From: Gentry, Nathan on behalf of Burke, Thomas
To: Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Yohannes, Lia; Knightes, Chris; Zambrana, Jose; Briskin, Jeanne; Teichman, Kevin
CC: Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos Ex. 4
Sent: 3/30/2015 9:06:29 AM
Subject: HF Drinking Water Chapter Comments: 1,2,3, and 5

CT: Nathan Gentry

Teleconference: Details TBD

Staff:

Notes: Discussion of comments for Chapters 1-3 and 5.

From: Yohannes, Lia
To: Briskin, Jeanne; Burden, Susan; Daiss, Rebecca; Gibbons, Dayna; Matthews, Lisa; Roberts, Cindy; Sharkey, Susan; Tinsley, Chuck; Watkins, Stephen; Wiser, Nathan; Frithsen, Jeff; LeDuc, Stephen; Cluff, Maryam; Singer, Alison; Williams, Larke; Bueno, Michael; Fleming, Megan; Ridley, Caroline; Dean, Jill; Corona, Elizabeth; Hubbard, Carolyn
CC: Maloney, Kelsey; Jonathan.Koplos Ex. 4 Shari.Ring Ex. 4 Knightes, Chris; MaryEllen.Tuccillo Ex. 4 Stanek, John; Weaver, Jim; eeyost Ex. 6
Sent: 3/10/2015 9:38:29 AM
Subject: HF Team Meeting

Hi all,

Just wanted to let you know that Tom Burke is planning on stopping by during the meeting today. Also, we may end the meeting early since many will be attending the HFDWA Review Discussion with Bob Kavlock at 11am.

Thanks!

Conference: Ex. 6

Liabeth Yohannes
Student Services Contractor
Office of Research and Development
U.S. Environmental Protection Agency
e: Yohannes.lia@epa.gov
p: 202.564.6755

From: Gibbons, Dayna
To: Burke, Thomas
Sent: 3/27/2015 1:03:49 PM
Subject: Accepted: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 2 - if needed)

From: Gibbons, Dayna
To: Burke, Thomas
Sent: 3/27/2015 12:57:50 PM
Subject: Accepted: HF Drinking Water Chapter Comments: 1,2,3, and 5

From: Burke, Thomas
To: Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John
CC: Kavlock, Robert; Kadeli, Lek; Jonathan.Koplos Ex. 4 Shari.Ring Ex. 4 MaryEllen.Tuccillo Ex. 4 Vandenberg, John; Walsh, Debra; Yost, Erin; Burgoon, Lyle; Fleming, Megan
Sent: 3/27/2015 1:28:27 PM
Subject: HF Drinking Water Chapter Comments: Executive Summary & chapter 4 (Discussion part 2 - if needed)

CT: Nathan Gentry

Teleconference: Ex. 6

Staff:

Notes: Discussion of comments for Chapters 6-10 and executive summary

From:	Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; LeDuc, Stephen; Fleming, Megan; Ridley, Caroline
CC:	Kavlock, Robert; Kadeli, Lek
Sent:	3/27/2015 1:28:47 PM
Subject:	HF Drinking Water Chapter Comments: Chapter 4

CT: Nathan Gentry

Notes: Discussion of comments for Chapter 4

From: Gentry, Nathan on behalf of Burke, Thomas
To: Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Yohannes, Lia; Knightes, Chris; Zambrana, Jose; Briskin, Jeanne; Teichman, Kevin
CC: Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos
Sent: 3/30/2015 9:06:29 AM
Subject: HF Drinking Water Chapter Comments: 1,2,3, and 5

Ex. 4

CT: Nathan Gentry

Teleconference: Details TBD

Staff:

Notes: Discussion of comments for Chapters 1-3 and 5.

From: Gentry, Nathan on behalf of Kavlock, Robert
To: Kavlock, Robert; Burke, Thomas
Sent: 3/18/2015 3:08:15 PM
Subject: SAB Hydraulic Fracturing Research Advisory Panel meeting
Attachments: Agenda 20151028 Panel Meeting.pdf

From: Frithsen, Jeff
Sent: Friday, April 17, 2015 4:18 PM
To: Smith, Kelley
Subject: HFDWA: SAB Review

Kelley:

Sharing as FYI and potentially for Tom's Calendar, dates for the SAB review of the HFDWA. The most important date is the ad hoc panel meeting in late October.

- 8/31/15: Monday, 12pm-5pm EST teleconference
- 9/1/15: Tuesday, 12pm-5pm EST teleconference
- 10/19/15: Monday, 12pm-5pm EST teleconference
- 10/28 through 10/30, 2015: Wednesday through Friday, 8am through 5pm Wednesday and Thursday, 8am through 3pm Friday: meeting in Washington DC

Cheers,
Jeff

From: Hanlon, Edward
Sent: Wednesday, March 18, 2015 7:54 AM
To: Frithsen, Jeff
Cc: Brennan, Thomas
Subject: current schedule for the SAB Hydraulic Fracturing Research Advisory Panel meeting and teleconferences - please pencil these dates into your calendars

Hi Jeff,

After checking in with you yesterday, I talked with Tom Brennan regarding our upcoming SAB Hydraulic Fracturing Research Advisory Panel meeting and teleconferences for our upcoming review of the USEPA 'Report of Results' of EPA's research on the potential effects of hydraulic fracturing on drinking water resources. With anticipation of receipt of the Report of Results and and charge questions on May 14th, we thus ask you to pencil in our anticipated meeting and teleconference dates.

Please pencil September 23-25 onto your calendars for a three day meeting in Washington DC. We also plan to hold several additional teleconferences of our Panel associated with this review; these dates are noted below. All teleconference calls would be scheduled to occur between 12 noon and 5pm EST. The 9/1 and 9/14 teleconferences may not be needed if we don't receive a large number of requests to present public comments at the 8/31 teleconference or 9/23-25 meeting.

Thus, please pencil in the following dates onto your calendars.

8/31/15: Monday, 12pm-5pm EST teleconference
9/1/15: Tuesday, 12pm-5pm EST teleconference

9/14/15: Monday, 12pm-5pm EST teleconference
9/23 through 9/25, 2015: Wednesday through Friday, 8am through 5pm: meeting in Washington DC
12/16/15: Wednesday, 12pm-5pm EST teleconference
1/20/16: Wednesday, 12pm-5pm EST teleconference

From: Smith, Kelley on behalf of Burke, Thomas
To: Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John
CC: Kavlock, Robert; Kadeli, Lek; Jonathan.Koplos Ex. 4 Shari.Ring Ex. 4 MaryEllen.Tuccillo Ex. 4 Vandenberg, John; Walsh, Debra; Yost, Erin; Burgoon, Lyle; Fleming, Megan
Sent: 3/31/2015 10:51:18 AM
Subject: HF Drinking Water Chapter Comments: Executive Summary & chapter 4 (Discussion part 2 - if needed)

CT: Nathan Gentry

Teleconference Ex. 6

Staff:

Notes: Discussion of comments for Chapters 6-10 and executive summary

From: Smith, Kelley on behalf of Burke, Thomas
To: Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John
CC: Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos@cadmusgroup.com; Shari.Ring Ex. 4 MaryEllen.Tuccillo Ex. 4 Vandenberg, John; Walsh, Debra; Burgoon, Lyle; Yost, Erin; Fleming, Megan; Knightes, Chris
Sent: 3/31/2015 10:51:10 AM
Subject: HF Drinking Water Chapter Comments: Executive Summary & chapters 6 & 9 (Discussion part 1)

CT: Nathan Gentry

Teleconference: Ex. 6

Staff:

Notes: Discussion of comments for Chapters 6-10 and executive summary

From: Gentry, Nathan on behalf of Burke, Thomas
To: Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Yohannes, Lia; Knightes, Chris; Zambrana, Jose; Briskin, Jeanne; Teichman, Kevin
CC: Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos
Sent: 3/30/2015 9:06:29 AM
Subject: HF Drinking Water Chapter Comments: 1,2,3, and 5

Ex. 4

CT: Nathan Gentry

Teleconference: Details TBD

Staff:

Notes: Discussion of comments for Chapters 1-3 and 5.

To: Auerbacher, Kevin[Auerbacher.Kevin@epa.gov]; Neugeboren, Steven[Neugeboren.Steven@epa.gov]; Levine, MaryEllen[levine.maryellen@epa.gov]
From: Parikh, Pooja
Sent: Wed 5/6/2015 2:04:19 PM
Subject: RE: My paper on Subpart E - for Wind River meeting on Thursday

Thanks for providing to Ethan. I'd be happy to discuss any of this with you or Ethan prior to the meeting, if that would be helpful.

Ex. 5

From: Auerbacher, Kevin
Sent: Wednesday, May 06, 2015 9:55 AM
To: Parikh, Pooja; Neugeboren, Steven; Levine, MaryEllen
Subject: RE: My paper on Subpart E - for Wind River meeting on Thursday

Pooja,

This is helpful. I would provide a copy to Ethan. Ex. 5

Ex. 5

From: Parikh, Pooja
Sent: Wednesday, May 06, 2015 8:55 AM
To: Neugeboren, Steven; Levine, MaryEllen; Auerbacher, Kevin
Subject: RE: My paper on Subpart E - for Wind River meeting on Thursday

Ex. 5

Pooja S. Parikh

Attorney- Advisor

U.S. Environmental Protection Agency

Office of General Counsel, Water Law Office

Phone: 202 564-0839

Email: parikh.pooja@epa.gov

From: Neugeboren, Steven
Sent: Tuesday, May 05, 2015 6:26 PM
To: Parikh, Pooja; Levine, MaryEllen; Auerbacher, Kevin
Subject: RE: My paper on Subpart E - for Wind River meeting on Thursday

I won't take a look at the paper but it's good you're doing it and please share it with region 8 orc as well when you distribute.

From: Parikh, Pooja
Sent: Tuesday, May 05, 2015 5:12 PM
To: Neugeboren, Steven; Levine, MaryEllen; Auerbacher, Kevin
Subject: My paper on Subpart E - for Wind River meeting on Thursday

It's still not clear to me who from OGC is attending the Wind River meeting with the R8 RA on Thursday. I'm not sure if it's principals only – or whether we would also be allowed to attend. If anyone has gotten any sense of that, please let me know.

Ex. 5

Ex. 5

I'm attaching both my paper (which is focused only on Subpart E), as well as the R8 paper (in case anyone hasn't seen it). Happy to discuss the paper or any of your questions/comments tomorrow. Thanks!

Pooja S. Parikh

Attorney- Advisor

U.S. Environmental Protection Agency

Office of General Counsel, Water Law Office

Phone: 202 564-0839

Email: parikh.pooja@epa.gov

To: Briskin, Jeanne[Briskin.Jeanne@epa.gov]
From: Frithsen, Jeff
Sent: Tue 7/7/2015 2:40:14 PM
Subject: Fwd: 2 more fracking FOIAs
FOIA Request 2 - UCS (1).pdf
ATT00001.htm
FOIA Request - UCS (1).pdf
ATT00002.htm

Sent from Jeff Frithsen's iPhone
Office phone: 703-347-8623

Ex. 5

Begin forwarded message:

From: "Mackay, Cheryl" <Mackay.Cheryl@epa.gov>
To: "Frithsen, Jeff" <Frithsen.Jeff@epa.gov>
Subject: 2 more fracking FOIAs

Hi Jeff,

If you are still around, can you give me a call on these two FOIAs? 202-564-2023. It looks like one was assigned to ORD and one was assigned to OCSPP. **Ex 5**

Ex 5

Non-Responsive

Thanks,

Cheryl

To: Briskin, Jeanne[Briskin.Jeanne@epa.gov]
From: Hauchman, Fred
Sent: Mon 7/6/2015 8:17:22 PM
Subject: RE: Decision on The U.S. EPA's Study of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources

Is this in STICS?

-----Original Message-----
From: Briskin, Jeanne
Sent: Monday, July 06, 2015 3:55 PM
To: Hauchman, Fred
Subject: FW: Decision on The U.S. EPA's Study of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources

Hi Fred,

The American Chemical Society accepted the book chapter they invited me to provide after the invited talk from last summer.

Attached are the comments/requests they provided, as well as the draft revision of the paper (in track changes). I have made all the changes that they requested, with a little sleight of hand on one of the footnotes to avoid having to type out the references for 8 papers by LBNL. Susan reviewed and provided comments that I accepted on the new text on the draft assessment, which is drawn from the executive summary.

I will fix the formating on the new title page by moving key information from the title page to my transmittal email (I'm using that page as a place to hold information so I don't forget it).

What are the next steps before I may send the revised chapter back to ACS?

Thanks,

Jeanne

-----Original Message-----
From: onbehalfof+c_matuska+technicaeditorial.com@manuscriptcentral.com
[mailto:onbehalfof+c_matuska+technicaeditorial.com@manuscriptcentral.com] On Behalf Of c_matuska@technicaeditorial.com
Sent: Wednesday, July 01, 2015 1:54 PM
To: Briskin, Jeanne
Cc: ddrogos@uwyo.edu; barton@iastate.edu
Subject: Decision on The U.S. EPA's Study of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources

01-Jul-2015

ACS Books
Book: "Hydraulic Fracturing: Environmental Issues"
Manuscript ID: bk-2015-00114s
Title: "The U.S. EPA's Study of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources"
Author(s): Briskin, Jeanne; Yohannes, Liabeth

Dear Ms. Briskin:

After carefully evaluating your manuscript, Drs. Drogos and Barton, Hydraulic Fracturing: Environmental Issues editors, have decided that revisions must be made before your chapter can be accepted for publication. The comments from the Editors and Reviewer are included at the bottom of this email.

Please note that NO GALLEY PROOF IS PROVIDED for Symposium Series chapters. Please make ALL NECESSARY desired changes or corrections (including typos and grammatical) with this revision.

You are encouraged to give full consideration to their recommendations, but you are not required to make every change that they suggest. However, we do require that upon submission of your revised manuscript, you address each reviewer's comments in the "Response to Editor's Comments" section.

We also encourage you to consult the ACS Books Author Guidelines when revising your chapter to ensure that it is formatted according to ACS Books standards. You can find the author guidelines at the following URL:
http://pubs.acs.org/page/books/submission/authors/index.html

The revision of your chapter is due no later than 22-Jul-2015. To revise your manuscript, log into the ACS Books Online Submission system at https://acs.manuscriptcentral.com/acsbooks and Select "Author Center." There you will find your manuscript title listed under "Manuscripts with Decisions." Click the link "create a revision" to initiate the submission. With the exception of your main text file, all of your original files will be available to you for review or replacement during the revision process.

If you have any questions or concerns, please feel free to contact me.

Sincerely,
Caitlyn

Caitlyn Matuska
ACS Books Editor
phone: 919-918-3912
c_matuska@technicaeditorial.com

AT REVISION:
- Please provide at least one reference for the EPA study.
- Please provide the corresponding author's email address below the affiliations.
- Please provide full mailing address for Drs. Briskin and Yohannes for the complimentary book copies.
- Please cite the EPA's website (www.epa.gov/hfstudy) from which the figure was pulled in the figure caption or as a reference citation (and then include in the references).

***In order to enable the editor to make a recommendation, please submit a point-by-point response to the reviewers' criticisms.

The following items should be included in your chapter:

- Title page including the title of your chapter, all authors, author affiliations including the department, institution, city, state, zip code and corresponding author email address.

- Abstract.

- Figures and Tables. Check that all Figures and Tables are cited consecutively in the text of your document. A figure caption should be placed immediately below its figure. Captions begin with the word "Figure" followed by the figure number. Please use Figure as opposed to "Fig." and make sure it is consistent throughout your manuscript.

- References. Indicate references in text by a number in parentheses (format the reference numbers in

italic) or a superscript number and number them sequentially as they occur in the Chapter text. Do not combine references. Each reference number should refer to a single source. Please do not use et al. (all authors should be listed), op cit., or ibid.

- Reference Citation Example for Journal Articles: Author, A. B.; Author, C. D. J. Abbrev. 19XX, vol, xx–yy. NOTE: Journal name should be ital. Year should be bold. No punctuation appears in journal abbreviations except periods. No conjunctions, articles, or prepositions appear in journal abbreviations. No comma or semicolon appears before or after journal titles. Consult CASSI for a complete list of abbreviations.

-Reference Citation Example for Books: Author, A. B. In Book Title; Editor, C. D., Ed.; Series Name and number; Publisher: City, STATE (2 letters), year; Vol. 3, pp xx–yy.

Author, A. B.; Author, C. D. Book Title; Series Name and number; Publisher: City, STATE (2 letters), year; Vol. 1, pp xx–yy.

NOTE: For books, the edition follows the title: Book Title, 2nd ed.; Book Title should be ital.

Editor Comments:

The USEPA just released their HF report 3 weeks ago. Perhaps the author can update with a summary of their findings.

Reviewer Comments:

Reviewer: 1

Recommendation: Publish as received or with minor corrections as indicated.

Comments:
I have recommended that this paper be published as is, given that it only discusses the nature of the study, and does not present results or conclusions from the study in regards to EPA policy on HF.

