0.0      0.0      0.0      0.0      0.0      0.0    ! DUPONT-
WILMINGTON/BRUNSWICK
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   4    32   0    2    0.0      0.0      0.0      0.0      0.0      0.0      0.0    ! DUPONT-
WILMINGTON/BRUNSWICK
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   4    32   0    3    0.0      0.0      0.0      0.0      0.0      0.0      0.0    ! DUPONT-
WILMINGTON/BRUNSWICK
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   4    27   0    4    0.0      0.0      0.0      0.0      0.0      0.0      0.0    ! ARTEVA
SPECIALTIES-WILMINGTON
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   4    27   0    5    0.0      0.0      0.0      0.0      0.0      0.0      0.0    ! ARTEVA
SPECIALTIES-WILMINGTON
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   4    63   0    6    0.0      0.0      0.0      0.0      0.0      0.0      0.0    ! FEDERAL
PAPER BD CO-RIEGELWD
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  23    10   0    8    0.0      0.0      0.0      0.0      0.0      0.0      0.0    ! SOUTHPORT,
TOWN-WWTP/SOUTHPORT
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  31    39   0    9    0.0      0.0      0.0      0.0      0.0      0.0      0.0    ! CAROLINA
BEACH, TOWN-WWTP
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  24    79   0   10    0.0      0.0      0.0      0.0      0.0      0.0      0.0    !
WILMINGTON-NORTHSIDE WWTP
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  28    63   0   11    0.0      0.0      0.0      0.0      0.0      0.0      0.0    !
WILMINGTON-SOUTHSIDE WWTP   17   64
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0
                        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  30    33   0   12    0.0      0.0      0.0      0.0      0.0      0.0      0.0    ! KURE BEACH
WWTP
```

```
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 23   18   0   13   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! ARCHER
DANIELS MIDLAND CO.
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  4   31   0   14   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! TAKEDA
CHEMICAL PRODUCTS
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  4   31   0   14   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! TAKEDA
CHEMICAL PRODUCTS, number 2
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  4   15   0   15   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! LELAND
INDUSTRIAL PARK WWTP
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 18   72   0   16   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! BELVILLE,
TOWN - WWTP
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  4   27   0   17   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! FORTRON
INDUSTRIES
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  4   85   0   18   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! cape fear
river
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  7   72   0   19   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! black
river
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 43   97   0   20   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! ne cape
fear river
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 43   21   0   21   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! NE Cape
Fear, estuary 1
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 43   35   0   22   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! NE Cape
Fear, estuary 2
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 43   93   0   23   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! NE Cape
Fear, estuary 3
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 43   87   0   24   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! NE Cape
Fear, estuary 4
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 43   47   0   25   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! NE Cape
Fear, estuary 5
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 43   79   0   26   0.0     0.0     0.0     0.0     0.0     0.0     0.0     ! NE Cape
Fear, estuary 6
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
```

```
   7   58  0  27    0.0      0.0      0.0      0.0      0.0      0.0      0.0   ! Black
River, estuary 1
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0     0.0
   7   41  0  28    0.0      0.0      0.0      0.0      0.0      0.0      0.0   ! Black
River, estuary 2
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0     0.0
   4   63  0  29    0.0      0.0      0.0      0.0      0.0      0.0      0.0   ! Cape Fear,
upper estuary 1
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0     0.0
   4   42  0  30    0.0      0.0      0.0      0.0      0.0      0.0      0.0   ! Cape Fear,
upper estuary 2
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0     0.0
   4   17  0  31    0.0      0.0      0.0      0.0      0.0      0.0      0.0   ! Cape Fear,
upper estuary 3
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0     0.0
   20  57  0  32    0.0      0.0      0.0      0.0      0.0      0.0      0.0   ! Cape Fear,
lower estuary 1
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0     0.0
   27  55  0  33    0.0      0.0      0.0      0.0      0.0      0.0      0.0   ! Cape Fear,
lower estuary 2
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0     0.0
   22  42  0  34    0.0      0.0      0.0      0.0      0.0      0.0      0.0   ! Cape Fear,
lower estuary 3
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0     0.0
   4   15  0  35    0.0      0.0      0.0      0.0      0.0      0.0      0.0   ! Brunswick
Co. WWTP, NC0086819
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0     0.0
   43  28  0  36    0.0      0.0      0.0      0.0      0.0      0.0      0.0   ! GE -
Wilmington, NC0001228
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0     0.0
   43  72  0  37    0.0      0.0      0.0      0.0      0.0      0.0      0.0   ! Occidental
Chemical, NC0003875
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0     0.0
   4   63  0  38    0.0      0.0      0.0      0.0      0.0      0.0      0.0   ! DO
injection, IP
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0
                    0.0      0.0      0.0      0.0      0.0      0.0      0.0     0.0
C-------------------------------------------------------------------------------
C49 FOUR TITLE CARDS FOLLOW:
$$ C49 Constant Dry Atmospheric Deposition (g/m2/day; MPN/m2/day)
$ DSQ       Bc        Bd        Bg        RPOC      LPOC      DOC
$ RPOP      LPOP      DOP       PO4t      RPON      LPON      DON
$ NH4       NO3       SU        SA        COD       DO        TAM       FCB
  0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
C-------------------------------------------------------------------------------
C50 FOUR TITLE CARDS FOLLOW:
$$ C50 Wet Atmospheric Deposition concentrations (mg/L; MPN/L)
$           Bc        Bd        Bg        RPOC      LPOC      DOC
$ RPOP      LPOP      DOP       PO4t      RPON      LPON      DON
$ NH4       NO3       SU        SA        COD       DO        TAM       FCB
```

```
            0.0       0.0       0.0       0.0       0.0       0.0
            0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0
C-----------------------------------------------------------------------------
C51 ONE TITLE CARD FOLLOWS:
$$ C51 File names for spatially/temporally varying parameters: lower case only $$
Restart file for end spatial distribution = wq3drst.out
File for initial conditions (ICIFN)       = NONE ICIFN.INP
File for algal growth, resp, pred (AGRFN) = NONE AGRFN.INP
File for settling of algae, POM (STLFN)   = NONE STLFN.INP
Input file for Io, FD, KT, Te (SUNFN)     = NONE SUNFN.INP
Input file for benthic fluxes (BENFN)     = benflux_tser.inp
Input file for point source input (PSLFN) = NONE PSLFN.INP
File for NPS input inc/atm input (NPLFN)  = NONE NPLFN.INP
Diagnostic file-negative conc. (NCOFN)    = NONE wq3dnc.log
```

```
#   Variable Benthic Flux, By Jim Bowen, Feb 2008, number of zones
#   date to begin new set of values
#    iwqz   FPO4   FNH4   FNO3   FSAD   FCOD   FSOD
  2
365.00
1      0.0    0.0    -0.0075      0.0    0.0    -0.188
2      0.0    0.0    -0.0113      0.0    0.0    -0.281
395.42
1      0.0    0.0    -0.0080      0.0    0.0    -0.199
2      0.0    0.0    -0.0119      0.0    0.0    -0.298
425.83
1      0.0    0.0    -0.0095      0.0    0.0    -0.237
2      0.0    0.0    -0.0142      0.0    0.0    -0.355
456.25
1      0.0    0.0    -0.0134      0.0    0.0    -0.336
2      0.0    0.0    -0.0202      0.0    0.0    -0.504
486.67
1      0.0    0.0    -0.0180      0.0    0.0    -0.449
2      0.0    0.0    -0.0270      0.0    0.0    -0.674
517.08
1      0.0    0.0    -0.0241      0.0    0.0    -0.601
2      0.0    0.0    -0.0300      0.0    0.0    -0.902
547.50
1      0.0    0.0    -0.0278      0.0    0.0    -0.696
2      0.0    0.0    -0.0300      0.0    0.0    -1.044
577.92
1      0.0    0.0    -0.0255      0.0    0.0    -0.638
2      0.0    0.0    -0.0300      0.0    0.0    -0.956
608.33
1      0.0    0.0    -0.0214      0.0    0.0    -0.535
2      0.0    0.0    -0.0300      0.0    0.0    -0.803
638.75
1      0.0    0.0    -0.0180      0.0    0.0    -0.449
2      0.0    0.0    -0.0270      0.0    0.0    -0.674
669.17
1      0.0    0.0    -0.0134      0.0    0.0    -0.336
2      0.0    0.0    -0.0202      0.0    0.0    -0.504
699.58
1      0.0    0.0    -0.0089      0.0    0.0    -0.223
2      0.0    0.0    -0.0134      0.0    0.0    -0.335
730.00
1      0.0    0.0    -0.0075      0.0    0.0    -0.188
2      0.0    0.0    -0.0113      0.0    0.0    -0.281
760.42
1      0.0    0.0    -0.0080      0.0    0.0    -0.199
2      0.0    0.0    -0.0119      0.0    0.0    -0.298
790.83
1      0.0    0.0    -0.0095      0.0    0.0    -0.237
2      0.0    0.0    -0.0142      0.0    0.0    -0.355
821.25
1      0.0    0.0    -0.0134      0.0    0.0    -0.336
2      0.0    0.0    -0.0202      0.0    0.0    -0.504
851.67
1      0.0    0.0    -0.0180      0.0    0.0    -0.449
2      0.0    0.0    -0.0270      0.0    0.0    -0.674
882.08
1      0.0    0.0    -0.0241      0.0    0.0    -0.601
2      0.0    0.0    -0.0300      0.0    0.0    -0.902
```

```
912.50
1       0.0     0.0     -0.0278     0.0     0.0     -0.696
2       0.0     0.0     -0.0300     0.0     0.0     -1.044
942.92
1       0.0     0.0     -0.0255     0.0     0.0     -0.638
2       0.0     0.0     -0.0300     0.0     0.0     -0.956
973.33
1       0.0     0.0     -0.0214     0.0     0.0     -0.535
2       0.0     0.0     -0.0300     0.0     0.0     -0.803
1003.75
1       0.0     0.0     -0.0180     0.0     0.0     -0.449
2       0.0     0.0     -0.0270     0.0     0.0     -0.674
1034.17
1       0.0     0.0     -0.0134     0.0     0.0     -0.336
2       0.0     0.0     -0.0202     0.0     0.0     -0.504
1064.58
1       0.0     0.0     -0.0089     0.0     0.0     -0.223
2       0.0     0.0     -0.0134     0.0     0.0     -0.335
1095.00
1       0.0     0.0     -0.0075     0.0     0.0     -0.188
2       0.0     0.0     -0.0113     0.0     0.0     -0.281
1125.42
1       0.0     0.0     -0.0080     0.0     0.0     -0.199
2       0.0     0.0     -0.0119     0.0     0.0     -0.298
1155.83
1       0.0     0.0     -0.0095     0.0     0.0     -0.237
2       0.0     0.0     -0.0142     0.0     0.0     -0.355
1186.25
1       0.0     0.0     -0.0134     0.0     0.0     -0.336
2       0.0     0.0     -0.0202     0.0     0.0     -0.504
1216.67
1       0.0     0.0     -0.0180     0.0     0.0     -0.449
2       0.0     0.0     -0.0270     0.0     0.0     -0.674
1247.08
1       0.0     0.0     -0.0241     0.0     0.0     -0.601
2       0.0     0.0     -0.0300     0.0     0.0     -0.902
1277.50
1       0.0     0.0     -0.0278     0.0     0.0     -0.696
2       0.0     0.0     -0.0300     0.0     0.0     -1.044
1307.92
1       0.0     0.0     -0.0255     0.0     0.0     -0.638
2       0.0     0.0     -0.0300     0.0     0.0     -0.956
1338.33
1       0.0     0.0     -0.0214     0.0     0.0     -0.535
2       0.0     0.0     -0.0300     0.0     0.0     -0.803
1368.75
1       0.0     0.0     -0.0180     0.0     0.0     -0.449
2       0.0     0.0     -0.0270     0.0     0.0     -0.674
1399.17
1       0.0     0.0     -0.0134     0.0     0.0     -0.336
2       0.0     0.0     -0.0202     0.0     0.0     -0.504
1429.58
1       0.0     0.0     -0.0089     0.0     0.0     -0.223
2       0.0     0.0     -0.0134     0.0     0.0     -0.335
1465.00
1       0.0     0.0     -0.0075     0.0     0.0     -0.188
2       0.0     0.0     -0.0113     0.0     0.0     -0.281
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United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

March 3, 2015

Ms. Elizabeth Kountis
DENR/ Division of Water Resources, Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611

Dear Ms. Kountis:

This letter conveys the U.S. Fish and Wildlife Service's (Service) comments on proposed reclassification of a section of the Cape Fear River (Brunswick and New Hanover Counties) from Class SC to Class SC Swamp (Sw) with a water quality management plan. The Division of Water Resources (DWR), on behalf of the Environmental Management Commission, seeks comments on the proposed changes which were detailed in a January 12, 2015 public hearing notice.

The Service is the principal Federal agency responsible for conserving, protecting and enhancing fish, wildlife and plants and their habitats for the continuing benefit of the American people. Among our priorities is the health and restoration of diadromous fish stocks in the area, including striped bass (*Morone saxatilis*), American shad (*Alosa sapidissima*), hickory shad (*Alosa mediocris*), blueback herring (*Alosa aestivalis*), alewife (*Alosa pseudoharengus*), shortnose sturgeon (*Acipenser brevirostrum*), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), and American eel (*Anguilla rostrata*). All diadromous species have complex life cycles entailing use of freshwater and marine habitats, so the proposed reclassification of the lower Cape Fear River is of interest to us and partners working on fish restoration.

We appreciate DWR's early coordination with us on the proposal. At your request, on April 23, 2014 we emailed references documenting 1) protected aquatic species and species of special management importance in the lower Cape Fear River, with emphasis on the lifestages present in late spring, summer and early fall when dissolved oxygen (DO) would be lowest (and therefore potentially most affected by a Sw reclassification); 2) DO tolerances of fish species of management concern, including references demonstrating adverse effects to fish early lifestages at DO concentrations less than the standard of 5 mg/L; and 3) concern that a Sw classification, allowing lower DO if caused by natural conditions, might make it more difficult to determine use support related to DO in the future without some mechanism to define a new lower bound on DO indicative of background conditions. The three April 23, 2014 emails are incorporated here by reference.

Last summer, a biologist with our Coastal Program (which is integrally involved in Cape Fear River fisheries and habitat restoration) met with reclassification proponents and consultants. From those meetings, supporting technical memoranda, and water quality modeling reports, we better understand the intention of the reclassification -- to document the large influence of

wetlands and sediment and lesser influence of local point sources on local DO conditions. That should allow stakeholders to refocus restoration efforts on those factors which have the greatest impact, including anthropogenic sources of oxygen consuming waste upstream of the reclassified reach. We offer four technical suggestions for DWR's consideration:

1) The proposed management plan concludes with "Any new or expanded permitted pollutant discharge of oxygen-consuming waste shall not cause the DO of the receiving water to drop more than 0.1 mg/l below the modeled in-stream DO at total permitted capacity." We suggest replacing "Any" with "All" so that the cumulative impact of all additional permitted oxygen consuming waste is a diminishment of less than 0.1 mg/L. This is important because the monitoring and modeling confirm the reach has essentially no assimilative capacity given DO already low due to natural conditions.

2) The management plan should include the means by which the 0.1 mg/L cap on lowered DO will be determined. Important details to establish and get reviewed by stakeholders include the model to be used, input parameters, season to be modeled, location for compliance, and whether compliance is to be based on instantaneous versus average conditions.

3) Modeling reports note that reductions of oxygen consuming waste upstream of the modeled reach could appreciably improve DO in the modeled reach -- reducing excursions below the 5 mg/L standard. In other words, upstream water quality improvements could positively influence DO in the lower Cape Fear River. The reclassification may help in addressing important anthropogenic sources upstream of the modeled reach (e.g., CAFO associated waste from the Northeast Cape Fear River; large BOD point sources upstream of the modeled reach). It would be helpful if the management plan included a path forward on how to improve lower Cape Fear River DO concentrations through watershed-wide waste load modeling, land use planning, and permitting so water quality restoration is linked to the reclassification.

4) The management plan should discuss how DO use support determinations will be made if there is no lower bound on the frequency and magnitude of DO concentrations. It would help to explain how natural conditions will be differentiated from other conditions such that DO impairments can be identified and remedied. In short, some way to define a new floor with which to evaluate monitoring and compliance data should be established.

There are no federally- listed threatened or endangered species under Service jurisdiction in the affected reach. Shortnose sturgeon and Atlantic sturgeon are under the jurisdiction of NOAA Fisheries' Protected Species Division and may be affected by the action, so we encourage your continued coordination with them.

We will be glad to further explore these suggestions so that the outcome results in restoration of water quality for the benefit of fish and people. If you would like additional detail on any of our recommendations, please contact me at 919-856-4520 x.21.

Sincerely,

Tom Augspurger
Ecologist

Petter, Lauren

From: Julie Youngman <jyoungman@selcnc.org>
Sent: Tuesday, March 03, 2015 5:51 PM
To: Petter, Lauren; Gordon, Lisa Perras
Cc: Lou Ann Phelps; Will Hendrick
Subject: FW: Proposed Cape Fear River swamp classification and management plan
Attachments: 20150303165927984.pdf

That is my fault – I see that I misspelled Lauren Pe*tt*er's name! I'm so sorry. Here are the comments we meant to cc you.

Julie Youngman
Senior Attorney
Southern Environmental Law Center
601 West Rosemary Street, Suite 220
Chapel Hill, NC 27516
(919) 967-1450
www.SouthernEnvironment.org

From: Lou Ann Phelps
Sent: Tuesday, March 03, 2015 5:18 PM
To: 'Gordon.lisaperras@Epa.gov'
Subject: Proposed Cape Fear River swamp classification and management plan

Dear Ms. Perras-Gordon,

Please see the attached comments from the Southern Environmental Law Center, submitted to the North Carolina Department of Environment and Natural Resources – Division of Water Resources Planning Section, on behalf of American Rivers, Cape Fear River Watch, and the North Carolina Conservation Network. I attempted to send these to your colleague Lauren Pedder, but was unable to find an email address for her in the staff directory. If she is indeed the person who should receive them, please forward them to her.

Thank you for your assistance.

Lou Ann Phelps
Administrative and Legal Assistant
North Carolina Certified Paralegal
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March 3, 2015

VIA ELECTRONIC MAIL
Elizabeth Kountis
DENR-DWR Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611
elizabeth.kountis@ncdenr.gov

Re: Proposed Cape Fear River swamp classification and management plan

Dear Ms. Kountis:

The Southern Environmental Law Center appreciates the opportunity to comment on the proposed classification and management plan on behalf of American Rivers, Cape Fear River Watch, and the North Carolina Conservation Network. Together, these organizations represent thousands of North Carolinians who drink, fish, swim, and paddle the state's rivers, including the Cape Fear; who place a high value on the quality of North Carolina's water resources; and who will be adversely affected by the degradation of water quality in the Cape Fear River.

The comments that follow explain and detail our objections to these proposals. Section I emphasizes changes in the goals of environmental protection that led the State to protect waters for use by aquatic life. Section II addresses the relationship between classifications that identify the uses for which waters must be protected and water quality standards designed to afford the desired protection. Section III focuses on the classification and standards applicable to swamp waters. The remaining sections state specific objections to the proposals under consideration, which we believe would ignore the best usage of the Cape Fear River and further impair use of this water body by aquatic life by, among other things, authorizing persistent lower dissolved pH and dissolved oxygen concentrations that would not be protective of species inhabiting the affected segment of the river.

I. Evolution of Protected Uses of North Carolina's Waters

The content of laws protecting North Carolina's waters has always been tied to the use for which our leaders sought to protect these natural resources. Between the colonial era and the 19th century, state and federal laws were enacted primarily to ensure use of water for drinking, navigation, and hydropower.[1] Although some 19th-century enactments designed to protect

[1] For instance, in 1899 Congress, primarily concerned with threats to the commercial use of interstate waterways, outlawed the "dumping of refuse that would obstruct navigation of navigable waters, except under a federal permit." River and Harbors Act of 1899, ch. 425, 30 Stat. 1121 (1899) (codified at 33 U.S.C. § 401-467). In North Carolina, the "first legislative acts concerning streams of the state were acts of the early colonial assembly to encourage

commerce or public health collaterally benefited aquatic life,[2] the primary legislative focus was on preserving the public's water supply source, and "[l]ittle or no protection was yet afforded other uses of surface waters."[3]

The enactment of pollution controls to protect drinking water continued into the 20th century.[4] Even laws reflecting consideration of the use of waters by aquatic life remained focused on protecting commerce or public health.[5] Between the Great Depression and World War II,[6] the focus on commerce and public health persisted, and relatively few advances in state water-pollution law occurred in that period.

After the war, federal and state governments returned their attention to controlling water pollution,[7] and the law increasingly recognized the need to protect water for reasons other than commerce and public health. In 1951, the North Carolina General Assembly enacted the State Stream Sanitation Act, observing that the "best interest of the people" was served when water resources were protected for a variety of uses, including use by aquatic life.[8] The Act created the State Stream Sanitation Committee (SSSC) and empowered it to "establish methods designed to protect the water requirement for health, recreation, fishing, agriculture, industry, and animal life."[9] This expanded approach to water pollution control was advanced by the federal Clean Water Act (CWA),[10] which sought to develop pollution-control programs to conserve water for

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navigation." David H. Howells, Quest for Clean Streams in North Carolina: An Historical Account of Stream Pollution Control in North Carolina, 258 Water Resources Res. Inst. of the Univ. of N.C. 3 (1990).

[2] *See, e.g.*, Public Laws and Resolutions, N.C. General Assembly 1883, ch. 290 (making it "unlawful for any person to put any poisonous substance or matter for the purpose of catching, killing, or driving of any fish in any of the waters of any creek or river within the state."); Public Laws and Resolutions, N.C. General Assembly 1889, ch. 52 (prohibiting sawmill owners from dumping sawdust "into any river, creek, or stream of water, whereby the channel may be obstructed or damage done to any oyster bed, or the health of any person may be impaired").

[3] Howells, *supra* n.1 at 7.

[4] *See, e.g.*, Public Laws and Resolutions, N.C. General Assembly 1903, ch. 159 (criminalizing the pollution of "any well, spring, drain, branch, brook or creek, or other source of public water supply used for drinking purposes."). Notably, the same law prohibited the discharge of raw sewage and spurred statewide advances in municipal sanitation. Howells, *supra* n.1 at 13.

[5] For instance, the Fisheries Commission Board was created in 1915 with the power to enforce new laws prohibiting the discharge of certain substances harmful to commercial fishing. Howells, *supra* n.1 at 17. Another law followed in 1927 prohibiting discharge of substances poisonous to fish in designated fish-producing waters, but "there were no prosecutions under either the 1915 or 1927 acts." *Id.* at 21-22 (noting that "the antipollution provision was never enforced by the board"). Later, in the 1920s, the State Board of Health began restricting shellfish areas where bacteriological contamination rendered harvested shellfish unsafe for human consumption. *Id.* at 18.

[6] By 1944, the State Board of Health claimed that stream sanitation was "becoming more critical each year." *Id.* at 41.

[7] The U.S. Congress enacted the Water Pollution Control Act of 1948 to provide technical and financial assistance to states for the creation of state water pollution control programs. Water Pollution Control Act, Pub. L. No. 80-845, 62 Stat. 1155 (1948).

[8] Session Laws and Resolutions, N.C. General Assembly 1951 ch. 606.

[9] *Id.*

[10] 33 U.S.C. § 1251(a). The Act sought to develop pollution control programs by giving "due regard" to the improvements necessary to conserve waters "for the protection and propagation of fish and aquatic life and wildlife, recreational purposes, and the withdrawal of such water for public water supply, agricultural, industrial, and other purposes." 33 U.S.C. § 1252(a).

various uses, including "the protection and propagation of fish and aquatic life and wildlife, recreational purposes, and the withdrawal of such water for public water supply, agricultural, industrial, and other purposes."[11]

Both federal and state leaders realized the need to categorize water resources by reference to the uses that they sought to protect by law. Accordingly, the North Carolina General Assembly required the SSSC to identify the "best usage" of the state's water resources, then to adopt associated water quality standards to protect those uses.[12] Regulations adopted to implement the CWA similarly required each state to "specify appropriate water uses to be achieved and protected" before adopting water quality standards.[13]

The early evolution of water pollution control in North Carolina serves as an important reminder that the use for which the law seeks to preserve our waters is the primary driver of the standards imposed on the regulated community. As explained below, one problem with the proposal to reclassify a portion of the Cape Fear River as a swamp is that it materially alters an important use for which the river is currently protected. In Section II, we examine the connection between use classifications and associated quality standards.

II. "Best Usage" and Classification of Water Bodies

Today, each state has a duty to adopt water quality standards under the CWA in order to protect public health or welfare, enhance the quality of water, and otherwise serve the purposes of the CWA.[14] As part of this first step in setting appropriately protective water quality standards, states must assign classifications to surface waters within their borders that identify the uses that each water body must support, and then set criteria necessary to protect the uses.

Accordingly, the uses for which the North Carolina Environmental Management Commission (EMC)[15] intends to protect North Carolina's waters are reflected in its assignment of water body classifications. The classification of a water body dictates the applicable water quality standards, which are in turn designed to protect the "best usage" of the waters with that classification.[16] The law requires the EMC to consider multiple factors before determining the classifications of waters. First, it must consider physical characteristics, including "the size, depth, surface area covered, volume, direction and rate of flow, stream gradient and temperature

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[11] *Id.* § 1252(a). North Carolina's water quality classifications must be consistent with the requirements of the CWA.
[12] Session Laws and Resolutions, N.C. General Assembly 1951 ch. 606.
[13] 40 C.F.R. § 131.10(a).
[14] 40 C.F.R. § 131.2.
[15] Many duties originally assigned to the State Stream Sanitation Committee, including those related to the classification of waters, were conferred on the Board of Water and Air Resources in 1967, 1967 N.C. Sess. Laws 1967-892 (1967), and then on the EMC in 1973, 1973 N.C. Sess. Laws 1973-1262 § 19 (1973).
[16] *See* N.C. Gen. Stat. 143-214.1(a)(1) (directing the EMC to develop "a series of classifications and the standards applicable to each such classification"); 15A N.C. Admin. Code 2B .0201 ("Existing uses . . . and the water quality to protect such uses shall be protected by properly classifying surface waters and having standards sufficient to protect these uses."); *see also* 40 C.F.R. § 131.11(a)(1) ("States must adopt those water quality criteria that protect the designated use. . . . For waters with multiple use designations, the criteria shall support the most sensitive use.")

of water."[17] It must also consider whether the "character of the district bordering said water" evinces suitability for, or established economic interest in, a particular use of the water.[18] Most importantly, the EMC must consider the uses that "have been made, are being made, or may in the future be made" of the water.[19] Ultimately, the EMC must adopt classifications and the associated standards "with primary reference to the best usage to be made of the waters to which such classification will be assigned."[20]

Pursuant to this statutory guidance, the EMC developed eight freshwater classifications, four saltwater classifications, and seven supplemental classifications for potential assignment to waters of the state.[21] Some classifications are based on the type of human use for which waters are protected.[22] Some classifications recognize that use of waters by aquatic life requires different protection in freshwater and saltwater.[23] Other classifications, particularly those designed to protect sources of drinking water, are based on the degree of development in the watershed.[24] And some of the primary classifications, like the two reserved for wetlands (Class WL for freshwater; Class SWL for saltwater) reference specific physical characteristics of the waters. The variety of available water body classifications demonstrates that the EMC realized that different uses require different protections. While these broad classifications are often sufficient to protect the best usage of waters, sometimes a more nuanced approach, involving the application of supplemental classifications, is required.

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[17] N.C. Gen. Stat. § 143-214.1.
[18] *Id.* § 143-214.1(d)(2).
[19] *Id.* § 143-214.1(d)(3) (requiring the EMC to consider "[t]he uses and extent thereof which have been made, are being made, or may in the future be made, of such water for domestic consumption, bathing, fish or wildlife and their culture, industrial consumption, transportation, fire prevention, power generation, scientific or research uses, the disposal of sewage, industrial wastes and other wastes, or any other uses"); *see also* 15A N.C. Admin. Code 2B .0101 (requiring consideration, in addition to the uses listed in G.S. 143-214.1(d), of "all existing uses" of the water body in question).
[20] N.C. Gen. Stat. § 143-214.1(b).
[21] 15A N.C. Admin. Code 2B .0101.
[22] For example, while waters in classes C, B, SC, and SB are all protected for "secondary recreation, fishing, aquatic life including propagation and survival, and wildlife," 15A N.C. Admin. Code 2B .0101(c)(1), (2); 15A N.C. Admin. Code 2B .0101(d)(1), (2), Class B and SB waters are also "protected for primary recreation." *Id.* 2B .0220(c)(1)-(2); *id.* 2B .0220(d)(1)-(2). "Primary recreation" contemplates uses "involving human body contact . . . on a frequent basis," *id.*2B .0202(52), while "secondary recreation" contemplates uses "involving human body contact with water . . . on an infrequent, unorganized, or incidental basis," *id.* 2B .0202(57).
[23] For fresh water, the default classification is Class C. 15A N.C. Admin. Code 2B .0211 ("The water quality standards for all fresh surface waters shall be the basic standards applicable to Class C waters. . . . Additional and more stringent standards applicable to other specific freshwater classifications are specified [elsewhere in] this Section."). For salt water, the default classification is Class SC. 15A N.C. Admin. Code 2B .0220 ("The water quality standards for all tidal salt waters shall be the basic standards applicable to Class SC waters. Additional and more stringent standards applicable to other specific tidal salt water classifications are specified in Rules .0221 and .0222 of this Section.").
[24] See 15A N.C. Admin. Code 2B .0101(c)(3)-(6) (listing different classifications for water supplies in "natural and undeveloped watersheds," "predominantly undeveloped watersheds," "low to moderately developed watersheds," "moderately to highly developed watersheds," and "moderately to highly developed watersheds").

Supplemental classifications are used to focus pollution control narrowly by enhancing protection in accordance with specific features of a water body. Many supplemental classifications are therefore based on the water body's physical, biological, or chemical characteristics. For instance, the "Nutrient Sensitive Waters" or "NSW" classification is reserved for "waters subject to growths of microscopic or macroscopic vegetation requiring limitations on nutrient inputs,"[25] and it requires development of strategies to control eutrophication "so that existing and designated uses of the water body are protected or restored."[26] Likewise, waters classified as trout waters (i.e., those that will "sustain and allow for trout propagation and survival of stocked trout on a year-round basis"[27]) are afforded additional protection against pollutants harmful to those fish.[28] Of particular relevance to the proposal under consideration, "waters which have low velocities and other natural characteristics which are different from adjacent streams" may be assigned a supplemental classification as "swamp waters."[29]

III. "Swamp Waters" Classification

The "swamp waters" classification is intended to protect the unique aquatic community adapted to natural conditions found in swamps. Accordingly, the water quality standards associated with the "swamp waters" classification are designed to protect the use of waters for aquatic life propagation and survival that naturally occur in swamp waters.[30] Specifically, the EMC allows certain swamp waters to have higher acidity (i.e., low pH) and lower dissolved oxygen (DO) concentrations.[31]

This is significant because the use of waters for the survival and propagation of aquatic life (i.e., aspects of the "best usage" of Class SC and Class C waters that are not also classified as swamp waters) usually requires *higher* pH and DO levels. Fish production is generally higher in more alkaline waters (i.e., those with high pH),[32] and low pH can limit development and survival

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[25] *Id.* 2B .0101(e)(3).
[26] 15A N.C. Admin. Code 2B .0223(e).
[27] 15A N.C. Admin. Code 2B .0202(65).
[28] *See, e.g.,* 15A N.C. Admin. Code 2B .0211 (stating different standards for chlorophyll-a, dissolved oxygen, cadmium, temperature, and turbidity for designated trout waters).
[29] *Id.* 2B .0101(e)(2).
[30] In contrast, other supplemental classifications result in application of more stringent water quality standards. *See, e.g.,* 15A N.C. Admin. Code 2B .0211(4) (more stringent freshwater chlorophyll-a standards for nutrient-sensitive waters and trout waters); *id.* 2B.011(6) (more stringent DO standards for trout waters); *id.* 2B .0211(19) (toluene standard applicable only to trout waters); *id.* 2B .0211(21) (more stringent turbidity standard for trout waters); *id.* 2B .0220(3) (more stringent saltwater chlorophyll-a standards for nutrient sensitive waters and trout waters); *id.* 2B .0223 (requiring development of nutrient control strategies in nutrient sensitive waters); *id.* 2B .0224 (stating standards applicable to high-quality waters); *id.* 2B .0225 (stating standards for outstanding resource waters). The State's antidegradation policy is also stricter for waters classified as high-quality waters or outstanding resource waters. *Id.* 2B .0201.
[31] 15A N.C. Admin. Code 2B .0211(6), (14) (permitting lower pH and DO standards for Class C waters with the supplemental "swamp waters" classification); 15A N.C. Admin. Code 2B .0220(5), (12) (permitting lower pH and DO standards for Class SC waters with the supplemental "swamp waters" classification).
[32] Louis A. Helfrich et al, *Liming Acidified Lakes and Ponds*, Virginia Cooperative Extension Pub. 420-254 (2009).

of shellfish by inhibiting shell development.[33] In addition, pH affects the solubility and biological availability of nutrients and heavy metals.[34] Low pH can therefore limit the nutrients available for plant growth and increase the toxicity of metals.

Similarly, DO is critical to the survival of fish and other aquatic life, and lower concentrations are typically detrimental.[35] The EMC recognized this fact when requiring higher DO concentrations in trout waters.[36] In waters with low levels of DO, finfish and mobile macroinvertebrates can experience negative impacts ranging from mortality to impaired reproduction, immune responses, and growth.[37] DO is also critical to the decomposition of organic matter in the water and bottom sediments.

In Class SC waters like the lower Cape Fear River, the normal dissolved oxygen standard is 5.0 mg/L.[38] But the law provides that "swamp waters . . . may have lower values if caused by natural conditions."[39] Similarly, while the pH in Class SC waters should be "normal for waters in the area, which range between 6.8 and 8.5,"[40] Class SC waters with the supplemental "swamp waters" classification "may have a pH as low as 4.3 if it is the result of natural conditions."[41] Indeed, the primary consequence of a supplemental designation as swamp waters is the lowering of pH and DO levels to ensure that the standards protect natural conditions.

Ultimately, the standards for pH and DO in swamp waters reflect the EMC's acknowledgment that certain aquatic species have adapted to conditions in relatively stagnant waters, where natural characteristics and processes have combined to alter the chemical composition of the aquatic environment.[42] However, lowering pH and DO where natural conditions have *not* prepared aquatic life for these stressors can have a negative impact on the usage of waters for the propagation and survival of aquatic life. This is why it is only acceptable

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[33] Saskia de Melker, *Coral Reefs and Shellfish Battle Acidifying Oceans*, PBS Newshour (Dec. 5, 2012) ("As acidity increases, animals like scallops, oysters, and clams have a harder time extracting the calcium carbonate they need to build their essential shells. Shells become thinner, growth slows down, and death rates rise."), *available at* http://www.pbs.org/newshour/updates/climate-change-july-dec12-acidification_12-05/

[34] US Geological Survey Water Science School, *ph – Water properties* (2014), available at http://water.usgs.gov/edu/ph.html.

[35] US EPA, Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras 4 (Nov. 2000) ("Oxygen is essential in aerobic organisms for the electron transport system of mitochondria. Oxygen insufficiency at the mitochondria results in reduction in cellular energy and a subsequent loss of ion balance in cellular and circulatory fluids."), *available at* http://water.epa.gov/scitech/swguidance/standards/upload/2007_03_01_criteria_dissolved_docriteria.pdf.

[36] 15A N.C. Admin. Code 2B .0220(6).

[37] Denise L. Brietburg et al, Hypoxia, Nitrogen, and Fisheries: Integrating Effects Across Local and Global Landscapes, 1 Annual Review of Marine Science 333-35 (2009), *available at* http://moritz.botany.ut.ee/~olli/eutrsem/Breitburg09.pdf.

[38] 15A N.C. Admin. Code 2B .0220(5).

[39] *Id.*

[40] 15A N.C. Admin. Code 2B 2B .0220(12).

[41] *Id.*

[42] US EPA, Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras 5 (Nov. 2000) ("Compensatory adaptations are well developed in marine animals that commonly experience hypoxia.").

for a water body designated as swamp waters to have lower pH and DO when "caused by" or the "result of" natural conditions.[43]

IV. The EMC Must Not Ignore the Defining Characteristics of Swamp Waters

The members of the Lower Cape Fear River Program (Petitioners), a collection of permitted wastewater dischargers, have asked the EMC to reclassify a segment of the Cape Fear River as swamp waters.[44] Although Petitioners argue that pH and DO levels in the Cape Fear River are the result of "natural conditions," they ignore the fact that the river lacks the natural *characteristics* that define swamp waters. The first problem with the proposal to reclassify this segment is that doing so would be directly contrary to the EMC's own definition of "swamp waters."

State regulations provide multiple definitions of "swamp waters," and in each the defining characteristic is low velocity.[45] Although Petitioners claim to support their reclassification request with "a wealth of research and technical assessment studies," data about velocity are conspicuously absent from their petition. The lack of velocity data is particularly notable given that Petitioners have a web of monitoring stations, including multiple stations in the affected segment; apparently none of the stations monitors or records velocity data.[46] Yet this is precisely the kind of "data and information required for determining" whether classification of the segment as "swamp waters" is appropriate.[47]

Given the dearth of data provided by Petitioners, it should be noted that data confirm that the Cape Fear River, in fact, has a high velocity. Studies by U.S. Army Corps of Engineers confirm that velocity in the lower Cape Fear River regularly exceeds 2 ft/s.[48] The National

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[43] 15A N.C. Admin. Code 2B .0211(6), (14); 15A N.C. Admin. Code 2B .0220(5), (12).

[44] Specifically, Petitioners seek reclassification of a portion of the river consisting of section 19-(71) from upstream of the mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut.

[45] 15A N.C. Admin. Code 02B .0101(e)(2) ("Swamp waters (Sw): waters which have low velocities and other natural characteristics which are different from adjacent streams"); 15A N.C. Admin. Code 02B .0202(62) ("Swamp waters mean those waters which are classified by the Environmental Management Commission and which are topographically located so as to generally have very low velocities and other characteristics which are different from adjacent streams draining steeper topography."); 15A N.C. Admin. Code 02B .0301(c) (defining swamp waters as "Waters which have low velocities and other natural characteristics which are different from adjacent streams").

[46] To its credit, the coalition has collected a wealth of data about other parameters, including temperature, pH, dissolved oxygen, conductivity, fecal coliform, enterococcus, turbidity, suspended residue, chlorophyll-a, NH3-N, TKN-N, NO2-NO3, Phosphorus, Cadmium, Chromium, Copper, Nickel, Lead, Zinc, Aluminum, Iron, Manganese, Mercury, Arsenic, and Hardness. http://lcfrp.uncw.edu/riverdatabase/queryAll.php?type=parameter.

[47] *See* 15A N.C. Admin. Code 2B .0101(b) (stating that the EMC may only make a classification determination after "appropriate studies of the identified waters to obtain the data and information required for determining the proper classification of the waters or segments of water are completed").

[48] Robert T. McAdory, Jr., *Cape Fear-Northest Cape Fear River, North Carolina, Numerical Model Study* (August 2000), *available at* http://acwc.sdp.sirsi.net/client/search/asset/1000633. Also, data collected by the US Geological Survey (USGS) at Lock & Dam 1 upstream of the affected segment shows that since 1982, the monthly mean discharge has ranged from 9,740 ft3/s in March to 2,940 ft3/s in August. *See* USGS, *Monitoring Station 02105769 on the Cape Fear River at Lock #1 near Kelly, NC* (2015),

Oceanic and Atmospheric Administration predicts that velocities at a monitoring station in the segment of the Cape Fear River proposed for reclassification will reach as high as 2.4 knots (4.1 ft/s) in 2015.[49] For comparison, the average velocity of the Mississippi River is near 1.2 miles per hour (1.8 ft/s) at the headwaters and 3 miles per hour (4.4 ft/s) near New Orleans.[50] Relatively high flow rates have also been documented in studies comparing the Cape Fear River estuary to others in the Southeast.[51] Indeed, the flushing effect of the high-velocity flow of the Cape Fear River has been credited with limiting the prevalence of harmful algal blooms,[52] influencing the migration patterns of local aquatic life,[53] and affecting the location of saltwater intrusion in the estuary.[54]

It would be contrary to the plain language of the law to apply to the fast-moving main stem of the Cape Fear River a "swamp water" classification reserved for waters with "low velocities" or "very low velocities." The EMC should not ignore the definition of the classification—which, critically, includes the velocity—in order to permit lower standards for DO and pH in a high-velocity segment of the river.[55] Notably, in addition to explicit consideration of velocity, the definition of "swamp waters" contemplates waters with "natural characteristics which are different from adjacent streams."[56] Yet Petitioners' argument rests on the alleged *similarity* of natural characteristics in adjacent streams.[57] The EMC should apply its

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http://waterdata.usgs.gov/nwis/monthly/?search_site_no=02105769&agency_cd=USGS&referred_module=sw&format=sites_selection_links.

[49] National Oceanic and Atmospheric Association, *Tides and Currents—2015 Tidal Current Predictions* (2015), http://tidesandcurrents.noaa.gov/get_predc.shtml?year=2015&stn=5133+Charleston Harbor&secstn=Wilmington&sbfh=%2B3&sbfm=52&fldh=%2B4&fldm=07&sbeh=%2B2&sbem=48&ebbh=%2B3&ebbm=07&fldr=0.8&ebbr=0.7&fldavgd=337&ebbavgd=153&footnote=

[50] U.S. National Park Service, Mississippi River Facts (2015), http://www.nps.gov/miss/riverfacts.htm

[51] Richard Dame et al, *Estuaries of the South Atlantic Coast of North America: Their Geographical Signatures*, 23 Estuaries 798 t.1 (2000). Of particular relevance, the data showed higher velocity flows in the Cape Fear estuary than in either the Pamlico or Neuse River estuaries. *Id.*

[52] Michael Mallin et al, *North and South Carolina Coasts*, 41 Marine Pollution Bulletin 56, 58 (2000) ("Well-flushed sounds or unconstrained rivers (such as the Cape Fear system) maintain much lower phytoplankton biomass and productivity."); *id.* at 60 (Well-flushed systems like euhaline sounds, and open rivers like the Cape Fear rarely host algal blooms)

[53] Michael P. Weinstein et al, *Retention of Three Taxa of Postlarval Fishes in an Intensively Flushed Tidal Estuary, Cape Fear River, North Carolina*, 78 Fishery Bulletin 419 (1980) (noting that "[t]idal velocities in the Cape Fear are high" and observing behavioral responses that enable fish to "avoid being flushed seaward"), *available at* http://fishbull.noaa.gov/78-2/weinstein.pdf.

[54] May Ling Becker, *Hydrodynamic Behavior of the Cape Fear River and Estuarine System: A Synthesis and Observational Investigation of Discharge-Salinity Intrusion Relationships*, 88 Estuarine, Coastal and Shelf Science 407 (May 2010).

[55] N.C. Gen. Stat. § 143-214.1.

[56] 15A N.C. Admin. Code 02B .0101(e)(2); 15A N.C. Admin. Code 02B .0301(c); see also 15A N.C. Admin. Code 02B .0202(62) (noting that swamp waters have, other than characteristically low velocity, "other characteristics which are different from adjacent streams draining steeper topography.").

[57] Petitioners contend that changing the classification of the river would "recognize the influence" of "riverine wetland and salt marsh systems that are ubiquitous" in the region and "be consistent with the classifications of [the] immediate upstream segment of the Cape Fear River and the tributaries which all currently carry the supplemental Sw classification." Chris May, Request for Reclassification of a Portion of the Lower Cape Fear River with the Supplemental Swamp Classification (March 5, 2014).

own definition of "swamp waters" and reject the proposal to misapply that supplemental classification to the lower Cape Fear River.

V. The EMC Must Not Prioritize Wastewater Discharge over Best Usage

In addition to ignoring the definition of "swamp waters" adopted by the EMC, Petitioners ignore the very purpose of classification: to protect the best usage of the water body. Petitioners make no argument that reclassification would protect the "best usage" of the segment in question. Nor do they challenge the State's oft-repeated observation that low pH and DO levels have impaired existing use of the river by aquatic life in the segment.[58] Indeed, Petitioners make no attempt to argue that classifying the river as "swamp waters" would adequately protect use of the river by aquatic life.[59]

Instead, Petitioners focus on *their* use of the river. Petitioners want the EMC to relax water quality standards so they can discharge wastewater into the river without implementing additional pollution controls necessary to protect aquatic life.[60] In other words, rather than trying to meet current standards designed to protect the best usage of the waters, Petitioners want the standards changed to accommodate their preferred usage. Since federal law explicitly prohibits the State from adopting "waste assimilation" as a designated use of the Cape Fear River,[61] Petitioners are asking the EMC to reclassify the river in a way that would allow their continued use of the river for precisely that purpose to the detriment of other designated uses.

To be clear, no one is arguing that Petitioners must stop discharging wastewater into the river. The water quality standards in place were drafted in contemplation of the effect of "the discharge of sewage, industrial wastes or other wastes including those from nonpoint sources and other sources of water pollution."[62] However, reclassification for the purpose of masking the impact of such water pollution on aquatic life is unacceptable.[63] If Petitioners want permission from the EMC to discharge effluent with pH and DO concentrations below those appropriate for class SC waters, they should seek a variance through the permitting process.[64] But the EMC must

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[58] *See, e.g.*, NC DENR, *North Carolina 303(d) List-2006* 19 (June 19, 2007) (noting impairment of use by aquatic life); NC DENR, *2014 Category 5 Water Quality Assessments-303(d) List* 3 (Dec. 19, 2014) (same).

[59] *But see* 40 C.F.R. § 131.10(a)(1) ("Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.").

[60] Current impairment of use of the river by aquatic life requires the development and implementation of a TMDL, which would include waste load allocations applicable to Petitioners.

[61] 40 C.F.R. § 131.10 ("In no case shall a State adopt waste transport or waste assimilation as a designated use for any waters of the United States.").

[62] 15A N.C. Admin. Code 2B .0205.

[63] *See* N.C. Gen. Stat. § 143-214.1(b) (directing the EMC to adopt classifications "with primary reference to the best usage to be made of the waters to which such classification will be assigned").

[64] N.C. Gen. Stat. § 143-215.3(e); 15A NCAC 2B.0226 ("Variances from applicable standards, revisions to water quality standards or site-specific water quality standards may be granted by the Commission on a case-by-case basis pursuant to G.S. 143-215.3(e), 143-214.3 or 143-214.1."). That way, their exemption, if granted from existing water quality standards could at least be reviewed as part of the triennial review of water quality standards required under federal law. *See* 15A N.C. Admin. Code 2B .0226.

not pretend that the "best usage" of the river is achieved through attainment of uncharacteristically and unnaturally low pH and DO standards that are associated with swamp waters.

Petitioners do not deny that their discharges contribute to the current impairment of the "best usage" of the river by aquatic life. This impairment was first recognized in 1998, when DENR observed that low DO concentrations meant the river was only providing "partial support" for designated use and opined that Petitioners may be to blame.[65] Even the materials offered in support of their petition establish that Petitioners' discharge contributes to the low pH and DO conditions observed in the river, although Petitioners maintain that their impact is "minor."[66]

Petitioners cite studies which they believe demonstrate that even with significant reductions in pollutant loads, dissolved oxygen in the lower Cape Fear River would occasionally fall below the current standard during summer months.[67] Petitioners apparently assume that aquatic life cannot be adequately protected if, following implementation of additional pollution controls, occasional seasonal drops in pH and DO are observed.[68] Consequently, they want the EMC to assign to the river a classification that would avoid the need to implement those additional pollution controls. Yet, when classifying the lower Cape Fear River as Class SC waters, the EMC recognized that "natural waters may on occasion, or temporarily, have characteristics outside of the normal range established by the standards" and "water quality standards will not be considered violated when values outside the normal range are caused by natural conditions."[69] In other words, the current SC classification is designed to protect use of the river for aquatic life propagation and survival *despite* occasional periods of low DO and pH in the summer months caused by natural conditions.[70] Since use of the river for aquatic life propagation and survival is possible with reasonable pollution control, the EMC should reject the proposal to lower water quality standards through reclassification and instead attempt to actually control pollution that is impairing existing use of the river by aquatic life.[71]

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[65] NC DENR, North Carolina's 1998 303(d) List T-6 (May 15, 1998) (Noting that of the 7,500 acres providing only "partial support" of designated uses, 5,000 were impaired by DO and listing wastewater treatment plants as a source of the impairment.), *available at* http://portal.ncdenr.org/c/document_library/get_file?uuid=2284d944-2134-4c57-a2d9-499c58076d4a&groupId=38364

[66] Letter from Chris May, Chair, Lower Cape Fear River Program Advisory Board, to Tom Reeder, Director, DENR-Division of Water Resources D-4 (March 5, 2014).

[67] *Id.* at D-5.

[68] Notably, oxygen solubility decreases with increasing water temperatures, so lower DO in warmer summer months is unremarkable.

[69] 15A N.C. Admin. Code. 2B .0205.

[70] Even if summertime exceedances of WQS could merit reclassification, there may exist reasonable alternatives to lowering the standards for the entire year. See 40 C.F.R. § 131.10(f) ("States may adopt seasonal uses as an alternative to reclassifying a water body or segment thereof to uses requiring less stringent water quality criteria. If seasonal uses are adopted, water quality criteria should be adjusted to reflect the seasonal uses, however, such criteria shall not preclude the attainment and maintenance of a more protective use in another season.").

[71] 40 C.F.R. § 131.10(d) (stating that "uses are deemed attainable if they can be achieved by the imposition of effluent limits . . . and cost-effective and reasonable best management practices for nonpoint source control").

By lowering pH and DO standards through reclassification, the EMC would instead further limit use of the river by aquatic life, the very use that has long been impaired by pH and DO levels, by allowing persistent, rather than occasional, conditions of low pH and DO. Essentially, reclassification would serve to authorize increased water pollution by existing point and nonpoint sources. The EMC must not apply a classification that would effectively remove an existing use.[72]

In sum, the proposal under consideration would see the EMC abandon efforts to protect the best usage of the Cape Fear River by aquatic life and instead substantially lower the applicable water quality standards for pH and DO to appease polluters who would otherwise be required to limit their pollution of North Carolina's waters. Rather than bless the degradation of water quality and wildlife habitat in the river, the EMC should reject the proposal to reclassify the Cape Fear River as swamp waters.

VI. The EMC Should Protect Use of the Cape Fear by Aquatic Life

The use of the lower Cape Fear River for the survival and propagation of aquatic life is too important to ignore or restrict through reclassification. Petitioners note that the segment in question was once classified as swamp waters, but fail to mention that the State explicitly admitted that this was the result of inadequate consideration of the best usage of the waters by aquatic life.[73] In 1981, the EMC observed that "a low pH is detrimental to shellfish propagation" and that "it is incompatible to have a classification of SA-Sw" in the lower Cape Fear River.[74] Accordingly, the EMC removed the swamp waters classification from the segment Petitioners now seek to have reclassified, as it was immediately upstream of waters classified for commercial production of shellfish and removal of the swamp waters designation was necessary to prevent impairment of the best usage of those downstream waters.[75]

In other words, swamp water classification was removed from this segment to protect aquatic life; the EMC should not repeat the mistake of ignoring effects on aquatic life by again classifying the river as swamp waters. As noted above, higher pH and DO concentrations are required to protect aquatic species unaccustomed to life in stagnant swamp waters. Low pH is

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[72] 40 C.F.R. § 131.10(h)(1) (prohibiting removal of an existing use unless a use requiring more stringent criteria is added). As previously discussed, swamp water classification involves less stringent criteria than are otherwise applicable to SC waters. At minimum, the State should conduct a use attainability analysis before applying a supplemental classification which requires less stringent criteria. 40 C.F.R.§ 131.10(j)(2).

[73] N.C. Dep't of Natural Resources and Community Development, Report of Proceedings Concerning the Proposed Reclassification of South Creek in the Tar-Pamlico River Basin and the Removal of the Swamp Water Designation from Waters in the Neuse River Basin and Cape Fear River Basin ii (1981) ("As a low pH is detrimental to shellfish propagation, it is incompatible to have a classification of SA-Sw. When the original classification of all river basins was done, this fact was recognized in all basins except the Neuse and Cape Fear.").

[74] *Id.*

[75] The segment Petitioners now seek to reclassify was immediately upstream of waters classified for commercial production of shellfish and removal of the swamp water designation was necessary prevent impairment of the best usage of those downstream waters. 40 C.F.R. § 131.10(d) ("In designating uses of a water body and the appropriate criteria for those uses, the State shall take into consideration the water quality standards of downstream waters and shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters."); 15A N.C. Admin. Code. 2B .0203.

particularly dangerous for shellfish, as noted when the EMC classified the segment as Class SC. Moreover, the portion of the river proposed for reclassification plays a critical role in the early life cycles of aquatic life and is home to endangered species.

In late winter, migratory fish including striped bass, Atlantic sturgeon, and American shad migrate from the ocean and lower Cape Fear estuary to spawn upstream in the main stem of the Cape Fear River.[76] Although adult fish return to the ocean or lower estuary after spawning, juveniles remain in nursery habitats through the summer before migrating seaward in late fall.[77] The segment proposed for reclassification includes habitat designated as primary nursery areas by the Division of Marine Fisheries (DMF).[78] Primary nursery areas (PNAs) are those "in the estuarine system where initial post-larval development takes place" and "populations are uniformly early juveniles."[79] The affected segment is also designated as an anadromous fish spawning area (AFSA) by DMF and the Wildlife Resources Commission.[80] This means "evidence of spawning anadromous fish has been documented in [DMF] sampling records through direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae."[81]

Although swamp water classification is not entirely inconsistent with labeling waters as a PNA or AFSA, care must be exercised to avoid inappropriate swamp water classification that would impact finfish at early stages of development. Low dissolved oxygen levels can be particularly problematic in spawning and nursery areas because hypoxia "causes substantial mortality of developing embryos."[82] For this reason, EPA recommends more stringent dissolved oxygen criteria for the early life stages of both coldwater and warmwater fish.[83]

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[76] Cape Fear River Partnership, Cape Fear River Basin Action Plan for Migratory Fish 18 (April 2013), *available at* http://www.habitat.noaa.gov/protection/capefear/pdf/CapeFearActionPlan.pdf

[77] *Id.*

[78] 15A N.C. Admin. Code 3R .0103.

[79] 15A N.C. Admin. Code 3I .0101; *see also* 15A N.C. Admin. Code 2B .0202 ("Primary Nursery Areas (PNAs) are tidal saltwaters which provide essential habitat for the early development of commercially important fish and shellfish and are so designated by the Marine Fisheries Commission.").

[80] 15A N.C. Admin. Code 3R .0115(25); see also Division of Marine Fisheries, Anadromous Fish Spawning Areas (AFSA): Cape Fear River Area, Map 7, *available at* http://portal.ncdenr.org/c/document_library/get_file?uuid=f810ae29-ea4d-4801-a04f-850ff2bc4467&groupId=38337

[81] Anadromous fish spawning areas are those "where evidence of spawning anadromous fish has been documented in Division sampling records through direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae." 15A N.C. Admin. Code 3I .0101(4)(b).

[82] Denise L. Brietburg et al, Hypoxia, Nitrogen, and Fisheries: Integrating Effects Across Local and Global Landscapes, 1 Annual Review of Marine Science 333 (2009)("Developing embryos are particularly sensitive because they lack the ability to behaviorally respond to low oxygen and because oxygen must diffuse across the chorion that encases the embryo."), *available at* http://moritz.botany.ut.ee/~olli/eutrsem/Breitburg09.pdf.

[83] US EPA, *Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*, app. I (Nov. 2000), *available at* http://water.epa.gov/scitech/swguidance/standards/upload/2007_03_01_criteria_dissolved_docriteria.pdf.

In addition to playing a role in the life cycles of multiple fish species, the lower Cape Fear River is home to two endangered species of sturgeon, suggesting a need for more stringent environmental protection.[84] "Maintenance and recovery of the water quality conditions required to sustain and recover federally-listed threatened and endangered aquatic animal species contributes to the support and maintenance of a balanced and indigenous community of aquatic organisms and thereby protects the biological integrity of the waters."[85] As such, the EMC should refrain from classification that could instead prove harmful to endangered aquatic life.

First, the lower Cape Fear is home to the Atlantic sturgeon, a species that NOAA's National Marine Fisheries Service first listed as endangered in 2012. Although the harvest of Atlantic sturgeon has been banned since 1991, the Atlantic States Marine Fisheries Commission (ASMFC) has stated that fishery management measures alone will not sustain stocks of Atlantic sturgeon without sufficient quality and quantity of habitat. As such, it bears emphasis that the estuarine waters of the lower Cape Fear river are precisely the type where juvenile Atlantic sturgeon "for months to years before emigrating to open ocean."[86] Moreover, ASMFC studies demonstrate that DO concentration is a "key habitat parameter[] for the structuring of juvenile Atlantic sturgeon habitat."[87] The EMC should not lower water quality standards in the Cape Fear and thereby further threaten the survival of this species.

The Lower Cape Fear also hosts a population of shortnose sturgeon, a species recognized by the federal government as endangered in 1967 and subject to a fishing moratorium since 1991. Juvenile shortnose sturgeon tend to locate in estuarine waters such as those in the segment proposed for reclassification. Consequently, "protection of essential habitats, especially nursery/summer habitats, from human caused dissolved-oxygen reductions and other impacts is critical."[88] The EMC should not relax such protection and subject this already endangered species to additional environmental stressors.

Instead, the EMC should hold the line in the fight against degrading water quality in the lower Cape Fear River. Petitioners would have the State simply quit trying to protect this resource for use by aquatic life that requires "normal" pH levels above 6.8 and/or DO levels of above 5.0 mg/L. Petitioners essentially claim that because their best efforts will not achieve universal year-round attainment of desired pH and DO levels and eliminate all naturally caused occasional exceedances of current standards, those standards should be replaced with standards designed to allow persistent low DO and pH levels to protect use of different aquatic environments. The EMC should not accept Petitioner's invitation to view the perfect as the

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[84] *See* Mary L. Moser & Steve W. Ross, *Habitat Use and Movements of Shortnose and Atlantic Sturgeon in the Lower Cape Fear River, North Carolina*, 124 Transactions of the American Fisheries Society 225 (1995).
[85] 15A N.C. Admin. Code 2B .0110.
[86] Atlantic Marine Fisheries Commission, *Habitat Addendum IV to Amendment I to the Fishery Management Plan for Atlantic Sturgeon* 2(Sept. 2012), *available at* http://www.asmfc.org/uploads/file/sturgeonHabitatAddendumIV_Sept2012.pdf
[87] *Id.*at 3.
[88] Mark R. Collins et al, *Primary Factors Affecting Sturgeon Populations in the Southeastern United States: Fishing Mortality and Degradation of Essential Habitats*, 66 Bulletin of Marine Science 917, 917 (2000), *available at*

enemy of the good. Instead, we urge the EMC to continue to manage the lower Cape Fear River so as to provide for the best usage of the water body.

VII. Management Plan

The management plan suggested by Petitioners is not designed to achieve best usage of the river and should also therefore be rejected by the EMC. Water quality management plans are supposed to be developed "to attain, maintain or enhance water quality."[89] Yet, the proposed management plan is only being put forth in recognition of the fact that classifying the lower Cape Fear River as swamp waters would lower water quality standards. As explained above, the best way for the EMC to attain, maintain or enhance water quality is to leave in place existing water quality standards and strive to attain them. Instead, the EMC is considering a management plan that starts from the premise that target goals for pH and DO in the river should be lowered.

There are a number of problems with the management plan beyond the fact that it represents a refusal to manage the river to achieve its currently defined "best usage." To begin, the plan would only apply to "new individual NPDES wastewater discharges and expansions of existing NPDES wastewater dischargers." As such, no currently permitted operations would be impacted (i.e., the effluent limits expressed in Petitioner's current NPDES permits would not be amended). In other words, just as Petitioners seek to minimize their responsibility for existing impairment of aquatic life use in the river, they also seek to minimize their responsibility for improving conditions in the river. Moreover, while Petitioners point to studies claiming that point sources contribute less than 10% of the waste load in the River, they propose a management plan that would do little to actually limit point source loading. First, due to its limitation to "individual" NPDES permittees, the management plan would not even apply to point sources operating under a general NDPES permit. The plan further limits its applicability to point sources with a provision noting that the State can impose "seasonal effluent limits for oxygen-consuming waste" on a "case-by-case basis in accordance with 15A NCAC 2B .0404." And even after substantial limitation, the management plan would not apply to point source loading in the tributaries that Petitioners claim are feeding low pH and DO waters into the segment they seek to protect through this management plan. In sum, the proposal would have the EMC adopt a management plan that applied only to a subset of point sources, only in the event of new or expanded operations, only if the permittee was not granted an exemption, and only in the area of the river where Petitioners insist point source waste loading is not resulting in impairment.[90]

Still, the greatest flaw of this management plant is that it makes no attempt to address the contribution of nonpoint sources to water pollution in the river, which are largely to blame for conditions in these tributaries. Most of the Concentrated Animal Feeding Operations (CAFOs) in the Cape Fear River basin, which produces 50% of North Carolina's swine and large numbers

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[89] *See* 15A NCAC 02B .0227.

[90] *See* Letter from Chris May, Chair, Lower Cape Fear River Program Advisory Board, to Tom Reeder, Director, DENR-Division of Water Resources D-18 (March 5, 2014) (claiming that the lower Cape Fear River estuary lacks "sensitivity to changes in point source loads").

of poultry, are in watersheds drained by blackwater streams.[91] Petitioners ignore scientific analysis showing that poorly regulated waste management practices of CAFOs mean that "large amounts of nitrogen and phosphorus enter the environment through runoff, percolation into groundwater, and volatilization of ammonia,"[92] all of which can exacerbate DO and pH levels. Indeed, Petitioners ignore data published on their own website showing a statistically significant increase in ammonium in the Northeast Cape Fear River (one of the tributaries Petitioners blame for impairment of the Cape Fear River) suggesting water quality degradation by animal farming operations.[93] "Hypoxia is regulated primarily by controlling nutrients (largely nitrogen) and other oxygen-demanding wastes."[94] Yet, the proposed management plan would neither attempt to limit nonpoint source loading of nutrients and oxygen-demanding waste in the segment Petitioners seek to reclassify nor address considerable loading in upstream tributaries that Petitioner's blame for currently impaired use of the river.

Lastly, the management plan does little to ensure its own effectiveness. The proposed language states that any new or expanded discharge "shall not cause the dissolved oxygen of the receiving water to drop more than 0.1 mg/L below the modeled in-stream dissolved oxygen at total permitted capacity." Again, the plan fails to require monitoring or reduction of the effects of pollutant loading by *existing* point sources or nonpoint sources. And, despite current impairment caused by low pH in the river, the plan would not monitor the effect on pH of additional pollutant loading. The plan also fails to explain how the State will identify the cause of potential future decreases of DO concentration; this is particularly problematic given that Petitioner's reclassification request highlights the difficulty of pinpointing the cause of decreases in DO concentration. Nor is there any explanation of how frequently waters will be monitored under the plan or how the prohibition against causing DO decreases will be enforced, if at all. Finally the plan makes no mention of biological monitoring to ensure that use of the river for aquatic life survival and propagation is actually improving.

Indeed, by disregarding its effect on aquatic life, the management plan bears strong resemblance to the associated reclassification proposal. The EMC should not grant Petitioner's request for permission to further impair use of the Cape Fear River by aquatic life, but should instead continue efforts to develop an appropriate Total Maximum Daily Load (TMDL) and strive to achieve currently applicable water quality standards.

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[91] Michael A. Mallin & Lawrence B. Cahoon, *Industrialized Animal Production—A Major Source of Nutrient and Microbial Pollution to Aquatic Ecosystems*, 24 Population and Environment 369, 369 (2003).
[92] *Id.* at 379.
[93] *Id.* at 376 (citing data "published by the Lower Cape Fear River Program (available at the website http://www.uncwil.edu/cmsr/aquaticecology/labrotory/lcfrp)
[94] US EPA, *Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*, at v (Nov. 2000), *available at* http://water.epa.gov/scitech/swguidance/standards/upload/2007_03_01_criteria_dissolved_docriteria.pdf.

VIII. Conclusion

For more than 30 years, the EMC has concluded that the best usage of the lower Cape Fear by aquatic life is protected by the water quality standards for pH and DO associated with Class SC waters and that swamp waters classification was not appropriate for that segment. More recently, the EMC has recognized that usage of the lower Cape Fear River by aquatic life is impaired by low pH and DO concentrations. The State should not abandon efforts to return these waters to the conditions that support their best usage. Rather than grant its imprimatur to increasing water pollution, the EMC should continue to strive to "maintain, protect, and enhance water quality within North Carolina.[95] Accordingly, we urge the EMC to reject the proposal to adopt the proposed classification and management plan.

Thank you for the opportunity to comment on this important matter.

Sincerely,

Will Hendrick

cc (by email):
Lauren Pedder, USEPA- Region 4
Peter Raabe, American Rivers
Grady McCallie, North Carolina Conservation Network
Kemp Burdette, Cape Fear RIVERKEEPER®
Julie Youngman, Southern Environmental Law Center

[95] N.C. Gen. Stat. § 143-215.2(b).

Petter, Lauren

From: Ryke Longest <longest@law.duke.edu>
Sent: Wednesday, April 15, 2015 2:59 PM
To: Godfrey, Annie
Cc: Petter, Lauren; kemp@cfrw.us; Frank Yelverton; Dacia Thompson; Sebastian Aviles; Kelly Hunter Foster; Gray Jernigan
Subject: Comments on the Lower Cape Fear River: swamp reclassification proposal by North Carolina
Attachments: Letter to EPA regarding the LCFR Reclassification proposal.pdf; Farm Bureau Lower Cape Fear Reclassification Comments 3-3-.pdf

Dear Ms. Godfrey,

Please see attached comments for your information. We look forward to helping clean up the lower Cape Fear River rather than reclassifying it as a swamp.

Ryke Longest
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April 15, 2015

Annie Godfrey
Chief, Water Quality Standards Section
U.S. Environmental Protection Agency, Region 4
61 Forsyth Street
Atlanta, Georgia 30303-8960
By electronic transmission to: godfrey.annie@epa.gov

Dear Ms. Godfrey,

This letter is in response to your comment letter on the "Proposed Swamp Reclassification with Water Quality Management Plan for Part of the Cape Fear River" ("the Proposal"). We have submitted comments in opposition to the proposal on behalf of the Waterkeeper Alliance and Cape Fear River Watch. We have attached our submitted comments for your review.

We are thrilled that you are participating in this process, and we generally agree with your comments and recommendations. But, we have requested that DENR reject the proposal outright and develop a TMDL for the LCFR. The proposal is just an end run around the TMDL process so that upstream CAFOs can continue polluting without regulation. Indeed, some CAFO supporters have already asserted that this proposal obviates the need for further regulation of CAFOs. (A copy of the North Carolina Farm Bureau's comments is attached for your information.) The technical memoranda fail to take account of the upstream CAFOs and instead attribute their contributions to natural causes. Consideration of non-natural sources in permitting decisions would be insufficient to address CAFO contributions to low DO because North Carolina refuses to regulate CAFOs in a manner which protects water quality in the Cape Fear River.

Please contact us with any questions or comments.

Sincerely,

/S/ Ryke Longest
Director

Attachments:
Duke Environmental Law and Policy Comments on behalf of Cape Fear River Watch and Waterkeeper Alliance
North Carolina Farm Bureau Comments

CC: Lauren Petter at petter.lauren@epa.gov

NORTH CAROLINA
FARM BUREAU FEDERATION, INC.

PO Box 27766, Raleigh, NC 27611 Phone: 919-782-1705 Fax: 919-783-3593 www.ncfb.org

March 3, 2015

Ms. Elizabeth Kountis
NC Division of Water Resources
Water Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611

Delivered via email: elizabeth.kountis@ncdenr.gov

Dear Ms. Kountis,

The North Carolina Farm Bureau (NCFB) is North Carolina's largest general farm organization, representing the interests of farm and rural people in our State. This letter is to comment on the proposed reclassification of a portion of the Lower Cape Fear River from Class SC to Class SC Sw waters by the Environmental Management Commission (EMC). This reclassification request was submitted by the Lower Cape Fear River Program, of which NCFB is an Advisory Board member. NCFB supports the reclassification request as proposed by the EMC.

The Lower Cape Fear River is currently on the 303(d) list as an impaired waterbody due to low dissolved oxygen. However, studies and modeling performed on behalf of the Lower Cape Fear River Program have established that the low dissolved oxygen is due to natural conditions. Specifically, natural drainage from riverine wetlands and marshes of the Black and Northeast Cape Fear Rivers results in dissolved oxygen levels less than 5 mg/l in the Lower Cape Fear River. Both the Black and Northeast Cape Fear Rivers currently have the supplemental Sw designations, and contribute significant flow to the Cape Fear River.

The supplemental Sw designation would allow dissolved oxygen to be less than 5 mg/l and the pH to be as low as 4.3, if caused by natural conditions. As demonstrated by the Lower Cape Fear River Program and discussed below, even significant reductions in both point and nonpoint source loadings would not result in attainment of the dissolved oxygen standard of 5 mg/l during summer months.

The Lower Cape Fear River Program developed a series of technical memos to support the reclassification request. Memo number two analyzes dissolved oxygen trends in the river since 1984. The analysis shows that dissolved oxygen levels have remained constant even with a 25 percent reduction in BOD loading from point sources over the same period. This analysis supports the conclusion that the dissolved oxygen impairment is a result of natural conditions. Memo number three analyzes water quality monitoring data at various locations in the watershed. The analysis shows that dissolved oxygen levels are consistently lower in the Black and Northeast Cape Fear Rivers (which currently carry the Sw designation) than at Lock and Dam 1 on the main stem of the Cape Fear. This analysis shows that dissolved oxygen levels in

the Lower Cape Fear River are negatively influenced by the natural swamp conditions of the Black and Northeast Cape Fear Rivers.

Memo number four summarizes two modeling efforts by Tetra Tech. The first model indicates that wetland/marsh and sediment oxygen demand accounts for 75 percent of oxygen demand in the Lower Cape Fear River. The second model shows that even with a 70 percent reduction in nonpoint source loading, the Lower Cape Fear River would still have dissolved oxygen levels below 5 mg/l 20 percent of the time in summer months. This memo demonstrates that natural conditions are the main contributor to the low dissolved oxygen levels of the lower Cape Fear River, and supports the Sw classification.

The proposed rule includes a point source management strategy. Due to existing requirements of the Primary Nursery Area designation and the accompanying HQW limits, DWR determined that there would be no additional cost to implement the point source strategy.

We recommend that no nonpoint source strategy be included in the final rule. Based on recent nutrient strategies (Jordan and Falls Lakes), any nonpoint source strategy will include all nonpoint source categories (agriculture, development, stormwater, etc.). Based on Tetra Tech models, even a 70% reduction in oxygen demanding load from nonpoint sources would not change the impaired status. However, adding a nonpoint source strategy would impose significant costs to the state for implementation, as well as to landowners, local governments, and farmers, without significant benefit.

NCFB supports this reclassification request as proposed, and encourages approval by the EMC without changes. As summarized above, the reclassification is warranted because the natural conditions of the Lower Cape Fear River, and the influence of the swamp waters of the Black and Northeast Cape Fear Rivers, result in dissolved oxygen levels below 5 mg/l.

Thank you for the opportunity to provide comments on the proposed Lower Cape Fear River reclassification. If you have questions about any of our comments or would like more information, you can contact me by phone at (919) 987-1257 or by email at keith.larick@ncfb.org.

Sincerely,

Keith Larick
Special Projects Director

Petter, Lauren

From: Petter, Lauren
Sent: Monday, April 20, 2015 4:25 PM
To: Ryke Longest
Subject: RE: Comments on the Lower Cape Fear River: swamp reclassification proposal by North Carolina

Ryke,

I did not see the comments to your letter attached, only the Farm Bureau comments. If they were in the hard copy only we can wait until we receive the hard copy if you don't have them handy electronically.