Additional Questions:
Technical quality: Average
Significance: Good
Comprehensiveness: Good
Originality (other than review papers): Poor
Clarity: Good
Is this paper a verbatim (or in major part) reproduction of a prior publication?: No

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ACS Publications Customer Services & Information (CSI)
Email: support@services.acs.org
Phone: 202-872-4357
Toll Free Phone: 800-227-9919 (USA/Canada only)

To: Egidi, Philip[Egidi.Philip@epa.gov]
Cc: MaryEllen.Tuccillo Ex. 4 Briskin, Jeanne[Briskin.Jeanne@epa.gov]
From: Ridley, Caroline
Sent: Wed 5/6/2015 3:41:45 PM
Subject: HF drinking water assessment text on landfills

Phil,

We have incorporated your comments Ex. 5

Ex. 5

Thanks,

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6
~~~~~~

To: Briskin, Jeanne[Briskin.Jeanne@epa.gov]
From: Yohannes, Lia
Sent: Fri 3/13/2015 8:04:25 PM
Subject: FW: American Chemical Society Chapter (DRAFT)_20150313dg.docx
American Chemical Society Chapter FINAL.docx

Hi Jeanne,

Approved version of the ACS chapter attached and below.

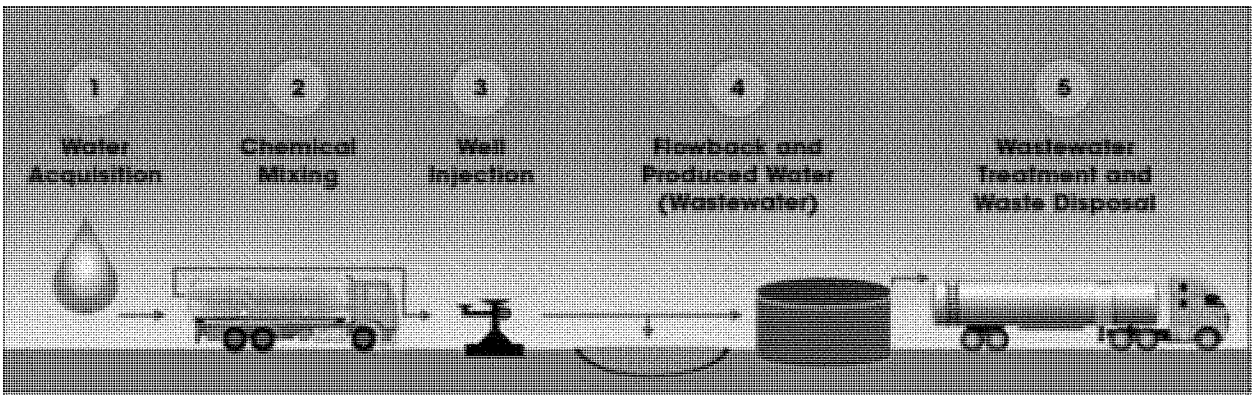
U.S. EPA's *Study of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources*

Responsible development of domestic oil and gas resources offers important economic and energy security benefits. However, the increase in hydraulic fracturing activities has raised public concerns about the potential for impacts to human health and the environment, including potential impacts to drinking water resources. In response to this concern, and the lack of publicly available scientific data, Congress urged the EPA to study the relationship between hydraulic fracturing and drinking water.

The purpose of the study is to assess the potential impacts of hydraulic fracturing for oil and gas on drinking water resources, and to identify the driving factors that may affect the severity and frequency of such potential impacts. The study will result in an assessment that integrates a comprehensive review of the existing literature with results from EPA research, input from stakeholders, and public comment to answer questions about the potential impacts of hydraulic fracturing on drinking water resources. The EPA's assessment will help to advance the state of science, increase the level of understanding about potential impacts of hydraulic fracturing on drinking water, and identify areas where data gaps may still exist.

The EPA designed the scope of the study around the hydraulic fracturing water cycle, which describes a set of activities associated with hydraulic fracturing that may interact with drinking water resources. The hydraulic fracturing water cycle consists of the following five stages: (1) acquisition of water needed to create hydraulic fracturing fluids; (2) mixing of water and chemicals on the well pad; (3) injection of fluids into the well to fracture the geologic formation; (4) management of the flowback and produced water on

the well pad for treatment or disposal; and (5) reuse, treatment and release of wastewater (flowback, produced water, and other waste generated at the well pad).



The research projects the EPA is conducting as part of the study can be categorized under five approaches: analysis of existing data, laboratory studies, computer modeling (scenario evaluations), toxicity studies, and case studies.

Specific research projects include:

Analysis of Data from FracFocus: The EPA is analyzing data on hydraulic fracturing-related chemical and water use based on chemical disclosures provided by oil and gas well operators in the FracFocus Chemical Disclosure Registry 1.0 between January 1, 2011, and February 28, 2013. FracFocus is the publicly accessible hydraulic fracturing chemical registry developed by the Ground Water Protection Council and the Interstate Oil and Gas Compact Commission. Oil and gas well operators may voluntarily submit or, in some states, are required to submit well-specific data on chemical and water use to FracFocus. This analysis will help the EPA better understand the chemicals and volumes of water used to hydraulically fracture oil and gas production wells in the United States and how chemical and water use vary in different locations across the country.

Spills Database Analysis: The EPA is analyzing spill data provided by nine states and industry (service companies, oil and gas well operators) to identify and characterize spills related to hydraulic fracturing that occurred between January 1, 2006, and April 30, 2012. The purpose of this analysis is to better understand what is known about spills associated with hydraulic fracturing, including whether or not spilled fluids reached water resources, types of materials spilled, spill causes and sources, and containment and response activities.

Well File Review: The EPA is assessing well construction and operation data from a statistically representative sample of oil and gas production wells hydraulically fractured by nine service companies across the continental United States in 2009 and 2010. The objective of the study was to describe, for these wells: (1) well design and construction characteristics of hydraulically fractured oil and gas production wells, (2) the relationship of drinking water resources to hydraulically fractured oil and gas production wells, and (3) the number and relative location of barriers (e.g., casing and cement) that can prevent subsurface fluid movement. The sample of oil and gas production wells analyzed includes vertical, horizontal, and deviated wells in a variety of geological environments that are representative of different geographic areas and companies of various sizes.

Analytical Method Development: The EPA is developing and verifying analytical methods for selected chemicals found in hydraulic fracturing fluids and wastewater. Development of robust methods is necessary to accurately and precisely determine the composition of hydraulic fracturing-related chemicals in ground and surface water, flowback and produced water, and treated wastewater. Chemicals selected for analytical method testing and development include acrylamide, alcohol ethoxylates and alkylphenol ethoxylates, glycols (diethylene glycol, triethylene glycol, tetraethylene glycol, 2-butoxyethanol and 2-methoxyethanol), and radionuclides (gross alpha and beta).

Source Apportionment Studies: The EPA is characterizing the potential impacts of hydraulic fracturing wastewater river discharges and other potential sources of pollutants measured at public drinking water supply intakes on the Allegheny River in Pennsylvania. This project will improve the understanding of the potential impacts from surface water disposal of treated oil and gas wastewater. This work involved collecting river samples upstream and downstream of public water intakes and at centralized wastewater treatment facilities that process oil and gas wastewater, including wastewater from hydraulic fracturing. These analyses will contribute to efforts to evaluate the impact of a variety of sources including treated waste from oil and gas production on water resources. The EPA is using the sampling data along with mathematical models to apportion impacts of discharges on downstream bromide, chloride, nitrate, and sulfate levels.

Subsurface Migration Modeling: The EPA is evaluating the potential for gas and fluid transport from fractured zones to drinking water aquifers using subsurface migration

models. The purpose of this research is to understand the behavior of hydraulic fracturing injection operations and whether, and under what situations, subsurface migration pathways may link oil and gas reservoirs to drinking water resources. Analyses include the potential effect of contaminant type, fluid pressure, and local geological properties on migration mechanisms.

Water Availability Modeling: The EPA is studying how water withdrawals from surface or ground water used for hydraulic fracturing operations may affect drinking water availability at various spatial and temporal scales in the Susquehanna (humid) and the Upper Colorado (semi-arid) River Basins, which experience concentrated hydraulic fracturing activity. The project combines analysis of state and regional water use data and scenario analysis with information on local water availability to develop an understanding of how much water is used, where it comes from and impacts on local sources at various levels of hydraulic fracturing activity.

Surface Water Modeling: The EPA is evaluating the potential impact from bromide in discharges from commercial wastewater treatment plants that treat oil and gas (including hydraulic fracturing) wastewaters in a number of scenarios. This study uses data from commercial wastewater treatment plants in western Pennsylvania and river flow data to develop models that illustrate the potential impacts from discharges into surface water (e.g. rivers and creeks) from commercial wastewater treatment plants that treat oil and gas wastewater.

Retrospective Case Studies: The EPA is conducting five retrospective case studies (Bradford Co., PA; Washington Co., PA; Wise Co., TX; Las Animas Co., CO; Dunn Co., ND) to investigate reported instances of drinking water resource contamination in areas where hydraulic fracturing has occurred. The goals of these studies are to determine whether drinking water resources were contaminated, and if so, to better understand the potential source(s) of contamination. Case study locations were prioritized and chosen based on a rigorous set of criteria, including geographic and geologic diversity, proximity of population and drinking water supplies at risk, characteristics of water resources, land use, as well as health and environmental concerns.

These EPA-led research projects will be combined with an extensive review of literature and information gathered through stakeholder engagement efforts and public comment. Together, these components will contribute to the EPA's assessment report on the state of the science regarding the potential impacts of hydraulic fracturing on drinking water resources. The study will inform the public and decision makers with scientific

information about the potential impacts of hydraulic fracturing and identify knowledge gaps. This state of the science assessment will not be a human health or exposure assessment, nor is it designed to evaluate policy options or best management practices.

To access more information about the EPA's study, including a report of progress and to subscribe to the EPA listserv, visit the study website: www.epa.gov/hfstudy.

The views expressed in this article are those of the authors and do not necessarily reflect the views or polices of the US Environmental Protection Agency.

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

From: Gibbons, Dayna
Sent: Friday, March 13, 2015 3:59 PM
To: Yohannes, Lia
Cc: Maloney, Kelsey
Subject: RE: American Chemical Society Chapter (DRAFT)_20150313dg.docx

Thanks! Look fine to me! Have a great weekend!

From: Yohannes, Lia
Sent: Friday, March 13, 2015 3:11 PM
To: Gibbons, Dayna
Cc: Maloney, Kelsey

Subject: RE: American Chemical Society Chapter (DRAFT)_20150313dg.docx

Hi Dayna,

Here's the final version with Fred's edits. I kept the track changes to facilitate your review.

Just let me know when you anticipate approval if you can. Ex. 6
Ex. 6

Thank you!

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

From: Yohannes, Lia
Sent: Friday, March 13, 2015 2:35 PM
To: Gibbons, Dayna
Cc: Maloney, Kelsey
Subject: RE: American Chemical Society Chapter (DRAFT)_20150313dg.docx

Hi Dayna,

Just got Fred's comments back. I'm incorporating them and will send you a revised version asap.

Thanks!

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

From: Gibbons, Dayna
Sent: Friday, March 13, 2015 1:23 PM
To: Yohannes, Lia
Cc: Maloney, Kelsey
Subject: RE: American Chemical Society Chapter (DRAFT)_20150313dg.docx

That works—thanks for following up w the NERL folks.

From: Yohannes, Lia
Sent: Friday, March 13, 2015 12:37 PM
To: Gibbons, Dayna
Cc: Maloney, Kelsey
Subject: RE: American Chemical Society Chapter (DRAFT)_20150313dg.docx

Here's the final version with Jennifer and Mark's edits. Once you and Dale approve, I'll share with Jeanne.

Thanks!

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

From: Gibbons, Dayna
Sent: Friday, March 13, 2015 11:56 AM
To: Yohannes, Lia
Cc: Maloney, Kelsey
Subject: RE: American Chemical Society Chapter (DRAFT)_20150313dg.docx

Ex. 5

From: Yohannes, Lia
Sent: Friday, March 13, 2015 11:55 AM
To: Gibbons, Dayna
Cc: Maloney, Kelsey
Subject: RE: American Chemical Society Chapter (DRAFT)_20150313dg.docx

Ex. 5

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

From: Gibbons, Dayna
Sent: Friday, March 13, 2015 11:53 AM
To: Yohannes, Lia
Cc: Maloney, Kelsey
Subject: RE: American Chemical Society Chapter (DRAFT)_20150313dg.docx

Ex. 5

From: Yohannes, Lia
Sent: Friday, March 13, 2015 11:51 AM
To: Gibbons, Dayna
Cc: Maloney, Kelsey
Subject: RE: American Chemical Society Chapter (DRAFT)_20150313dg.docx

Thanks for your edits, Dayna. Incorporating them now. Ex. 5

Ex. 5

Thanks!

lia

Ex. 5

Ex. 5

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

From: Gibbons, Dayna
Sent: Friday, March 13, 2015 11:45 AM
To: Yohannes, Lia
Cc: Maloney, Kelsey
Subject: American Chemical Society Chapter (DRAFT)_20150313dg.docx

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Briskin, Jeanne
Sent: Thur 7/9/2015 8:38:30 PM
Subject: FW: Fracking Study update

I used the talking points to provide an update on the draft assessment. The only question was "when is the SAB meeting?"

From: Gorke, Roger
Sent: Monday, June 29, 2015 4:12 PM
To: Briskin, Jeanne; Pat Lambert
Subject: Fracking Study update

Jeanne,

We were wondering if you might be available to give a brief update on the fracking study to the WSWC Water Quality Committee July 9, 1:15 PDT. You would probably go on at 2 pm (5 pm EDT).

You probably wouldn't need to do the detail you did for us before, just an update and results on the draft report.

Thanks,

Roger

Roger Gorke

Senior Policy Advisor

Office of Water

U.S. Environmental Protection Agency

PH: 202-564-0470

FAX: 202-564-0500

gorke.roger@epa.gov

To: Susan Burden (Burden.Susan@epa.gov)[Burden.Susan@epa.gov]; Wiser, Nathan[Wiser.Nathan@epa.gov]; Hauchman, Fred[hauchman.fred@epa.gov]
From: Briskin, Jeanne
Sent: Tue 5/12/2015 1:05:53 PM
Subject: FW: HFDWA: Presentation for Regions and States
HFDWA Briefing_Regions-States 20150511v2.pptx

Fyi

From: Frithsen, Jeff
Sent: Tuesday, May 12, 2015 8:16 AM
To: Burke, Thomas
Cc: Smith, Kelley; Smith, Kelly; Briskin, Jeanne; Gibbons, Dayna; Matthews, Lisa; Teichman, Kevin; Zambrana, Jose; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Ridley, Caroline
Subject: HFDWA: Presentation for Regions and States

Tom:

Attached is the presentation to be used to brief regions and states on the assessment. Talk with you later today.

Jeff

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries

Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

Cc: Dean, Jill[Dean.Jill@epa.gov]; Hillenbrand, Charles[Hillenbrand.Charles@epa.gov]
To: Burden, Susan[Burden.Susan@epa.gov]; Wiser, Nathan[Wiser.Nathan@epa.gov]; Tinsley, Chuck[Tinsley.Chuck@epa.gov]; Daiss, Rebecca[Daiss.Rebecca@epa.gov]; Sharkey, Susan[Sharkey.Susan@epa.gov]; Fleming, Megan[Fleming.Megan@epa.gov]; Williams, Larke[Williams.Larke@epa.gov]; Singer, Alison[Singer.Alison@epa.gov]; Cluff, Maryam[Cluff.Maryam@epa.gov]
From: Briskin, Jeanne
Sent: Thur 5/7/2015 12:27:58 PM
Subject: Fwd: Schedule for release of HF Study Reports and Draft Assessment

FYI

Begin forwarded message:

From: "Frithsen, Jeff" <Frithsen.Jeff@epa.gov>
Date: May 7, 2015 at 7:45:31 AM EDT
To: "Briskin, Jeanne" <Briskin.Jeanne@epa.gov>, "Teichman, Kevin" <Teichman.Kevin@epa.gov>, "Gibbons, Dayna" <Gibbons.Dayna@epa.gov>, "Zambrana, Jose" <Zambrana.Jose@epa.gov>, "Matthews, Lisa" <Matthews.Lisa@epa.gov>