Thanks,
Lauren Petter

From: Ryke Longest [mailto:longest@law.duke.edu]
Sent: Wednesday, April 15, 2015 2:59 PM
To: Godfrey, Annie
Cc: Petter, Lauren; kemp@cfrw.us; Frank Yelverton; Dacia Thompson; Sebastian Aviles; Kelly Hunter Foster; Gray Jernigan
Subject: Comments on the Lower Cape Fear River: swamp reclassification proposal by North Carolina

Dear Ms. Godfrey,

Please see attached comments for your information. We look forward to helping clean up the lower Cape Fear River rather than reclassifying it as a swamp.

Ryke Longest
Clinical Professor of Law
Duke University School of Law
210 Science Drive
Box 90360
Durham, NC 27708-0360

Petter, Lauren

From: Ryke Longest <longest@law.duke.edu>
Sent: Wednesday, April 22, 2015 1:18 PM
To: Godfrey, Annie
Cc: Petter, Lauren; 'kemp@cfrw.us'; Frank Yelverton; Dacia Thompson; Sebastian Aviles; Kelly Hunter Foster; Gray Jernigan
Subject: RE: Comments on the Lower Cape Fear River: swamp reclassification proposal by North Carolina
Attachments: WKA CFRW ELPC Comments on Cape Fear Reclassification.pdf

Dear Ms. Godfrey,

I am embarrassed to say that I completely failed to send our comments as an attachment to our electronic letter. I apologize for the omission.

In order to reduce paper, we had not planned to send hard copies of these comments. If you would like one, we can still send you one. Once again, I apologize for my mistake.

Best,

Ryke Longest

Ryke Longest, Director
Duke Environmental Law and Policy Clinic
Box 90360
Durham, NC 27708-0360

"I have a friend whose guiding theology for all political matters is the editorial page of the Wall Street Journal. He could never quite understand that there is a direct and beneficial connection between a healthy environment and a prosperous economy until I described the connection in the jargon of his business world. I said to him, 'Look at it this way and the connection becomes obvious. It is this: The economy is a wholly owned subsidiary of the environment. All economic activity is dependent upon that environment with its underlying resource base. When the environment is finally forced to file under Chapter 11 because its resource base has been polluted, degraded, dissipated, irretrievably compromised, then, the economy goes down into bankruptcy with it because the economy is just a subset within the ecological system.'"—Gaylord Nelson on Earth Day XXV

From: Ryke Longest
Sent: Wednesday, April 15, 2015 2:59 PM
To: 'godfrey.annie@epa.gov'
Cc: 'petter.lauren@epa.gov'; kemp@cfrw.us; Frank Yelverton; Dacia Thompson; Sebastian Aviles; 'Kelly Hunter Foster'; Gray Jernigan
Subject: Comments on the Lower Cape Fear River: swamp reclassification proposal by North Carolina

Dear Ms. Godfrey,

DUKE LAW

NICHOLAS SCHOOL OF THE ENVIRONMENT
DUKE UNIVERSITY
forging a sustainable future

Environmental Law & Policy Clinic
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March 3, 2015

Elizabeth Kountis
DENR-Division of Water Resources
Planning Section
1611 Mail Service Center
Raleigh, NC 27699-1611
Fax: (919) 807-6497
Email: elizabeth.kountis@ncdenr.gov

RE: Comments on Proposed reclassification of portions of the Cape Fear River

Dear Ms. Kountis:

On behalf of the Cape Fear River Watch, Cape Fear Riverkeeper and Waterkeeper Alliance, we are submitting the following comments pursuant to the Notice issued by your office for the proposal captioned "Proposed Swamp Reclassification with Water Quality Management Plan for Part of Cape Fear River." This proposed reclassification apparently originated from a request on behalf of persons who had been meeting to discuss the development and implementation of a Total Maximum Daily Load for the Lower Cape Fear River.[1] Based upon review of the materials presented, as well as readily available peer-reviewed literature, this proposal suffers the following deficits: constitutes an unlawful attempt to evade the Clean Water Act's directives to correct water quality problems through implementation of Total Maximum Daily Load requirements and to prevent backsliding on Water Quality Standards once they are set; violates the policy declared by the State's constitution and implementing statutory directives to the North Carolina Environmental Management Commission (Commission) and the North Carolina Department of Environment and Natural Resources (Department) to protect and conserve the waters of the state for the benefit of all its citizens; fails to correct the water pollution created by Animal Operations under the regulatory authority of the Commission and CAFOs as regulated by the Clean Water Act, which together are causing impairments for copper, turbidity, pH and low dissolved oxygen (DO); lacks scientific support; and does not comply with the requirements of the North Carolina Administrative Procedures Act (APA).

[1] The letterhead of the request is the Lower Cape Fear River Program, but the request is signed by Chris May, identified as the Executive Director of the Cape Fear Council of Governments. We raise this issue in order to preserve, in any subsequent appeal, the question as to whether Mr. May was acting with actual authority on behalf of a person with legal power to make the request.

I. The Clean Water Act Requires the State of North Carolina to Implement a Total Maximum Daily Load Allocation in the Cape Fear River

The Lower Cape Fear River (LCFR) presents the classic situation that the Clean Water Act (CWA) provisions on Total Maximum Daily Load (TMDL) were designed to address: chronic violations of water quality standards that NPDES-imposed effluent limitations alone are unable to correct. The modern-day CWA was first passed in 1972 in response to growing concern about the continued degradation of many major rivers under inadequate state regulatory schemes. The CWA's stated objective is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." CWA § 101(a). To achieve this objective, the CWA lays out several goals, including the elimination of the discharge of pollutants into navigable waters. The statute sets up several programs to achieve these goals, including the TMDL process.

A. State Water Quality Standards Must Meet CWA Minimum Requirements and Protect Designated Uses

State water quality standards must be approved by the United States Environmental Protection Agency under § 303 of the Clean Water Act, 33 U.S.C. § 1313. Under the Clean Water Act, water quality standards consist of three elements: (1) one or more existing or designated "uses" of a water body (such as fish and aquatic life, fishing, boating, aesthetic quality, irrigation and water supply), (2) water quality "criteria" indicating the amount of a pollutant that may be present in the water body while still protecting the uses, and (3) a provision restricting degradation of certain types of waters. When met, these standards must be stringent enough to protect the designated uses. States are responsible for enforcing their water quality standards on intrastate waters. See 33 U.S.C. § 1319(a).

B. North Carolina's General Statutes Require More Protection of Uses than the CWA Minimum Requirements

Under the provisions of Article 21 of Chapter 143, the North Carolina General Assembly has set forth guidelines for the Commission to use when enacting water quality standards and specifically sets forth criteria more stringent and more specific than the Clean Water Act. North Carolina's standards must be designed to:

1) protect human health,
2) prevent injury to plant and animal life,
3) prevent damage to public and private property,
4) insure the continued enjoyment of the natural attractions of the State,
5) encourage the expansion of employment opportunities,
6) provide a permanent foundation for healthy industrial development,
7) secure for the people of North Carolina, now and in the future, the beneficial uses of these great natural resources.

See N.C. Gen. Stat. § 143-211(c).

State water quality standards established under § 303 provide an important "supplementary basis . . . so that numerous point sources, despite individual compliance with effluent limitations, may be further regulated to prevent water quality from falling below acceptable levels." EPA v. California ex rel. State Water Res. Control Bd., 426 U.S. 200, 205 n.12 (1976). States therefore may impose more stringent water quality controls. See 33 U.S.C. § 1311(b)(1)(c). The CWA standards are a floor, but states are expected to set standards to protect uses based on the water quality issues in their waters. For example, North Carolina requires that water quality standards ensure "the ability of an aquatic ecosystem to support and maintain a balanced and indigenous community of organisms . . . . " 15A NCAC § 2B.0202(11).

Numerous state water quality issues are implicated within the Cape Fear River basin and the State has adopted a broad array of requirements affecting water quality to protect the public welfare and serve the purposes of the Clean Water Act. For the portions of the Cape Fear River system classified as Class SC waters, state regulations provide specific water quality criteria implicated by these classifications. These include chlorophyll, dissolved oxygen, solids or sludge attributable to wastes, dissolved gases, fecal coliform, pH, oils, temperature, turbidity, toxic substances, pesticides, and metals, among others. See15A NCAC § 02B .0220 The Lower Cape Fear River fails to meet the standards imposed for DO, pH, turbidity, and copper. Consequently, the state is required to identify the sources that contribute to these violations and then take corrective action. "[S]ources of water pollution which preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard." 15A NCAC § 2B.0211(2).

C. CWA Requires North Carolina to Allocate Pollutant Loading From Point Sources, Including CAFOs, and From Nonpoint Sources Under TMDL

The CWA requires states to address both point sources[2] and nonpoint sources in order to protect designated uses. Under the CWA scheme, states must designate uses for waterbodies within the state and then develop water quality standards for those waterbodies to ensure achievement of the designated uses. Effluent limitations must be imposed on every point source discharger, including concentrated animal feeding operations (CAFOs),[3] in an effort to meet the water quality standards and maintain the designated uses. Waterbodies that do not meet their standards are placed on the 303(d) list of impaired waters. For those waterbodies, the states must develop TMDLs for the contaminant(s) causing the violation to return the waters to the standards appropriate for the designated use. To achieve a TMDL, CWA § 303 requires the state to undergo a

[2] CWA § 502(14) defines "point source" as "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged."

[3] As discussed more in Section III, North Carolina also regulates all Animal Operations activities involving Animal Waste, even when these operations have not been designated as CAFOs. We do not endorse the Department's decision to use general permits for Animal Operations in this basin and have previously commented on the inadequacy of those permits to prevent the types of problems seen in the LCFR.

continuing planning process and determine appropriate load allocations for all sources, whether categorized as point or nonpoint. The TMDL must consider point and nonpoint sources contributing to impairment and not merely those adjacent to the impaired stretch. The state must incorporate the TMDL waste load allocations into the NPDES permits for each point source discharger and the load allocation for nonpoint sources are to be implemented through regulatory, non-regulatory and voluntary compliance mechanisms depending on the source.

Since 1998, the LCFR segment from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut has been on North Carolina's 303(d) list of impaired waters due to low dissolved oxygen (DO). In 2006, the state added impairment for pH, copper, and turbidity to the 303(d) list for this segment. The CWA requires the state to develop a TMDL for the impairing pollutants and then incorporate the TMDL into NPDES permits for point sources and controls on nonpoint sources necessary to meet the loading limits in the state plans.[4] For example, TMDLs are to be incorporated into the state's Water Quality Management Plan, which must also include effluent limitations and the regulatory, non-regulatory, and other mechanisms necessary to control nonpoint sources and meet water quality standards. The proposed reclassification would avoid this process and allow the waterbody to violate the 5 mg/L DO standard. In doing so, it fails to further the goals of the CWA and violates its express provisions.

The CWA intends for TMDLs to cover pollution from point and nonpoint sources. The TMDL program sets the total amount of a pollutant that a waterbody can assimilate while still achieving its designated uses. The state must set the TMDL with an eye toward the designated use, and then must manage its contributing point and nonpoint sources to meet the TMDL. The CWA requires states to incorporate the TMDL into NPDES permits for point sources and into the regulatory, non-regulatory and other actions in state plans for nonpoint sources. Thus, the TMDL process should comprehensively consider all sources, which this proposed reclassification fails to do by ignoring CAFOs and nonpoint sources. Further, CAFOs are defined as point sources within the CWA (and in more detail by EPA regulations). So, the statute is clearly and explicitly intended for the TMDL process to cover discharges from CAFOs. The proposed reclassification entirely ignores the discharges from these sources, even though there are millions of hogs, poultry, turkeys, and cattle in the basin that contribute to the violations of applicable water quality standards. The proposed reclassification is thus impermissible.

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[4] See, e.g. 33 U.S.C. §§1313(e) and 1319; *Pronsolino v. Nastri, 291 F. 3d. 1123 (9th Cir. 2002)* (Upholding EPA's TMDL for a waterbody impaired solely by nonpoint source pollution); U.S. EPA What is a TMDL? http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/overviewoftmdl.cfm ("Load allocations (LAs) are implemented by nonpoint sources through a wide variety of state, local, and federal programs (which may be regulatory, non-regulatory, or incentive-based, depending on the program), as well as voluntary action by citizens.");

D. The Proposed Reclassification Violates the Anti-Degradation Provisions in Both State and Federal Law

The CWA also includes anti-degradation provisions that prohibit the states from allowing the degradation of navigable waters by lowering the standards to achieve compliance. See 33 U.S.C. § 1313(d)(4). Under the federal antidegradation policy, the states are required to develop and adopt statewide antidegradation policies that ensure that "existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected." 40 C.F.R. § 131.12. North Carolina has incorporated this requirement by reference into its water quality standards, and further adopted the requirement that "[e]xisting uses, as defined by Rule .0202 of this Section, and the water quality to protect such uses shall be protected by properly classifying surface waters and having standards to protect these uses." 15A NCAC 02B § .0201 (a) and (b). Existing uses are defined as: "uses actually attained in the water body, in a significant and not incidental manner, on or after November 28, 1975, whether or not they are included in the water quality standards, which either have been actually available to the public or are uses deemed attainable by the Environmental Management Commission. At a minimum, uses shall be deemed attainable if they can be achieved by the imposition of effluent limits and cost-effective and reasonable best management practices (BMPs) for nonpoint source control." See 15A NCAC 02B § .0202(30). The proposed reclassification violates both the CWA and the state's supplemental antidegradation policy regulations because it will not protect and maintain the existing uses in the LCFR, would weaken water quality standards and would allow for further degradation of water quality.

Additionally, EPA regulations prohibit the removal of a designated use where that use is an existing use, which the EPA regulations define as uses "actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards." 40 C.F.R. § 131.10(h)(1). The EPA regulations deem a use attainable if it "can be achieved by the imposition of effluent limits required [for point sources] under sections 301(b) and 306 of the Act and cost-effective and reasonable best management practices for nonpoint source control." 40 C.F.R. §131.10(d). The EPA regulations also prohibit removing a designated use where "[s]uch uses will be attained by implementing effluent limits required under sections 301(b) and 306 of the Act and by implementing cost-effective and reasonable best management practices for nonpoint source control." 40 C.F.R. § 131.10 (h)(2). As demonstrated by materials submitted by the proponents of this reclassification and the comments of Dr. Burkholder set forth below, the SW classification protects an existing use and the designated uses for the LCFR can be achieved through reasonable pollution controls.

If these prohibitions did not apply, a state could seek to remove a designated use where naturally occurring pollutant concentrations prevent the attainment of the use: "States may remove a designated use which is not an existing use, as defined in § 131.3, or establish sub-categories of a use if the State can demonstrate that attaining the designated use is not feasible because: (1) Naturally occurring pollutant concentrations prevent

the attainment of the use." See 40 C.F.R. § 131.10(g)(1). The supplemental Sw "Swamp" classification is an example of such a sub-category of use for SC waters of the LCFR. NC law builds upon these restrictions with supplemental provisions, allowing revision to the water quality standards if the naturally occurring pollutant concentrations are the result of natural background conditions.

Under NC law, "any person subject to the provisions of G.S. 143-215.1 may petition the Commission for a hearing pursuant to G.S. 143-215.4 for a revision to water quality standards adopted pursuant to G.S. 143-214.1 as such water quality standards may apply to a specific stream segment into which the petitioner discharges or proposes to discharge." See N.C. Gen. Stat. § 143-214.3. This section also sets forth the procedure and burdens of proof needed in making such a request. However, the provision specifies that revisions to water quality standards are permitted only when the proponent meets particular criteria, including proving that "natural background conditions on the stream segment preclude the attainment of the applicable water quality standards." As we set forth in Sections III and IV, the proposed reclassification does not meet that burden.

The Commission must also consider several matters prior to granting a reclassification request, including the following factors: "the use and value of State waters for public water supply, propagation of fish and wildlife, recreation, agriculture, industrial and other purposes, use and value for navigation, and ... an estimate ... of the environmental impact, the economic and social costs necessary to achieve the proposed standards, the economic and social benefits of such achievement and an estimate of the date of such achievement." N.C. Gen. Stat. § 143-214.1(d)(4). Since the CWA and its rules set the minimum requirements, this provision is supplemental to that which is required by the CWA's anti-degradation policy. It does not appear that the proponent has provided any support for the Commission to conduct such an analysis.

Thus, under the state and federal regulations, DWR would have to establish that the use is not an existing use, that the use cannot be attained by implementing effluent limits and nonpoint source controls, and that low DO in the LCFR is being caused by naturally occurring pollutant concentrations that make attainment of the use infeasible. This is a burden that cannot be met as set forth in greater detail below in Section III and IV, as well as attached comments by Dr. Joann Burkholder, Ph.D. In any event, because the SC classification includes uses that are specified in CWA Section 101(a)(2), the state cannot remove a designated use or adopt subcategories of uses that require less stringent criteria without conducting a Use Attainability Analysis. See 40 CFR 131.10(j) and 131.3(g). The state has not done so in this instance and, thus, the Commission may not proceed with the reclassification.

II. North Carolina Law Requires the Environmental Management Commission to Correct Impairments Including Low Dissolved Oxygen in LCFR

North Carolina's Constitution and its General Statutes require the Commission to correct pollution in the Cape Fear River to support fish and other aquatic life. The fisheries resources are public trust assets, as are the waters of the Cape Fear River itself. Now that the Commission has designated uses for the Cape Fear River, studied the causes of its impairment and evaluated measures for correcting the same, the Commission must act to correct the problems identified. Reclassifying the Cape Fear River to swamp waters does not fulfill the duties entrusted to the Commission by North Carolina's laws.

More generally, a reclassification and a codification of rules that allow for worsened water quality clearly violate North Carolina's Constitution, which imposes a duty of water quality protection upon this Commission:

> "It shall be the policy of this State to conserve and protect its lands and waters for the benefit of all its citizenry, and to this end it shall be a proper function of the State of North Carolina and its political subdivisions to acquire and preserve park, recreational, and scenic areas, to control and limit the pollution of our air and water, to control excessive noise, and in every other appropriate way to preserve as a part of the common heritage of this State its forests, wetlands, estuaries, beaches, historical sites, openlands, and places of beauty." N.C. Const. Art. XIV, § 5.

The Commission must remember that the people have enshrined this duty in the Constitution of North Carolina. Limiting and controlling pollution is a duty of the State and all its political subdivisions. This provision imposes a duty on the Commission to carry out its powers to protect the lands and waters for the benefit of all its citizenry.

Forty years ago, our General Assembly advanced this Constitutional mission by enacting the General Statutes which protect these values, including the laws which empower the Department and the Commission, such as Chapters: 113, 113A, 113B, 130A, 130B, 132, 139, 143, 143B, 146, 150B, 156, 159, 159A, 159B, 159C, 159G and 162A. Among this comprehensive system of laws is found Article 21 of Chapter 143, captioned, "Water and Air Resources." Within Article 21, the General Assembly declares its intent for those laws: "to achieve and to maintain for the citizens of the State a total environment of superior quality. **Recognizing that the water and air resources of the State belong to the people, the General Assembly affirms the State's ultimate responsibility for the preservation and development of these resources** in the best interest of all its citizens and declares the prudent utilization of these resources to be essential to the general welfare." N.C. Gen. Stat. § 143-211(a) (emphasis added).

The General Assembly's enactments clearly show their intent to clarify the legal points that (a) water and wildlife resources belong to the people and (b) the State bears responsibility to preserve and develop these resources as a public trust. This trust may

not be devolved to private interests through permits or approvals that give perpetual rights to pollute and degrade the public trust resources of the people. See N.C. Const. art. I, §§ 32 and 34.

Under the provisions of Article 21 of Chapter 143, the North Carolina General Assembly has set forth the guidelines for the Commission to use when enacting these standards and specifically sets forth criteria more stringent and more specific than the Clean Water Act. At the core of EPA-approved state water quality standards under 33 U.S.C. § 1313, states are responsible for enforcing their water quality standards on intrastate waters. See 33 U.S.C. § 1319(a).

In setting water quality standards, the General Assembly directed the following be considered: "Standards of water and air purity shall be designed to protect human health, to prevent injury to plant and animal life, to prevent damage to public and private property, to insure the continued enjoyment of the natural attractions of the State, to encourage the expansion of employment opportunities, **to provide a permanent foundation for healthy industrial development and to secure for the people of North Carolina, now and in the future, the beneficial uses of these great natural resources**." N.C. Gen. Stat. § 143-211(c) (emphasis added). These provisions clearly show the recognition of a duty to protect uses of our state's waters for the benefit of today's users and those in the future. Removing the protections from the Lower Cape Fear River does not meet the purposes of North Carolina's Constitution, Law or Rules.

III. Neither the Low DO Conditions Nor the Animal Wastes That Cause Them are Naturally Occurring

As stated above, the proposed reclassification violates numerous provisions of state and federal laws relating to TMDLs, water quality standards, antidegradation policies, and the requirements for removing and establishing designated uses. These hurdles cannot be overcome. However, assuming for the sake of discussion that they could, under North Carolina and federal law, the Commission would have to determine that natural background conditions on the stream segment preclude the attainment of the use in order to consider the proposal. N.C. Gen. Stat. § 143-214.3; 40 C.F.R. 131.10(g)(1). The burden of proof is on the applicant to prove this to the Commission. Neither the applicant nor the Commission can meet this burden, and in any event, the Commission could not classify the LCFR as "swamp waters" as the river does not meet the regulatory definition which requires low velocities, among other things. See 15A NCAC 02B .0101(e)(2), 15A NCAC 02B .0202(62), 15A NCAC 02B .0301(c), and Comments of Dr. Burkholder.

A. North Carolina's Statutes Regulate Animal Operations, Feedlots and Animal Waste, Even When Not Designated as CAFOs, and Legally Recognize the Water Quality Problems Created by Livestock Manure[5]

North Carolina's General Assembly adopted laws to regulate Animal Operations and Feedlots in response to concerns that growth in the numbers of Animal Operations harmed water quality. As the General Assembly found, "The growth of animal operations in recent years has increased the importance of good animal waste management practices to protect water quality. It is critical that the State balance growth with prudent environmental safeguards." N.C. Gen. Stat. § 143-215.10A.

In addition, the General Assembly found the need to control and limit nutrients leaving the Animal Operations by specifying that Animal Waste be applied with careful attention to the both nitrogen and phosphorus as rate limiting elements for applying Animal Waste to land. See N.C. Gen. Stat. § 143-215.10C. The General Assembly also declared that zinc and copper levels in the soils shall be monitored, and alternative crop sites shall be used when these metals approach excess levels. These legislative requirements reflect specific legislative findings as to the water quality problems caused by excess nitrogen, phosphorus, zinc and copper.

These North Carolina legislative findings of fact are supported by studies from federal agencies. The United States Environmental Protection Agency ("EPA") and United States Department of Agriculture's ("USDA") have identified livestock manure as the largest cause of water quality impairment in the country's rivers, streams, lakes, ponds, and reservoirs, and the fifth leading contributor to impairment of estuaries.[6] They contribute to the impairment of approximately 37% of the nation's surveyed rivers and streams.[7]

North Carolina law defines Animal Waste to include livestock or poultry waste. N.C. Gen. Stat. § 143-215.10B. A feedlot is defined as a lot or building or combination intended for the confined feeding, breeding, raising, or holding of animals. N.C. Gen. Stat. § 143-215.10B. An Animal Operation is defined as a feedlot involving 250 or more swine, 100 or more confined cattle, 75 or more horses, 1,000 or more sheep, or 30,000 or

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[5] North Carolina and the federal government provide different definitions for CAFOs, but these specific definitions and thresholds do not change the underlying arguments about the shortcomings of the current proposal. Just because the state has not identified something as a CAFO through its case-by-case assessment does not mean that it is not one.

[6] CLAUDIA COPELAND, CONG. RESEARCH SERV., RL31851, ANIMAL WASTE AND WATER QUALITY: EPA REGULATION OF CONCENTRATED ANIMAL FEEDING OPERATIONS (CAFOS) 4 (2002) (citing U.S. EPA, EPA-841-R-08-001, NATIONAL WATER QUALITY INVENTORY: REPORT TO CONGRESS FOR THE 2004 REPORTING CYCLE 18–19 (2009)).

[7] Stephen Harden, Characterization of Surface-Water Quality Associated with Swine CAFOs in Eastern North Carolina, Proposal submitted to the N.C. DEP'T OF ENV'T AND NATURAL RES., DIV. OF WATER QUALITY 1, 3 (May 9, 2011) (citing the EPA's 2002 National Water Quality Inventory).

more confined poultry with liquid waste handling. N.C. Gen. Stat. § 143-215.10B. Thus, any Feedlot with more than 250 swine is an Animal Operation subject to the Commission's regulatory authority as related to its handling of Animal Waste. The Commission has the regulatory authority and a duty to act to reduce the impact of livestock manure on the LCFR through its regulation of Animal Operations and Animal Waste. This must also be done through a TMDL in order to correct low DO in the Lower Cape Fear River.

B. Prior to 1999, the LCFR Experienced Explosive Growth in Animal Operations

The LCFR was not listed as impaired until large numbers of Animal Operations had been built in the basin. North Carolina in general, and the Cape Fear River basin in particular, experienced dramatic increases in the number and size of Animal Operations from the mid-1980s through the late-1990s. During that time, the swine population in the counties in the basin increased fourfold, turkey production doubled, chickens increased by 50%, and beef cattle by 25%. According to a study by scientists from the University of North Carolina at Wilmington, the Cape Fear River basin houses more than half the hog population in North Carolina.[8] The surplus nutrients are excreted in the livestock manure, which in turn feeds nutrients into the Cape Fear River through its tributaries.

The situation in the basin is so severe that analysts with the USDA's Natural Resources Conservation Service ("NRCS") found that the Cape Fear River basin and surrounding land area was the number one priority watershed in the United States based on its vulnerability to livestock manure nutrient pollution.[9] This finding is consistent with an earlier NRCS review as well.[10]

The proliferation of CAFOs in the Cape Fear River watershed is the best explanation for the low DO levels in the lower portion of the river, and this explanation is supported by the science. Research from the University of North Carolina at Wilmington shows that ammonium levels have increased in the river since the mid-1990s.[11] Ammonium is a form of nitrogen in swine and poultry waste that can be transported via runoff, subsoil movement, and volatilization and deposition.[12] This ammonium can be transported downstream to the section of the LCFR at issue here, where it can cause algal

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[8] See "Nitrogen and Phosphorus Imports to the Cape Fear and Neuse River Basins to Support Intensive Livestock Production" by Lawrence B. Cahoon, Jill A. Mikucki, and Michael A. Mallin Environ. Sci. Technol., 1999, 33 (3), pp 410–415.

[9] See "Potential Priority Watersheds for Protection from Manure Nutrients" by Robert Kellogg, available online at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_012227.pdf (Accessed Feb, 17, 2015)

[10] See "Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the United States" by Robert Kellogg et al., available online at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_012133.pdf (Accessed Feb. 17, 2015)

[11] Michael A. Mallin & Lawrence B. Cahoon, *Industrialized Animal Production—A Major Source of Nutrient and Microbial Pollution to Aquatic Ecosystems*, 24 POPULATION & ENVT. 369, 376 (2003) (internal citations omitted).

[12] *Id.*

blooms.[13] These algal blooms eventually die, and feed bacteria, generating a high biological oxygen demand (BOD), which in turn causes low DO.[14]

The single major land use change that could account for this increase in ammonia concentrations (and drop in DO) is the rapid growth of CAFOs during the 1980s and 1990s.[15, 16] This research reinforces the NRCS's finding that this area should be a priority watershed for protecting against nutrients from livestock manure.Trends showed a significant importation of these nutrients to the Cape Fear River basin from feed grown outside the basin.[17] (Early studies by UNC-W's Center for Marine Science also found a correlation between fecal coliform indicators and biological oxygen demand in the River.)[18] The Cape Fear River Basinwide Assessment Report of 1996 went even further, finding in 1995 that nitrogen and phosphorous from livestock manure exceeded the assimilative capacity of cropland by more than 400% in several counties within the watershed.[19] This troubling data caused DENR's analysts to state:

> "It should be noted that these figures do not take into account commercial fertilizer applications in the counties. It is clear based on this information, that animal waste management in a number of counties in the basin is becoming a critical issue, and that the animal carrying capacity of these lands (from a waste disposal standpoint) needs to be closely examined. Alternatives to cropland application need to be considered in these counties such as application on forest land or transportation/distribution of the collectable manure to counties that have capacity and could use this nutrient source in lieu of commercial fertilizers." [20]

Nutrients imported to the basin in the form of grain to feed the swine create a nutrient imbalance that this Commission must address.

Of course, since 1995, the numbers of swine, turkeys, layers and cattle have only increased in the Cape Fear River Basin. Their numbers are not a naturally occurring condition and their manure is not a naturally occurring pollutant. The record shows the DO violations are caused by animal feeding operations and other upstream sources, and not by naturally occurring conditions. Accordingly, the Commission must reject the proposed reclassification, and instead take measures to control pollution from animal

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[13] *Id.* at 378, and Figure 2.
[14] *Id.*
[15] *Id.*
[16] We are not suggesting that CAFOs are the only source of the DO problem, but the state has the obligation to control the contributions of CAFOs rather than move forward with the reclassification.
[17] See "Nitrogen and Phosphorus Imports to the Cape Fear and Neuse River Basins to Support Intensive Livestock Production" by Lawrence B. Cahoon, Jill A. Mikucki, and Michael A. Mallin Environ. Sci. Technol., 1999, 33 (3), pp 410–415..
[18] See "Environmental Assessment of the Lower Cape Fear River System: 2002-2003" by Michael Mallin et al. CMS Report 03-03 (2003).
[19] See "Cape Fear River Basinwide Water Quality Plan" by NC DENR (1996). Available online at: http://portal.ncdenr.org/web/wq/ps/bpu/basin/capefear/1996 (Accessed Feb. 17, 2015)
[20] Id. at 3-17 through 3-19 and referenced figure.

waste at animal feeding operations and other upstream sources in order to restore water quality.

IV. The Technical Memoranda Do Not Carry the Burden of Proof on Naturally-Occurring Pollutant or Condition Causing the LCFR Impairments

The proponent for reclassification argues that natural conditions result in levels of DO and pH that excuse the violations of water quality standards and offers four Technical Memoranda ("TM") as factual support for the proposal. These TM are grossly deficient and misleading, and they omit significant information. While water quality in the Cape Fear River is influenced by the conditions found in the swamp and estuarine areas, low DO accompanied by high copper levels can be explained only by the contribution of animal waste and other upstream sources.

A. Experts Have Shown the Correlation Between Animal Operations and Eutrophication in the Lower Cape Fear

Dr. Joann Burkholder directs the Center for Applied Aquatic Ecology at North Carolina State University. An internationally recognized expert in her field, Dr. Burkholder has studied and published articles in peer-reviewed journals on topics directly relevant to assessing the causes of impairment in the LCFR: chronic effects of nutrient over-enrichment and other chemical environmental contaminants on aquatic plants; the impacts of cyanobacteria, dinoflagellates, haptophytes, and raphidophytes on aquatic ecosystems; and influences of long-term changes in watershed land use and pollution sources on surface water quality.

Dr. Burkholder reviewed the proposed reclassification, surveyed past literature and research and provided comments regarding the TM and the merits of the proposal itself. These comments, which constitute expert opinion, show that Animal Waste, Animal Operations and CAFOs are the primary cause of impairments for DO, pH, copper and turbidity. A copy of Dr. Burkholder's review is attached to these Comments and is incorporated by reference.

Dr. Burkholder notes that CAFOs are also point sources, and that they should be treated as such in the modelling, but were not evaluated this way. Even though CAFOs in the LCFR are the most concentrated per unit surface area in the entire nation, they are not addressed in the TM. Further, even though supporting data and research showing their contribution to low DO was readily available from peer-reviewed literature, they were not mentioned, evaluated or considered. The TM did not use the best science available, but rather singled-out the information which supported the proposal. The weight of science contradicts the TM and this Commission should reject the Proposal. The applicants have failed to meet their burden of proof to support a reclassification.

B. Impairment for Copper in the LCFR and the TMDL Trigger for those Impairments Also Point to Animal Waste as the Cause

The TM selectively present information to support the proposed reclassification, but the record of research in the Cape Fear Basin demonstrates that manure nutrients from Animal Waste are both contributing to the DO deficit and are subject to the Commission's control. Copper is recommended to be added to animal feeds to promote growth.[21] Professors working at North Carolina State University studied the composition of Animal Waste using samples and the statistics on statewide inventories of livestock animals.[22] In this study, Dr. Barker and Dr. Zublena totaled all the nutrients found in all of the Animal Waste in all of North Carolina's Animal Operations as they existed in 1993. Their published findings show that more than 290 tons of copper per year were present in the Animal Waste produced by North Carolina's Animal Operations. Subsequent studies showed that nitrogen concentrations had slightly declined between 1995 and 2005, but that copper and zinc values have remained steady, with the highest concentration found in liquid animal waste produced at dairies and swine operations, followed by litters produced at broiler and turkey operations.[23] [24] In 2012, North Carolina reported more than 300 miles of streams as impaired for copper on the CWA 303(d) list. The LCFR is part of those stream miles, from just outside Navassa into the area covered by the proposal. A TMDL is needed to address the impairment caused by excess copper.

Neither swamps nor estuaries contribute copper as a naturally occurring pollutant, whereas the scientific literature shows that copper is supplemented in feed to livestock and that hundreds of tons of it are excreted in Animal Waste produced by Animal Operations. Copper impairment on the Cape Fear River is thus a red flag, a fact that the four TM conveniently omit. Coupled with the impairments for low pH and turbidity, and the TMDL previously identified as needed for the LCFR, all signs point to Animal Waste as a primary cause. (The only exception is mercury impairment). Despite this evidence, the four TM omit any information about the contribution of Animal Waste to impairment; to the extent they insist that DO problems in the LCFR are caused by "natural conditions," they are misusing that term.

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[21] See "Swine Feeding Suggestions" by Clemson University Extension, Circular 505 (1995), available online at: http://www.clemson.edu/psapublishing/pages/ADVS/EC509.PDF (last accessed Feb. 26, 2015)

[22] See "Livestock Manure Nutrients in North Carolina" by Dr. J.C. Barker and J.P. Zublena (1996), available online at: http://www.bae.ncsu.edu/programs/extension/evans/assess.html (last accessed Feb. 26, 2015)

[23] See "North Carolina Trends in Animal Waste Nutrient Concentrations" by Casteel, S., B. Cleveland, D. Osmond, and C. Hudak-Wise. 2007. In Proc. Soil Science Society of America Natl. Conf. – New Orleans, LA.

[24] Researchers and policymakers for the European Commission looking at allowable concentrations of copper supplements in livestock feed found that copper had negligible benefits to animal health except for piglets and recommended research to evaluate environmental impacts of copper excreted in livestock manure.See "Opinion of the Scientific Committee for Animal Nutrition on the use of copper in feedingstuffs" by the European Commission's Health and Consumer Protection's Directorate-General (2003) available online at: http://ec.europa.eu/food/fs/sc/scan/out115_en.pdf (last accessed Feb. 26, 2015)

C. A Proper Interpretation of the Bowen Model Supports the Use of TMDL to Reduce Loading to the LCFR from sources in the Cape Fear River, Black River and Northeast Cape Fear, Including Animal Operations

The modeling effort for predicting how decreasing loading of pollution to the LCFR would impact DO levels was conducted by Dr. Jim Bowen at UNC- Charlotte (Bowen Model).[25] The Bowen Model ran several scenarios that incorporated assumptions obscuring the impacts of loadings from Animal Operations, including CAFOs. Pollution from Animal Operations, including CAFOs, was treated as given input to the modelling. The Bowen Model lumped together all upstream sources, both natural and anthropogenic, in waste load figures from the three major rivers upstream of the LCFR. Thus, the pollutant load from all sources discharging pollutants into the Northeast Cape Fear River above the LCFR model segment were lumped together into a single pollutant source. This single pollutant load is a combination of types of sources. In developing the load allocations for a TMDL, each of the upstream rivers should be evaluated further to document the contribution from each type of source, including naturally occurring conditions, whether classified as non-point or point sources. There are several NPDES-permitted facilities, including CAFOs, upstream of the LCFRP.[26] Just because the Bowen Model lumps these loads into input categories labeled by the name of their original subbasin, the supporters of the reclassification lumps together with all other upstream sources as "natural." These permitted facilities are obviously not natural sources and should be addressed by the state through the TMDL process.

In the case of the Northeast Cape Fear River, the Bowen Model labeled the upstream pollutant load under the category upstream river source number 20. Likewise the Cape Fear River and Black River were treated as source numbers 18 and 19, respectively. (See Bowen Model, Table 9, p. 47) Based on this assumption, no attempt was made to identify the sources of loadings to the Northeast Cape Fear River, Cape Fear River or the Black River. The model did not consider how much of the loads from these upstream rivers came from naturally-occurring pollutants and how much came from NPDES-permitted discharges or from Animal Waste. Thus, the Bowen Model cannot be used to support any determination that conditions are the result of naturally-occurring pollutants because it lumped the naturally-occurring and anthropogenic pollutants together in each of the three major rivers that flow into the LCFR.

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[25] See: "Development and Use of a Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the Lower Cape Fear River Estuary, North Carolina available online at: http://webpages.uncc.edu/~jdbowen/LCFR/LCFR_DOModelReport_Final.pdf (last accessed Feb. 26, 2015)

[26] For example, the following permits appear as NPDES permitted facilities run in connection with livestock operations upstream of LCFR: Godwin Farms Permit no. NCA282225; Dixie Chops, Inc. Permit No. NCA282143; Timothy Smith Farm Permit No. NCA231656; and Troy Sloan Farm Permit No. NCA231655. In addition, the Smithfield Packing Company holds Permit No. NC0078344 allowing up to 3 million gallons per day of water contaminated with pollutants such as those responsible for causing the types of impairments observed in LCFR. In addition, hundreds of Animal Operations in the basin operate under state level permits for handling animal waste. These sources are not naturally occurring and the Bowen Model does not make them such based on its inputs labelling scheme.

The Bowen Model also treated the estuarine tributaries in the same fashion as the three major rivers. Therefore, the Bowen Model cannot be used to support any determination that conditions there are the result of naturally-occurring pollutants because it lumped the naturally-occurring and anthropogenic pollutants together for these tributaries. A total of 20 wastewater treatment plants (WWTPs) with NPDES permits were also evaluated. The Bowen Model concluded that reducing loadings from these 20 WWTPs would not correct DO impairment, although they did have an effect on the amount of DO impairment. The Bowen Model can be interpreted to say that reduced loadings from these 20 WWTPs will not correct DO in the LCFR, but stretching the Bowen Model to prove that the LCFR are swamp waters is unsupported scientifically and is a misreading of the Bowen Model.

Significantly, the Bowen Model did conclude that reducing the combined loading from the Northeast Cape Fear River, Cape Fear River, the Black River and the estuarine tributaries would produce significant DO improvement. This Scenario was dubbed the "Clean River" Scenario. The Report states:

> "The load reductions of riverine, creek, and wetland inputs were found to have a significant impact on the estimated dissolved oxygen concentrations during the summer months in the impaired region of the Lower Cape Fear River Estuary. At the 10th percentile level, DO concentrations for the three load reduction scenarios increased by 0.2, 0.3, and 0.4 mg/L respectively, from 4.3 mg/l to either 4.5, 4.6, or 4.7 mg/L (Figure 80). Unlike the scenarios described in the previous section in which wastewater loading decreases were investigated, the level of increase in DO concentration was maintained at the higher percentiles when reductions in the river, creek, and wetland loadings were made. In fact, for this "clean river" scenario, the median DO concentration increased to even a greater extent than the 10th percentile value, increasing from 5.6 to 5.85 mg/L for the 30% reduction (an increase of 0.25 mg/L), and from 5.6 to 6.2 mg/L (an increase of 0.6 mg/L) for the 70% reduction scenario (Figure 80)." See Bowen Model at page 142, Scenario 6-3.

The Bowen Model then concluded that cleaning up the riverine and estuarine tributaries was still not enough to meet the DO standard. But that was not the end of the modelling efforts. The Bowen team recognized that lowering the inputs from the Black River, Cape Fear River and Northeast Cape Fear River would reduce accumulation of organic materials in the sediments and thus would also reduce Sediment Oxygen Demand (SOD). In most of the model runs, the Bowen Model had held SOD contribution as constant and as uniform. Dr. Burkholder rightly critiques this assumption as a flaw in the model.

To test whether reducing both loadings from SOD and from the Black River, Cape Fear River and Northeast Cape Fear River would meet DO standards, they ran

another scenario, dubbed a "Clean River Scenario." They found that by reducing the loadings from both SOD and upstream riverine and estuarine sources, 99% of the values achieved compliance with the DO standard. As the Bowen Model report noted:

> "In this scenario we examine what conditions would be necessary to produce summertime DO concentrations above 5.0 mg/L. In addition, one limitation of the analysis done previously is that it ignores possible changes that might occur in the benthos if organic matter loadings were reduced. For instance, it is likely that a reduction of 30% or 50% or 70% in organic matter loading would in the long-term also result in lower sediment oxygen demands. The cumulative effect of decreasing both organic matter loading and sediment oxygen demand are examined in this scenario." See Bowen Model at page 146, Scenario 6-5.

The Bowen Model thus shows that a TMDL would work and the designated uses can be protected. These model runs demonstrated that a reduction in the loadings from the Cape Fear River, the Black River and the Northeast Cape Fear River, and the Estuarine Tributaries would reduce loading to SOD. Taken together, this approach would correct DO and achieve compliance. Under the Clean Rivers scenario, DO would exceed the standard 99% of the time. Dr. Bowen's team writes:

> "The 50% reduction case had an even lower rate of water quality violations, but these were not completely eliminated. With both SOD and oxygen demanding wastes decreased, approximately 7% of summertime DO concentrations in the impaired region are below 5.0 mg/L, as compared to 27% when only the oxygen demanding wastes are decreased (Figure 82). There is also a large increase in the minimum predicted DO concentration for this case. The base case had a minimum predicted DO concentration of approximately 3.2 mg/L, whereas the minimum when SOD and oxygen demanding wastes are reduced by 50% is approximately 4.6 mg/L (Figure 82). A decrease in SOD of 70% and a reduction in river load of 70%, however, does almost completely eliminate dissolved oxygen concentrations below 5.0 mg/L (Figure 82). For this case, only about 1% of the predicted dissolved oxygen concentrations are below the water quality standard value." See Bowen Model at page 142, Scenario 6-5.

The TM erred in their use of the Bowen Model by treating the Cape Fear River, Black River and Northeast Cape Fear River inputs as naturally-occurring conditions. This faulty position fails to acknowledge that each of these rivers receive large loadings from pollutant sources – mainly Animal Operations and CAFOs themselves. Once you unpack the assumptions built into the Bowen Model, you see that it actually supports a TMDL effort to reduce the loading impact from the Cape Fear River, Black River and Northeast Cape Fear River to correct the low DO in the LCFR. Loading from Animal Operations, including CAFOs, in these three tributary rivers clearly have caused an increase in LCFR DO concentrations.

D. The TM Are Incorrect in Ascribing Large Loading of Pollution to the LCFR from Riparian Wetlands

Dr. Burkholder further noted that the data do not support the assertion that inputs from riparian wetlands are "significant contributors to the tremendous loads of oxygen-demanding materials." While the Bowen Model treated loadings from the three major rivers and the estuarine tributaries as if they were discharges from giant WWTPs, the Bowen Model does not attempt to distinguish between the pollutant loading caused by anthropogenic activities and those from naturally-occurring pollutants or conditions. Riparian wetlands often act to reduce the impact of pollutants to surface waters.

Other experts have identified Animal Waste as especially significant for Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) from ammonia, in the Northeast Cape Fear River system (e.g., Mallin et al. 1997). Dr. Burkholder points out that TetraTech focused on the three largest NPDES permitted dischargers and showed that reducing loading from these sources would not correct the problem. Once again, this does not prove natural conditions. Rather, it proves that the problem can be corrected only by reducing the impact of Animal Waste and the loading coming to LCFR from the Cape Fear River, Black River and the North East Cape Fear River as supported by the Bowen Model.

Similarly, the TM authored by CH2M HILL contains a description of surface water quality conditions in summer that omits any discussion of the massive contribution of organic-rich, oxygen-demanding materials from Animal Waste. Dr. Burkholder's research, and that of her cited colleagues, shows that Animal Waste is a cause of the impairments currently found in the LCFR: copper, pH, turbidity and low DO. All available data show that past pollution must be dealt with if the Cape Fear River is to continue to serve its role as a public resource. In order to uphold its duty to the people of this State, the Commission and Department must deny the request.

V. Other Issues Prevent this Commission from Approving the Proposal as Submitted

Other problems with this proposal prevent the Commission from proceeding as proposed and require that the sidetracked TMDL proceed again to a conclusion. Even if a reclassification were an appropriate substitute for a TMDL in this case, two oversights would have to be corrected first: (1) the state failed to perform a Use Attainability Analysis (UAA) which could be approved only if the state can show that the current designated use is in fact unattainable; and (2) the fiscal assessment is grossly inadequate.

Under EPA regulations, the state must conduct a UAA if it is removing a designated use or adopting subcategories that impose less stringent water quality criteria. 40 CFR 131.10(j). The proposed reclassification would create a new subcategory for this waterbody, an action that plainly requires the completion of a UAA to demonstrate that attainment of the designated uses is not feasible. The state has not performed a UAA for

this section of the LCFR, so it has not met its obligations under EPA regulations. If the state elects to continue pursuing this reclassification, it must perform a UAA before submitting a reclassification proposal.

In addition, the state is required to prepare a fiscal note under the NC Administrative Procedures Act (APA). The current fiscal analysis claims that there will be no "quantifiable" impacts, positive or negative, of the proposal. No factual support or analysis is made for this claim. Where the extent and quantification of fiscal impacts is uncertain, the agency is forbidden from just assuming that there are none. "If an agency is not sure whether a proposed rule change would have a substantial economic impact, the agency shall ask the Office of State Budget and Management to determine whether the proposed rule change has a substantial economic impact. Failure to prepare or obtain approval of the fiscal note as required by this subsection shall be a basis for objection to the rule under G.S. 150B-21.9 (a)(4)." N.C. Gen. Stat. § 150B-21.4. The fiscal analysis provided for this proposal is plainly insufficient to meet APA requirements.

Here, we provide a few examples of the substantive inadequacies of the current fiscal analysis. First, there would be costs to the implementing agencies, as they would be required to apply the narrative swamp standards and determine whether violations were caused by natural conditions or dischargers. This would be time-intensive, and therefore costly, for the implementing agencies. Second, this proposal poses clear threats to the environment and ecosystem of the LCFR. These include negative impacts on the fish populations (and the fishing and recreation economies of the area) from the permission of decreased DO concentrations (from the reclassification that will potentially allow more lenient permits based on "natural" conditions and from the codification that will allow new permits to result in a 0.1mg/L drop in DO).

Third, the benefits associated with future planning are created by the codification component of the proposal, and entirely unrelated to the reclassification element of the proposal. Indeed, the reclassification might have the opposite effect because it will be difficult to anticipate how the state will apply the narrative standard for swamp waters. Fourth, there will plainly be economic benefits to dischargers who will have the option of dropping the DO concentration (based on the proposed codification) and the opportunity to argue that the natural conditions now being recognized also should have been considered at the time of their original permit issuance, making them eligible for an exception to the anti-backsliding policies (based on the reclassification). The economic analysis even admits that "[d]ischarges (sic) may in the future be granted additional wasteload allocations." Fifth, there is no discussion of the benefits to CAFOs, Animal Operations and Feedlots. CAFOs and Animal Operations may benefit by avoiding their federal and state obligations under NPDES or under a mandatory state TMDL program.

The Commission is not excused from its duties under the APA when impacts are difficult to quantify. It is simple to understand where the weight of the impacts resides -- doing nothing allows continued harm to the river and allows those who are polluting under the status quo to continue their behaviors. Without quantifying the impacts, it is clear that the reclassification part of the proposal is harming the local communities and

the environment, while it is benefiting the Animal Operations that are the original source of the problem. The reclassification is not economically justifiable and should be abandoned. In addition, the current document combines the fiscal analysis of the reclassification and codification components of the proposal. These should be analyzed separately, as they could be separated by the EMC, legislature, or RRC since neither one is necessary for the other. If the proposals are separated in the future, it will be important to understand if they are independently economically justifiable. The current analysis sheds no light on this issue.

VI. Starting a Conversation or Stopping it Cold

A representative from the LCFRP participated in the oral comment process and mentioned that this proposal was meant to "start the conversation" about problems on the LCFR. The actual proposal will not start a conversation, but end it. Once approved, this proposal will put an end to any discussions of the DO water quality of the LCFR. Once the existing NPDES permit holders are off-the-hook, we should expect new NPDES applicants to demand the same consideration and eliminate the management protections as the next step. In addition, low DO will continue to worsen as nutrient cycling creates a worse situation in the sediments. The current proposal is an illegal end-run around the TMDL process, which is squarely counter to the CWA's objectives and scheme. The end point of the CWA was never to surrender to water quality degradation, but to fight for clean water. Our law requires the Commission to reject this proposal.

Very Truly Yours,

/s/

Ryke Longest, Director
Duke Environmental Law and Policy Clinic

cc: EPA Region IV Administrator

Comments on the Proposed Reclassification
of the Lower Cape Fear River and Estuary to a Class Sc (Sw) Swamp

Prepared for Waterkeeper Alliance by JoAnn M. Burkholder, Ph.D., March 3, 2015

I. Overview

Since 1998, the lower Cape Fear River Estuary (LCFRE) segment from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut has been on North Carolina's 303(d) list of officially "impaired" (degraded) waters due to low dissolved oxygen (DO). In 2006, the state added impairment for pH, copper and turbidity to the 303(d) list for this segment. Throughout the past several decades, a subset of regulated point sources (i.e., with wastes mainly discharged to surface waters through one or more pipes) have been the state's focus for water quality improvement. In 2014, the North Carolina Division of Water Resources within the Department of Environment and Natural Resources (NCDENR-DWR) received a request from a group including various point source dischargers to reclassify the LCFRE from Class Sc to Class Sc-Swamp (Sw) (May 2014). The rationale given for the request included two points - first, that a recent modeling effort (Bowen et al. 2009) had assessed the 20 largest point sources in the lower Cape Fear River basin and concluded that the sources have little influence on water-column DO concentrations in the LCFRE; and second, the group asserted that significant reductions in pollutant loading from other sources which they call "background" loads would not achieve attainment for certain periods of the summer. The request specifically stated,

> ...modeling results indicate that [the 20 assessed] point-source discharges have a relatively minor impact on DO levels, and that even significant reductions in background (both natural and nonpoint source) loads would not result in attainment of the current standard for considerable periods of time during the summer. - May (2014)

Based on this request and information, NCDENR-DWR recently proposed to reclassify the LCFRE to a swamp (Sw) based on the misleading claim that, since the LCFRE cannot meet its present DO standard ($\geq$ 5 mg/L) by controlling the 20 identified point sources alone as assessed in Bowen et al.'s (2009) model, a TMDL (total maximum daily load) to achieve the DO standard would be inappropriate. The proposed reclassification of the LCFRE to a swamp is not consistent with sound science or the law for three reasons:

1. The available evidence shows that the major sources of oxygen-demanding materials in the LCFRE are due to pollution from human activities which are subject to regulation and can be controlled. The major sources of oxygen-demanding materials are **not** natural wetland drainage or other natural background sources. Natural wetland drainage appears to add only a fraction of the massive contribution of oxygen-demanding materials, high levels of toxic copper, high turbidity, and many other pollutants that are being contributed by pollution from point sources, other regulated sources and nonpoint sources (see Sections IIID-E of these Comments).

2. Under the Clean Water Act, the required TMDL for the LCFRE must address ***all*** pollution sources, including point sources, other regulated sources, and nonpoint sources, in the watershed (see Section IIID of these Comments). In its proposed action, NCDENR-DWR has *not* considered ~22 NPDES-permitted point sources in the lower Cape Fear basin, or *any* of the ~153 NPDES-permitted point sources in the upper and middle Cape Fear River basin, which contribute to the impaired (degraded) water quality of the LCFRE which is at the receiving, lower end of the basin. NCDENR-DWR *also* failed to consider the impact of the nearly 1,000 industrial-scale swine Animal Feeding Operations as well as an unknown number of industrial-scale poultry Animal Feeding Operations, many of which are Concentrated (Confined) Animal Feeding Operations (CAFOs) and, thus, point sources under the Clean Water Act. These sources were also omitted from specific analysis in the Bowen et al. (2009) model, although many of the industrial facilities are located in the lower basin (see Section IIIE of these Comments). As a scientist, I first approached their inclusion in these Comments by checking the formal definition of CAFOs in the Clean Water Act (Section 502(14)). *CAFOs are formally defined there as point sources.* They are supposed to be regulated using National Pollution Elimination Discharge System (NPDES) permits, as other industrial point sources are regulated. There are about five million swine in the Cape Fear basin. Each swine produces, on average, about four times more sewage than one person (see Section IIIE). Therefore, the swine CAFO point sources, which are predominantly in the lower Cape Fear basin, contribute roughly the same amount of sewage to that relatively small area, *per year*, as 15 million people. Moreover, swine wastes are much richer in oxygen-demanding materials than human sewage. Industrialized poultry production, also massive in the Cape Fear River basin, contributes to oxygen-demanding materials and other water quality degradation of the LCFRE as well (see Section IIIE). Overall, ~175 NPDES-permitted point sources in the Cape Fear River watershed, and nearly 1,000 swine CAFO point sources as well as an unknown number of poultry CAFOs, were not identified and appropriately evaluated by Bowen et al. (2009) and NCDENR-DWR. These sources are not simply "background" as misleadingly characterized in the materials underlying the NCDENR-DWQ Proposal to reclassify the LCFRE and in the Proposal itself. Collectively, and often individually, these facilities are **extreme**, chronic pollution sources of oxygen-demanding materials to the LCFRE. They can be, and should be, addressed through state regulatory programs, the Clean Water Act and a TMDL for the LCFRE.

3. *Significant reductions in the erroneously termed "background" loads* **would** *achieve attainment of the present DO standard in the LCFRE segment.* As explained above, what was misleadingly and inaccurately called "background" in the lower Cape Fear basin includes the point source pollution from ~175 NPDES-permitted point sources in the Cape Fear River watershed, and from nearly 1,000 swine CAFOs and an unknown number of poultry CAFOs. All of these pollution sources were not among the 20 considered by Bowen et al. (2009) as the main point source contribution to the LCFRE. These sources were, at least, tacitly included in Bowen et al.'s (2009) model within a category called "tributary inputs." The model predicts that a reduction of 30% of the "tributary inputs" would result in median DO levels in the LCFRE that exceed 5 mg/L -- that is, higher than the state standard -- and that a

70% reduction in the "tributary inputs" and the internal oxygen demand (below) largely resulting from these inputs would bring the LCFRE into compliance 99% of the time.

If the proposed reclassification occurs, NCDENR-DWR will accomplish a contrived, highly artificial "official change" of a major, strongly flowing estuary of national importance to a "swamp" with no scientific basis. Rather than providing cleanup and protection of the impaired segment -- which has been officially designated as impaired and in need of improved protection for nearly two decades -- this action would allow much more pollution to occur there, in violation of the Clean Water Act. Consequently, NCDENR-DWR's proposed reclassification would jeopardize the designated uses of the LCFRE. The LCFRE should *not* be reclassified as a swamp.

The scientific facts briefly mentioned above, which accurately describe the status of the LCFRE and the pollution affecting it, are explained in detail in the following comments, supported by peer-reviewed science literature and findings from federal agencies such as the U.S. Department of Agriculture (USDA) and the U.S. Environmental Protection Agency (USEPA).

II. The Mighty Cape Fear River

The Cape Fear River basin, completely contained within North Carolina, is the largest watershed in the state, covering ~16.5% (~9,324 square miles) of total land area. It also contains the largest number of stream miles (6,204) in North Carolina (Lin et al. 2006, Bowen et al. 2009 and references therein). The 26 counties within or overlapping the watershed are expected to grow from 3 million to about 5 million people over the next 20 years.[1] There presently are about 1.7 hogs per person in the Cape Fear basin, and industrialized swine production as well as turkey production in the lower basin are among the most concentrated in the world (Mallin et al. 2003).

The LCFRE is "extremely important... because of its function as a nursery for juvenile fish, crabs, and shrimp . . . The river is also an important natural resource that supports many uses including industry, transportation, recreation, drinking water, and aesthetic enjoyment" (Bowen et al. 2009). On a popular tourism website[2] are quotes such as the following about the LCFRE (emphasis added):

- Hard to review a river! It's *wild, powerful,* beautiful in all seasons....
- Amazing to walk down on the observation area and look at *how fast the river moves through this area.* You can understand how and why it got its name.
- *Cape Fear river current is very swift and strong.*

Thus, casual observers can discern that this segment of the LCFRE is highly river-influenced with strong flow. Bowen et al. (2009, p. 2-4) wrote, "[f]rom a hydrodynamic perspective,

[1] (NDENR) http://www.eenorthcarolina.org/images/River%20Basin%20Images/final_web_capefear.pdf.

[2] (http://www.tripadvisor.com/ShowUserReviews-g49673-d107702-r242913110-Cape_Fear_River-Wilmington_North_Carolina.html#REVIEWS

the Cape Fear has approximately a two-meter [~6-foot] tide range and strong tidal currents (> 0.5 meter per second) in the navigational channel of the open estuary and in the narrower tidal river channels of the three major tributaries (the mainstem freshwater river, and the Northeast Cape Fear and Black Rivers)." The LCFRE system is, in fact, documented in the science literature as strongly flowing down to its confluence with the Atlantic Ocean (e.g. Ensign et al. 2004, Lin et al. 2006, Becker et al. 2010). The strong flow minimizes stagnant areas and helps to add oxygen from the overlying air (Wetzel 2001).

It has been erroneously suggested in the NCDENR-DWQ Proposal and supporting materials that this strongly flowing, high-volume river is so strongly influenced by oxygen-demanding materials from natural drainage of freshwater wetlands and saltmarshes that the LCFRE is "swamp-like" with respect to DO conditions. Slowly flowing blackwater streams with instream wetlands in the Coastal Plain of the southeastern U.S. *can* receive high inputs of DO-demanding materials from the wetlands, and DO can range from 4-6 mg/L (Mallin 2000, Todd et al. 2009, and references therein). However, *such characteristics of slow flow and in-stream wetlands do not characterize most of the LCFRE system.* One area of the estuary north of Wilmington which receives major influx of swine wastes from CAFOs, near the junction of the Cape Fear, Black, and Northeast Cape Fear Rivers, has been described as prone to low DO levels during summer-early fall, but the low DO levels there have been related to *high anthropogenic pollution* along with inputs of natural organic materials (Mallin et al. 2003). Water quality in that area, as throughout the segment, would be greatly improved by reducing the high anthropogenic pollution coming into the segment from the many regulated pollutions sources in the Cape Fear watershed that were inappropriately excluded from consideration or lumped in with background sources in the NCDENR-DWR Proposal and supporting materials.

III. Sources of Water Quality Impairment

A. Historic Background, Assessments, and Erroneous Assertions

Historically, the LCFRE system was considered non-eutrophic because of its rapid flushing (Ensign et al. 2004). In the upper and middle Cape Fear River during 1955-1980, Crawford (1985) noted that DO concentrations at Lock 1 averaged 8.2-8.4 mg/L depending on the data source, and that on only two occasions from 1975 to 1980, DO samples were above 4 mg/L but less than 5 mg/L. Similarly, NCDENR (1999) described the upper portions of the estuary in the 1990s as rarely having sustained low DO levels that caused problems (assumed to refer to problems for aquatic life). The present-day LCFRE, however, is impaired due to major pollution from the upper, middle, and lower watershed (Cahoon et al. 1999, Mallin 2000, Mallin et al. 2003). As a result of declining water quality due to many pollution sources, for the past ~15 years the Cape Fear Estuary has been characterized as moderately eutrophic (= moderately nutrient-polluted; Bricker et al. 1999).

As described by NCDENR (2005),

> The [Cape Fear] watershed (about 9,149 square miles) is the most heavily industrialized in North Carolina with 244 permitted wastewater discharges and (as of 2000) over 1.83 million people residing in the basin....

Approximately 24% of the land use in the watershed is devoted to agriculture and livestock production.

Historically, post-European settlement, the lower Cape Fear River and Estuary received mostly raw (untreated) or partially treated wastes from the Riegel Paper Corporation (in Wilmington; became Federal Paperboard Company, and then International Paper from 1996 to the present) and the various, relatively small human population centers that developed along it (State Stream Sanitation Committee 1957, CH2MHill 2014a - Technical Memo 1 in May 2014, used to support the request for reclassification of the LCFRE segment). CH2MHill (2014a) described the previous situation as "significant impacts from untreated and poorly treated wastewater under low to moderate flow conditions in the river" prior to improvements in waste treatment. In the mid-1950s on one date (August 30, 1955), low DO (1.3-2 mg/L) and low pH (5-6) were measured in the Northeast Cape Fear and Black Rivers, the two main tributaries to the Cape Fear Estuary other than the mainstem Cape Fear River as mentioned. On two dates (July 23-24, 1956) during moderate flows from these two tributaries and high flow from the mainstem Cape Fear River, DO and pH in the lower river were 2.8-4.9 mg/L and 6.8-7.2, respectively. The interpretation from this sparse information (three dates, ~60 years ago) was that "*under some situations,* swamp drainage conditions *could* significantly influence DO and pH conditions in the river. . .." (emphasis added) (State Stream Sanitation Committee 1957, CH2MHill 2014a).

From there, however, a major "leap" occurred in CH2MHill's (2014a) writing (p.D-15 in May 2014): Riparian wetlands -- that is, natural wetland drainage -- were described, without any other supporting data, as the "significant contributors to the tremendous loads of oxygen-demanding materials." CH2MHill (2014a, p.D-15) secondarily acknowledged that inputs of biochemical oxygen demand (BOD) have also been contributed by raw and partially treated sewage, and from swine wastes, although CH2MHill mistakenly stated that swine wastes only contribute pollution to the LCFRE when cess pits breach. As corrective information, swine wastes *routinely* contaminate the LCFRE (see Section IIIE of these Comments), and researchers have evaluated swine CAFO wastes as a major source of BOD in the LCFRE (e.g. Mallin et al. 1997, 2006; Mallin 2000). Yet, the remainder of CH2MHill's (2014a) writing implicated natural drainage from wetlands as the major contributor of oxygen-demanding materials to the LCFRE. In the 1950s, the Cape Fear basin had less industrialization and fewer point sources (including no CAFOs), but the present reality is far different. As explained above, the Cape Fear River basin is *now* described as the largest, most industrialized watershed in North Carolina (Mallin et al. 2003, NCDENR 2005).

TetraTech (2014 - Technical Memo 2 in May 2014, used to support the request for reclassification) considered BOD loads from three specific point sources, which they erroneously described as contributing about 90% of all point source loads to the LCFRE. In reality, these three point sources contribute only a small fraction of the total point source loads - see Section IIID-E of these Comments. Based on data from the previous 20 years, TetraTech reported a significant downward trend (~23% decrease over time) in oxygen-demanding pollutant loads from the three selected point sources, without a corresponding decrease in water-column DO. The lack of a corresponding decrease in average DO should have been expected, considering that TetraTech *did not* assess ~1,194 other regulated sources in the Cape Fear watershed that are contributing oxygen-demanding materials and other pollution to the LCFRE. Over the same 20-year period in the Cape Fear River basin,

the human population increased by ~0.66 million and swine production increased by ~5 million animals per year (compiled from U.S. Census Bureau data, Burkholder et al. 1997, and Cahoon et al. 1999). Yet, TetraTech (2014) implicated wetlands as the major contributor to oxygen-demanding materials in the the LCFRE. TetraTech stated that the information from its recent analysis supported its previous assessments of the LCFRE (TetraTech 2001, 2003), and erroneously maintained that its assessment supported reclassification of the LCFRE segment to a swamp.

CH2MHill (2014b - Technical Memo 4 in May 2014, used to support the request for reclassification) described an analysis of surface water quality conditions in summer (which was defined as April-October) at main inflows to the Cape Fear River Estuary including the Middle Cape Fear River, the Black River, and the Northeast Cape Fear River. Importantly, *the Northeast Cape Fear River and the Black River stations were* ***erroneously*** *described as characteristic of "water quality as water leaves areas currently classified as swamps."* These segments are classified as swamps, but their present water quality reflects massive pollution, not natural wetland inputs (see Section IIID, p.18 below). During the early to mid-1990s, the relatively small areas of the Northeast Cape Fear and Black River watersheds sustained an influx of more than 800 swine CAFOs with more than 3 million swine produced per year (NCDENR 2005; and F*igures 1 and 2*). They contribute roughly the same amount of wastes as 12 million people, and the wastes are poorly regulated (see Section IIID).

Bowen et al. (2009) tacitly included pollution from swine feeding operations in "tributary inputs" although they were not specifically mentioned. CH2MHill (2014b) and TetraTech (2014) not only failed to mention them (and in CH2MHill 2014a, there was only one, partly inaccurate mention of swine operations as described above), but also omitted them from consideration. All of the other point source contributions from the upper and middle watershed were not considered as well. The omission of CAFO wastes and most other point sources in the watershed from consideration in assessments of oxygen demand in the LCFRE is irrational rather than science-based. The extreme error of omission in those reports is compounded by an equally extreme error of co-mission - repeatedly attributing to natural wetland drainage the massive oxygen-demanding pollution known to be contributed by other sources including CAFOs (e.g. Dewi et al. 1994, Burkholder et al. 2007 and references therein; see Section IIID below). Similarly, NCDENR was described by May (2014, p.D-3) as having stated, erroneously, that "changes in the classification of the LCFRE might be appropriate to recognize the influence of natural drainage from riverine and saltwater marsh systems in the watershed on DO concentration."

There is no basis in fact - no data - supporting major attribution to natural freshwater wetlands and saltmarshes of what CH2MHill (2014a) described as "tremendous" loads of oxygen-demanding materials in the LCFRE, while "overlooking" the massive pollution from ~98% of the point and other regulated sources in the watershed.

B. Processes Influencing DO Conditions, and Available Information for the LCFRE

Several major processes influence water-column DO concentration in rivers (*Figure 3*). Oxygen demand from two general sources controls water-column DO: *external* (incoming)

materials from land-based sources, upstream waters and the overlying airshed, usually referred to as the BOD in the water column, and the "*internal*" oxygen demand from biota respiration and river bottom sediments, usually called the sediment oxygen demand (SOD).

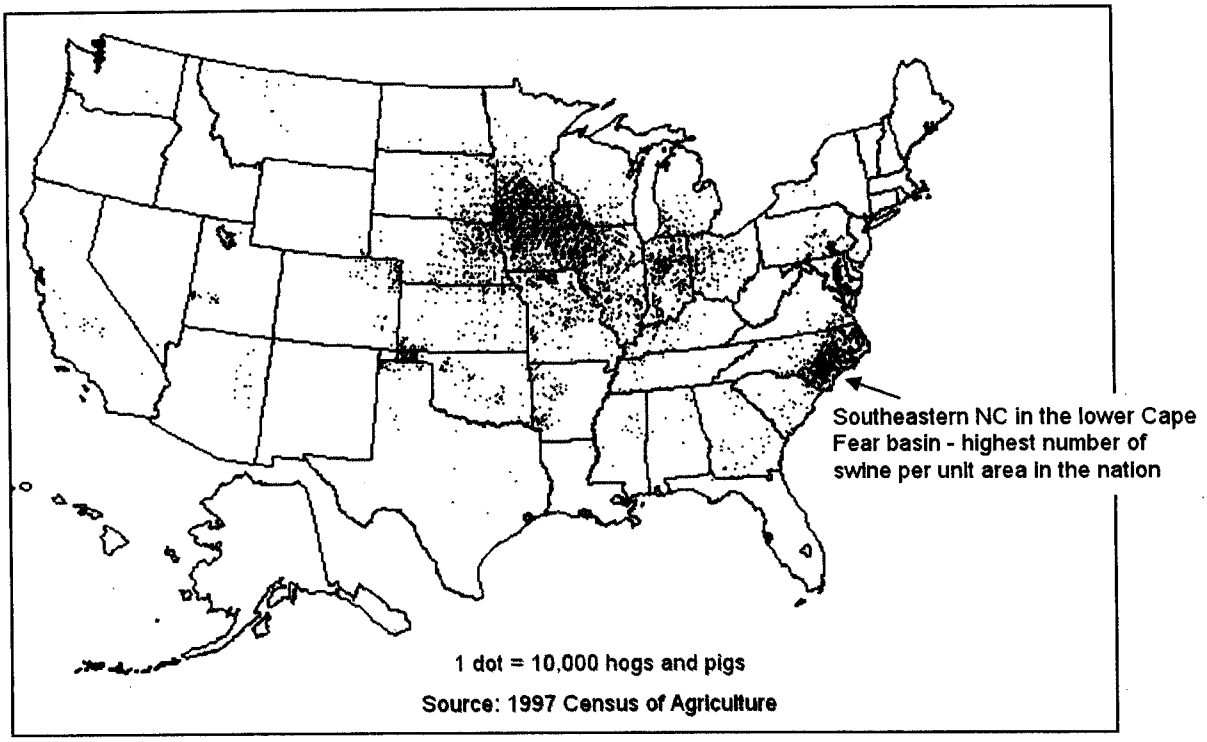

Figure 1. Map showing the number swine in southeastern North Carolina, with most CAFOs in the lower Cape Fear River basin area (source: http://scorecard.goodguide.com/env-releases/aw/nc-riverbasin.tcl?image_id=030300&huc6=030300). This map, produced by the USDA based on 1997, data, is supported by a more recent map, available at http://www.agcensus.usda.gov/Publications/2012/Online_Resources/Ag_Atlas_Maps/Economics/Market_Value_of_Agricultural_Products_Sold/12-M030.php, which shows the value of hogs and pigs sold in 2012 as the percent of the total market value. The highest concentration of swine per unit surface area across the nation is in the lower Cape Fear River basin.

BOD (units, milligrams per liter, mg/L) is the sum of carbonaceous and nitrogenous oxygen demands; it is a measure of the molecular oxygen used in the water column during a specific incubation period, usually 5 days, for the biochemical degradation of organic material (carbona-ceous demand) and the oxygen used to oxidize inorganic material (nitrogenous demand), as well as the amount of oxygen used to reduce forms of nitrogen (Eaton et al.1995, MacPherson 2003).