Subject: Schedule for release of HF Study Reports and Draft Assessment

FYI: I sent the following to Jennifer, Cindy, and Fred this morning.

May promises to be a very busy month for ORD and for the Agency. There are lots of activities coming to completion not only in our world of hydraulic fracturing, but in other parts of the Agency as well. Scheduling all those activities has become a bit of a challenge.

Ex. 5

Ex. 5

Thanks all! Almost there. Really!!

Jeff

To: Phillips, Anna[Phillips.Anna@epa.gov]
From: Briskin, Jeanne
Sent: Wed 3/4/2015 1:23:02 PM
Subject: UK 030415.pptx
UK 030415.pptx

Hi Anna,

Here is the standard slide set I am planning to use.

Jeanne

To: Williams, Larke[Williams.Larke@epa.gov]
From: Briskin, Jeanne
Sent: Wed 3/4/2015 12:38:15 PM
Subject: Fwd: BNA: More Data Needed to Assess Effects Of Fracking on Water Quality, USGS Finds
Bowen et al. 2015 USGSrptFrack.pdf
ATT00001.htm

Any more Articles usgs to expect beyond this one?

Begin forwarded message:

From: "Frithsen, Jeff" <Frithsen.Jeff@epa.gov>
To: "Briskin, Jeanne" <Briskin.Jeanne@epa.gov>, "Gibbons, Dayna" <Gibbons.Dayna@epa.gov>, "Matthews, Lisa" <Matthews.Lisa@epa.gov>, "Teichman, Kevin" <Teichman.Kevin@epa.gov>, "Zambrana, Jose" <Zambrana.Jose@epa.gov>, "Burden, Susan" <Burden.Susan@epa.gov>, "Frithsen, Jeff" <Frithsen.Jeff@epa.gov>, "LeDuc, Stephen" <LeDuc.Stephen@epa.gov>, "Ridley, Caroline" <Ridley.Caroline@epa.gov>, "Anna Weber" [redacted] Ex. 4 "Bates, William" <bates.william@epa.gov>, "Brent Ranalli" [redacted] Ex. 4 "Burgoon, Lyle" <Burgoon.Lyle@epa.gov>, "Clark, Christopher" <Clark.Christopher@epa.gov>, "Cluff, Maryam" <Cluff.Maryam@epa.gov>, "Daiss, Rebecca" <Daiss.Rebecca@epa.gov>, "Dean, Jill" <Dean.Jill@epa.gov>, "Deniz (Inci) Demirkanli" [redacted] Ex. 4, "Fleming, Megan" <Fleming.Megan@epa.gov>, "Glen Boyd [redacted] Ex. 6" [redacted] Ex. 4, "Impellitteri, Christopher" <Impellitteri.Christopher@epa.gov>, "Jonathan.Koplos@cadmusgroup.com" [redacted] Ex. 4, "Ken Klewicki [redacted] Ex. 4, "Knightes, Chris" <Knightes.Chris@epa.gov>, "MaryEllen.Tuccillo@cadmusgroup.com" <MaryEllen.Tuccillo@cadmusgroup.com>, "Sandie Koenig" [redacted] Ex. 4 <Shari.Ring[redacted] Ex. 4, "Singer, Alison" <Singer.Alison@epa.gov>, "Stanek, John" <Stanek.John@epa.gov>, "Todd, Jason" <Todd.Jason@epa.gov>, "Weaver, Jim" <Weaver.Jim@epa.gov>, "Williams, Larke" <Williams.Larke@epa.gov>, "Yohannes, Lia" <Yohannes.Lia@epa.gov>, "Yost, Erin" <Yost.Erin@epa.gov>, "Jonathan.Koplos[redacted] Ex. 4
Subject: FW: BNA: More Data Needed to Assess Effects Of Fracking on Water Quality, USGS Finds

Article attached. Seems to be relevant to the assessment!

Thanks for forwarding Susan.

Jeff

Jeff Frithsen
USEPA-ORD-NCEA
703-347-8623 (office phone)

From: Burden, Susan
Sent: Wednesday, March 04, 2015 6:02 AM
To: Frithsen, Jeff; Ridley, Caroline; LeDuc, Stephen
Subject: FW: BNA: More Data Needed to Assess Effects Of Fracking on Water Quality, USGS Finds

Do we know about the USGS study mentioned below?

Thanks,

Susan

Susan Burden, Ph.D.
Office of Research and Development
US Environmental Protection Agency
Phone: (202) 564-6308
Email: burden.susan@epa.gov<mailto:burden.susan@epa.gov>

From: Flaharty, Stephanie
Sent: Wednesday, March 04, 2015 5:57 AM
To: Grevatt, Peter; Clark, Becki; Bergman, Ronald; Hydraulic Fracturing_SG; Greene, Ashley; Bates, William; Bayer, MaryRose; Branby, Jill; Carey, Kyle; Codrington, Ann; Comerford, Sherri; Dean, Jill; Ginsberg, Marilyn; Green, Holly; Jollie, Jeff; Kelly, Suzanne; Kobelski, Bruce; Kumar, Chitra; Lopez-Carbo, Maria; Maloney, Kelsey; Moore, Keara; Muse, Mike; Phillips, Anna; Shekar, Navin; Smith, Robert-Eu; Waxmonsky, Gary
Subject: BNA: More Data Needed to Assess Effects Of Fracking on Water Quality, USGS Finds

42 DEN A-9
Hydraulic Fracturing
More Data Needed to Assess Effects Of Fracking on Water Quality, USGS Finds

March 3 — There are not enough data available to assess potential risks to water quality associated with hydraulic fracturing, according to a U.S. Geological Survey study. Additional data in electronic formats on water acquisition, usage, treatment and disposal or recycling associated with unconventional oil and gas well development and completion are needed, the USGS said March 3.
The study<http://op.bna.com/env.nsf/r?Open=smiy-9u9sts> found no widespread and

consistent trends in water quality, such as chloride and specific conductance, in areas where oil and gas wells are present, it said.

"We mined the national water-quality databases from 1970 to 2010 and were able to assess long-term trends in only 16 percent of the watersheds with unconventional oil and gas resources," Zack Bowen, USGS scientist and principal author of the study, said in a statement.

Unconventional oil and gas resources include those that are trapped in tight shale formations underground and are typically produced using horizontal drilling and fracking, which involves high-pressure injection of water, sand and chemicals into wellbores.

No Monitoring Program

Because no national water quality monitoring program is in place that focuses on oil and gas development, the USGS study, published Jan. 30 online in American Geophysical Union's Water Resources Research, focused on existing USGS and Environmental Protection Agency water quality databases and data on fracking to assess trends in oil and gas areas, the survey said.

Comprehensive, published and publicly available information regarding the extent, location and character of hydraulic fracturing and potential effects on regional or national water quality in the United States is scarce, the USGS said.

"We found that these data were often not available or accessible and that these records are not uniform across the U.S.," the survey said.

To contact the reporter on this story: Tripp Baltz in Denver at abaltz@bna.com<mailto:abaltz@bna.com>

To contact the editor responsible for this story: Larry Pearl at lpearl@bna.com<mailto:lpearl@bna.com>

For More Information

The USGS report is available at http://op.bna.com/env.nsf/r?Open=smiy-9u9sts.

To: Briskin, Jeanne[Briskin.Jeanne@epa.gov]
From: Briskin, Jeanne
Sent: Thur 2/19/2015 12:45:33 AM
Subject: Fwd: HF pChem & Tox datasets - DRAFT 4Feb2015
HF_ChemsIndex_DRAFT_4Feb2015.xlsx
ATT00001.htm

Begin forwarded message:

From: "Daiss, Rebecca" <Daiss.Rebecca@epa.gov>
To: "Briskin, Jeanne" <Briskin.Jeanne@epa.gov>
Subject: FW: HF pChem & Tox datasets - DRAFT 4Feb2015

Hi Jeanne, Here is the deliverable from Cadmus. Becky

From: Jonathan Koplos Ex. 4
Sent: Wednesday, February 04, 2015 1:19 PM
To: Daiss, Rebecca; Ridley, Caroline
Cc: LeDuc, Stephen; John Martin
Subject: HF pChem & Tox datasets - DRAFT 4Feb2015

Hi Becky and Caroline,

Please find attached the compilation of the pCHem and toxicological datasets including glossaries. The attached file includes 18 tabs which present the compilation of all the data you provided to us plus glossaries and definitions we've developed working with you over the last few weeks. Hopefully the name of each tab is fairly self-explanatory. This is a draft for your consideration; we look forward to your comments and suggestions.

In the attached file, the first two tabs consist of a brief discussion of the sources used to compile the list of 1,173 chemicals and their reference citations. The index tab is the crosswalk of chemicals and sources in which they can be found. The tab All_HFChems_1173 compiles the names, CASRNs, synonyms and additional qualifying

information regarding the chemicals.

Next is the toxicology section, with an introductory tab that describes each source briefly (generally taken more or less word for word from each website) followed by the data for the seven toxicology data sources and then the toxicology glossary.

Next is the properties section, with an introductory tab that describes each source briefly (generally taken more or less word for word from each website) followed by the data for the three properties data sources and then the properties glossary.

A couple of things to note:

Ex. 5

Please let us know if you would like revisions, additions, etc.

Jonathan and John

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

Ex. 4

www.cadmusgroup.com

Follow us on social media:

To: Briskin, Jeanne[Briskin.Jeanne@epa.gov]; Burden, Susan[Burden.Susan@epa.gov]; Hauchman, Fred[hauchman.fred@epa.gov]; Dean, Jill[Dean.Jill@epa.gov]; Daiss, Rebecca[Daiss.Rebecca@epa.gov]; Sharkey, Susan[Sharkey.Susan@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]; Vandenberg, John[Vandenberg.John@epa.gov]; Stanek, John[Stanek.John@epa.gov]; Ridley, Caroline[Ridley.Caroline@epa.gov]; LeDuc, Stephen[LeDuc.Stephen@epa.gov]; Sonich-Mullin, Cynthia[Sonich-Mullin.Cynthia@epa.gov]; Smith, Kelly[Smith.Kelly@epa.gov]; Wilkin, Rick[Wilkin.Rick@epa.gov]; Beak, Doug[Beak.Doug@epa.gov]; Ludwig, Ralph[Ludwig.Ralph@epa.gov]
From: Kraemer, Stephen
Sent: Tue 7/7/2015 5:34:05 PM
Subject: RE: Study Finds 15 Frack Fluids Would Be Dangerous in Groundwater
Hildenbrand_etal_2015_ES&T_comprehensive_WQ_Barnett.pdf

Thanks Jeanne.

Another article on WQ in the Barnett.

From: Briskin, Jeanne
Sent: Tuesday, July 07, 2015 12:33 PM
To: Burden, Susan; Hauchman, Fred; Dean, Jill; Daiss, Rebecca; Sharkey, Susan; Frithsen, Jeff; Vandenberg, John; Stanek, John; Ridley, Caroline; LeDuc, Stephen; Sonich-Mullin, Cynthia; Smith, Kelly; Wilkin, Rick; Beak, Doug; Ludwig, Ralph; Kraemer, Stephen
Subject: RE: Study Finds 15 Frack Fluids Would Be Dangerous in Groundwater

The full article is attached.

From: Briskin, Jeanne
Sent: Tuesday, July 07, 2015 12:12 PM
To: Susan Burden (Burden.Susan@epa.gov); Hauchman, Fred; Dean, Jill; Daiss, Rebecca; Sharkey, Susan; Frithsen, Jeff; Vandenberg, John; Stanek, John; Ridley, Caroline; LeDuc, Stephen; Cynthia Sonich-Mullin (Sonich-Mullin.Cynthia@epa.gov); kelly smith (Smith.Kelly@epa.gov); Wilkin, Rick; Beak, Doug; Ludwig, Ralph; Kraemer, Stephen
Subject: Study Finds 15 Frack Fluids Would Be Dangerous in Groundwater

FYI

Study Finds 15 Frack Fluids Would Be Dangerous in Groundwater

Natural Gas Intelligence

A study led by researchers at the University of Colorado (UC) found that of the hundreds of compounds used in **hydraulic fracturing** (fracking) ...

Flag as irrelevant

Study Finds 15 Frack Fluids Would Be Dangerous in Groundwater

Charlie Passut

July 6, 2015

SEARCH **acrylamide** / **aquifers** /**fracfocus** / **fracking** / **groundwater**

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Analyst Says Impact Minimal From DOI Fracking Rule

Judge Blocks BLM Frack Rule on Public, Tribal Lands

Chemicals Tiny Fraction of Frack Water, But It Adds Up, EPA Finds

A study led by researchers at the University of Colorado (UC) found that of the hundreds of compounds used in hydraulic fracturing (fracking) operations, 15 are of particular concern if they ever become groundwater contaminants due to several factors, including toxicity.

In a seven-page paper published online in *Environmental Science & Technology Letters*, which is published by the American Chemical Society, researchers tested 659 of the 996 compounds that the Environmental Protection Agency (EPA) and the website registry FracFocus have listed as compounds for use in fracking.

Under a fast groundwater transport scenario, the researchers found that 15 compounds listed on at least 50 FracFocus reports had an elevated exposure potential -- defined as 10% or more -- of their initial concentrations

remaining after a transport distance of 94 meters (308.4 feet), a distance roughly the equivalent to the average setback for oil and gas wells in the United States.

The researchers tested more than 50,000 wells in four states -- Colorado, North Dakota, Pennsylvania and Texas -- since 2011.

"We wanted to evaluate which compounds we should be paying attention to based not just on toxicity but also on the extent a particular compound travels from one place to another through groundwater," said CU Professor Joseph Ryan, the lead researcher. "We found 41 compounds that were considered mobile and persistent, and a handful of those we would not want in our drinking water."

Of the 15 compounds, two -- naphthalene and 2-butoxyethanol -- were identified on more than 20% of FracFocus reports. "Both compounds are commonly identified as ingredients in surfactants, corrosion inhibitors, and non-emulsifiers, and naphthalene is a constituent of some petroleum-based additives," the study said.

The study also found three of the 15 compounds -- acrylamide, and the petroleum hydrocarbons ethylbenzene and xylenes -- have Maximum Contaminant Level (MCLs) standards set by the EPA.

"The occurrence of these compounds at concentrations above their MCLs would necessitate regulatory action," the study said. "Acrylamide was identified on 3.2% of FracFocus reports as a residual ingredient in non-hazardous acrylamide polymers commonly used in fracturing fluids as friction reducers.

"The petroleum hydrocarbons were rarely identified as individual additives on FracFocus...but they are minor constituents of some petroleum-based additives like hydrotreated light petroleum distillates...identified as an ingredient in friction reducers on 70% of reports. Benzene, also a minor constituent of petroleum distillates, was predicted to be sufficiently mobile and persistent by the screening framework but was individually identified on [less than] 50 reports."

Ryan said that although the study may soothe concern that hundreds of chemicals used in fracking are at risk of contaminating groundwater, "it also demonstrates a subset of these compounds could result in potentially hazardous exposures following spills or well failures."

According to Ryan, the researchers used a screening process that included degradation rates of particular organic compounds as they are horizontally transported from a point of release. They also considered the chemical structure and stability of each compound, its behavior in water, and employed a wastewater treatment process simulator called BIOWIN 4 to help estimate the biodegradation of the organic compounds over time.

Ryan said the researchers used two transport scenarios: a highly porous aquifer with relatively fast groundwater velocity, and a less porous aquifer with slower velocity. The compounds were evaluated for potential toxicity using the National Primary Drinking Water Regulations and Health Assessment Information.

"Just because a compound has been put into the ground doesn't mean it is going to migrate to a place where humans will be exposed to it," Ryan said. "On the other hand, problems with particular compounds in groundwater could take a decade or so to even show up. We don't know enough about some of these processes right now."

CU said the researchers may next evaluate chemical products produced by the breakdown of fracking fluids, or consider the return of known fracking compounds to the surface. The research is being funded through a $12 million grant by the National Science Foundation (NSF), and is supported by the NSF's Sustainability Research Network program and the EPA's STAR Fellowship program.

To: LeDuc, Stephen[LeDuc.Stephen@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]; Knightes, Chris[Knightes.Chris@epa.gov]
Cc: Ridley, Caroline[Ridley.Caroline@epa.gov]; Burden, Susan[Burden.Susan@epa.gov]
From: Shari Ring
Sent: Tue 5/19/2015 5:33:43 PM
Subject: RE: Comments on executive summary

Hi Steve,

Does the para still look like the one below (sorry, I am losing track)? The topic sentence doesn't go w/ the rest of it – it should start with something like this:

Ex. 5

Shari Ring

The Cadmus Group, Inc.

703.247.6159

From: LeDuc, Stephen [mailto:LeDuc.Stephen@epa.gov]

Sent: Tuesday, May 19, 2015 1:09 PM
To: Shari Ring; Frithsen, Jeff; Knightes, Chris
Cc: Ridley, Caroline; Burden, Susan