SOD (units, grams of molecular oxygen per square meter per day, g O_2 /m^2/day) is defined as the rate of DO removal from the water column due to the decomposition of organic matter in the bottom sediments (Hatcher 1986). It consists of biological sediment oxygen demand (usually at the sediment surface, dominated by bacteria that consume organic materials) and chemical sediment oxygen demand (usually ~2 inches down in the sediment, where anaerobic

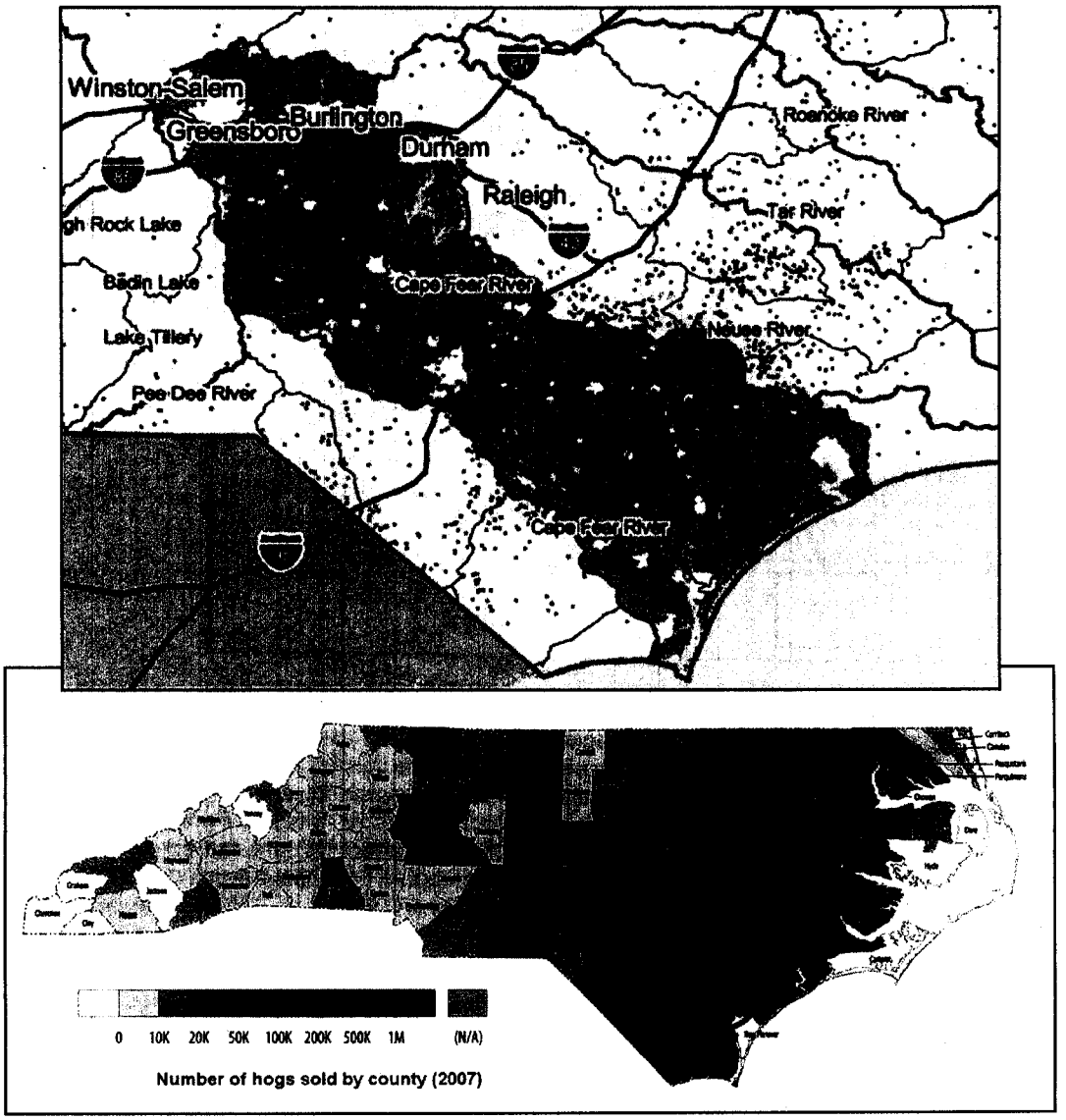

Figure 2. Upper panel - map showing the locations of swine CAFOs in North Carolina, indicating the preponderance of CAFOs in the lower Cape Fear River basin (source: http://scorecard.goodguide.com/env-releases/aw/nc-riverbasin.tcl?image_id=030300&huc6=030300, last accessed in February 2015). Lower panel: Map showing the numbers of hogs sold in North Carolina counties during 2007 (K ≡ thousands, M ≡ millions; U.S. Census data), modified from Learn NC, a program of the University of North Carolina School of Education (available at http://www.learnnc.org/lp/editions/nchist-recent/6257, last accessed in August 2014). The darker area "down east" on the Coastal Plain of the state has, as mentioned, the highest concentration of swine per unit area in the nation (National Hog Farmer 2014.).

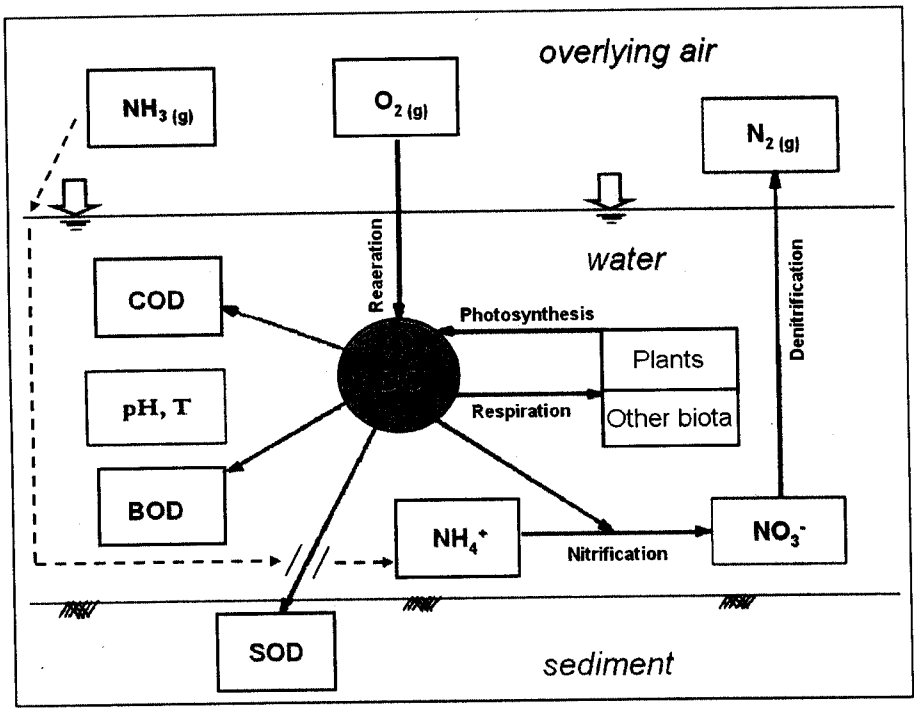

Figure 3. A schematic of the major processes influencing the water-column ("water") DO concentration in rivers: O_2 = the oxygen gas diffusing into the water from the atmosphere; N_2 - the nitrogen gas diffusing out of the water into the atmosphere; COD - the immediate chemical oxygen demand; T - temperature; NH_4^+ - ammonium; NO_3^- - nitrate. Arrows directed toward DO indicate DO sources; arrows directed away from DO indicate DO users (consumers or "sinks"). Parameters in red are oxygen-demanding. Other environmental conditions that can affect DO are represented by pH and temperature (T). The dashed-line arrow indicates that ammonia from the overlying airshed, largely contributed in southeastern North Carolina by swine CAFOs (Walker et al. 2000, Aneja et al. 2003), is mostly ionized to ammonium in neutral to alkaline waters and becomes a source of nitrogenous oxygen demand in forming nitrate. Modified from Cox (2003).

anaerobic bacteria degrade organic matter in a process that produces reduced ions that react with oxygen when they diffuse upward to an oxidized area (Walker and Snodgrass 1986).

The organic materials contributing to SOD can come from outside the system (such as leaf litter or settling of organic particles from human or animal wastes), or from within the system (such as decomposing algae). SOD is positively related to the amount of organic carbon content (i.e., bioavailable organic materials) in the sediment (MacPherson 2003 and references therein). Basically, the rate at which the sediment community consumes oxygen indicates whether the sediment area is degraded by too much organic matter (Massachusetts Water Resources Authority 2002). Once organic material reaches the bottom sediments of the river segment, SOD is influenced by two different processes: the rate at which oxygen diffuses into the sediments and is consumed there, and the rate at which reduced organic substances move into the water column and are then oxidized (Bowie et al. 1985, Todd et al. 2009).

Thus, SOD is the combination of the respiration of bottom-dwelling organisms in the sediment from decomposition of organic matter, and chemical oxidation of reduced substances in the sediment (Todd et al. 2009, and references therein). SOD can create oxygen deficits by reducing the amount of available oxygen in the overlying water (Seiki et al. 1994), and it can be a significant percentage of the total oxygen consumed in a given river or estuary (Caldwell and Doyle 1995). SOD rates serve as proxies for the effects of pollution on the biological activity of the bottom (benthic) community; for example, a nutrient-polluted system generally has an increased demand for oxygen (Natural Research Council 2000). Extreme levels of SOD (~20 $g/m^2/day$) can occur from oxygen consumption by animal wastes or sewage materials that settled out to the bottom (Davis 1950). Reduction in the amount of incoming organic materials from such pollution can lower the SOD as the system recovers (see Massachusetts Water Resources Authority 2002).

The sophisticated three-dimensional, Environmental Fluid Dynamics Code model used by Bowen et al. (2009) requires extensive information for the many factors needed to construct (parameterize) it for a specific river segment (Hamrick 1992; Bowen et al. 2009 - see p.v, Table 1, and Figure 2 in that document). Adequate measurements from the LCFRE for many of these factors were/are not available, and they vary considerably from river to river (Hamrick 1992, Todd et al. 2009, and references therein). The required missing or sparse (inadequate) information includes oxygen fluxes between the water column and the bottom sediment of the river. The information was instead "prescribed" (estimated, or taken from general literature not specific to the LCFRE) (Bowen et al. 2009, p.2-1). Bowen et al.'s (2009) model development revealed that, as in many if not most lower rivers along coastlands, SOD has an especially significant impact on DO concentrations. *SOD varies by as much as three orders of magnitude (1,000-fold) from river to river*, with rates ranging from ~0.1 to 18 grams of oxygen [demand] per square meter per day ($g/m^2/day$) (Rolley and Owens 1967, Chapra 1997, Todd et al. 2009). Importantly,

> The effect of SOD on the oxygen budget of an entire river system should not be underestimated, as it can be a critical sink of DO (Wu 1990). Indeed, in some rivers SOD can account for over half of the total oxygen demand and can play a primary role in the water quality....[Yet] this parameter is often assumed (or estimated) in water quality models (Hatcher 1986, Matlock et al. 2003). Errors in this measurement could lead to inaccurate models for the stream environment, at great biological and financial cost. - Todd et al. (2009)

Only sparse, dated SOD information was available for the LCFRE, taken more than a decade ago by the former NCDENR – DWQ (Division of Water Quality) at five locations on only five dates during summer/fall of one year, 2003 (Bowen et al. 2009, pp. 2-14, 2-15). At a given location, SOD is known to vary substantially by season and from year to year (Hatcher 1986, MacPherson 2003 and references therein). Lacking sufficient data and, thus, finding these sparse data to be a poor fit for the model overall, Bowen et al. (2009) "selected" SOD values until they found one that best fit their model for predicting water-column DO data, which had been constructed using available water-column DO measurements. In other words, Bowen et al. knew what the water-column DO had been because it had been measured during the period of focus, so they tried different SOD values until the model generally "fit" the water-column DO data. The SOD value (adjusted in an attempt to allow

for seasonal changes) was applied to most of the LCFRE; a second, nearly four-fold higher value for SOD was applied to the Northeast Cape Fear River which is heavily influenced by swine CAFOs (see p.18 below). Bowen et al.'s (2009) approach to estimate SOD technically requires that all rates except SOD have been accurately determined based on data for the specific system (Cox 2003). In reality, some of the data needed to accurately estimate the major rates of processes shown in *Figure 3* of these Comments (photosynthesis, respiration, nitrification, denitrification, reaeration) are lacking at representative points along the LCFRE system. Such data should include at least monthly measurements from April through October during dry, average-precipitation, and wet years (Hatcher 1986 and references therein).

C. The Model Predicted 90% Control of LCFRE DO Levels by the "Tributary Inputs," and Compliance with the DO Standard by Reducing Those Inputs

Despite the above-described weaknesses, Bowen et al.'s (2009) model *did* predict - as would be expected from knowledge of pollution sources in the LCFRE basin - that the 20 point sources they considered had only a small effect on the water-column DO concentrations. In contrast, "tributary inputs," loosely defined as excluding the 20 point sources, were evaluated as the major controlling influence on DO. Importantly, when Bowen et al. artificially forced SOD to remain constant over time despite imposing reductions of 30%, 50%, or 70% in BOD loads from the "tribuary inputs," the model predicted that the BOD decreases alone would increase median DO concentrations to well above the present DO standard of 5 mg/L. In addition, if BOD from tributary inputs and SOD were both reduced by 30%, the model predicted that summer DO violations would decrease from 45% to 22%, down to only 7% with a 50% reduction, and down to 1% with a 70% reduction. Such a scenario of decreasing BOD and SOD is realistic, as SOD is known to decrease over time with decreasing water-column BOD inputs, and related decreases in the bioavailabilty of organic matter that settles out to the sediments (Hatcher 1986, MacPherson 2003 and references therein).

Bowen et al. (2009) did not attempt to address the predominant sources in the "tributary inputs." They aptly noted (pp. vii-viii) that their model indicated the importance of benthic fluxes of oxygen. They also aptly recommended additional work to assess SOD and also, importantly, to separately consider the effects of wetland (natural) versus "riverine" (pollution carried by the river and tributaries) loadings to DO conditions in the estuary. The subsequent work in support of this proposal did not conduct these evaluations.

D. Point Source Pollution from NPDES-Permitted Facilities Upstream from the LCFRE

Given the above predictions from Bowen et al.'s (2009) model, control of "tributary inputs" *would* allow the LCFRE to attain the present DO standard. Therefore, a TMDL for the LCFRE segment is entirely appropriate. Moreover, as stated, the available scientific information indicates that human-related pollution - not natural wetland drainage - is the major source of oxygen-demanding materials to this segment (see pp. 18-19 below).

The U.S. EPA states that:[3]

[3] http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/overviewoftmdl.cfm#tmdlrequired

the objective of a TMDL is to determine the loading capacity of a given water body and to allocate that load among different pollutant sources so that the appropriate control actions can be taken and water quality standards achieved....**All contributing sources of the pollutants** (point and nonpoint sources) are identified, and they are allocated a portion of the allowable load...." (emphasis added).

Thus, a TMDL for the LCFRE should consider the entire watershed above that segment as potentially contributing to pollution in that segment. According to NC DENR[4], the upper-middle Cape Fear basin has 38 major point sources (discharging ≥ 1 mgd; *Figure 4*) and ~115 minor point sources (< 1 mgd) with NPDES permits. The lower Cape Fear basin contains 10 major point sources and 33 minor point sources with NPDES permits. Thus, the river sustains loading from 195 NPDES-permitted point sources including nearly 50 major NPDES-permitted point sources and nearly 150 minor NPDES-permitted point sources. Consider the following example of a major point source that was not among the 20 specifically assessed by Bowen et al. (2009):

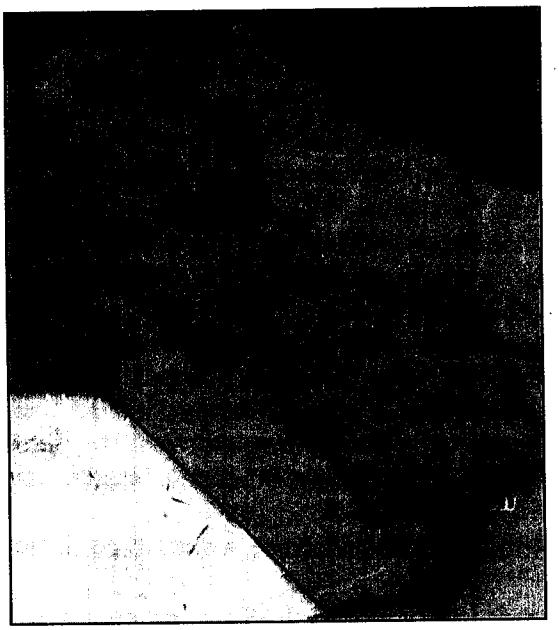

Figure 4. Map showing the locations of major point sources with NPDES permits from NC DENR in the Cape Fear River basin (red dot, Smithfield Packing Company; red line - approximate location of the LCFRE segment proposed for reclassification). Modified from NC DENR (see websites given in footnote 4).

The Smithfield Packing Company at Tar Heel in the mid-Cape Fear River basin, ~60 miles upstream from the LCFRE (location indicated by the red dot in *Figure 4*), is permitted to discharge up to 3 mgd of effluent containing up to 250 pounds of BOD_5 per day during April - October as a monthly average, and up to 500 pounds of BOD_5 as a daily maximum (NC DENR permit #NC0078344). During November-March, the plant is permitted to discharge double those amounts (i.e., 500 pounds per day, monthly average; 1,000 pounds per day, daily maximum, equivalent to 45 mg of biochemical oxygen-demanding materials/L). Rivers are considered to be stressed with too much BOD_5 if concentrations exceed 3 mg/L (Mallin et al. 2006). The plant is also permitted to discharge 30 pounds of ammonia-N/day as a monthly average during April-October, and 60 pounds of ammonia-N per day (7.5 mg/L) as a daily maximum. In November-March, these numbers, as pounds per day, can double. As explained, ammonia is oxygen-demanding, highly toxic to sensitive aquatic life, and a form of inorganic nitrogen that, at concentrations of only 0.1-0.2 mg/L, can stimulate noxious and toxic algal outbreaks (Bricker et al. 1999 and references therein, Mallin 2000). Other inorganic nitrogen forms, nitrate+nitrite, in discharges from the plant can be up to ~120 mg/L as a monthly average, and up to ~185 mg/L as a daily maximum. As stated,

[4] 2014 - http://portal.ncdenr.org/web/wq/npdes-major-facility-map, and http://portal.ncdenr.org/web/wq/npdes-minor-facility-map.

only 0.1-0.2 mg/L of inorganic nitrogen is needed to stimulate noxious and toxic algal outbreaks. Thus, extremely high oxygen-demanding materials and inorganic nitrogen nutrient forms are permitted for discharge by this major point source.

Overall, nearly 150 NPDES-permitted point sources in the Cape Fear River watershed are upstream from or adjacent to the LCFRE. Some pollutants from these point sources, such as the highly soluble nitrogen species, nitrate, are highly soluble; nitrate, for example, is known to travel distances of hundreds of miles downstream from upper to lower watersheds in North Carolina and elsewhere (Mallin et al. 1993, Houser and Richardson 2010, Houser et al. 2010). That is why, for example, various pollutants from the upper Mississippi River drainage are known to contribute to the "dead zone" of little or no oxygen all the way down in southern Louisiana, near the river's confluence with the Gulf of Mexico (Goolsby and Battaglin 2001, Jacobson et al. 2011). Nutrient pollution contributes to oxygen-demanding materials by stimulating algal blooms that die and are then decomposed by bacteria which use oxygen for that process (Burkholder and Glibert 2013, and references therein). Based on the fact that nitrate, much less soluble pollutants such as phosphorus, and oxygen-demanding organic carbon materials can travel much longer distances than 60 miles (above references, Minshall et al. 1983, Meyer and Edwards 1990), the excessive nitrate in the Smithfield Packing Company discharge should be expected to contribute to oxygen-demanding materials in the LCFRE ecosystem. The same is true of other upstream point sources, other regulated sources and nonpoint sources.

E. Point Source Pollution from Animal Production in the Lower Cape Fear Basin

In addition to the ~150 NPDES-permitted point sources that should be considered by NCDENR in developing a TMDL to improve DO in the LCFRE, there are nearly 1,000 swine CAFO point sources in the lower Cape Fear basin (and an unknown number of poultry CAFOs, based on Mallin 2014). The available scientific information shows that swine CAFO point sources are the major source of water quality impairment in the lower Cape Fear basin.

Major degradation of the natural resources in the lower Cape Fear basin due to swine CAFO point sources -- encompassing degradation to the airshed, soils, groundwaters, and surface waters -- has been well-documented and is briefly summarized below. It merits mention that, throughout these Comments, the focus when considering CAFOs is on swine production because relatively little information about poultry production is available to scientists or other members of the general public (e.g. see Rothenberger et al. 2009a). North Carolina is second in poultry production among the states, but nearly all of the operations have fewer animals than are defined by the state legislature as a poultry CAFO, and most information is allowed to the general public only for poultry CAFOs. Thus, most information given below for industrialized animal production in the Cape Fear basin is substantially underestimated because it focuses only on swine.

The available information *does* show that poultry production is a major source of pollution in the Cape Fear watershed (Cahoon et al. 1999). According to the North Carolina Department of Agriculture (http://www.ncagr.gov/stats/coest/Index.htm), in 2012 the lower Cape Fear basin (Brunswick, Pender, Duplin, Sampson, and Cumberland Counties, and estimates for parts of Bladen and Onslow Counties) contained about 5 million swine,

21.5 million poultry, 123 million chickens, and 72,000 cattle. The facilities which produce these animals are *not* required to have streamside buffers, or to control of ammonia or hydrogen sulfide emissions etc. They *are* required to have what can only be described as grossly inadequate waste management because it clearly does not prevent major impacts to public trust natural resources (below). Cahoon et al. (1999) provided the following estimates for the Cape Fear River basin (recall that most swine production occurs in the lower basin):

- Swine: more than 7 million tons of fresh manure per year added to the lower basin;
- Poultry: 2.18 million tons of fresh manure per year;
- Cattle: 2.08 million tons of fresh manure per year;
- Total from this animal production: 82,700 tons of nitrogen (N) and 25,950 tons of phosphorus (P) (Cahoon et al. 1999), the two nutrients that are known to cause major noxious algal outbreaks (Burkholder and Glibert 2013).

Cahoon et al. (1999) concluded that:

> The eutrophication threat to these river basins [which included the Cape Fear River basin]... with expanding animal populations from the potential large nutrient loadings associated with intensive livestock operations is substantial.

Many contaminants are present in swine CAFO wastes and runoff, including extremely high levels of nutrients N and P, more than 100 microbes known to cause human disease, pharmaceutical chemicals that harm beneficial aquatic life, toxic heavy metals (especially copper and zinc), and pesticides such as toxic dithiocarbamates from sprayfield applications (Barker and Zublena 1995; Burkholder et al. 1997, 2007 and references therein, Iowa State University and The University of Iowa Study Group 2002, Extension Toxicology Network 2003). These contaminants can enter the surrounding environment through pathways such as leakage from poorly constructed cesspits, or during major precipitation events that cause cess pit overflow and runoff from recent sprayfield application, or atmospheric deposition followed by wet or dry fallout (Burkholder et al. 2007 and references therein). The magnitude and direction of transport depends on factors such as soil properties, contaminant properties, hydraulic loading characteristics, and crop management practices. Over-application of swine wastes to sprayfields can result in contaminants leaching through permeable soils into vulnerable aquifers (see Section IIIE - Groundwater Degradation from Swine CAFO Point Sources, below).

Contamination of surrounding public-trust surface waters such as the LCFRE in southeastern North Carolina is a common, routine problem *at recommended application rates* as well (e.g. Barker and Zublena 1995; Westerman et al. 1995; Zublena et al. 1995; Stone et al. 1995, 1998; Walker et al. 2000; Aneja et al. 2001, 2003). Improper disposal of animal carcasses and abandoned swine CAFO facilities also contribute to water quality problems. Siting of CAFOs in areas prone to flooding or where there is a shallow water table, such as in the lower Cape Fear basin, increases the potential for contamination of public trust natural resources as well.

Swine CAFO point sources in the lower Cape Fear basin - Swine CAFOs in southeastern North Carolina mostly were installed from the late 1980s through 1995. These CAFOs store

animal wastes in large cess pits (which the industry calls "lagoons") (*Figure 5*). After the solids mostly settle out, the liquid wastes are applied to relatively small sprayfields. The soils in the area are mainly sandy and shallow; the water table is only about three feet from the land surface (Burkholder et al. 1997 and references therein). The shallow, sandy soils simply cannot absorb the massive amounts of waste applied to them by the CAFOs, time after time per season, year after year (see example in *Figure 4*). Waste that is applied to the fields mostly percolates into the shallow groundwater and then moves to receiving streams and rivers (e.g. Evans et al. 1984). Most cess pits for these swine CAFOs were installed in North Carolina prior to 1993, when linings of clay or other materials were not required (Burkholder 1997 and references therein).

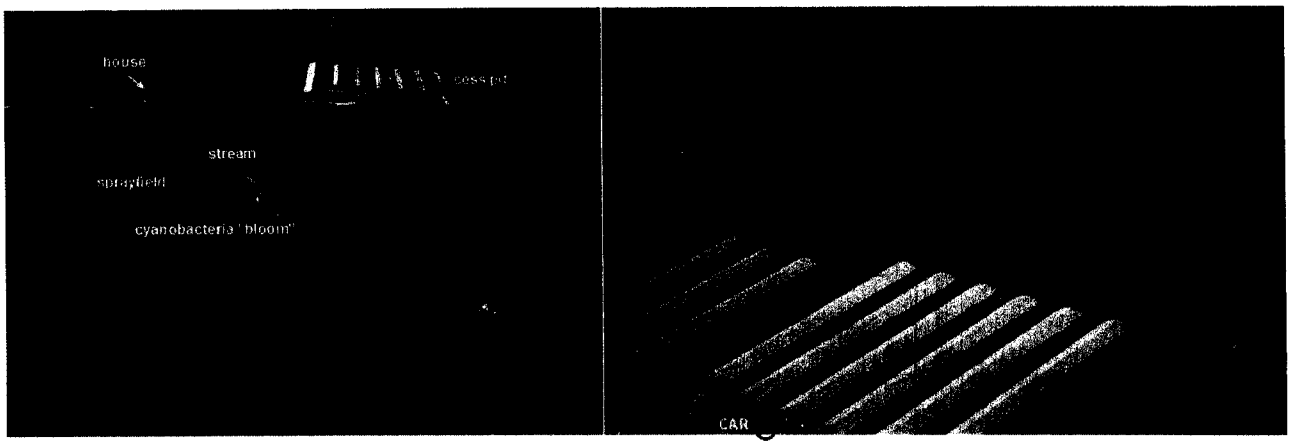

Figure 5. Left: A swine CAFO in the lower Cape Fear River basin, showing (from top to bottom) a house (noted for scale), the buildings that contain about 5,000 animals, the adjacent cess pit, the sprayfield, a stream that has been transformed to a gully conveying wastes from the field into a wetland, and a dense bloom of cyanobacteria (blue-green algae), potentially toxic to humans, that was fueled by the high nutrients in the CAFO wastes (see Burkholder et al. 1997, 2007 for supporting information). Thus, clearly the wastes were moving off-site to contaminate adjacent natural resources. This relatively small field with a shallow layer of soil above the water table, and the cess pit, are "supposed to" adequately treat the liquid wastes, year after year, from 5,000 swine per year, equivalent to the amount of wastes produced by 20,000 people (1 swine produces the equivalent amount of wastes, roughly, of 4 people; see below). Photo: M. Mallin. Right: Two swine CAFO cess pits (the car is circled for scale). The pinkish color is due to anaerobic sulfur bacteria and is suggestive of very high levels of hydrogen sulfide gas, which is toxic to humans (Burkholder et al. 1997, and references therein). Photo: R. Dove, Waterkeeper Alliance.

The general situation was described as follows:

> [CAFO] technology, originally designed for application in upland areas with adequate soil depth above the water table, was embraced in counties where 60-80% of the area put into production was originally low-lying wetlands adjacent to rivers and estuaries. The operations were exempt from land zoning laws and mandatory inspection programs. Waste lagoons were not required to have leakage-reducing liners; some were constructed below the water table less than 20 m [50 feet] from neighboring homes and wells . . . The NC Division of Water

> Quality, charged with water resources management, lacked the personnel and resources necessary to adequately monitor surface or groundwater quality. More fundamentally, the North Carolina Department of Agriculture legally refused to provide the Division of Water Quality with basic data such as the location and number of existing and planned animal operations . . . After considerable effort the North Carolina Environmental Management Commission . . . passed rules in 1993 for design of animal waste lagoons and effluent treatment. These rules mandated use of clay or other suitable liners in future construction of lagoons associated with [CAFOs with] 250 or more swine. They included a grandfather clause to exempt existing operations from having to alter their lagoon design . . ..(Burkholder et al. (1997; references included therein).

The information presented below for airshed, soil and groundwater contamination is included because pollution of those natural resources by swine CAFOs can substantially contribute to surface water contamination, which is the main subject of these Comments regarding the state's classification of the LCFRE segment.

Airshed degradation from swine CAFO point sources

Swine CAFOs emit copious air pollutants known to adversely impact human health and, indirectly, surface waters. For example, ammonia and hydrogen sulfide are emitted at levels toxic to humans (U.S. EPA 1998; also Aneja et al. 2001, Liu et al. 2014). Within a 60-mile radius from where it is emitted, the volatilized ammonia tends to return to the land and surface waters with rain (Aneja et al. 2003), where it can adversely affect river ecosystems (below; e.g. Rothenberger et al. 2009b).

Swine CAFO production in the lower Cape Fear basin has caused a significant increase in air pollutants such as ammonia (Aneja et al. 2003, Wing et al. 2012 and references therein). Surface waters and groundwater are also being adversely impacted; Burkholder et al. (2006) documented a significant increase in ammonia concentrations within the lower Cape Fear River where swine CAFOs are highly concentrated. Cahoon et al. (1999) wrote,

> Aerial deposition of nitrogen, principally ammonia-nitrogen, is recognized as a contributing threat to coastal water quality . . . Some studies estimate that up to 90% of the manure nitrogen produced by swine volatilizes and is deposited downwind [to the land and surface waters] (NC DENR Division of Air Quality 1997).

Sampson County (946 square miles), in the Cape Fear River basin, had 1.8 million swine as of 1998. The National Atmospheric Deposition Program has monitored atmospheric ammonia there since 1978. Mallin (2000) noted that during the 1988-1998 decade, there was a concurrent rise in atmospheric ammonia and the swine population; and that from linear regression analysis, 72% of the variability in airborne ammonia could be explained by changes in the county swine population alone. Upwind in the North Carolina Piedmont, counties with low swine populations showed no ammonia increase during the same period.

Soil degradation from swine CAFO point sources

Swine feed contains metals such as copper act as micronutrients in low concentrations, but

as toxic substances at higher levels. The metals persist in the extremely high amounts of swine wastes (Cahoon et al. 1999; see p.10 of these Comments), which are then applied to fields. Sensitive crops often cannot withdraw the metal in the soil, and leave it behind to accumulate. Research done in eastern North Carolina has explained how waste application contributes to metals pollution in field and, importantly, also has shown that as long ago as the mid-1990s, several counties in the lower Cape Fear River basin could no longer be used to grow metal-sensitive crops and would not need to fertilize with nitrogen or phosphorus for decades (Barker and Zublena 1995, Zublena et al. 1995). Runoff from the contaminated soil during/following precipitation events adds some of these toxic pollutants to adjacent surface waters.

Groundwater degradation from swine CAFO point sources

Areas around the cess pits of swine CAFOs in eastern North Carolina have been shown to receive leakage high in contaminant levels. Wells and subsurface seepage near the cess pits can be contaminated with extremely high levels of nitrate and ammonia (e.g. Huffman and Westerman 1995, Westerman et al. 1995, Ham and DeSutter 2000). The high nitrate levels are a result of the high ammonia levels because the ammonia is oxidized to nitrate as it moves away from the waste sources (see Burkholder et al. 1997, 2007, and references therein). High concentrations of nitrate are hazardous to human health, especially for babies and small children (who can be afflicted with methemoglobinemia or 'blue-baby syndrome'), because nitrate competes with oxygen for hemoglobin in the human bloodstream (Smith 2009, Knobeloch et al. 2010).

Many North Carolinians in the Coastal Plain area rely upon groundwater as their drinking water source (North Carolina Groundwater Association, http://www.ncgwa.org). North Carolina's drinking water standard for nitrate is less than 10 milligrams per liter (mg/L).[5] The available data suggest that many unlined swine effluent cess pits in eastern North Carolina cause nitrate pollution to nearby wells at levels that violate the 10 mg/L drinking water standard (e.g. Huffman 2004, Huffman and Westerman 1995, Westerman et al. 1995). Working in Sampson County within the Cape Fear River basin, Westerman et al.'s (1995, p.1749) study illustrates high contamination from unlined cess pit leakage:

> Two swine manure, anaerobic lagoons located in sandy, coastal plain soil were investigated. Both continued to have significant seepage after 3.5 to 5 years of receiving waste. Monitoring wells indicated *broad seepage plumes* [emphasis added], and much variation in concentrations of several parameters with well location, time, and depth of well . . . In some cases, ammonia and chloride concentrations in well samples were as high or higher than the lagoon liquid.

The last sentence of the above quote is especially of concern - that nearby monitoring wells had ammonia concentrations even higher than the lagoon liquid swine waste. Such

[5] (NC DENR Classifications and Water Quality Standards Applicable to Surface Waters of North Carolina, NC Admin. Code Section 15A NCAC 2B .0200, Environmental Management Commission, Raleigh, NC; http://portal.ncdenr.org/c/document_library/get_file?uuid=ad77b198-aa3d-4874-9723-54ce730b3a8d&groupId=38364).

information points to a major threat to shallow drinking water wells located only short distances, as little as 50 feet, from a swine lagoon cess pit.

Based on the available science literature, substantial groundwater contamination also is contributed by lined cess pits if not properly operated, as described by Westerman et al. (1985, p.1750):

> Ritter and Chirnside (1987) . . . reported high concentrations of NH_3-N and NO_3-N in groundwater monitoring wells near a clay-lined anaerobic lagoon for a hog-finishing unit. Some of the high NH_3-N concentrations were possibly due to lagoon overflow, which occurred several times. They suggested that the lagoon management of completely emptying the lagoon twice a year led to drying and cracking of the clay liner, resulting in seepage. They concluded that if clay-lined lagoons are not operated properly, they will have a serious impact on groundwater quality in loamy sand or sandy loam soils.

Ritter and Chirnside (1990) also reported extreme *average* ammonia-N concentrations, up to 1,000 mg/L, and extreme average nitrate-N up to 50 mg/L, in some wells near a clay-lined swine waste cess pit on the Delmarva Peninsula.

Swine CAFOs (both the land application practices and cess pit leakage) additionally pose a significant threat to well water via contamination by other harmful substances and pathogenic microbes (e.g. Stone et al. 1998, Krapac et al. 2002). Moreover, much lower concentrations of nitrate and ammonia can cause disease and death of beneficial aquatic life in receiving surface waters (see below). During summer low flow conditions on the North Carolina Coastal Plain, at least half of stream and river flow can be contributed by groundwater (Garrett et al. 2012 and references therein). Thus, groundwater contamination by swine CAFOs can contribute significantly to surface water contamination. Cahoon et al. (1999, p.414) wrote,

> An important water quality problem in North Carolina deriving from animal waste inputs is nitrogen loading to surface and groundwaters. Nitrogen frequently limits phytoplankton production in North Carolina's coastal waters, so increased nitrogen loads have stimulated noxious and toxic algal blooms and helped cause fish kills.

Surface water degradation from swine CAFOs

The wastes applied to sprayfields, emitted to the overlying airshed during the spraying activity, or leached into groundwater can make their way into surface waters as explained above. In addition, when the sprayfield soils are saturated with contaminants or with water during moderate to high precipitation periods, or due to over-application, the additional applied wastes rapidly move overland, through tile drains, and through the many ditches in the area to nearby surface waters. Thus, working in eastern North Carolina, Westerman et al. (1985) found high levels of nitrate (3-6 mg/L) in surface runoff from swine CAFO sprayfields that received swine waste effluent ***at recommended rates*** - that is, as a result of routine, accepted practices. For comparison, ~0.1 mg/L of nitrate (and ~0.08

mg/L of phosphorus - below) can cause noxious algal blooms (Mallin 2000, Wetzel 2001, and references therein). Working in Duplin County within the Cape Fear River basin, Stone et al. (1995) measured 6-8 mg of total inorganic nitrogen/L (= nitrate + nitrite + ammonia or ammonium) and 0.7-1.3 mg of phosphorus/L, another important nutrient that can fuel noxious and toxic algal outbreaks (Burkholder 2009), in a stream adjacent to swine effluent sprayfields:

> Mean nitrate-N concentrations of water leaving the [two] watershed outlet[s] were two- and four-times higher than background concentrations . . . Daily mean nitrate-N concentrations [at a tributary adjacent to a swine CAFO] sometimes exceeded 10 mg/L and frequently exceeded 6 mg/L. Over-applied swine lagoon effluent and undersized, overloaded lagoons were likely contributors . . . Mean ammonium-N concentrations . . . were approximately two- and four-times higher than background concentrations. Ammonium-N concentrations [at one watershed outlet] exceeded limits considered harmful to humans (0.5 mg/L) and fish (2.5 mg/L) (U.S. EPA 1973). During the first month of the sampling period, daily ammonium-N concentrations ranged from 6 to 12 mg/L . . . These high concentrations indicated that a significant discharge of animal waste products into the waterway had occurred . . . while storm flows are contributing to the total flux of nitrate-N, the majority of the nitrate-N flux is coming directly from the base flow [in other words, the high contamination occurred with and without precipitation/runoff]. - Stone et al. (1995)

Evans et al. (1984) reported 7-30 mg nitrate/L in subsurface flow draining a sprayfield for swine wastes that were applied at recommended rates:

> The potential for nutrient transport was much greater for subsurface drainage [than for surface drainage] . . . Nitrogen application at the recommended rate resulted in phosphorus application at nearly three times the recommended rate. Although this soil fixes [adsorbs] phosphorus, there was evidence of phosphorus movement in subsurface runoff by the fifth year of waste application at a higher rate. Continued phosphorus application even at the low [recommended] rate would eventually result in movement of P in subsurface runoff as the soil's assimilatory capacity for phosphorus would eventually be exceeded. - Evans et al. (1984)

These reports all describe *excessive* levels of inorganic nitrogen and phosphorus in comparison to what is needed to fuel a noxious or harmful algal outbreak. Evans et al. (1984) highlighted another problem -- that recommended rates of nitrogen application resulted in major excesses of phosphorus that, within a relatively short time, would saturate the soil and contaminate receiving adjacent surface- and ground-waters.

As mentioned, the extremely high nitrate in surface waters and groundwater near swine CAFOs comes from the high ammonia in swine wastes that combines with oxygen. Much lower nitrate levels (0.25-0.28 mg/L) than found in the above-described studies can cause disease and death of beneficial aquatic life (Camargo et al. 2005, Camargo and Alonso 2006). Nitrate can interfere with steroid hormone synthesis, adversely affect sperm

motility and viability, depress fecundity, and can be toxic to embryos (Edwards et al. 2004). It can also decrease immune response, act as an endocrine disruptor, and induce harmful hematological and biochemical changes in beneficial aquatic life (Guillette and Edwards 2005).

Although much of the ammonia which contaminates surface waters from swine CAFOs is oxidized to nitrate, before that occurs the ammonia can cause high toxicity to beneficial aquatic life, or can stimulate noxious algal outbreaks. Ammonia is a preferred form of nitrogen for many algal species including various harmful algae that can cause serious human illness (compiled from Bollos and Berge, Twomy et al. 2005, Herndon and Cochlan 2006, Burkholder 2009). Burkholder et al. (1997) reported ammonia concentrations as high as ~40 mg/L in a stream contaminated by a swine cess pit rupture. Such concentrations can be highly toxic to aquatic life (Camargo et al. 2005, Camargo and Alonso 2006), and would also be expected to stimulate noxious/harmful algal growth as the concentration became more dilute downstream (as was observed by Burkholder et al. 1997 and Mallin et al. 1997).

Swine CAFOs can cause other major surface water impacts from suspended solids loads and turbidity. The water near swine CAFOs is often dark and murky, and inhibits beneficial plant growth (Burkholder et al. 1997, Mallin 2000, and references therein). Swine wastes are acidic (pH ~6.5 - Zu et al. 2001 and references therein) and can impart acidity to receiving surface waters, although the lower mainstem Cape Fear River is well buffered due to the ocean's influence. Toxic levels of metals such as copper occur in runoff from swine effluent sprayfields because copper and other "trace elements" are added to swine feed to promote growth and control disease (Payne et al. 1988). These toxic substances can accumulate in sediments, water, and biota, to levels that are toxic to plants and lead to reproductive impairment, poor body condition, and immune system suppression in beneficial animals (Stubbs and Cathey 1999). Copper from swine and other livestock operations can be added to surface waters via overland discharge and groundwater leachate (U.S. EPA 2013).

Many impacts on surface waters from swine CAFOs are only beginning to be examined. Surface waters in Duplin County, also within the Cape Fear River basin, were recently assessed for fecal indicator bacteria (fecal coliforms, *Escherichia coli*, and *Enterococcus*) and candidate swine-specific microbial source-tracking bacteria over an annual period, both upstream and downstream from swine CAFO sprayfields. The authors noted, importantly, that the proximal "upstream" locations were potentially influenced by numerous upstream swine CAFO sprayfields, and also by poultry CAFO dry litter land application sites. The highest fecal indicator bacteria concentrations were found immediately downstream from swine CAFO sprayfields in spring and summer. The findings were summarized as follows:

> Testing of 187 samples showed high fecal indicator bacteria concentrations at both up- and downstream sites . . . Overall, 40%, 23%, and 61% of samples exceeded state [criteria] and federal recreational water quality guidelines for fecal coliforms, E. coli, and Enterococcus, respectively. Two swine indicator bacteria were 2.30 to 2.47 times as prevalent proximal down- than proximal upstream of swine CAFOs . . . *Results suggest diffuse and overall poor sanitary*

quality of surface waters where swine CAFO density is high [emphasis added].
- Heaney et al. (2015)

The water column of receiving rivers is not the only area affected by CAFO contamination. Burkholder et al. (1997) tracked surface water impacts from a swine cess pit rupture upstream from the New River Estuary near of the Cape Fear River basin. Fecal coliform bacteria densities were in the millions of colony-forming units [CFU] per 100 mL, whereas the state standard for safe human contact of the water is 200 CFU/100 mL. The state does not monitor contamination of bottom sediments by CAFO wastes. After 14 days, water-column fecal coliforms along the surface of the bottom sediments mostly yielded 10,000 CFU/100 mL, one to two orders of magnitude higher than elsewhere in the system. Even after 60 days, fecal bacterial densities in the surficial sediments of the affected area were at 1,000-10,000 CFU/100 mL. The data showed that bottom sediments contaminated by CAFO wastes can function as a repository source of fecal coliform bacteria and, likely, for co-occurring harmful microbes, for weeks to more than a month after a waste spill. The organic materials from the wastes that settled out would have been expected to greatly increase the SOD as well.

Surface waters presently classified as C (Sw) waters in areas draining swine and poultry CAFOs in the lower Cape Fear basin are extremely degraded

There is presently ongoing, persistent, extreme degradation of surface waters in the lower Cape Fear basin due to allowed practices of swine and poultry production. A recent description of a Class C (Sw) stream illustrates this reality:

Stocking Head Creek (8-digit Hydrologic Unit Code 003030007), a second-order tributary of the Northeast Cape Fear River, is presently classified by DWR as Class C (Sw) waters. This small stream (length 13.7 miles) drains 7.6 square miles of area containing 40 swine CAFOs and an estimated 11 poultry CAFOs, with total capacity for more than 94,000 swine and more than 1.3 million broiler chickens; it also includes some unconfined cattle (Mallin et al. 2014). Seven sites along the stream were sampled on 5 dates each in a 30-day period in summer and in fall of 2013. The data indicate a situation of persistent, extreme water quality degradation regardless of weather conditions; the excessive pollutant levels were similar whether the stream was sampled in dry or wet (rainy) periods.

The water quality conditions documented in Stocking Head Creek consistently were hazardous to human health at most stations. Geometric means for fecal coliform bacteria were in the thousands (as colony-forming units per 100 milliliters, CFU/100 mL) at 5 of the 7 sites. The state standard for safe human contact is less than 200 CFU of fecal coliform bacteria/100 mL (geometric mean, based on at least 5 consecutive samples during any 30-day period); and surface waters are supposed to have fewer than 400 CFU of fecal coliform baceria/100 mL in at least 80% of samples examined during the 30-day period. At 5 of the 7 sites on Stocking Head Creek, fecal coliform bacteria exceeded 400 CFU/100 mL on all, or nearly all, sampling dates.

Nutrient levels also demonstrated extreme water quality degradation. Some samples had more than 10 mg of nitrate/L. By comparison, the U.S. EPA (2000) recommends that nitrate should be 0.04 mg/L or less in streams within level III nutrient sub-ecoregion #63,

which includes southeastern North Carolina. The maximum ammonium concentration was 38 mg/L near swine waste sprayfields. BOD (5-day) exceeded 10 mg/L in 11 of 70 stream samples, with a maximum at 88 mg/L. Average total phosphorus (TP) per site ranged from 0.15 to 2.83 mg/L. By comparison, the U.S. EPA (2000) recommends that stream TP concentrations should be less than 0.052 mg/L for streams in this area.

Based on more than 30 years of experience as a water quality specialist, I assess these conditions, ongoing and persistent in this representative stream in the Northeast Cape Fear River basin upstream from the LCFRE segment, as comparable to the filthy conditions that occur just downstream from raw sewage discharge.

Swine CAFO wastes versus the 20 point source wastes and wetlands in the lower Cape Fear basin

Swine wastes are very rich in organic, oxygen-demanding materials in comparison to human wastes. Treated and raw domestic sewage contains ~20-60 mg BOD/L and ~300-400 mg BOD/L, respectively; swine waste slurries contain ~20,000-30,000 mg BOD/L (Webb and Archer 1994; also see Spellman and Whiting 2007). Surface waters contaminated with these wastes rapidly become oxygen-depleted, causing fish to suffocate to death (Burkholder et al. 1997, U.S. EPA 1998, Mallin 2000).

The contribution of oxygen-demanding materials from nearly 1,000 swine CAFO sources, mostly in the lower Cape Fear basin, clearly overwhelms the contribution from the 20 point sources considered by DWR. As stated, about 5 million swine are produced annually in the lower Cape Fear basin in CAFOs (Cahoon et al. 1999). It has been estimated that each animal contributes roughly the equivalent amount of waste -- much richer in oxygen-demanding materials -- of four people (derived from U.S. EPA 2004; see *Table 1* below). The population of the City of Wilmington as of 2014 was ~112,000 people. Overall in the lower Cape Fear basin, the 5 million swine produced per year in CAFOs produce ~179 times more wastes than the largest human population center, Wilmington. Moreover, pound for pound the swine wastes, conservatively estimated, contain about 10 times more oxygen-demanding materials than treated human wastes. Thus, in the lower Cape Fear basin, swine CAFO point sources are estimated to produce three orders of magnitude (~1,790 times) more oxygen-demanding materials than treated human wastes.

These Comments have several times referred to the Northeast Cape Fear River and Black River as having sustained major impacts from swine CAFOs. According to NCDENR (2005), the small sub-watersheds drained by the Northeast Cape Fear River and the Black River, alone, have 896 CAFOS that contain ~3,764,121 animals, roughly the same amount of sewage as more than 15 million people. Stocking Head Creek illustrates the surface water quality of streams draining such areas.

Based on the available information, *the massive contribution of organic-rich, oxygen-demanding materials from swine CAFOs also overwhelms the potential contribution from natural wetlands in the LCFRE.* The sparse available SOD data for the LCFRE (give in Bowen et al. 2009, p.3-20) ranged from 0.1900 to 0.6951 grams of oxygen demand per square meter per day ($g/m^2/day$). The highest values measured were near swine CAFOs, 0.5189 to

Table 1. Manure production per 1,000 pounds (lb) live weight on an annual basis. According to this information from the U.S. EPA (2004, Table 3.3), one 250-lb pig produces 7,250 lb of manure per year (19.86 lb/day), whereas one 150-lb human produces 183 lb of manure/yr (0.5 lb/day). A swine CAFO with 1,000 animals thus would produce about the same amount of waste as a city of 39,617 people. As the U.S. EPA (2004) wrote,

> The important difference lies in the fact that human waste is treated before discharge into the environment, but animal waste is either not treated at all or minimally treated....

It has been argued that swine wastes are about 10-fold more liquid than human wastes; if that dilution factor is taken into account, 1 animal would produce about the same amount of waste of 3.96 people, rounded to a ratio of 1:4.

Manure production per 1000 pounds live weight, on an annual basis.

Animal Species	Manure produced lbs./yr	Typical Handling System
Swine	29,000	Liquid
Poultry		
Broilers	28,000	Solid
Layers	22,000	Liquid
Turkeys	16,000	Solid
Beef	21,000	Solid
Dairy	30,000	Liquid
Humans	1,223[1]	Liquid

[1] Based on 150 lb avg. wt. per person producing 0.5 lb of fecal material per day

0.6951 g/m²/day; even areas near urban Wilmington had lower SOD (0.4440 to 0.4679 g/m²/day). Bowen et al. (p.4-42) used an estimated SOD of ~0.4 g/m²/day except for an area heavily influenced by swine CAFOs, the Northeast Cape Fear River sub-basin, where they used an estimated SOD of 1.5 g/m²/day. This information suggests that the swine CAFO-rich Northeast Cape Fear River alone, contributes excessive SOD in comparison to the rest of the LCFRE, expected since that small sub-watershed contains 502 swine CAFOs with 2,021,000 animals, or the equivalent amount of more than 8 million people's wastes per year (NCDENR 2005).

III. Summary and Recommendations

These Comments have explained the following main points regarding DWR's proposed reclassification of a segment of the LCFRE, from upstream of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut, from Class Sc waters to Class Sc (Sw) (= swamp):

- ✓ NCDENR-DWR has proposed to reclassify the lower reaches of one of the most powerful rivers in the nation, a portion of the LCFRE, as a swamp because the agency's efforts to control the relatively small amount of pollution from 20 point sources will not allow that segment to meet present standard for DO (or for pH, turbidity, and toxic copper). This was based on a recent modeling effort (Bowen et al. 2009) which predicted that

the 20 arbitrarily selected point sources have little effect on DO levels in the LCFRE segment. In addition, the segment was described as inappropriate for development of a TMDL, based on two erroneous claims -- that natural wetland drainage is the major contributor of oxygen-demanding materials to the LCFRE segment, and that significant reductions in "background" sources of oxygen-demanding materials would not allow the LCFRE segment to meet the present DO standard.

- ✓ According to the U.S. EPA, assessment of whether a TMDL is needed to improve DO in the LCFRE segment is supposed to consider all point and nonpoint sources in the watershed. In focusing on only 20 point sources, DWR omitted consideration of massive pollution that could be reduced in the so-called "background" loads, including 175 NPDES-permitted, upstream and adjacent point sources in the Cape Fear River basin, and nearly 1,000 swine CAFOs (as well as an unknown number of poultry CAFOs) which are formally defined by the Clean Water Act as point sources. The ~5 million swine produced in the lower Cape Fear River basin contribute the equivalent of ~20 million people's wastes per year, and the massive wastes are much richer in oxygen-demanding materials than human wastes.

- ✓ The available evidence shows that pollution from human activities, not natural drainage from wetlands, is the major source of oxygen-demanding materials to the LCFRE segment, and that the massive pollution also contributes low pH, toxic copper, high turbidity, fecal bacteria, and many other contaminants to the LCFRE segment.

- ✓ The recent modeling effort by Bowen et al. (2009) tacitly included the many other NPDES-permitted point sources and swine/poultry CAFOs within a modeling category called "tributary inputs." The model predicted that a reduction of only 30% of the "tributary inputs" would result in median DO levels higher than the state standard; and that a 70% reduction in the "tributary inputs" would bring the LCFRE into compliance 99% of the time. Thus, reducing the massive pollution from other sources **would** enable the LCFRE segment to attain compliance with its present DO standard.

To protect the health of many North Carolinians of all ages who depend upon this river and estuary to meet its present designated uses, and to protect the LCFRE surface water segment of focus as well as other public trust natural resources in the lower Cape Fear basin, the LCFRE segment should not be reclassified as a Class Sc Swamp (Sw). Instead, DWR should be directed toward efforts to meaningfully reduce the massive pollution from swine_CAFOs and NPDES-permitted point sources in the lower Cape Fear Basin (and from poultry production as well, which are a major pollution source with much less available information), which would make it possible for the LCFRE to meet the presently pplicable DO standard, and would also enable the LCFRE to improve in water quality with respect to pH, copper levels, and turbidity.

References

Aneja, V.P., P.A. Roelle, G.C. Murray, J. Southerland, J.W. Erisman, D. Fowler, W.A.H. Asman, and N. Patni. 2001. Atmospheric nitrogen compounds II: emissions, transport, transformation, deposition and assessment. *Atmospheric Environment* 35: 1903-1911.

Aneja, V.P., D.R. Nelson, P.A. Roelle, and J.T. Walker. 2003. Agricultural ammonia emissions and ammonium concentrations associated with aerosols and precipitation in the southeast United States. *Journal of Geophysical Research* 108: ACH12-1 - 12-11.

Barker, J.C. and J.P. Zublena. 1995. *Livestock Manure Nutrient Assessment in North Carolina.* Final Report. North Carolina Agricultural Extension Service, NC State University, Raleigh, NC.

Becker, M.L., R.A. Luettich Jr., and M.A. Mallin. 2010. Hydrodynamic behavior of the Cape Fear River and estuarine system: A synthesis and observational investigation of discharge-salinity intrusion relationships. *Estuarine, Coastal and Shelf Science* 88: 407-418.

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin and J. Williams. 2009. *Development and Use of a Three-Dimensional Water Quality Model to Predict Dissolved Oxygen Concentrations in the lower Cape Fear Estuary, North Carolina.* Department of Civil Engineering, University of North Carolina Charlotte.

Bowie, G.L., W.B. Mills, D.B. Porcella, C.L. Campbell, J.R. Pagenkopf, G.L. Rupp, K.M. Johnson, P.W.H. Chan, S.A. Gherini, and C.E. Chamberlin. 1985. *Rates, Constants, and Kinetic Formulations in Surface Water Quality Modeling*, 2nd edition. Report #EPA/600/3-85/040. U.S. Environmental Protection Agency, ORD, Athens, GA.

Bricker, S. B., C. G. Clement, D. E. Pirhalla, S. P. Orland, and D. G. G. Farrow. 1999. *National Estuarine Eutrophication Assessment: A Summary of Conditions.* National Oceanic and Atmospheric Administration, Silver Spring, MD.

Burkholder, J.M. 2009. Harmful algal blooms, pp. 264-285. In: *Encyclopedia of Inland Waters, Volume 1*, by Likens GE (ed.) Elsevier, Oxford, UK.

Burkholder, J.M. and P.M. Glibert. 2013. Eutrophication and oligotrophication, pp. 347-371. In: *Encyclopedia of Biodiversity*, 2nd edition, Volume 3, by Levin S (ed.). Academic Press, Waltham, MA.

Burkholder, J.M., D.A. Dickey, C. Kinder, R.E. Reed, M.A. Mallin, G. Melia, M.R. McIver, L.B. Cahoon, C. Brownie, N. Deamer, J. Springer, H. Glasgow, D. Toms, and J. Smith (2006) Comprehensive trend analysis of nutrients and related variables in a large eutrophic estuary: A decadal study of anthropogenic and climatic influences. *Limnology and Oceanography* 51: 463-487.

Burkholder, J.M., M.A. Mallin, H.B. Glasgow, L.M. Larsen, M.R. McIver, G.C. Shank, N. Deamer-Melia, D.S. Briley, J. Springer, B.W. Touchette, and E.K. Hannon. 1997. Impacts to a coastal
river and estuary from rupture of a large swine waste holding lagoon. *Journal of Environ-mental Quality* 26: 1451-1466.

Burkholder, J.M., B. Libra, P. Weyer, S. Heathcote, D. Kolpin, P.S. Thorne, and M. Wichman 2007. Impacts of waste from concentrated animal feeding operations on water quality. *Environmental Health Perspectives* 115: 308-312.

Chapra S.C. 1997. *Surface Water-Quality Modeling.* Civil Engineering Series, McGraw-Hill International editions (originally Waveland Press, Inc., Long Grove, IL).

Dewi. I.A., R.F.E. Axford. I. Faycz, M. Marai, and H. Omed (eds.). 1994. *Pollution in Livestock Production Systems.* CAB International, Wallingford, United Kingdom.

Cahoon, L.B., J.A. Mickucki and M.A. Mallin. 1999. Nutrient imports to the Cape Fear and Neuse River basins to support animal production. *Environmental Science and Technology* 33: 410-415.

Caldwell, J. M. and M.C. Doyle. 1995. *Sediment Oxygen Demand in the Lower Willamette River, Oregon, 1994.* United States Geological Survey Water-Resources Investigations Report 95-4196. USGS, Reston, VA.

Camargo, J.A., A. Alonso, and A. Salamanca. 2005, Nitrate toxicity to aquatic animals: A review with new data for freshwater invertebrates, *Chemosphere* 58: 1255-126.

Camargo, J.A. and A. Alonso 2006. Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: A global assessment. *Environment International* 32: 831-849.

CH2MHill. 2014a (February 25). Technical Memo: Task 1 - Summary of Background Information and Previous Studies for the Lower Cape Fear River. Prepared for the Lower Cape Fear River Program. In May (2014).

CH2MHill. 2014b. Technical Memo: Task 3 - Analysis of Water Quality Data at Cape [Fear] River Estuary Model Boundaries. Prepared for the Lower Cape Fear River Program. In May (2014).

Collos, Y. and J.A. Berge. Undated. *Nitrogen Metabolism in Phytoplankton.* Encyclopedia of Life Support Systems - http://www.eolss.net/sample-chapters/c09/E2-27-03-03.pdf.

Cox, B.A. 2003. A review of dissolved oxygen modelling techniques for lowland rivers. *The Science of the Total Environment* 314-316: 303-334.

Crawford, J.K. 1985. *Water Quality of North Carolina Streams - Water-Quality Characteristics for Selected Sites on the Cape Fear River, North Carolina, 1955-80.* United States Geological Survey (USGS) Water-Supply Paper 2185-F. USGS, Alexandria, Virginia.

Davis, W.S. 1950. Brief history of sediment oxygen demand investigations. In: *Sediment Oxygen Demand*, by K.J. Hatcher (editor). Institute of Natural Resources, University of Georgia, Athens, GA.

Eaton, A.D., L.S. Clesceri, and A.E. Greenberg. 1995. *Standard Methods for the Examination of Water and Wastewater*. United Book Press Inc., Baltimore, MD.

Edwards, T.M., L.J. Guillette Jr., K. McCoy, and T. Barbeau. 2004. *Effects of Nitrate/Nitrite on Two Sentinel Species Associated with Florida's Springs*. Final report prepared for the Florida Department of Environmental Protection, Tallahassee, FL.

Ensign, S.H., J.N. Halls, and M.A. Mallin. 2004. Application of digital bathymetry data in an analysis of flushing times of two large estuaries. *Computers & Geosciences* 30: 501-511.

Evans, R.O., P.W. Westerman, and M.R. Overcash. 1984. Subsurface drainage water quality from land application of swine lagoon effluent. *Transactions of the American Society of Agricultural Engineers* 27: 473-480.

Extension Toxicology Network 2003. Exotoxnet - A Pesticide Information Project of the Cooperative Extension Offices of Cornell University, Michigan State University, Oregon State University, and the University of California at Davis. U.S. Department of Agriculture, Extension Service, and the National Agricultural Pesticide Impact Assessment Program. Available at http://ace.orst.edu/info/extoxnet/.

Garrett, C. G., V.M. Vulava, and M.L. Jones. 2012. Groundwater-surface water interactions in a lowland watershed: source contribution to stream flow. *Hydrological Processes* 26: 3195-3206.

Guillette, L.J. Jr. and T.M. Edwards 2005. Is nitrate an ecologically relevant endocrine disruptor in vertebrates? *Integrative and Comparative Biology* 45: 19-27.

Ham, J.M. and T.M. DeSutter. 2000. Toward site-specific design standards for animal-waste lagoons: protecting groundwater quality. *Journal of Environmental Quality* 29: 1721-1732.

Hamrick, J.M. 1992. *A Three-Dimensional Environmental Fluid Dynamics Computer Code: Theoretical and Computational Aspects.* Special Report 317. Virginia Institute of Marine Science, The College of William and Mary, Gloucester, VA.

Hatcher, K.J. 1986. *Sediment Oxygen Demand: Processes, Modeling, and Measurement.* Institute of Natural Resources, University of Georgia, Athens, GA.

Heaney, C.D., K. Myers, S. Wing, D. Hall, D. Baron, and J.R. Stewart. 2015. Source tracking swine fecal waste in surface water proximal to swine concentrated animal feeding operations. *Science of the Total Environment* 511: 676-683.

Herndon, J. and W.P. Cochlan. 2006. Nitrogen utilization by the raphidophyte *Heterosigma akashiwo*: growth and uptake kinetics in laboratory cultures, *Harmful Algae* 6: 260-270.

Hu, W.F., W. Lo, H. Chua, S.N. Sin, and P.H.F. Yu. 2001. Nutrient release and sediment oxygen demand in a eutrophic land-locked embayment in Hong Kong. *Environment International*
26: 369-375.

Huffman, R.L. 2004. Seepage evaluation of older swine lagoons in North Carolina. *Transactions of the American Society of Agricultural Engineers* 47: 1507-1512.

Huffman, R.L. and P.W. Westerman. 1995. Estimated seepage losses from established swine waste lagoons in the lower coastal plain of North Carolina. *Transactions of the American Society of Agricultural Engineers* 38: 449-453.

Iowa State University and The University of Iowa Study Group. 2002. *Iowa Concentrated Animal Feeding Operation Air Quality Study*. Final Report. Environmental Health Sciences Research Center, Iowa City, IA. February 2002. Website - http://www.public-health.uiowa.edu/ehsrc/CAFOstudy.html.

Jacobson, L.M., M.B. David, and L.E. Drinkwater. 2011. A spatial analysis of phosphorus in the Mississippi river basin. *Journal of Environmental Quality* 40: 931-941.

Knobeloch, L., B. Salna, A. Hogan, J. Postle, and H. Anderson. 2000. Blue babies and nitrate-contaminated well water. *Environmental Health Perspectives* 108: 675-678.

Krapac, I.G., W.S. Dey, W.R. Roy, C.A. Smyth, E. Storment, S.L. Sargent, and J.D. Steele. 2002. Impacts of swine manure pits on groundwater quality. *Environmental Pollution* 120: 475-492.

Lin, J., L. Xie, L.J. Pietrafesa, J. Shen, M.A. Mallin, and M.J. Durako. 2006. Dissolved oxygen stratification in two micro-tidal partially-mixed estuaries. *Estuarine, Coastal and Shelf Science* 70: 423-437

Liu, Z., W. Powers, J. Murphy, and r. Maghirang. 2014. Ammonia and hydrogen sulfide emissions from swine production facilities in North America: a meta-analysis. *Journal of Animal Science* 92: 1656-1665.

MacPherson, T.A. 2003. *Sediment Oxygen Demand and Biochemical Oxygen Demand: Patterns of Oxygen Depletion in Tidal Creek Sites*. M.S. Thesis. Program in Marine Science, University of North Carolina Wilmington, Wilmington, NC.

Mallin, M.A. 2000. Impacts of industrial-scale swine and poultry production on rivers and estuaries. *American Scientist* 88: 26-37.

Mallin, M.A., J.M. Burkholder, G.C. Shank, M.R. McIver, H.B. Glasgow, J. Springer, and B.W. Touchette. 1997b. Comparative effects of poultry and swine waste lagoon spills on the quality of receiving stream waters. *Journal of Environmental Quality* 26: 1622-1631.

Mallin, M.A., V.L. Johnson, S.H. Ensign and T.A. MacPherson. 2006. Factors contributing to hypoxia in rivers, lakes and streams. *Limnology and Oceanography* 51: 690-701.

Mallin, M., M. McIver, and J. Merritt. 2008. *Environmental Assessment of the Lower Cape Fear River System, 2007*. CMSR Report No. 08-03, Center for Marine Science, University of North Carolina Wilmington, Wilmington, North Carolina.

Mallin, M., M. McIver, and J. Merritt. 2013. *Environmental Assessment of the Lower Cape Fear River System, 2012*. CMSR Report No. 13-02. Center for Marine Science Research, University of North Carolina Wilmington, Wilmington, NC.

Mallin, M.A., M.R. McIver, A.R. Robuck, and A.K. Dickens. 2014. *Stocking Head Creek 2013 Water Quality Investigation*. Final Report. Center for Marine Sciences, University of North Carolina Wilmington, Wilmington, NC.

Mallin, M., M. McIver, H. Wells, M. Williams, T. Lankford, and J. Merritt. 2003. *Environmental Assessment of the Lower Cape Fear River System, 2002-2003*. CMSR Report No. 03-03. Center for Marine Science, University of North Carolina Wilmington, Wilmington, NC.

Mallin, M. A., H. W. Paerl, J. Rudek, and P. W. Bates. 1993. Regulation of estuarine primary production by watershed rainfall and river flow. *Marine Ecology Progress Series* 93: 199-203.

Mallin, M.A., M.H. Posey, M.L. Moser, G.C. Shank, M.R. McIver, T.D. Alphin, S.H. Ensign, and J.F. Merritt. 1997a. *Water Quality in the Lower Cape Fear River System, 1996-1997*. Center for Marine Science, University of North Carolina Wilmington, Wilmington, NC.

Massachusetts Water Resources Authority. 2002. *The State of Boston Harbor - Mapping the Harbor's Recovery*. Available at: http://www.mwra.state.ma.us/harbor/enquad/pdf/2002-09.pdf.

Matlock, M.D., K.R. Kasprzak, and G.S. Osborn. 2003. Sediment oxygen demand in the Arroyo Colorado River. *Journal of the American Water Resources Association* 39: 267-275.

May, C. 2014 (5 March). Request for Reclassification of a Portion of the Lower Cape Fear River with the Supplemental Swamp Classification. Letter from Mr. May, Chair of the Lower Cape Fear River Program Advisory Board and Executive Director of the Cape Fear River Council of Governments, to Mr. Tom Reeder, Director of the NC DENR DWR.

Meyer J.L. & Edwards R.T. (1990) Ecosystem metabolism and turnover of organic carbon along a blackwater river continuum. *Ecology* 71: 668–677.

Minshall, G.W., R.C. Petersen, K.W. Cummins, T.L. Bott, J.R. Sedell, C.E. Cushing, C. E., and R.L. Vannote. 1983. Interbiome comparison of stream ecosystem dynamics. *Ecological Monographs* 53: 1-25.

Natural Resource Council. 2000. *Clean Coastal Waters- Understanding and Reducing the Effects of Pollution*. National Academy Press, Washington, DC.

North Carolina Department of Environment and Natural Resources (NC DENR). 1997. *Assess-ment Plan for Atmospheric Nitrogen Compounds: Emissions, Transport, Transformation, and Deposition*. Division of Air Quality, NC DENR, Raleigh, NC

North Carolina Department of Environment and Natural Resources (NC DENR). 2005. *Cape Fear River Basinwide Water Quality Plan.* Division of Water Quality, NC DENR, Raleigh, NC. Available at: http://portal.ncdenr.org/c/document_library/get_file?uuid=2eddbd59-b382-4b58-97ed-c4049bf4e8e4&groupId=38364.

Payne, G.G., D.C. Martens, E.T. Kornegay, and M.D. Lindermann. 1988. Availability and form of copper in three soils following eight annual applications of copper-enriched swine manure. *Journal of Environmental Quality* 17: 740-746.

Ritter, W. F. and A. E. M. Chirnside. 1987. Influence of agricultural practices on nitrates in the water table aquifer. *Biological Wastes* 19: 165-178.

Ritter, W. F., and A. E. M. Chirnside. 1990. Impact of animal waste lagoons on groundwater quality. *Biological Wastes* 34: 39–54.

Rolley, H.JL. and M. Owens. 1967. Oxygen consumption rates and some chemical properties of river muds. *Water Research* 1: 759-766.

Rothenberger, M., J.M. Burkholder, and C. Brownie. 2009a. Long-term effects of changing land use practices on surface water quality in a coastal river and lagoonal estuary. *Environmental Management* 44: 505-523.

Rothenberger, M., J.M. Burkholder, and T. Wentworth. 2009b. Multivariate analysis of phytoplankton and environmental factors in a eutrophic estuary. *Limnology and Oceanography* 54: 2107-2127.

Seiki, T., H. Izawa, E. Date, and H. Sunahara. 1994. Sediment oxygen demand in Hiroshima Bay. *Water Research* 28: 385-393.

Smith, R.P. 2009. The blue baby syndromes. *American Scientist* 97: 94-96.

Spellman, F.R. and N.E. Whiting. 2007. *Environmental Management of Concentrated Animal Feeding Operations (CAFOs).* CRC Press, Boca Raton, FL.

State Stream Sanitation Committee. 1957. *Cape Fear River Basin Pollution Survey Report 1957 (1954-1956).* North Carolina State Board of Health, Division of Water Pollution Control, Raleigh, North Carolina.

Stone, K.C., P.G. Hunt, F.J. Humenik, and M.H. Johnson. 1998. Impact of swine waste application on ground and stream water quality in an eastern Coastal Plain watershed. *Transactions of the American Society of Agricultural Engineers* 41: 1665-1670.

Stone, K.C., P.G. Hunt, S.W. Coffey, and T.A. Matheny. 1995. Water quality status of a USDA water quality demonstration project in the Eastern Coastal Plain. *Journal of Soil and Water Conservation* 50: 567-571.

Stubbs, K. and K. Cathey. 1999. CAFOs feed a growing problem. *Endangered Species Bulletin* 24: 14-15.

Tetra Tech. 2001 (May). *3-Dimensional EFDC Water Quality Model of the Lower Cape Fear River and its Estuary.* Prepared for the City of Wilmington and New Hanover County, North Carolina.

Tetra Tech. 2003 (January 6). Technical Memo: Results of Dissolved Oxygen and Pollutant Loading Trend Analyses. Submitted to Hugh Caldwell, Ken Vogt, and Wyatt Blanchard from Trevor Clements and Jason Doll.

Tetra Tech. 2014 (February). *Technical Memo: The Relationship of Adjacent Wetlands and Salt Marsh to Dissolved Oxygen in the Lower Cape Fear River Estuary.* Prepared for the Lower Cape Fear River Program. In May (2014).

Todd, M.J., G. Vellidis, R.R. Lowrance, and C.M. Pringle. 2009. High sediment oxygen demand within an instream swamp in southern Georgia: implications for low dissolved oxygen levels in coastal blackwater streams. *Journal of the American Water Resources Association* 45: 1493-1507.

Twomey, L.J., M.F. Piehler, and H.W. Paerl. 2005, Phytoplankton uptake of ammonium, nitrate and urea in the Neuse River Estuary, NC, USA. *Hydrobiologia* 533: 123-134.

U.S. Environmental Protection Agency (U.S. EPA). 1998. *Environmental Impacts of Animal Feeding Operations.* Office of Water, Standards and Applied Sciences Division, U.S. EPA, Washington, DC.

U.S. Environmental Protection Agency (U.S. EPA). 2004. Risk Management Evaluation for Concentrated Animal Feeding Operations. Report #EPA/600/R-04/042. Office of Research and Development, U.S. EPA, Cincinnati, OH. Available at: http://nepis.epa.gov/Adobe/PDF/901V0100.pdf.

Walker, J., V. Aneja and D. Dickey. 2000. Atmospheric transport and wet deposition of ammonium in North Carolina. *Atmospheric Environment* 34: 3407-3418.

Walker, R.R. and W.J. Snodgrass. 1986. Model for sediment oxygen demand in lakes. *Journal of Environmental Engineering* 112: 25-43.

Westerman, P.W., R.L. Huffman, and J.S. Feng. 1995. Swine-lagoon seepage in sandy soil. *Transactions of the American Society of Agricultural Engineers* 38: 1749-1760.

Westerman. P.W., M.R. Overcash, R.O. Evans. L.D. King, J.C. Burns, and G.A. Cummings. 1985. Swine lagoon effluent applied to coastal bermudagrass: III. Irrigation and rainfall runoff. *Journal of Environmental Quality* 14: 22-25.

Wetzel, R.G. 2001. *Limnology*, 3rd edition. Academic Press, New York, NY

Wing, S., R.A. Horton, and K.M. Rose. 2012. Air pollution from industrial swine operations and blood pressure of neighboring residents. *Environmental Health Perspectives* 121: 92-96.

Wu, R.S.S. 1990. A respirometer for continuous, in situ, measurements of sediment oxygen-demand. *Water Research* 24: 391-394.

Zu, J., A. Luo, and P. Ndegwa. 2001. Raising pH by low-level aeration for soluble phosphorus removal of swine manure. *Transactions of the American Society of Agricultural Engineers* 44: 391-396.

Zublena, J.P., J.C. Barker, and D.A. Crouse. 1995. C*apacity of North Carolina Crops to Use Animal Manures: A Nutrient Balance Approach*. Soil Science Notes, NC Agricultural Extension Service, NCSU, Raleigh, NC.

JoAnn M. Burkholder

JoAnn M. Burkholder, Ph.D.

Mayor and City Council

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Bill Saffo

Mayor Pro Tem
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Council Members
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CITY OF WILMINGTON NORTH CAROLINA

April 30, 2018

Mr. Trey Glenn, Regional Administrator
Environmental Protection Agency, Region 4
61 Forsyth Street SW
Atlanta, GA 30303

Re: North Carolina's April 9, 2018 Request for Approval of Modifications to the Water-Quality Classification for the Lower Cape Fear River

Dear Mr. Glenn:

It has come to my attention that the North Carolina Department of Environmental Quality has requested that the U.S. Environmental Protection Agency approve a revised water-quality standard reclassifying the Lower Cape Fear River as "swamp water." I write today to state my strong concern over the potential reclassification and to ask that the Department's request be not be approved, until the citizens of Wilmington, North Carolina can be educated on the likely impacts to our already impaired stretch of river.

The Cape Fear River is currently in crisis. In June of 2017 we learned that the drinking water supply for a quarter of a million people in the Cape Fear watershed is contaminated with "GenX" and other PFAS compounds that Chemours and DuPont have been knowingly discharging into the Cape Fear River, the drinking water source for Wilmington, for decades.

The North Carolina Department of Environmental Quality, the Cape Fear Public Utility Authority, and Chemours have been working around the clock to address the situation. Enforcement actions and lawsuits have been filed, countless hearings have been held, and numerous scientific studies and modeling efforts are underway to discern the extent of the contamination, but the problem is not close to being resolved. The people of Wilmington are fearful and, rightfully, frustrated.

Now is absolutely not the time to make such a change to the designation of our river which could weaken water quality protections for the Cape Fear River. Our citizens already share great public and environmental health concerns and this is a proposal that has not been fully vetted with our local leaders and community at large. Thus far, as Mayor, I have

received differing responses to my pointed questions on how this change will impact the health of this section of river. Some experts have said that this will be a positive change while others that I have great respect for have voiced grave concerns. In light of all that has taken place regarding the Lower Cape Fear River, we deserve to have answers and be included in such a decision process.

The City of Wilmington requests that the request for reclassification of the Lower Cape Fear River not be approved until our community has an opportunity to be fully informed of likely impacts and have the opportunity to provide feedback. We urge you to not approve the North Carolina Department of Environmental Quality's request to approve the reclassification until such time.

Sincerely,

Bill Saffo

Mayor, City of Wilmington NC

CC: Michael Regan, Secretary, NCDEQ

Petter, Lauren

From: Mary Maclean Asbill <mmasbill@selcnc.org>
Sent: Thursday, April 26, 2018 4:42 PM
To: Petter, Lauren
Subject: SELC opposition to Reclassification of the Lower Cape Fear River
Attachments: SELC Letter to EPA re Cape Fear Reclassification (Apr. 26, 2018).pdf

Dear Lauren,

I've attached a courtesy copy of the letter we sent this afternoon. Thanks, and please don't hesitate to call with questions.

Mary Maclean Asbill
Southern Environmental Law Center
Telephone: 919-389-2636
Email: mmasbill@selcnc.org

Attachment not reprinted due to length, hard copy received is in my files

Effects of hypoxia and temperature on survival, growth, and respiration of juvenile Atlantic sturgeon, *Acipenser oxyrinchus**

David H. Secor
Troy E. Gunderson
Chesapeake Biological Laboratory
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The University of Maryland System
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Abstract.—Hypoxia in Chesapeake Bay has increased during the past century, coincident with the disappearance of Atlantic sturgeon spawning stocks. We hypothesized that Atlantic sturgeon young-of-the-year (YOY) might be more susceptible than other estuarine fishes to high temperature and low oxygen conditions, now prevalent in Chesapeake Bay. Atlantic sturgeon (10–70 g) were reared under conditions of hypoxia (2–3 mg/L dissolved oxygen) and normoxia (6–7 mg/L) at 19°C and 26°C for 10 days. High-temperature hypoxia resulted in lower survival (mean=6.3%) and respiration rate (mean=0.136 mg O_2/(g·h)). Low-temperature hypoxia resulted in a mean survival of 78% and mean respiration rate of 0.212 mg/(g·h). Under hypoxia, mean weight-specific growth rate was 1.27%/d, ca. threefold less than growth under normoxia. Temperature alone did not significantly affect growth rates. When sturgeon were denied access to the surface, growth rates were significantly diminished in both normoxic and hypoxic treatments. At low ambient oxygen levels and high temperature, denial of surface access was fully lethal within 30 hours. We conclude that increased incidence of summertime hypoxia during this century has degraded sturgeon nursery habitats in Chesapeake Bay.

Manuscript accepted 6 October 1997.
Fishery Bulletin 96:603–613 (1998).

An economically important population of Atlantic sturgeon, *Acipenser oxyrinchus*, once inhabited Chesapeake Bay. During the late nineteenth century, Chesapeake Bay supported the second greatest caviar fishery in the eastern United States (Murawski and Pacheco, 1977). In the early 1900s, the population collapsed. In Maryland, fishery landings declined from 74,500 kg, in 1904, to 320 kg in 1920 (Hildebrand and Schroeder, 1928). Atlantic sturgeon have not recovered in Chesapeake Bay (Spier and O'Connell, 1996). The last fish legally harvested in Chesapeake Bay, a mature female, was captured in 1970 from the Potomac River. The spawning population of Atlantic sturgeon may have been extirpated from Chesapeake Bay (Speir and O'Connell, 1996; Grogan and Boreman[1]).

State, federal, academic, and nonprofit organizations have begun to mobilize public interest and support for an aquaculture-based restoration program for Atlantic sturgeon in Chesapeake Bay. A principal assumption for Atlantic sturgeon restoration is that deleterious conditions that led to the extirpation of the population (e.g. loss of habitat or over fishing) are now abated. Therefore, it is critical to evaluate possible causes for Atlantic sturgeon extirpation from Chesapeake Bay before state and federal agencies move forward with a large-scale aquaculture-based restoration program.

We hypothesize that increased hypoxia in Chesapeake Bay resulted in reduced habitat for Atlantic sturgeon and contributed to their decline. During this century, periodic increases (albeit small) in Atlantic sturgeon abundances have occurred in the southern and northern extent of the species' range (Murawski and Pacheco, 1977). However, no evidence exists for periodic recoveries of Atlantic sturgeon in Chesapeake Bay. The period of population decline and low abundance in Chesapeake Bay corresponds to a period of poor water quality, from 1950 to present, caused by increased nutrient loading and increased spatial and temporal frequency of hypoxia (Officer et al., 1984; Mackiernan, 1987; Jordan et al., 1992; Kemp et al., 1992; Cooper and Brush, 1993).

* Contribution 3060 of the Chesapeake Biological Laboratory, Center for Environmental Science, University of Maryland, Solomons, MD 20688-0038.

[1] Grogan, C. S., and J. Boreman 1997. Determining the probability that historical populations of fish species are now extirpated. Unpubl. manuscr., U. Mass. Amherst, MA. 25 p.

The goal of the study was to investigate the effects of dissolved oxygen and temperature on growth, survival, and respiration of juvenile (young-of-the-year) Atlantic sturgeon. High temperatures are known to amplify negative effects of hypoxia on growth and survival of estuarine fishes (Coutant, 1985). Habitats in Chesapeake Bay that satisfy both temperature and dissolved oxygen (DO) preferences of Atlantic sturgeon may be limiting during the summer as have been demonstrated for striped bass (Coutant and Benson, 1990; Brandt and Kirsch, 1993). In this study we define hypoxia as oxygen concentrations <4.0 mg/L. Hypoxia has been defined previously as <2 mg/L for Chesapeake Bay (Phil et al., 1991; Harding et al., 1992), an ambient oxygen level that is detrimental to benthic infaunal production. This definition, however, may be too stringent for fishes because oxygen concentrations at this level are often lethal (Brett, 1970; Jordan et al., 1992).

A nested-multifactorial experiment was designed to investigate the effects of temperature and dissolved oxygen on growth, respiration, and survival of young-of-the-year Atlantic sturgeon. During the course of our experiments we observed that fish in hypoxic conditions frequently surfaced, often breaking the surface of the water with their snout. Therefore we included surface access as a third factor in our investigation—whether this behavior might benefit growth and survival under conditions of oxygen stress.

Methods

Experimental material

Juvenile Atlantic sturgeon were obtained from the U.S. Fish and Wildlife Service, Northeast Fishery Center, Lamar, Pennsylvania (Hendrix, 1995). During June 1995, Center personnel collected a large female (2.4-m total length) and three male Atlantic sturgeon from the Hudson River near Hyde Park (River km 135). Fish were transported to the Center for artificial spawning and for larval rearing. Larvae and early juveniles were reared at the Center at 17°C and 1 ppt salinity. A failure in the water heating system at the Center caused juveniles, age 45 to 60 days after hatching, to experience low water temperatures, ca. 10°C. At 60 days after hatching, 500 juveniles (0.3–2.0 g wet weight) were transported in an oxygenated container to Chesapeake Biological Laboratory and acclimated to 19°C and 2 ppt salinity over a 10-d period. Juveniles were reared in sixteen 40-liter tanks and fed Biokyowa© fry feed (700–2000 μm diameter) ad libitum until they were ca. 5 grams wet weight (>10 cm total length) and large enough to be handled with little or no stress for scute-clips (see below).

Nested growth and survival experiments

A nested multivariate experiment (Fig. 1) evaluated survival and growth rates in relation to access to surficial water (sealed or unsealed tank), temperature (~20°C and ~26°C), dissolved oxygen (~3 mg/L or ~7 mg/L), and tank replication. The nested design directed the analysis of variance to occur in hierarchical order at four levels. The model of the nested design for growth rate was

$$y_{ijklm} = \mu + \tau_i + \beta_{j(i)} + \gamma_{k(ij)} + \theta_{\lambda(ijk)} + \varepsilon_{(ijkl)m},$$

where y_{ijklm} = the growth rate response by individual juveniles;
μ = overall mean;
τ_i = the effect of the ith surface access category;
$\beta_{j(i)}$ = the effect of the jth temperature;
$\gamma_{k(ij)}$ = the effect of the kth oxygen level;
$\theta_{l(ijk)}$ = the effect of the lth tank (replicate); and
$\varepsilon_{(ijkl)m}$ = the random error component.

The model of the nested design for survival rate was

$$S_{ijkl} = \mu + \tau_i + \beta_{j(i)} + \gamma_{k(ij)} + \varepsilon_{l(ijk)},$$

where S_{ijkl} = the arcsine-transformed survival rate for each replicate.

Statistical significance for factors was accepted at $\alpha = 0.05$ (type-I sum of squares for type-I error). To remove possible effects due to differences in fish size among experiments and experimental levels, initial fish weight was included in ANOVAs as a covariate. Calculations of variances and significance tests were performed by using PC-SAS, PROC NESTED (SAS, 1982). Survival data were arcsine transformed to meet assumptions of normally distributed error.

Four 10-day experiments were conducted under the four combinations of surface access, temperature, and dissolved oxygen, each replicated twice. In the high-temperature hypoxia treatments, high mortality was observed. Because we wished to have greater confidence in associating low survival with high-temperature hypoxia, we repeated the treatments with surface access and high temperature (at both low and high DO levels) for a total of four replicates (Fig. 1).

Experimental tank dimensions were 78-cm diameter, 46-cm height, and 220-liter volume. External

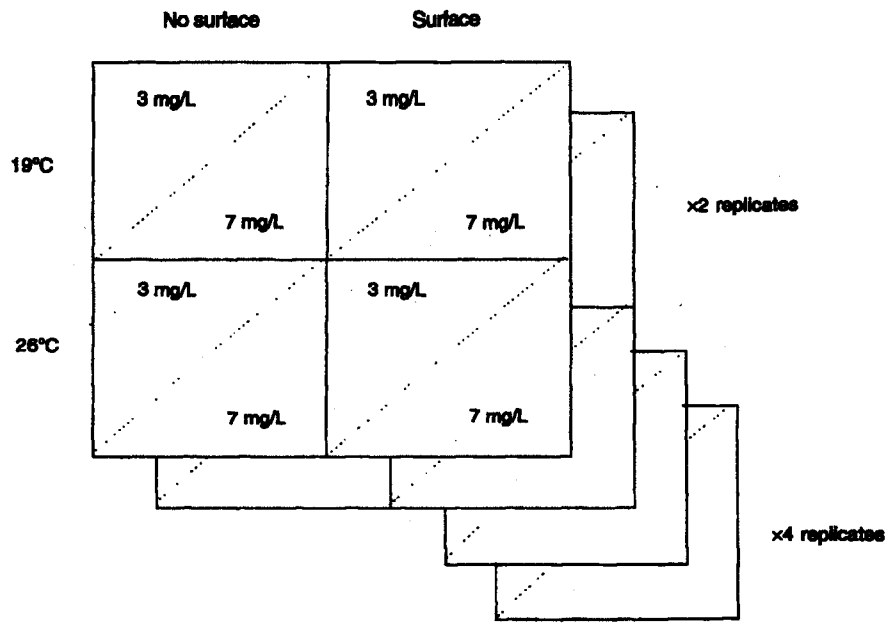

Figure 1

Nested experimental design. Replicates are presented as layers. Dissolved oxygen rates (3 or 7 mg/L) were nested within temperature and surface access levels.

stand-pipes for flow-through water allowed sturgeon to use the entire bottom surface. During the experiments clear plexiglass lids were attached to the tanks with clamps and duct tape. A large hole (5-cm diameter) in each lid, fitted with a stopper, permitted access to the tank for feeding of fish, for periodic checks of water quality, and for removal of dead individuals. Hoses for air and water supply also passed through the lid. In the tanks that permitted access to the air-water interface, water level was maintained at 5 cm below the lid. In treatments designed to limit access to the surface, lids were sealed to the tank and tanks were filled completely. Two head tanks delivered water at either 19°C or 26°C to experimental tanks, each maintained at a rate of 1.2 –1.5 L of flow-through water/min. Dissolved oxygen was controlled by maintaining hypoxic conditions in head-tanks and by adding aeration directly to normoxic treatment tanks. Hypoxic levels (2.5–3.0 mg/L) were maintained in head-tanks by mixing hypoxic well water (<2 mg/L) with oxygenated Patuxent estuary water (6 mg/L). Thus, salinity varied slightly between experiments but was always within the range 1.5–3 ppt. When necessary, water was aerated to bring oxygen levels to 2.5 mg/L in the head-tank. Normoxic treatment water was a mixture of well water and Patuxent estuary water. Dissolved oxygen levels were well mixed (homogenous) in the tanks owing to their shallow design, flow-through water, and constant swimming of YOY sturgeon. Lighting was provided on a 12:12 h light:dark cycle.

With the exception of the 26°C and no-surface-access treatment, temperature and oxygen concentrations were maintained within 10% of their prescribed levels (19 or 26°C, 3 or 7 mg/L). In the 26°C sealed experiment, aeration supplied to the head-tank was insufficient to attain oxygen conditions close to 7 mg/L for the normoxic treatment (mean replicate dissolved oxygen concentrations were 5.10 and 5.25 mg/L). In the hypoxic sealed treatment (mean replicate dissolved oxygen concentrations were 3.76 and 4.44 mg/L), dissolved oxygen was deliberately held above 3 mg/L because this level with high temperature had been observed previously to be lethal in unsealed tanks. Despite these elevated "hypoxic" conditions, the combination of high temperature and low oxygen was fully lethal in the sealed tanks (see below).

Juveniles (8 to 30 grams wet weight) were acclimated to experimental conditions over a 4-d period. On day 0 of each experiment, lengths and wet weights (juveniles weighed in water on a top-loading balance) were recorded and a dorsal scute(s) clipped to identify each individual. In preliminary trials, we found that scute clips did not significantly affect growth

rate. Regeneration of the scute did not obscure the clip during the 10-d experiments. Six to eight juveniles were placed in each experimental tank and fed the formulated diet (2-mm pellets) at 2.5% body weight per day. Fish were fed at 06:00, 10:00, 14:00, 18:00, and 20:00 h. Water quality was checked during feeding times and any remaining food or feces were siphoned prior to feeding. Food amounts were adjusted when mortalities occurred. On day 10 of the experiment, individual weights and lengths were recorded. Weight-specific absolute and instantaneous growth rates were determined for the experimental period according to Ricker (1975). In instances where juveniles died before the end of the experiment, individuals surviving >3 days of experimental conditions were included in the analysis of treatment effects on growth.

Respiration experiment

Respiration was estimated over a 42-h period for four combinations of temperature (19 or 26°C) and dissolved oxygen (~3 or ~7 mg/L) each replicated once. Juveniles were acclimated for a 4-day period and starved 12 h prior to the start of respiration measures. Seven juveniles were weighed (in water) and placed in each tank "respirometer." The tanks were sealed (no air gap). Oxygen levels were maintained by aerating the head-tanks, rather than each experimental tank. There was no feeding during the 42-h experiments. Inflow and outflow temperature, salinity, oxygen content, and flow rate were measured in experimental and control "blank" tanks (Cech, 1990) at 06:00, 10:00, 14:00, 18:00 and 22:00.

Experimental conditions of temperature were maintained within 1°C of the prescribed treatment level (19 or 26°C) (Table 1). Oxygen levels varied substantially from the prescribed levels between temperatures. For the hypoxic treatments, oxygen was provided at significantly higher levels (P=0.001) at 26°C (4.09 ±0.07 mg/L) than at 19°C (2.51 ±0.05 mg/L). This was intentional because survival and growth experiments had shown that DO levels <3.5 mg/L in concert with high temperature were lethal. Despite this precaution, all fish at 26°C and at low oxygen level perished within 24 hours. At the high-level DO treatments, oxygen conditions were ca. 1 mg/L higher at 19°C than at 26°C. Total biomass of the 7 fish per tank ranged from 157.6 to 248.2 grams (Table 1).

Respiration (i.e. oxygen uptake) was estimated (Cech, 1990) as

$$R = (M_E - M_C)/B$$
$$M_{E,C} = ((C_I - C_O)V$$

where R = weight-specific O_2 consumption rate (mg O_2/(g·h);
$M_{E,C}$ = O_2 consumption rate in experimental E or control C tanks (mg O_2/h);
B = combined wet weight (biomass) of sturgeon juveniles (g);
C_I = O_2 concentration in inflowing water (mg O_2/L);
C_O = O_2 concentration in outflowing water (mg O_2/L); and
V = water flow rate (L/h).

Results

Survival

Deaths were observed only in hypoxic treatments (Table 2). At hypoxic level, survival was substantially lower at 26°C (mean=6.3% survival) than at 19°C

Table 1

Replicate tank environmental conditions and respiration rates (mean ± standard error) for respiration experiment. Dissolved oxygen (DO) levels, low or high, refer to prescribed levels of 3 mg/L and 7 mg/L, respectively. Inflow oxygen and tank temperature refer to actual conditions provided to tanks. Biomass is the total initial weight of the seven sturgeon used in each replicate.

Temperature level	DO level	Inflow oxygen mg/L	Tank temperature	Biomass (g)	Respiration rate mg O_2/g·h
26°C	Low	3.762 ± 0.163	25.20 ± 0.04	216.6	0.175 ± 0.042
		4.436 ± 0.209	25.34 ± 0.02	181.3	0.103 ± 0.030
	High	6.310 ± 0.075	25.54 ± 0.02	188.1	0.245 ± 0.028
		6.259 ± 0.088	25.47 ± 0.02	179.6	0.307 ± 0.020
19°C	Low	2.536 ± 0.029	19.51 ± 0.02	196.3	0.202 ± 0.028
		2.495 ± 0.020	19.43 ± 0.02	157.6	0.214 ± 0.022
	High	7.361 ± 0.060	19.73 ± 0.06	189.5	0.228 ± 0.028
		7.273 ± 0.058	19.67 ± 0.04	249.2	0.207 ± 0.020

Table 2

Replicate tank deaths during the nested survival and growth experiment. Experiments are labeled according to the temperature treatment and whether tanks were sealed or unsealed (unsealed tanks permitted access by sturgeon to surface water). Dissolved oxygen (DO) levels, low and high, refer to prescribed levels of 3 mg/L and 7 mg/L, respectively. Rep. = replicate(s).

Experiment	DO level	Rep.	Experimental day 1	2	3	4	5	6	7	8	9	10	Survival (%)
26°C unsealed 1	Low	1			6	1	1						0
		2			2		4					2	0
		3		4			1	2	1				0
		4				1		1		1	1		50
26°C unsealed 2	High	1											100
		2											100
		3											100
		4											100
26°C sealed	Low	1	8										0
		2	7	1									0
	High	1											100
		2											100
19°C unsealed	Low	1			1		1						75
		2			1			1					75
	High	1											100
		2											100
19°C sealed	Low	1							1				88
		2						1	1				75
	High	1											100
		2											100

(mean=78.3% survival). No significant difference was found in overall survival rate between sealed and unsealed tanks (P=0.54). In unsealed tanks, deaths were distributed throughout the 10-d experimental period. In the 26°C sealed-hypoxic level tanks, all individuals succumbed within the first 30 hours of the experiment. Moribund sturgeon were observed at the air-water interface in unsealed tanks, or just below the lid in sealed tanks. Fin margins of dead individuals were perfused with blood, an indicator of oxygen deprivation (Jobling, 1995).

Growth

Across replicates, growth rates ranged in weight from 0.3% to 5.1% per day (Table 3). Sturgeon experienced positive growth in weight and length under all experimental conditions. Initial mean weights and lengths varied substantially among experiments; range was 10.94 to 69.20 g in weight and 14.59 to 26.60 cm in length. Absolute growth in weight was positively related to initial size (regression analysis; P<0.01); tanks with fish having initial mean weights greater than 50 g showed the highest absolute growth rates (>1.0 mg/d). Because initial size covaried with growth rate, initial weight was used as a covariate in statistical analyses of treatment effects.

Analysis of variance of instantaneous growth rate showed significant effects due to surface access and oxygen level (Table 4); temperature, replicate, and individual fish did not explain significant variance, although at 7 mg/L DO there was a trend for lower growth rates at 26°C than at 19°C (Fig. 2, Table 3). Mean growth rates were 2.9 times less at 3 mg/L (1.27%/d) than at 7 mg/L (3.62%/d). Sealed tanks showed consistently lower growth rates than those with surface access. The effect was greatest at 3 mg/L oxygen. Only 0.3%/d weight-specific growth was observed in the 19°C sealed tanks, and all fish perished before growth determinations could be made in the 26°C sealed tanks. Absolute growth in weight was significantly affected by surface access, temperature, surface access in combination with temperature interaction, and by oxygen level. Absolute growth rate was higher when surface access was allowed and at the higher DO level; absolute growth rate was inversely related to temperature.

Respiration

Respiration rates measured over the entire experiment ranged from 0.05 to 0.55 mg O_2/(g·h) (Fig. 3). Respiration rates were normally distributed for the high oxygen treatment with a mean of 0.245 ± 0.013

Table 3

Growth rates (mean ± standard error) of Atlantic sturgeon during the laboratory experiment. Growth rates in weight and length are instantaneous rates. Absolute growth rates in weight is presented under the heading mg/d. Experiments are labeled according to the temperature level and whether tanks were sealed or unsealed (unsealed tanks permitted access by sturgeon to surface water). Dissolved oxygen (DO) levels, low and high, refer to prescribed levels of 3 mg/L and 7 mg/L, respectively. *n* = number of individuals in each tank. Rep. = replicate(s).

Experiment	DO level	Rep.	Growth rate in weight (per day)	mg/d	Growth rate in length (per day)	*n*
26°C unsealed	Low	1	0.023 ± .006	0.345 ± 0.094	~0	2
		2	0.013 ± 0.003	0.202 ± 0.056	~0	6
		3	0.006 ± 0.005	0.093 ± 0.062	0.003 ± 0.001	4
		4	0.029 ± 0.019	0.324 ± 0.192	0.003 ± 0.001	8
	High	1	0.037 ± 0.004	0.524 ± 0.076	0.010 ± 0.001	8
		2	0.037 ± 0.006	0.643 ± 0.116	0.012 ± 0.002	8
		3	0.036 ± 0.007	0.587 ± 0.112	0.012 ± 0.002	8
		4	0.036 ± 0.004	0.789 ± 0.117	0.015 ± 0.001	8
26°C sealed	Low	1	Lethal			0
		2	Lethal			0
	High	1	0.029 ± 0.001	2.220 ± 0.059	0.006 ± 0.001	6
		2	0.025 ± 0.001	2.015 ± 0.178	0.007 ± 0.001	6
19°C unsealed	Low	1	0.013 ± 0.002	0.185 ± 0.029	0.005 ± 0.001	7
		2	0.011 ± 0.003	0.129 ± 0.037	0.005 ± 0.001	7
	High	1	0.050 ± 0.005	0.721 ± 0.057	0.014 ± 0.001	8
		2	0.045 ± 0.002	0.719 ± 0.044	0.015 ± 0.001	8
19°C sealed	Low	1	0.003 ± 0.001	0.072 ± 0.030	0.004 ± 0.001	8
		2	0.003 ± 0.001	0.071 ± 0.031	0.004 ± 0.001	8
	High	1	0.028 ± 0.003	1.887 ± 0.253	0.009 ± 0.001	6
		2	0.031 ± 0.002	2.270 ± 0.197	0.008 ± 0.001	6

Table 4

Nested analysis of variance of surface access, temperature, oxygen level, replicate and individual effects on growth rate. Initial weight was used as a covariate in the analyses. Sealed refers to whether tanks were sealed or unsealed (unsealed tanks permitted access by sturgeon to surface water). Designated temperature and oxygen levels were 19°C and 26°C, and 3 mg/L and 7 mg/L, respectively. Factors in parentheses indicate the nesting procedure. For example "Oxygen (Sealed-Temperature)" refers to variance explained by oxygen level nested within combinations of surface access and temperature.

Type of variable	Variable	df	Sum of squares	Significance level (*P*)
Instantaneous growth rate in weight				
Covariate	Initial weight	1	0.3892	0.0001
Class variables	Sealed	1	0.0392	0.019
	Temperature (sealed)	2	0.0086	0.54
	Oxygen (sealed-temperature)	3	0.0981	0.0039
	Tank (sealed-temperature-oxygen)	7	0.0097	0.99
	Individual (sealed-temperature-oxygen-tank)	14	0.0077	0.99
Absolute growth rate in weight				
Covariate	Initial weight	1	0.0839	0.0001
Class variables	Sealed	1	0.0445	0.0001
	Temperature (sealed)	2	0.0523	0.0002
	Oxygen (sealed-temperature)	3	0.7734	0.0001
	Tank (sealed-temperature-oxygen)	7	0.0293	0.17
	Individual (sealed-temperature-oxygen-tank)	14	0.0194	0.92

mg O_2/(g·h). In relation to the high oxygen treatment, hypoxic oxygen treatment respiration rates were skewed towards lower rates with a mean of 0.174 ±0.016 mg O_2/(g·h). Two individual tank respiration rates for the hypoxic treatment were exceptionally high (Fig. 3). These data were measured at 0 hours from tanks at 19°C and 26°C and may have reflected an insufficiently long period of acclimation prior to the experiments. Therefore, we chose to exclude measures taken at 0 hours in the analysis of variance on respiration rates.

Respiration rates were significantly influenced by oxygen level (P=0.001), by the interactions between temperature and oxygen (P=0.04), and by the interaction among temperature, oxygen, and replicate (P=0.04). Mean respiration rates were 0.187 ± 0.012 and 0.247 ± 0.015 mg O_2/(g·h) under hypoxia and normoxia, respectively (Table 1). At high oxygen levels, 26°C respiration rates (mean=0.281 ±0.023 mg O_2/(g·h)) tended to be higher than 19°C respiration rates (mean=0.210 ±0.021 mg O_2/(g·h)). However, the converse was true at hypoxic levels; mean respiration rate at 26°C (0.136 ±0.027 mg O_2/(g·h)) was significantly lower than at 19°C (0.212 ±0.021 mg O_2/(g·h)). For all but the 26°C and hypoxic-level combination, replicate rates were similar. Respiration for the second replicate for the 26°C and hypoxic-level combination was substantially lower than other replicates that may have produced the significant interaction among temperature, oxygen, and replicate factors in the analysis of variance. In a procedure to reduce bias associated with deviations of actual inflow DO levels from those prescribed, an analysis of variance was conducted for which the inflow oxygen concentration was a covariate. After viariance associated with individual tank DO conditions was removed, the effect of oxygen level (high or low) remained significant (P=0.04).

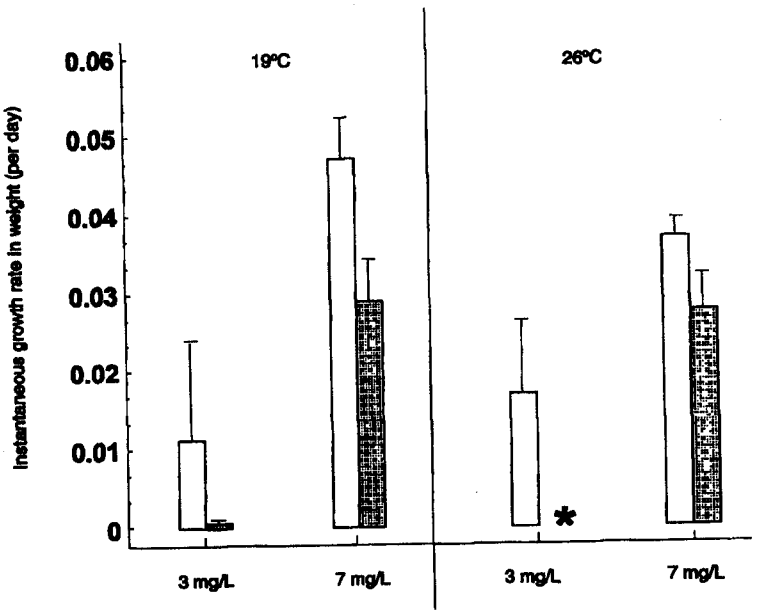

Figure 2

Effects of dissolved oxygen concentration on instantaneous growth rates in weight (per day) (mean ± 95% confidence interval) of young-of-the-year Atlantic sturgeon at two temperatures and different tank configurations. Stippled bars indicate treatments denying surface access. Replicate tanks were combined for each treatment level comination. The asterisk indicates that complete mortality occurred for that treatment.

Discussion

Juvenile Atlantic sturgeon were vulnerable to conditions of high temperature and low oxygen. In five out of six replicates (sealed and unsealed tanks combined) at 26°C and ~3 mg/L DO, all juveniles died. All sturgeon that died showed a perfusion of blood along the margins of their fins, indicative of oxygen deprivation (Jobling, 1995). Reduced oxygen levels resulted in a threefold reduction in growth rate and a 50% reduction in routine respiration rate. At 19°C, respiration rates were similar between hypoxic and normoxic treatments. But, at the 26°C hypoxic treatment, mean respiration rates dropped below 2 mg O_2/(g·h) and all sturgeon died. We speculate that these fish were unable to supply sufficient oxygen to their tissues at this level of reduced respiration.

Despite reduced survival and respiration in conditions of low dissolved oxygen, feeding continued and fish grew. Apparently, Atlantic sturgeon were able to reduce activity but still feed and allocate some energy to growth. In unsealed tanks, weight gain ranged from 1.1% to 2.9%, and from 3.6% to 5.0% body weight per day, at ~3 and ~7 mg O_2/L, respectively. Cech et al. (1984) also observed continued growth by juvenile white sturgeon (*Acipenser transmontanus*) (ca. 0.5 to 5 g) under conditions of hypoxia. Daily weight-specific growth rates of white sturgeon varied between 1.6% (15°C) and 2.9% (25°C) under normoxic conditions and between 0.6% (15°C) and 2.3% (25°C) under hypoxic conditions. Growth rates measured by Cech et al. (1984) under hypoxia were substantially higher than those that we ob-

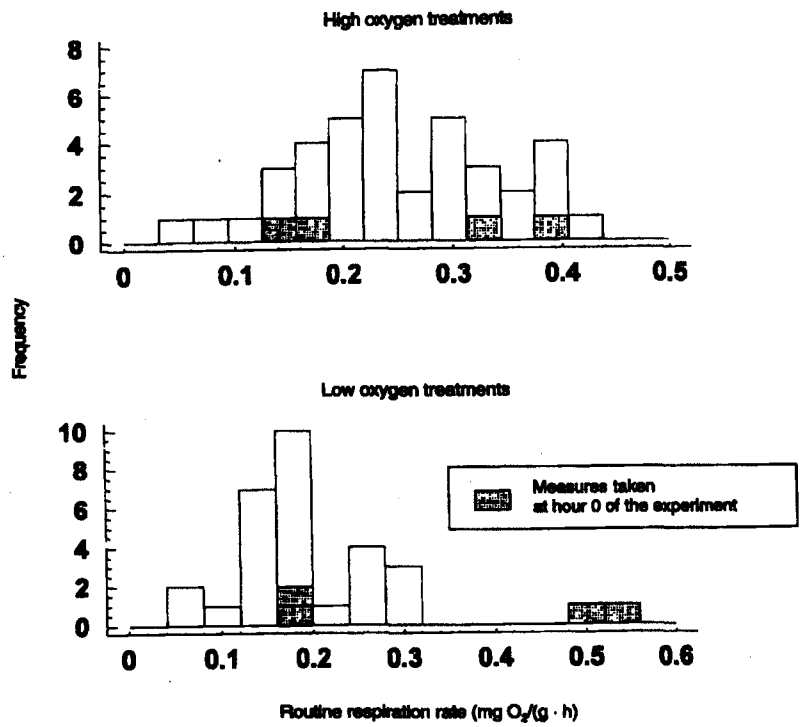

Figure 3

Frequency histogram of respiration rates for young-of-the-year Atlantic sturgeon exposed to either high (7 mg/L) or low levels (3 mg/L) of dissolved oxygen. Measures taken at the initiation of the experiment (hour 0) are stippled.

served. This may be attributable to a higher designated oxygen level for hypoxic treatments (<5 mg/L), differences between the two species, or an ontogenetic effect. Juvenile white sturgeon were substantially smaller (initial weight 0.5 grams) than those used in our study (mean initial weight=23.7 grams).

Our study was unique in examining the effects of long-term hypoxia on routine metabolism. Other studies have examined the effects of hypoxia on sturgeon respiration in short-term respirometry studies (Table 5). Investigations on white sturgeon and Siberian sturgeon (*Acipenser baeri*) have indicated reduced rates of respiration under hypoxic conditions. An ontogenetic trend of decreasing routine metabolic rates with increased mass, which is typical in fishes, was also suggested in the comparison of studies. Metabolic rates under normoxic conditions ranged from 0.9 mg O_2/(g·h) (1–2 g fish) to 0.055 mg O_2/(g·h) (1800-g fish). Metabolic rates (0.2

Table 5

Summary of studies on hypoxia and routine metabolism for sturgeons. Oxygen concentrations and consumption rates have been converted to common units (mg O_2/L or mg O_2/(g·h) from reported units (e.g. mm Hg or µmol O_2/kg(g·h) for several of the studies. Wt = wet weight; Hyp = hypoxia treatment; Norm = normoxia treatment; Swim = velocities were provided in respirometer to induce swimming velocities; S = salinity; and T = temperature.

Species	Wt (g)	Treatments	Routine metabolism mg/(g·h)	S (ppt)	T (°C)	Study duration	Reference
Acipenser transmontanus	0.5–5	Hyp: 4.7 - 5.7 mg/L Norm: 6.8 - 8.2 mg/L	Not measured	0	15, 20, 25	30 d	Cech et al., 1984
A. baeri	1–2	High density Low density	0.3 to 0.5 0.4 to 0.9	0	22–24	2–12 h	Khakimullin, 1987
A. baeri	3–7	Routine Swim: 5–30 cm/sec	0.3 to 0.7 0.4 to 3.6	0	22–24	3 h	Khakimullin, 1988
A. oxyrinchus	12–69	Hyp: 2.5–4.4 mg/L Norm: 6.3–7.4 mg/L	0.1 to 0.2 0.2 to 0.3	1.8–2.5	19, 26	10 d	This study
A. transmontanus	950	Hyp: 1.7–6.3 mg/L Norm: 9.8 mg/L	~0 to 0.015 0.079	0	15	4.5 h	Burggren and Randall, 1978
A. baeri	1800	Hyp: 1.3–3.8 mg/L Norm: 8.2 mg/L	0.023 0.055	0	15	3.5 h	Nonnotte et al., 1993
A. transmontanus	2000	Hyp: 4.7–5.9 mg/L Norm: 7.7–8.9mg/L	0.090 0.098	0 0	18	24 h	Ruer et al., 1987

to 0.3 mg O_2/(g·h) and fish sizes (12 to 69 g) in our experiments were both intermediate within this range.

Surface behavior

In the nested growth and survival experiment, surface access influenced both growth and survival rates. Eliminating surface accesses in tanks reduced growth rates by ca. 35%, and fivefold at high and low levels of DO, respectively. The effects of denying surface access under "hypoxia" at 26°C was fully lethal within a 30-h period. In the 26°C hypoxic treatments that allowed surface access, the majority of juveniles survived the first 5 days of exposure, although they too eventually died.

Many fishes surface in hypoxic environments to convey relatively oxygen-rich water, located at the air-water interface, across their gills. In laboratory experiment, access to surface waters may have increased the effective level of DO above nominal levels, resulting in improved growth and survival. Alternatively, aerial respiration cannot be ruled out for sturgeon that are physostomous. Histological studies should be undertaken to investigate whether the swim bladder of Atlantic sturgeon contains a vascular structure, apart from the gas gland, which meets the criteria for an aerial respiratory organ. No such structure has been identified in any sturgeon species.

Reasons for decline of Atlantic sturgeon in Chesapeake Bay

We conclude that increased frequency of hypoxia in Chesapeake Bay during this century (Officer et al., 1984; Cooper and Brush, 1993) was detrimental to Atlantic sturgeon production. Recent water quality monitoring has shown that during summer months (mid-June through mid-September), temperatures >25°C and DO levels <4.0 mg O_2/L are prevalent in Chesapeake Bay benthic habitats (Breitburg, 1990, 1992; Phil et al., 1991). Our laboratory experiments showed that juvenile Atlantic sturgeon were less tolerant of summertime hypoxia than were other juvenile estuarine species. Young-of-the-year spot, *Leiostomus xanthurus* (total length 10–20 cm), survived long-term (>1 week) experimental exposure of 2.4–3.0 mg/L at 25°C, but 0.8–1.0 mg/L DO was fully lethal (Phil et al., 1991). Juvenile and adult hogchokers, *Trinectes maculatus* (Phil et al., 1991), and naked gobies, *Gobiosoma bosc* (Brietburg, 1992), can tolerate several-day periods of 0.5–1.0 mg/L DO.

Our laboratory experiments did not consider behaviors that can 1) reduce exposure to hypoxic waters and 2) compensate for reduced dissolved oxygen levels. Phil et al. (1991) and Brietburg (1992) have provided field evidence that fish will escape hypoxic conditions through local migrations. These include vertical or shoalward emigrations from hypoxic or anoxic bottom habitats. Following hypoxic events, bottom habitats are recolonized. Further, short-term episodic hypoxia may benefit bottom-feeding fish. Burrowing macrobenthic prey will emerge at DO levels <2 mg/L, increasing their vulnerability to predation by fish that can tolerate short-term excursions into hypoxic waters (Phil et al., 1992). If unable to escape hypoxic conditions, sturgeon may be able to compensate by either surfacing to exploit higher oxygen concentrations in surficial water or in the atmosphere or by adjusting their metabolic rate (e.g. through reduced swimming [Cech et al., 1984]).

Hudson River "strain" Atlantic sturgeon, used in our experiment, might have exhibited a different response to hypoxia than a strain native to Chesapeake Bay. The Hudson River rarely becomes hypoxic (Cooper et al., 1988). Therefore, Hudson River Atlantic sturgeon may not have been adapted to hypoxic conditions. An aquaculture study by Serov et al. (1988) on stellate sturgeon (*A. stellatus*) showed that heterozygosity in the LDH gene conferred survival advantages to hypoxia and high temperature. Therefore, it is conceivable that selection of Chesapeake Bay Atlantic sturgeon to hypoxic conditions could have occurred over several generations. However, because generation time is extremely high in Atlantic sturgeon (c.a. 29 years [Stevenson and Secor, 1996]) and because hypoxia increased rapidly during this century in the Chesapeake Bay, Chesapeake Bay Atlantic sturgeon may not have been able to recoup historical abundances by dint of selection to low-oxygen conditions. In addition, Hudson River Atlantic sturgeon juveniles >80 cm TL are known to visit Chesapeake Bay during summer months (Dovel and Berggren, 1983). Presumably, these fish could have adapted to Chesapeake Bay conditions. Serov et al.'s (1988) observation that water quality experienced by juveniles in culture influences genotypic frequencies has important implications for the use of hatchery-produced sturgeon in restoration programs and merits additional research.

Scientists and managers are now considering a restoration program for Atlantic sturgeon in Chesapeake Bay and elsewhere (St. Pierre, 1994; Secor, 1995). The feasibility of a sturgeon restoration program must address the same issues that led to the sturgeon's decline. If these conditions persist in Chesapeake Bay, a restoration program cannot be easily justified. Necessary conditions for population recovery must include increased population abundance, and improvement in the quality and size and number of essential habitats. Population abundance

can be increased by deliberately releasing artificially produced progeny (parentage from an outside population like the Hudson River population), by imposing a moratorium on sturgeon harvests, and by making efforts to reduce sturgeon taken as bycatch in other fisheries.

A critical and unresolved question is whether habitat quality remains sufficient at present in the Chesapeake Bay to support Atlantic sturgeon growth, survival, and reproduction. An encouraging finding has been a trend in improved water quality and macrobenthic production in Chesapeake Bay tributary nursery habitats, the apparent result of nutrient abatement programs (Dauer, 1995).

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Literature cited

Brandt, S. B., and J. Kirsch.
1993. Spatially explicit models of striped bass growth potential in Chesapeake Bay. Trans. Am. Fish. Soc. 122:845–869.

Breitburg, D. L.
1990. Near-shore hypoxia in the Chesapeake Bay: patterns and relationships among physical factors. Estuarine Coastal Shelf Sci. 30:593–609.
1992. Episodic hypoxia in Chesapeake Bay: interacting effects of recruitment, behavior, and physical disturbances. Ecol. Monogr. 62:525–546.

Brett, J. R.
1970. The metabolic demand for oxygen in fish, particularly salmonids, with a comparison with other vertebrates. Respir. Physiol. 14:151–170.

Berggren, W. W., and D. J. Randall.
1978. Oxygen uptake and transport during hypoxic exposure in the sturgeon *Acipenser transmontanus*. Respir. Physiol. 34:171–183.

Cech, J. J.
1990. Respirometry. *In* C. B. Schreck and P. B. Moyle (eds.), Methods for fish biology, p. 335–362. Am. Fish. Soc., Bethesda, MD.

Cech, J. J., S. J. Mitchell, and T. E. Wragg.
1984. Comparative growth of juvenile white sturgeon and striped bass: effects of temperature and hypoxia. Estuaries 7:12–18.

Cooper, J. C., F. R. Cantelno, and C. E. Newton.
1988. Overview of Hudson River Estuary. Am. Fish. Soc. Monogr. 4:11–24.

Cooper, S. R., and G. S. Brush.
1993. A 2,500-year history of anoxia and eutrophication in Chesapeake Bay. Estuaries 16:617–626.

Coutant, C. C.
1985. Striped bass, temperature, and dissolved oxygen: a speculative hypothesis for environmental risk. Trans. Am. Fish. Soc. 114:31–61.

Coutant, C. C., and D. L. Benson.
1990. Summer decline in habitat suitability for striped bass in Chesapeake Bay: reflections on a population decline. Trans. Am. Fish. Soc. 119:757–778.

Dauer, D. M.
1995. Long-term trends in macrobenthos of the lower Chesapeake Bay (1985–92). *In* P. Hill and S. Nelson (eds.), Toward a sustainable watershed: the Chesapeake experiment. Chesapeake Research Consortium Publ. 149, Edgewater, MD.

Dovel, W. L., and T. J. Berggren.
(1983). Atlantic sturgeon of the Hudson Estuary, New York. NY Fish and Game J. 30:140–172.

Harding, L. W., M. Leffler, and G. E. Mackiernan.
1992. Dissolved oxygen in the Chesapeake Bay: a scientific consensus. Maryland Sea Grant, College Park, MD, 18 p.

Hendrix, M. A.
1995. Update—U.S. Fish and Wildlife Service and Atlantic sturgeon. Sturgeon Notes 3:10–11.

Hildebrand, S. F., and W. C. Schroeder.
1928. Fishes of the Chesapeake Bay. U.S. Bureau of Fisheries, Washington, D.C., 388 p.

Jobling, M.
1995. Environmental biology of fishes. Chapman and Hall, New York, NY, 455 p.

Jordan, S., C. Stenger, M. Olson, R. Batiuk, and K. Mountford.
1992. Chesapeake Bay dissolved oxygen goal for restoration of living resource habitats. Maryland Department of Natural Resources, Annapolis, MD, 81 p.

Kemp, W. M., P. A. Sampou, J. Garber, J. Tuttle, and W. R. Boynton.
1992. Seasonal depletion of oxygen form bottom waters of Chesapeake Bay: roles of benthic and planktonic respiration and physical exchange processes. Mar. Ecol. Prog. Ser. 85:137–152.

Khakimullin, A. A.
1987. Intensity of gas exchange in individuals and groups of juvenile siberian sturgeon, *Acipenser baeri*. Vop. Ikht. 6:978–983.
1988. Intensity of gas exchange of hatchery siberian sturgeon, *Acipenser baeri*, under muscular load. Vop. Ikht. 1988:282–288.

Mackiernan, G. B.
1987. Dissolved oxygen in the Chesapeake Bay: processes and effects. Maryland Sea Grant, College Park, MD, 177 p.

Murawski, S. A., and A. L. Pacheco.
1977. Biological and fisheries data on Atlantic sturgeon,

Acipenser oxyrhynchus (Mitchill). National Marine Fisheries Service, NOAA, Highlands, NJ, 69 p.

Nonnotte, G., V. Maxime, J. P. Truchot, P. Williot, and C. Peyraud.
1993. Respiratory responses to progressive ambient hypoxia in the sturgeon, *Acipenser baeri*. Respir. Physiol. 91:71–82.

Officer, C. B., B. B. Biggs, J. L. Taft, L. E. Cronin, M. A. Tyler, and W. R. Boynton.
1984. Chesapeake Bay anoxia: origin, development, and significance. Science 223:22–27.

Phil, L., S. P. Baden, and R. J. Diaz.
1991. Effects of periodic hypoxia on distribution of demersal fish and crustaceans. Mar. Biol. 108:349–360.

Phil, L., S. P. Baden, R. J. Diaz, and L. C. Schaffner.
1992. Hypoxia-induced structural changes in the diet of bottom-feeding fish and crustaceans. Mar. Biol. 112:349–361.

Ricker, W. E.
1975. Computation and interpretation of biological statistics of fish populations. Canada Fisheries and Oceans, Ottawa, Ontario, 382 p.

Ruer, P. M., J. J. Cech and S. I. Doroshov.
1987. Routine metabolism of the white sturgeon, *Acipenser transmontanus*: effect of population density and hypoxia. Aquaculture 62:45–52.

SAS.
1982. Statistical analysis system user guide: statistics. SAS Institute, Inc., Cary, NC, 585 p.

Secor, D. H.
1995. Chesapeake Bay Atlantic sturgeon: current status and future recovery. Chesapeake Biological Laboratory, Solomons, MD, 10 p.

Serov, D. V., S. I. Kikonorov, and E. S. Asadullaeva.
1988. Genetic selection in young stellate sturgeon. Rybn. Khov. 4: 64–65.

Speir, H., and T. O'Connell.
1996. Status of Atlantic sturgeon in Maryland's Chesapeake Bay. MD Dep. Natur. Resources, Annapolis, MD, 7 p.

St. Pierre, R. A.
1994. The national strategy for the management and conservation of paddlefish and sturgeon species in the United States. *In* V. J. Birstein (ed.), The international conference on sturgeon biodiversity and conservation. Hudson River Foundation, New York.

Stevenson, J. T., and D. H. Secor.
1996. Demographic analysis of Atlantic sturgeon fisheries in the New York Bight. Chesapeake Biological Laboratory, Solomons, MD, 17 p.

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Dissolved oxygen, temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon in estuarine waters: I. Laboratory results

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ABSTRACT

Dissolved oxygen and salinity are relevant structuring factors which should be incorporated into habitat and bioenergetic models for estuarine fishes. We measured growth, food consumption, routine and postprandial metabolism, egestion and survival responses of juvenile Atlantic sturgeon (young-of-the-year: YOY, 6–48 g) in an incomplete factorial array of temperature, salinity and dissolved oxygen levels. Complementary measures were also conducted on yearlings (1 year-old, 70–300 g) to evaluate size and age effects upon food consumption and growth. All three factors had a significant effect on major bioenergetic responses, as well as several of their first order interactions. Maximum growth and food consumption rates were observed above 70% dissolved oxygen saturation, at 20 °C, and between salinities of 8 and 15. Postprandial metabolism was reduced and egestion increased under hypoxia (50% DO saturation), suggesting compensatory mechanisms aimed to reduce assimilation rates. A significant shift in growth responses with age indicated higher tolerance to salinity in yearlings than in YOY. No other size dependent changes were significant, either for hypoxia or for temperature effects. Survival tended to increase with dissolved oxygen saturation, and decreased at the highest temperature and salinity levels. Our results indicated both additive and synergistic effects of tested environmental factors upon ecophysiological responses and highlighted the need to consider these in new bioenergetic models.

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1. Introduction

Estuarine fish habitats are structured spatially by strong gradients in salinity, temperature and dissolved oxygen. While salinity and temperature variability are inherent features of most estuaries worldwide, hypoxia in shallow estuaries is a seasonal phenomenon, which has become more pervasive during the past century in populated areas, the likely consequence of anthropogenic organic enrichment (Officer et al., 1984; Cooper and Brush, 1991a). Although high physiological plasticity is expected in estuarine species, strong effects of temperature, salinity and dissolved oxygen have been reported upon behavior, distribution, physiology, energetics, growth and survival (Fry, 1971; Brett, 1979; Brandt, 1993; Boeuf and Payan, 2001).

The importance of hypoxia curtailments on estuarine fish habitats is supported by a rich literature, which relates fish distribution, survival, growth and behavior responses to water quality in estuarine habitats, and particularly to dissolved oxygen levels (Cech et al., 1984; Susanto and Peterson, 1996; Secor and Gunderson, 1998; Breitburg et al., 1999; Pichavant et al., 2001; Marcus et al., 2004; Stierhoff et al., 2006). Substantial literature has also assessed critical (lethal) hypoxia levels, such as LC_{50} (Scholz and Waller, 1992; Jenkins et al., 1993; Plante et al., 1998; Miller et al., 2002; Landman et al., 2005; Shimps et al., 2005; Goodman and Campbell, 2007). A relevant part of this body of information has been compiled and used for defining management goals and regulatory thresholds in highly impacted estuaries such as the Chesapeake Bay (US-EPA, 2003).

Although there is strong evidence that temperature, salinity and other environmental factors may interact with dissolved oxygen, modifying its effects upon growth and survival of estuarine species (Fry, 1971; Claireaux and Lagardere, 1999; Yamashita et al., 2001; Niklitschek and Secor, 2005), most dissolved oxygen goals and thresholds have been established as fixed criteria, neglecting such interactions. More integral approaches are restrained by a limited availability of multivariable response models for estuarine species.

In the present work we measured and modeled (Niklitschek and Secor, 2009-this issue) the effects of dissolved oxygen, temperature, salinity and their interactions upon growth, survival and other major bioenergetic responses in Atlantic sturgeon *Acipenser oxyrinchus*. Sturgeons have been considered as indicator species due to their particularly low tolerance to hypoxia, which can exceed well known oxyphilic species such as Oncorhynchus mykiss (Klyashtorin, 1982). This tolerance has been shown to be reduced at high temperature (Secor and Gunderson, 1998) and salinity levels (Niklitschek, 2001), suggesting that the areas of suitable nursery habitats could be largely reduced in summer months (Collins et al., 2000; Niklitschek and Secor, 2005).

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Atlantic sturgeon once inhabited a wide geographic range along the Atlantic coast of North America (Evermann and Bean, 1898; Leim and Day, 1959; Vladykov and Greeley, 1963). After initial depletion by severe overfishing in the late 1900s (Secor and Waldman, 1999), most Atlantic sturgeon populations have not recovered despite decades of strict fishing regulations and a fishing moratorium since 1998 (ASMFC, 1998). Hence, reduced suitability of spawning and nursery habitats have been identified as key issues in sturgeon recovery (ASMFC, 1998; Atlantic Sturgeon Status Review Team, 2007). Nursery habitats in fresh and brackish waters, where Atlantic sturgeon juveniles spend their first 3–5 years of life, have been seriously affected by increasing pollution, nutrient uploads and hypoxia during the 20th century (Officer et al., 1984; Cooper and Brush, 1991b). Regulated flow regimes in dammed rivers and global warming trends (Najjar et al., 2000; Preston, 2004) would further affect suitable nursery areas for Atlantic sturgeon and other sturgeons (Niklitschek and Secor, 2005).

Our investigations on ecophysiological responses of juvenile sturgeons to estuarine conditions have been divided in two companion papers: in the present one we measure and test the main effects and interactions between dissolved oxygen, temperature, salinity and size/age-class (age 0 and age 1 juveniles) on metabolic, growth, and survival responses. The companion paper (Niklitschek and Secor, 2009-this issue) uses these ecophysiological responses in the development of a mass-balance predictive bioenergetics model, suitable for Atlantic sturgeon and other estuarine species.

2. Materials and methods

Survival, growth and main bioenergetic responses to dissolved oxygen saturation (DO_{SAT}), salinity and temperature were measured in microcosm studies, conducted on hatchery-produced Atlantic sturgeon juveniles, offspring from Hudson River parents, spawned in 1996. Fish were made available by the US Fish and Wildlife Service, Northeast Fisheries Science Center (Mohler, 2000). Because fish were of limited supply, the experimental design was accommodated to gain maximum use from a few hundred individuals. Two age classes were used in the present work: young-of-the-year (YOY, 6–48 g) and yearlings (100–300 g).

All fish were tagged and identified through subcutaneous visible elastomer inclusions (Northwest Marine Technologies) injected in the pectoral fins, several weeks before starting the experiments. Fish were acclimated to experimental conditions at transition rates no greater than 1 (salinity), 1 °C and 5% DO_{SAT} per day. Salinity was maintained within ±5% of targeted levels by mixing local well water with filtered ambient brackish water (salinity 3–18, Patuxent River, Chesapeake Bay). Artificial salt (Instant Ocean®) was added when necessary. Dissolved oxygen was kept within ±10% of targeted levels by mixing nitrogen with ambient air. Temperature was regulated within ±8% of targeted levels by using a combination of room-temperature control, water baths, and individual heaters. Water quality parameters were checked at least 3 times each day unless otherwise stated.

2.1. Growth and food consumption

Temperature, salinity and DO effects on food consumption and growth rates were tested on YOY via an incomplete factorial design (Mead, 1988) that included 23 combinations of four temperatures: 6, 12, 20 and 28 °C; four levels of dissolved oxygen: 30, 40, 70 and 100% DO_{SAT}; and five salinity levels: 1, 8, 15, 22 and 29 (Table 1). This design allowed us to evaluate responses to main effects and first order interactions between temperature, salinity and dissolved oxygen.

To assess size or age effects upon functional responses to hypoxia, temperature and salinity, we conducted an additional set of food consumption and growth experiments on yearlings. In this case we followed a simplified multi-axial design aimed to test only main effects at three levels of temperature: 12, 20 and 28 °C; three dissolved oxygen treatments: 40, 70 and 100% DO_{SAT}; and four levels of salinity: 1, 15, 22 and 29 (Table 1).

Table 1
Summary of the incomplete experimental designs used to evaluate bioenergetics and survival effects of dissolved oxygen saturation, temperature and salinity upon juvenile Atlantic sturgeon.

Temperature	Dissolved oxygen saturation	Salinity 1	8	15	22	29
6	70		3			
12	40		3			
	70	3	6	3(3)		
	100		3			
20	30		3			
	40	3	5	4(3)		
	70	3(3)	6	3(3)	4(3)	2(3)
	100	2	5	2(3)		
28	40		2			
	70	4	5	4(3)		
	100		3			

Number of replicates corresponding to each growth-consumption experiments indicated for YOY and yearlings (in parenthesis).

Fish were fasted for 24 h, measured, weighed and left to recover for 12 h before each experiment. During the following 10 days, fish were fed *ad libitum* 3-mm Biokyowa® pellets thrice a day, and measured and weighed again 12 h after the last feeding. Non-consumed food was removed 30–40 min after each feeding and dried to constant weight (≥48 h) at 60 °C. Apparent consumption was reduced by an empirically derived factor of 5% to account for pellet losses in the tank. Average energy-density in Biokyowa pellets, estimated by wet digestion (Maciolek, 1962), was equal to 21.9 kJ g^{-1}. Daily consumption rates were calculated for each tank by dividing total consumed food by the expected tank biomass, back-calculated from observed growth.

We planned to obtain six replicates for the treatment representing center conditions for YOY trials (20 °C, 70% DO_{SAT}, salinity 8), and at least three replicates for all the remaining treatments and yearlings. However, low survival occurred at high salinity, high temperature and/or low DO_{SAT}. To minimize harm to individual fish and preserve sufficient experimental animals, lethal treatments were not always replicated, causing some unequal replication (Table 1).

A total of 81 experiments were successfully completed for YOY in seven sequential runs, using 34-l glass aquaria with either one or two fish per tank. Preliminary experiments showed no difference in growth or food consumption between fish reared individually and in pairs (Niklitschek, 2001). Individuals were sequentially allocated to a maximum of three experiments, using a semi-random balanced design. Yearlings were individually reared in 70-l tanks, conducting a total of 63 experiments, distributed along three sequential runs.

Daily instantaneous growth rates (G) were calculated for each individual, and averaged within each tank, using the relationship: $G = [\log_e(W_t) - \log_e(W_0)]/(t - t_0)$, where, W_t is final weight at time t; and W_0 is initial weight at time t_0.

2.2. Respirometry

Energy costs of both routine metabolism and postprandial metabolism were estimated by respirometry. In routine metabolism trials we aimed to measure the energy consumption of fasted fish at rest. Although noise and light stimuli where minimized, some spontaneous activity occurred and obvious activity spikes were deleted from the data set. Oxygen consumption was measured for individual fish using either 2-l flow-through or 15.4-l static respirometers. The smaller flow-through units (0.35 l min^{-1}) were used for fish up to 18 g, and the larger respirometers for fish between 14 and 37 g. Previous experiments indicated oxygen consumption results

were not significantly affected by respirometer type (Niklitschek, 2001). In each trial 6 to 8 respirometers were run simultaneously, including 1 or 2 respirometers without fish as blanks to correct final results for microbial oxygen consumption. Fish were placed in respirometers for at least 12 h prior to any respiration measures. Salinity, oxygen and temperature levels were maintained within ± 10% of targeted values; any respiration reading outside those limits were excluded. All temperature, dissolved oxygen and salinity measurements were made using a YSI-85 sensor, re-calibrated in saturated water every time a new sequence of readings at a given temperature was initiated. Apparent oxygen consumption values from flow-through respirometers were corrected later for hydraulic residence time (Niklitschek, 2001). Measured consumed oxygen was then transformed into consumed energy using an oxycalorific coefficient of 13.55 kJ g-O_2^{-1} (Brett and Groves, 1979).

Routine metabolism respirometry experiments were done immediately before or after growth-consumption experiments, for the same fish and under the same 23 combinations of temperature, salinity and dissolved oxygen conditions (Table 1). Due to the use of small and static respirometers, targeted DO_{SAT} for normoxia treatments was defined to be 90% rather than the 100% DO_{SAT} used in food consumption and growth experiments. Two to six replicates were obtained for each treatment, depending on fish availability. We tested a total of 128 fish, which were randomly allocated into 17 respirometry experiments. Oxygen consumption rates were measured every 45 min for at least 4 h or until 4 stable readings were obtained.

Respirometry experiments for measuring postprandial metabolism (classically named specific dynamic action, SDA) were based upon a factorial design with three replicates at three temperatures: 12, 20 and 28 °C and two levels of oxygen saturation: 50 and 100%. Salinity was 8 across all experiments. Actual conditions during SDA experiments were kept within 1 °C, 5% DO_{SAT} and 1 salinity unit from prescribed values. All experiments were conducted in 15.4-l flow-through respirometers, suitable for long-term rearing and retrieval of non-consumed food. To increase precision in dissolved oxygen measurements, hermetic probe holders with magnetic stirring systems were used at tank inflows and outflows.

After measuring routine oxygen consumption for about 4 h, flow was interrupted and fish were allowed to eat Biokyowa® pellets for 30 min. After that period, excess food was removed, flow restored ($\leq$0.6 l min^{-1}) and oxygen consumption measured every 1–2 h during the first 16 h, and every 2–4 h thereafter (48–60 h) until oxygen consumption was observed to decline to the previously observed routine metabolism levels. A noticeable peak in metabolism, observed within 0.5–1 h after feeding, was interpreted as the result of feeding activity and/or manipulation stress. Consequently, data between 0 and 2 h post-feeding were excluded and substituted by extrapolated values. Postprandial respiration was calculated as the area under the curve, decremented by routine respiration for each trial. The curve was fit using non linear regression and Niklitschek's (2001) modified version of Thornton and Lessem's (1978) algorithm, which facilitates both computing total oxygen consumption (area under the curve) and comparing the shape of SDA responses between treatments.

2.3. Egestion

Egestion experiments were conducted with the same fish and under the same combination of temperature and DO_{SAT} we used in SDA experiments. In addition to these abiotic variables, we tested 3 ration sizes: 10, 55 and 100% of the mean consumption per meal observed when fish were fed *ad libitum*, during the acclimation period. Before each experiment, fish were fasted for 60 h, weighed, rinsed and transferred to a clean 38-l tank with filtered (5 μm) and salinity = 8 water, and left to recover overnight (12–14 h). Three tanks with one fish per tank were used as replicates for all treatment levels.

Fish were then fed *ad libitum* three times at 2.5-h intervals. Non-consumed food was removed after 30 min, dried (24 h at 60 °C) and weighed. Observed feces were pipetted out three times a day and then frozen for further analysis. After 60 h the experiments were concluded, fish were rinsed, removed and weighed. Two control tanks were included in each run, using a randomly selected set of environmental conditions. To estimate non-fecal contributions of energy from the fish to the water, one of these control tanks contained one fish, but did not receive any food during the experiment. To estimate energy leakages from the food to the water, the other tank contained no fish but was "fed" the average amount of food given to the other tanks. Water contained in all experimental and control tanks was filtered (polycarbonate 35 μm) for further analysis. Feces and filters were dried at 60 °C for 48 h or until weight was stable. All feces samples were weighed and divided into 1–3 sub-samples (~10 mg each) for energy content analysis through a colorimetric variant of Maciolek's (1962) technique. Here, closed reflux digested samples were analyzed using a standard spectrophotometer at 600 nm wavelength, and compared with a standard potassium hydrogen phthalate solution, which had a theoretical chemical oxygen demand of 9408 μg O_2 ml^{-1}. Organic matter in fasted fish control tanks accounted for an average of 0.024 kJ ± 0.0070 (SE) per gram of fish (wet weight), which was subtracted from the fecal energy content estimated from experimental tanks. Energy content in filtrates from water corresponding to experimental and no fish control tanks was below the sensitivity of the dichromate technique.

2.4. Survival

The same YOY individuals and experimental design used for growth and food consumption experiments (Table 1) were used to evaluate the sub-acute effects of temperature, dissolved oxygen and salinity on fish survival. Fish were kept under the same conditions described in growth/food consumption experiments (see above) for at least 21 d after growth experiments were concluded. Thus, survival was monitored on 172 fish, which were randomly distributed among 23 treatments and six consecutive experimental runs.

2.5. Hypotheses testing

We tested the main linear and quadratic effects, and first order interactions between temperature, DO_{SAT} and salinity; and the $\log_e$-transformed fish weight effect using a mixed model regression approach (MIXED Procedure; SAS-Institute, 1997). This framework, based in maximum likelihood theory, allows means, residuals and standard errors to be adjusted for the effect of covariates (random effects) that are beyond the inference scope of the analysis (Hinkelmann and Kempthorne, 2005). The linear mixed model we used to test null hypotheses about measured bioenergetics responses followed the general form,

$$Y = X\beta + Zu + e$$

where

- Y — Measured response (instantaneous growth rate, food consumption, routine metabolism, SDA, or $\log_e$-transformed egestion ratio).
- X — Design matrix for fixed effects, including $\log_e$-transformed weight, linear and quadratic effects for temperature, dissolved oxygen, salinity, ration size and/or interactions between linear components. For exploring age-class effects, a categorical "dummy" variable was added to this matrix with values 0 and 1, for YOY and yearlings, respectively.
- β — Vector of coefficients for each of the fixed effects (included the intercept)

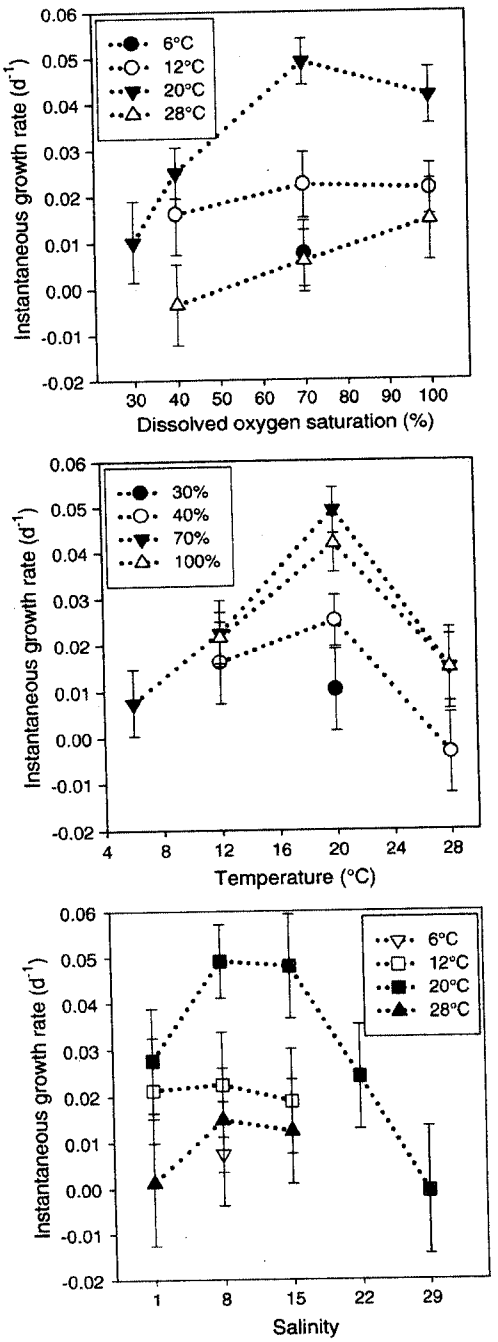

Fig. 1. Effects of dissolved oxygen saturation, temperature, and salinity on instantaneous growth rates of juvenile Atlantic sturgeon (means ± SE). Figures show variability caused by two factors at the time, while keeping the third one at fixed conditions (salinity = 8 for the top and middle panels, $DO_{SAT} \geq 70\%$ for the bottom panel). Means are connected by lines to facilitate interpretation.

Z	Design matrix for random effects (experimental set).
μ	Vector of coefficients for the random effects $\sim N(0,G)$; G = matrix of variance–covariance for the random effects
e	Vector of random errors $\sim N(0,R)$; R = matrix of variance–covariance for the random errors

Log-transformation of egestion observations was required to meet the assumptions regarding homogeneity of variances and normality in error distribution. Original scales were used for all other response variables. To avoid colinearity derived from polynomials and interactions, all explanatory variables were centered by subtracting their respective means.

Survival results were analyzed using a non parametric maximum likelihood version of Cox proportional hazard regression (Allison, 1995) implemented in SAS, PHREG procedure (SAS-Institute, 1997). Assuming no-time dependence in the effect of the covariates (i.e., temperature, dissolved oxygen level, and salinity) on survivorship, we simplified the Cox survivor function to the expression,

$$S(t) = S_0(t)^{\mathrm{EXP}(\beta X)}$$

where,

$S(t)$	Probability of surviving beyond time t.
$S_0(t)$	Baseline survivorship function when all covariates are zero.
EXP	Exponential function
β	Vector of regression coefficients for explanatory variables
X	Matrix of covariates: dissolved oxygen, temperature and salinity treatments.

A significance threshold of alpha = 0.1 was used for all tests, unless otherwise stated. Cases where the probability dropped below 0.05 were regarded as highly significant.

3. Results

3.1. Growth

Instantaneous growth rate was strongly affected by temperature, salinity and dissolved oxygen, as well as by fish weight (Table 2). Significant linear and quadratic effects, identified for all three environmental factors, suggested asymptotic patterns for dissolved oxygen and dome-shaped patterns for temperature and salinity, with maximum growth rates at 70–100% DO_{SAT}, 20 °C and salinity 8–15. We found a significant interaction between temperature and dissolved oxygen ($p<0.05$), which was reflected in very different slopes in the response of growth rates to dissolved oxygen between high and low temperatures. While at 28 °C growth rates increased continuously along the DO_{SAT} gradient, at 12 and 20 °C growth remained relatively constant above 70% DO_{SAT} (Fig. 1). These 70% DO_{SAT} levels are equivalent to 7.9 mg l^{-1} at 12 °C, and 6.7 mg l^{-1} at 20 °C. Temperature–salinity interaction was significant only at $p = 0.1$. No evidence of salinity-dissolved oxygen interaction was found.

Table 2
Linear regression analysis of dissolved oxygen (DO), temperature (T), salinity (SAL) and individual weight (W) effects upon instantaneous growth rate in juvenile Atlantic sturgeon.

Effect	Estimate ± SE	DDF	F-value	p>F
Intercept	0.043 ± 0.009	13.4	22.5	<0.001
T	0.047 ± 0.01	103.7	23.2	<0.0001
T^2	−0.048 ± 0.01	103.6	23.0	<0.0001
DO	0.029 ± 0.011	105.0	6.8	<0.05
DO^2	−0.024 ± 0.011	105.4	4.5	<0.05
SAL	0.016 ± 0.004	101.0	13.6	<0.001
SAL^2	−0.027 ± 0.007	105.9	15.7	<0.001
Ln(W)	−0.005 ± 0.002	18.0	4.4	<0.05
DO·T	0.003 ± 0.002	96.4	4.6	<0.05
Ln(W)·SAL^2	0.002 ± 0.001	105.7	4.0	<0.05
Ln(W)·DO	−0.001 ± 0.002	95.2	0.7	>0.1
Ln(W)·T^2	0.014 ± 0.011	98.5	1.6	>0.1
SAL·lnW	−0.006 ± 0.004	100.0	2.9	>0.05
T·SAL	0.005 ± 0.002	97.5	3.7	>0.05

Backward selection procedure on centered variables; alpha = 0.05. Results for regressors with $p>0.5$ are omitted. Numerator degrees of freedom = 1; DDF = denominator degrees of freedom (Satterthwaite's approximation).

Although different in magnitude, similar shapes were observed in the response of growth to temperature and dissolved oxygen between YOY and yearlings (Fig. 2). No significant differences were found between linear or quadratic coefficients for temperature or dissolved oxygen effects between age classes ($p>0.1$). Salinity effects, on the other hand, were significantly different between them, with maximum growth rates shifted from salinity = 15 for YOY to salinity = 22 for yearlings (Fig. 2).