Subject: RE: Comments on executive summary

OK, thank you Shari. We will consider how to use/note in the ES. It definitely seems appropriate in your chapter. Best, Steve

From: Shari Ring Ex. 4
Sent: Monday, May 18, 2015 3:01 PM
To: Frithsen, Jeff; LeDuc, Stephen; Knightes, Chris
Cc: Ridley, Caroline; Burden, Susan
Subject: RE: Comments on executive summary

Ex. 5

Shari Ring

The Cadmus Group, Inc.

703.247.6159

From: Frithsen, Jeff [mailto:Frithsen.Jeff@epa.gov]
Sent: Monday, May 18, 2015 2:59 PM
To: LeDuc, Stephen; Shari Ring; Knightes, Chris
Cc: Ridley, Caroline; Burden, Susan
Subject: RE: Comments on executive summary

Ex. 5

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: LeDuc, Stephen
Sent: Monday, May 18, 2015 2:51 PM
To: Shari.Ring Ex. 4 Knightes, Chris
Cc: Ridley, Caroline; Frithsen, Jeff; Burden, Susan
Subject: FW: Comments on executive summary

Hi Shari and Chris,

Ex. 5

From: Frithsen, Jeff
Sent: Monday, May 18, 2015 12:57 PM
To: Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Ridley, Caroline
Subject: FW: Comments on executive summary

Additional comments on executive summary….

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Briskin, Jeanne
Sent: Monday, May 18, 2015 12:12 PM
To: Frithsen, Jeff
Cc: Hauchman, Fred; Burden, Susan
Subject: Comments on executive summary

Please let me know which if any of the edits I've recommended you can incorporate, so I can follow up with Fred, elevate quickly if necessary.

This is a short summary. You'll find some additional context in the annotated attachment

Ex. 5

Ex. 5

These points probably need to be fixed in the assessment too. There are a couple of additional points in track changes and comment boxes of the attachment.

To: Burden, Susan[Burden.Susan@epa.gov]; Fleming, Megan[Fleming.Megan@epa.gov]
From: LeDuc, Stephen
Sent: Tue 5/19/2015 3:29:39 PM
Subject: RE: Environmental Science & Technology Vol. 49, No. 10, May 19, 2015 is now available online

Thanks Susan. However, we did determine that this was the wrong Scanlon et al. 2014 cited in the ES and the Water Chapter. Best, Steve

From: Burden, Susan
Sent: Tuesday, May 19, 2015 11:25 AM
To: Fleming, Megan; LeDuc, Stephen
Subject: FW: Environmental Science & Technology Vol. 49, No. 10, May 19, 2015 is now available online

Hey,

See the TOC below. There's a comment and response to a Scanlon et al., 2014 paper that is cited in the assessment report.

Thanks,

Susan

Susan Burden, Ph.D.

Office of Research and Development

US Environmental Protection Agency

Phone: (202) 564-6308

Email: burden.susan@epa.gov

From: ACS e-Alerts Service [mailto:journalalerts@acs.org]
Sent: Tuesday, May 19, 2015 10:31 AM
To: Burden, Susan
Subject: Environmental Science & Technology Vol. 49, No. 10, May 19, 2015 is now available online

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May 19, 2015

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- Remediation and Control Technologies
- Sustainability Engineering and Green Chemistry
- Ecotoxicology and Human Environmental Health
- Energy and the Environment
- Correspondence
- Additions and Corrections

Comment

My New Sofa

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David L. Sedlak

Publication Date (Web): Apr 23, 2015
pp. 5843–5844

DOI: 10.1021/acs.est.5b01935

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Viewpoints

Community Sewage Sensors for Monitoring Public Health

Zhugen Yang, Barbara Kasprzyk-Hordern, Christopher G. Frost, Pedro Estrela, and Kevin V. Thomas

Publication Date (Web): May 8, 2015
pp. 5845–5846

DOI: 10.1021/acs.est.5b01434

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The Rise of Stem Cell Toxicology

Francesco Faiola, Nuoya Yin, Xinglei Yao, and Guibin Jiang

Publication Date (Web): May 5, 2015
pp. 5847–5848

DOI: 10.1021/acs.est.5b01549

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Critical Reviews

Recycling Metals from Wastes: A Novel Application of Mechanochemistry

Quanyin Tan and Jinhui Li

Publication Date (Web): Apr 17, 2015
pp. 5849–5861

DOI: 10.1021/es506016w

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Electrochemical Analyses of Redox-Active Iron Minerals: A Review of Nonmediated and Mediated Approaches

Michael Sander, Thomas B. Hofstetter, and Christopher A. Gorski

Publication Date (Web): Apr 9, 2015
pp. 5862–5878

DOI: 10.1021/acs.est.5b00006

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Policy Analysis

Deriving Persistence Indicators from Regulatory Water-Sediment Studies – Opportunities and Limitations in OECD 308 Data

Mark Honti and Kathrin Fenner

Publication Date (Web): May 11, 2015
pp. 5879–5886

DOI: 10.1021/acs.est.5b00788

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Characterization of Natural and Affected Environments

Organic Matter Remineralization Predominates Phosphorus Cycling in the Mid-Bay Sediments in the Chesapeake Bay

Sunendra R. Joshi, Ravi K. Kukkadapu, David J. Burdige, Mark E. Bowden, Donald L. Sparks, and Deb P. Jaisi

Publication Date (Web): Jan 29, 2015
pp. 5887–5896

DOI: 10.1021/es5059617

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Ecological Restoration and Its Effects on a Regional Climate: The Source Region of the Yellow River, China

Zhouyuan Li, Xuehua Liu, Tianlin Niu, De Kejia, Qingping Zhou, Tianxiao Ma, and Yunyang Gao

Publication Date (Web): Apr 20, 2015
pp. 5897–5904

DOI: 10.1021/es505985q

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Effects of Ionic Strength on the Chromophores of Dissolved Organic Matter

Yuan Gao, Mingquan Yan, and Gregory V. Korshin

Publication Date (Web): Apr 21, 2015
pp. 5905–5912

DOI: 10.1021/acs.est.5b00601

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Implications of Stein's Paradox for Environmental Standard Compliance Assessment

Song S. Qian, Craig A. Stow, and YoonKyung Cha

Publication Date (Web): Apr 13, 2015
pp. 5913–5920

DOI: 10.1021/acs.est.5b00656

ActiveView PDF | PDF | PDF w/ Links | Full Text HTML | Abstract

Wildfire Altering Terrestrial Precursors of Disinfection Byproducts in Forest Detritus

Jun-Jian Wang, Randy A. Dahlgren, Mahmut S. Erşan, Tanju Karanfil, and Alex T. Chow

Publication Date (Web): Apr 20, 2015
pp. 5921–5929

DOI: 10.1021/es505836m

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Importance of Open Marine Waters to the Enrichment of Total Mercury and Monomethylmercury in Lichens in the Canadian High Arctic

K. A. St. Pierre, V. L. St. Louis, J. L. Kirk, I. Lehnherr, S. Wang, and C. La Farge

Publication Date (Web): Apr 16, 2015
pp. 5930–5938

DOI: 10.1021/acs.est.5b00347

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Isotopic and Geochemical Tracers for U(VI) Reduction and U Mobility at an in Situ Recovery U Mine

Anirban Basu, Shaun T. Brown, John N. Christensen, Donald J. DePaolo, Paul W. Reimus, Jeffrey M. Heikoop, Giday Woldegabriel, Ardyth M. Simmons, Brian M. House, Matt Hartmann, and Kate Maher

Publication Date (Web): Apr 24, 2015

pp. 5939–5947

DOI: 10.1021/acs.est.5b00701

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Environmental Processes

Geochronologies of Pharmaceuticals in a Sewage-Impacted Estuarine Urban Setting (Jamaica Bay, New York)

Pablo A. Lara-Martín, Alisha A. Renfro, J. Kirk Cochran, and Bruce J. Brownawell

Publication Date (Web): Apr 17, 2015
pp. 5948–5955

DOI: 10.1021/es506009v

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Anaerobic Arsenite Oxidation by an Autotrophic Arsenite-Oxidizing Bacterium from an Arsenic-Contaminated Paddy Soil

Jun Zhang, Wuxian Zhou, Bingbing Liu, Jian He, Qirong Shen, and Fang-Jie Zhao

Publication Date (Web): Apr 23, 2015
pp. 5956–5964

DOI: 10.1021/es506097c

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Contrasting Effects of Marine and Terrestrially Derived Dissolved Organic Matter on Mercury Speciation and Bioavailability in Seawater

Amina T. Schartup, Udonna Ndu, Prentiss H. Balcom, Robert P. Mason, and Elsie M. Sunderland

Publication Date (Web): Apr 16, 2015
pp. 5965–5972

DOI: 10.1021/es506274x

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Molecular Insights into Ternary Surface Complexation of Arsenite and Cadmium on TiO_2

Shan Hu, Li Yan, Tingshan Chan, and Chuanyong Jing

Publication Date (Web): Apr 29, 2015

pp. 5973–5979

DOI: 10.1021/es5062903

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Proteomics and Genetics for Identification of a Bacterial Antimonite Oxidase in *Agrobacterium tumefaciens*

Jingxin Li, Qian Wang, Mingshun Li, Birong Yang, Manman Shi, Wei Guo, Timothy R. McDermott, Christopher Rensing, and Gejiao Wang

Publication Date (Web): Apr 24, 2015
pp. 5980–5989

DOI: 10.1021/es506318b

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Differential Photoactivity of Aqueous [C_{60}] and [C_{70}] Fullerene Aggregates

Kyle J. Moor, Samuel D. Snow, and Jae-Hong Kim

Publication Date (Web): May 7, 2015
pp. 5990–5998

DOI: 10.1021/acs.est.5b00100

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Recycling Acetic Acid from Polarizing Film of Waste Liquid Crystal Display Panels by Sub/Supercritical Water Treatments

Ruixue Wang, Ya Chen, and Zhenming Xu

Publication Date (Web): Apr 27, 2015
pp. 5999–6008

DOI: 10.1021/acs.est.5b00104

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Flume Experiments To Investigate the Environmental Fate of Pharmaceuticals and Their Transformation Products in Streams

Zhe Li, Anna Sobek, and Michael Radke

Publication Date (Web): Apr 22, 2015
pp. 6009–6017

DOI: 10.1021/acs.est.5b00273

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Anaerobic Microbial Transformation of Halogenated Aromatics and Fate Prediction Using Electron Density Modeling

Myriel Cooper, Anke Wagner, Dominik Wondrousch, Frank Sonntag, Andrei Sonnabend, Martin Brehm, Gerrit Schüürmann, and Lorenz Adrian

Publication Date (Web): Apr 24, 2015
pp. 6018–6028

DOI: 10.1021/acs.est.5b00303

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Carbon Stable Isotope Fractionation of Sulfamethoxazole during Biodegradation by *Microbacterium* sp. Strain BR1 and upon Direct Photolysis

Jan Birkigt, Tetyana Gilevska, Benjamin Ricken, Hans-Hermann Richnow, Davide Vione, Philippe F.-X. Corvini, Ivonne Nijenhuis, and Danuta Cichocka

Publication Date (Web): Apr 23, 2015
pp. 6029–6036

DOI: 10.1021/acs.est.5b00367

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Cytoplasmic pH-Stat during Phenanthrene Uptake by Wheat Roots: A Mechanistic Consideration

Xinhua Zhan, Xiu Yi, Le Yue, Xiaorong Fan, Guohua Xu, and Baoshan Xing

Publication Date (Web): Apr 29, 2015
pp. 6037–6044

DOI: 10.1021/acs.est.5b00697

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Equilibrium, Kinetics, and Spectroscopic Studies of SF_6 Hydrate in NaCl Electrolyte Solution

Youngrok Seo, Donghyun Moon, Changho Lee, Jeong-Woo Park, Byeong-Soo Kim, Gang-Woo Lee, Pratik Dotel, Jong-Won Lee, Minjun Cha, and Ji-Ho Yoon

Publication Date (Web): Apr 20, 2015
pp. 6045–6050

DOI: 10.1021/acs.est.5b00866

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Environmental Modeling

Transferability and Generalizability of Regression Models of Ultrafine Particles in Urban Neighborhoods in the Boston Area

Allison P. Patton, Wig Zamore, Elena N. Naumova, Jonathan I. Levy, Doug Brugge, and John L. Durant

Publication Date (Web): Apr 13, 2015
pp. 6051–6060

DOI: 10.1021/es5061676

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Dispersants Have Limited Effects on Exposure Rates of Oil Spills on Fish Eggs and Larvae in Shelf Seas

Frode B. Vikebø, Petter Rønningen, Sonnich Meier, Bjørn Einar Grøsvik, and Vidar S. Lien

Publication Date (Web): Apr 15, 2015
pp. 6061–6069

DOI: 10.1021/acs.est.5b00016

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Environmental Measurements Methods

Occurrence and Spatial Distribution of Microplastics in River Shore Sediments of the Rhine-Main Area in Germany

Sascha Klein, Eckhard Worch, and Thomas P. Knepper

Publication Date (Web): Apr 22, 2015
pp. 6070–6076

DOI: 10.1021/acs.est.5b00492

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Using Linoleic Acid Embedded Cellulose Acetate Membranes to in Situ Monitor Polycyclic Aromatic Hydrocarbons in Lakes and Predict Their Bioavailability to Submerged Macrophytes

Yuqiang Tao, Bin Xue, and Shuchun Yao

Publication Date (Web): Apr 15, 2015

pp. 6077–6084

DOI: 10.1021/acs.est.5b00863

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Field Assessment of the Village Green Project: An Autonomous Community Air Quality Monitoring System

Wan Jiao, Gayle S. W. Hagler, Ronald W. Williams, Robert N. Sharpe, Lewis Weinstock, and Joann Rice

Publication Date (Web): Apr 23, 2015
pp. 6085–6092

DOI: 10.1021/acs.est.5b01245

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Matrix Normalized MALDI-TOF Quantification of a Fluorotelomer-Based Acrylate Polymer

Keegan Rankin and Scott A. Mabury

Publication Date (Web): Apr 11, 2015
pp. 6093–6101

DOI: 10.1021/es505931v

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Uncertainties of Gaseous Oxidized Mercury Measurements Using KCl-Coated Denuders, Cation-Exchange Membranes, and Nylon Membranes: Humidity Influences

Jiaoyan Huang and Mae Sexauer Gustin

Publication Date (Web): Apr 16, 2015
pp. 6102–6108

DOI: 10.1021/acs.est.5b00098

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Numerical Evaluation of Lateral Diffusion Inside Diffusive Gradients in Thin Films Samplers

Jakob Santner, Andreas Kreuzeder, Andrea Schnepf, and Walter W. Wenzel

Publication Date (Web): Apr 15, 2015
pp. 6109–6116

DOI: 10.1021/acs.est.5b00134

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Fast and Selective Preconcentration of Europium from Wastewater and Coal Soil by Graphene Oxide/Silane@Fe_3O_4 Dendritic Nanostructure

Santanu Patra, Ekta Roy, Rashmi Madhuri, and Prashant K. Sharma

Publication Date (Web): Apr 20, 2015
pp. 6117–6126

DOI: 10.1021/acs.est.5b00182

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Increased Frequency of Nontuberculous Mycobacteria Detection at Potable Water Taps within the United States

Maura J. Donohue, Jatin H. Mistry, Joyce M. Donohue, Katharine O'Connell, Dawn King, Jules Byran, Terry Covert, and Stacy Pfaller

Publication Date (Web): Apr 22, 2015
pp. 6127–6133

DOI: 10.1021/acs.est.5b00496

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Quantitative Headspace Analysis of Selected Odorants from Latrines in Africa and India

Charles Jean-François Chappuis, Yvan Niclass, Christine Vuilleumier, and Christian Starkenmann

Publication Date (Web): May 7, 2015
pp. 6134–6140

DOI: 10.1021/acs.est.5b00692

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Detection and Characterization of ZnO Nanoparticles in Surface and Waste Waters Using Single Particle ICPMS

Madjid Hadioui, Vladimir Merdzan, and Kevin J. Wilkinson

Publication Date (Web): Apr 29, 2015
pp. 6141–6148

DOI: 10.1021/acs.est.5b00681

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Evolved Bacterial Biosensor for Arsenite Detection in Environmental Water

Luzhi Li, Junting Liang, Wei Hong, Yun Zhao, Shuang Sun, Xiao Yang, An Xu, Haiying Hang, Lijun Wu, and Shaopeng Chen

Publication Date (Web): Apr 22, 2015
pp. 6149–6155

DOI: 10.1021/acs.est.5b00832

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Remediation and Control Technologies

Direct and Complete Phosphorus Recovery from Municipal Wastewater Using a Hybrid Microfiltration-Forward Osmosis Membrane Bioreactor Process with Seawater Brine as Draw Solution

Guanglei Qiu, Yi-Ming Law, Subhabrata Das, and Yen-Peng Ting

Publication Date (Web): Apr 28, 2015
pp. 6156–6163

DOI: 10.1021/es504554f

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Quantitatively Predicting Bacterial Adhesion Using Surface Free Energy Determined with a Spectrophotometric Method

Xinru Zhang, Qian Zhang, Tao Yan, Zeyi Jiang, Xinxin Zhang, and Yi Y. Zuo

Publication Date (Web): Apr 21, 2015
pp. 6164–6171

DOI: 10.1021/es5050425