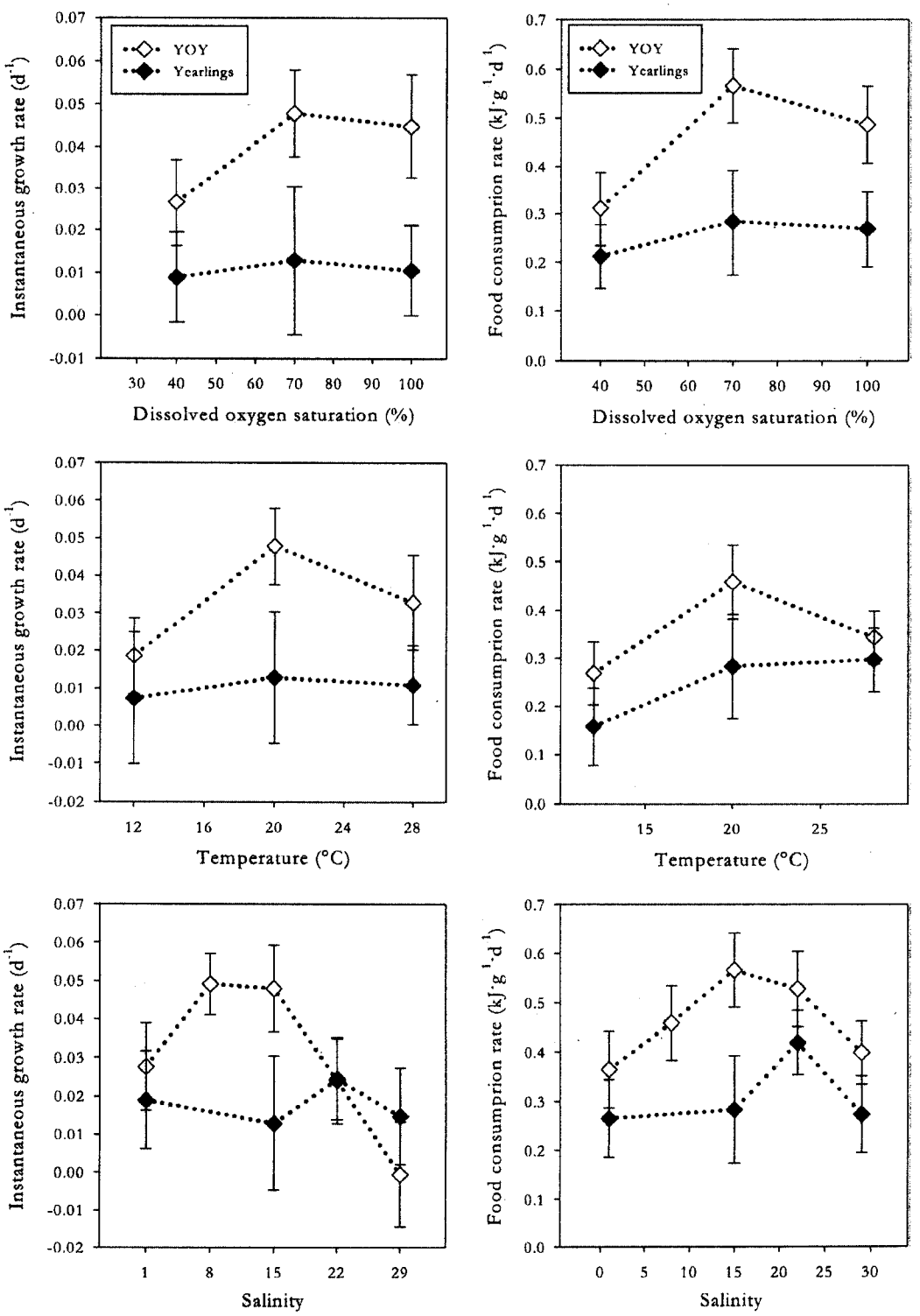

Fig. 2. Comparative effects of temperature and salinity upon instantaneous growth (left pane) and food consumption (right panel) rates in YOY (6–64 g) and yearlings (100–300 g) Atlantic sturgeon. Figures show variability caused by dissolved oxygen, temperature, and salinity (top, middle and lower panel, respectively), while keeping the remaining two factors at fixed conditions (≥70% DO_{SAT}, 20 °C, and/or salinity = 8). Means are connected by lines to facilitate interpretation.

3.2. Food consumption

Mean daily consumption rates measured in YOY showed a range between 0.3 and 0.7 kJ g^{-1} d^{-1} across all treatments (Fig. 3). Linear regression analysis indicated that food consumption was significantly affected by fish weight and by both main and quadratic components of dissolved oxygen, temperature and salinity (Table 3). After a sharp increase between 30 and 40% DO_{SAT}, food consumption continued to increase with oxygen at a smaller and rather continuous rate at 12 °C and 20 °C (Fig. 3). Although steeper DO responses were suggested by results at 28 °C, no significant interactions between explanatory variables DO and temperature were detected.

Food consumption responses to temperature showed a maximum at 20 °C for all treatments except at 100% DO_{SAT} where food consumption was similar at 20 and 28 °C (Fig. 3). Responses to salinity suggested a dome-shaped response with maximum values at intermediate salinities (8–22) and lowest values at salinity 29, the highest tested level (Fig. 3).

Analysis of food consumption responses to environmental factors by age classes showed similar patterns to those observed for growth responses. While parallel curves were observed in response to temperature and dissolved oxygen, a shift in salinity responses was suggested, where maximum consumption rates occurred at salinity 15 and 22 in YOY and yearlings, respectively (Fig. 2). This difference between age classes was only significant at the alpha = 10% level.

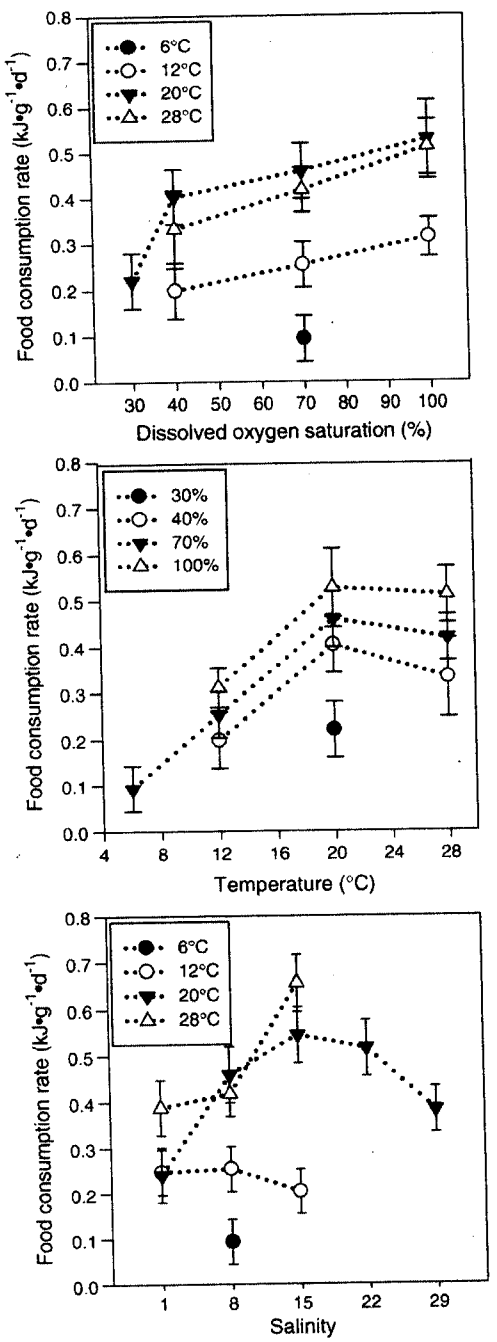

Fig. 3. Effects of dissolved oxygen saturation, temperature, and salinity on food consumption rates of YOY Atlantic sturgeon (means ± SE). Figures show variability caused by two factors at the time, while keeping the third at fixed conditions (salinity = 8 for the top and middle panels, $DO_{SAT} \geq 70\%$ for the bottom panel). Means are connected by lines to facilitate interpretation.

Table 3
Linear regression analysis of dissolved oxygen (DO), temperature (T), salinity (SAL) and individual weight (W) effects upon food consumption in juvenile Atlantic sturgeon (kJ g^{-1} d^{-1}).

Effect	Estimate ± SE	DDF	F-value	p>F
Intercept	0.63 ± 0.077	5.4	67.0	<0.001
T	0.421 ± 0.089	34.3	22.5	<0.0001
T^2	−0.367 ± 0.09	32.9	16.7	<0.001
DO_{SAT}	0.287 ± 0.077	68.2	13.7	<0.001
DO^2_{SAT}	−0.247 ± 0.076	67.7	10.6	<0.01
SAL	0.099 ± 0.035	66.0	8.1	<0.01
SAL^2	−0.094 ± 0.036	69.2	6.8	<0.05
$log_e(W)$	−0.071 ± 0.02	6.4	13.3	<0.01
$log_e(W) \cdot DO^2_{SAT}$	0.059 ± 0.083	68.3	0.5	>0.1
$log_e(W) \cdot T$	−0.079 ± 0.095	35.4	0.7	>0.1
$log_e(W) \cdot SAL^2$	0.006 ± 0.008	67.1	0.5	>0.1

Backward selection procedure on centered variables; alpha = 0.05. Results for regressors with p > 0.5 are omitted. Numerator degrees of freedom = 1; DDF = denominator degrees of freedom (Satterthwaite's approximation).

3.3. Routine and postprandial metabolism

Routine oxygen consumption was significantly affected by dissolved oxygen, temperature, salinity and fish mass ($p<0.05$; Table 4). The only significant interaction detected was a positive interaction between dissolved oxygen and temperature. Thus, although routine metabolism increased with dissolved oxygen saturation at all tested temperatures, effects were larger as temperature increased (Fig. 4).

Table 4
Linear regression analysis of dissolved oxygen (DO), temperature (T), salinity (SAL) and individual weight (W) effects upon juvenile Atlantic sturgeon routine metabolism (mg O_2 g^{-1} h^{-1}).

Effect	Estimate ± SE	DDF	F-value	p>F
T	0.100 ± 0.019	83.6	27.6	<0.0001
T^2	−0.033 ± 0.018	83.5	3.4	<0.1
DO	0.095 ± 0.032	87.6	8.7	<0.01
DO^2	−0.054 ± 0.026	88.7	4.3	<0.05
SAL	−0.023 ± 0.011	80.9	4.2	<0.05
SAL^2	0.028 ± 0.010	84.2	7.6	<0.01
DO*T	0.021 ± 0.008	90.4	6.6	<0.05
$Log_e(W)$	−0.025 ± 0.011	90.6	4.9	<0.05
$Log_e(W) \cdot DO_{SAT}$	0.132 ± 0.128	82.8	1.1	>0.1
$Log_e(W) \cdot T^2$	−0.124 ± 0.094	79.9	1.7	>0.1
$Log_e(W) \cdot T$	0.014 ± 0.019	84.4	0.5	>0.1
T·SAL	−0.011 ± 0.008	84.6	1.8	>0.1
$DO_{SAT} \cdot SAL$	−0.012 ± 0.009	88	1.6	>0.1
$Log_e(W) \cdot SAL$	0.017 ± 0.011	88	2.1	>0.1

Backward selection procedure on centered variables; alpha = 0.05. Results for regressors with p > 0.5 are omitted. Numerator degrees of freedom = 1; DDF = denominator degrees of freedom (Satterthwaite's approximation).

For instance, differences between DO_{SAT} levels were minor at 12 °C, but circa 2-fold between 40% and 70% DO_{SAT} at 28 °C (Fig. 4).

Salinity effects upon routine metabolism followed an inverse dome-shaped response, reflected in significantly negative linear and positive quadratic coefficients for this factor. Higher oxygen consumption rates were observed at the most extreme tested salinities (1 and 29), while the minimum oxygen consumption rate was measured at salinity 8. This overall pattern was consistent across temperature and DO_{SAT} tested levels (Fig. 4), with no significant interactions estimated between these factors (Table 4).

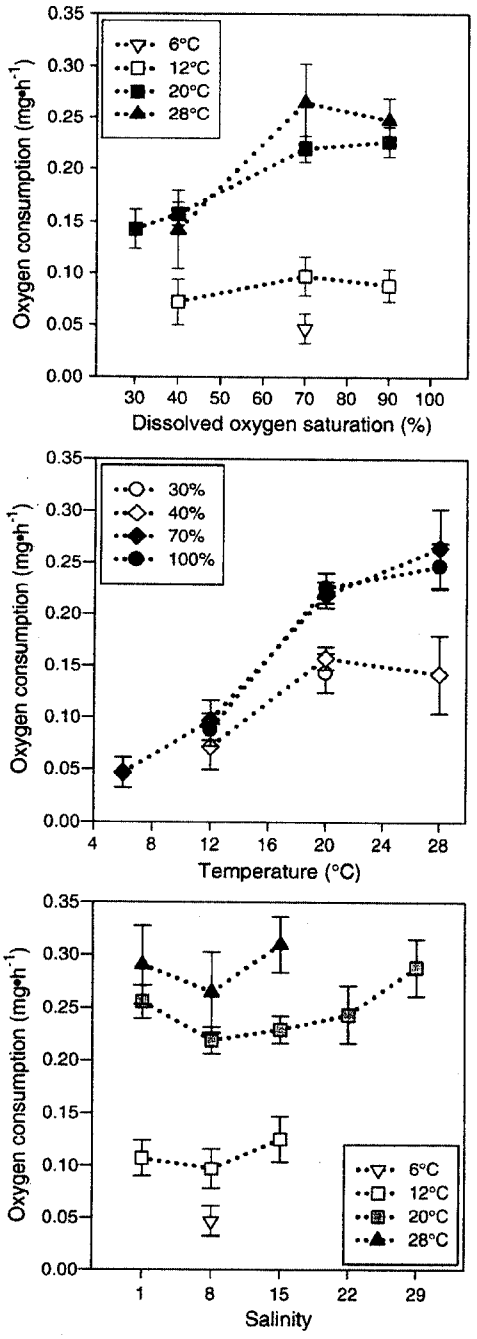

Fig. 4. Effects of dissolved oxygen saturation, temperature and salinity on routine metabolic rates of YOY Atlantic sturgeon (means ± SE). Figures show variability caused by two factors at the time, while keeping the third at fixed conditions (salinity = 8 for the top and middle panels, $DO_{SAT} \geq 70\%$ for the bottom panel). Means are connected by lines to facilitate interpretation.

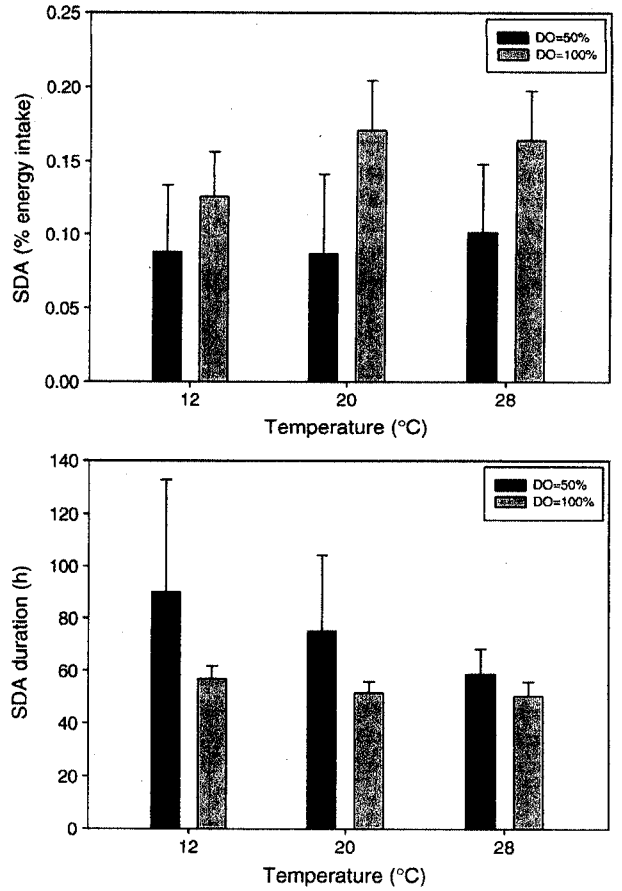

Fig. 5. Postprandial metabolism (SDA) of YOY Atlantic sturgeon at three temperatures (12, 20 and 28 °C) and two dissolved oxygen treatments: 50 and 100% DO_{SAT}. Bars represent mean SDA cost, as a proportion of energy intake (upper panel), and mean SDA duration (lower panel). Error whiskers represent standard errors in both panels.

Postprandial metabolism (SDA) ranged across treatments between 0.010 and 0.034 kJ g^{-1} $meal^{-1}$, with an average value of 0.024 kJ g^{-1} $meal^{-1}$ ± 0.0025 (SE), equivalent to 13% ± 1.3 (SE) of total energy intake. Mixed model regression analysis showed absolute SDA was affected by energy intake (ration size), temperature, DO_{SAT} and fish weight ($p<0.05$). However, when postprandial metabolism was expressed as a proportion of total energy intake ($SDA_{\%}$), only DO_{SAT} was found to have a significant and positive effect upon $SDA_{\%}$ (Fig. 5). While temperature showed a marginally positive effect ($0.05<p<0.1$), ration size and fish weight showed p-values > 0.1. Mean $SDA_{\%}$ increased from 11% ± 2.9 (SE) at 50% DO_{SAT} to 16% ± 2.3 (SE) at 100% DO_{SAT} Mean temperature effects were of similar magnitude to DO_{SAT} in the tested range, where $SDA_{\%}$ increased from 12% ± 2.6 (SE) at 12 °C to 14% ± 2.8 (SE) at 28 °C (Fig. 5).

Postprandial metabolism tended to be lower in magnitude, but longer in duration under limited oxygen saturation conditions. Duration appeared longer at lower temperatures (Fig. 5), although both DO_{SAT} linear effects and its interaction with temperature resulted in significance only at the 10% level ($p = 0.09$). As an example, at 12 °C, mean postprandial duration increased from 57 h under normoxia to 90 h under hypoxia (50% DO_{SAT}). At 28 °C, a marginal change in duration from 56 to 60 h occurred over this same change in DO_{SAT} (Fig. 5).

3.4. Egestion

Mean egestion ratio across all treatments was 18% ± 2.3 (SE) of total energy intake, being significantly affected by temperature and

dissolved oxygen and ration size ($p<0.05$). Salinity effects were not tested in this case. Egestion ratio was inversely related to temperature ($p<0.05$) and dissolved oxygen saturation ($p<0.1$), with no conclusive evidence of ration size effects (Fig. 6). Mean egestion ratio at 100% DO_{SAT} (across all temperatures) was estimated to be 11% ± 5.6 (SE) of ingested energy, which increased to 19% ± 9.6 (SE) at 50% DO_{SAT}. Mean egestion ratio at both DO_{SAT} levels decreased with temperature from 21% ± 10.6 (SE) at 12 °C to 11% ± 5.5 (SE) at 28 °C. Regression analysis detected no significant interaction between dissolved oxygen and temperature ($p>0.1$), or significant effects due to fish weight.

3.5. Survival

YOY Atlantic sturgeon survival was significantly affected by dissolved oxygen, temperature and salinity (Cox' survival analysis, $p<0.01$). While low to nil mortality was observed at 100% DO_{SAT}, regardless of the corresponding salinity or temperature treatment, it increased sharply at hypoxic conditions. At 30% DO_{SAT}, estimated mortality (0.041 d^{-1} ± 0.0090 SE) was two-fold higher than that estimated at 40% DO_{SAT}, and was 4-fold higher than that estimated at 70% DO_{SAT} (Fig. 7).

While no mortality was observed at 6 °C, mortality increased with temperature at 40 and 70% DO_{SAT} (Fig. 7). A non linear u-shaped mortality response to salinity was apparent at 20 °C and 70% DO_{SAT}, where the wider range of salinity treatments was applied (Fig. 7). Here, the lowest mortality was observed at salinity 15 (100% survival), increasing toward both extremes, particularly toward salinity 29, where it reached a maximum of 0.033 d^{-1} ± 0.0048 SE. Despite apparent interactions between dissolved oxygen, temperature and salinity, these crossed relationships were not significant under the Cox model ($p>0.1$).

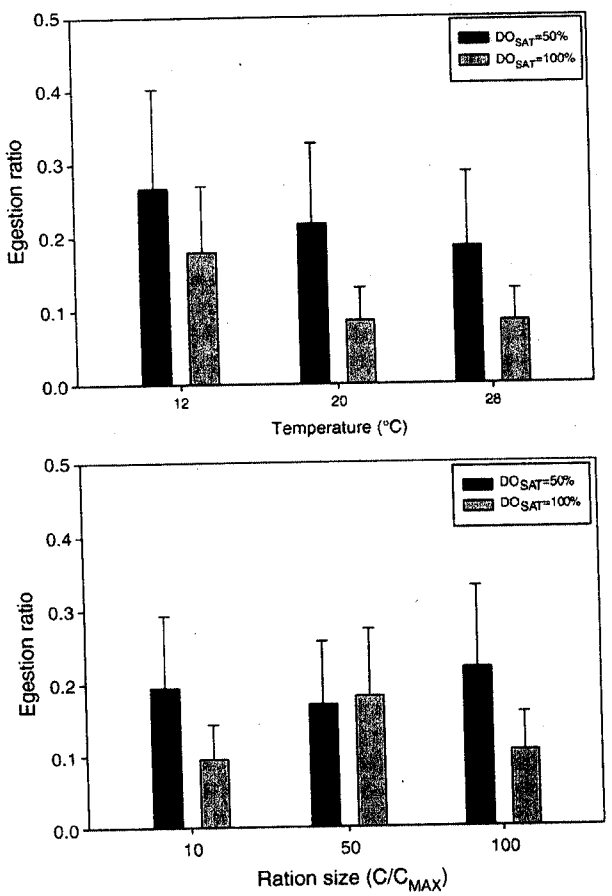

Fig. 6. Effects of temperature (upper panel) and ration size (lower panel) on egestion rates of YOY Atlantic sturgeon (mean ± SE) at 50% and 100% DO_{SAT}.

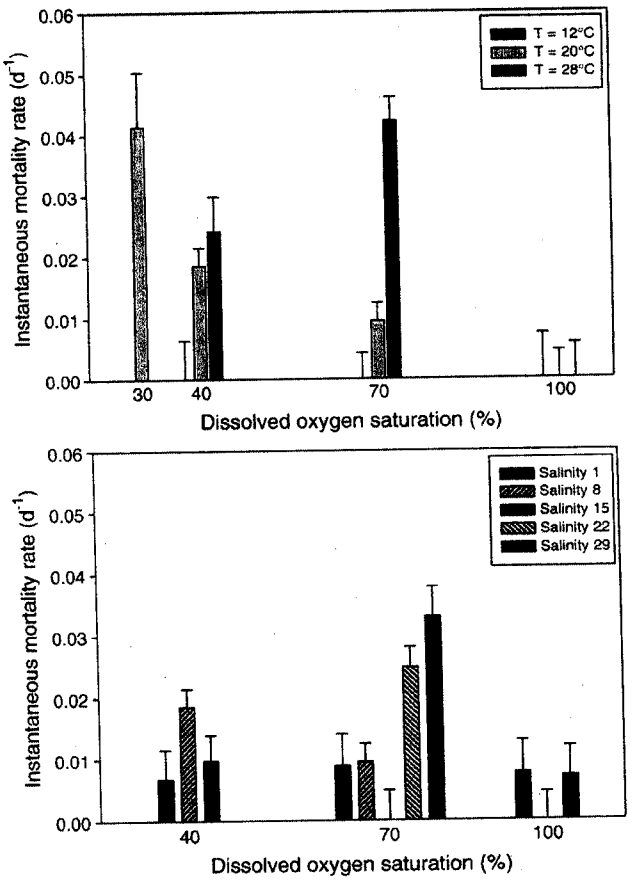

Fig. 7. Instantaneous mortality rate (d^{-1}) for YOY Atlantic sturgeon, previously acclimated to an incomplete factorial combination of dissolved oxygen saturation, temperature and salinity conditions. Upper panel shows dissolved oxygen and temperature effects at a fixed salinity of 8. Lower panel shows dissolved oxygen saturation and salinity effects at 20 °C.

4. Discussion

4.1. Sensitivity of sturgeons to hypoxia

Our results support the idea that average sensitivity of sturgeons to hypoxia is higher than in other fishes, exceeding well known oxyphyllic species, such as rainbow trout *Oncorynchus mykiss* (Klyashtorin, 1976; Secor and Niklitschek, 2002). A heightened sensitivity of sturgeons to hypoxia has been ascribed to an inefficient oxyregulatory system associated with ancestral morphological and

Table 5
Type I deviance explained by temperature (*T*), dissolved oxygen saturation (DO) and salinity (SAL) in mixed regression models for tested responses, expressed both as absolute and relative quantities.

	Type I deviance				Relative contribution			
	T	DO	SAL	*T*×DO	*T*	DO	SAL	*T*×DO
Growth	12.0	9.3	12.1	5.9	31%	24%	30%	15%
Food consumption	22.9	11.9	13.8	0	47%	25%	28%	0
Routine metabolism	94.5	29.5	10.1	4.1	68%	22%	7%	3%
Postprandial metabolism	1.7	2.9	n.t.	n.t.	37%	63%	n.t.	n.t.
Egestion	5.1	6.3	n.t.	n.t.	45%	55%	n.t.	n.t.
Survival	32.8	3.1	12.4	0	68%	6%	26%	0

Explanatory variables added following the order *T*, DO, SAL, *T*×DO; n.t. = non-tested.

physiological traits (Klyashtorin, 1976, 1982). These traits include less efficient gill ventilation, low cardiac performance (Agnisola et al., 1999), and lower affinity of hemoglobin to oxygen (Baker et al., 2005). This overall pattern of especially high sensitivity of sturgeons to hypoxia seems counterintuitive. Many sturgeon populations may have historically used shallow warm estuaries, where hypoxia occurred naturally in the deepest waters before recent anthropogenic effects (Burggren and Randall, 1978; Crocker and Cech, 1997). At the same time, this limited ability to adapt to hypoxia could explain the lack of recovery observed for sturgeon populations inhabiting heavily eutrophied estuaries along the East Coast of the United States (Collins et al., 2000).

Scarce literature has focused on estimating lethal hypoxia effects on sturgeon species. Here, we provided new information on sub-acute lethal DO levels, although we avoided short-term lethal treatments to conserve a limited supply of experimental animals and to prevent undue animal suffering. Accumulated mortality (21 d) in our experiments reached 30% under hypoxia (40% DO_{SAT}) at 20 °C (salinity = 8), increasing to nearly 50% at 28 °C. Secor and Gunderson (1998) found much higher mortality rates (>85%) under similar hypoxia levels (37%–44% DO saturation) after 10-d exposure experiments conducted at 26 °C. Different laboratory settings or source of juveniles (different Hudson River parentage) may have contributed to these differences, but they suggest that survival responses reported here may be conservative. Jenkins et al. (1993) conducted acute mortality (6 h) experiments on YOY Atlantic sturgeon and observed 86–100% mortality for 25–64 d old fish at 30% DO saturation and 22.5 °C, while older juveniles (100–310 d old) experienced only 12–20% mortality under the same conditions. The latter mortality rates are consistent with results reported here for older YOY.

4.2. Ecophysiological responses of Atlantic sturgeon to hypoxia, temperature, and salinity

Our experiments focused on multiple ecophysiological responses to hypoxia, salinity and temperature. Although interactive effects of these three variables were suggested for most responses, such interactions were only significant for growth and routine metabolism under the applied experimental design (Tables 2 and 4). Comparing the deviance explained by each of these three environmental factors across measured responses (Table 5) we observed that temperature was the most important explanatory factor for most responses, except SDA and egestion, where DO_{SAT} was the most influential factor. Dissolved oxygen and salinity explained similar proportions (24–30%) of observed variability in food consumption and growth responses. The effects of salinity upon routine metabolism were rather limited, explaining < 10% of model deviance. The much larger effects of salinity upon food consumption and growth are in agreement with the idea that salinity effects upon fish bioenergetics can exceed what would be expected due to osmoregulation costs alone (Boeuf and Payan, 2001).

The lack of an age-class effect on food consumption and growth responses to hypoxia was somewhat unexpected. We expected tolerance to sub-lethal hypoxia to increase, as mass-specific oxygen demand by metabolism decreases with size (Ishibashi et al., 2005). Although this effect could be mitigated as oxygen delivery rates also decrease with size (Pauly, 1981). Hence, observed higher tolerance of larger organisms to hypoxia in the wild might be related to the ability to escape and/or to endure unfavorable conditions for longer periods (Breitburg, 1992), rather than to a higher physiological tolerance.

The influence of hypoxia on respiration in sturgeons has received large scientific attention (e.g., Klyashtorin, 1976). The most sensitive response has been reported by Burggren and Randall (1978), where movement-restrained white sturgeon *A. transmontanus* exhibited reduced respiration at experimental DO_{SAT} conditions <90% (8.1 mg l^{-1}, 18 °C). At the other extreme, Nonnotte et al. (1993) observed that Siberian sturgeon *A. baeri* maintained standard metabolism down to 25% DO_{SAT} (2.4 mg l^{-1}) at 15 °C. The effects of DO_{SAT} on Atlantic sturgeon that we observed were intermediate to these previous studies, and highly temperature-dependent. We observed similar metabolic rates at 70 and 100% DO_{SAT}, followed by a strong reduction in routine metabolism when dissolved oxygen saturation was lowered from 70% to 40%. Such saturation values are equivalent to DO concentrations of 5.24 and 2.99 mg l^{-1}, respectively, at 28 °C and salinity 8. Milder responses to low DO_{SAT} were observed as temperature decreased to 20 °C and, then, to 12 °C (Fig. 4). Beyond possible species-specific differences (Taylor et al., 1999), discrepancy among previous results could be related to routine metabolism being more responsive to hypoxia than standard metabolism. In fact, a reduction in locomotor activity might be a primary reaction to hypoxia (Nilsson et al., 1993; Crocker and Cech, 1997; Taylor et al., 1999).

We found hypoxia effects were also evident for egestion and postprandial metabolism, which actually showed much larger relative responses to hypoxia than food consumption and routine metabolism. The average egestion ratio we estimated (18% ± 2.3 SE of the energy intake) was somewhat lower than egestion levels reported for teleosts, which average 20% (Brett and Groves, 1979), but higher than the 15% assumed for white sturgeon by Bevelhimer (2002). Although our results might be biased by the use of commercial food pellets, the estimate for mean egestion ratio at normoxia (11%) was quite close to equivalent egestion ratios found in other Acipenserids fed natural food (Dawrowski et al., 1987; Gershanovich and Pototskij, 1992; Cui et al., 1996). High assimilation efficiency (and low egestion rates) might be expected in sturgeons due to the high absorptive surface provided by the presence of the spiral valve in the intestine (Buddington and Christofferson, 1985).

While egestion ratio increased ca. 2-fold, postprandial metabolism decreased by half under hypoxia. These results are consistent with recent findings in cod (Jordan and Steffensen, 2007), and support the idea that fish reduce not only food consumption, but also assimilation rate when metabolic scope is limited by hypoxia (Jobling, 1981; Pauly, 1981). In this way, sturgeons might avoid toxic concentrations of unstable amino acids accumulating in the blood when catabolism is limited (van Dam and Pauly, 1995). It is not clear how fishes might reduce assimilation rates under hypoxia, but it has been hypothesized that fish might increase egestion by reducing irrigation of absorptive intestinal tissues (Brett, 1979; Jobling, 1981).

4.3. Size and age responses to salinity and temperature

We observed a size (and age) dependent shift in growth and food consumption responses to salinity, reaching maximum rates at higher salinities for yearlings (salinity = 22) than for YOY (salinity = 15) Atlantic sturgeon. This shift is consistent with their life cycle and also with physiological expectations from fish allometric growth. In terms of their life cycle, YOY Atlantic sturgeon are restricted to upstream estuarine sections and do not migrate to more coastal saline waters until their second year or later (Secor et al., 2000). The change of influence of salinity with size is consistent with what Fry (1971) termed a directive factor: an ontogenetic physiological adaptation well known in smoltification or anadromous salmons. Alternatively, it could reflect the reduction of the exposed gill surface area relative to body biomass (Pauly, 1981). Using similar isometric considerations, a larger body biomass might increase thermo-regulatory capabilities in larger sturgeons dampening their responsiveness to temperature. Although this was not evident in our results, an increase temperature tolerance in larger fish has been found in walleye *Stizostedion vitreum* and mullet *Liza aurata* (Shekk et al., 1990; Clapp et al., 1997).

4.4. Defining hypoxia thresholds for juvenile Atlantic sturgeon and other estuarine fishes

The additive and interactive effects we found for DO, temperature and salinity should have major consequences for juvenile Atlantic

sturgeon in the wild. In historical nursery areas, such as the Chesapeake Bay and other U.S. southeastern estuaries, high temperatures coincide with hypoxia every summer (Collins et al., 2000; Niklitschek and Secor, 2005). Under this scenario the limiting effects of hypoxia would reduce physiological scopes to a point where the relative importance of salinity effects becomes critical. For instance, in Virginia estuaries that support juvenile Atlantic sturgeon, summer temperatures become super-optimal in freshwater, but brackish oligohaline bottom waters are often hypoxic (<40% DO_{sat}). A potential refuge from sub-lethal conditions of high temperature and hypoxia exists in the lower Chesapeake Bay (due to marine influence), which is normoxic and cooler, but here salinity is super-optimal (Niklitschek and Secor, 2005). Hence a three-way "habitat squeeze" (sensu Coutant, 1987) can be envisaged, which could be further reduced by anthropogenic perturbations such us pollution, freshwater flow reductions and global warming (Niklitschek and Secor, 2005).

Our results show the importance of considering temperature and salinity as relevant covariates for hypoxia criteria definitions: considering both their effects upon physiological rates and upon oxygen solubility in water and blood (Holeton and Randall, 1967). For illustration purposes, if optimal growth or survival rates were used as criteria to set a hypoxia threshold for juvenile Atlantic sturgeon, that value would rise from 40 to 70% DO_{SAT} if temperature increased from 12 to 20 °C. At salinity 1 these values would correspond to concentrations of 4.3 and 6.3 mg l^{-1}, respectively. At salinity 29, on the other hand, the same thresholds would correspond to concentrations of 3.6 and 5.4 mg l^{-1}, respectively. At this point, it must be emphasized that "percent DO saturation" or "partial pressure of DO" are the biologically relevant factors for hypoxia, since these, rather than oxygen concentration, represent what physically determines fish oxygen uptake from the surrounding water (Cech, 1990; Kiceniuk and Colbourne, 1997).

Hypoxia has been frequently defined by fixed oxygen criteria, commonly at either 2 ml l^{-1} or 2 mg l^{-1} (Diaz and Rosenberg, 1995; Diaz, 2001; Wu, 2002; US-EPA, 2003). A broader operational definition considers hypoxia as any oxygen concentration reduced from full saturation that impairs living (US-EPA, 2003). To expand this definition further, we propose to define hypoxia as any oxygen concentration reduced from full saturation that produces measurable negative effects upon physiological and survival rates of a given species. Under this conceptual approach, hypoxia thresholds should be species-specific (Klyashtorin, 1976; Goodman and Campbell, 2007), and incorporate those significant environmental and biological covariates known to affect fish responses to hypoxia. In a companion paper (Niklitschek and Secor, 2009-this issue), we develop and test a model that can generate predictions of ecophysiological response based upon multiple environmental and biological variables.

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References

Agnisola, C., McKenzie, D.J., Pellegrino, D., Bronzi, P., Tota, B., Taylor, E.W., 1999. Cardiovascular responses to hypoxia in the Adriatic sturgeon (*Acipenser nacarii*). J. Appl. Ichthyol. 15, 67–72.

Allison, P.D., 1995. Survival analysis using the SAS system: a practical guide. SAS Institute, Inc., Cary, NC.

ASMFC, 1998. Review of the Atlantic States Marine Fisheries Commission Fishery Management Plan for Atlantic sturgeon (*Acipenser oxyrhynchus*. Atlantic States Marine Fisheries Commission (ASMFC, Washington, D.C.

Atlantic Sturgeon Status Review Team, 2007. Status Review of Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*). Report to National Marine Fisheries Service, Northeast Regional Office, Gloucester, MA (USA).

Baker, D.W., Wood, A.M., Kieffer, J.D., 2005. Juvenile Atlantic and shortnose sturgeons (family: Acipenseridae) have different hematological responses to acute environmental hypoxia. Physiol. Biochem. Zool. 78, 916–925.

Bevelhimer, M.S., 2002. A bioenergetics model for white sturgeon *Acipenser transmontanus*: assessing differences in growth and reproduction among Snake River reaches. J. Appl. Ichthyol. 18, 550–556.

Boeuf, G., Payan, P., 2001. How should salinity influence fish growth? Comp. Biochem. Physiol., C 130, 411–423.

Brandt, S.B., 1993. Effects of thermal fronts on fish growth: a bioenergetics evaluation of food and temperature. Estuaries 16, 142–159.

Breitburg, D.L., 1992. Episodic hypoxia in Chesapeake Bay — interacting effects of recruitment, behavior, and physical disturbance. Ecol. Monogr. 62, 525–546.

Breitburg, D.L., Rose, K.A., Cowan, J.H., 1999. Linking water quality to larval survival: predation mortality of fish larvae in an oxygen-stratified water column. Mar. Ecol. Prog. Ser. 178, 39–54.

Brett, J.R., 1979. Environmental factors and growth. In: Hoar, W.S., Randall, D.J., Brett, J.R. (Eds.), Fish Physiology. Academic Press, New York, pp. 599–675.

Brett, J.R., Groves, T.D.D., 1979. Physiological energetics. In: Hoar, W.S., Randall, D.J., Brett, J.R. (Eds.), Fish Physiology. Academic Press, New York, pp. 279–352.

Buddington, R.K., Christofferson, J.P., 1985. Digestive and feeding characteristics of the chondrosteans. Env. Biol. Fishes. 14, 31–41.

Burggren, W.W., Randall, D.J., 1978. Oxygen uptake and transport during hypoxic exposure in the sturgeon *Acipenser transmontanus*. Resp. Physiol. 34, 171–183.

Cech Jr., J.J., 1990. Respirometry. In: Schreck, C.B., Moyle, P.B. (Eds.), Methods for Fish Biology: Amer. Fish. Soc., Bethesda, MD., pp. 335–356.

Cech Jr., J.J., Mitchell, S.J., Wragg, T.E., 1984. Comparative growth of juvenile white sturgeon and striped bass: effects of temperature and hypoxia. Estuaries 7, 12–18.

Claireaux, G., Lagardere, J.P., 1999. Influence of temperature, oxygen and salinity on the metabolism of the European sea bass. J. Sea. Res. 42, 157–168.

Clapp, D.F., Bhagwat, Y., Wahl, D.H., 1997. The effect of thermal stress on walleye fry and fingerling mortality. N. Am. J. Fish. Manage. 17, 429–437.

Collins, M.R., Rogers, S.G., Smith, T.I.J., Moser, M.L., 2000. Primary factors affecting sturgeon populations in the Southeastern United States: fishing mortality and degradation of essential habitats. Bull. Mar. Sci. 66, 917–928.

Cooper, S.R., Brush, G.S., 1991a. A 2, 500-year history of anoxia and eutrophication in the Chesapeake Bay. Estuaries 16, 617–626.

Cooper, S.R., Brush, G.S., 1991b. Long-term History of Chesapeake Bay Anoxia. Science (Wash., D.C.) 254, 992–996.

Coutant, C.C., 1987. Thermal preference: when does an asset become a liability? Env. Biol. Fishes 18, 161–172.

Crocker, C.E., Cech, J.J., 1997. Effects of environmental hypoxia on oxygen consumption rate and swimming activity in juvenile white sturgeon, *Acipenser transmontanus*, in relation to temperature and life intervals. Env. Biol. Fishes 50, 383–389.

Cui, Y.B., Hung, S.S.O., Zhu, X., 1996. Effect of ration and body size on the energy budget of juvenile white sturgeon. J. Fish. Biol. 49, 863–876.

Dawrowski, K., Kaushik, S.J., Fauconneau, B., 1987. Rearing of sturgeon (*Acipenser baeri* Brandt) larvae. 3. Nitrogen and energy metabolism and amino acid absorption. Aquaculture 65, 31–41.

Diaz, R.J., 2001. Overview of hypoxia around the world. J. Environ. Qual. 30, 275–281.

Diaz, R.J., Rosenberg, R., 1995. Marine benthic hypoxia: a review of its ecological effects and the behavioural responses of benthic macrofauna. Oceanogr. Mar. Biol. Annu. Rev. 33, 245–303.

Evermann, B.W., Bean, B.A., 1898. Indian River and its fishes. Rep. U.S. Comm. Fish 1896, 227–248.

Fry, F.E.J., 1971. The effect of environmental factors on the physiology of fish. In: Hoar, W.S., Randall, D.J. (Eds.), Fish Physiology. Academic Press, New York, pp. 1–98.

Gershanovich, A.D., Pototskij, I.V., 1992. The peculiarities of nitrogen excretion in sturgeons (*Acipenser ruthenus*) (Pisces, Acipenseridae)-I. The influence of ration size. Comp. Biochem. Physiol. 103A, 609–612.

Goodman, L.R., Campbell, J.G., 2007. Lethal levels of hypoxia for Gulf Coast estuarine animals. Mar. Biol. 152, 37–42.

Hinkelmann, K., Kempthorne, O., 2005. Design and Analysis of Experiments, Volume 2: Advanced Experimental Design. Wiley, New York, NY (USA).

Holeton, G.F., Randall, D.J., 1967. The effect of hypoxia upon the partial pressure of gases in the blood and water afferent and efferent to the gills of rainbow trout. J. Exp. Biol. 46, 317–327.

Ishibashi, Y., Inoue, K., Nakatsukasa, H., Ishitani, Y., Miyashita, S., Murata, O., 2005. Ontogeny of tolerance to hypoxia and oxygen consumption of larval and juvenile red sea bream, *Pagrus major*. Aquaculture 244, 331–340.

Jenkins, W.E., Smith, T.I.J., Heyward, L.D., Knott, D.M., 1993. Tolerance of shortnose sturgeon, *Acipenser brevirostrum*, juveniles to different salinity and dissolved oxygen concentrations. Proc. Annu. Conf. South Eastern Assoc. Fish and Wildlife Agencies.

Jobling, M., 1981. The influences of feeding on the metabolic rate of fishes: a short review. J. Fish Biol. 18, 385–400.

Jordan, A.D., Steffensen, J.F., 2007. Effects of ration size and hypoxia on specific dynamic action in the cod. Physiol. Biochem. Zool. 80, 178–185.

Kiceniuk, J.W., Colbourne, E., 1997. Relating oxygen levels in the Newfoundland offshore waters to the physiology of Atlantic cod (*Gadus morhua*). Can. J. Fish. Aquat. Sci. 54 (Suppl. 1), 81–87.

Klyashtorin, L.B., 1976. The sensitivity of young sturgeons to oxygen deficiency. J. Ichthyol. 16, 677–682.
Klyashtorin, L.B., 1982. The ability of sturgeons (*Acipenseridae*) to regulate gas exchange. J. Ichthyol. 21.
Landman, M.J., Van Den Heuvel, M.R., Ling, N., 2005. Relative sensitivities of common freshwater fish and invertebrates to acute hypoxia. N.Z. J. Mar. Freshw. 39, 1061–1067.
Leim, A.H., Day, L.R., 1959. Records of uncommon and unusual fishes from eastern Canadian waters, 1950–1958. J. Fish. Res. Board Can. 16, 503–514.
Maciolek, J.A., 1962. Limnological Organic Analyses by Quantitative Dichromate Oxidation. United States Department of the Interior, Fish and Wildlife Service.
Marcus, N.H., Richmond, C., Sedlacek, C., Miller, G.A., Oppert, C., 2004. Impact of hypoxia on the survival, egg production and population dynamics of *Acartia tonsa* Dana. J. Exp. Mar. Biol. Ecol. 301, 111–128.
Mead, R., 1988. The Design of Experiments: Statistical Principles for Practical Applications. Cambridge University Press, Melbourne, Australia.
Miller, D.C., Poucher, S.L., Coiro, L., 2002. Determination of lethal dissolved oxygen levels for selected marine and estuarine fishes, crustaceans, and a bivalve. Mar. Biol. 140, 287–296.
Mohler, J.W., 2000. Early culture of the American Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus* Mitchill, 1815 and preliminary stocking trials. Bol. Inst. Esp. Oceanogr. 16, 203–208.
Najjar, R.G., Walker, H.A., Anderson, P.J., Barron, E.J., Bord, R.J., Gibson, J.R., Kennedy, V.S., Knight, C.G., Megonigal, J.P., O'Connor, R.E., Polsky, C.D., Psuty, N.P., Richards, B.A., Sorenson, L.G., Steele, E.M., Swanson, R.S., 2000. The potential impacts of climate change on the mid-Atlantic coastal region. Clim. Res. 14, 219–233.
Niklitschek, J.E., 2001. Bioenergetics modeling and assessment of suitable habitat for juvenile Atlantic and shortnose sturgeons (*Acipenser oxyrinchus* and *A. brevirostrum*) in the Chesapeake Bay. Dissertation. University of Maryland at College Park, Marine Estuarine Environmental Science Program. College Park, MD. 262 pp.
Niklitschek, E., Secor, D.H., 2005. Modeling spatial and temporal variation of suitable nursery habitats for Atlantic sturgeon in the Chesapeake Bay. Est. Coast Shelf Sci. 64, 135–148.
Niklitschek, E., Secor, D.H., 2009. Dissolved oxygen, temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon in estuarine waters: II. Model development and testing. J. Exp. Mar. Biol. Ecol. 381, S161–S172 (this issue).
Nilsson, G.E., Rosen, P., Johannson, D., 1993. Anoxic depression of spontaneous locomotor activity in crucian carp quantified by a computarized imaging technique. J. Exp. Biol. 180, 153–162.
Nonnotte, G., Maxime, V., Truchot, J.P., Williot, P., Peyraud, C., 1993. Respiratory responses to progressive ambient hypoxia in the sturgeon, *Acipenser baeri*. Resp. Physiol. 91, 71–82.
Officer, C.B., Biggs, R.B., Taft, J.L., Cronin, L.E., Tyler, M.A., Boynton, W.R., 1984. Chesapeake Bay Anoxia: Origin, development, and Significance. Science (Wash., D.C.) 223, 22–27.
Pauly, D., 1981. The relationship between gill surface area and growth performance in fish: a generalization of von Bertanffy's theory of growth. Meereforsch 28, 251–282.
Pichavant, K., Le Ruyet, J.P., Le Bayon, N., Severe, A., Le Roux, A., Boeuf, G., 2001. Comparative effects of long-term hypoxia on growth, feeding and oxygen consumption in juvenile turbot and European sea bass. J. Fish Biol. 59, 875–883.
Plante, S., Chabot, D., Dutil, J.D., 1998. Hypoxia tolerance in Atlantic cod. J. Fish Biol. 53, 1342–1356.
Preston, B.L., 2004. Observed winter warming of the Chesapeake Bay estuary (1949–2002): implications for ecosystem management. Environ. Manage. 34, 125–139.
SAS-Institute, 1997. Changes and Enhancements Through Release 6.12. SAS Institute Inc, Cary, NC.
Scholz, U., Waller, U., 1992. The oxygen requirements of 3 fish species from the German bight — cod *Gadus-Morhua*, plaice *Pleuronectes-Platessa*, and dab *Limanda-Limanda*. J. Appl. Ichthyol. 8, 72–76.
Secor, D.H., Gunderson, T.E., 1998. Effects of hypoxia and temperature on survival, growth, and respiration of juvenile Atlantic sturgeon *Acipenser oxyrinchus*. Fish. Bull. 96, 603–613.
Secor, D.H., Niklitschek, J.E., 2002. Sensitivity of sturgeons to environmental hypoxia: physiological and ecological evidence. Fish Physiology, Toxicology, and Water Quality, Sixth International Symposium: Environmental Protection Agency Office of Research and Development, Ecosystems Research Division, Athens, Georgia., La Paz, Mexico, pp. 61–78.
Secor, D.H., Niklitschek, E., Stevenson, J.T., Gunderson, T.E., Minkkinnen, S., Florence, B., Mangold, M., Skjeveland, J., Henderson-Arzapalo, A., 2000. Dispersal and growth of yearling Atlantic sturgeon *Acipenser oxyrinchus* released into the Chesapeake Bay. Fish. Bull. 98, 800–810.
Secor, D.H., Waldman, J.R., 1999. Historical abundance of Delaware Bay Atlantic sturgeon and potential rate of recovery. Am. Fish. Soc. Symp. 23, 203–216.
Shekk, P.B., Kuliova, N.I., Rudenko, V.I., 1990. Age-dependent changes in the reaction of the Black sea mullet, *Liza aurata*, to low temperature. J. Ichthyol. 30, 94–106.
Shimps, E.L., Rice, J.A., Osborne, J.A., 2005. Hypoxia tolerance in two juvenile estuary-dependent fishes. J. Exp. Mar. Biol. Ecol. 325, 146–162.
Stierhoff, K.L., Targett, T.E., Miller, K., 2006. Ecophysiological responses of juvenile summer and winter flounder to hypoxia: experimental and modeling analyses of effects on estuarine nursery quality. Mar. Ecol. Prog. Ser. 325, 255–266.
Susanto, G.N., Peterson, M.S., 1996. Survival, osmoregulation and oxygen consumption of YOY coastal largemouth bass, *Micropterus salmoides* (Lacepede) exposed to saline media. Hydrobiologia 323, 119–127.
Taylor, E.W., McKenzie, D.J., Whiteley, N.M., Bronzi, P., 1999. Cardiovascular and respiratory physiology of sturgeon. J. Appl. Ichthyol. 15, 295–296.
Thornton, K.W., Lessem, A.S., 1978. A temperature algorithm for modifying biological rates. Trans. Am. Fish. Soc. 107, 284–287.
US-EPA, 2003. Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll *a* for the Chesapeake Bay and its Tidal Tributaries. US-EPA, Chesapeake Bay Program Office, Annapolis, Maryland.
van Dam, A.A., Pauly, D., 1995. Simulation of the effects of oxygen on food consumption and growth of nile tilapia, *Oreochromis niloticus* (L.). Aquac. Res. 26, 427–440.
Vladykov, V.D., Greeley, J.R., 1963. Order Acipenseroidei. Fishes of the Western North Atlantic. Part III. In: Memoirs of the Sears Foundation for Marine Research, 1. Yale University, pp. 24–60.
Wu, R.S.S., 2002. Hypoxia: from molecular responses to ecosystem responses. Mar. Pollut. Bull. 45, 35–45.
Yamashita, Y., Tanaka, M., Miller, J.M., 2001. Ecophysiology of juvenile flatfish in nursery grounds. J. Sea Res. 45, 205–218.

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Dissolved oxygen, temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon in estuarine waters: II. Model development and testing

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ABSTRACT

Hypoxia–temperature interactions can have major effects upon fish physiology and energetics. In estuarine species, such effects can be also modified by natural salinity gradients leading to a three-way habitat contraction under extreme conditions. In this paper we use Fry's paradigm to propose an explanatory framework and to expand traditional mass balance bioenergetic models, incorporating dissolved oxygen and salinity effects. Water temperature was modeled as the controlling factor that establishes maximum potential rates and minimum oxygen demand; dissolved oxygen was considered to constrain physiological responses whenever oxygen demands exceed oxygen delivery rates; salinity was incorporated as a masking (loading) factor, demanding both energy and oxygen for osmoregulation processes. This general framework was expressed as a set of algorithms, with a total of 30 parameters, which were estimated using results from a large set of laboratory experiments conducted on young-of-the-year and yearling Atlantic sturgeons, as well as from other published studies. Compared to an empirical quadratic fit of these laboratory data, the model was more informative (lower AIC), suggesting that measured responses followed theoretical expectations. The model was tested in mesocosm trials, where strong correlations were observed between predicted and observed monthly and seasonal growth rates but modest to poor correlations were observed for predicted daily instantaneous growth rate. Sensitivity tests showed that uncertainty in activity cost and food consumption ratio parameters contributed most to model error.

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1. Introduction

Dissolved oxygen, temperature and salinity are key environmental factors affecting most physiological and many ecological responses in estuarine species. A relevant fraction of such effects can be generalized in the form of single bioenergetic responses or integrated bioenergetic models describing energy flow within individuals (Brett, 1979). Further, bioenergetics has been intimately linked with population dynamics and fitness by considering the ratio of instantaneous mortality over growth ($\mu\ G^{-1}$) as an integral that can relate habitat to cohort production (Werner et al., 1983; MacCall, 1989; Heath, 1996; Houde, 1997; Secor, 1999). As a result, bioenergetic models, largely based upon Winberg's (1956) energy balance equation, have been shown to be useful tools for testing ecological hypotheses (Kitchell and Breck, 1980; Stewart et al., 1981; Brandt, 1993; Hartman and Brandt, 1995b; Kitchell et al., 1997; Essington et al., 2002), indexing habitat quality (Brandt and Kirsch, 1993; Mason et al., 1995; Hondorp and Brandt, 1996) and fisheries management (Johnson et al., 1992; Hansen et al., 1993; Luo et al., 2001). In more recent years, bioenergetic approaches have also been used for reconstructing and forecasting the effects of environmental stressors such as hypoxia and climate change on fishes (Niklitschek and Secor, 2005; Woodland et al., 2009).

Largely influenced by freshwater species investigations (Kitchell et al., 1974, 1977; Stewart et al., 1981) and available software (Hewett and Johnson, 1992; Hanson et al., 1997), most published bioenergetic models have focused on forage and temperature as key environmental factors (Bosclair and Sirois, 1993; Hansen et al., 1993; Hartman and Brandt, 1995a; Bevelhimer, 2002). Although other factors such as dissolved oxygen and salinity are well known to play key roles in the bioenergetics of estuarine species (Lankford and Targett, 1994; Neill et al., 1994; Luo et al., 2001; McKenzie et al., 2001; Wuenschel et al., 2004a,b; Stierhoff et al., 2006; Del Toro-Silva et al., 2008), limited advances have been made in extending such models to incorporate additional environmental factors. A noticeable exception is the Ecophys.Fish model, which contains a set of empirical relationships that incorporate temperature, salinity, dissolved oxygen (DO), pH and food effects into a mass balance model suitable for estuarine fishes (Neill et al., 2004). Parallel efforts made in this direction have included Niklitschek's (2001) and Wuenschel's (2002) dissertation work, both of which are unpublished thus far.

In the present work we provide model development and testing for a theory-based bioenergetic model developed by Niklitschek (2001),

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which was subsequently applied in studies of sturgeon nursery habitat suitability by Niklitschek and Secor (2005) and Woodland et al. (2009). Here, we specify an underlying theoretical basis for the inclusion of DO and salinity in bioenergetic models and develop predictive equations that may have general use for estuarine fishes, but focus in applying this model to juvenile Atlantic sturgeon *Acipenser oxyrinchus*. This species was chosen because of its known sensitivity to the interactions of DO, temperature and salinity, and because hypoxia has been identified as a principal factor limiting the recovery of this threatened species (Secor and Gunderson, 1998; Collins et al., 2000). Model parameters for juvenile Atlantic sturgeon were estimated using laboratory measured responses, reported in a companion paper (Niklitschek and Secor, 2009-this issue). We contrasted the goodness of fit in our model against a purely empirical fit using a multinomial regression model, and evaluated model sensitivity to uncertainty in parameter estimation. Finally, we conducted an independent test of the model against a new data set obtained from a 4-mo mesocosm study.

2. Methods

2.1. Model framework

Our overall modeling approach was based upon a balanced energy equation (Winberg, 1956; Kitchell et al., 1977), constrained by aerobic scope and described by the general form,

$$G = \mathrm{FC} - (\mathrm{RM} + \mathrm{SDA} + \mathrm{ACT}) - (\mathrm{EG} + U) \quad (1)$$

where, G = growth, FC = food consumption, RM = routine metabolism, ACT = activity cost, SDA = postprandial metabolism (classically named specific dynamic action), EG = egestion, and U = excretion. Dissolved oxygen, temperature and salinity effects upon bioenergetic components from Eq. (1) were modeled using the conceptual framework proposed by Fry (1971), which classifies environmental factors in five categories: controlling, limiting, masking, lethal and directive factors. Controlling factors (e.g., temperature, pH) set the potential rate of biochemical reactions. Limiting factors are resources (e.g., oxygen, ration) that, when insufficient, restrict such reaction rates. Masking factors (i.e., salinity) impose additional energy expenditures that increase standard metabolism. Lethal factors (e.g., severe hypoxia, toxins) induce short-term animal death. Finally, directive factors (e.g., photoperiod) guide fish behavior or induce physiological changes. Below we describe the theoretical framework of the bioenergetic model. Details of actual model construction are given in Appendix S1.

Following Fry's (1971) paradigm and traditional bioenergetic models (Hanson et al., 1997), we incorporated temperature as the main controlling factor, which determines the maximum rates for food consumption, routine metabolism and egestion. Through these direct effects upon predicted FC, RM and EG, temperature also affects activity cost, postprandial metabolism and excretion rates, which were modeled to be proportional to one or more of the first three components (FC, RM, EG). Temperature effects upon food consumption and routine metabolism reaction rates were modeled using Thornton and Lessem's (1978) algorithm, while its effects upon egestion rate were included into a modified version of Elliot's (1976) equation (see Appendix S1).

We included dissolved oxygen as a limiting factor that sets an upper limit for total metabolism under hypoxia. Although anaerobic responses to hypoxia are feasible as immediate short-term responses, such responses are not sustainable if total oxygen demand (OD) due to metabolic processes (RM, ACT and SDA) exceeds the maximum oxygen delivery rate (DO_{IN}). This assumption implies the inequality,

$$\mathrm{RM_{OD}} + \mathrm{ACT_{OD}} + \mathrm{SDA_{OD}} \leq \mathrm{DO_{IN}}. \quad (2)$$

Given Eq. (2), we assumed that, under limited oxygen supply, basal metabolism required to sustain vital processes is prioritized over all remaining energy/oxygen expenditures. Thus, the aerobic scope (AS) available for activity and growth corresponds to the difference between potential (maximum) oxygen delivery rate (DO_{IN}) and basal metabolic oxygen demand, which can be approximated by routine metabolic oxygen demand (RM_{OD}) for practical purposes (Fig. 1). This concept of aerobic scope is closely related, although not fully equivalent, to the concept of metabolic scope, which is defined as the difference between maximum (active) metabolic and basal metabolic rates (Fry, 1971; see also Neill et al., 2004). When maximum metabolism becomes limited by oxygen delivery rate, both quantities (aerobic scope and metabolic scope) become directly proportional to each other.

From previous considerations, we forecast strong interactions between dissolved oxygen, temperature and salinity effects upon aerobic scope. While dissolved oxygen saturation limits potential oxygen delivery rate (DO_{IN}), temperature controls baseline oxygen demand (RM_{OD}), which is loaded by the extra cost of osmoregulation imposed by the corresponding salinity level. Under moderate hypoxia, aerobic scope decreases and TM_OD might exceed DO_IN (Fig. 1). Here, ACT and SDA are necessarily diminished, while RM might remain unaffected. Below critical DO levels, RM will also be reduced, first by lowering spontaneous activity (Crocker and Cech, 1997), and then by initiating anaerobic production of ATP to sustain vital processes such as ion equilibrium and membrane polarity, until acidosis reached lethal levels (Nilsson and Östlund-Nilsson, 2008).

To model hypoxia effects upon RM and FC reaction rates, we constructed a simple mathematical expression (Appendix S1, Fig. 2), defined by two biologically relevant points: the critical DO threshold (DOC) at which decreasing DO_{SAT} starts to affect RM or FC, and the reaction rate at the lowest tested DO_{SAT} level (KO1). Both points were modeled to be functions of metabolic oxygen demand, as detailed in Appendix S1. Postprandial metabolism (SDA) was modeled as a constant proportion of assimilated energy (and nutrients), which decreases under hypoxia due to both curtailed food consumption (FC) and increased egestion rates (EG) (Appendix S1). Such proportionality results from presumed feedback regulation mechanisms connecting aerobic scope, metabolism, stomach fullness, intestinal irrigation and food consumption (Jobling, 1981). Under hypoxia, a limiting aerobic scope would reduce anabolism and intestinal irrigation, therefore curtailing intestinal absorption and SDA, while increasing the egested fraction of consumed food. As a result, appetite, food intake and assimilation rates would be also reduced, maintaining

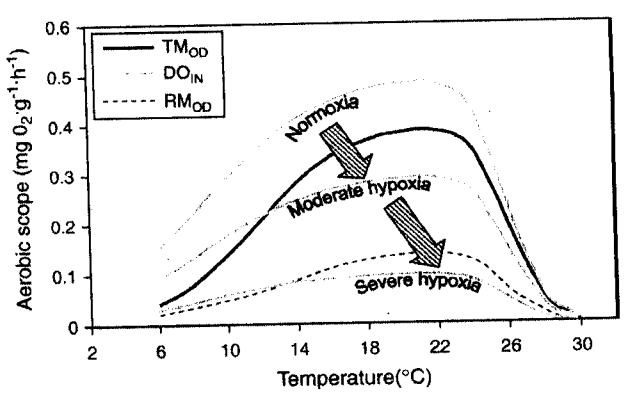

Fig. 1. Aerobic scope (mg O_2 g^{-1} h^{-1}) for growth and activity under three scenarios (long-term responses). Under normoxia, maximum oxygen delivery rate (DO_{IN}) exceeds total metabolism oxygen demand (TM_{OD}); thus total metabolism reaches its full potential in response to directive and masking factors. At moderate hypoxia, total metabolism becomes limited by DO_{IN}, and locomotory activity and/or growth rates are reduced, although routine metabolism oxygen demand (RM_{OD}) is still satisfied. Below critical DO level, routine metabolism is limited by hypoxia and vital functions cannot be sustained.

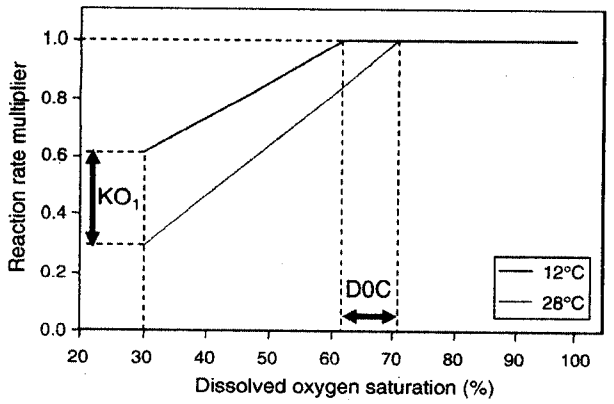

Fig. 2. Schematic representation of modeled routine metabolism and food consumption responses to dissolved oxygen saturation. KO_1 represents reaction rate at the minimum tested DO_{SAT} level, while DOC represents the lower DO_{SAT} threshold at which reaction rate becomes independent from DO_{SAT}. Although both KO_1 and DOC were modeled as functions of temperature and salinity, only temperature effects are represented in this diagram.

amino acid and free radical concentrations in the blood below toxic levels (Jobling, 1981; van Dam and Pauly, 1995).

As a second addition to traditional bioenergetic models we incorporated the effects of salinity (a masking factor) associated to the increased cost of osmoregulation (Fry, 1971). We modeled this as a "loading effect" (Neill et al., 2004) that increases routine metabolism at both hyper- and hypo-osmotic salinities (Fig. 3), causing a reduction both in aerobic scope and surplus energy available for activity and growth. As a result, SDA and therefore food consumption rates would decrease. Besides such interactions, there is strong evidence of direct salinity effects upon food consumption rates from several field and laboratory studies (Peters and Boyd, 1972; Lankford and Targett, 1994; Swanson, 1998; Boeuf and Payan, 2001; Imsland et al., 2001; Wuenschel et al., 2004a; Rubio et al., 2005; Niklitschek and Secor, 2009-this issue). Such an outcome might result from reduced intestinal irrigation to reduce ion-interchange or from endocrinous responses to salinity (cortisol, GH, prolactin), observed in salmonids and other species (Ron et al., 1995; Nakano et al., 1998; Kelly and Woo, 1999; Boeuf and Payan, 2001). Since food consumption responses to salinity are highly variable between species (Imsland et al., 2001), we used again Thornton and Lessem's (1978) algorithm as a very flexible model, to incorporate these direct salinity effects into our food consumption sub-model (Appendix S1).

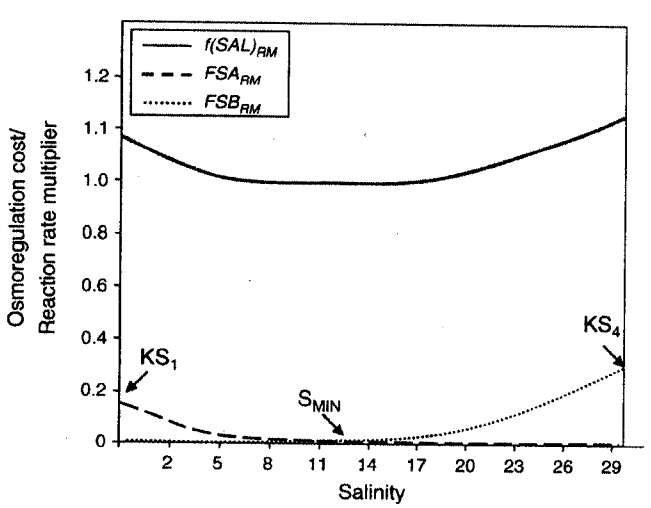

Fig. 3. Schematic representation of modeled routine metabolism responses to salinity. $f(SAL)_{RM}$. Hyper-osmotic (FSA_{RM}) and hypo-osmotic (FSB_{RM}) osmoregulation costs are scaled to zero at iso-osmotic conditions (SAL_{MIN}), reaching maximum values of KS_4 and KS_1 at maximum and minimum tested salinities, respectively. $f(SAL)_{RM}$ represents the increment in routine metabolism relative to iso-osmotic conditions, where the function reaches a value of 1.

2.2. Model application

We applied the proposed model (Appendix S1) and estimated corresponding parameters from the raw data set of laboratory results for young-of-the-year (YOY) and age 1 (yearling) Atlantic sturgeon described by Niklitschek and Secor (2009-this issue). In that work, we measured temperature, dissolved oxygen and salinity effects upon all major bioenergetic components except excretion and activity. Conservative values were assumed for excretion losses, although scaled to our routine metabolism laboratory results. Activity cost proportionality coefficient was estimated using a balance equation approach and observed consumption-growth, as described in Appendix S2.

All parameters within each bioenergetic sub-model (Appendix S2) were simultaneously estimated by non-linear mixed regression (NLMIXED procedure) in SAS 9.1 (SAS Institute, 2004). This platform allowed us to implement a Gauss–Newton iterative method, within a maximum likelihood framework, where we accounted for correlation within experimental runs by including them as a random source of covariance in the mixed model (Littel et al., 1996). We used an information theory approach (Akaike's information criteria; AIC) for model comparison (Burnham and Anderson, 2002). Because some sub-models used predicted responses from other sub-models, the overall fitting procedure followed the required sequence: RM→FC→EG→SDA→U→ACT. Estimated model parameters are reported in Table S1, while a full and explicit formulation of the applied model is specified in Appendix S2, along with special considerations related to this particular application of the proposed model to juvenile Atlantic sturgeon.

2.3. Model assessment

2.3.1. Laboratory results

We compared the goodness of fit between proposed food consumption, routine metabolism and egestion sub-models against alternative, purely empirical, regression sub-models, which followed the general polynomial form,

$$Y = \beta_0 + \beta_1 \cdot T + \beta_2 \cdot T^2 + \beta_3 \cdot DO_{SAT} + \beta_4 \cdot DO_{SAT}^2 + \beta_5 \cdot SAL + \beta_6 \cdot SAL^2 + \beta_7 \cdot log_e(W).$$

Goodness of fit comparison was based upon Akaike's information criteria, which penalizes overfitting (due to increased number of parameters) and has been shown to be theoretically sound and robust under a range of modeling situations, including maximum likelihood procedures to what it is naturally related (Burnham and Anderson, 2002).

To provide a more intuitive index for the quality of the fit, we also computed the proportion of the total variance observed in the laboratory data that was explained by each sub-model, according to the relationship,

$$EV_{\%} = 100 \cdot \left[1 - \frac{\sum \left(Y_i - \hat{Y}_i \right)^2}{\sum \left(Y_i - \bar{Y} \right)^2} \right] \quad (3)$$

where,

$EV_{\%}$ explained variance (%)
Y_i measured value at observation i
$\hat{Y}_i$ model predicted value for observation i.

2.3.2. Error analysis

To evaluate the sensitivity of bioenergetic models to experimental error and parameter uncertainty, we conducted a series of error analyses (Bartell et al., 1986) based upon a Monte Carlo simulation approach. A total of 5000 samples were randomly obtained for each parameter probability distribution function, under the assumption of normal or log-normal error distributions (depending upon each sub-model formulation), using estimated standard errors as surrogates for actual standard deviations. We assumed independence between parameters for all sub-models, with the exception of food consumption, routine metabolism and egestion, where correlation between some parameters exceeded $r = 0.7$. For each of these three sub-models we used restricted maximum likelihood covariance estimates (Littel et al., 1996) to generate a Cholesky matrix suitable to simulate correlated parameter values. Since we lacked reliable estimates for uncertainty in excretion parameters, we arbitrarily set standard errors at 20% of the mean parameter estimates.

The random perturbations of each parameter were combined to generate equal number of daily growth predictions. Growth dependance upon model parameters was then analyzed through multiple linear regression, using relative partial sum of squares ($RPSS_{\%}$) as the main ranking criteria. We defined $RPSS_{\%}$ as the percent of the residual variance explained by a given parameter, after adjusting for the effects of all the other parameters in the model (Bartell et al., 1986). To evaluate whether the sensitivity of the model depended upon the particular set of environmental variables considered for forecasting bioenergetic responses, we repeated the described error analysis procedure under four water quality scenarios, representing optimal, hypoxia, high salinity and high temperature conditions (Table 1).

2.3.3. Mesocosm validation

A mesocosm validation experiment was conducted to test model predictions against a data set that was independent from the one used for estimating model parameters and represented a higher degree of realism. Four mesocosm trials were conducted in outdoor 3200-L tanks with 10 fish each; trials lasted 130 days between March and July 1999. Tanks received ambient brackish water from the Patuxent River, with temperature, salinity and dissolved oxygen varying according to natural river conditions and monitored at least three times a day. Oxygen saturation reached super-saturation levels at noon during March, probably due to enhanced primary production (Table 2). The fish were fed Biokyowa® pellets three times a day, a ration equivalent to 1.3 times the maximum daily consumption rate predicted by the bioenergetic model. Actual consumption was not assessed due to tank size and water turbidity.

Individual weight and total length were recorded once a week. Five fish from the initial stock and three fish from each tank were sacrificed at the beginning and at the end of each experiment and used to estimate energy content through a modified Maciolek's (1962) technique (Niklitschek, 2001). Spearman's correlation was used to evaluate parallelism between observed and predicted growth rates. A t-test (alpha = 0.05) was used to evaluate if final weights were significantly different from model predictions for each tank.

Table 1
Simulated water quality conditions used for error analysis of the Atlantic sturgeon bioenergetic model.

Scenario #	Temperature (°C)	Salinity	Dissolved oxygen (%)	Environmental conditions represented
1	23	9	100	Optimal
2	23	9	40	Hypoxia
3	28	9	100	High temperature
4	23	29	100	High salinity

Table 2
Average and range of water quality conditions in mesocosm experiments for Atlantic sturgeon.

Variable	Mean ± SD	Range
Salinity	13.2 ± 1.3	11.3–15.5
Temperature (°C)	18.3 ± 6.1	4.5–28.7
Oxygen saturation (%)	102.5 ± 9.2	78.4–127.5

3. Results

3.1. Application to laboratory results

The routine metabolism sub-model explained 78% of the variance observed in laboratory results (AIC = 76.5), outperforming the multiple linear regression model (AIC = 87.9). Predicted routine metabolism showed a sigmoid response to temperature, with a maximum rate predicted at 38 °C, beyond the highest tested temperature of 28 °C (Fig. 4). Predicted RM responses were clearly affected by the hypoxia-temperature interaction. For instance, at salinity 8, a temperature increase from 6 °C to 28 °C produced a rise in critical oxygen threshold (DOC) from 46 to 74% DO_{SAT}. Modeled routine metabolism increased towards low and high salinity conditions, with minimum values estimated at salinity 9 ± 2.9 (Fig. 4). These loading effects of salinity were equivalent to an increase of 5 and 29% in routine metabolism at salinities 1 and 29, respectively (100% DO_{SAT}).

The food consumption sub-model explained 66% of observed variance and was more informative (AIC = 52.7) than the alternative linear regression model (AIC = 132.1). Food consumption was predicted to increase with temperature, mostly from 6 to 20 °C (Fig. 5). As temperature exceeded 26 °C, predicted consumption rates were sharply reduced. In agreement with observed responses, the sub-model predicted very strong effects and interactions between dissolved oxygen and temperature upon food consumption (Fig. 5). The critical level (DOC) for food consumption increased with temperature, reaching values of 34 and 66% DO_{SAT} for 6 and 28 °C, respectively. Highest consumption rates were predicted to occur close to iso-osmotic conditions (salinity 9), with the lowest food consumption rates predicted at the highest tested salinity (29). These inhibiting effects of salinity were equivalent to 42% and 60% of maximum food consumption at salinities 1 and 29, respectively.

Although the egestion sub-model performed much better (AIC = 20.3) than its alternative multiple linear regression model (AIC = 92.5), it explained only 29% of observed variance in experimental results. Egestion ratio was predicted to increase by c. 50% between normoxia and hypoxia (40% DO_{SAT}, Fig. Fig. 6). As an example, at 20 °C and salinity 9, predicted egestion ratio for a 20-g fish increased from 6.3 to 12.4%, when DO_{SAT} was reduced from 100% to 40%. The SDA model explained 52% of observed variance and was more informative (AIC = 46.8) than either a constant proportion of ingested energy (AIC = 49.5) or a multiple linear regression model (AIC = 62.5). Limiting effects of hypoxia upon SDA increased with temperature, with a reduction of c. 50% between normoxia and 40% DO_{SAT} predicted at 28 °C (Fig. 6). Applying the excretion sub-model to laboratory data, a 20-g fish was predicted to exhibit excretion rates of 4.1 to 4.5% of consumed energy, depending upon temperature, DO and salinity conditions.

Predictive regressions constructed using either food consumption or routine metabolism as single explanatory variables explained significant fractions of variation attributed to active metabolism (Fig. 7). The most informative of these two models (AIC = 654.1) predicted ACT as a direct proportion (0.29 ± 0.036 SE) of predicted maximum food consumption rate. The alternative model based upon routine metabolism was much less informative (AIC = 1122.7) although still significant ($p < 0.05$). Here, activity cost was predicted to be 1.89 times ± 0.044 SE predicted routine metabolism rate, which corresponds to a Winberg's multiplier of 2.89.

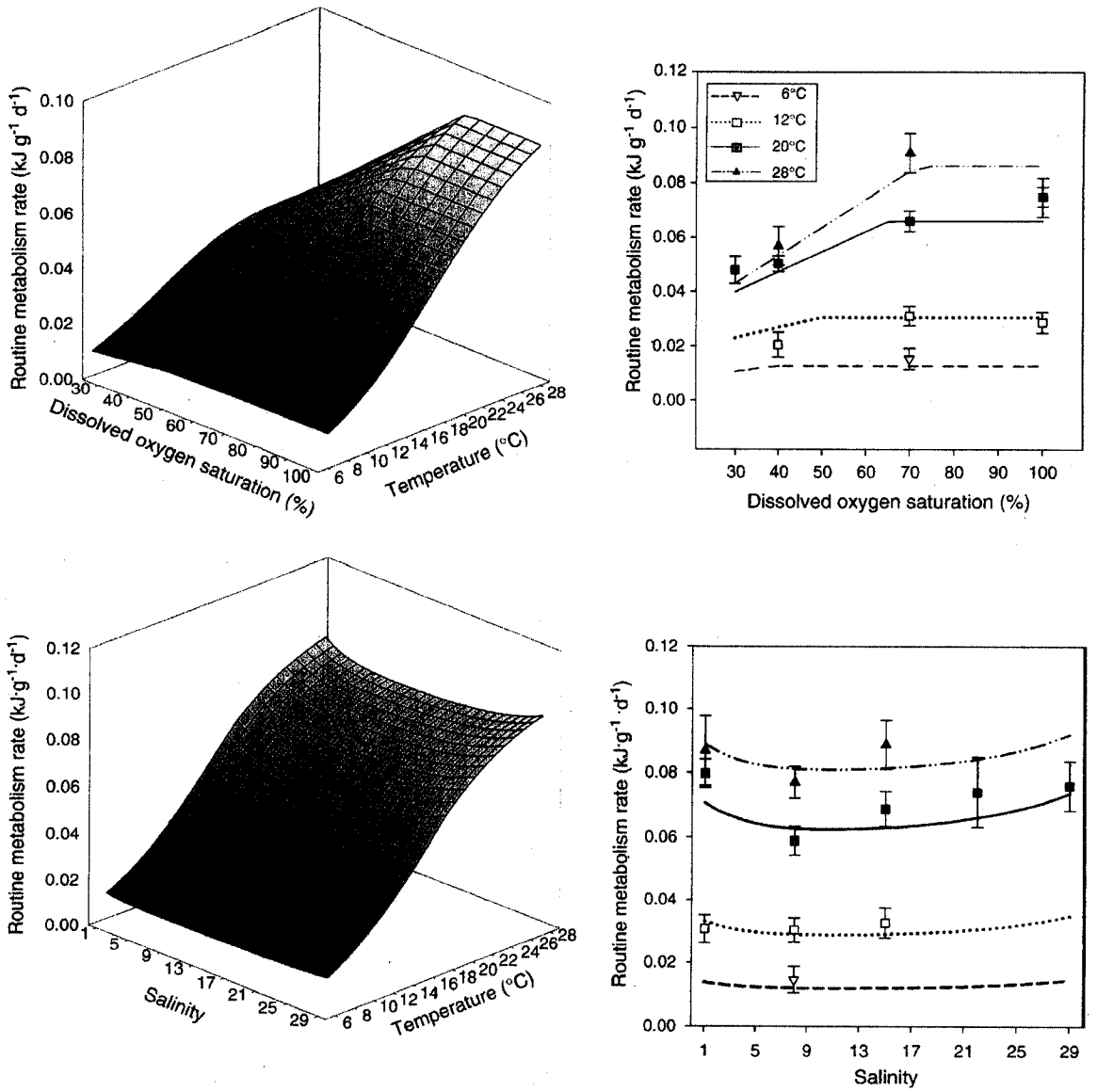

Fig. 4. Predicted (left panels) and mean observed ± SE (right panels) effects of temperature, dissolved oxygen saturation and salinity on routine metabolism rate in juvenile Atlantic sturgeon. Figures show variability caused by two factors at a time, holding the third at fixed conditions (salinity 9 for top panels, 100% DO_{SAT} for bottom panels). Predicted and observed values are weight-normalized to represent a 20-g fish.

The integrated bioenergetic model explained 60% of variance in observed growth from laboratory experiments, when used to predict growth from measured food consumption. When used to predict both growth and food consumption simultaneously, the integrated model explained 48% of variance in observed growth. In both applications, the model outperformed an alternative multiple linear regression model, which explained 43% of observed variance in growth. Due to several direct and indirect relationships among temperature, dissolved oxygen and salinity, predicted growth was characterized by strong three-way interactions between these environmental factors (Fig. 8).

At normoxia (100% DO_{SAT}) and iso-osmotic (salinity 9) conditions, maximum growth was predicted at 23 °C, with an instantaneous rate of 0.052 d^{-1} for a 20-g Atlantic sturgeon. This optimal temperature for growth decreased with dissolved oxygen saturation (Fig. 8) to 17 °C at 40% DO_{SAT} and to 16 °C at 30% DO_{SAT} (salinity 9, in both cases). Keeping the fish at normoxia, but manipulating salinity would also affect the predicted optimal temperature for growth, which would become 20 °C at salinity 1, and 16 °C at salinity 29. A drop in dissolved oxygen to 40% saturation would produce a reduction of 52% in instantaneous growth rate, while an increase in salinity to 29 would reduce instantaneous growth rate by 88%, both compared to maximum growth conditions (23 °C, 100% DO_{SAT}, salinity 9).

3.2. Error analysis

Growth predictions were highly sensitive to uncertainty in the food consumption sub-model (Fig. 9), which explained 20–67% of residual variance, and was the main source of errors in scenarios 3 (high salinity) and 4 (high temperature); Table 3. Uncertainty in activity cost showed the second largest effect on total model errors, explaining 12–63% of residual variance, and was the most sensitive bioenergetic component under scenarios 1 (optimal) and 2 (hypoxia). Model sensitivity to uncertainty in routine metabolism parameters ranked third among all components, explaining between 5 and 43% of total residual variance. Error contributions from egestion, SDA and

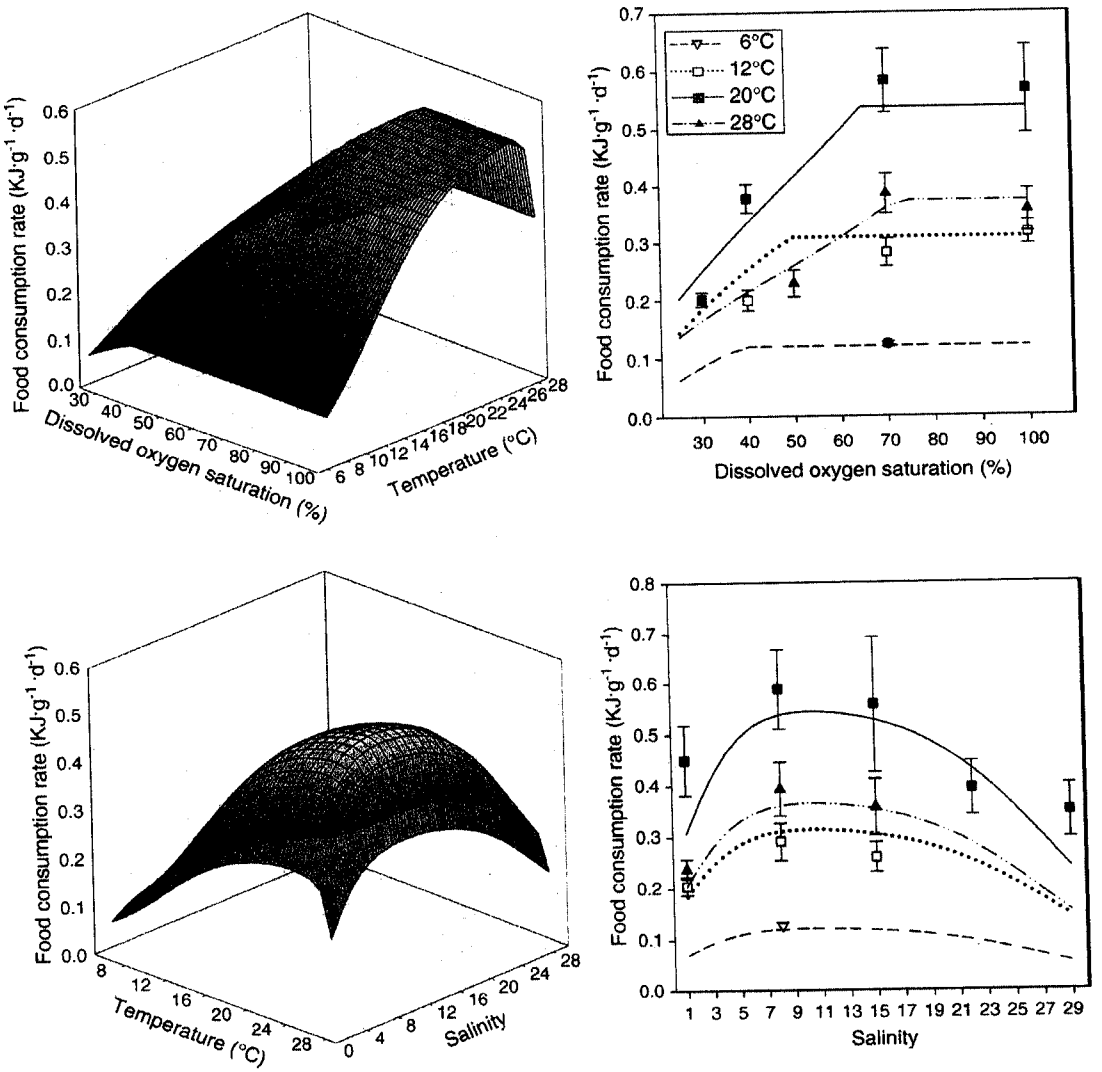

Fig. 5. Predicted (left panels) and mean observed ± SE (right panels) effects of temperature, dissolved oxygen saturation and salinity on food consumption rate in juvenile Atlantic sturgeon. Figures show variability caused by two factors at a time, holding the third at fixed conditions (salinity 9 for top panels, 100% DO_{SAT} for bottom panels). Predicted and observed values are weight-normalized to represent a 20-g fish.

excretion sub-models were the lowest, always below 6% of total residual variance (Table 3).

In terms of individual parameters (see Table S1 for definitions), uncertainty in a_{ACT}, the proportionality coefficient for activity cost, had the largest overall effect upon predicted errors (Fig. 9), being the dominant error contributor under scenarios 1 (optimal) and 2 (hypoxia). Under scenario 3 (high temperature), the largest source of model errors was the parameter $TK4_{FC}$, which corresponds to the food consumption reaction rate at the highest tested temperature level. Analogously, under scenario 4 (high salinity), the largest impact upon model uncertainty was related to parameter k_{FC}, that defines food consumption reaction rate at the highest tested salinity.

3.3. Mesocosm validation

Our bioenergetic model tended to overestimate both final weight and instantaneous growth rates observed in mesocosm experiments (Fig. 10). Thus, observed mean fish weight at the end of the experiments (180 g ± 15 SE) was significantly lower than the predictive value of 220 g ± 15 (SE). Significant differences were also found between predicted and observed growth rates, with overall means of 0.023 d^{-1} ± 0.0014 (SE) and 0.021 d^{-1} ± 0.0014 (SE), respectively. A weekly-based analysis of instantaneous growth rates showed a low, but still significant correlation between observed and predicted growth rates (Spearman's $r = 0.28$; <0.05). When computed on a monthly basis, correlation between predicted and observed growth rates increased to $r = 0.6$ ($p < 0.05$). Poor correlation was particularly evident at the beginning of the experiments, when there was a noticeable trend to overestimate observed growth rates. Improved agreement between predicted and observed values occurred during the second and third months of the experimental period (Fig. 10).

4. Discussion

4.1. Expanding bioenergetic model into a multi-variable framework

In the present work we have proposed a multi-variable bioenergetic model, which incorporates formally and explicitly the expected effects of hypoxia and salinity on different fish bioenergetic processes. The application of this model to a comprehensive set of laboratory and mesocosm results for juvenile Atlantic sturgeon showed reasonable model performance and gave support to the theoretical basis and

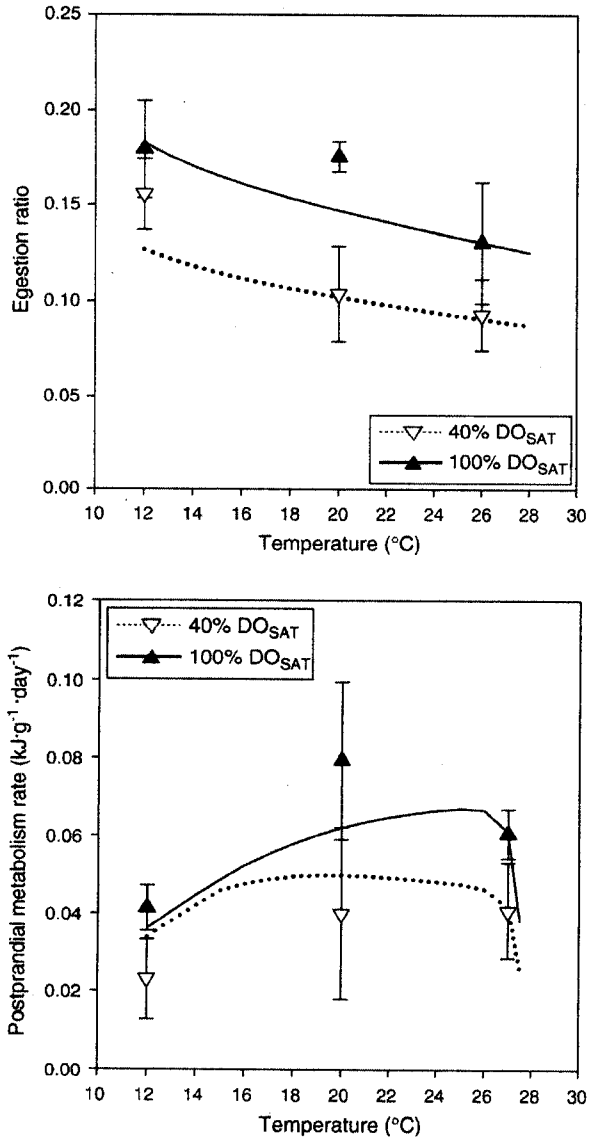

Fig. 6. Mean observed ± SE (triangles) and predicted (lines) effects of temperature and dissolved oxygen upon egestion (upper panel) and postprandial metabolism (lower panel) rates in YOY Atlantic sturgeon at salinity 9.

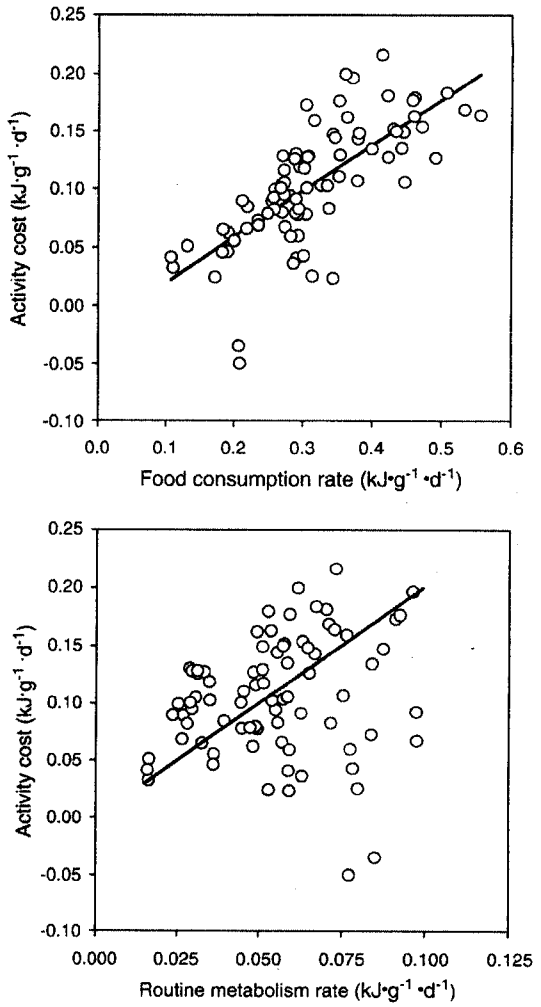

Fig. 7. Apparent activity cost computed by difference between food consumption and realized growth rate. Calculated values (circles) are plotted against food consumption rate (upper panel) and routine metabolism rate (lower panel) corresponding to each observation. Predicting lines correspond to constant proportions of either *x*-axis.

assumptions used to build the model. Such basis and assumptions were strongly related to Fry's (1971) concept of controlling, limiting and masking factors, as well as to Winberg's (1956) energy balance and van Dam and Pauly's (1995) metabolic oxygen balance concepts. The vertical and horizontal integrations of controlling, limiting and masking effects in the model allowed for simultaneous analysis of potential maximum rates, controlled by temperature, and realized ones, as limited by aerobic scope or modified by osmoregulation costs.

Model structure and results from its application to juvenile Atlantic sturgeon matched the expectations that oxygen and salinity play major roles shaping bioenergetic responses in juvenile sturgeon and should not be ignored in bioenergetic models for estuarine species (Niklitschek and Secor, 2005; Breitburg et al., 2009). Overall, we consider this as a case where increasing model complexity has resulted in significant improvements in its predictive capabilities. Further, we wished to advance a bioenergetic framework that better integrated and synthesized scientific understanding about key eco-physiological processes than those that focus on temperature and forage or rely on statistical description alone (Bartell et al., 1986). A reasonable balance is needed between desired realism, parsimony, and experimental efforts needed to estimate model parameters. Hence, a detailed scrutiny of model sensitivity and uncertainty in the required data (Brandt and Hartman, 1993; Hanson et al., 1997) might allow for a reduction in the number of model parameters, which currently reach a total of 30 parameters in our proposed model.

Developed as parallel efforts, there is a noteworthy convergence between our model and Neill et al.'s (2004) Ecophys.Fish model. For instance, both frameworks use Fry's (1971) paradigm to guide model construction and use routine (standard) metabolism to canalize the bulk of masking and limiting effects. Our concept of aerobic scope is closely related, although not identical, to Neill et al.'s (2004) concept of marginal metabolic scope. Although algorithms used to forecast bioenergetic responses are different, overall consistency exists also in the shape of responses predicted by both models. Unlike Neill et al. (2004), we ignored pH controlling effects, but included hypoxia limiting effects upon SDA, egestion and excretion rate.

In our view, efforts to construct more elaborate and refined multivariate bioenergetic models are justified by increased scientific and public agendas to manage for habitat suitability in estuaries where strong salinity gradients and regular (seasonal) hypoxia are highly relevant ecophysiological factors (Diaz, 2001; Breitburg et al., 2009). The increasing availability of spatially-explicit time series of data from

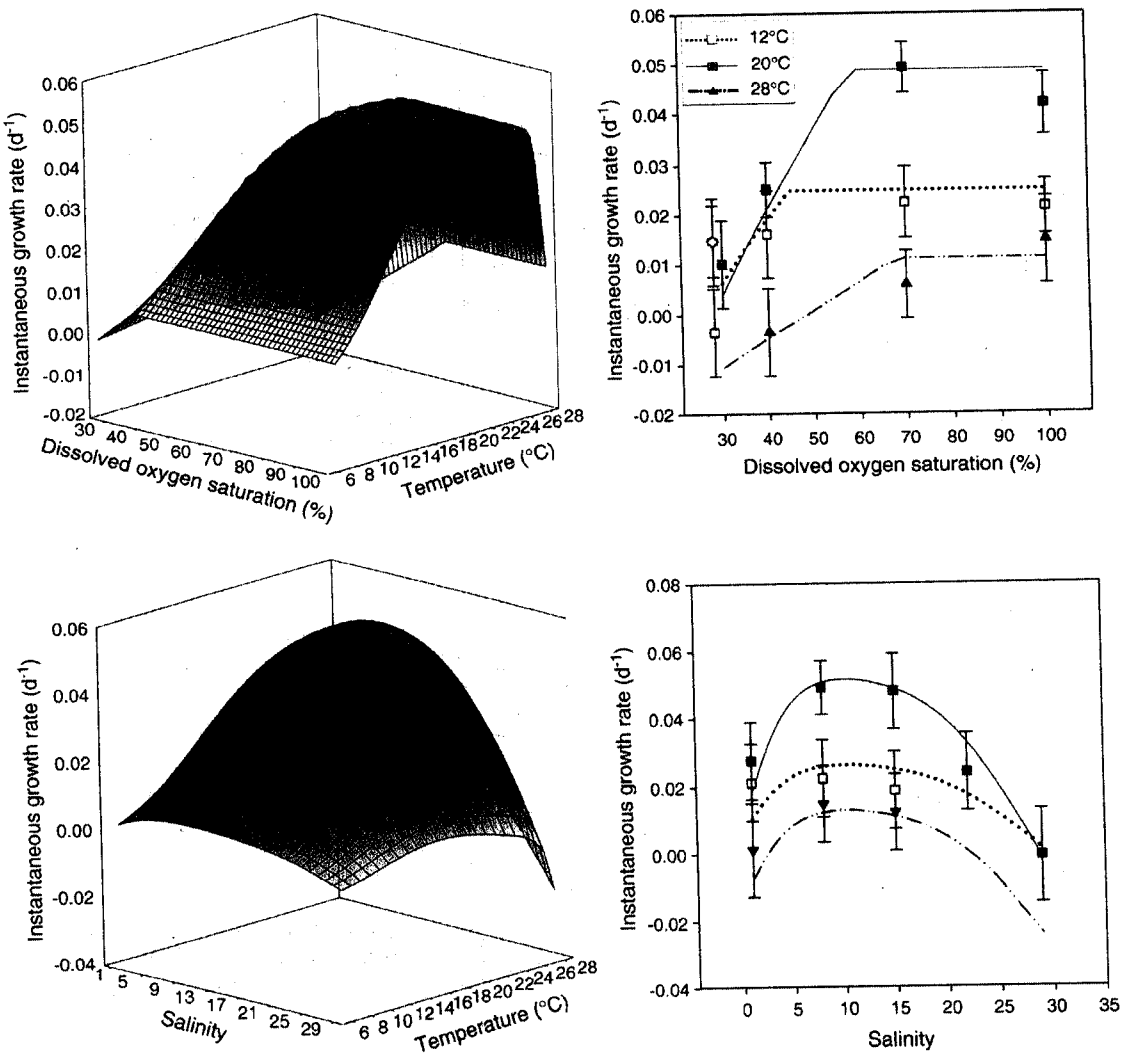

Fig. 8. Predicted (left panels) and mean observed ± SE (right panels) effects of temperature, dissolved oxygen saturation and salinity on instantaneous growth rate in juvenile Atlantic sturgeon. Figures show variability caused by two factors at a time, holding the third at fixed conditions (salinity 9 for top panels, 100% DO_{SAT} for bottom panels). Predicted values are weight-normalized to represent a 20-g fish.

intense and regular monitoring programs, such as the Chesapeake Bay Program, transform such models into integrative tools suitable for evaluating or forecasting trophic interactions (Hartman and Brandt, 1995b) and habitat value (Niklitschek and Secor, 2005; Woodland et al., 2009) for estuarine species, among other applications. Moreover, model approaches of this nature might exist as the only option to identify essential habitats when observational data on fish abundance and distribution are scarce or missing, as in the case of many sturgeon populations (Secor and Niklitschek, 2002).

Table 3
Relative partial sum of squares (% RPSS) attributed to each major bioenergetic component of Atlantic sturgeon model under optimal water quality conditions and 3 alternative modeling scenarios (see Table 1 for scenarios).

Bioenergetic component	Scenario (temperature/salinity/$DO_{\%}$)			
	23/9/100 (optimal)	23/9/40 (hypoxia)	23/29/100 (high salinity)	28/9/100 (high temp.)
AM	63.4	42.1	12.3	25.2
FC	20.1	42.6	43.5	66.5
EG	3.3	5.1	0.5	1.1
RM	8.6	7.6	42.8	5.0
SDA	3.8	2.0	0.8	2.0
U	0.8	0.6	0.3	0.2

4.2. Overall performance of model application to juvenile Atlantic sturgeon

The application of proposed sub-models to juvenile Atlantic sturgeon laboratory results showed better fits (lower AIC's) than multinomial linear regression models for all studied bioenergetic responses, although in many cases they demanded a larger set of parameters or depended upon parameters from other sub-models. Growth predictions from our model outperformed a purely empirical (polynomial) fitting and explained 48% of the variance in laboratory growth responses to a range of environmental conditions, representative of what juvenile Atlantic sturgeon would face during their first 2–3 years of life in North American estuaries. Neglecting the modeled effects of temperature, dissolved oxygen or salinity reduced explained variance from 48% in the full model to values of 18, 24 and 38%, respectively. Thus, temperature was the most influential factor, followed by dissolved oxygen and salinity. Still, a single-variable model based only on temperature explained no more than 17% of observed variance in laboratory results.

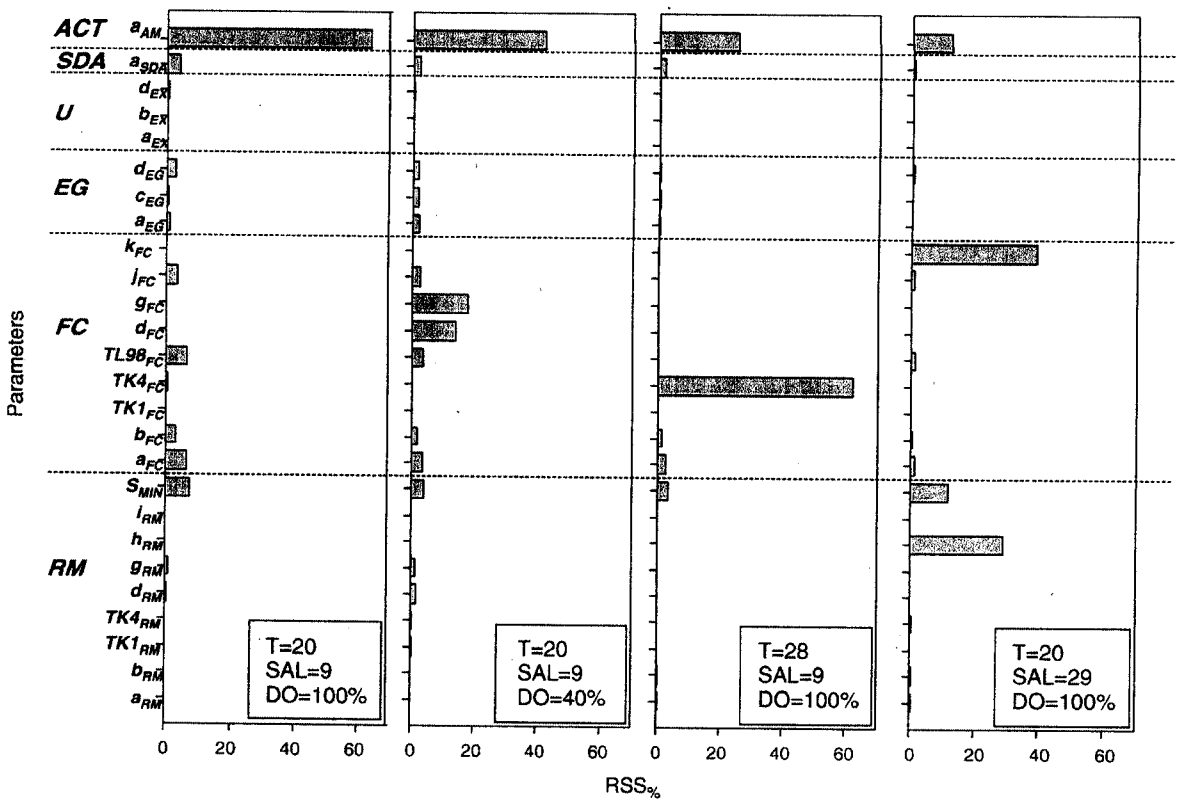

Fig. 9. Percent of residual variance ($RSS_{\%}$) explained by uncertainty in individual parameters estimated for the Atlantic sturgeon bioenergetic model, under 4 simulation scenarios of temperature (T), salinity (S) and dissolved oxygen saturation (DO). See Table S1 for variable definitions. ACT = activity cost; SDA = postprandial metabolism; EG = egestion; U = excretion; RM = routine metabolism; FC = food consumption.

While model predictions overestimated observed growth in mesocosm experiments by 20%, a least square estimation of the realized proportion of maximum consumption, p-value (Hanson et al., 1997), indicated a cumulated difference of just 4% between maximum and actual consumption rates. Although we fed the fish 1.3 times their predicted ration, tank size relative to the fish might have delayed feeding and increased nutrients leaching into the water. Since larger discrepancies between predicted and observed growth rates were concentrated in the first weeks of the mesocosm experiment (early fall, temperature range 6–11 °C), an alternative, or maybe complementary, explanation is model overestimation of growth rates at low temperature. While a limited number of experimental units was allocated by Niklitschek and Secor's (2009-this issue) experimental design to 6 °C treatments, other authors have found a severe drop in food consumption, growth and/or survival at c. 5 °C in partially sympatric species like Atlantic croaker *Micropogonias undulatus* (Lankford and Targett, 1994) and striped bass *Morone saxatilis* (Hurst and Conover, 2001).

As expected, the model exhibited much higher errors predicting growth rates on a weekly basis than on over a monthly period. This is consistent with Rice and Cochran's (1984) verification study, that concluded that finer (daily) resolution dynamics of metabolic processes were not well captured by the applied bioenergetic model. By the end of our mesocosm experiments, fish grew to c. 180 g. Although this weight was close to the maximum weight of 200 g recorded from yearlings used in routine metabolism and food consumption experiments, the most comprehensive set of laboratory data we used to estimate model parameters belonged to YOY fish with a maximum size of 60 g. Thus, we suggest a primary application of model parameters reported in this paper to YOY, which are expected to reach c. 120 g at the end of their first year in the wild (Stevenson and Secor, 1999). Only a cautious extension of the model to older/larger fish would be advisable before new validations were conducted.

In terms of model uncertainty, the activity cost proportionality coefficient (a_{ACT}) was the single parameter having the largest impact on total model error under optimal and normoxia scenarios. Activity cost has been shown to be a very sensitive and highly variable parameter in bioenergetic models (Kitchell et al., 1977; Bartell et al., 1986; Bosclair and Sirois, 1993; Hansen et al., 1993; Ney, 1993; Guénard et al., 2008), even under semi-controlled experimental conditions (Bosclair and Sirois, 1993; Guénard et al., 2008). Moreover, accurate measurement of activity levels in the field faces methodological constraints recognized since Winberg (1956), related to the inherently random nature of spontaneous activity and short-term responses to environmental stimuli. Even the most modern approaches remain expensive in time and resources, and can lead to highly variable results, which continue to confound the accurate inclusion of active metabolism in bioenergetic models (Guénard et al., 2008).

We found that inferred activity cost in YOY Atlantic sturgeon experiments was more closely related to maximum food consumption rate than to routine metabolism. This finding matched theoretical expectations that both activity and food consumption would be limited under hypoxia (Jobling, 1981), and was also consistent with the general expectation that foraging (as well as predator avoidance) represents a major component in total fish activity at the wild (Rennie et al., 2005). A close correlation between consumption and activity finds support in empirical evidence from several authors (Madon and Culver, 1993; Swanson, 1998; Rennie et al., 2005), although it has not been the case in other studies (Sirois and Boisclair, 1995; Qian et al., 2001).

Under extreme temperature and salinity scenarios, the proposed model was highly sensitive to food consumption parameters that defined reaction rates at the highest tested temperature ($TK4_{FC}$) and salinity (k_{FC}) conditions. This was the combined result of higher

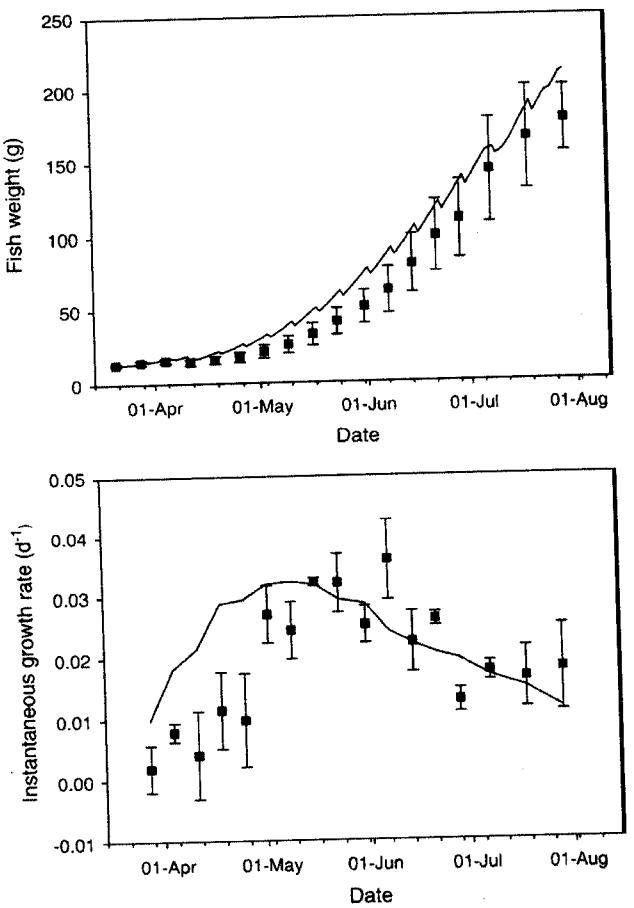

Fig. 10. Weight (upper panel) and growth rates (lower panel) in juvenile Atlantic sturgeon during a 4-month mesocosm validation experiment. Squares represent observed values, while lines represent predictions from the bioenergetic model. Error bars correspond to standard errors from 4 replicates (tanks).

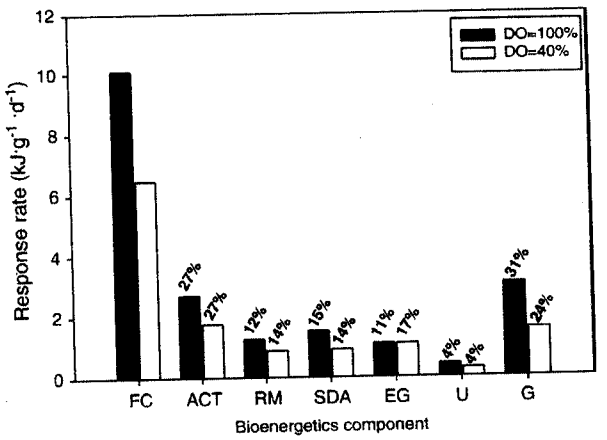

Fig. 11. Energy partitioning among main bioenergetic components in juvenile Atlantic sturgeon under hypoxia (40% DO_{SAT}) and normoxia (100% DO_{SAT}), at constant temperature and salinity conditions (20 °C, salinity 9). Percent labels are in reference to predicted consumption rates (FC) at each DO_{SAT} condition.

variability in actual responses and comparatively low replication due to both the experimental design and higher mortality rates. Complementary experiments focused on testing activity cost and feeding rate responses at extreme conditions should be conducted to reduce such uncertainty in future applications.

4.3. Energy partitioning in juvenile Atlantic sturgeon

We estimated that, under optimal conditions (23 °C, salinity = 9 and 100% DO_{SAT}), YOY Atlantic sturgeon transformed an average of 31% of consumed energy into fish biomass (Fig. 11). This efficiency was slightly higher than the average 29% estimated for "well fed" carnivorous teleosts by Brett and Groves (1979), but lower than the 43.5% reported by Winberg (1956) for 11–21 g *A. gueldenstaedtii*, and the 35% net conversion efficiency calculated for 2–23 g white sturgeon by Cui et al. (1996). Conversion efficiency and energy allocation patterns departed, however, from this optimal value depending upon environmental conditions (Fig. 11). We predicted that the proportion of consumed energy allocated to growth would decrease to 24% under sub-lethal hypoxia (40% DO_{SAT}) at 20 °C (salinity 9), and to null values at 28 °C. Similar hypoxia-driven reductions in the amount of energy allocated to growth were observed in rainbow trout *Oncorynchus mykiss* by Pedersen (1987), although the magnitude of this drop was more pronounced, exhibiting negative growth rates at 40% DO_{SAT} and only 15 °C.

The proportion of the energy budget allocated to routine metabolism and activity under hypoxia (Fig. 11) increased from 39 to 41%, with minor changes in the proportions corresponding to excretion and postprandial metabolism. Egestion showed the largest relative change under hypoxia, increasing c. 60% relative to normoxic conditions. This change reflects our findings, which indicate that besides lowering their feeding rates, sturgeons reduce assimilation rates under hypoxia, shunting energy and oxygen supply from SDA towards respiration (Niklitschek and Secor, 2009, this issue).

Osmoregulation cost at extreme salinities was higher at hyper-osmotic than at hypo-osmotic conditions in agreement with results from Allen and Cech (2007). Instead of the compensatory increase in food consumption described in other species (Wuenschel et al., 2004a) we found (Niklitschek and Secor, 2009, this issue) and modeled a decrease in food consumption toward extreme salinities. Hence, consequences of extreme salinities upon juvenile sturgeon growth largely exceeded the direct effects upon osmoregulation cost. While the predicted cost of osmoregulation for a 20-g fish increased from 0 to 11% of consumed energy between salinities 9 and 29, food consumption was reduced by 60% between the same salinities. As a result, an 88% drop in growth rate was predicted between salinities 9 and 29. This reduction in food consumption might be a direct response aimed to reduce ion exchange at the intestine, or a more indirect result from other physiological effects of salinity upon hormonal balance, tissue permeability and/or ventilatory performance (Swanson, 1998; Boeuf and Payan, 2001). Relative effects of salinity upon predicted consumption and growth were modeled to decrease with size, in agreement with previous studies showing an ontogenetic increase in salinity tolerance, observed in several species, included sturgeons (Altinok et al., 1998; Allen and Cech, 2007).

4.4. Model implementation and future development

There are currently two main bioenergetic packages available for the fish ecology scientific community. The "Wisconsin" Bioenergetics 3.0© model (Hanson et al., 1997), which is a closed-code copyrighted self-contained software and the Ecophys.Fish model (Neill et al., 2004), which is a non-licensed freely available script that runs on the copyrighted general package Stella©. While Bioenergetics 3.0 is the most widely used package, it has the limitations inherent to self-contained software, which make it harder or plainly impossible to add new explanatory variables or other custom needs, such as spatially explicit factors. The Ecophys.Fish model has the advantage of great flexibility, which might facilitate an integration with models already written for Stella© (Bevelhimer, 2002) or with other models, like ours, written in general graphic languages such as R or SAS©. Currently, our

model is written as a SAS© script and is freely available for non-commercial purposes upon request.

Beyond software implementation, comparing our results to published ones for other species suggests relative consistency within sturgeons, but low transferability of salinity and hypoxia responses regarding other fish taxa. Therefore, anticipating eventual applications of our model to other species, we strongly recommend prioritizing species-specific laboratory work aimed at sensitive parameters

Acknowledgements

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jembe.2009.07.019.

References

Allen, P.J., Cech, J.J., 2007. Age/size effects on juvenile green sturgeon, *Acipenser medirostris*, oxygen consumption, growth, and osmoregulation in saline environments. Environ. Biol. Fishes 79, 211–229.

Altinok, I., Galli, S.M., Chapman, F.A., 1998. Ionic and osmotic regulation capabilities of juvenile Gulf of Mexico sturgeon, *Acipenser oxyrinchus de sotoi*. Comp. Biochem. Physiol. A 120, 609–616.

Bartell, S.M., Breck, J.E., Gardner, R.H., Brenkert, A.L., 1986. Individual parameter perturbation and error analysis of fish bioenergetic models. Can. J. Fish. Aquat. Sci. 43, 160–168.

Bevelhimer, M.S., 2002. A bioenergetics model for white sturgeon *Acipenser transmontanus*: assessing differences in growth and reproduction among Snake River reaches. J. Appl. Ichthyol. 18, 550–556.

Boeuf, G., Payan, P., 2001. How should salinity influence fish growth? Comp. Biochem. Physiol. C 130, 411–423.

Bosclair, D., Sirois, P., 1993. Testing assumptions of fish bioenergetics models by direct estimation of growth, consumption, and activity rates. Trans. Am. Fish. Soc. 122, 784–796.

Brandt, S.B., 1993. Effects of thermal fronts on fish growth: a bioenergetics evaluation of food and temperature. Estuaries 16, 142–159.

Brandt, S.B., Hartman, K.L., 1993. Innovative approaches with bioenergetics models: future applications to fish ecology and management. Trans. Am. Fish. Soc. 122, 731–735.

Brandt, S.B., Kirsch, J., 1993. Spatially explicit models of striped bass growth potential in Chesapeake Bay. Trans. Am. Fish. Soc. 122, 845–869.

Breitburg, D.L., Craig, J.K., Fulford, R.S., Rose, K.A., Boynton, W.R., Brady, D., Ciotti, B.J., Diaz, R.J., Friedland, K.D., Hagy III, J.D., Hart, D.R., Hines, A.H., Houde, E.D., Kolesar, S.E., Nixon, S.W., Rice, J.A., Secor, D.H., Targett, T.E., 2009. Nutrient enrichment and fisheries exploitation: Interactive effects on estuarine living resources and their management. Hydrobiologia 629, 31–47.

Brett, J.R., 1979. Environmental factors and growth. In: Hoar, W.S., Randall, D.J., Brett, J.R. (Eds.), Fish Physiology. Academic Press, New York, pp. 599–675.

Brett, J.R., Groves, T.D.D., 1979. Physiological energetics. In: Hoar, W.S., Randall, D.J., Brett, J.R. (Eds.), Fish Physiology. Academic Press, New York, pp. 279–352.

Burnham, K.P., Anderson, D.R., 2002. Model Selection and Multimodel Inference: A Practical–Theoretic Approach. 2nd. Springer-Verlag, Amsterdam, The Netherlands.

Collins, M.R., Rogers, S.G., Smith, T.I.J., Moser, M.L., 2000. Primary factors affecting sturgeon populations in the Southeastern United States: fishing mortality and degradation of essential habitats. Bull. Mar. Sci. 66, 917–928.

Crocker, C.E., Cech, J.J., 1997. Effects of environmental hypoxia on oxygen consumption rate and swimming activity in juvenile white sturgeon, *Acipenser transmontanus*, in relation to temperature and life intervals. Environ. Biol. Fishes 50, 383–389.

Cui, Y.B., Hung, S.S.O., Zhu, X., 1996. Effect of ration and body size on the energy budget of juvenile white sturgeon. J. Fish Biol. 49, 863–876.

Del Toro-Silva, F.M., Miller, J.M., Taylor, J.C., Ellis, T.A., 2008. Influence of oxygen and temperature on growth and metabolic performance of *Paralichthys lethostigma* (Pleuronectiformes: Paralichthyidae). J. Exp. Mar. Biol. Ecol. 358, 113–123.

Diaz, R.J., 2001. Overview of hypoxia around the world. J. Environ. Qual. 30, 275–281.

Elliot, J.M., 1976. Energy losses in the waste products of brown trout (*Salmo trutta* L.). J. Anim. Ecol. 45, 561–580.

Essington, T.E., Kitchell, J.F., Boggs, C., Schindler, D.E., Olson, R.J., Hillborn, R., 2002. Alternative fisheries and the predation rate of yellowfin tuna in the eastern Pacific. Ocean. Ecol. Appl. 12, 724–734.

Fry, F.E.J., 1971. The effect of environmental factors on the physiology of fish. In: Hoar, W.S., Randall, D.J. (Eds.), Fish Physiology. Academic Press, New York, pp. 1–98.

Guénard, G., Bosclair, D., Ugedal, O., Forseth, T., Jonsson, B., 2008. Comparison between activity estimates obtained using bioenergetics and behavioural analysis. Can. J. Fish. Aquat. Sci. 65, 1705–1720.

Hansen, M.J., Boisclair, D., Brandt, S.B., Hewett, S.W., Kitchell, J.F., Lucas, M.C., Ney, J.J., 1993. Applications of bioenergetic models to fish ecology and management: where do we go from here? Trans. Am. Fish. Soc. 122, 1019–1030.

Hanson, P.C., Johnson, T.B., Schindler, D.E., Kitchell, J.F., 1997. Fish Bioenergetics 3.0. University of Wisconsin System. Sea Grant Institute, Center for Limnology.

Hartman, K.J., Brandt, S.B., 1995a. Comparative energetics and the development of bioenergetics models for sympatric estuarine piscivores. Can. J. Fish. Aquat. Sci. 52, 1647–1666.

Hartman, K.J., Brandt, S.B., 1995b. Trophic resource partitioning, diets, and growth of sympatric estuarine predators. Trans. Am. Fish. Soc. 124, 520–537.

Heath, M.R., 1996. The consequences of spawning time and dispersal patterns of larvae for spatial and temporal variability in survival to recruitment. In: Watanabe, Y., Yamashita, Y., Oozeki, Y. (Eds.), Survival strategies in early stages of marine resources. A.A. Balkema, Rotterdam, The Netherlands, pp. 175–208.

Hewett, S.W., Johnson, B.L., 1992. Fish Bioenergetics Model 2., UW Sea Grant Technical Report No. WIS-SG-92-250. University of Wisconsin Sea Grant Institute.

Hondorp, D.W., Brandt, S.B., 1996. Spatially-explicit models of fish growth rate: tools for assessing habitat quality. Great Lakes Res. Rev. 2, 11–19.

Houde, E.D., 1997. Patterns and consequences of selective processes in teleost early life histories. In: Chambers, R.C., Trippel, E.A. (Eds.), Early life history and recruitment in fish populations. Kluwer Academic Publishers, Dordrecht, pp. 173–196.

Hurst, T.P., Conover, D.O., 2001. Diet and consumption rates of overwintering YOY striped bass, *Morone saxatilis*, in the Hudson River. Fish. Bull. 99, 545–553.

Imsland, A.K., Foss, A., Gunnarsson, S., Berntssen, M.H.G., FitzGerald, R., Bonga, S.W., Ham, E.V., Nævdal, G., Stefansson, S.O., 2001. The interaction of temperature and salinity on growth and food conversion in juvenile turbot *Scophthalmus maximus*. Aquaculture 198, 353–367.

Jobling, M., 1981. The influences of feeding on the metabolic rate of fishes: a short review. J. Fish Biol. 18, 385–400.

Johnson, B.M., Luecke, C., Stewart, R.S., Staggs, M.D., Gilbert, S.J., Kitchell, J.F., 1992. Forecasting effects of harvest regulations and stocking of walleyes on prey fish communities in Lake Mendota, Wisconsin. North Am. J. Fish. Manage. 12, 797–807.

Kelly, S.P., Woo, N.Y.S., 1999. The response of sea bream following abrupt hyposmotic exposure. J. Fish Biol. 55, 732–750.

Kitchell, J.F., Breck, J.F., 1980. Bioenergetics model and foraging hypothesis for sea lamprey (*Petromyzon marinus*). Can. J. Fish. Aquat. Sci. 37, 2159–2168.

Kitchell, J.F., Koonce, J.F., O'Neill, R.V., Shugart, H.H., Magnuson, J.J., Booth, R.S., 1974. Model of fish biomass dynamics. Trans. Am. Fish. Soc. 103, 786–798.

Kitchell, J.F., Schlindler, D.E., Ogutu-Ohwayo, R., Reinthal, P.N., 1997. The Nile perch in Lake Victory: interactions between predation and fisheries. Ecol. Appl. 7, 653.

Kitchell, J.F., Stewart, D.J., Weininger, D., 1977. Applications of a bioenergetics model to yellow perch (*Perca flavescens*) and walleye (*Stizostedion vitreum vitreum*). J. Fish. Res. Board Can. 34, 1922–1935.

Lankford, T.E., Targett, T.E., 1994. Suitability of estuarine nursery zones for juvenile weakfish (*Cynoscion regalis*): effects of temperature and salinity on feeding, growth and survival. Mar. Biol. 119, 611–620.

Littel, R.C., Milliken, G.A., Stroup, W.W., Wolfinger, R.D., 1996. SAS System for Mixed Models. SAS Institute Inc., Cary, N.C.

Luo, J., Hartman, K.J., Brandt, S.B., Cerco, C.F., Rippetoe, T.H., 2001. A spatially-explicit approach for estimating carrying capacity: an application for the Atlantic menhaden (*Brevoortia tyrannus*) in Chesapeake Bay. Estuaries 24, 545–556.

MacCall, A.D., 1989. Dynamic Geography of Marine Fish Populations. University of Washington Press, Seattle and London.

Maciolek, J.A., 1962. Limnological Organic Analyses by Quantitative Dichromate Oxidation. United States Department of the Interior, Fish and Wildlife Service.

Madon, S.P., Culver, D.A., 1993. Bioenergetics model for larval and juvenile walleyes: an in situ approach with experimental ponds. Trans. Am. Fish. Soc. 122, 797–813.

Mason, D.M., Goyke, A., Brandt, S.B., 1995. A spatially explicit bioenergetics measure of habitat quality for adult salmonines: comparison between Lakes Michigan and Ontario. Can. J. Fish. Aquat. Sci. 52, 1572–1583.

McKenzie, D.J., Cataldi, E., Romano, P., Owen, S.F., Taylor, E.W., Bronzi, P., 2001. Effects of acclimation to brackish water on the growth, respiratory metabolism, and swimming performance of young-of-the-year Adriatic sturgeon (*Acipenser naccarii*). Can. J. Fish. Aquat. Sci. 58, 1104–1112.

Nakano, K., Tagawa, M., Takemura, A., Hirano, T., 1998. Temporal changes in liver carbohydrate metabolism associated with seawater transfer in *Oreochromis mossambicus*. Comp. Biochem. Physiol. B 119, 721–728.

Neill, W., Brandes, T., Burke, B., Craig, S., Dimichele, L., Duchon, K., Edwards, R., Fontaine, L., Gatlin, D., Hutchins, C., Miller, J.M., Ponwith, B., Stahl, C., Tomasso, J., Vega, R., 2004. Ecophys.Fish: a simulation model of fish growth in time varying environmental regimes. Rev. Fish. Sci. 12, 233–288.

Neill, W.H., Miller, J.M., van Der Veer, H.W., Winemiller, K.O., 1994. Ecophysiology of marine fish recruitment: a conceptual framework for understanding interannual variability. Neth. J. Sea Res. 32, 135–152.

Ney, J.J., 1993. Bioenergetics modeling today: growing pains on the cutting edge. Trans. Am. Fish. Soc. 122, 736–748.

Niklitschek, J.E., 2001. Bioenergetics modeling and assessment of suitable habitat for juvenile Atlantic and shortnose sturgeons (*Acipenser oxyrinchus* and *A. brevirostrum*) in the Chesapeake Bay. Dissertation. University of Maryland at College Park, Marine Estuarine Environmental Science Program. College Park, MD. 262 pp.

Niklitschek, E., Secor, D.H., 2005. Modeling spatial and temporal variation of suitable nursery habitats for Atlantic sturgeon in the Chesapeake Bay. Estuar. Coast. Shelf Sci. 64, 135–148.

Niklitschek, E., Secor, D.H., 2009. Dissolved oxygen, temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon in estuarine waters: I. Laboratory results. J. Exp. Mar. Biol. Ecol. 381, S150–S160 (this issue).

Nilsson, G.E., Östlund-Nilsson, S., 2008. Does size matter for hypoxia tolerance in fish? Biol. Rev. 83, 173–189.

Pedersen, C.L., 1987. Energy budgets for juvenile rainbow trout at various oxygen concentrations. Aquaculture 62, 289–298.

Peters, D.S., Boyd, M.T., 1972. The effect of temperature, salinity, and availability of food on the feeding and growth of the hogchoker, *Trinectes maculatus* (Bloch & Schneider). J. Exp. Mar. Biol. Ecol. 7, 201–207.

Qian, X., Cui, Y., Xiong, B., Xie, S., Zhu, X., Yang, Y., 2001. Spontaneous activity was unaffected by ration size in Nile tilapia and gibel carp. J. Fish Biol. 58, 594–598.

Rennie, M.D., Collins, N.C., Shuter, B.J., Rajotte, J.W., Couture, P., 2005. A comparison of methods for estimating activity costs of wild fish populations: more active fish observed to grow slower. Can. J. Fish. Aquat. Sci. 62, 767–780.

Rice, J.A., Cochran, P.A., 1984. Independent evaluation of a bioenergetics model for largemouth bass. Ecology 65, 732–739.

Ron, B., Shimoda, S.K., Iwama, G.K., Grau, E.G., 1995. Relationships among ratio, salinity, 17alpha-methyltestosterone and growth in the euryhaline tilapia, *Oerochromis mossambicus*. Aquaculture 135, 185–193.

Rubio, V.C., Sanchez-Vazquez, F.J., Madrid, J.A., 2005. Effects of salinity on food intake and macronutrient selection in European sea bass. Physiol. Behav. 85, 333–339.

SAS Institute, 2004. SAS/STAT 9.1 User's Guide, Volumes 1–7. SAS Institute, Cary, North Carolina.

Secor, D.H., 1999. Specifying divergent migrations in the concept of stock: the contingent hypothesis. Fish. Res. 43, 13–34.

Secor, D.H., Gunderson, T.E., 1998. Effects of hypoxia and temperature on survival, growth, and respiration of juvenile Atlantic sturgeon *Acipenser oxyrinchus*. Fish. Bull. 96, 603–613.

Secor, D.H., Niklitschek, J.E., 2002. Sensitivity of sturgeons to environmental hypoxia: physiological and ecological evidence. Fish Physiology, Toxicology, and Water Quality, Sixth International Symposium. Environmental Protection Agency Office of Research and Development, Ecosystems Research Division, Athens, Georgia., La Paz, Mexico, pp. 61–78.

Sirois, P., Boisclair, D., 1995. The influence of prey biomass on activity and consumption rates of brook trout. J. Fish Biol. 46, 787–805.

Stevenson, J.T., Secor, D.H., 1999. Age determination and growth of Hudson River Atlantic sturgeon, *Acipenser oxyrinchus*. Fish. Bull. 97, 153–166.

Stewart, D.J., Kitchell, J.F., Crowder, L.B., 1981. Forage fishes and their salmonid predators in Lake Michigan. Trans. Am. Fish. Soc. 110, 751–763.

Stierhoff, K.L., Targett, T.E., Miller, K., 2006. Ecophysiological responses of juvenile summer and winter flounder to hypoxia: experimental and modeling analyses of effects on estuarine nursery quality. Mar. Ecol. Prog. Ser. 325, 255–266.

Swanson, C., 1998. Interactive effects of salinity on metabolic rate, activity, growth and osmoregulation in the euryhaline milkfish (*Chanos chanos*). J. Fish Biol. 201, 3355–3366.

Thornton, K.W., Lessem, A.S., 1978. A temperature algorithm for modifying biological rates. Trans. Am. Fish. Soc. 107, 284–287.

van Dam, A.A., Pauly, D., 1995. Simulation of the effects of oxygen on food consumption and growth of Nile tilapia, *Oreochromis niloticus* (L.). Aquac. Res. 26, 427–440.

Werner, E.E., Mittelbach, G.G., Hall, D.J., Gilliam, J.F., 1983. Experimental tests of optimal habitat use in fish: the role of relative habitat profitability. Ecology 64, 1525–1539.

Winberg, G.G., 1956. Rate of Metabolism and Food Requirements of Fishes. Belorussian State University, Minsk. (Transl. by Fish. Res. Board. Can. Transl. Ser. No. 194, 1960), Minsk.

Woodland, R.J., Secor, D.H., Niklitschek, E.J., 2009. Response of nursery habitat of an endangered population of shortnose sturgeon to changes in dissolved oxygen and temperature. American Fisheries Society Symposium 69, 589–604.

Wuenschel, M.J., 2002. Bioenergetics of larval and juvenile spotted seatrout (*Cynoscion nebulosus*). Dissertation. State University of New York, College of Environmental Science and Forestry. Syracuse, NY. 201 pp.

Wuenschel, M.J., Jugovich, A.R., Hare, J.A., 2004a. Effect of temperature and salinity on the energetics of juvenile gray snapper (*Lutjanus griseus*): implications for nursery habitat value. J. Exp. Mar. Biol. Ecol. 312, 333–347.

Wuenschel, M.J., Werner, R.G., Hoss, D.E., 2004b. Effect of body size, temperature, and salinity on the routine metabolism of larval and juvenile spotted seatrout. J. Fish Biol. 64, 1088–1102.

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SENSITIVITY OF STURGEONS TO ENVIRONMENTAL HYPOXIA: A REVIEW OF PHYSIOLOGICAL AND ECOLOGICAL EVIDENCE

D.H. Secor[1] and E.J. Niklitschek[2]

ABSTRACT

In this essay, three lines of evidence are developed that sturgeons in the Chesapeake Bay and elsewhere are unusually sensitive to hypoxic conditions: 1. In comparison to other fishes, sturgeons have a limited behavioral and physiological capacity to respond to hypoxia. Basal metabolism, growth, feeding rate, and survival are sensitive to changes in oxygen level, which may indicate a relatively poor ability of sturgeons to oxyregulate. 2. During summertime, temperatures >20°C amplify the effect of hypoxia on sturgeons and other fishes due to a temperature oxygen "squeeze" (Coutant 1987). In bottom waters, this interaction results in substantial reduction of habitat; in dry years, sturgeon nursery habitats in the Chesapeake Bay may be particularly reduced or even eliminated. 3. While evidence for population level effects due to hypoxia is circumstantial, there are corresponding trends between the absence of Atlantic sturgeon reproduction in estuaries like the Chesapeake Bay where summertime hypoxia predominates on a system-wide scale. Also, the recent and dramatic recovery of shortnose sturgeon in the Hudson River (4-fold increase in abundance from 1980 to1995) may have been stimulated by improvement of a large portion of the nursery habitat that was restored from hypoxia to normoxia during the period 1973-1978.

INTRODUCTION

Sensitivity by sturgeons and other fishes to temperature, oxygen and their interaction is evaluated experimentally through respirometry. As an example, the basal metabolism of the stellate sturgeon *Acipenser stellatus*, measured over a range of temperatures and oxygen levels, increases with temperature, but is only affected by oxygen at lower oxygen levels, above which there is little response (Figure 1). The point of inflection in the curve of metabolic response to dissolved oxygen (DO) is called the critical concentration. Oxygen levels below that point will constrain metabolism, growth, swimming activity, and feeding rate (Fry 1971, Chiba 1988, Kaufmann and Wieser 1992). As basal metabolism increases due to increased temperature, the critical concentration becomes higher (Figures 1-3). In other words, as basic metabolic requirements increase with temperature, so too will oxygen demand. This increase in oxygen demand will outpace increased oxygen availability at higher temperatures due to decreased oxygen solubility.

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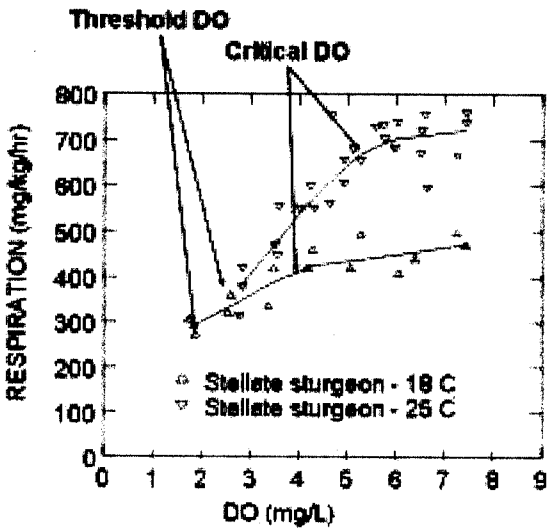

Figure 1. Basal metabolic responses of young-of-the-year stellate sturgeon (*A. stellatus*). Data from Winberg 1956, Figure 20. Critical DO is specified as the inflection point indicating the point of metabolic responsiveness. Threshold DO indicates lethality where basal metabolism can no longer be maintained.

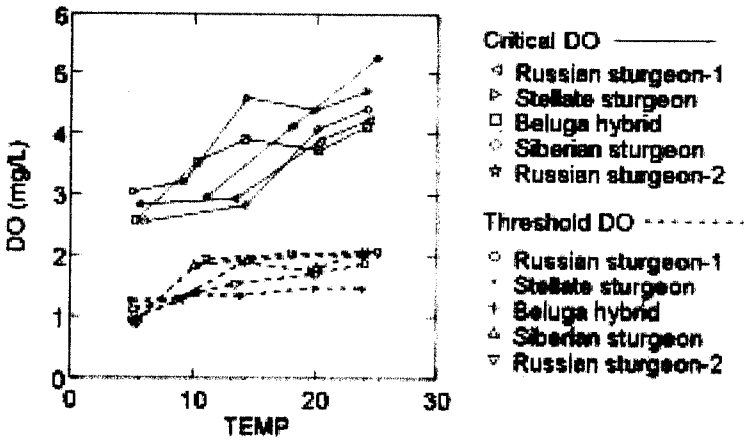

Figure 2. Critical and Threshold DO concentrations for Eurasian sturgeons (*A. gueldenstaedtii, A. stellatus, H. huso X A.ruthensus, A. baeris*) as a function of temperature. Data from Klyashtorin 1976, Figure 3 (DO levels were recalculated from partial pressures to concentration). Critical DO is specified as the inflection point indicating the point of metabolic responsiveness. Threshold DO indicates lethality where basal metabolism can no longer be maintained. Russian sturgeon-1 and Russian sturgeon-2 designate two separate experiments. All data are for young-of-the-year stage sturgeons.

At very low oxygen concentrations, metabolism decreases rapidly to nil and the fish dies. This is termed the threshold concentration (Figures 1-3). Both critical and threshold concentrations were substantially higher for sturgeons in comparison to freshwater fishes (Figure 3). Critical concentrations for Eurasian sturgeons (*A. güldenstädtii, A. baeri, A. stellatus* and the hybrid *Huso huso x A. ruthensus*) ranged between 25-60% saturation, increasing with temperature. At 20°C, critical concentration was 3.6 mg/L (42% saturation) (Figures 2,3), which was ca. 20% higher than that reported for rainbow trout. At 24°C, critical concentration was 4.5 mg/L (54% saturation) for the Eurasian sturgeons. The heightened sensitivity of metabolism to oxygen levels may be characteristic of sturgeons, and has been ascribed to an inefficiently functioning oxyregulatory system. Klyashtorin (1982) concluded that ancestral morphological and physiological traits caused sturgeons to be less efficient in respiration than other fishes. These traits included less efficient gill ventilation, low cardiac performance (Agnisola *et al.* 1999), and lower affinity of hemoglobin to oxygen.

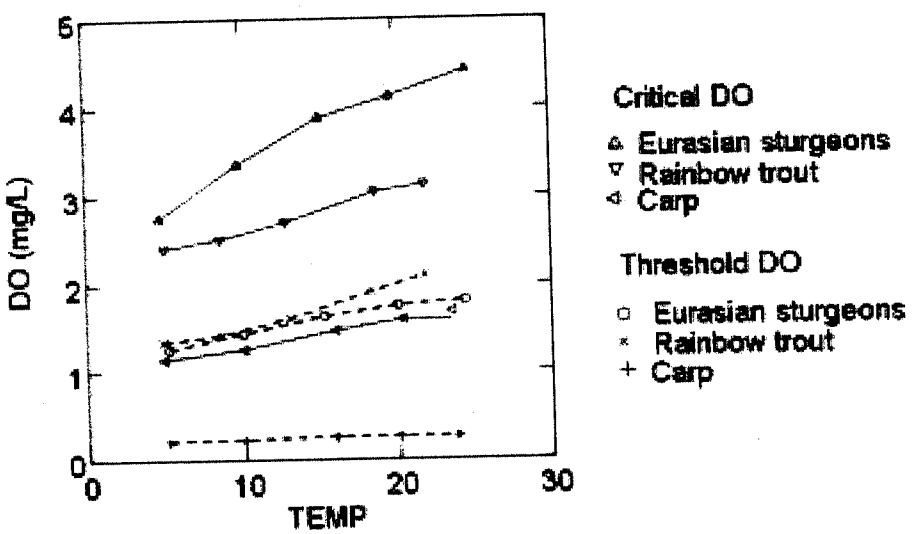

Figure 3. Critical and Threshold DO concentrations for various fish species. Data from Klyashtorin 1976, Figure 6 (DO levels were recalculated from partial pressures to concentration). Critical DO is specified as the inflection point indicating the point of metabolic responsiveness. Threshold DO indicates lethality where basal metabolism can no longer be maintained. Data for Eurasian sturgeons represents a pooled mean response. All data are for young-of-the-year stage sturgeons, trout and carp.

In experiments on Atlantic and shortnose sturgeons *A. oxyrinchus* and *A. brevirostrum*, Niklitschek (2001) observed substantial reductions in routine metabolism, consumption, feeding metabolism, growth, and survival at 40% vs. 70% DO (Figures 4-6). Again the effect of oxygen level was conditional on temperature. In comparison to normoxia at 20°C, 40% DO saturation

(3.3 mg/L) yielded a 33% and 30% reduction in growth, a 29% and 27% reduction in consumption, and a 23% and 17% reduction in routine metabolism, for Atlantic and shortnose sturgeons, respectively. At 27°C and 40% saturation (2.9 mg/L), there was 77% and 69% reduction in growth, a 38% and 45% reduction in consumption, and a 28% and 21% reduction in routine metabolism for Atlantic and shortnose sturgeon, respectively. Because routine metabolism was investigated rather than basal metabolism, estimates of critical DO concentrations were not possible. In a separate laboratory study, Secor and Gunderson (1998) reported 2- and 4-fold reductions in growth rate due to hypoxia at 26 and 19°C, respectively.

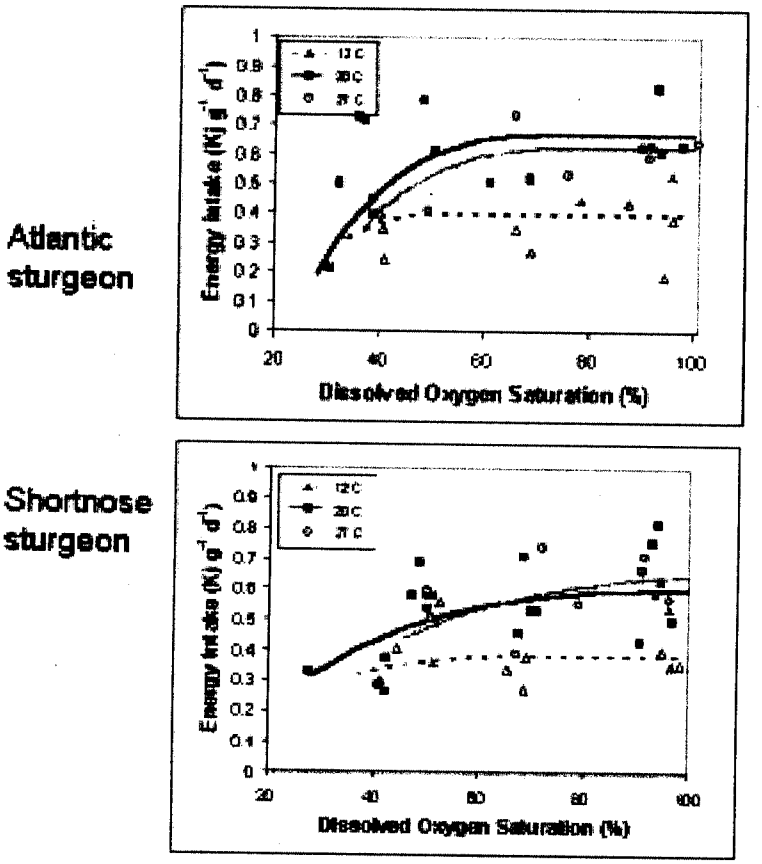

Figure 4. Effect of DO and temperature on consumption by Atlantic and shortnose sturgeon young-of-the-year. 10-d laboratory experiments conducted by Niklitschek (2001).

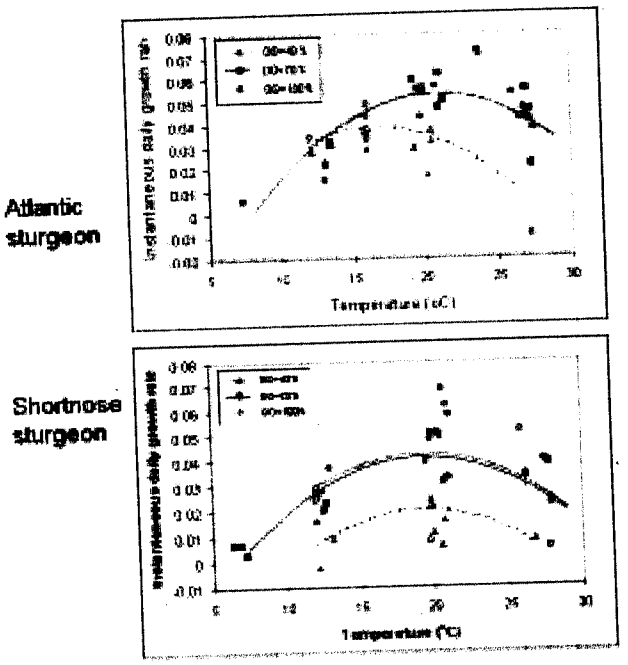

Figure 5. Effect of DO and temperature on growth of Atlantic and shortnose sturgeon young-of-the-year. 10-d laboratory experiments conducted by Niklitschek (2001).

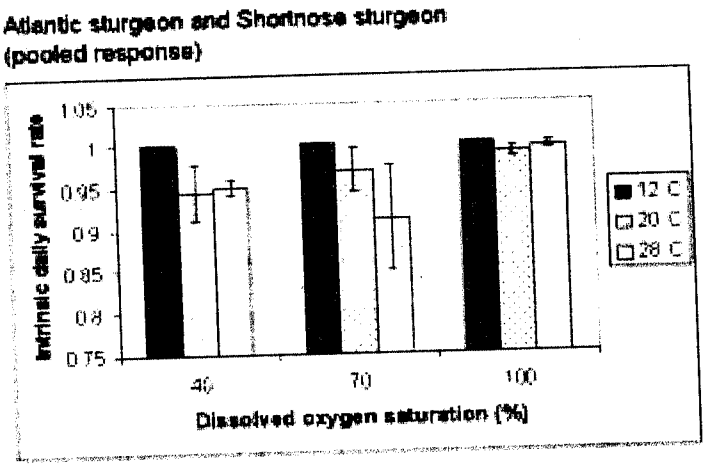

Figure 6. Effect of DO and temperature on long-term survival (20-45 d trials) of Atlantic and shortnose sturgeon young-of-the-year. Laboratory experiments conducted by Niklitschek (2001). Bars represent standard errors.