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Microbial Mats as a Biological Treatment Approach for Saline Wastewaters: The Case of Produced Water from Hydraulic Fracturing

Benay Akyon, Elyse Stachler, Na Wei, and Kyle Bibby

Publication Date (Web): Apr 13, 2015
pp. 6172–6180

DOI: 10.1021/es505142t

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Macroscopic and Spectroscopic Investigations of the

Adsorption of Nitroaromatic Compounds on Graphene Oxide, Reduced Graphene Oxide, and Graphene Nanosheets

Xiaoxiao Chen and Baoliang Chen

Publication Date (Web): Apr 16, 2015
pp. 6181–6189

DOI: 10.1021/es5054946

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Improving the Visible Light Photoactivity of Supported Fullerene Photocatalysts through the Use of [C_{70}] Fullerene

Kyle J. Moor, Dhyan C. Valle, Chuanhao Li, and Jae-Hong Kim

Publication Date (Web): May 7, 2015
pp. 6190–6197

DOI: 10.1021/es505888d

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Transformation of Chloroform in Model Treatment Wetlands: From Mass Balance to Microbial Analysis

Yi Chen, Yue Wen, Junwei Zhou, Qi Zhou, Jan Vymazal, and Peter Kuschk

Publication Date (Web): Apr 22, 2015
pp. 6198–6205

DOI: 10.1021/es506357e

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Electrochemical and Spectroscopic Evidence on the One-Electron Reduction of U(VI) to U(V) on Magnetite

Ke Yuan, Eugene S. Ilton, Mark R. Antonio, Zhongrui Li, Peter J. Cook, and Udo Becker

Publication Date (Web): Apr 20, 2015
pp. 6206–6213

DOI: 10.1021/acs.est.5b00025

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Identification of 4-Hydroxycumyl Alcohol As the Major MnO_2-Mediated Bisphenol A Transformation Product and Evaluation of Its Environmental Fate

Jeongdae Im, Carson W. Prevatte, Shawn R. Campagna, and Frank E. Löffler

Publication Date (Web): Apr 28, 2015
pp. 6214–6221

DOI: 10.1021/acs.est.5b00372

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Biochar and Activated Carbon for Enhanced Trace Organic Contaminant Retention in Stormwater Infiltration Systems

Bridget A. Ulrich, Eugenia A. Im, David Werner, and Christopher P. Higgins

Publication Date (Web): Apr 24, 2015
pp. 6222–6230

DOI: 10.1021/acs.est.5b00376

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Investigation of Intertidal Wetland Sediment as a Novel Inoculation Source for Anaerobic Saline Wastewater Treatment

Xueqing Shi, Kok Kwang Ng, Xiao-Ran Li, and How Yong Ng

Publication Date (Web): Apr 17, 2015
pp. 6231–6239

DOI: 10.1021/acs.est.5b00546

ActiveView PDF | PDF | PDF w/ Links | Full Text HTML | Abstract

Facet-Dependent Catalytic Activity of Nanosheet-Assembled Bismuth Oxyiodide Microspheres in Degradation of Bisphenol A

Meilan Pan, Haijun Zhang, Guandao Gao, Lu Liu, and Wei Chen

Publication Date (Web): Apr 21, 2015
pp. 6240–6248

DOI: 10.1021/acs.est.5b00626

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Simultaneous Removal of Harmful Algal Blooms and Microcystins Using Microorganism- and Chitosan-Modified Local Soil

Hong Li and Gang Pan

Publication Date (Web): Apr 22, 2015
pp. 6249–6256

DOI: 10.1021/acs.est.5b00840

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Sustainability Engineering and Green Chemistry

Enhancing Toxic Metal Removal from Acidified Sludge with Nitrite Addition

Fangzhou Du, Stefano Freguia, Zhiguo Yuan, Jürg Keller, and Ilje Pikaar

Publication Date (Web): Apr 15, 2015
pp. 6257–6263

DOI: 10.1021/es504507m

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Red Phosphorus: An Earth-Abundant Elemental Photocatalyst for "Green" Bacterial Inactivation under Visible Light

Dehua Xia, Zhurui Shen, Guocheng Huang, Wanjun Wang, Jimmy C. Yu, and Po Keung Wong

Publication Date (Web): Apr 20, 2015
pp. 6264–6273

DOI: 10.1021/acs.est.5b00531

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Ecotoxicology and Human Environmental Health

Developmental Exposure to Aroclor 1254 Alters Migratory Behavior in Juvenile European Starlings (*Sturnus vulgaris*)

Leanne M. Flahr, Nicole L. Michel, Alexander R. D. Zahara, Paul D. Jones, and Christy A. Morrissey

Publication Date (Web): Apr 20, 2015
pp. 6274–6283

DOI: 10.1021/acs.est.5b01185

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Toxicity Assessment of 4-Methyl-1-cyclohexanemethanol and Its Metabolites in Response to a Recent Chemical Spill in West Virginia, USA

Jiaqi Lan, Man Hu, Ce Gao, Akram Alshawabkeh, and April Z. Gu

Publication Date (Web): May 11, 2015
pp. 6284–6293

DOI: 10.1021/acs.est.5b00371

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Mutagenic Effects of Perfluorooctanesulfonic Acid in *gpt* Delta Transgenic System Are Mediated by Hydrogen Peroxide

Yichen Wang, Xuefeng Zhang, Meimei Wang, Yiyi Cao, Xinan Wang, Yun Liu, Juan Wang, Jing Wang, Lijun Wu, Tom K. Hei, Yang Luan, and An Xu

Publication Date (Web): Apr 15, 2015
pp. 6294–6303

DOI: 10.1021/acs.est.5b00530

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Experimental Dosing of Wetlands with Coagulants Removes Mercury from Surface Water and Decreases Mercury Bioaccumulation in Fish

Joshua T. Ackerman, Tamara E. C. Kraus, Jacob A. Fleck, David P. Krabbenhoft, William R. Horwath, Sandra M. Bachand, Mark P. Herzog, C. Alex Hartman, and Philip A. M. Bachand

Publication Date (Web): Apr 20, 2015
pp. 6304–6311

DOI: 10.1021/acs.est.5b00655

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Independent Data Validation of an in Vitro Method for the Prediction of the Relative Bioavailability of Arsenic in Contaminated Soils

Karen D. Bradham, Clay Nelson, Albert L. Juhasz, Euan Smith, Kirk Scheckel, Daniel R. Obenour, Bradley W. Miller, and David J. Thomas

Publication Date (Web): May 12, 2015
pp. 6312–6318

DOI: 10.1021/acs.est.5b00905

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Evaluation of Estrogenic Activity of Wastewater:

Comparison Among In Vitro ERα Reporter Gene Assay, In Vivo Vitellogenin Induction, and Chemical Analysis

Masaru Ihara, Tomokazu Kitamura, Vimal Kumar, Chang-Beom Park, Mariko O. Ihara, Sang-Jung Lee, Naoyuki Yamashita, Shinichi Miyagawa, Taisen Iguchi, Seiichiro Okamoto, Yutaka Suzuki, and Hiroaki Tanaka

Publication Date (Web): Apr 22, 2015
pp. 6319–6326

DOI: 10.1021/acs.est.5b01027

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Energy and the Environment

Optimal Intensity and Biomass Density for Biofuel Production in a Thin-Light-Path Photobioreactor

Aadhar Jain, Nina Voulis, Erica E. Jung, Devin F. R. Doud, William B. Miller, Largus T. Angenent, and David Erickson

Publication Date (Web): Apr 24, 2015
pp. 6327–6334

DOI: 10.1021/es5052777

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Chemical Reactions of Portland Cement with Aqueous CO_2 and Their Impacts on Cement's Mechanical Properties under Geologic CO_2 Sequestration Conditions

Qingyun Li, Yun Mook Lim, Katharine M. Flores, Kelly Kranjc, and Young-Shin Jun

Publication Date (Web): Apr 20, 2015
pp. 6335–6343

DOI: 10.1021/es5063488

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Current and Future Environmental Balance of Small-Scale Run-of-River Hydropower

John Gallagher, David Styles, Aonghus McNabola, and A. Prysor Williams

Publication Date (Web): Apr 24, 2015
pp. 6344–6351

DOI: 10.1021/acs.est.5b00716

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Correspondence

Comment on "*Sphagnum* Mosses from 21 Ombrotrophic Bogs in the Athabasca Bituminous Sands Region Show No Significant Atmospheric Contamination of 'Heavy Metals'"

Jules M. Blais and William F. Donahue

Publication Date (Web): May 5, 2015
pp. 6352–6353

DOI: 10.1021/acs.est.5b00475

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Response to Comment on "*Sphagnum* Mosses from 21 Ombrotrophic Bogs in the Athabasca Bituminous Sands Region Show No Significant Atmospheric Contamination of 'Heavy Metals'"

William Shotyk, Rene Belland, John Duke, Heike Kempter, Michael Krachler, Tommy Noernberg, Rick Pelletier, Melanie A. Vile, Kelman Wieder, Claudio Zaccone, and Shuangquan Zhang

Publication Date (Web): May 5, 2015
pp. 6354–6357

DOI: 10.1021/acs.est.5b01229

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Comment on "Comparison of Water Use for Hydraulic Fracturing for Unconventional Oil and Gas versus Conventional Oil"

David J. Lampert

Publication Date (Web): May 4, 2015
pp. 6358–6359

DOI: 10.1021/acs.est.5b00963

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Response to Comment on "Comparison of Water Use for Hydraulic Fracturing for Unconventional Oil and Gas versus Conventional Oil"

Bridget R. Scanlon, Robert C. Reedy, and J.-P. Nicot

Publication Date (Web): May 4, 2015
pp. 6360–6361

DOI: 10.1021/acs.est.5b01497

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Additions and Corrections

Correction to Atom Exchange between Aqueous Fe(II) and Structural Fe in Clay Minerals

Anke Neumann, Lingling Wu, Weiqiang Li, Brian L. Beard, Clark M. Johnson, Kevin M. Rosso, Andrew J. Frierdich, and Michelle M. Scherer

Publication Date (Web): May 5, 2015
pp. 6362–6362

DOI: 10.1021/acs.est.5b01659

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Correction to Effect of Silicate on the Formation and Stability of Ni–Al LDH at the γ-Al_2O_3 Surface

Xiaoli Tan, Ming Fang, Xuemei Ren, Huiyang Mei, Dadong Shao, and Xiangke Wang

Publication Date (Web): May 5, 2015
pp. 6363–6363

DOI: 10.1021/acs.est.5b02019

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Sent: Tue 5/12/2015 12:10:14 PM
Subject: RE: Schedule for release of HF Study Reports and Draft Assessment

Man, that's a brutal schedule…

Jill Dean

Physical Scientist

Office of Ground Water & Drinking Water

dean.jill@epa.gov

Phone: 202-564-8241

From: Briskin, Jeanne
Sent: Thursday, May 07, 2015 8:28 AM
To: Burden, Susan; Wiser, Nathan; Tinsley, Chuck; Daiss, Rebecca; Sharkey, Susan; Fleming, Megan; Williams, Larke; Singer, Alison; Cluff, Maryam
Cc: Dean, Jill; Hillenbrand, Charles
Subject: Fwd: Schedule for release of HF Study Reports and Draft Assessment

FYI

Begin forwarded message:

From: "Frithsen, Jeff" <Frithsen.Jeff@epa.gov>
Date: May 7, 2015 at 7:45:31 AM EDT
To: "Briskin, Jeanne" <Briskin.Jeanne@epa.gov>, "Teichman, Kevin" <Teichman.Kevin@epa.gov>, "Gibbons, Dayna" <Gibbons.Dayna@epa.gov>, "Zambrana, Jose" <Zambrana.Jose@epa.gov>, "Matthews, Lisa" <Matthews.Lisa@epa.gov>
Subject: Schedule for release of HF Study Reports and Draft Assessment

FYI: I sent the following to Jennifer, Cindy, and Fred this morning.

May promises to be a very busy month for ORD and for the Agency. There are lots of activities coming to completion not only in our world of hydraulic fracturing, but in other parts of the Agency as well. Scheduling all those activities has become a bit of a challenge.

Ex. 5

Thanks all! Almost there. Really!!

Jeff

To: Burden, Susan[Burden.Susan@epa.gov]
From: Frithsen, Jeff
Sent: Mon 5/4/2015 12:31:46 PM
Subject: RE: HF Spills

Good morning sunshine!

Non-Responsive Also will get comments on the HFDWA Executive Summary.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

Non-Responsive

Non-Responsive

To: Hauchman, Fred[hauchman.fred@epa.gov]
From: Burden, Susan
Sent: Thur 5/7/2015 12:58:39 PM
Subject: FW: Schedule for release of HF Study Reports and Draft Assessment

FYI...

Thanks,

Susan

Susan Burden, Ph.D.

Office of Research and Development

US Environmental Protection Agency

Phone: (202) 564-6308

Email: burden.susan@epa.gov

From: Frithsen, Jeff
Sent: Thursday, May 07, 2015 7:52 AM
To: Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Jonathan.Koplos@cadmusgroup.com; Fleming, Megan; Knightes, Chris; Shari.Ring@cadmusgroup.com; Weaver, Jim; MaryEllen.Tuccillo@cadmusgroup.com; Cluff, Maryam; Stanek, John; Yost, Erin
Subject: Schedule for release of HF Study Reports and Draft Assessment

Team:

May promises to be a very busy month for ORD and for the Agency. There are lots of activities coming to completion not only in our world of hydraulic fracturing, but in other parts of the Agency as well. Scheduling all those activities has become a bit of a challenge.

Ex. 5

Thanks all! Almost there. Really!!

Jeff

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Burden, Susan
Sent: Mon 5/4/2015 1:53:10 PM
Subject: RE: HF: Draft EOP Briefing

Comments for your consideration:

Ex. 5

Ex. 5

Thanks,

Susan

Susan Burden, Ph.D.

Office of Research and Development

US Environmental Protection Agency

Phone: (202) 564-6308

Email: burden.susan@epa.gov

From: Frithsen, Jeff
Sent: Monday, May 04, 2015 9:21 AM
To: Burden, Susan
Subject: HF: Draft EOP Briefing

See attached. Quick review and comment……

Jeff

Jeffrey B. Frithsen, Ph.D.

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Washington, DC 20460

703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries

Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

To: kristacarman@[redacted] Ex. 6 dglatt@nd.gov[dglatt@nd.gov]; creinke@nd.gov[creinke@nd.gov]; amritter@nd.gov[amritter@nd.gov]
Cc: lhelms@nd.gov[lhelms@nd.gov]; atravnicek@nd.gov[atravnicek@nd.gov]; tdwelle@nd.gov[tdwelle@nd.gov]; McGrath, Shaun[McGrath.Shaun@epa.gov]; Card, Joan[Card.Joan@epa.gov]; Marks, Teresa[Marks.Teresa@epa.gov]; Burke, Thomas[Burke.Thomas@epa.gov]
From: Matthews, Lisa
Sent: Fri 5/22/2015 4:42:10 PM
Subject: Follow-up to briefing on EPA's retrospective case study in Killdeer, ND
state QA.docx

Thank you for participating in today's briefing on EPA's retrospective case study in Killdeer, ND.

We appreciate your thoughtful comments on our work and on how we communicate the major messages of the report.

We know you will likely receive media inquiries about various aspects of the draft assessment and the states' role and activities. To help you prepare for these inquiries, we've compiled some common questions (attached) we think you may receive.

These questions do not include results or findings from the assessment. Rather, they are based on the research questions and chapters of the assessment and are meant to give an overview of key topics and help you prepare your own communication materials.

We hope you'll provide feedback on the draft assessment during the public comment and SAB review process. We look forward to our continued partnership on this and other environment and public health matters.

Please let us know if you have any further questions. Please also remember that the information presented at today's briefing and discussed is embargoed until the reports are publicly released.

Enjoy the holiday weekend!

Regards,

Lisa Matthews

Senior Advisor – State Engagement

US EPA Office of Research and Development

202-564-6669 office

202-577-4035 mobile

matthews.lisa@epa.gov

Questions States are Likely to Receive following Release of Assessment

1. **Retrospective Case Studies:** Is the state going to continue with the research EPA conducted for the retrospective case studies or take further actions?
2. **Retrospective Case Studies:** What actions did the state take related to concerns or incidents associated with the retrospective case study in your state?
3. **Frac Focus:** Does the state require the use of FracFocus? If not, how does the state track this information?
4. **Water Acquisition:** Does the state feel that cumulative water withdrawals for current or increased use of hydraulic fracturing will affect drinking water quality or availability?
5. **Water Acquisition:** If hydraulic fracturing does increase in a given area does the state have policies or regulations in place to protect drinking water resources?
6. **Water Acquisition:** What regulations, policies or best practices does the state have in place to monitor or regulate water used for hydraulic fracturing?
7. **Chemical Mixing:** Is the state aware of the identities and volumes of chemicals being used at sites for hydraulic fracturing?
8. **Chemical Mixing:** What regulations, policies or best practices does the state have in place to monitor or regulate chemicals used for hydraulic fracturing?