Few studies have addressed lethal effects of hypoxia on sturgeons (Table 1). Jenkins *et al.* (1994) observed 86 - 100% mortality for 25-64 day old fish in an acute 6 hr exposure to 2.5 mg/L DO at 22.5°C (30% saturation). Older juveniles (100-310 days old) experienced 12-20 % mortality under the same conditions. Short-term exposure to 3.0 mg/L (35% saturation) resulted in 18-38% mortality for juveniles 20-77 days in age. No mortality was observed for exposures to > 3.5 mg/L (42% saturation). Long term exposure (10 days) of Atlantic sturgeon young-of-the-year juveniles (150-200 days old) to hypoxia at 26°C (37%-44% DO saturation; 2.8 - 3.3 mg/L) resulted in complete mortality over the ten day period in three of four replicates (Secor and Gunderson 1998). The fourth replicate experienced 50% mortality. At 20°C and hypoxia at 27%-37% saturation (2.3 - 3.2 mg/L), the latter researchers observed 12-25% mortality. No mortality was observed for normoxic treatments. In preliminary experiments, Niklitschek (2001) observed lethality for young-of-the-year Atlantic and shortnose sturgeon reared at 30% oxygen saturation (27°C; 2.35 mg/L) for 24 hours. Thus, he selected 40% saturation to observe sub-lethal physiological effects and avoid loss and suffering of experimental animals. At this "sub-lethal" level (2.8 mg/L at 28°C; 3.3 mg/L at 20°C), daily survival rates were significantly reduced in comparison to survival under normoxia (Figure 6). Threshold oxygen levels (levels below which basal metabolism cannot be sustained) reported for Eurasian sturgeons occurred at 1.7-2.0 mg/L (25% saturation) for temperatures 20-24°C (Figure 2; Klyashtorin 1975). At 20°C, threshold oxygen concentrations were about 20% higher for rainbow trout than for Eurasian sturgeons, but at temperatures less than 18°C, threshold values were similar between the sturgeon and rainbow trout (Figure 3).

In a direct comparison between juvenile white sturgeon and striped bass, the bass growth rate was substantially more depressed under hypoxia than that for the white sturgeon *A. transmontanus* (Cech *et al.* 1984). Sturgeon growth rates under hypoxia (90 torr ~ 4.5 mg/L) and temperatures 20-25°C were 20-25% lower than those under normoxia (130 torr ~ 7 mg/L). Striped bass reared under identical conditions experienced an additional 7-9% growth rate depression under hypoxia. During the 34-day long experiment, higher mortalities of both species occurred under relatively mild hypoxia in comparison to normoxic treatments.

Beyond metabolic response, sturgeons undertake other physiological and behavioral responses to hypoxia. Niklitschek (2001) observed that egestion levels for Atlantic and shortnose sturgeon juveniles increased significantly under hypoxia, indicating that consumed food was incompletely digested. This response could serve as a useful means to shunt energy towards respiration and other life support functions. Behavioral studies indicate that Atlantic sturgeon and shortnose sturgeon are quite sensitive to ambient conditions of oxygen and temperature. In a series of choice experiments, juvenile sturgeons consistently selected normoxic over hypoxic conditions (Figure 7; Niklitschek 2001). On the other hand, larval stage Siberian sturgeon *A. baeri* did not actively avoid or disperse from experimental hypoxic conditions (2-3 mg/L at 19°C; Khakimullin 1988). Beyond escape or avoidance, sturgeons respond to hypoxia (< 40% saturation) through increased ventilation, increased surfacing (to ventilate relatively oxygen-rich surficial water), and decreased swimming and routine metabolism (Nonnette *et al.* 1993, Croker and Cech 1997, Secor and Gunderson 1998, Niklitschek 2001). Historically, sturgeons were at

Table 1. Results of lethality experiments on shortnose sturgeon and Atlantic sturgeon.

Species and test temperature	Age (days)	D.O. (mg/L)	Survival rate (%)	Reference and comments
Shortnose, 22.5°C	46	2.0	8	Ref. (a) Fig. 2, mean of 6 replicates, 6-hour test
	110	2.0	78	
	25	2.5	0	
	32	2.5	3	
	64	2.5	14	
	104	2.5	88	
	20	3.0	62	
	39	3.0	82	
	77	3.0	67	
	103	3.0	100	
	19	3.5	78	
	90	3.5	100	
Atlantic, 26°C	150-200	2.8-3.3	12.5	Ref. (b) Mean of 4 replicates, 10-day test, 4 tanks open to air
Atlantic, 20°C	150-200	2.3-3.2	78	Ref. (b) Mean of 4 replicates, 10-day test, 2 tanks were sealed and 2 tanks were open to air
Atlantic, 20-26°C	150-200	> 5.0	100	Ref. (b)

(a) Jenkins *et al.* 1993 (b) Secor and Gunderson 1998

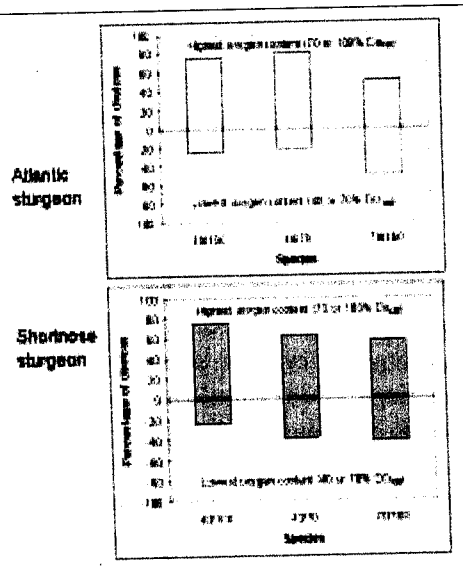

Figure 7. Selection of hypoxia (40% saturation) over normoxia (70 or 100% saturation) by Atlantic and shortnose sturgeon young-of-the-year based on experiments conducted by Niklitschek (2001). Positive % of choices indicates selection of higher DO, negative % indicates selection of lower DO level.

the center of a debate on whether or not fishes could oxyconform to hypoxia: that is, could fish tolerate declines in dissolved oxygen delivery to their tissues? (Burggren and Randall 1978, Klyashtorin 1982, Nonnette *et al.* 1993). Oxyregulation by the typical vertebrate mechanism of anaerobic metabolism has since been demonstrated for sturgeons (Nonnette *et al.* 1993, McKenzie *et al.* 1995), providing evidence against physiological oxyconformity. Still, behavioral means to oxyregulate in sturgeons may be relatively more important since critical concentrations are higher for sturgeons than other teleosts (Klyashtorin 1982). As evidence of this, white sturgeon juveniles were 3- to 9-fold less active under hypoxia (80 mm Hg ~ 5 mg/L or 50% saturation at 16°C) than under normoxia (Croker and Cech 1997). Secor and Gunderson (1998) observed that lethality to hypoxia increased when surfacing behavior was blocked.

In summary, sturgeons endemic to the Chesapeake Bay, and sturgeons in general, are unusually sensitive to hypoxia in terms of their metabolic and behavioral responses. The critical concentration at which sturgeons metabolically respond to dissolved oxygen is higher or similar to that of rainbow trout. Bioenergetic and behavioral responses indicate that young-of-the-year juveniles (~30 to 200 days old) will experience lost production in those habitats with less than 60% oxygen saturation. For summertime temperatures (22-27°C), this level corresponds to dissolved oxygen concentrations of 4.3 - 4.7 mg/L DO. Acute and chronic lethal effects for shortnose and Atlantic sturgeon were observed at levels of 3.3 mg/L at summertime temperatures. Threshold concentrations for Eurasian sturgeons were somewhat lower, ranging between 1.7 and 2.0 mg/L for temperatures 20-24°C.

A Habitat Squeeze for Chesapeake Bay Sturgeons?

Coutant and Benson (1990) proposed that habitats of Chesapeake Bay striped bass were severely curtailed during summer months due to thermal preference compounded by hypoxia. During summer, striped bass adults select narrow lenses within the water column characterized by < 25°C water and normoxia (Cheek *et al.* 1985). In many instances, it was expected that such summertime refugia would curtail prey availability and growth. Coutant's concept, known popularly as the "habitat squeeze," was a prevailing hypothesis to describe the decline of striped bass during the 1980s. Using bioenergetic models (Hartman and Brandt 1995), Brandt and Kirsch (1993) mapped habitat suitability for striped bass in the Chesapeake Bay, and predicted substantial habitat restrictions in summer, leading to negative or static growth during the summer months.

Sturgeons are particularly vulnerable to a habitat squeeze (*i.e.*, synergism between temperature and dissolved oxygen effects on habitat availability) due to their demersal lifestyle and unique bioenergetic responses to hypoxia. While sturgeons do occasionally surface, they depend almost exclusively on benthic substrates and bottom waters for spawning, feeding, migration, and refuge from predation or stressful environments (*e.g.* flow and temperature refugia). Their specialized underslung jaw, diets, electrosensory and olfactory systems, poor vision, body form, and heterocercal tail are but a few features that attest to their demersal lifestyle (Burggren 1978, Bemis and Kynard 1997, Carlson and Simpson 1987, Haley 1999, Secor *et al.* 2000). Atlantic sturgeons are known to occur at depths between 1 m to greater than 25 m; shortnose sturgeons have been observed between 1 and 12 m (Kieffer and Kynard 1997, Savoy

and Shake 2000, Welsh *et al.* 2000). In the Chesapeake Bay during winter, Atlantic sturgeon select deeper habitats occurring in the deep channel (Secor *et al.* 2000, Welsh *et al.* 2000). Thus, sturgeons are not limited by bathymetry within the Bay and would be expected to utilize sub-pychnocline waters contingent upon water quality.

In dissertation research, Niklitschek (2001) developed spatially explicit bioenergetic models for Chesapeake Bay sturgeons to evaluate the influences of water quality on sturgeon habitats. This is appropriate for sturgeons because opportunities to directly observe habitat use is curtailed given their threatened or extirpated status. Habitat value was assigned based upon expected growth and survival responses, predicted by a bioenergetics model filtered through Chesapeake Bay Program Monitoring data (1990-1999). Potential production rates for young-of-the-year Atlantic and shortnose sturgeons in the Chesapeake Bay reflected the strong seasonal cycle in potential production driven by the interaction of temperature, salinity and dissolved oxygen. Summer represented the most critical season in which hypoxia and high temperature conditions caused severe habitat fragmentation for both species, restricting suitable habitat to a small fraction of the Bay (Figure 8). Negative potential production areas closely mirrored hypoxic regions occurring in the middle mainstem, as well as the lower Patuxent, Potomac and Rappahannock rivers, major tributaries on the western shore of the Chesapeake Bay. Negative production areas were also predicted near the Bay mouth where very high salinities masked the otherwise improved conditions of dissolved oxygen and temperature. As a result, null or positive production was restricted to very limited areas that coincide only in part between the two sturgeon species.

For Atlantic sturgeon, summer refuges for an average year were restricted to the upper Bay between the Magothy River and the Susquehanna Flats. Slightly negative areas were expected around Fishing Bay-Nanticoke River, between the Severn and Choptank rivers and in the upper Potomac River. For shortnose sturgeon, most of the suitable habitat in the mainstem would be restricted to the Bay head above the Sassafras River. Other areas of positive production included the upper sections of the Potomac and James rivers, as well as most of the Nanticoke River. The total area supporting positive production (suitable habitat) under average July conditions corresponded to 1,586 and 1,076 km^2, for Atlantic and shortnose sturgeons, respectively. These surface areas represent only 8.5% and 5.8% of the total surface area of the Bay mainstem and tidal sections of its tributaries, respectively. The best summer condition for both sturgeons was predicted for 1996, where suitable habitat reached circa 4,200 km^2 for Atlantic sturgeon and 2,050 km^2 for shortnose sturgeon. In 1996, average temperature and salinity were the second lowest in the study period and the average dissolved oxygen conditions were above the study period average. This year also exhibited the highest July freshwater inflow of the study period. The worst conditions for Atlantic sturgeon were observed in July 1999, where suitable habitat was down to about 1 km^2. Also in 1999, overall salinity was the highest in the study period time series. This higher than usual salinity reduced the habitat value of the upper Bay section, which is typically the most productive section of the Chesapeake Bay due to its favorable temperature and oxygen conditions.

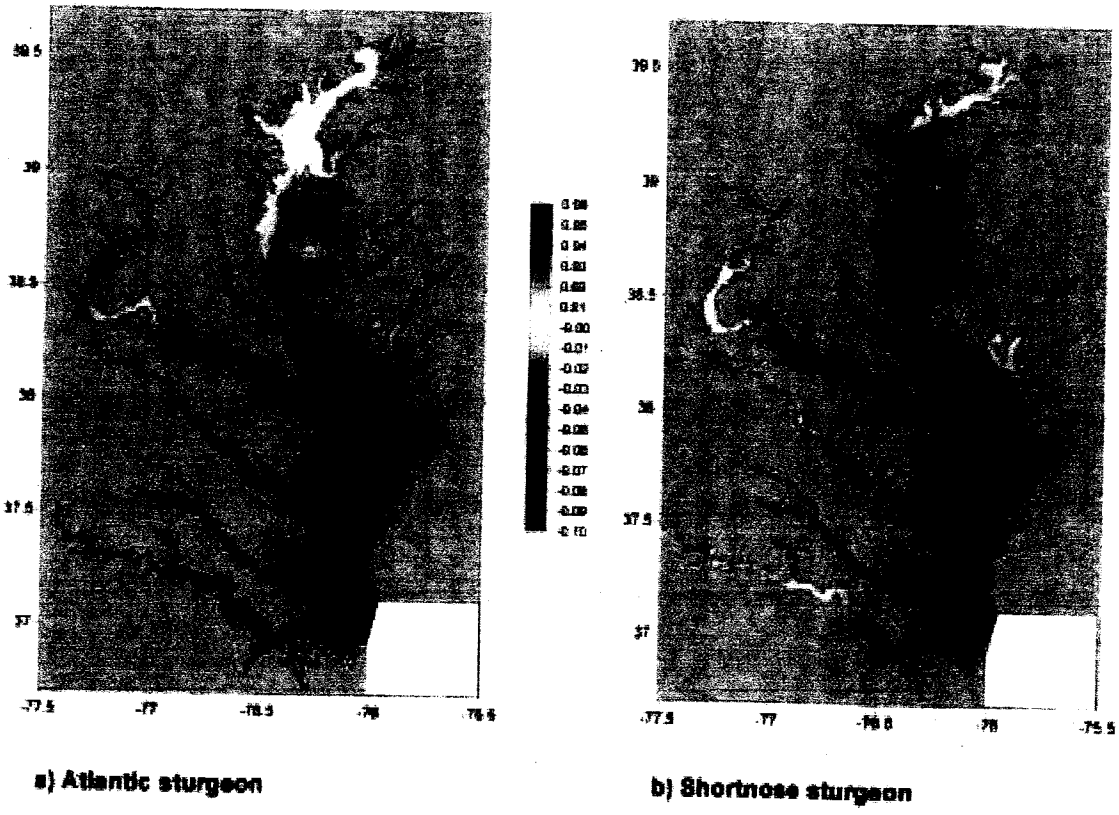

Figure 8. Spatially explicit maps of habitat suitability (potential production) by Atlantic and shortnose sturgeon young-of-the-year in the Chesapeake Bay during July (1990-1999). From Niklitschek (2001).

In summary, due to avoidance, sub-lethal, or lethal effects sturgeon summertime habitats are expected to be restricted in comparison to historical times when hypoxia was less prevalent (Officer *et al.* 1984, Cooper *et al.* 1991). The habitat squeeze phenomenon is particularly relevant to sturgeons due to the synergism of temperature, dissolved oxygen and salinity effects during their first year of life. In dry years, the interaction of high salinity, warm temperatures, and hypoxic waters in summer severely reduces sturgeon habitats and in some years can virtually eliminate all habitats for Atlantic sturgeon. The fragmented distribution and small volume of productive habitats imposed by summertime hypoxia represents a substantial hurdle to overcome in the restoration of Chesapeake Bay sturgeons.

Chesapeake Bay Sturgeons: Where Are They Now?

Shortnose sturgeon is in all probability extirpated from the Chesapeake Bay. Shortnose sturgeon recently observed in the region of Susquehanna flats and in the Potomac River have been confirmed to be immigrants from the Delaware Bay population, presumably having migrated through the C&D Canal (Grunwald *et al.* in review). The status of Atlantic sturgeon in the Chesapeake Bay is less certain (Grogan and Boreman 1998). There has been no evidence of reproduction in the Maryland portion of the Chesapeake Bay for over 25 years (Secor 1995). Recently, evidence of reproduction (capture of young-of-the-year Atlantic sturgeon) occurred for the York and Rappahannock Rivers (NMFS 1998). Based upon historical catch data, Secor (2000) estimated that 19th century adults may have numbered > 100,000 in the Chesapeake Bay. Their numbers were decimated by over-exploitation at the turn of the 19th century. During the past 100 years, there has been no evidence of recovery.

Secor and Gunderson (1998) hypothesized that due to their unusual sensitivity to hypoxia, Atlantic sturgeon may have been extirpated from Maryland Bay waters due, in part, to the increased prevalence of hypoxia in the 20th century. Atlantic sturgeon populations recovered in South Carolina estuaries and in the Hudson River following relief from the intensive 19th century fishing (Smith *et al.* 1985, NMFS 1998), but not in the Chesapeake Bay. Secor (2000) recorded that cycles of overfishing and recovery for this species occur over a 50-year period. Prevalence of hypoxia increased in critical habitats of sturgeons due to post-WWII agricultural practices (synthetic fertilizers) and residential development (increased wastewater). These factors may have curtailed any 20th century cycle of recovery within the Chesapeake Bay. There are also other important factors that may have prevented recovery, including lost spawning grounds due to siltation and reductions in abundance due to incidental catch (there has been no directed fishery for sturgeons in over a century in the Chesapeake Bay). Circumstantial evidence for a relationship between increased hypoxia and loss of sturgeons this past century includes the absence of sturgeons in systems that are prevalently hypoxic in summer (Collins *et al.* 2000).

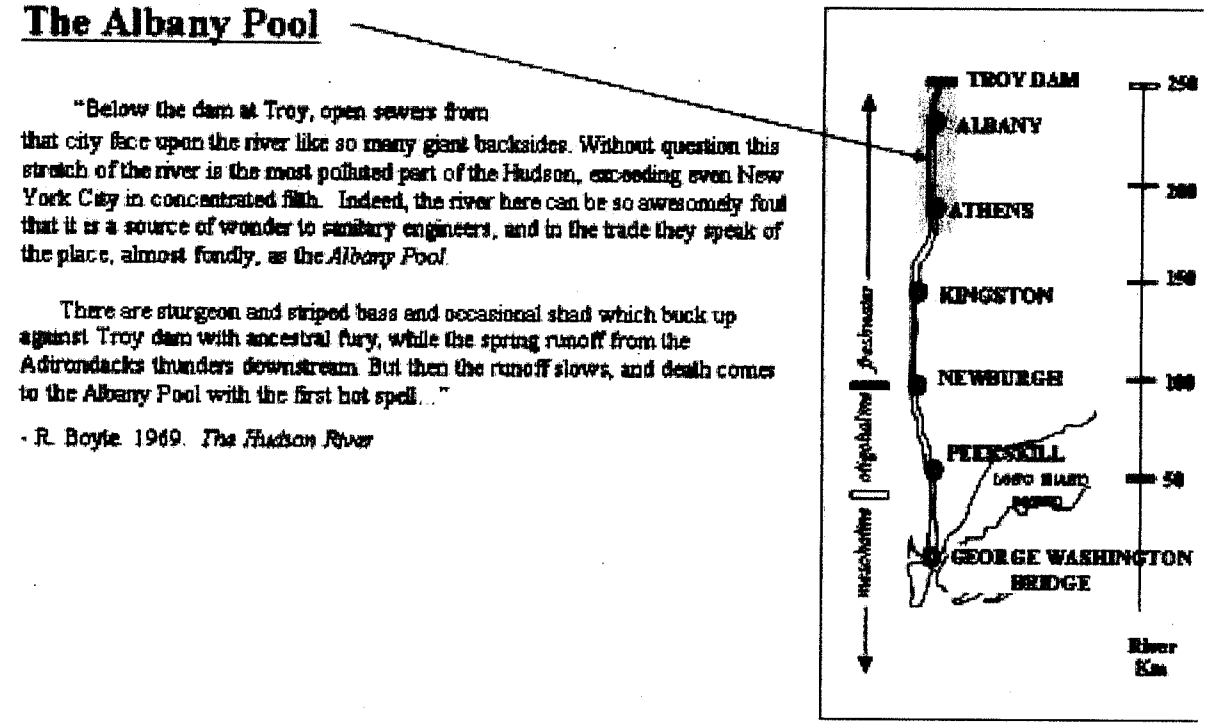

Figure 9. Region of persistent hypoxia known as the Albany Pool in the Hudson River. This region overlaps broadly with shortnose sturgeon nursery habitat that occurs throughout the freshwater tidal reach of the estuary.

The recent recovery of shortnose sturgeon abundance in the Hudson River is also consistent with the idea that hypoxia may be important in controlling sturgeon populations. Bain *et al.* (2000) has compared mark-recapture population estimates for the period 1980 - 1995. During this period, sub-adult and adult shortnose sturgeon increased from about 13,000 to 57,000 - a four-fold increase in abundance! This yields a population growth rate of 10% per year that is remarkably high for a long-lived, late maturing species such as shortnose sturgeon. Prior to 1974, a pervasive hypoxic/anoxic summertime region known as the "Albany Pool" (Figure 9) overlapped approximately 40% of the expected nursery habitat for shortnose sturgeon (*i.e.* 40% of the tidal freshwater area of the Bay). Levels of pervasive hypoxia there (<30% saturation) would have been lethal to shortnose sturgeon juveniles (Figures 10, 11). Few fish, sturgeon or otherwise, were documented in the in the 60 km river stretch of the "Albany Pool" during July - October (Leslie *et al.* 1988). In 1974, >80% of the region's wastewater began to receive secondary and tertiary treatment, and in less than two years the system recovered fully to normoxia (Figures 10, 11). Subsequent monitoring data has revealed a dramatic faunal recovery in the number of fish species returning to the Albany Pool region (Leslie *et al.* 1988). In 1983, a relatively strong year-class (high abundance of juveniles) was reported by two independent studies (Carlson and Simpson 1987, Dovel *et al.* 1992). Such year-classes may have stimulated recovery of Hudson River shortnose sturgeon during the past 20 years.

In summary, absence or diminished populations of sturgeons correspond to systems where summertime hypoxia is prevalent. Recovery of normoxia to the Hudson River estuary corresponded with a remarkable recovery of shortnose sturgeon there. These case studies provide circumstantial evidence that summertime hypoxia might substantially diminish population recovery or perhaps even lead to extirpation. Sturgeons represent the only resource species in the Chesapeake Bay that is threatened or extinct. Future recovery of sturgeons coincident with improved water quality in the Chesapeake Bay would be a quite a success story.

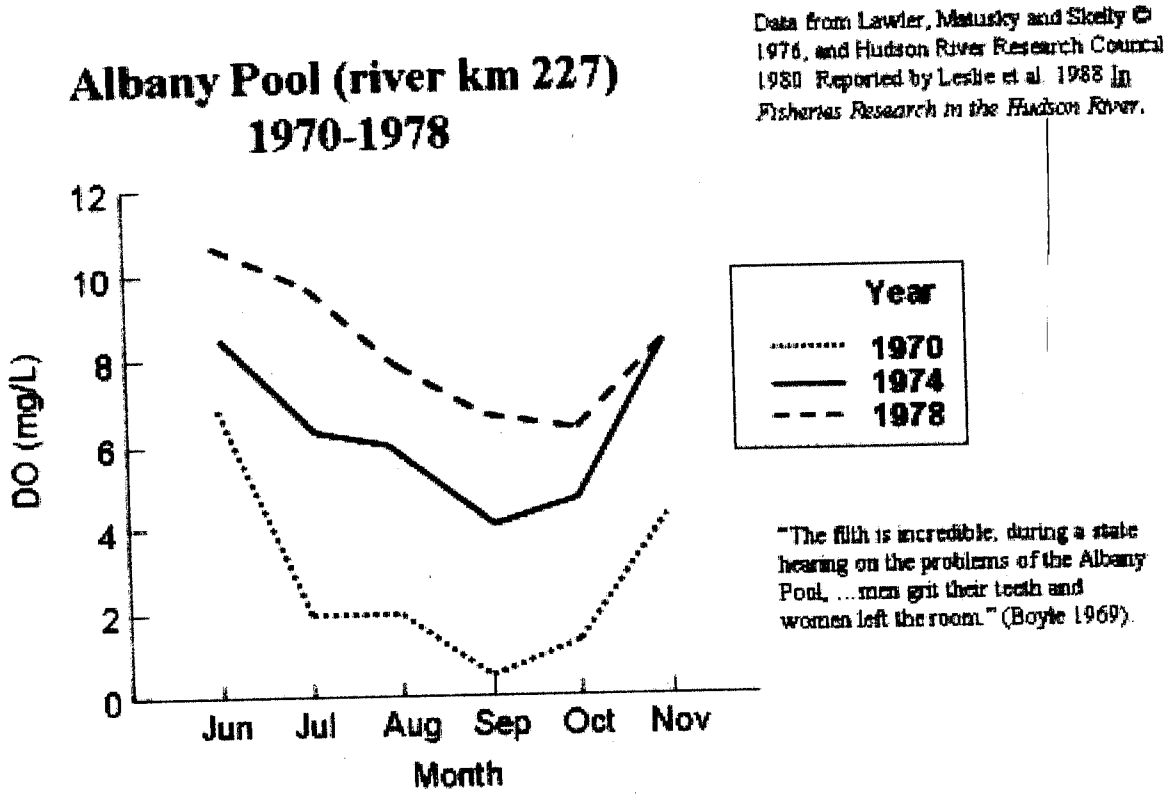

Figure 10. DO levels for an "Albany Pool" station during summer and fall months.

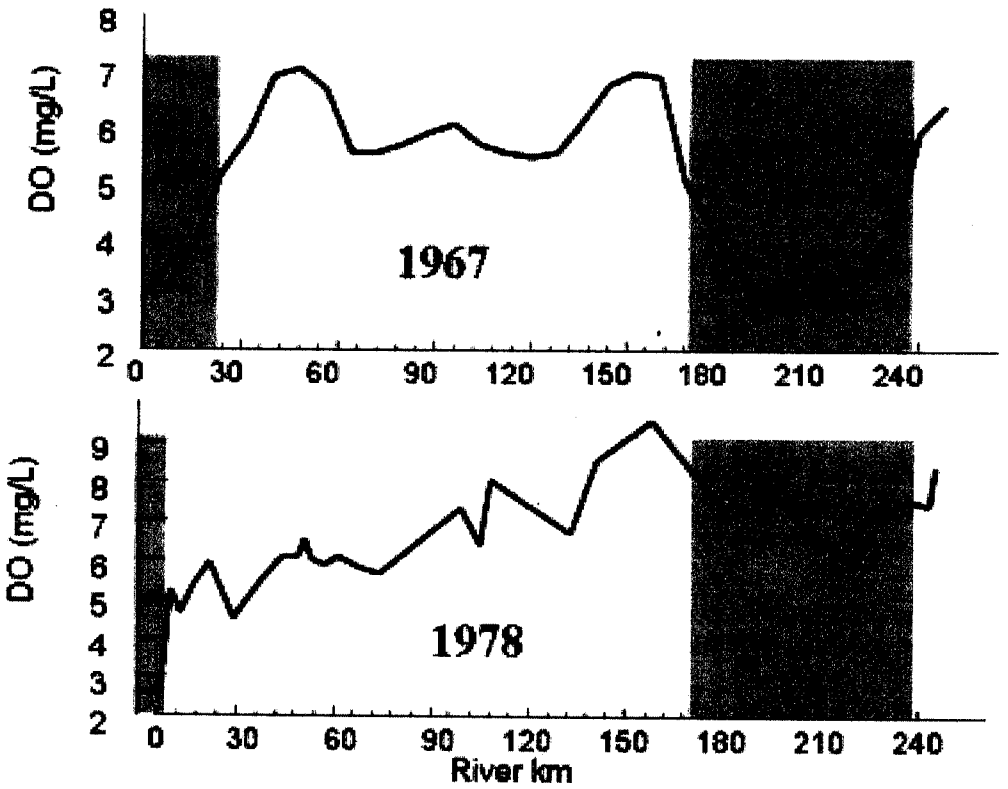

Figure 11. DO levels throughout the Hudson River estuary before (1967) and after (1978) system recovery from hypoxia. The "Albany Pool" region upriver is shown in gray, the NY City effect area in gray at the mouth.

REFERENCES

Agnisola, C., D.J. McKenzie, D. Pellegrino, P. Bronzi, B. Tota, and E.W. Taylor. 1999. Cardiovascular responses to hypoxia in the Adriatic sturgeon (*Acipenser naccarii*). Journal of Applied Ichthyology 15: 67-72.

Bain, N.B., N. Haley, D.L. Peterson, K.K. Arend, K.E. Mills, and P.J. Sullivan. 2000. Shortnose sturgeon of the Hudson River: an Endangered Species recovery story. Biology, Management and Protection of Sturgeon Symposium Pre-Print. EPRI. Palo Alto, California, USA.

Barrowman, T.M. and M.L. O'Shea. 1996. Long-term improvements in water quality due to sewage abatement in the Lower Hudson River. Estuaries 19: 890-900.

Bemis, W.E. and B. Kynard. 1997. Sturgeon rivers: an introduction to acipenseriform biogeography and life history. Environmental Biology of Fishes 46: 167-183.

Boyle, R.H. 1969. The Hudson River; a natural and unnatural history. Norton, New York. pp. 304.

Brandt, S.B. and J. Kirsch. 1993. Spatially explicit models of striped bass growth potential in Chesapeake Bay. Transactions of American Fisheries Society 122: 845-869.

Burggren, W.W. and D.J. Randall. 1978. Oxygen uptake and transport during hypoxic exposure in the sturgeon *Acipenser transmontanus*. Respiration Physiology 34: 171-183.

Carlson, D.M. and K.W. Simpson. 1987. Gut contents of juvenile shortnose sturgeon in the upper Hudson Estuary. Copeia 1987: 796-802.

Cheek, T.E., M.J. Van Den Avyle, and C.C. Coutant. 1985. Influence of water quality on distribution of striped bass in a Tennessee River impoundment. Transactions of American Fisheries Society 114: 67-76.

Chiba, K. 1988. The effect of dissolved oxygen on the growth of young striped bass. Nippon Suisan Gakkaishi 54: 599-606.

Claireaux, G. and J. Lagardere P. 1999. Influence of temperature, oxygen and salinity on the metabolism of the European sea bass. Journal of Sea Research 42: 157-168.

Collins, M.R. S.G. Rogers, T.I.J. Smith, and M.L. Moser. 2000. Primary factors affecting sturgeon populations in the southeastern United States. Fishing mortality and degradation of essential fish habitats. Bulletin of Marine Science 66: 917-928.

Cooper, S.R. and G.S. Brush. 1993. A 2,500-year history of anoxia and eutrophication in Chesapeake Bay. Estuaries 16: 617-626.

Coutant, C.C. 1987. Thermal preference: when does an asset become a liability. Environmental Biology of Fishes 18: 161-172.

Coutant, C.C. and D.L. Benson. 1990. Summer decline in habitat suitability for striped bass in Chesapeake Bay: reflections on a population decline. Transactions of American Fisheries Society 119: 757-778.

Crocker, C.E. and J.J. Chech. 1997. Effects of environmental hypoxia on oxygen consumption rate and swimming activity in juvenile white sturgeon, *Acipenser transmontanus*, in relation to temperature and life intervals. Environmental Biology of Fishes 50: 382-389.

Croker, C.E. and J.J. Cech. 1996. The effects of hypercapnia on the growth of juvenile white sturgeon, *Acipener transmontanus*. Aquaculture 147: 293-299.

Croker, C.E. and J.J. Cech. 1997. Effects environmental hypoxia on oxygen consumption rate and swimming activity in juvenile white sturgeon, *Acipenser transmontanus*, in relation to temperature and life intervals. Environmental Biology of Fishes 50: 383-389.

Dadswell, M. J. 1979. Biology and population characteristics of the shortnose sturgeon, *Acipenser brevirostrum* Le Seuer 1818 (Osteichthyes: Acipseridae), in the Saint John Estuary, New Brunswick, Canada. Canadian Journal of Zoology 57:2186-2210.

Dovel, W.L. and T.J. Berggren. 1983. Atlantic sturgeon of the Hudson Estuary, New York. New York Fish and Game Journal 30: 140-172.

Dovel, W.L., A.W. Pekovitch, and T.J. Berggren. 1992. Biology of the shortnose sturgeon (*Acipenser brevirostrum* LeSueur, 1818) in the Hudson River Estuary, New York,. *In* Estuarine Research in the 1980s. C.L. Smith (ed.).State University New York, Stony Brook, New York. pp. 187-227.

Fry, F. E. J. 1971. The effect of environmental factors on the physiology of fish. *In:* Fish Physiology.Volume VI. W. S. Hoar and D. J. Randall (eds.). Academic Press, New York. pp. 1-98.

Grogan, C. S., and J. Boreman. 1998. Determining the probability that historical populations of fish species are extirpated. North. American Journal of Fish Management 18:522-529.

Gross, MR, J. Repka, C. Robertson, D.H. Secor, and W. VanWinkle.2000. Conserving ancient fish: life history and demography of sturgeon. American Fisheries Society Symposium 28:13-30.

Grunwald, C., J. Stabile, J. R. Waldman, R. Gross, and I. I. Wirgin. In review. Population genetics of shortnose sturgeon, Acipenser brevirostrum, based on sequencing of the mitochondrial DNA control region. Molecular Ecology 11(10):1885-1898.

Haley, N.J. 1999. Habitat characteristics and resource use patterns of sympatric sturgeons in the Hudson River Estuary. M.S. Thesis, University of Massachusetts, Amherst, Massachusetts. 124 pp.

Hartman, K.J. and S.B. Brandt. 1995. Comparative energetics and the development of bioenergetics models for sympatric estuarine piscivores. Canadian Journal of Fisheries and Aquatic Science 52: 1647-1666.

Jenkins, W.E., T.I.J. Smith, L.D. Heyward and David M. Knott. 1995. Tolerance of shortnose sturgeon, Acipenser brevirostrum, juveniles to different salinity and dissolved oxygen concentrations. Proceedings Southeastern Association of Fish and Wildlife Agencies 47:476-484.

Hildebrand, S. F., and W. C. Schroeder. 1927. Fishes of the Chesapeake Bay. U.S. Bureau of Fisheries, Washington, D.C. 388 pp.

Kaufmann, R. and W. Wieser. 1992. Influence of temperature and ambient oxygen on the swimming energetics of cyprinid larvae and juveniles. Environmental Biology of Fishes 33: 87-95.

Khakimullin, A.A. 1987. Oxygen preferendum (preferred oxygen regime) of hatchery young of the siberian sturgeon, *Acipenser baeri*. Voprosy Ikhtiologii 1987: 693-696.

Kieffer, M. C., and B. Kynard. 1993. Annual movements of shortnose and Atlantic sturgeon in the Merrimack River, Massachusetts. Transactions of American Fisheries Society 122:1088-1103.

Klyashtorin, L.B. 1982. The ability of sturgeons (Acipenseridae) to regulate gas exchange. Ichthyology : 141-144.

Klyashtorin, L.B. 1976. The sensitivity of young sturgeons to oxygen deficiency. Journal of Ichthyology 16: 677-681.

Leslie, J.A., K.A. Abood, E.A. Maikish, and P.J. Keeser. 1988. Recent dissolved oxygen trends in the Hudson River,] *In*: Fisheries Research in the Hudson River. C.L. Smith (ed). State University of New York, Albany. p. 287-303

McKenzie, D.J., J.F. Steffensen, C.L. Bolis, P. Bronzi, and E.W. Taylor. 1995. Effects of diet on spontaneous locomotor activity and oxygen consumption in Adriatic sturgeon *Acipenser naccarii*. Fish Physiology and Biochemistry 14: 341-355.

National Marine Fisheries Service. 1998. Status review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). NMFS, Gloucester, Massachusetts, USA. 124 pp.

Niklitschek, E. J. 2001. Bioenergetics Modeling and Assessment of Suitable Habitat for Juvenile Atlantic and Shortnose Sturgeons in the Chesapeake Bay. Ph.D. thesis, University of Maryland, College Park, Maryland, USA.

Nonnotte, G., V. Maxime, J.P. Truchot, P. Williot, and C. Peyraud. 1993. Respiratory responses to progressive ambient hypoxia in the sturgeon, *Acipenser baeri*. Respiration Physiology 91: 71-82.

Officer, C. B., R. B. Biggs, J. L. Taft, L. E. Cronin, M. A. Tyler, and W. R. Boynton. 1984. Chesapeake Bay anoxia: Origin, development, and significance. Science (Washington, D.C). 223:22-27.

Paerl, H.W., J.L. Pinckney, J.M. Fear, and B.L. Peierls. 1998. Ecosystem responses to internal and watershed organic matter loading: consequences for hypoxia in the eutrophying Neuse River Estuary, North Carolina, USA. Marine Ecology Progress Series 166: 17-25.

Petersen, J.K. and L. Pihl. 1995. Responses to hypoxia of plaice, *Pleuronectes platessa* and dab, *Limanda limanda*, in the southeast Kattegat: distribution and growth. Environmental Biology of Fishes 43: 311-321.

Ruer, P.M., J.J. Cech, and S.I. Doroshov. 1987. Routine metabolism of the white sturgeon, *Acipenser transmontanus*: Effect of population density and hypoxia. Aquaculture 62: 45-52.

Sauriau, P.-G., J.-P. Robin, and J. Marchand. 1993. Les Mortalites estivales du mulet *Liza ramada* en loire: dysfunctionnement cyclique du role de voie de migration d'un estuarie. Bulletin of Ecology 24: 87-91.

Savoy, T. and D. Shake. 2000. Atlantic sturgeon, *Acipenser oxyrinchus*, movements and important habitats in Connecticut waters. Biology, Management and Protection of Sturgeon Symposium Pre-Print. EPRI. Palo Alto, California, USA.

Secor, D.H. 2000. Atlantic sturgeon fisheries and stock abundance during the late 19th Century. American Fisheries Society Symposium. 28:89-98.

Secor, D.H., E. Niklitschek, J. T. Stevenson, T. E. Gunderson, S.Minkkinen, B. Florence, M. Mangold, J. Skjeveland and A.Henderson-Arzapalo. 2000. Dispersal and growth of yearling Atlantic sturgeon *Acipenser oxyrinchus* released into the Chesapeake Bay. Fisheries Bulletin 98(4): 800-810.

Secor, D. H. and J. R. Waldman. 1999. Historical abundance of Delaware Bay Atlantic sturgeon and potential rate of recovery. *In:* Life in the slow lane: ecology and conservation of long-lived marine animals. J.A. Musick (ed). American Fisheries Society Symposium 23: 203-216.

Secor, D.H. and T.E. Gunderson. 1998. Effects of hypoxia and temperature on survival, growth, and respiration of juvenile Atlantic sturgeon, *Acipenser oxyrinchus*. Fisheries Bulletin. 96: 603-613.

Secor, D. H. 1995. Chesapeake Bay Atlantic sturgeon: Current status and future recovery. Chesapeake Biological Laboratory, Solomons, Maryland, USA. 11 pp.

Smith, T.I.J. 1985. The fishery, biology, and management of Atlantic sturgeon, *Acipenser oxyrhynchus*, in North America. Environmental Biology of Fishes 14: 61-72.

Welsh, S.A., S.E. Eyler, M.F. Mangold, and A.J. Spells. 2000. Capture locations and growth rates of Atlantic sturgeon in the Chesapeake Bay. American Fisheries Society Symposium 28:183-194.

Winberg, G.G. 1960. New Information on Metabolic Rate in Fishes. Fisheries Research Board of Canada, Nanaimo, British Columbia, Canada. 234 pp.

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Acute Sensitivity of Juvenile Shortnose Sturgeon to Low Dissolved Oxygen Concentrations

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Abstract.—There is considerable concern that factors such as eutrophication, industrial pollution, and dredging are adversely affecting the habitats of the endangered shortnose sturgeon *Acipenser brevirostrum*. Specific knowledge of the environmental requirements of this species is required if environmental managers are to adequately protect it. We conducted experiments to obtain information on the acute sensitivity of young-of-year shortnose sturgeon to a low dissolved oxygen (DO) concentration. Flow-through tests were conducted with hatchery-produced fish exposed to the ranges of DO, salinity, and temperature expected in the southeastern United States coastal river–estuary interfaces during spring and summer. The estimated concentration lethal to 50% of the test organisms (the LC50 value) after 24 h that we derived for approximately 77-d-old fish tested at 2‰ salinity and a nominal temperature of 25°C was 2.7 mg/L (32% saturation). An estimated LC50 of 2.2 mg/L (26% saturation) was obtained for approximately 104-d-old fish tested at 4‰ and 22°C. The 24-h, 48-h, and 72-h LC50 values for approximately 134-d-old fish tested at 4.5‰ and 26°C were also 2.2 mg/L (28% saturation). However, the test with approximately 100-d-old fish at 2‰ and a nominal temperature of 30°C yielded a 24-h LC50 of 3.1 mg/L (42% saturation). These data should be of value in derivating DO-protective values for shortnose sturgeon inhabiting estuaries along the Atlantic coast.

The anadromous shortnose sturgeon *Acipenser brevirostrum* occurs on the East Coast of North America from the St. John River, New Brunswick south to the St. Johns River, Florida (Vladykov and Greeley 1963). Historically, it was abundant enough that it was commercially harvested as part of the fishery for Atlantic sturgeon *A. oxyrinchus* (Murawski and Pacheco 1977), but by 1967 the populations had declined to the point that the species was listed as endangered (Hall et al. 1991). In the Savannah River estuarine system, juvenile shortnose sturgeon appear to occur primarily in low-salinity estuarine and tidal freshwater habitats (Collins and Smith 1997). Under normal flow conditions, the Savannah River becomes brackish between 33 and 38 km upstream of the jetties, and tidal influences extend to river kilometer (rkm; measured from the river's mouth) 83 (Hall et al. 1991). Adult shortnose sturgeon are reported to occur primarily in the same areas as juveniles except during the January–April spawning season (Collins and Smith 1997), when some adults have migrated as far inland as rkm 275–278 (Hall et al. 1991). In their review of the distribution of shortnose sturgeon in South Carolina, Collins and Smith (1997) reported that records for this species from the Atlantic Ocean were primarily from river plume areas and that their occurrence in the ocean itself is apparently rare. Kynard (1997) reported that most adult shortnose sturgeon stay within their natal river or estuary.

A number of anthropogenic impacts, such as fishing mortality (bycatch and poaching), water quality deterioration, dredging, and loss of essential habitat have been identified as factors affecting shortnose sturgeon populations (Collins et al. 1996, 2000; Kynard 1997). Collins et al. (2000) reported that the deterioration of dissolved oxygen (DO) in summer refugia utilized by shortnose and Atlantic sturgeon may be creating a recruitment bottleneck in some southeastern U.S. estuarine areas. In their review of the critical effects of hypoxia and temperature on sturgeon, Secor and Niklitschek (2001) concluded that, in terms of their metabolic and behavioral responses, sturgeon in general are unusually sensitive to hypoxia.

In studies of the salinity and DO tolerance of juvenile shortnose sturgeon, Jenkins et al. (1995) determined that younger fish were more susceptible to low DO than older fish. In their 6-h tests at 22.5°C, 86% of the 64-d-old fish exposed to 2.5 mg DO/L in freshwater died, whereas fish more than 100 d old that were tested under nearly the same conditions (5‰ salinity) experienced less than 20% mortality. In preliminary studies with young-of-year shortnose and Atlantic sturgeon, Niklitschek (2001) observed poor survival of both species at DO concentrations less than 40% saturation. Niklitschek (2001) also determined that

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the proportion of energy allocated to growth by juvenile Atlantic and shortnose sturgeon decreased as the DO concentration decreased.

Our studies were performed with hatchery-reared fish to obtain conventional estimates of the concentrations lethal to 50% of the test organisms (the LC50 values) for juvenile shortnose sturgeon exposed to low DO concentrations using the ranges of DO, salinity, and temperature that might be expected at the mouths of southeastern U.S. coastal rivers during spring and summer. These data should be of value to environmental managers with responsibility for protecting shortnose sturgeon and their habitat.

Methods

The exposure water used in these experiments was derived by diluting salt water to achieve the lower salinity desired for testing. Salt water was pumped from Santa Rosa Sound, Florida, through sand filters and a 20-μm cartridge filter, after which it was pumped into large, aerated fiberglass tanks. Freshwater was obtained from a municipal water supply and carbon filtered to remove possible contaminants, including chlorine, and then passed through 20-μm cartridge filters. Salt water and freshwater were then mixed to achieve the desired salinity and delivered to two 40,000-L fiberglass holding tanks. Both holding tanks were aerated to remove any residual chlorine in the water. Once each tank was filled, chlorine measurements were taken to ensure that the concentrations of chlorine-produced oxidants were within acceptable limits. Chlorine analyses were performed with a Wallace and Tiernan (Belleville, New Jersey) Series A-790 amperometric titrator with a sensitivity exceeding 0.0005 mg/L.

The dissolved oxygen concentrations used in testing were obtained by means of a computer-controlled exposure apparatus. The water was pumped through three sets of filter banks and filtered to 0.45 μm before entering a saturation column. The water in the saturation column cascaded over polypropylene packing with a large surface area as air was blown up through the column, effectively saturating the water with DO. The DO-saturated water was transferred to a 900-L holding tank, and the water temperature was brought to test conditions. Hydrolab minisonde units (Hydrolab Corporation, Austin, Texas) were used to measure and transmit the DO content, temperature, pH, and salinity of the water to the controlling computer. Once the saturation column was filled and the oxygen and temperature requirements of the experiment were met, the water was pumped into the desaturation column. A microlayer of water flowed through the desaturation column, which was also filled with polypropylene packing. This column was under vacuum pressure and removed the dissolved gases from the water. The water was then transferred into a 450-L holding tank. Degassed water in the desaturation column was continuously cycled to maintain a low DO concentration. The temperature in the degassed tank was also controlled.

Once the appropriate DO concentrations, water levels, and temperature levels were met, the water was delivered to the dosing aquaria. Computer-controlled metering pumps proportionally mixed flows of DO-saturated and deoxygenated water to obtain the desired flow rates and oxygen concentrations.

Fish were exposed to selected DO concentrations in glass exposure aquaria (24 × 41 × 23 cm) with a capacity of 21 L. The water filled the aquaria and seeped out between the silicone seal and the glass lid, effectively preventing air spaces in the aquaria. Two replicate aquaria were used for each of the five DO concentrations. The aquaria were partially immersed in a temperature-controlled water bath. Flows to all aquaria were measured and adjusted before the beginning of each test.

Test animals were young-of-year shortnose sturgeon obtained from the U.S. Fish and Wildlife Service's Bears Bluff National Fish Hatchery in South Carolina. According to hatchery personnel, fish were captured from the Savannah River drainage and artificially spawned during the mid-1980s to produce a captive broodstock at the Bears Bluff Hatchery. The fish provided for our experiments were from artificial spawns of the captive broodstock. All fish tested during 1999 were the progeny of one female and one male; similarly, fish tested during 2000 were the progeny of one pair of fish. The hatch date for the fish that we obtained on June 30, 1999, was about April 15, 1999; the fish obtained on June 15, 2000, hatched about April 18, 2000. Upon arrival at our laboratory, the fish were distributed among aquaria receiving flowing filtered seawater of the same salinity as used in testing. The acclimation aquaria were located in a temperature-controlled water bath and continuously aerated. The photoperiod during both acclimation and testing was 14 h light : 10 h dark. Fish were usually fed two or more times per day during acclimation and holding. The foods provided were frozen bloodworms that were purchased commercially and a pelletized food (Rangen, Inc., Frank-

TABLE 1.—Exposure conditions in tests to determine the acute sensitivity of juvenile shortnose sturgeon to low dissolved oxygen (DO) concentrations.

Variable	Fish age (d)			
	~77	~100	~104	~134
Acclimation period (d)[a]	12	12	13	15
DO concentration (mg/L; range)[b]	2.2–8.0	2.2–7.4	1.9–8.4	1.6–7.8
pH (range)	8.2–8.3	8.3–8.4	7.9–8.1	7.9–8.2
Salinity (‰)	2	2	4	4.5
Nominal temperature (°C)	25	30	22	26
Mean wet weight ± SD (g)[c]	2.6 ± 0.5 (20)	2.6 ± 0.5 (20)	2.4 ± 0.8 (10)	2.3 ± 0.8 (25)
Year tested	2000	2000	1999	1999

[a] Number of days within 1°C of nominal test temperature prior to testing.
[b] Range in mean measured exposure concentrations.
[c] Sample sizes are in parentheses.

linton, Louisiana). Fish were acclimated to the nominal test temperature (±1°C) for 12–15 d prior to testing (Table 1).

Once the dosing aquaria were filled and the desired oxygen concentrations achieved, fish were randomly transferred to the exposure aquaria without acclimation to low DO. Ten fish were placed in each of two replicate aquaria for each of the five exposure concentrations. Because of concerns about loading in our test system, the fish selected for the initial test were among the largest fish in our holding aquaria in both 1999 and 2000. The highest DO concentration in each test was near the saturation concentration and served as the control. The temperature, pH, salinity, and DO content of the water and the mortality of the test animals were usually recorded at 0, 2, 4, and 24 h. Four acute tests were performed; the test conditions are presented in Table 1. Fish were not fed during testing except in the 72-h test, in which they were provided bloodworms at least once daily. The mean wet weights of a sample of fish from each test are provided in Table 1; the sample was usually the fish that succumbed during the test. As a quality assurance measure, two control fish from the June 28, 2000, test were preserved in Lugol's solution for subsequent histological examination of gill tissues.

TABLE 2.—Estimated median lethal concentrations (LC50s) and 95% confidence intervals (CIs) for young-of-year shortnose sturgeon of different ages exposed to low dissolved oxygen at selected temperatures.

Fish age (d)	Temperature (°C)	Duration (h)	LC50 (mg/L)	95% CI (mg/L)
~77	24.6–25.0	24	2.7	2.3–3.1
~100	~28.4–29.2	24	3.1	[a]
~104	21.8–22.4	24	2.2	2.2–2.3
~134	26.0–26.4	24	2.2	2.0–2.4
		48	2.2	1.9–2.4
		72	2.2	1.9–2.4

[a] Not determined.

Dissolved oxygen concentrations were determined by titration (APHA et al. 1995) and by use of Nester Model 8500 (Nester Instruments, North Wales, Pennsylvania) and Orion Model 862A (Orion Research, Inc., Boston, Massachusetts) DO meters. Estimated LC50 values and 95% confidence intervals (CIs) were derived by linear interpolation combined with bootstrapping using ToxCalc (TidePool Scientific Software 1994).

Results

Most of the mortality in our experiments occurred fairly rapidly. For the four tests, 53–90% of the mortality occurred within the first 2 h and 79–96% within the first 4 h. The signs of stress observed in fish exposed to low DO were reduced swimming and feeding activity and increased ventilation frequency.

The median LC50 values obtained in the four tests ranged from 2.2 to 3.1 mg/L (Table 2). The youngest age-group tested, which was approximately 77 d old, yielded a 24-h LC50 of 2.7 mg/L (95% CI = 2.5–2.8 mg/L) when exposed to low DO at 25°C. Fish that were approximately 104 d old and that were tested at 22°C and fish that were approximately 134 d old and tested at 26°C had identical 24-h LC50 values of 2.2 mg/L with 95% confidence intervals that differed only slightly (2.2–2.3 mg/L and 2.0–2.4 mg/L). In the 72-h test conducted with approximately 134-d-old fish, the 24-h, 48-h, and 72-h LC50 values were also 2.2 mg/L, with only slight differences in the 95% confidence intervals (Table 2). Fish that were approximately 100 d old and that were tested at 29°C were the most sensitive to low DO, yielding a 24-h LC50 of 3.1 mg/L. However, during their acclimation to

a nominal 30°C, the fish were exposed to temperatures as high as 31°C, which may be near their upper temperature tolerance limit. The survival of fish in control treatments, which contained near-saturation concentrations of DO, was 100% during each test.

The concentrations of chlorine-produced oxidants in our low-salinity dilution water were less than the U.S. Environmental Protection Agency's water quality criteria final chronic value of 7.5 μg/L (EPA 1985). Histological examination of gill arches from two control fish from the June 28, 2000, test revealed no evidence of any pathological abnormalities.

Discussion

Our data and those of Jenkins et al. (1995) demonstrate that juvenile shortnose sturgeon up to 134 d old are quite sensitive to low DO in acute tests at low salinities. Adult and older juvenile shortnose sturgeon are known to inhabit low-salinity areas (Gilbert 1989; Flournoy et al. 1992; Collins and Smith 1997), but there are uncertainties regarding the habitats used by fish of the ages tested in our experiments and in those of Jenkins et al. (1995). The LC50 values derived in our studies and those of Jenkins et al. (1995) are greater than those for 10 species of juvenile estuarine fish tested by Miller et al. (2002). However, the mean LC50 value of 2.4 mg/L reported for postlarval striped bass *Morone saxatilis* (Miller et al. 2002) is similar to the LC50 values that we derived for shortnose sturgeon at 22–26°C.

The LC50 values derived in our studies tend to support the findings by Jenkins et al. (1995) that younger sturgeon are more sensitive to low dissolved oxygen than are older fish. However, factors such as different test conditions, genetic variability, and test variability may have contributed to the apparent difference in sensitivity between the fish that were approximately 77 d old and those that were approximately 104 and 134 d old.

Shortnose sturgeon appear to be particularly vulnerable at high water temperatures. Flournoy et al. (1992) reported that shortnose sturgeon in the rivers of the Deep South seek out certain deep holes when water temperatures approach lethal levels. They also reported that at water temperatures exceeding 28°C many recaptured sturgeon from such holes in the Altamaha River, Georgia, exhibited weight loss. Secor and Gunderson (1998) reported that juvenile Atlantic sturgeon are vulnerable to conditions of hypoxia and high temperature: all fish exposed to a temperature of 26°C and a DO concentration of approximately 3 mg/L without access to the air died within the first 30 h of their experiment.

Although the information obtained in our studies will be useful to environmental managers involved in protecting the endangered shortnose sturgeon, there remain a number of questions about the effects of DO. These include (1) the acute sensitivity of older juveniles and adult fish to low DO and the influences of salinity and temperature on their sensitivity; (2) possible chronic effects of low DO; (3) the age-specific ability of shortnose sturgeon to avoid low DO concentrations and the possible effect of temperature on such responses; and (4) the habitat of young-of-year fish with respect to salinity during approximately their first 200 d after hatching.

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References

APHA (American Public Health Association), American Water Works Association, and Water Environment Federation. 1995. Standard methods for the examination of water and wastewater, 15th edition. APHA, Washington, D.C.

Collins, M. R., S. G. Rogers, and T. I. J. Smith. 1996. Bycatch of sturgeons along the southern Atlantic Coast of the USA. North American Journal of Fisheries Management 16:24–29.

Collins, M. R., S. G. Rogers, T. I. J. Smith, and M. L. Moser. 2000. Primary factors affecting sturgeon populations in the southeastern United States: fishing mortality and degradation of essential habitats. Bulletin of Marine Science 66(3):917–928.

Collins, M. R., and T. I. J. Smith. 1997. Distributions of shortnose and Atlantic sturgeons in South Car-

olina. North American Journal of Fisheries Management 17:995–1000.

EPA (U.S. Environmental Protection Agency). 1985. Ambient water quality criteria for chlorine, 1984. EPA Report 440/5-84-030, Washington, D.C.

Flournoy, P. H., S. G. Rogers, and P. S. Crawford. 1992. Restoration of shortnose sturgeon in the Altamaha River, Georgia. Final Report to the U.S. Fish and Wildlife Service, Atlanta, Georgia.

Gilbert, C. R. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (mid-Atlantic Bight)—Atlantic and shortnose sturgeons. U.S. Fish and Wildlife Service, National Wetlands Research Center, Biological Report 82 (11.122), Washington, D.C., and U.S. Army Corps of Engineers, Waterways Experiment Station, TR EL-82-4, Vicksburg, Mississippi.

Hall, J. W., T. I. J. Smith, and S. D. Lamprecht. 1991. Movements and habitats of shortnose sturgeon, *Acipenser brevirostrum*, in the Savannah River. Copeia 1991:695–702.

Jenkins, W. E., T. I. J. Smith, L. D. Heyward, and D. M. Knott. 1995. Tolerance of shortnose sturgeon, *Acipenser brevirostrum*, juveniles to different salinity and dissolved oxygen concentrations. Proceedings of the Annual Conference Southeastern Fish and Wildlife Agencies 47(1993):476–484.

Kynard, B. 1997. Life history, latitudinal patterns, and status of the shortnose sturgeon, *Acipenser brevirostrum*. Environmental Biology of Fishes 48:319–334.

Miller, D. C., S. L. Poucher, and L. Coiro. 2002. Determination of lethal dissolved oxygen levels for selected marine and estuarine fishes, crustaceans, and a bivalve. Marine Biology 140:287–296.

Murawski, S. A., and A. L. Pacheco. 1977. Biological and fisheries data on the Atlantic sturgeon, *Acipenser oxyrhynchus* (Mitchill). U.S. National Marine Fisheries Service, Technical Series Report 10, Highlands, New Jersey.

Niklitschek, E. J. 2001. Bioenergetics modeling and assessment of suitable habitat for juvenile Atlantic and shortnose sturgeons *Acipenser oxyrinchus* and *A. brevirostrum* in the Chesapeake Bay. Doctoral dissertation. University of Maryland, Center for Environmental Science, Solomons.

Secor, D. H. and T. E. Gunderson. 1998. Effects of hypoxia and temperature on survival, growth, and respiration of juvenile Atlantic sturgeon, *Acipenser oxyrhynchus*. Fishery Bulletin 96:603–613.

Secor, D. H. and E. J. Niklitschek. 2001. Hypoxia and sturgeons. Report to the Chesapeake Bay Program Dissolved Oxygen Criteria Team. Chesapeake Biological Laboratory, Technical Report Series Number TS-314-01-CBL, Solomons, Maryland.

TidePool Scientific Software. 1994. ToxCalc version 5.0 for Microsoft Excel 5.0. TidePool Scientific Software, McKinleyville, California.

Vladykov, V. D. and J. R. Greeley. 1963. Order Acipenseroidei. Pages 24–60 *in* Y. H. Olsen, editor. Fishes of the western North Atlantic, part 3. Sears Foundation for Marine Research, Yale University, New Haven, Connecticut.

Tolerance of Shortnose Sturgeon, *Acipenser brevirostrum*, Juveniles to Different Salinity and Dissolved Oxygen Concentrations[1]

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Abstract: Cultured shortnose sturgeon juveniles, age 11–330 days, were exposed to different salinity (0–35 ppt) and dissolved oxygen concentrations (2.0–5.0 mg/liter) in a series of experiments designed to examine tolerance levels. Tolerance to increased salinity improved with age. Fish 76 days old experienced 100% mortality in a 96-hour test when exposed to salinities ≥15 ppt while 330-day-old fish tolerated salinities as high as 20 ppt for a duration of 18 hours but exhibited 100% mortality at 30 ppt. Younger fish were also more susceptible to low oxygen concentrations than older fish. In a 6-hour test, fish 64 days old exhibited 86% mortality when exposed to DO concentrations of 2.5 mg/liter. However, sturgeon >100 days old were able to tolerate concentrations of 2.5 mg/liter with <20% mortality.

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During the past century, environmental perturbations have been partly responsible for the decline in abundance of anadromous shortnose sturgeon, *Acipenser*

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brevirostrum, which is now listed as an endangered species in the United States (Miller 1972). Although spawning and culture techniques have been developed (Smith and Jenkins 199, Smith et al. 1985, 1986), little is known of the environmental requirements of this species. Information is now being collected on the habitat requirements and movements in southern rivers, particularly the Savannah River (Hall et al. 1991, Smith and Collins 1993). These studies have indicated that adult shortnose sturgeon utilize the entire river system during the January–April spawning migrations and spend a portion of the summer months in the estuarine portion (Hall et al. 1991, Collins and Smith 1993). Juvenile shortnose sturgeon appear to utilize the lower section of the river, especially river kilometer 32, as a nursery area (Smith and Collins 1993). The lower Savannah River is highly industrialized and is impacted by stream modifications such as dredging and point source discharges. This portion of the estuary experiences substantial water quality degradation, especially in the Back River which is influenced by a tide gate (Winn and Knott 1992). In addition, natural resource managers regularly receive requests for permits that may further impact water quality in this river. Due to the lack of information on the environmental tolerances of shortnose sturgeon, these permit requests are often reviewed in absence of sufficient data to assess potential impact on shortnose sturgeon.

This study was conducted as part of a cooperative effort between the South Carolina Wildlife and Marine Resources Department and the U.S. Fish and Wildlife Service. Our objective was to obtain basic information on effects of salinity and dissolved oxygen on shortnose sturgeon of various ages. This information is critical for evaluating the potential impact of current and proposed environmental modifications. Also, such information will be useful in refining and optimizing culture systems for shortnose sturgeon. Due to various constraints including limitations of facilities and test animals, strictly controlled and standardized methods could not be followed in all tests. The findings reported should be considered as preliminary until such time as more rigorous testing can be accomplished. Funding was provided by the U.S. Fish and Wildlife Service AFS-17. We thank Bob Steffen, Robert Van Dolah, and Richard Winn who assisted with the tests and Karen Swanson who provided assistance with graphics.

Methods

Experimental fish were obtained by spawning wild adult fish captured in the Savannah River and rearing the larvae in captivity (Smith et al. 1985). Fish were reared in 2 m diameter × 1 m deep cylindrical tanks which received partially exchanged fresh water. Small juveniles were fed a combination of natural and commercial pelleted feeds (Smith et al. 1993). Test animals were removed directly from nursery systems just prior to initiation of the tolerance tests. All experiments utilized fish which ranged in age from 11–330 days (17–339 mm TL). As fish got older they were exposed to progressively higher salinity and lower oxygen (DO) concentrations. During each oxygen experiment an observer regularly recorded

sturgeon behavior and mortality; during the salinity tests, fish were monitored only during regular work hours. Control groups of fish similarly were monitored in both series of tests. In salinity studies, fish held at 0 ppt served as controls, while in DO trials, fish held at 7–8 mg/liter oxygen concentration served as controls.

Analysis of variance and a Student Newman Keuls test were used to determine if there were significant differences in survival among fish at the test DO concentration or salinities. Arc-sin transformations were used on all percentage data. Experimental groups which were not normally distributed or had non-homogenous variances were analyzed using Krushal-Wallis and Dunn's tests. A computerized statistical analysis system was used for all analyses (Sigma Stat 1992). Significance was examined at the 0.05 level.

Salinity Experiments

The salinity tests were performed using fish ranging in age from 17 to 330 days. Young sturgeon were subjected to lower salinities (range 0–11 ppt) while older sturgeon were subjected to higher levels (range 13–35 ppt). At least 3 replicates were used for each treatment, with size test container varying depending on the size of fish being tested. At the beginning of each salinity test, sturgeon were removed from 0 ppt water in the culture system, weighed, and measured and placed in test chambers containing fresh water. Acclimation to the test salinity was accomplished over a 4-hour period by adding filtered 32 ppt seawater from Charleston Harbor to the test container. In tests where higher salinity was required, salt (Instant Ocean, Aquarium Systems, Mentor, Oh) was added to reach the desired treatment level. Salinity levels were monitored a minimum of every 24 hours with a conductivity meter (YSI Model 33 S-C-T meter, Yellow Springs Instrument Co., Yellow Spring, Oh) and were further verified with a temperature compensated refractometer or a Hydrolab unit. Oxygen and temperature were measured with a Yellow Springs Model 57 meter. Each container was aerated via a central air blower system and dissolved oxygen was maintained at 7–8 mg/liter and temperature averaged 21°–23° C. Other water quality parameters including pH, ammonia, nitrate, and nitrite were monitored with colorimetric test kits manufactured by Lamotte Chemical Co. Satisfactory levels were maintained through water exchange. Mortality was recorded at least every 24 hours.

The salinity tolerance tests were conducted using fish aged 17, 22, 39, 63, 76, and 330 days old. The first series of tests using 17-day-old fish (20 mm TL) was run for 96 hours in 20-cm diameter glass petri dishes. Each salinity treatment (0, 1, 3, and 5 ppt) had 4 replicates with 5 fish/replicate. A second test was conducted on 22-day-old fish (22 mm TL) using the same experimental design except duration was 48 hours and salinity treatments were 5, 7, 9, and 11 ppt. The tests utilizing 39- (54 mm TL) and 76- (81 mm TL) day-old sturgeon utilized 3 replicates of 5 fish. The tests with 63-day-old fish (62 mm TL) were conducted with 3 replicates of 10 fish/replicate. The tests for 39- and 76-day-old fish were conducted in 38-liter aquaria for 96 hours while the 63-day-old fish were tested in 4-liter aquaria for 48 hours. The salinity concentrations tested for each age group were as fol-

lows: 39-day-old fish - 0, 5, 7 and 9 ppt; 63-day-old fish - 0, 5, 15, and 20 ppt; 76-day-old fish - 0, 7, 9, 11, 13, 15, 17, and 19 ppt. The final series of salinity tests were conducted on 330-day-old fish (339 mm TL) at salinities of 15, 20, 25, 30, and 35 ppt for a duration of 18 hours with 4 replicates containing 3 fish/replicate (12 fish/treatment).

Oxygen Experiments

The ability of sturgeons to tolerate hypoxia was examined in a series of trials. Dissolved oxygen levels of 2.0–5.0 mg/liter were tested on fish from 11–310 days old. Oxygen levels were maintained through use of a proportional flowmeter (Aalborg, Inc., Monsey, N.Y.) which mixed pressurized nitrogen and oxygen before it was delivered to each treatment container through air stones. Oxygen tests on fish ≤125 days old were conducted with 5 replicates containing 5 fish/replicate (25/treatment). Two tests on fish 307 and 310 days old were conducted with 3 replicates stocked with 3 fish/replicate. As in salinity trials, size of test chambers varied based on the size of animals. Fish were removed from the main culture system and without acclimation were placed directly into the test chamber containing the desired treatment concentration of oxygen. Control treatment groups were established for each trial. Oxygen in control tanks was maintained at 7.5 mg/liter. All tests were conducted at mean temperature of 22.5° C and were run for 6 hours. Dissolved oxygen levels were monitored every 30 minutes throughout the experiment with an oxygen meter (YSI Model 57) that had been calibrated against a Winkler titration (Am. Public Health Assoc. 1980). Adjustments were made to the gas mixture and flow as needed to keep oxygen concentration at appropriate treatment levels. The majority of the tests were conducted in fresh water. However, fish between 84 and 109 days old which were being reared at 5 ppt were tested at that salinity to avoid any synergistic effect of having to adjust to both a change in DO concentration and salinity at the same time. Other water quality parameters (pH, ammonia, nitrate, nitrite) were monitored as described for the salinity trials. Water quality parameters were monitored every hour during each trial and each parameter remained at satisfactory levels.

Results

In the first salinity trial, 17-day-old fish were able to tolerate salinities up to 5 ppt with no mortalities for 96 hours (Fig. 1). When the test was terminated the fish were behaving and swimming normally in all salinity treatments. Fish 22 days old tested for 48 hours survived significantly better at 5 and 7 ppt than those tested at 11 ppt (Fig. 1). The survival of fish stocked at 9 ppt (40%) was substantially higher than that of fish stocked at 11 ppt (90% mortality) (Fig. 1). The 39-day-old fish also exhibited a survival of 100% when tested at salinities to 7 ppt for 96 hours. However, 80% of fish from this age group survived exposure to 9 ppt (Fig. 1). Fish 63 days old had a statistically similar tolerance to salinity levels of 15 ppt and the lower 0 or 5 ppt treatment levels. Mortality in this treatment (15 ppt) was 47% after

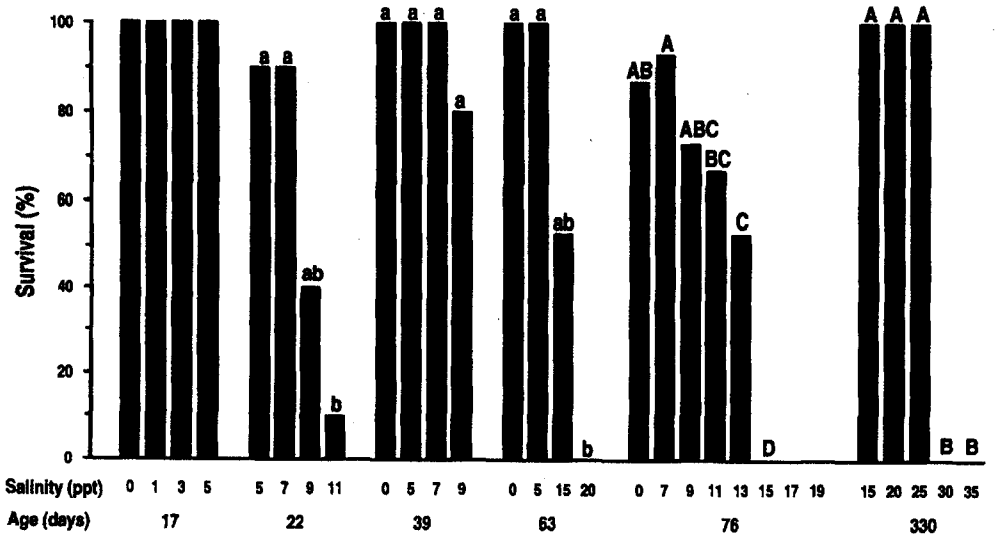

Figure 1. Survival of shortnose sturgeon exposed to different salinity concentrations. Test durations were as follows: 18 hours, 330-day-old fish; 48 hours, fish 22 and 63 days old; 96 hours, fish 17, 39, and 76 days old. Data with the same letter (anova=uppercase; Kruskal-Wallis=lower case) within a particular age group are not significantly different.

48 hours. Fish exposed to 20 ppt showed signs of stress almost immediately after the salinity treatment level was reached and mortality was 100% after 6 hours. The 76-day-old fish were tested over a more gradual salinity gradient for 96 hours. The salinity levels tested ranged from 0–19 ppt with a 2 ppt interval from 7–19 ppt. Survival at 0, 7 and 9 ppt was similar; however, survival of fish at 9 ppt was also similar to those stocked at 11 and 13 ppt which had survival levels of 67% and 53%, respectively, at the end of the test. All fish stocked at salinities ≤ 13 ppt survived at a significantly better than fish stocked at the higher test salinities. All fish stocked at salinities ≥15 ppt experienced 100% mortality during the 96-hour test (Fig. 1). The final series of salinity tolerance test was conducted on 330-day-old fish for 18 hours. Survival for fish stocked at 15, 20, and 25 ppt was 100% when the study was terminated. At that time, the fish in the 15 and 20 ppt treatments were behaving and swimming normally in the test containers; however, the fish stocked at 25 ppt treatment were visibly stressed and would probably have died if the experiment had lasted any longer. Mortality at the higher salinities tested (30–35 ppt) was 100% (Fig. 1). Examination of dead fish indicated that the fish had experienced significant osmoregulatory stress during this trial. The dead fish were dehydrated and had lost weight. Sampling indicated that fish in the 15 and 20 ppt treatments had lost 5% and 6% of their total weight, respectively, during the 18-hour trial. In comparison, fish in the 25 ppt treatment experienced a significantly higher 9% weight loss. The weight losses for the fish in the 30 and 35 ppt salinity treatments were significantly higher than all groups in the test (17% and 20%, respectively).

The hypoxia experiments were conducted using fish which were 11 to 310 days old (17–365 mm TL). Different aged fish were exposed to the same DO concentration for the same duration. In each test survival of the control groups was >95%. Fish ≤13 days old were tested at DO concentrations of 4.0, 4.5, and 5.0 mg/liter. No mortalities were observed at these treatment levels for any group of fish tested (Fig. 2). When treatment concentration was lowered to 3.5 mg/liter, 19-day-old fish (26 mm TL) experienced 22% mortality. However, this was not significantly lower than 90-day-old fish (92 mm TL, 100% survival) exposed to the same DO concentration (Fig. 2). Five groups of fish (20–307 days old) were tested at a concentration of 3.0 mg/liter. Fish <80 days old experienced significantly higher mortality than the 103-day-old (97 mm TL) for which no mortalities were observed (Fig. 2). The 307-day-old fish could not be compared. Six groups of fish (25–310 days old) were exposed to a DO concentration of 2.5 mg/liter. As in the test at 3.0 mg/liter, survival among the younger fish was substantially lower than that recorded for older fish (Fig. 2). There was no statistical difference in survival of 64-, 104-, and 125-day-old fish tested at 2.5 mg/liter. However, there was a significant difference between the survival of 125-day-old control fish and the same age fish in the treatment. There was no difference between the 104- and their 310-day-old fish and their corresponding control groups. Fish 310 days old survived at the same rate (88%) as the 104-day-old group. When the test DO concentration was lowered to 2.0 mg/liter the control group (DO 7.5mg/liter) survived significantly better than all groups held at the test concentration. Within the test group there was no difference between survival of 110- and 125-day-old fish (Fig. 2). The 46-day-old fish experienced significantly higher mortality than either group of older fish (Fig. 2).