9. **Chemical Mixing/Spills:** The EPA report looked at spills potentially related to hydraulic fracturing/unconventional oil and gas activities. What actions did the state take or require to prevent or mitigate these spills if any?
10. **Chemical Mixing/Spills:** What regulations, policies or best practices does the state have in place for chemical spills?
11. **Well Integrity:** How does the state keep track of well construction practices before, during and after hydraulic fracturing?
12. **Well Integrity:** What regulations, policies or best practices does the state have in place for well design, construction, operation and abandonment?
13. **Flowback and Produced Water:** What regulations, policies or best practices does the state have in place to manage flowback and produced water?
14. **Flowback and Produced Water:** Does the state keep track of the frequency, severity and causes of spills of flowback and produced water?
15. **Flowback and Produced Water:** Does the state require monitoring or analysis of flowback and produced water?
16. **Wastewater Treatment and Disposal:** What regulations, policies or best practices does the state have in place to manage wastewater and disposal?
17. **Wastewater Treatment and Disposal:** What treatment standards does the state use/follow for wastewater treatment and disposal?
18. **Wastewater Treatment and Disposal:** Does the state feel that conventional publically owned treatment works and commercial treatment systems are effective in removing contaminants of concern in hydraulic fracturing wastewater?
19. **Wastewater Treatment and Disposal:** What is the state doing to prevent the formation of brominated disinfection byproducts potentially formed during drinking water treatment processes?
20. **Hazard Evaluation of Chemicals Across the Water Cycle Stages:** Was the state aware of the toxicological properties and potential risks associated with chemicals used in hydraulic fracturing prior to the EPA study?
21. **Hazard Evaluation of Chemicals Across the Water Cycle Stages:** What regulations, policies or best practices does the state have in place to protect human health and the environment from risks (known or unknown) from chemicals used or produced in hydraulic fracturing?

To: Burke, Thomas[Burke.Thomas@epa.gov]
From: Tom Burke
Sent: Sun 5/17/2015 3:15:15 PM
Subject: ORD/OSA Weekly Report

Hydraulic Fracturing

We are moving ahead with the outreach in preparation for the release of the draft drinking water assessment. Last week working with Regional Administrators Shaun McGrath, Ron Curry, and Shawn Garvin we provided briefings to Regions 8, 6 and 3 states and Tribes. The briefings were well attended and went very well. This week we are scheduled to brief Colorado state officials on the Raton Basin case study, North Dakota on the Killdeer case study. Other aspects of the assessment completion continue to move forward.

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Non-Responsive

Non-Responsive

To: fhensley_c-a-tribes.org[fhensley@c-a-tribes.org]; melissarobinson@choctawnation.com[melissarobinson@choctawnation.com]; jyoshioka@iowanation.org[jyoshioka@iowanation.org]; Ex. 6 mbalber@c-a-tribes.org[mbalber@c-a-tribes.org]; Jeremy.Fincher@sacandfoxnation-nsn.gov[Jeremy.Fincher@sacandfoxnation-nsn.gov]; Jason.Scott@Chickasaw.net[Jason.Scott@Chickasaw.net]; Ex. 6

Cc: Curry, Ron[Curry.Ron@epa.gov]; Coleman, Sam[Coleman.Sam@epa.gov]; Gee, Randy[Gee.Randy@epa.gov]; Lawrence, Rob[Lawrence.Rob@epa.gov]; Overbay, Michael[overbay.michael@epa.gov]; Marks, Teresa[Marks.Teresa@epa.gov]; Burke, Thomas[Burke.Thomas@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]; Bueno, Michael[Bueno.Michael@epa.gov]; Byrne, Andrew[Byrne.Andrew@epa.gov]; Rodia, Monica[Rodia.Monica@epa.gov]

From: Matthews, Lisa

Sent: Thur 5/14/2015 8:32:59 PM

Subject: Follow-up to Region 6 tribal briefing on EPA's Draft Hydraulic Fracturing Drinking Water Assessment

Thank you for participating in our tribal briefing on EPA's Draft Hydraulic Fracturing Drinking Water Assessment.

We appreciated your thoughtful comments on our work and on how we communicate the major messages of the draft assessment.

We will work with Randy Gee, Regional Tribal Coordinator, to alert you when the draft assessment and final EPA reports are released.

We hope you'll provide feedback on the draft assessment during the public comment and SAB review process. We look forward to our continued partnership on this and other environment and public health matters.

If you have any questions, please feel free to contact Randy or me. Please remember that the information presented and discussed at this meeting is restricted to briefing participants only and cannot be shared until the reports are publicly released.

Regards,

Lisa Matthews

US EPA Office of Research and Development

202-564-6669 office

Ex. 6

matthews.lisa@epa.gov

To: tojohns@southernute-nsn.gov[tojohns@southernute-nsn.gov]; charten@southernute-nsn.gov[charten@southernute-nsn.gov]; 'elisa@navajopublicwater.org'['elisa@navajopublicwater.org']; 'nnepauic@frontiernet.net'['nnepauic@frontiernet.net']; 'dean.goggles@northernarapaho.org'['dean.goggles@northernarapaho.org']; 'darwin.stclair@e-shoshone.com'['darwin.stclair@e-shoshone.com']; atwobears@standingrock.org[atwobears@standingrock.org]; '2horses@nemont.net'['2horses@nemont.net']; 'sbabits@wyoming.com'['sbabits@wyoming.com']; rortiz@northernarapaho.com[rortiz@northernarapaho.com]; 'sbaker@mhanation.com'['sbaker@mhanation.com']; 'prestonm@utetribe.com'['prestonm@utetribe.com']
Cc: Curry, Ron[Curry.Ron@epa.gov]; Coleman, Sam[Coleman.Sam@epa.gov]; Gee, Randy[Gee.Randy@epa.gov]; Lawrence, Rob[Lawrence.Rob@epa.gov]; Overbay, Michael[overbay.michael@epa.gov]; Ebbert, Laura[Ebbert.Laura@epa.gov]; Albright, David[Albright.David@epa.gov]; Marks, Teresa[Marks.Teresa@epa.gov]; Burke, Thomas[Burke.Thomas@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]; Bueno, Michael[Bueno.Michael@epa.gov]; Byrne, Andrew[Byrne.Andrew@epa.gov]; Rodia, Monica[Rodia.Monica@epa.gov]
From: Matthews, Lisa
Sent: Thur 5/14/2015 8:24:07 PM
Subject: RECALL Follow-up to Region 8 and CA tribal briefing on EPA's Draft Hydraulic Fracturing Drinking Water Assessment

Please DISREGARD. Apologies…pressed send button too soon. Copied wrong region. I'll send correction.

From: Matthews, Lisa
Sent: Thursday, May 14, 2015 4:12 PM
To: tojohns@southernute-nsn.gov; charten@southernute-nsn.gov; 'elisa@navajopublicwater.org'; 'nnepauic@frontiernet.net'; 'dean.goggles@northernarapaho.org'; 'darwin.stclair@e-shoshone.com'; atwobears@standingrock.org; '2horses@nemont.net'; 'sbabits@wyoming.com'; rortiz@northernarapaho.com; 'sbaker@mhanation.com'; 'prestonm@utetribe.com'
Cc: Curry, Ron; Coleman, Sam; Gee, Randy; Lawrence, Rob; Overbay, Michael; Ebbert, Laura; David Albright (albright.david@epa.gov); Teresa Marks (Marks.Teresa@epa.gov); Burke, Thomas; Jeff Frithsen (Frithsen.Jeff@epa.gov); Bueno, Michael; Byrne, Andrew; Rodia, Monica
Subject: Follow-up to Region 8 and CA tribal briefing on EPA's Draft Hydraulic Fracturing Drinking Water Assessment

Thank you for participating in our tribal briefing on EPA's Draft Hydraulic Fracturing Drinking Water Assessment.

We appreciated your thoughtful comments on our work and on how we communicate the major messages of the draft assessment.

We will work with our Regional Tribal Coordinators to alert you when the draft assessment and final EPA reports are released.

We hope you'll provide feedback on the draft assessment during the public comment and SAB review process. We look forward to our continued partnership on this and other environment and public health matters.

If you have any questions, please feel free to contact your Regional Tribal Coordinator or me. Please remember that the information presented and discussed at this meeting is restricted to briefing participants only and cannot be shared until the reports are publicly released.

Regards,

Lisa Matthews

US EPA Office of Research and Development

202-564-6669 office

Ex. 6

matthews.lisa@epa.gov

To: Burke, Thomas[Burke.Thomas@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]
Cc: Smith, Kelley[Smith.Kelley@epa.gov]
From: Matthews, Lisa
Sent: Thur 5/14/2015 2:00:04 PM
Subject: Follow-up to state briefing on EPA's Draft Hydraulic Fracturing Drinking Water Assessment

Sharing draft to see if you have any input...I'd like to get this out today. Thanks!

DRAFT

Ex. 5

If you have any questions, please feel free to contact me.

Regards,
Lisa Matthews
Senior Advisor – State Engagement
US EPA Office of Research and Development
202-564-6669 office
Ex. 6 mobile
matthews.lisa@epa.gov

To: Michael.lamoureux@governor.arkansas.gov[Michael.lamoureux@governor.arkansas.gov]; keogh@adeq.state.ar.us[keogh@adeq.state.ar.us]; larry.bengal@aogc.state.ar.us[larry.bengal@aogc.state.ar.us]; randy.young@arkansas.gov[randy.young@arkansas.gov]; nathaniel.smith@arkansas.gov[nathaniel.smith@arkansas.gov]; kyle.plotkin@la.gov[kyle.plotkin@la.gov]; peggy.hatch@la.gov[peggy.hatch@la.gov]; stephen.chustz@la.gov[stephen.chustz@la.gov]; jake.causey@la.gov[jake.causey@la.gov]; jim.welsh@la.gov[jim.welsh@la.gov]; james.ross@state.nm.us[james.ross@state.nm.us]; ryan.flynn@state.nm.us[ryan.flynn@state.nm.us]; david.martin@state.nm.us[david.martin@state.nm.us]; Katie.altshuler@gov.ok.gov[Katie.altshuler@gov.ok.gov]; michael.teague@ee.ok.gov[michael.teague@ee.ok.gov]; scott.thompson@deq.ok.gov[scott.thompson@deq.ok.gov]; jd.strong@owrb.ok.gov[jd.strong@owrb.ok.gov]; rockym@health.ok.gov[rockym@health.ok.gov]; jerry.strickland@governor.state.tx.us[jerry.strickland@governor.state.tx.us]; bryan.shaw@tceq.texas.gov[bryan.shaw@tceq.texas.gov]; marshall.coover@tceq.texas.gov[marshall.coover@tceq.texas.gov]; milton.rister@rrc.state.tx.us[milton.rister@rrc.state.tx.us]; richard.hyde@tceq.texas.gov[richard.hyde@tceq.texas.gov]; lori.wrotenbery@rrc.state.tx.us[lori.wrotenbery@rrc.state.tx.us]; John.Villanacci@dshs.state.tx.us[John.Villanacci@dshs.state.tx.us]; sheila.kuschke@dshs.state.tx.us[sheila.kuschke@dshs.state.tx.us]; stephen.lee@LA.GOV[stephen.lee@LA.GOV]; Gary.snellgrove@la.gov[Gary.snellgrove@la.gov]; David.Catanach@state.nm.us[David.Catanach@state.nm.us]; leslie.savage@rrc.state.tx.us[leslie.savage@rrc.state.tx.us]; peter.pope@rrc.state.tx.us[peter.pope@rrc.state.tx.us]; thomas.harris@la.gov[thomas.harris@la.gov]; benefield@adeq.state.ar.us[benefield@adeq.state.ar.us]; Jenniffer.Sheppard@LA.GOV[Jenniffer.Sheppard@LA.GOV]; jodi.mckee@ee.ok.gov[jodi.mckee@ee.ok.gov]; cindy.przekurat@deq.ok.gov[cindy.przekurat@deq.ok.gov]; keith.sheedy@tceq.texas.gov[keith.sheedy@tceq.texas.gov]; Lori.Wilson@tceq.texas.gov[Lori.Wilson@tceq.texas.gov]; Barbara.Robinson@tceq.texas.gov[Barbara.Robinson@tceq.texas.gov]; Jeffery.Stone@arkansas.gov[Jeffery.Stone@arkansas.gov]; Engelman, Alexa[ENGELMAN.ALEXA@EPA.GOV]; t.baker@occemail.com[t.baker@occemail.com]; v.hullinger@occemail.com[v.hullinger@occemail.com]
Cc: Curry, Ron[Curry.Ron@epa.gov]; Coleman, Sam[Coleman.Sam@epa.gov]; Lawrence, Rob[Lawrence.Rob@epa.gov]; Burke, Thomas[Burke.Thomas@epa.gov]; Marks, Teresa[Marks.Teresa@epa.gov]; Smith, Kelley[Smith.Kelley@epa.gov]; Gibbons, Dayna[Gibbons.Dayna@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]; Bueno, Michael[Bueno.Michael@epa.gov]
From: Bueno, Michael
Sent: Tue 5/12/2015 8:07:13 PM
Subject: Invitation - Briefing for States on EPA's Draft Hydraulic Fracturing Drinking Water Assessment
HF state briefing draft agenda.docx

Good Afternoon,

Thank you to those who have confirmed your participation to our *Briefing for States on EPA's Draft Hydraulic Fracturing Drinking Water Assessment* on May 13, 2015 at 10:30am (CDT). Attached is a draft meeting agenda.

We are providing a list of in-person attendees to the EPA's guard station. Please note you will be required to check-in with security and present government-issued photo identification. Please allow an additional 15 minutes for security screening.

If you are not attending in person, audio will be provided via a call-in line that at our operator will manage to ensure only confirmed participants can connect. Audio will not be provided through your computer, so you must be registered in order to listen in. Below is the webinar and call-in information.

Webinar: https://epa.connectsolutions.com/r95b0pzdjvr/

Ex. 6

EPA must provide the conference call operator with a list of participants in advance of the meeting, so we ask that you please RSVP no later than 24 hours before the meeting. If you have not already done so, please confirm your participation by emailing both Michael Bueno (bueno.michael@epa.gov) and me (matthews.lisa@epa.gov).

We ask that you call in 15 minutes before the meeting to ensure that you are connected to the conference on time. When joining the webinar please type in your full name and organization so that we can keep track of attendance.

If you have any questions about this meeting, please contact me (matthews.lisa@epa.gov / 202-577-4035 mobile) or Michael Bueno (bueno.michael@epa.gov / 202-564-5051).

Thank you,

Lisa Matthews

Senior Advisor – State Engagement

US EPA Office of Research and Development

202-564-6669 office

Ex. 6

matthews.lisa@epa.gov

Briefing for States on EPA's Draft Hydraulic Fracturing Drinking Water Assessment - Region 6 states (Arkansas, Louisiana, New Mexico, Oklahoma and Texas)

US EPA Region 6 office
1445 Ross Ave, Dallas, TX 75202
(Fountain Place Building, corner of Ross Ave and Field St)
12th Floor Conference Center

Ex. 6

Webinar: https://epa.connectsolutions.com/r95b0pzdjvr/

May 13, 2015
10:30-12:30 am CDT

Purpose: *Briefing on the EPA's draft report, Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources. This assessment provides an evaluation of the potential impacts of hydraulic fracturing on drinking water resources and identifies key vulnerabilities.* ***The information presented at this meeting and discussed is embargoed until publicly released.***

Draft Agenda

10:30 am **Welcome and State Introductions**
Ron Curry, Regional Administrator, US EPA Region 6
Teresa Marks, Principal Advisor on Unconventional Oil and Gas, US EPA
Dr. Tom Burke, Deputy Assistant Administrator and EPA Science Advisor, US EPA Office of Research and Development

10:40 am **Opening Remarks/Study Overview**
Dr. Tom Burke

10:50 am **Presentation on EPA's Draft Assessment**
Dr. Jeff Frithsen, US EPA Office of Research and Development

11:20 am **State–EPA Discussion**
All (led by Dr. Tom Burke)
- *Questions and answers*
- *Messaging*
- *Communications*

12:20 am **Wrap-Up**
Dr. Tom Burke and Teresa Marks

12:30 am **Adjourn**

To: cltecube@yahoo.com[cltecube@yahoo.com]; stephenbetsitty@navajo-nsn.gov[stephenbetsitty@navajo-nsn.gov]; kenj@astribe.com[kenj@astribe.com]; prentissdonna@yahoo.com[prentissdonna@yahoo.com]; pedwards.cn@gmail.com[pedwards.cn@gmail.com]; njohn@cherokee.org[njohn@cherokee.org]; fhensley_c-a-tribes.org[fhensley@c-a-tribes.org]; Linda.robins@chickasaw.net[Linda.robins@chickasaw.net]; melissarobinson@choctawnation.com[melissarobinson@choctawnation.com]; showard@potawatomi.org[showard@potawatomi.org]; brians@comanchenation.com[brians@comanchenation.com]; ismith@delawarenation.com[ismith@delawarenation.com]; jyoshioka@iowanation.org[jyoshioka@iowanation.org]; dshields@kickapootribeofoklahoma.com[dshields@kickapootribeofoklahoma.com]; nethkuplega@yahoo.com[nethkuplega@yahoo.com]; delb@mcn-nsn.gov[delb@mcn-nsn.gov]; jannhayman@osagenation-nsn.gov[jannhayman@osagenation-nsn.gov]; mmatlock@pawneenation.org[mmatlock@pawneenation.org]; Jeremy.Fincher@sacandfoxnation-nsn.gov[Jeremy.Fincher@sacandfoxnation-nsn.gov]; douglas.m@sno-nsn.gov[douglas.m@sno-nsn.gov]; jason.prince@wichitatribe.com[jason.prince@wichitatribe.com]; Byrne, Andrew[Byrne.Andrew@epa.gov]; mbalber@c-a-tribes.org[mbalber@c-a-tribes.org]
Cc: Curry, Ron[Curry.Ron@epa.gov]; Coleman, Sam[Coleman.Sam@epa.gov]; Lawrence, Rob[Lawrence.Rob@epa.gov]; Burke, Thomas[Burke.Thomas@epa.gov]; Marks, Teresa[Marks.Teresa@epa.gov]; Smith, Kelley[Smith.Kelley@epa.gov]; Gibbons, Dayna[Gibbons.Dayna@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]; Bueno, Michael[Bueno.Michael@epa.gov]
From: Bueno, Michael
Sent: Tue 5/12/2015 8:07:09 PM
Subject: Invitation - Briefing for Tribes on EPA's Draft Hydraulic Fracturing Drinking Water Assessment
HF tribe briefing draft agenda.docx

Good Afternoon,

Thank you to those who have confirmed your participation to our *Briefing for Tribes on EPA's Draft Hydraulic Fracturing Drinking Water Assessment* on May 13, 2015 at 2pm (CDT). Attached is a draft meeting agenda.

We are providing a list of in-person attendees to the EPA's guard station. Please note you will be required to check-in with security and present government-issued photo identification. Please allow an additional 15 minutes for security screening.

If you are not attending in person, audio will be provided via a call-in line that at our operator will manage to ensure only confirmed participants can connect. Audio will not be provided through your computer, so you must be registered in order to listen in. Below is the webinar and call-in information.

Webinar: https://epa.connectsolutions.com/r8oahtqcn0m/

Ex. 6

EPA must provide the conference call operator with a list of participants in advance of the meeting, so we ask that you please RSVP no later than 24 hours before the meeting. If you have not already done so, please confirm your participation by emailing both Michael Bueno (bueno.michael@epa.gov) and me (matthews.lisa@epa.gov).

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If you have any questions about this meeting, please contact me (matthews.lisa@epa.gov / 202-577-4035 mobile) or Michael Bueno (bueno.michael@epa.gov / 202-564-5051).

Thank you,

Lisa Matthews

Senior Advisor – State Engagement

US EPA Office of Research and Development

202-564-6669 office

Ex. 6

matthews.lisa@epa.gov

To: Blackburn, Elizabeth[Blackburn.Elizabeth@epa.gov]; Hubbard, Carolyn[Hubbard.Carolyn@epa.gov]; Kim, Hyon[Kim.Hyon@epa.gov]
From: Maguire, Megan
Sent: Mon 5/11/2015 7:55:03 PM
Subject: Weekly Report, ORD, May 15 - 24, 2015

Office of Research and Development
Environmental Protection Agency
May 15– 24, 2015
30-60 Day Outlook

Ex. 5 EPA expects to release its draft assessment of the potential impacts of hydraulic fracturing for oil and gas on drinking water resources, along with another 9 peer reviewed EPA Reports written as part of the study. The draft assessment is based upon extensive review of literature, results from EPA research projects, and technical input from state, industry, non-governmental organizations, the public, and other stakeholders. Ultimately, it will help advance the state of our science and provide a new lens to help our states and communities understand the potential impacts on our drinking water resources from hydraulic fracturing. EPA plans to conduct state focused and public webinars as part of the release of the papers.

Non-Responsive

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Thanks,

Megan

Megan Maguire

US EPA, Office of Research and Development

RRB 41261

O: (202)564-6636

Ex. 6

To: marykay.hill@wyo.gov[marykay.hill@wyo.gov]; jerimiah.rieman@wyo.gov[jerimiah.rieman@wyo.gov]; todd.parfitt@wyo.gov[todd.parfitt@wyo.gov]; mark.watson@wyo.gov[mark.watson@wyo.gov]; wendy.braund@wyo.gov[wendy.braund@wyo.gov]; kristacarman@mac.com[kristacarman@mac.com]; dglatt@nd.gov[dglatt@nd.gov]; lhelms@nd.gov[lhelms@nd.gov]; amatheson@utah.gov[amatheson@utah.gov]; amandasmith@utah.gov[amandasmith@utah.gov]; johnbaza@utah.gov[johnbaza@utah.gov]; jena.griswold@state.co.us[jena.griswold@state.co.us]; larry.wolk@state.co.us[larry.wolk@state.co.us]; martha.rudolph@state.co.us[martha.rudolph@state.co.us]; mike.king@state.co.us[mike.king@state.co.us]; Robert.randall@state.co.us[Robert.randall@state.co.us]; matt.lepore@state.co.us[matt.lepore@state.co.us]; Katie.wheelermathews@wdc.ca.gov[Katie.wheelermathews@wdc.ca.gov]; SectyRodriquez@calepa.ca.gov[SectyRodriquez@calepa.ca.gov]; mark.nechodom@conservation.ca.gov[mark.nechodom@conservation.ca.gov]; Jonathan.Bishop@waterboards.ca.gov[Jonathan.Bishop@waterboards.ca.gov]; mark.starr@cdph.ca.gov[mark.starr@cdph.ca.gov]; steven.bohlen@conservation.ca.gov[steven.bohlen@conservation.ca.gov]; Saul.Gomez@resources.ca.gov[Saul.Gomez@resources.ca.gov]; jason.marshall@consrv.ca.gov[jason.marshall@consrv.ca.gov]; daynedoucet@utah.gov[daynedoucet@utah.gov]; steveschneider@utah.gov[steveschneider@utah.gov]; christine.stickley@wyo.gov[christine.stickley@wyo.gov]; mark.thiesse@wyo.gov[mark.thiesse@wyo.gov]; cameron.nazminia@wyo.gov[cameron.nazminia@wyo.gov]; tom.kropatsch@wyo.gov[tom.kropatsch@wyo.gov]; kent.kuster@state.co.us[kent.kuster@state.co.us]; Albright, David[Albright.David@epa.gov]; Loraine.Cory@conservation.ca.gov[Loraine.Cory@conservation.ca.gov]; kathleen.staks@state.co.us[kathleen.staks@state.co.us]
Cc: McGrath, Shaun[McGrath.Shaun@epa.gov]; Card, Joan[Card.Joan@epa.gov]; Blumenfeld, Jared[BLUMENFELD.JARED@EPA.GOV]; Strauss, Alexis[Strauss.Alexis@epa.gov]; Albright, David[Albright.David@epa.gov]; Burke, Thomas[Burke.Thomas@epa.gov]; Marks, Teresa[Marks.Teresa@epa.gov]; Bueno, Michael[Bueno.Michael@epa.gov]
From: Bueno, Michael
Sent: Mon 5/11/2015 6:25:58 PM
Subject: Invitation: Briefing for States on EPA's Draft Hydraulic Fracturing Drinking Water Assessment
HF state briefing draft agenda.docx

Good Afternoon,

Thank you to those who have confirmed your participation to our *Briefing for States on EPA's Draft Hydraulic Fracturing Drinking Water Assessment* on May 12, 2015. Attached is a draft meeting agenda.

We are providing a list of in-person attendees to the EPA's guard station. Please note you will be required to check-in with security and present government-issued photo identification. Please allow an additional 15 minutes for security screening.

If you are not attending in person, audio will be provided via a call-in line that at our operator

will manage to ensure only confirmed participants can connect. Audio will not be provided through your computer, so you must be registered in order to listen in. Below is the webinar and call-in information.

Webinar: https://epa.connectsolutions.com/r81lsmqs51c/

Ex. 6

EPA must provide the conference call operator with a list of participants in advance of the meeting, so we ask that you please RSVP no later than 24 hours before the meeting. If you have not already done so, please confirm your participation by emailing both Michael Bueno (bueno.michael@epa.gov) and me (matthews.lisa@epa.gov).

We ask that you call in 15 minutes before the meeting to ensure that you are connected to the conference on time. When joining the webinar please type in your full name and organization so that we can keep track of attendance.

If you have any questions about this meeting, please contact me (matthews.lisa@epa.gov / 202-
Ex. 5 mobile) or Michael Bueno (bueno.michael@epa.gov / 202-564-5051).

Thank you,

Lisa Matthews

Senior Advisor – State Engagement

US EPA Office of Research and Development

202-564-6669 office

Ex. 6

matthews.lisa@epa.gov

Briefing for States on EPA's Draft Hydraulic Fracturing Drinking Water Assessment - Region 8 states (Colorado, North Dakota, Utah and Wyoming) and California

US EPA Region 8 office
1595 Wynkoop Street, Denver, CO 80202
9th Floor Regional Administrator's conference room
Webinar: https://epa.connectsolutions.com/r81lsmqs51c/

Ex. 6

May 12, 2015
9:30-11:30 am MDT

Purpose: *Briefing on the EPA's draft report, Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources. This assessment provides an evaluation of the potential impacts of hydraulic fracturing on drinking water resources and identifies key vulnerabilities.* ***The information presented at this meeting and discussed is embargoed until publicly released.***

Draft Agenda

9:30 am **Welcome and State Introductions**
Shaun McGrath, Regional Administrator, US EPA Region 8
Teresa Marks, Principal Advisor on Unconventional Oil and Gas, US EPA
Dr. Tom Burke, Deputy Assistant Administrator and EPA Science Advisor, US EPA Office of Research and Development

9:40 am **Opening Remarks/Study Overview**
Dr. Tom Burke

9:50 am **Presentation on EPA's Draft Assessment**
Dr. Jeff Frithsen, US EPA Office of Research and Development

10:20 am **State–EPA Discussion**
All (led by Dr. Tom Burke)
- *Questions and answers*
- *Messaging*
- *Communications*

11:20 am **Wrap-Up**
Dr. Tom Burke and Teresa Marks

11:30 am **Adjourn**

To: Burke, Thomas[Burke.Thomas@epa.gov]; Kadeli, Lek[Kadeli.Lek@epa.gov]; Robbins, Chris[Robbins.Chris@epa.gov]; Kavlock, Robert[Kavlock.Robert@epa.gov]; Blackburn, Elizabeth[Blackburn.Elizabeth@epa.gov]; Hubbard, Carolyn[Hubbard.Carolyn@epa.gov]
Cc: Smith, Kelley[Smith.Kelley@epa.gov]; Corona, Elizabeth[Corona.Elizabeth@epa.gov]; Piantanida, David[Piantanida.David@epa.gov]; Gwinn, Maureen[gwinn.maureen@epa.gov]; Routt, Christiane[Routt.Christiane@epa.gov]; ORD-Exec-Council[ORDExecCouncil@epa.gov]; Steenbock, John[Steenbock.John@epa.gov]; Walling, Joyce[Walling.Joyce@epa.gov]; Hartzell, Evelyn[hartzell.evelyn@epa.gov]; Bowling, Charlena[Bowling.Charlena@epa.gov]
From: Sonich-Mullin, Cynthia
Sent: Thur 5/7/2015 10:11:33 PM
Subject: NRMRL Weekly Report - May 4-8

This week:

Non-Responsive

Hydraulic Fracturing Retrospective Case Studies and Assessment Reports. NRMRL staff (Kelly Smith and PI's in our division in Ada, Oklahoma), continue to work diligently to finalize the retrospective case study reports and develop the associated communications materials that will accompany their release along with the Assessment Report and be presented to ND, CO, PA and TX. Regional briefings convened last week were successful.

Next Week:

Non-Responsive

Non-Responsive

Non-Responsive

Cynthia Sonich-Mullin

Director, National Risk Management Research Laboratory

Office of Research and Development

U.S. Environmental Protection Agency

26 W. Martin Luther King Jr. Dr.

Cincinnati, Ohio 45268

Phone: 513-569-7923

Mobile: Ex. 6

To: Burke, Thomas[Burke.Thomas@epa.gov]
From: Burke, Thomas
Sent: Thur 6/11/2015 12:55:58 AM
Subject: Fwd: HFDWA: Example locations for vulnerabilities in assessment
HFDWA Impact locations v2.docx
ATT00001.htm

Sent from my iPhone

Begin forwarded message:

From: "Frithsen, Jeff" <Frithsen.Jeff@epa.gov>
Date: June 3, 2015 at 4:08:28 PM EDT
To: "Burke, Thomas" <Burke.Thomas@epa.gov>
Cc: "Hanley, Mary" <Hanley.Mary@epa.gov>, "Perry, Dale" <Perry.Dale@epa.gov>, "Briskin, Jeanne" <Briskin.Jeanne@epa.gov>, "Gibbons, Dayna" <Gibbons.Dayna@epa.gov>, "Matthews, Lisa" <Matthews.Lisa@epa.gov>, "Teichman, Kevin" <Teichman.Kevin@epa.gov>, "Zambrana, Jose" <Zambrana.Jose@epa.gov>, "Burden, Susan" <Burden.Susan@epa.gov>, "Frithsen, Jeff" <Frithsen.Jeff@epa.gov>, "LeDuc, Stephen" <LeDuc.Stephen@epa.gov>, "Ridley, Caroline" <Ridley.Caroline@epa.gov>
Subject: HFDWA: Example locations for vulnerabilities in assessment

Attached is a file showing examples of locations for the vulnerabilities identified in the assessment. The examples provides the information for general questions concerning where we found impacts.

Jeff

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries

Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

To: Matthews, Lisa[Matthews.Lisa@epa.gov]
Cc: Smith, Kelley[Smith.Kelley@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Burke, Thomas
Sent: Wed 6/10/2015 2:12:24 PM
Subject: Re: How is the HF Meeting in CO going?

Great report. Thanks for representing us so well.

Tom

Sent from my iPhone

On Jun 10, 2015, at 9:53 AM, Matthews, Lisa <Matthews.Lisa@epa.gov> wrote:

The Aspen Institute shale gas forum was excellent. Nice diversity of perspectives. We didn't get many questions about the draft assessment. Non-Responsive

Non-Responsive

Forum participants were very appreciative of our efforts to engage with stakeholders and the opportunity to provide input for the EPA study. Michael Dunkel (formerly with Pioneer) acknowledged our stakeholder engagement and outreach efforts as part of his comments at the meeting.

Thank you very much for the opportunity to participate.

From: Smith, Kelley
Sent: Monday, June 08, 2015 11:13 AM
To: Frithsen, Jeff; Matthews, Lisa
Subject: How is the HF Meeting in CO going?

Hope all is well and you travel safe back to DC.

Also- HF news clips continue to appear to be as expected and mostly fair in my opinion. Not sure if you both saw the Charleston Gazette story from Dr. Burke's interview on Friday but it appears to be pretty fair too:

http://www.wvgazette.com/article/20150607/GZ01/150609432

Best,

KS

Kelley Smith

Program Advisor

Office of Research and Development

Environmental Protection Agency

202.564.2308 (Desk)

Ex. 6

Smith.Kelley@epa.gov

To: D'Amico, Louis[DAmico.Louis@epa.gov]
From: Burke, Thomas
Sent: Fri 6/5/2015 2:09:37 AM
Subject: Re: NCEA Weekly Report: 6/1-6/12
image001.png

Thanks. You are working too late!

Best,

Tom

Sent from my iPhone

On Jun 4, 2015, at 10:08 PM, D'Amico, Louis <DAmico.Louis@epa.gov> wrote:

<image001.png>

National Center for Environmental Assessment
Weekly Report: June 1 – June 12

Non-Responsive

Safe and Sustainable Water Resources (SSWR):

Product Updates

•□□□□□□□□ On June 4, EPA released its draft assessment of the potential impacts of hydraulic fracturing for oil and gas on drinking water resources, along with another 9 peer reviewed EPA Reports written as part of the study. The draft assessment is based upon extensive review of literature, results from EPA research projects, and technical input from state, industry, non-governmental organizations, the public, and other stakeholders.

Non-Responsive

Louis D'Amico, Ph.D.

Acting Communications Director

National Center for Environmental Assessment | U.S. EPA - Office of Research and Development

Mail Code 8601P | 1200 Pennsylvania Ave, NW | Washington, DC 20460

Physical/Overnight Delivery Address: U.S. EPA | Two Potomac Yard (North Building), N-7651 | 2733 S. Crystal Drive| Arlington, VA 22202

Office: 703-347-0344 | **Ex. 6** | Fax: 703-347-8689 | email: damico.louis@epa.gov

To: Tom Burke Ex. 6
From: Burke, Thomas
Sent: Mon 3/2/2015 6:41:57 PM
Subject: Worry List 03032015 0600.docx
Worry List 03032015 0600.docx
ATT00001.txt

From: Frithsen, Jeff
Location: Ex. 6 Teleconference
Importance: High
Subject: HFDWA: Comments on definitions
Categories: Hydrofracking
Start Date/Time: Tue 5/19/2015 5:00:00 PM
End Date/Time: Tue 5/19/2015 5:30:00 PM

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
Cc: Jonathan.Koplos[redacted] Ex. 4
From: Glen Boyd
Sent: Thur 2/26/2015 9:26:32 AM
Subject: RE: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 1
Review of HF AR Chpt 4-8-grb-26feb2015.docx

Jeff,

For your information, I am attaching my comments on Chapters 4 thru 8. I emailed my individual chapter comments to the appropriate Chapter lead per your email below. I reviewed the Major Findings in the ES and compared it to data and information contained in each Chapter. I will follow up with the Chapter leads directly, as needed.

Please let me know if you would like any additional information.

Thanks,

Glen

From: Frithsen, Jeff [mailto:Frithsen.Jeff@epa.gov]
Sent: Monday, February 23, 2015 6:50 PM
To: Anna Weber; Bates, William; Brent Ranalli; Burden, Susan; Burgoon, Lyle; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca; Dean, Jill; Deniz (Inci) Demirkanli; Fleming, Megan; Frithsen, Jeff; Glen Boyd; Impellitteri, Christopher; Jonathan Koplos; Ken Klewicki; Knightes, Chris; LeDuc, Stephen; Mary Ellen Tuccillo; Ridley, Caroline; Sandie Koenig; Shari Ring; Singer, Alison; Stanek, John; Todd, Jason; Weaver, Jim; Williams, Larke; Yohannes, Lia; Yost, Erin