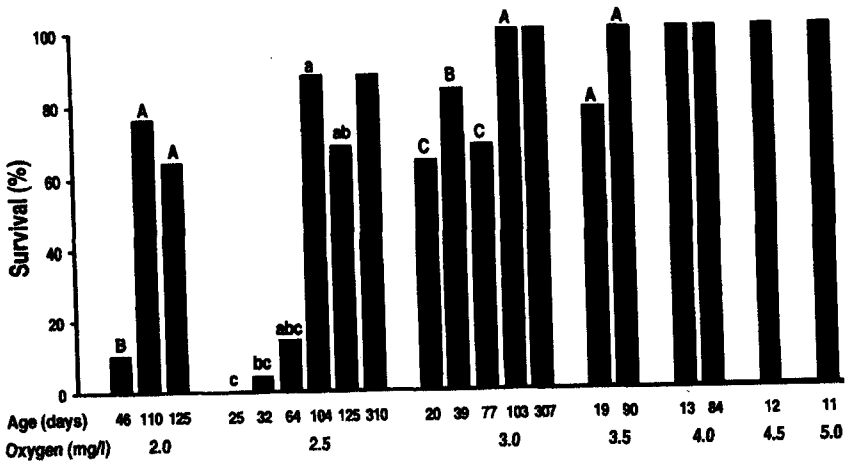

Figure 2. Survival of various aged shortnose sturgeon exposed to different oxygen concentrations. Data with same letter (anova=uppercase; Kruskal-Wallis=lowercase) within a particular test concentration are not significantly different.

Discussion

Researchers have demonstrated that shortnose sturgeon adults utilize both estuarine areas of rivers as well as near shore ocean habitats (Dadswell et al. 1984). Information on salinity tolerance for juveniles is limited. Studies in Russia on 3 species of sturgeon indicate that salinity tolerance increases with age and size (Krayushkina and Dyubin 1974). Although results of the present experiments are difficult to compare directly because of the differences in experiment duration, comparisons within test groups are possible and general trends support the hypothesis of increasing tolerance with increasing size and age. Survival among all groups held at salinities up to 7 ppt was excellent and suggests that small sturgeon could be raised at this salinity. In fact, fish reared in our nursery system are now routinely cultured at salinities of 5 ppt after day 30. A salinity of 9 ppt appeared to be a threshold at which significant mortalities began to occur, especially among the youngest fish. Fish 22 days old experienced 60% mortality after 48 hours at 9 ppt, but the 39-day-old fish experienced only 20% mortality after 96 hours. Survival of each group was significantly lower than that for the same age fish held at 7 ppt. As salinity was increased to 11 ppt, survival among the 22-day-old group declined to 10%. However, 67% of 76-day-old fish survived the 96-hour test at 11 ppt. This survival level was statistically similar to the same age fish held at 0 ppt and indicates an increased tolerance to higher salinities. The 53% survival for 63-day-old fish at a salinity of 15 ppt was higher than that recorded for 76-day-old fish but the shorter duration of the test for 63-day-old fish may be responsible for the differences. The 330-day-old fish were able to tolerate salinities up to 25 ppt for 18 hours but observations indicated that these fish were stressed. Fish in both the 15 and 20 ppt treatment levels appeared to be behaving normally but each group had lost weight during the test. The duration of the test makes it difficult to determine the 330-day-old fish's maximum tolerance level but there is little doubt that they could not tolerate salinities ≥30 ppt with the short acclimation they received in these tests. These data support the importance of estuarine habitat as nursery areas for juvenile shortnose sturgeon.

Hypoxia tests results indicated that older fish were able to tolerate low oxygen levels for short periods. A dissolved oxygen level of 2.5 killed 100% of fish 25 days old, 96% of fish 32 days old, and 86% of fish 64 days old but only 12% of the 104- and 310-day-old fish. Young fish also died at significantly higher rates at oxygen levels of 3.0 mg/liter while this concentration did not appear to adversely affect fish >77 days old. Finally, all age groups tested at 2.0 mg/liter died at significantly higher rates than the control groups. However, the older fish tested survived significantly better than the 46-day-old fish. In each test at a DO concentration of ≤3.0 mg/liter, changes in the fishes behavior were noted. The fish would become immobile and the only movement that could be detected would be the rhythmic movements of the operculum as it pumped water over the fishes' gills. This behavior has been noted and examined in detail by researchers studying white sturgeon, *Acipenser transmontanus*, and appears to be an adaption to living and

feeding on the bottom (Burggren and Randall 1978). Older and larger fish may be able to more efficiently pump water during hypoxic conditions, and this may be why older fish tolerated low DO concentrations better than the young fish in these experiments.

The dissolved oxygen levels tolerated in these short tests should be considered absolute minimum tolerance levels. Chronic levels of ≈5.3 mg/liter have been shown to cause mortality and reduced growth among white sturgeon (Cech et al. 1984).

In situations involving shortnose sturgeon, this data should serve as a preliminary guide until more rigorous tests can be conducted to determine absolute values. In addition, this data should be of use in development of future culture and stocking protocols.

Literature Cited

American Public Health Association. 1980. Standard methods for the examination of water and wastewater. 15th ed. Am. Public Health Assoc., N.Y. 1,134pp.

Burggren, W. W. and D. J. Randall. 1978. Oxygen uptake and transport during hypoxic exposure in the sturgeon *Acipenser transmontanus*. Respiration Physiol. 34:171–183.

Cech, J. J., S. J. Mitchell, and T. E. Wragg. 1984. Comparative growth of juvenile white sturgeon and striped bass: effects of temperature and hypoxia. Estuaries 7:12–18.

Collins, M. R. and T. I. J. Smith. 1993. Characteristics of the adult segment of the Savannah River population of shortnose sturgeon. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 47:000–000.

Dadswell, M. J., B. D. Taubert, T. S. Squiers, D. E. Marchette, and J. Buckley. 1984. Synopsis of biological data on shortnose sturgeon *Acipenser brevirostrum*. Lesur 1818. Natl. Ocean. Atmos. Admin. Tech. Tech Report NMFS 14. 45pp.

Hall, J. W., T. I. J. Smith, and S. D. Lamprecht. 1991. Movements and Habitats of shortnose sturgeon, *Acipenser brevirostrum*, in the Savannah River. Copeia (3):695–702.

Krayushkina, L. S. and V. P. Dyubin. 1974. The reaction of juvenile sturgeon to alteration of environmental salinity. J. Ichtylogy 14:971–977.

Miller, R. R. 1972. Threatened freshwater fishes of the United States. Trans. Am. Fish. Soc, 101:239–252.

Sigma Stat. 1992. Users Manual. Jandel Scientific. San Rafael, Ca. 711pp.

Smith, T. I. J., M. R. Collins, and E. T. Kennedy. 1993. Identification of critical habitat requirements of shortnose sturgeon in South Carolina. Final Rep. U.S. Fish and Wildl. Serv. Proj. SC-AFS-17. 94pp.

——— and W. E. Jenkins. 1991. Development of a shortnose sturgeon *Acipenser brevirostrum* stock enhancement program in North America. Pages 329–336 *in* P. Williot, ed. Acipenser. CEMAGREF, Bordeaux, France.

———, L. D. Heyward, W. E. Jenkins, and M. R. Collins. 1993. Culture and stock enhancement of shortnose sturgeon, *Acipenser brevirostrum*, in the southern United States. 2nd Internatl. Symp. on Sturgeon, Moscow, Russia. In press.

———, E. K. Dingley, R. D. Lindsey, S. B. Van Sant, R. A. Smiley, and A. D. Stokes. 1985. Spawning and culture of shortnose sturgeon, *Acipenser brevirostrum*. J. World Maricult. Soc. 16:104–113.

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Hypoxia and Sturgeons

Report to the Chesapeake Bay Program Dissolved Oxygen Criteria Team

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ABSTRACT

In this essay, three lines of evidence are developed that sturgeons in the Chesapeake Bay and elsewhere are unusually sensitive to hypoxic conditions: 1. In comparison to other fishes, sturgeons have a limited behavioral and physiological capacity to respond to hypoxia. Basal metabolism, growth, and consumption are quite sensitive to changes in oxygen level, which may indicate a relatively poor ability by sturgeons to oxyregulate. 2. During summertime, temperatures >20 C amplify the effect of hypoxia on sturgeons and other fishes due to a temperature*oxygen "squeeze" (Coutant 1987). In bottom waters, this interaction results in substantial reduction of habitat; in dry years, nursery habitats in the Chesapeake Bay may be particularly reduced or even eliminated. 3. While evidence for population level effects by hypoxia are circumstantial, there are corresponding trends between the absence of Atlantic sturgeon reproduction in estuaries like the Chesapeake Bay where summertime hypoxia predominates on a system-wide scale. Also, the recent and dramatic recovery of shortnose sturgeon in the Hudson River (4-fold increase in abundance from 1980 to1995) may have been stimulated by improvement of a large portion of the nursery habitat that was restored from hypoxia to normoxia during the period 1973-1978.

CRITICAL EFFECTS OF HYPOXIA AND TEMPERATURE ON STURGEONS

Sensitivity by sturgeons and other fishes to temperature, oxygen and their interaction has been evaluated experimentally through respirometry. As an example, basal metabolism of the stellate sturgeon *Acipenser stellatus*, measured over a range of temperatures and oxygen levels shows that metabolism increases with temperature, but is only affected by oxygen only at lower oxygen levels, above which there is no response (Figure 1). The point of inflection in the curve of metabolic response to dissolved oxygen is called the critical concentration. Oxygen levels below that point will constrain metabolism, growth, swimming activity, and consumption (Fry 1971; Chiba 1988; Kaufmann and Wieser 1992). As basal metabolism increases due to increased temperature, the critical concentration becomes higher (Figures 1-3). In other words, as basic metabolic requirements increase with temperature, so too will oxygen demand. This increase in oxygen demand will outpace increased oxygen availability at higher temperatures (i.e. due to increased vapor pressure).

At very low oxygen concentrations, metabolism decreases rapidly to nil and the fish dies. This is termed the threshold concentration (Figures 1-3). Both critical and threshold concentrations were substantially higher for sturgeons in comparison to freshwater fishes (Figure 3). Critical concentrations for Eurasian sturgeons (*A. güldenstädtii, A. baeri, A. stellatus* and the hybrid *Huso huso x A. ruthensus*) ranged between 25-60% saturation, increasing with temperature. At 20 C, critical concentration was 3.6 mg/L (42% saturation) (Figures 2,3), which was c. 20% higher than that reported for rainbow trout. At 24 C, critical concentration was 4.5 mg/L (54% saturation) for the Eurasian sturgeons. The heightened response of metabolism to oxygen levels may be characteristic of sturgeons, and has been ascribed to an inefficiently functioning oxyregulatory system. Klyashtorin (1982) concluded that ancestral morphological and physiological traits caused sturgeons to be less efficient in respiration than other fishes. These traits included less efficient gill ventilation and lower affinity of hemoglobin to oxygen.

In experiments on Atlantic and shortnose sturgeons *A. oxyrinchus* and *A. brevirostrum*, Niklitschek (2001) observed substantial reductions in routine metabolism, consumption, feeding metabolism, growth, and survival at 40% v. 70% DO (Figures 4-7). Again the degree of effect due to oxygen level was conditional on temperature. In comparison to normoxia at 20 C, 40% DO saturation (3.3 mg/L) yielded a 76% and 54% reduction in growth, a 29% and 27% reduction in consumption, and an 23% and 17% reduction in

routine metabolism, for Atlantic and shortnose sturgeons, respectively. At 27 C and 40% saturation (2.9 mg/L), there was 86% and 51% reduction in growth, and 35% and 34% reduction in consumption, and a 28% and 21% reduction in routine metabolism, for Atlantic and shortnose sturgeons, respectively. Because routine metabolism was investigated rather than basal metabolism, estimates of critical concentrations were not possible. Secor and Gunderson (1998) reported c. 2- and 4-fold reductions in growth rate due to hypoxia at 26 and 19 C, respectively.

Few studies have addressed lethal effects of hypoxia on sturgeons (Table 1). Jenkins et al. (1994) observed 86 - 100% mortality for 25-64 day old fish in an acute 6 hr exposure to 2.5 mg/L at 22.5 C (30% saturation). Older juveniles 100-310 days old experienced 12-20 % mortality under the same conditions. Short-term exposure to 3.0 mg/L (35% saturation) resulted in 18-38% mortality for juveniles ranging 20-77 days in age. No mortality was observed for exposures to > 3.5 mg/L (42% saturation). Long term exposure (10 days) of Atlantic sturgeon young-of-the-year juveniles (c. 150-200 days old) to hypoxia at 26 C (37%-44% DO saturation; 2.8 - 3.3 mg/L) resulted in complete mortality over a ten day period in three of four replicates (Secor and Gunderson 1998). The fourth replicate experienced 50% mortality. At 20 C and hypoxia at 27%-37% saturation (2.3 - 3.2 mg/L), they observed 12-25% mortality over the 10 day period. No mortality was observed for normoxic treatments. In preliminary experiments, Niklitschek (2001) observed lethality for young-of-the-year Atlantic and shortnose sturgeon reared at 30% oxygen saturation (27 C; 2.3 mg/L) for 24 hours. Thus, he selected 40% saturation to observe sub-lethal physiological effects and avoid loss and suffering of experimental animals. At this "sub-lethal" level (2.8 mg/L at 28 C; 3.3 mg/L at 20 C), daily survival rates were significantly reduced in comparison to survival under normoxia (Figure 6). Threshold oxygen levels (levels below which basal metabolism cannot be sustained) reported for Eurasian sturgeons occurred at 1.7-2.0 mg/L (c. 25% saturation) for temperatures 20-24 C (Figure 2; Klyashtorin 1975). At 20 C, threshold oxygen concentrations were c. 20% higher for rainbow trout than for Eurasian sturgeons, but at temperatures less than 18 C, threshold values were quite similar between the sturgeons and rainbow trout (Figure 3).

Table 1. Results of lethality experiments on shortnose and Atlantic sturgeon.

Species, temperature	age (days)	DO (mg/L)	Survival	Ref/Comments
Shortnose, 22.5 C	46	2.0	8%	Jenkins et al. 1994, Figure 2, mean of 6 repl.s, run for 6 hr. duration.
	110	2.0	78%	
	25	2.5	0%	
	32	2.5	3%	
	64	2.5	14%	
	104	2.5	88%	
	20	3.0	62%	
	39	3.0	82%	
	77	3.0	67%	
	103	3.0	100%	
	19	3.5	78%	
	90	3.5	100%	
Atlantic, 26 C	150-200	2.8-3.3	12.5%	Secor and Gunderson 1998, mean of 4 repl.s run for 10 day duration, tanks open to air.
Atlantic, 20 C	150-200	2.3-3.2	78%	Secor and Gunderson 1998, mean of 4 repl.s run for 10 days duration, tanks sealed and open to air
Atlantic, 20-26 C	150-200	>5.0	100%	Secor and Gunderson 1998

In a direct comparison between juvenile white sturgeon and striped bass, growth rate was substantially more depressed under hypoxia in white sturgeon *A. transmontanus* (Cech et al. 1984). Growth rates under hypoxia (90 torr ~ 4.5 mg/L) and temperatures 20-25 C were 20-25% lower than those under normoxia (130 torr ~ 7 mg/L) for sturgeon. Striped bass reared under identical conditions experienced 7-9% growth depression under hypoxia. During the 34-day long experiment, higher mortalities of both species occurred under relatively mild hypoxia in comparison to normoxic treatments.

Beyond metabolic response, sturgeons undertake other important physiological and behavioral responses to hypoxia. Niklitschek (2001) observed that egestion levels for Atlantic and shortnose sturgeon juveniles increased significantly under hypoxia, indicating that consumed food was incompletely digested. This

response could serve as a useful means to shunt energy towards respiration and other life support functions (Figure 7). Behavioral studies indicate that Atlantic sturgeon and shortnose sturgeon are quite sensitive to ambient conditions of oxygen and temperature. In a series of choice experiments, juvenile sturgeons consistently selected normoxic over hypoxic conditions (Figure 8; Niklitschek 2001). On the other hand, larval stage Siberian sturgeon *A. baeri* did not actively avoid or disperse from experimental hypoxic conditions (2-3 mg/l at 19 C; Khakimullin 1988). Beyond escape or avoidance, sturgeons respond to hypoxia (< 40% saturation) through increased ventilation, increased surfacing (to ventilate relatively oxygen-rich surficial water), and decreased swimming and routine metabolism (Nonnette et al. 1993; Croker and Cech 1997; Secor and Gunderson 1998; Niklitschek 2001). Historically, sturgeons were at the center of a debate on whether or not fishes could oxyconform to hypoxia: that is, could fish tolerate declines in dissolved oxygen delivery to their tissues? (Burggren and Randall 1978; Klyashtorin 1982; Nonnette et al. 1993). Oxyregulation by the typical vertebrate mechanism of anaerobic metabolism has been since demonstrated for sturgeons (Nonnette et al. 1993; McKenzie et al. 1995), providing solid evidence against physiological oxyconformity. Still, behavioral means to oxyregulate in sturgeons may be relatively more important since critical concentrations are higher for sturgeons than other teleosts (Klyashtorin 1982). As evidence of this, white sturgeon juveniles were 3- to 9-fold less active under hypoxia (80 mm Hg ~ 5 mg/L or 50% saturation @16 C) than under normoxia (Croker and Cech 1997). Secor and Gunderson (1998) observed that lethality to hypoxia increased when surfacing behavior was blocked.

In summary, sturgeons endemic to the Chesapeake Bay, and sturgeons in general, are unusually sensitive to hypoxia in terms of their metabolic and behavioral responses. The critical concentration at which sturgeons metabolically respond to dissolved oxygen is higher or similar to that of rainbow trout. Bioenergetic and behavioral responses indicate that young-of-the-year juveniles (~30 to 200 days old) will experience lost production in those habitats with less than 60% saturation. For summertime temperatures (22-27 C), this level corresponds to c. 4.3 - 4.7 mg/L. Acute and chronic lethal effects for shortnose and Atlantic sturgeons were observed for levels ≤3.3 mg/L at summertime temperatures. Threshold concentrations for Eurasian sturgeons were somewhat lower ranging between 1.7 and 2.0 mg/L for temperatures 20-24 C.

A HABITAT SQUEEZE FOR CHESAPEAKE BAY STURGEONS?

Coutant and Benson (1990) proposed that habitats of Chesapeake Bay striped bass were severely curtailed during summer months due to thermal preference compounded by hypoxia. During summer, striped bass adults selected narrow lenses within the water column characterized by < 25 C water and normoxia (Cheek et al. 1985). In many instances, it was expected that such summertime refugia would curtail prey availability and growth. Coutant's concept, known popularly as the "habitat squeeze," was a prevailing hypothesis on the decline of striped bass during the 1980s. Using bioenergetic models (Hartman and Brandt 1995), Brandt and Kirsch (1993) mapped habitat suitability for striped bass in the Chesapeake Bay and predicted substantial habitat restrictions in summer, leading to negative or static growth during summer months.

Sturgeons are particularly vulnerable to a habitat squeeze (i.e. synergism between temperature and dissolved oxygen effects on habitat availability) due to their demersal lifestyle and unique bioenergetic responses to hypoxia. While sturgeons do occasionally surface, they depend almost exclusively on benthic substrates and bottom waters for spawning, feeding, migration, and refuge from predation or stressful environments (e.g. flow and temperature refugia). Their specialized underslung jaw, diets, electrosensory and olfactory systems, poor vision, body form, and heterocercal tail are but a few features that attest to their demersal lifestyle (Burggren 1978; Bemis and Kynard 1997; Carlson and Simpson 1987; Haley 1999; Secor et al. 2000). Atlantic sturgeons are known to occur at depths between 1 m to greater than 25 m; shortnose sturgeons have been observed between 1 and 12 m (Kieffer and Kynard 1997; Savoy and Shake 2000; Welsh et al. 2000). In the Chesapeake Bay during winter, Atlantic sturgeon selected deeper habitats occurring in the deep channel (Secor et al. 2000; Welsh et al. 2000). Thus, sturgeons are not limited by bathymetry within the Bay and would be expected to utilize sub-pychnocline waters contingent upon water quality.

In dissertation research, Niklitschek (2001) developed spatially explicit bioenergetic models for both Chesapeake Bay sturgeons to evaluate the influences of water quality parameters on sturgeon habitats. This is particularly appropriate for sturgeons because opportunities to directly observe habitat use is curtailed given their threatened or extirpated status. Habitat value was assigned based upon expected growth and survival responses, predicted by a bioenergetics model filtered through Chesapeake Bay Program Monitoring data (1990-1999).

Potential production rates for young-of-the-year Atlantic and shortnose sturgeons in the Chesapeake Bay reflected the strong seasonal cycle in potential production driven by the interaction of temperature, salinity and dissolved oxygen. Summer represented the most critical season in which hypoxia and high temperature conditions caused severe habitat fragmentation for both species, restricting suitable habitat to a small fraction of the Bay. Negative potential production areas closely mirrored hypoxic regions occurring in the middle mainstem, as well as the lower Patuxent, Potomac and Rappahannock rivers (Figures 9-10). Negative production areas were also predicted near the Bay mouth where very high salinities masked the otherwise improved conditions of dissolved oxygen and temperature. As a result, null or positive production was restricted to very limited areas, which coincide only in part between sturgeon species (Figure 9).

For Atlantic sturgeon, summer refuges for an average year were restricted to the upper Bay between the Magothy River and the Susquehanna Flats. Slightly negative areas were expected around Fishing Bay-Nanticoke River, between the Severn and Choptank rivers and in the upper Potomac River. For shortnose sturgeon, most suitable habitat in the mainstem would be restricted to the Bay head above Sassafras River. Other areas of positive production included the upper sections of the Potomac and James rivers, as well as most of the Nanticoke River. The total area supporting positive production (suitable habitat) under average July conditions corresponded to 1,586 and 1,076 km^2, for Atlantic and shortnose sturgeons, respectively. These surfaces represent 8.5% and 5.8% of the total surface area of the mainstem and tidal sections of its tributaries. The best summer condition for both sturgeons was predicted for 1996, where suitable habitat reached circa 4,200 km^2 for Atlantic sturgeon and 2,050 km^2 for shortnose sturgeon. In 1996, average temperature and salinity were the second lowest in the studied period, while average dissolved oxygen conditions were above the average. This year also exhibited the highest July freshwater inflow of the studied period. The worst conditions for Atlantic sturgeon were observed in July 1999, where suitable habitat was close to 1 km^2. In 1999, overall salinity was highest in the time series. This higher than usual salinity reduced the habitat value of the upper Bay section, which is typically the most productive section of the Chesapeake Bay due to favorable temperature and oxygen conditions.

In summary, due to avoidance, sub-lethal, or lethal effects, sturgeon summertime habitats are expected to be restricted in comparison to historical times when hypoxia was less prevalent (Officer et al. 1984; Cooper et al. 1991). The habitat squeeze phenomenon is particularly relevant to sturgeons due to the synergism of temperature, dissolved oxygen and salinity during their first year of life. In dry years, the interaction of

high salinity, warm temperatures, and hypoxic waters reduces sturgeon habitats and in some years can virtually eliminate all habitats for Atlantic sturgeon. The fragmented distribution and small volume of productive habitats imposed by summertime hypoxia represents a substantial hurdle to overcome in the restoration of Chesapeake Bay sturgeons.

CHESAPEAKE BAY STURGEONS: WHERE ARE THEY NOW?

Shortnose sturgeon are in all probability extirpated from the Chesapeake Bay. Those shortnose recently observed in the region of Susquehanna flats and in the Potomac River have been confirmed to be immigrants from the Delaware Bay population, presumably having migrated through the C&D Canal (Wirgin et al. in review). The status of Atlantic sturgeon in the Chesapeake Bay is less certain (Grogan and Boreman 1998). There has been no evidence of reproduction in the Maryland portion of the Chesapeake Bay for over 25 years (Secor 1995). Recently, evidence of reproduction (capture of young-of-the-year Atlantic sturgeon) occurred for the York and Rappahannock Rivers (NMFS 1998). Based upon historical catch data, Secor (in press) estimated that 19th century adults may have numbered > 100,000 in the Chesapeake Bay. Their numbers were decimated by over-exploitation at the turn of the 19th-20th century. During the past 100 years, there has been no evidence of recovery.

Secor and Gunderson (1998) hypothesized that due to their unusual sensitivity to hypoxia, Atlantic sturgeon may have been extirpated in Maryland waters due in part to the increased prevalence of hypoxia in the 20th century. Atlantic sturgeon populations recovered in South Carolina estuaries and in the Hudson River after the intensive 19th century fishery (Smith et al. 1985; NMFS 1998) but not in the Chesapeake Bay. Secor (in press) recorded that cycles of overfishing and recovery for this species occur over a 50 year period. Prevalence of hypoxia increased in critical habitats of sturgeons due to post-WWII agricultural practices (industrial fertilizers) and residential development (increased waste water). These factors may have curtailed any 20th century cycle of recovery within the Chesapeake Bay. Still, there are other important factors which also may have prevented recovery, including lost spawning grounds due to siltation and reductions in abundance due to incidental catch (there has been no directed fishery for sturgeons in over a century in the Chesapeake Bay). Circumstantial evidence for a relationship between increased hypoxia and loss of sturgeons this past century includes the absence of sturgeons in systems that are prevalently hypoxic in summer (Collins et al. 2000).

The recent recovery of shortnose sturgeon abundance in the Hudson River is also consistent with the idea that hypoxia may be important in controlling sturgeon populations. Bain et al. (2000) have compared mark-recapture population estimates for the period 1980 - 1995. During this period, sub-adult and adult shortnose sturgeon increased from c. 13,000 to 57,000 - a four-fold increase in abundance! This yields a population growth rate of 10% per year that is remarkably high for a long-lived, late maturing species such as shortnose sturgeon. Prior to 1974, a pervasive hypoxic/anoxic summertime region known as "Albany Pool" (Figure 11) overlapped c. 40% of the expected nursery habitat for shortnose sturgeon (i.e. 40% of tidal freshwater). Levels of pervasive hypoxia (<30% saturation) would have been lethal to shortnose sturgeon juveniles (Figures 12, 13). Few fish, sturgeon or otherwise, were documented in the in the 60 km river stretch during July - October (Leslie et al. 1988). In 1974, >80% of the region's wastewater received secondary and tertiary treatment, and in less than two years the system recovered fully to normoxia (Figures 12, 13). Monitoring data showed a dramatic faunal recovery in the number of fish species returning to the Albany Pool region (Leslie et al. 1988). In 1983, a relatively strong year-class (high abundances of juveniles) was reported by two independent studies (Carlson and Simpson 1987; Dovel et al. 1992). This year-classes may have stimulated recovery of Hudson River shortnose sturgeon during the past 20 years.

In summary, absence or diminished populations of sturgeons correspond to systems where summertime hypoxia is prevalent. Recovery of normoxia to the Hudson River estuary corresponded with a remarkable recovery of shortnose sturgeon there. These case studies provide circumstantial evidence that summertime hypoxia might substantially diminish population recovery or perhaps even lead to extirpation. Sturgeons represent the only threatened or extinct resource species in the Chesapeake Bay. Future recovery of sturgeons that was coincident with improved water quality in the Chesapeake Bay would be a quite a success story.

References

Bain, N.B., N. Haley, D.L. Peterson, K.K. Arend, K.E. Mills, and P.J. Sullivan. 2000. Shortnose sturgeon of the Hudson River: an Endangered Species recovery story. Biology, Management and Protection of Sturgeon Symposium Pre-Print. EPRI. Palo Alto, CA.

Barrowman, T.M. and M.L. O'Shea. (1996). Long-term improvements in water quality due to sewage abatement in the Lower Hudson River. Estuaries. 19: 890-900.

Bemis, W.E. and B. Kynard. (1997). Sturgeon rivers: an introduction to acipenseriform biogeography and life history. Environ. Biol. Fishes. 46: 167-183.

Brandt, S.B. and J. Kirsch. (1993). Spatially explicit models of striped bass growth potential in Chesapeake Bay. Trans. Am. Fish. Soc. 122: 845-869.

Burggren, W.W. and D.J. Randall. (1978). Oxygen uptake and transport during hypoxic exposure in the sturgeon *Acipenser transmontanus*. Respir. Physiol. 34: 171-183.

Carlson, D.M. and K.W. Simpson. 1987. Gut contents of juvenile shortnose sturgeon in the upper Hudson Estuary. Copeia 1987: 796-802.

Cheek, T.E., M.J. Van Den Avyle, and C.C. Coutant. (1985). Influence of water quality on distribution of striped bass in a Tennessee River impoundment. Trans. Am. Fish. Soc. 114: 67-76.

Coutant, C.C. and D.L. Benson. (1990). Summer decline in habitat suitability for striped bass in Chesapeake Bay: reflections on a population decline. Trans. Am. Fish. Soc. 119: 757-778.

Chiba, K. (1988). The effecto do dissolve oxygen on the growth of young striped bass. Nipp. Suis. Gakk. 54: 599-606.

Claireaux, G. and J. Lagardere P. (1999). Influence of temperature, oxygen and salinity on the metabolism of the European sea bass. J. Sea Res. 42: 157-168.

Collins, M.R. S.G. Rogers, T.I.J. Smith, and M.L. Moser. 2000. Primary factors affecting sturgeon populations in the southeastern United States. Fishing mortality and degradation of essential fish habitats. Bull. Mar. Sci. 66: 917-928.

Cooper, S.R. and G.S. Brush. (1993). A 2,500-year history of anoxia and eutrophication in Chesapeake Bay. Estuaries. 16: 617-626.

Coutant, C.C. (1987). Thermal preference: when does an asset become a liability. Environ. Biol. Fishes. 18: 161-172.

Crocker, C.E. and J.J. Chech. (1997). Effects of environmental hypoxia on oxygen consumption rate and swimming activity in juvenile white sturgeon, *Acipenser transmontanus*, in relation to temperature and life intervals. Environ. Biol. Fishes. 50: 382-389.

Croker, C.E. and J.J. Cech. (1996). The effects of hypercapnia on the growth of juvenile white sturgeon, *Acipener transmontanus*. Aquacult. 147: 293-299.

Croker, C.E. and J.J. Cech. (1997). Effects envrironmental hypoxia on oxygen consumption rate and swimming activity in juvenile white sturgeon, *Acipenser transmontanus*, in relation to temperature and life intervals. Environ. Biol. Fishes. 50: 383-389.

Dadswell, M. J. 1979. Biology and population characteristics of the shortnose sturgeon, *Acipenser brevirostrum* Le Seuer 1818 (Osteichthyes: Acipseridae), in the Saint John Estuary, New Brunswick, Canada.

Can. J. Zool. 57:2186-2210.

Dovel, W.L. and T.J. Berggren. 1983. Atlantic sturgeon of the Hudson Estuary, New York. NY Fish and Game Journal 30: 140-172.

Dovel, W.L., A.W. Pekovitch, and T.J. Berggren. 1992. Biology of the shortnose sturgeon (*Acipenser brevirostrum* LeSueur, 1818) in the Hudson River Estuary, New York, p. 187-227. In C.L. Smith (ed.). Estuarine Research in the 1980s. State Univ. New York, Stony Brook, NY.

Grogan, C. S., and J. Boreman. 1998. Determining the probability that historical populations of fish species are extirpated. N. Am. J. Fish. Mgmt. 18:522-529.

Gross, MR, J. Repka, C. Robertson, D.H. Secor, and W. VanWinkle. in press. Conserving ancient fish: life history and demography of sturgeon. Am. Fish. Soc. Symp.

Haley, N.J. (1999): Habitat characteristics and resource use patterns of sympatric sturgeons in the Hudson River Estuary. M.S. Thesis, Univ. Mass., Amherst. 124 p.

Hartman, K.J. and S.B. Brandt. (1995). Comparative energetics and the development of bioenergetics models for sympatric estuarine piscivores. Can. J. Fish. Aquat. Sci. 52: 1647-1666.

Jenkins, W.E., T.I.J. Smith, L.D. Heyward, and D.M. Knott. (1994). Tolerance of shortnose sturgeon, *Acipenser brevirostrum*, juveniles to different salinity and dissolved oxygen concentrations. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. : .

Hildebrand, S. F., and W. C. Schroeder. 1927. Fishes of the Chesapeake Bay. U.S. Bureau of Fisheries, Washington, D.C. 388 pp.

Kaufmann, R. and W. Wieser. (1992). Influence of temperature and ambient oxygen on the swimming energetics of cyprinid larvae and juveniles. Environ. Biol. Fishes. 33: 87-95.

Khakimullin, A.A. (1987). Oxygen preferendum (preferred oxygen regime) of hatchery young of the siberian sturgeon, *Acipenser baeri*. Vop. Ikht. 1987: 693-696.

Kieffer, M. C., and B. Kynard. 1993. Annual movements of shortnose and Atlantic sturgeon in the Merrimack River, Massachusetts. Trans. Am. Fish. Soc. 122:1088-1103.

Klyashtorin, L.B. (1982). The ability of sturgeons (Acipenseridae) to regulate gas exchange. Ichthyology. : 141-144.

Klyashtorin, L.B. 1976. The sensitivity of young sturgeons to oxygen deficiency. J. Icthyol. 16: 677-681.

Leslie, J.A., K.A. Abood, E.A. Maikish, and P.J. Keeser. 1988. Recent Dissolved Oxygen Trends in the Hudson River, p. 287-303 In C.L. Smith [ed.] Fisheries Research in the Hudson River. State University of New York, Albany. 407 pp.

McKenzie, D.J., J.F. Steffensen, C.L. Bolis, P. Bronzi, and E.W. Taylor. (1995). Effects of diet on

spontaneous locomotor activity and oxygen consumption in adriatic sturgeon *Acipenser naccarii*. Fish Phys. and Biochem. 14: 341-355.

National Marine Fisheries Service. 1998. Status review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). NMFS, Gloucester, MA. 124 pp.

Niklitschek, E. J. 2001. Bioenergetics Modeling and Assessment of Suitable Habitat for Juvenile Atlantic And Shortnose Sturgeons in the Chesapeake Bay. Ph.D. thesis, University of Maryland, College Park, MD.

Nonnotte, G., V. Maxime, J.P. Truchot, P. Williot, and C. Peyraud. (1993). Respiratory responses to progressive ambient hypoxia in the sturgeon, *Acipenser baeri*. Respir. Physiol. 91: 71-82.

Officer, C. B., R. B. Biggs, J. L. Taft, L. E. Cronin, M. A. Tyler, and W. R. Boynton. 1984. Chesapeake Bay anoxia: Origin, development, and significance. Science (Wash., D.C). 223:22-27.

Paerl, H.W., J.L. Pinckney, J.M. Fear, and B.L. Peierls. (1998). Ecosystem responses to internal and watershed organic matter loading: consequences for hypoxia in the eutrophying Neuse River Estuary, North Carolina, USA. Mar. Ecol. Prog. Ser. 166: 17-25.

Petersen, J.K. and L. Pihl. (1995). Responses to hypoxia of plaice, *Pleuronectes platessa* and dab, *Limanda limanda*, in the south-east Kattegat: distribution and growth. Environ. Biol. Fishes. 43: 311-321.

Ruer, P.M., J.J. Cech, and S.I. Doroshov. (1987). Routine metabolism of the white sturgeon, *Acipenser transmontanus*: Effect of population density and hypoxia. Aquacult. 62: 45-52.

Sauriau, P.-G., J.-P. Robin, and J. Marchand. (1993). Les Mortalites estivales du mulet *Liza ramada* en loire: dysfunctionnement cyclique du role de voie de migration d'un estuarie. Bull. Ecol. 24: 87-91.

Savoy, T. and D. Shake. 2000. Atlantic sturgeon, *Acipenser oxyrinchus*, movements and important habitats in Connecticut waters. Biology, Management and Protection of Sturgeon Symposium Pre-Print. EPRI. Palo Alto, CA.

Secor, D.H. In press. Atlantic sturgeon fisheries and stock abundances during the late 19th Century. Am. Fish. Soc. Symp.

Secor, D.H., E. Niklitschek, J. T. Stevenson, T. E. Gunderson, S.Minkkinen, B. Florence, M. Mangold, J. Skjeveland and A.Henderson-Arzapalo. 2000. Dispersal and growth of yearling Atlantic sturgeon *Acipenser oxyrinchus* released into the Chesapeake Bay. Fish. Bull. 98(4): 800-810.

Secor, D. H. and J. R. Waldman. 1999. Historical abundance of Delaware Bay Atlantic sturgeon and potential rate of recovery, p. 203-216 In J.A. Musick [ed.] Life in the slow lane: ecology and conservation of long-lived marine animals. Am. Fish. Soc. Symp. 23: 203-216.

Secor, D.H. and T.E. Gunderson. (1998). Effects of hypoxia and temperature on survival, growth, and respiration of juvenile Atlantic sturgeon, *Acipenser oxyrinchus*. Fish. Bull. 96: 603-613.

Secor, D. H. 1995. Chesapeake Bay Atlantic sturgeon: Current status and future recovery. Chesapeake Biological Laboratory, Solomons, MD. 11 pp.

Smith, T.I.J. (1985). The fishery, biology, and management of Atlantic sturgeon, *Acipenser oxyrhynchus*, in North America. Environ. Biol. Fishes. 14: 61-72.

Welsh, S.A., J.E. Skjeveland, M.F. Mangold, and S.M. Eyler. 2000. Distributions of wild and hatchery-reared Atlantic sturgeon in the Chesapeake Bay, MD. Biology, Management and Protection of Sturgeon Symposium Pre-Print. EPRI. Palo Alto, CA.

Winberg, G.G. 1960. New Information on Metabolic Rate in Fishes. Fisheries Research Board of Canada, Nanaimo, B.C. 234 pp.

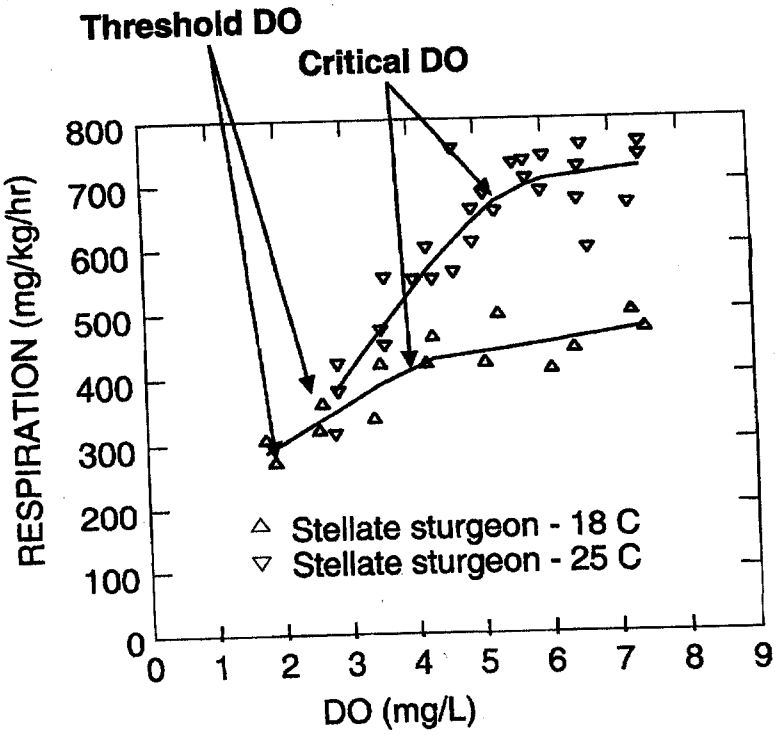


Figure 1. Basal metabolic responses by young-of-the-year stellate sturgeon (*A. stellatus*). Data from Winberg 1956, Figure 20. Critical DO is given for inflection point indicating the point of metabolic responsiveness. Threshold DO indicates lethality where basal metabolism can no longer be maintained..

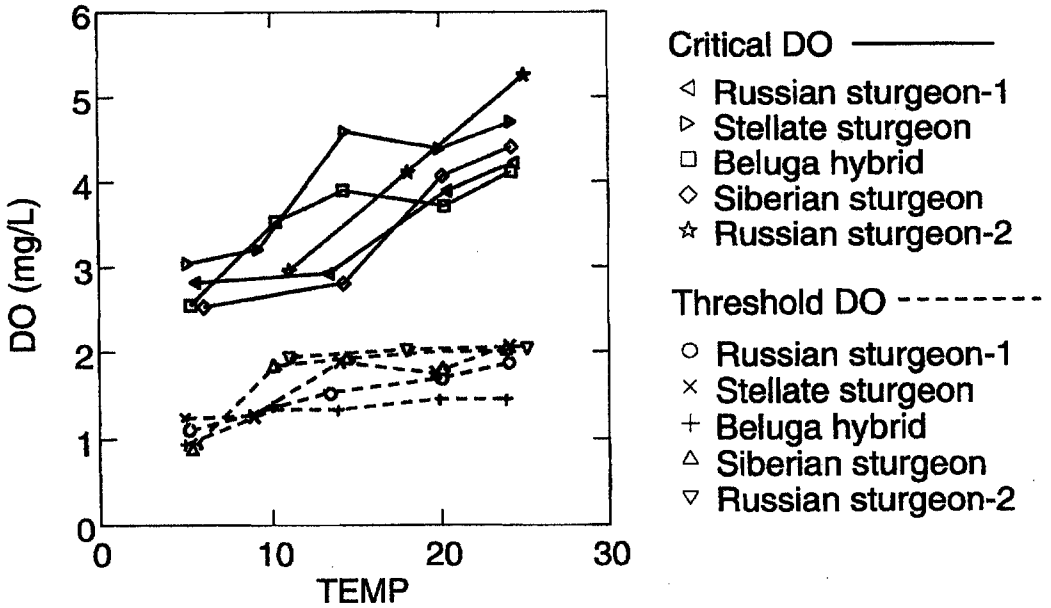


Figure 2. Critical DO concentrations for Eurasian sturgeons (*A. gueldenstaedtii, A. stellatus, H. huso X A. ruthensus, A. baeris*). Data from Klyashtorin 1976, Figure 3 (DO levels were recalculated from partial pressures to concentration). Critical DO is given for inflection point indicating the point of metabolic responsiveness. Threshold DO indicates lethality where basal metabolism can no longer be maintained. Russian sturgeon-1 and Russian sturgeon-2 designate two separate experiments. All data for young-of-the-year stage sturgeons.

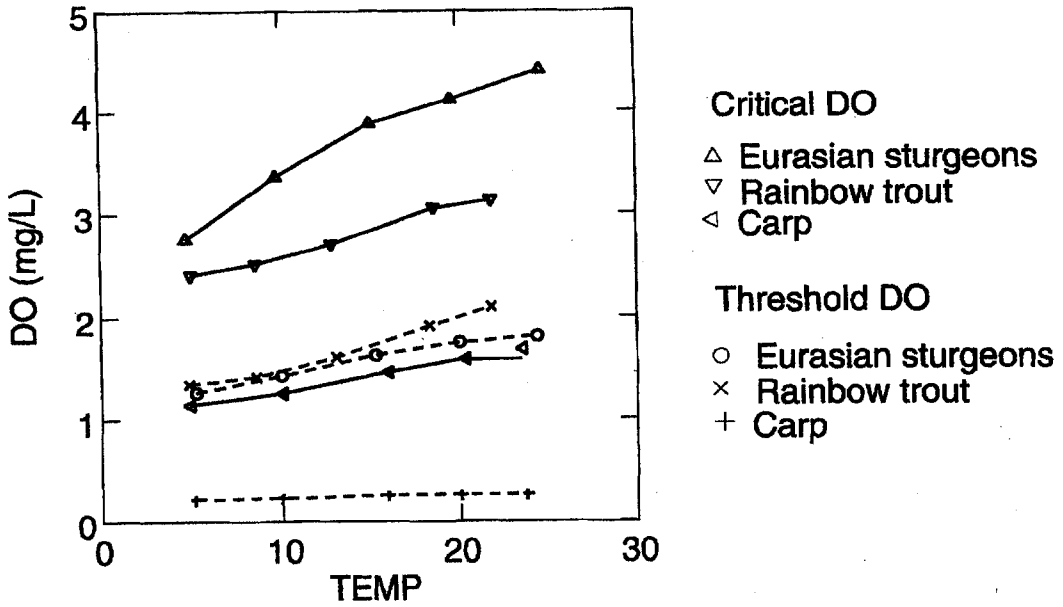
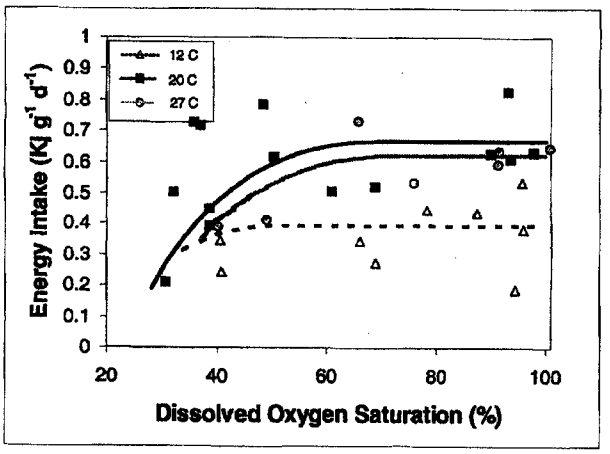


Figure 3. Critical DO concentrations for Eurasian sturgeons (*A. gueldenstaedtii, A. stellatus, H. huso X A. ruthensus, A. baeris*). Data from Klyashtorin 1976, Figure 6 (DO levels were recalculated from partial pressures to concentration). Critical DO is given for inflection point indicating the point of metabolic responsiveness. Threshold DO indicates lethality where basal metabolism can no longer be maintained. Data for Eurasian sturgeons represents a pooled mean response. All data for young-of-the-year stage sturgeons, trout and carp.

Atlantic sturgeon



Shortnose sturgeon

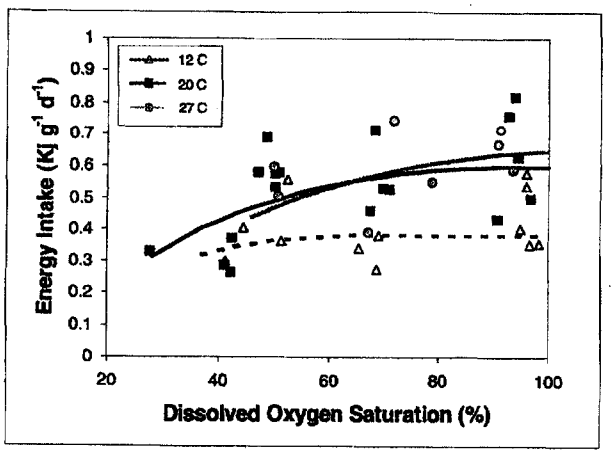


Figure 4. Effect of DO and temperature on consumption by Atlantic and shortnose sturgeon young-of-the-year. 10-d laboratory experiments conducted by Niklitschek (2001).

Atlantic sturgeon

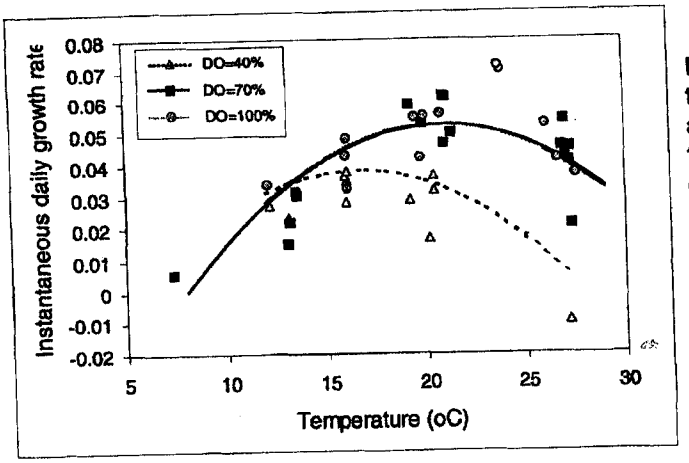
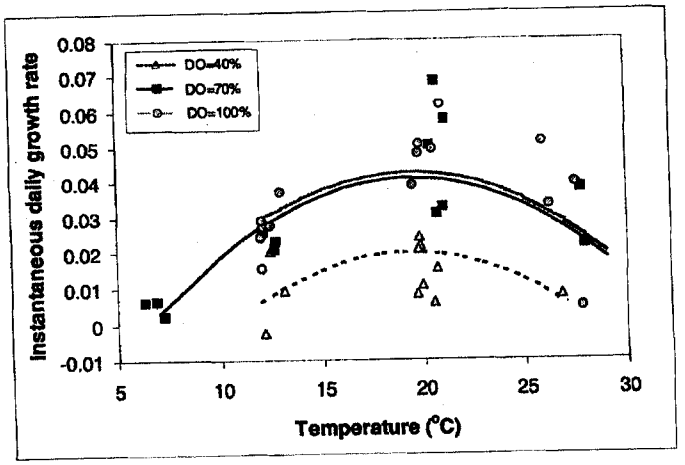


Figure 5. Effect of DO and temperature on growth by Atlantic and shortnose sturgeon young-of-the-year. 10-d laboratory experiments conducted by Niklitschek (2001).

Shortnose sturgeon



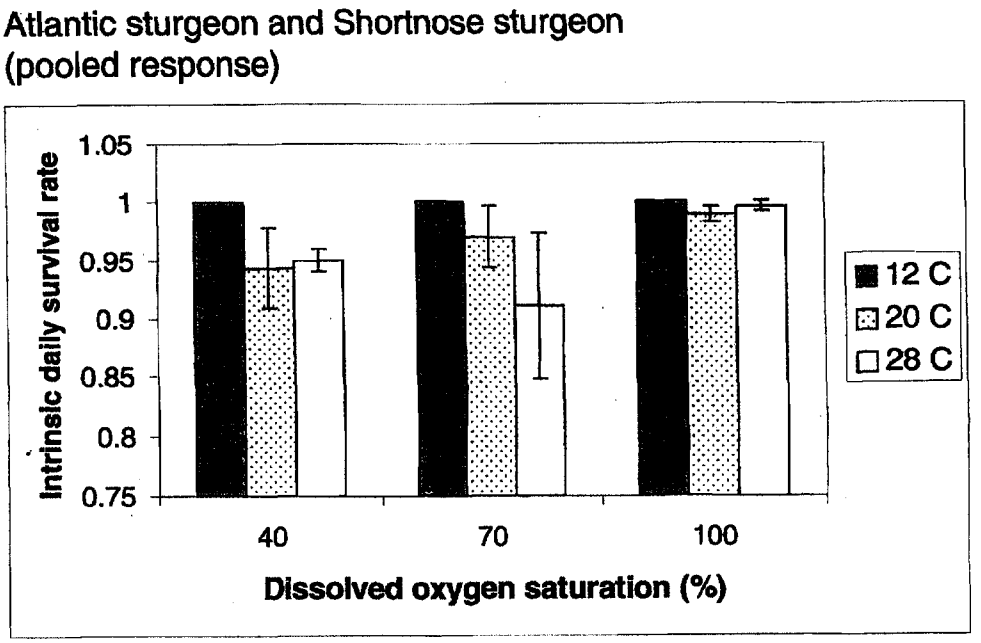
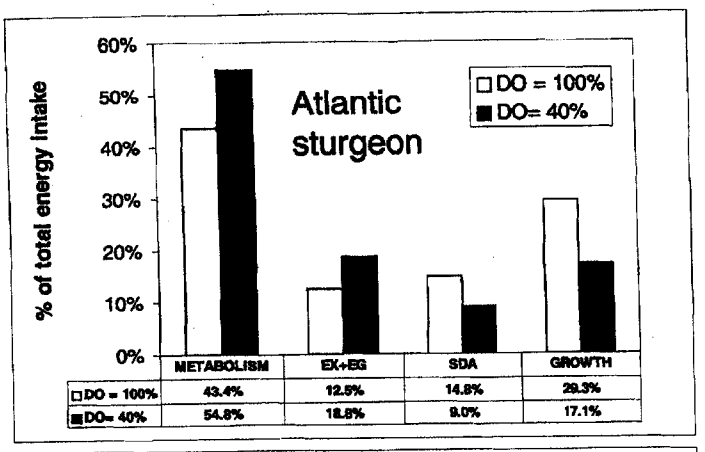


Figure 6. Effect of DO and temperature on long-term survival (20-45 d trials) by Atlantic and shortnose sturgeon young-of-the-year. Laboratory experiments conducted by Niklitschek (2001). Bars represent standard errors.



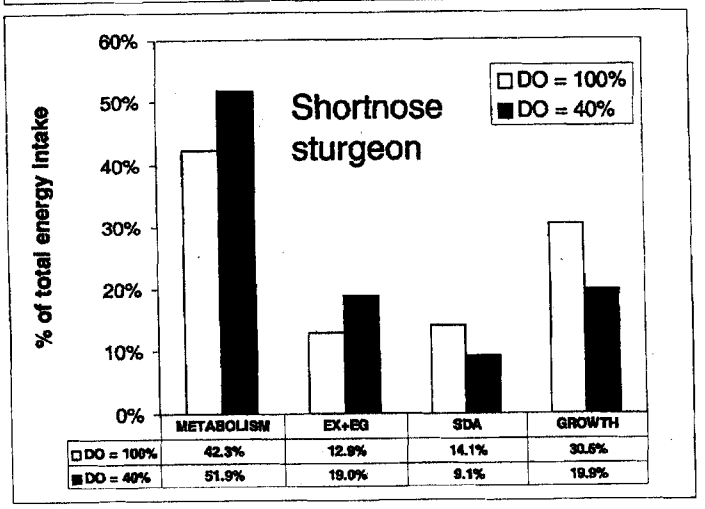
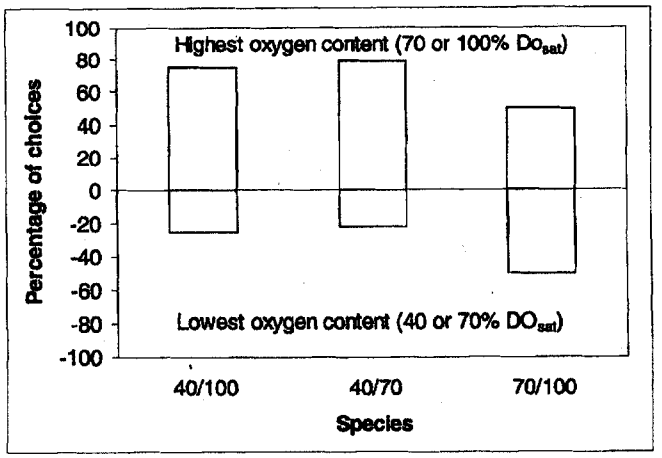


Figure 7. Effect of DO on energy allocation patterns for Atlantic and shortnose sturgeon young-of-the-year, based upon laboratory experiments by Niklitschek (2001). Allocation modeled for temperature=20 C and salinity=8 ppt.

Atlantic sturgeon



Shortnose sturgeon

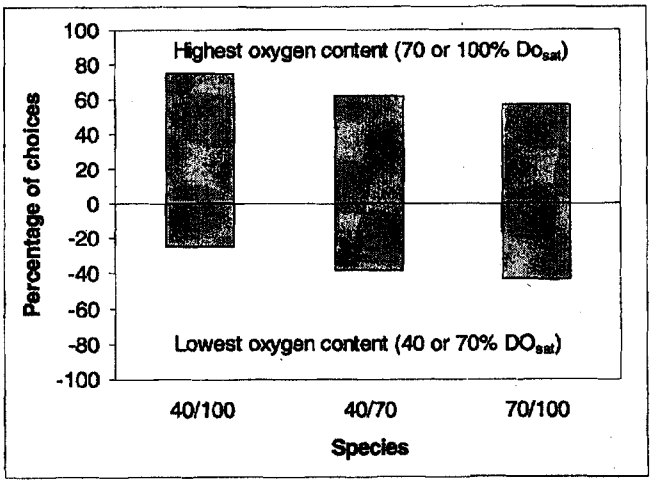


Figure 8. Selection of hypoxia (40% saturation) over normoxia (70 or 100% saturation) by Atlantic and shortnose sturgeon young-of-the-year. Based upon selection experiments conducted by Niklitschek (2001). Positive % of choices indicates selection of higher DO, negative % indicates selection of lower DO level.

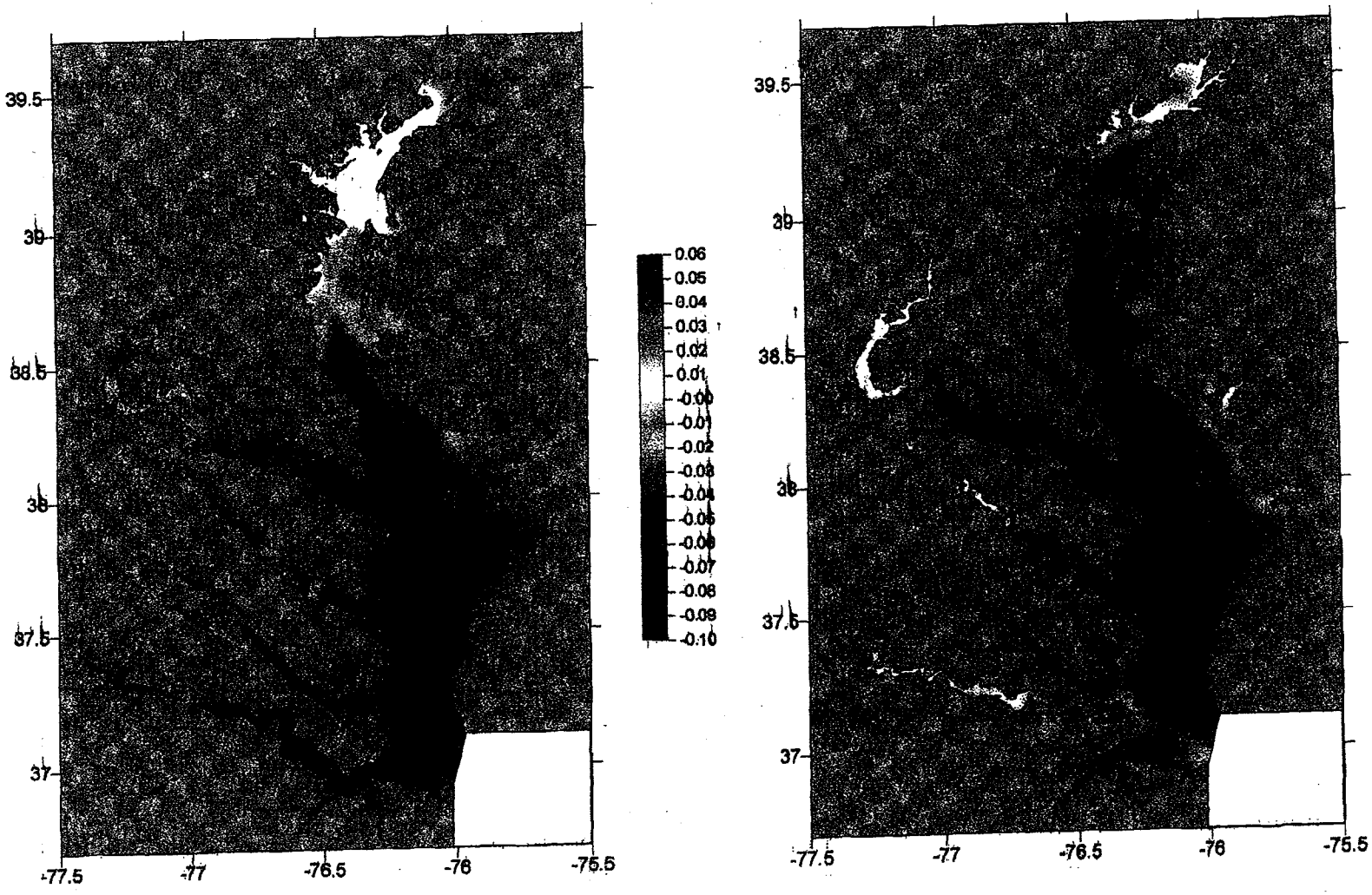


Figure 9. Spatially explicit maps of habitat suitability (potential production) by Atlantic and shortnose sturgeon young-of-the-year in the Chesapeake Bay during July (1990-1999). From Niklitschek (2001).

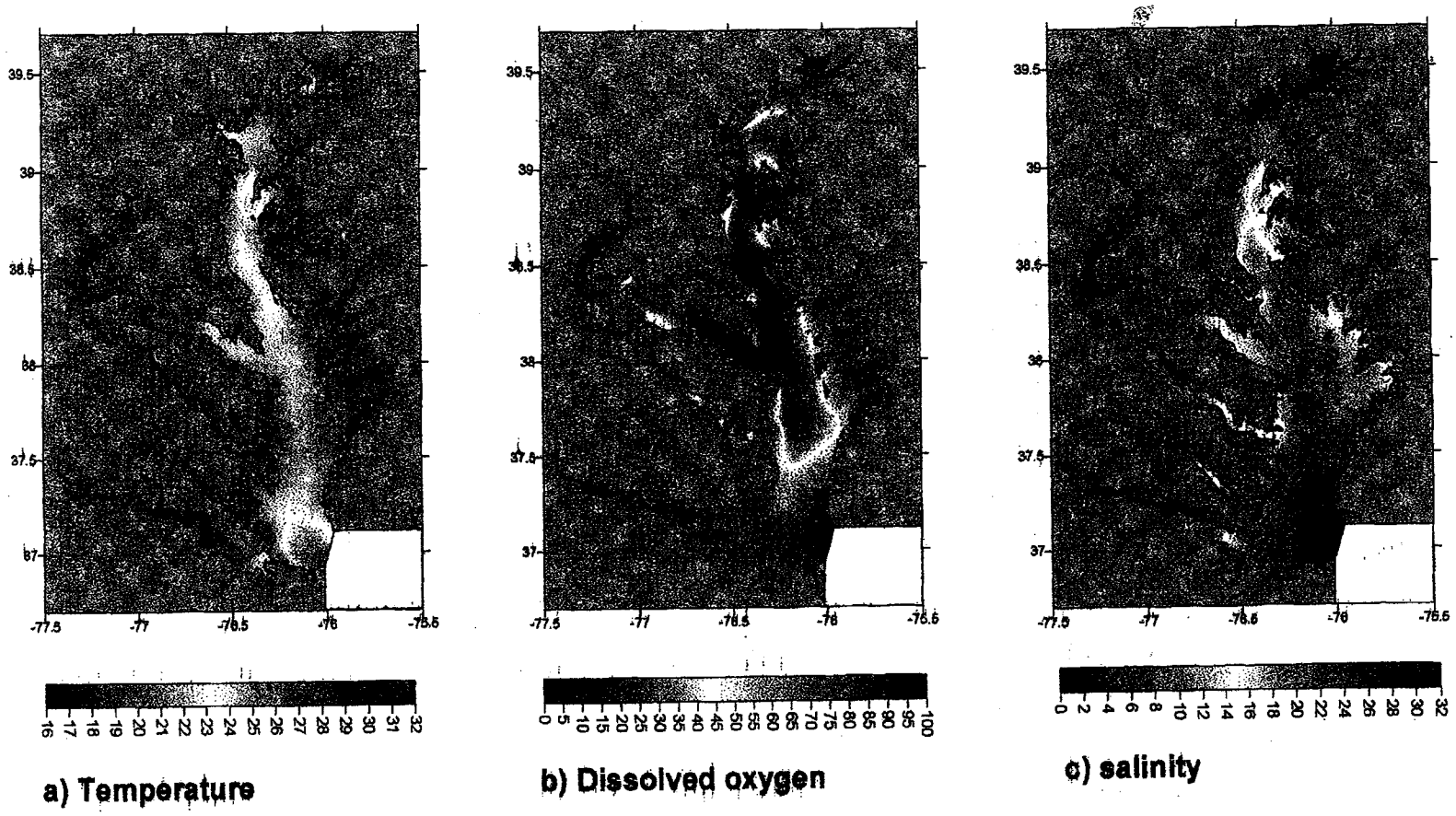


Figure 10. Bottom water quality conditions in the Chesapeake Bay. From Niklitschek (2001).

The Albany Pool

"Below the dam at Troy, open sewers from that city face upon the river like so many giant backsides. Without question this stretch of the river is the most polluted part of the Hudson, exceeding even New York City in concentrated filth. Indeed, the river here can be so awesomely foul that it is a source of wonder to sanitary engineers, and in the trade they speak of the place, almost fondly, as the *Albany Pool.*

There are sturgeon and striped bass and occasional shad which buck up against Troy dam with ancestral fury, while the spring runoff from the Adirondacks thunders downstream. But then the runoff slows, and death comes to the Albany Pool with the first hot spell..."

- R. Boyle. 1969. *The Hudson River*

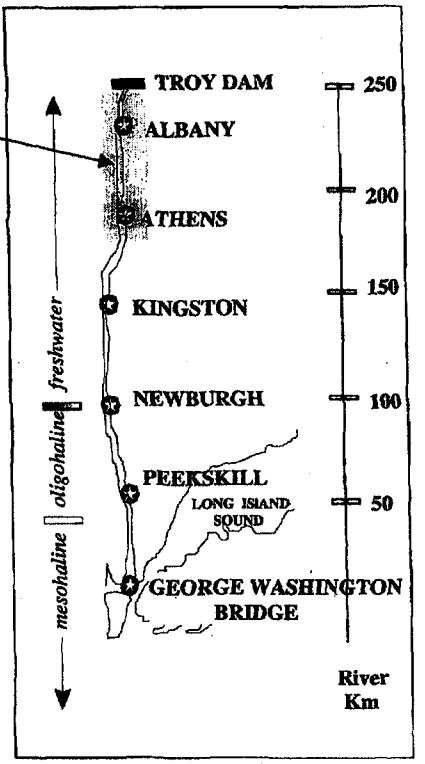
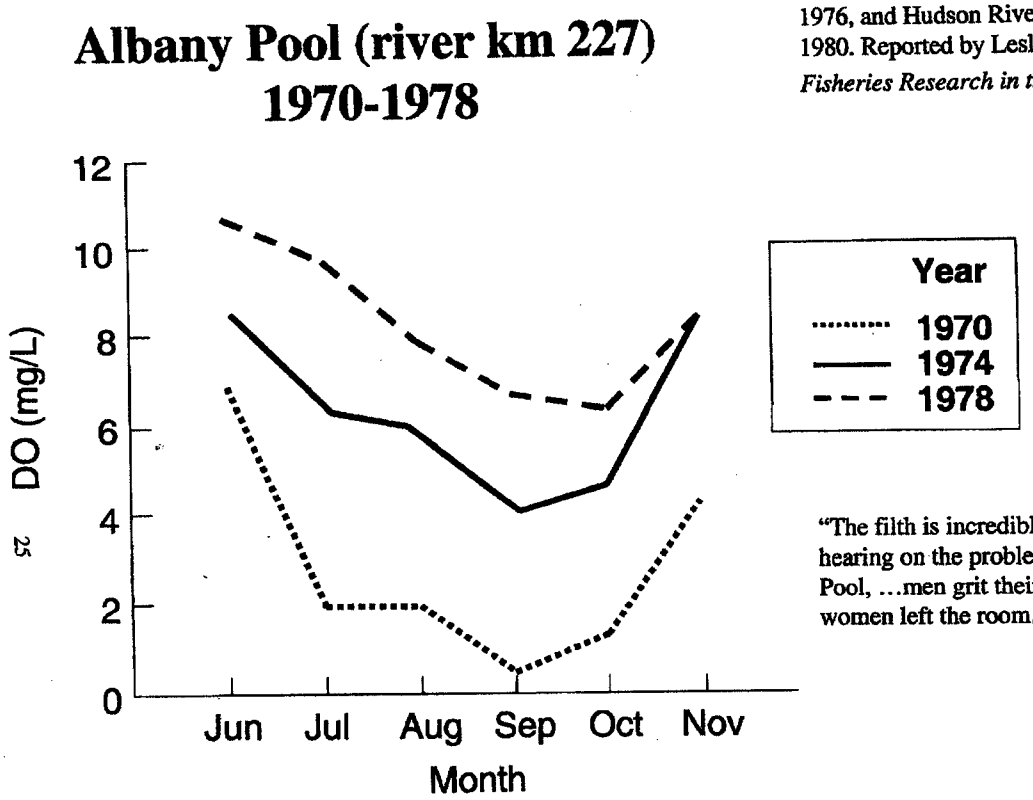


Figure 11. Region of persistent hypoxia known as Albany Pool in the Hudson River. This region overlaps broadly with shortnose sturgeon nursery habitat that occurs throughout the freshwater tidal reach of the estuary.

Data from Lawler, Matusky and Skelly © 1976, and Hudson River Research Council 1980. Reported by Leslie et al. 1988 In *Fisheries Research in the Hudson River.*



"The filth is incredible; during a state hearing on the problems of the Albany Pool, ...men grit their teeth and women left the room." (Boyle 1969).

Figure 12. DO levels for an "Albany Pool" station during summer and fall months.

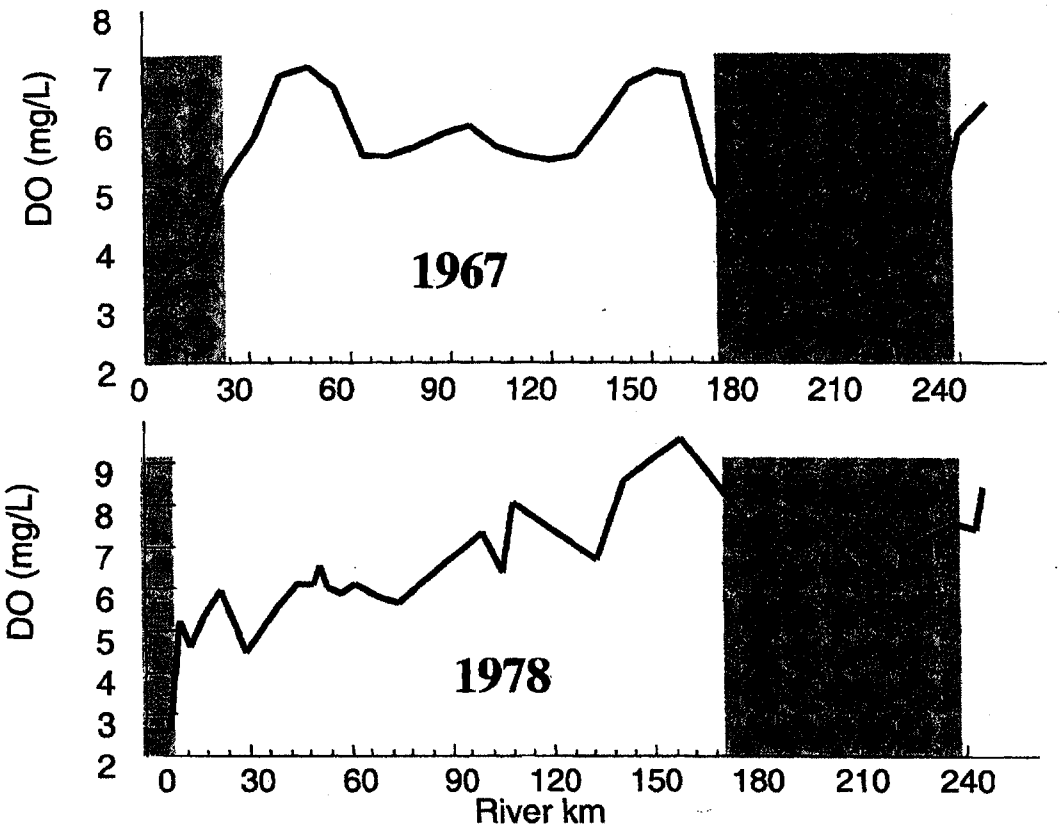


Figure 13. DO levels throughout the Hudson River estuary before (1967) and after (1978) system recovery from hypoxia. "Albany Pool" is shown in gray for upriver DO sag (1967).