Subject: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 1

Team:

We now have a near complete version of the preliminary external review draft of the hydraulic

fracturing drinking water assessment report. I know much hard work and thought has gone into getting us this far. Congratulations for a job well done!

We still have a way to go before we can turn over the final external review draft to the SAB. We have promised the Administrator that we will do that on May 14. Here's what we need to do this week to move us along towards that goal.

With this email, I am passing along a PDF file with the draft report frontmatter, executive summary and Chapters 1 through 4. In a separate email, I will be sending a second PDF file with Chapters 5 through 10. Everyone receiving this email is listed as an author of the assessment report, which means that we are all jointly responsible for its content. **Please block out the next two days and read through the two PDF files.** Don't just read the chapter on which you worked. We want your comments on the entire assessment.

The draft report has gone through at least two rounds of editing so I'm not very concerned about typographical errors and spelling at this point. Instead, focus on the big picture. Are the main results and conclusions of the draft assessment clear stated and fully supported by the data and information presented in the chapters? Have we done what we can to address the questions outlined in the HF Study Plan? Have we brought into the assessment the appropriate results and conclusions from ORD's HF study reports and journal publications? Have we missed something significant?

Please pass along your comments on this draft to the appropriate Chapter lead no later than start of business day (Eastern Time) Thursday, February 26. Just to remind everyone, our chapter leads are as follows:

Executive Summary – Steve LeDuc;

Chapter 1 – Caroline Ridley;

Chapter 2 – Caroline Ridley;

Chapter 3 – Lia Yohannes;

Chapter 4 – Megan Fleming;

Chapter 5 – Chris Knightes;

Chapter 6 – Shari Ring (Cadmus);

Chapter 7 – Jim Weaver;

Chapter 8 – Mary Ellen Tuccillo (Cadmus);

Chapter 9 – John Stanek;

Chapter 10 – Steve LeDuc.

Chapter leads will use Thursday to consolidate and evaluate comments and revise their chapters as appropriate. Chapter leads will be able to access their Chapters in MS Word format on a SharePoint site. Caroline will send out additional information about the SharePoint site. **Chapter leads should return their revised chapters to Jonathan Koplos (Cadmus) with a copy to Caroline as soon as possible, hopefully by noon Thursday, but no later than COB Thursday.** Chapter leads should focus on text changes and not be concerned with formatting.

Our Cadmus team will work to complete revisions and turn around the revised preliminary external review draft on **Monday, March 2**. It will be this next draft that we will use to complete ORD review and clearance.

I draw your attention to the following notes concerning this draft. First, the references are not yet finalized, so reviewers can ignore odd-looking citations (including parentheses with no spaces in between them and "ENREF" errors). Second, in the Word files, some of the internal comments are just FYI-types notes or notes that are for internal Cadmus needs only. Third, some Chapter 8 formatting (e.g., table formatting, text box placement) is still in progress.

Should you have any concerns about this draft, or you are unable to review, please contact me immediately to discuss.

Thanks again for all the hard work. We are getting closer to being able to deliver a completed external review draft that will make a difference.

Jeff

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries

Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Yohannes, Lia
Sent: Wed 2/18/2015 5:09:00 PM
Subject: RE: HFDWA Schedule
HFDWA ERD Schedule with Outreach and Comms 20150209.xlsx

Ah OK. Thanks!

Let me know if you'd like me to just send along the 2/9/15 version (attached).

Lia

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

From: Frithsen, Jeff
Sent: Wednesday, February 18, 2015 12:04 PM
To: Yohannes, Lia
Subject: Re: HFDWA Schedule

Yes. But will need to get back to my computer!

Sent from Jeff Frithsen's iPhone

Office phone: 703-347-8623

Ex. 6

On Feb 18, 2015, at 11:45 AM, Yohannes, Lia <Yohannes.Lia@epa.gov> wrote:

Hi Jeff,

Can you send me the latest version of the HFDWA schedule? Lisa would like to add details regarding outreach/stakeholder engagement before she sends it out the HF Leader group as Kevin requested.

Thanks!

Lia

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Bob Hughes
Sent: Sat 6/20/2015 2:04:30 AM
Subject: Re: Review a short Opinion Article?
Zhang et al..docx

Non-Responsive

By the way, does USEPA plan to conduct a study/review of the ecological/environmental effects of fracking in addition to its drinking water study? The Council of Aquatic Scientific Societies would like to review it.

Cheers,
Bob

Robert M. Hughes
Immediate Past-President
American Fisheries Society

On Fri, Jun 19, 2015 at 6:12 PM, Frithsen, Jeff <Frithsen.Jeff@epa.gov> wrote:

Non-Responsive

From: Bob Hughes [mailto:hughes.bob@amnisopes.com]
Sent: Sunday, June 14, 2015 1:36 PM
To: Davis, Wayne; Jackson, Susank; Frithsen, Jeff; Ringold, Paul; Kaufmann, Phil
Cc: 张波
Subject: Review a short Opinion Article?

Non-Responsive

Thank you,

Bob

Robert M. Hughes

Immediate Past-President

American Fisheries Society

To: Ridley, Caroline[Ridley.Caroline@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Jonathan Koplos
Sent: Mon 6/15/2015 9:43:12 PM
Subject: FW: Draft press release text
HF_report_2015.docx

If this looks ok, we'll forward it along to Cathy Basu.

Thanks! (Sorry for this tangent.)

From: Jonathan Koplos
Sent: Friday, June 12, 2015 4:08 PM
To: 'Frithsen, Jeff'; Caroline Ridley (ridley.caroline@epa.gov)
Subject: Draft press release text

Hi Jeff and Caroline,

We did check contract language regarding press release information. Because the information we'll provide in this press release is all public information (available from EPA's website), the contract does not require approval from EPA prior to the release.

Nonetheless, I provide it here for your review. Please let me know if there is anything that gives you pause. After your review, our contracts staff here (Joel Demasi) would like to provide a copy to Cathy Basu as a courtesy as well, telling Cathy that we've developed this, have kept you both posted on what we were doing in this regard, and also gave you a chance to review it.

The general distribution plan (if the draft meets you approval) is as follows:

Ex. 5

If this look ok to you, our contracts person will forward it to Cathy before we publish it.

Thank you!

Jonathan

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

100 5th Avenue, Suite 100

Waltham, MA 02451

Ex. 4

Ex. 6

www.cadmusgroup.com

Follow us on social media:

To: Johnson, Maureen[Johnson.Maureen@epa.gov]
Cc: Ridley, Caroline[Ridley.Caroline@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]; Walsh, Debra[Walsh.Debra@epa.gov]
From: Meacham, Connie
Sent: Mon 5/25/2015 10:43:16 PM
Subject: RE: PDF of the Chapters .... Plus Front & Back Cover
_Chapters_HF__v31.pdf
HFDWA front cover June2015.pdf
cvr-Soto_May2015_Back_kl copy.pdf

Hi again Maureen –

Here's the Review-PDF of the Main Document HFDWA (and the front and back covers).

The PDF didn't take very long to make on the virtual machine – that was nice!

Of course, I see a few format-related things that should be fixed in this version (v31), but it's really just for review, as we know Caroline will have content changes anyway.

Best,

-Connie

From: Meacham, Connie
Sent: Monday, May 25, 2015 6:18 PM
To: Johnson, Maureen
Cc: Ridley, Caroline; Frithsen, Jeff; Walsh, Debra
Subject: RE: The Word File of the chapters - is too big for the email system!

From: Meacham, Connie
Sent: Monday, May 25, 2015 6:14 PM
To: Johnson, Maureen
Cc: Ridley, Caroline; Frithsen, Jeff; Walsh, Debra
Subject: The PDF of the HFDWA Appendices is ready for you Maureen. The Main Doc (Chapters) is also on the O-Drive, but I won't have a "sample" PDF til Tuesday am.

Hi Maureen –

Here are the PDF pieces of the Appendices to the Hydraulic Fracturing Drinking Water Assessment.

(PDF of whole Appendices, Front Cover, and Back Cover). Vicki Soto made the Covers.

Within the PDF, each appendix has a 'cover page' and a separate bibliography. All citations are HERO links.

The PDF has bookmarks for navigation.

I think I added alternate text to all graphics – but you can tell if I missed any when your contractors run the 508 checker.

Please have your team spiff up the PDF (any additional 508ness needed), add the front and back covers, and break out each Appendix (as 10 separate PDF files – coordinate with Caroline Ridley on that).

Also coordinate with Caroline if there are any emergency content changes to the Appendices.

I've put all the pieces you need (& the Word File [*HF_Appendices_v25pdf.docx*] of the Appendices too) in this folder on the O-Drive:

O:\PRIV\NCEA_Group\Progr_Prod\HERO\hydraulic fracturing_HF_Main&Appendix_May2015\Ready for Maureen May 25th 2015

If you need to go back to make changes in the Word File, when you are done, send me back the Word File, so I can change the HERO Links to HERONet Links. (Although Samantha Jones knows how to do that too, but I can do it). Then, if you have done the final PDF of the Appendices, I'll send you the HERONet Word File to make the HERONet PDF on the same computer…. So the Page numbers and Line numbers

match between the HERO-Plain (Public) PDF and the HERONet (SAB Reviewers') PDF.

I have the Word File of the Main Document *[_Chapters_HF-v31.docx*] similarly pulled together into one document, etc.

The Word document is on the same O-Drive folder.

The computer is building a PDF of that now – it should be ready sometime this evening, and I'll put it in the same folder on the O-Drive in the morning. I know Caroline need to make some changes to the Executive Summary and to Chapter 10, so your contractors will need to make the PDF of that (after Caroline sends you her track changes). When you start making the PDF, send me back the Word File – I'll update the HERO Links to HERONet Links & send back to you to make the HERONet PDF too.

I'll see if I can send the Word Version of the Chapters via email – in a few minutes. It may be too large for the email system. 37.2 kb.

Let me and/or Caroline know if you have questions!

Best regards,

-Connie

Connie Meacham, M.S.

Biologist

HERO Project Lead

U.S. EPA, ORD, NCEA

NCEA-RTP IO

Office: B240L

Phone: **919-541-3908** Ex. 6

email: meacham.connie@epa.gov

To: Matthews, Lisa[Matthews.Lisa@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]
Cc: Bueno, Michael[Bueno.Michael@epa.gov]
From: Smith, Kelley
Sent: Tue 5/12/2015 1:47:19 AM
Subject: FW: Invitation: Briefing for Tribes on EPA's Draft Hydraulic Fracturing Drinking Water Assessment
HF state briefing draft agenda.docx

Good Evening Lisa and Jeff,

Per my flag early this morning Tom will likely not be able to call in since he will be in transit to the airport. For the Tribal Meeting can we announce a schedule change first thing in the morning and replace Dr. Burke with Teresa and Jeff? If Tom stays in the office to video in or call in he may not be able to make his flight.

Best,

KS

Kelley Smith

Program Advisor

Office of Research and Development

Environmental Protection Agency

202.564.2308 (Desk)

202.308.6587 (Cell)

Smith.Kelley@epa.gov

Begin forwarded message:

From: "Bueno, Michael" <Bueno.Michael@epa.gov>
Date: May 11, 2015 at 2:25:55 PM EDT
To: "dean.goggles@northernarapaho.org" <dean.goggles@northernarapaho.org>,

"darwin.stclair@e-shoshone.com" <darwin.stclair@e-shoshone.com>, "tojohns@southernute-nsn.gov" <tojohns@southernute-nsn.gov>, "atwobears@standingrock.org" <atwobears@standingrock.org>, "edmundbaker@mhanation.com" <edmundbaker@mhanation.com>, "ferrons@utetribe.com" <ferrons@utetribe.com>, "sclow@utemountain.org" <sclow@utemountain.org>, "2horses@nemont.net" <2horses@nemont.net>, "ronnieben@navajo-nsn.gov" <ronnieben@navajo-nsn.gov>, "sbabits@wyoming.com" <sbabits@wyoming.com>, "rortiz@northernarapaho.com" <rortiz@northernarapaho.com>, "charten@southernute-nsn.gov" <charten@southernute-nsn.gov>, "Byrne, Andrew" <Byrne.Andrew@epa.gov>, "sbaker@mhanation.com" <sbaker@mhanation.com>, "elisa@navajopublicwater.org" <elisa@navajopublicwater.org>, "nnepauic@frontiernet.net" <nnepauic@frontiernet.net>
Cc: "McGrath, Shaun" <McGrath.Shaun@epa.gov>, "Card, Joan" <Card.Joan@epa.gov>, "Mitre, Alfreda" <Mitre.Alfreda@epa.gov>, "Strauss, Alexis" <Strauss.Alexis@epa.gov>, "Albright, David" <Albright.David@epa.gov>, "Ebbert, Laura" <Ebbert.Laura@epa.gov>, "Marks, Teresa" <Marks.Teresa@epa.gov>, "Burke, Thomas" <Burke.Thomas@epa.gov>, "Bueno, Michael" <Bueno.Michael@epa.gov>
Subject: Invitation: Briefing for Tribes on EPA's Draft Hydraulic Fracturing Drinking Water Assessment

Good Afternoon,

Thank you to those who have confirmed your participation to our *Briefing for Tribes on EPA's Draft Hydraulic Fracturing Drinking Water Assessment* on May 12, 2015. Attached is a draft meeting agenda.

We are providing a list of in-person attendees to the EPA's guard station. Please note you will be required to check-in with security and present government-issued photo identification. Please allow an additional 15 minutes for security screening.

If you are not attending in person, audio will be provided via a call-in line that at our operator will manage to ensure only confirmed participants can connect. Audio will not be provided through your computer, so you must be registered in order to listen in. Below is the webinar and call-in information.

Webinar: https://epa.connectsolutions.com/r2xa3xhpcow/

Call-in #: Ex. 6

Conference ID: Ex. 6

EPA must provide the conference call operator with a list of participants in advance of the meeting, so we ask that you please RSVP no later than 24 hours before the meeting. If you have not already done so, please confirm your participation by emailing both Michael Bueno (bueno.michael@epa.gov) and me (matthews.lisa@epa.gov).

We ask that you call in 15 minutes before the meeting to ensure that you are connected to the conference on time. When joining the webinar please type in your full name and organization so that we can keep track of attendance.

If you have any questions about this meeting, please contact me (matthews.lisa@epa.gov / 202-577-4035 mobile) or Michael Bueno (bueno.michael@epa.gov / 202-564-5051).

Thank you,

Lisa Matthews

Senior Advisor – State Engagement

US EPA Office of Research and Development

202-564-6669 office

Ex. 6 mobile

matthews.lisa@epa.gov

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Smith, Kelley
Sent: Mon 5/11/2015 1:50:33 PM
Subject: RE: HF: Presentation for States and REgions

Printing now

Best,

KS

Kelley Smith

Program Advisor

Office of Research and Development

Environmental Protection Agency

202.564.2308 (Desk)

Ex. 6

Smith.Kelley@epa.gov

From: Frithsen, Jeff
Sent: Monday, May 11, 2015 9:30 AM
To: Smith, Kelley
Subject: Fwd: HF: Presentation for States and REgions

Sent from Jeff Frithsen's iPhone

Office phone: 703-347-8623

Ex. 6

Begin forwarded message:

From: "Frithsen, Jeff" <Frithsen.Jeff@epa.gov>
To: "Burke, Thomas" <Burke.Thomas@epa.gov>
Cc: "Briskin, Jeanne" <Briskin.Jeanne@epa.gov>, "Gibbons, Dayna" <Gibbons.Dayna@epa.gov>, "Matthews, Lisa" <Matthews.Lisa@epa.gov>, "Teichman, Kevin" <Teichman.Kevin@epa.gov>, "Zambrana, Jose" <Zambrana.Jose@epa.gov>, "Burden, Susan" <Burden.Susan@epa.gov>, "Frithsen, Jeff" <Frithsen.Jeff@epa.gov>, "LeDuc, Stephen" <LeDuc.Stephen@epa.gov>, "Ridley, Caroline" <Ridley.Caroline@epa.gov>
Subject: HF: Presentation for States and REgions

Attached is a draft of the presentation for states and regions. My understanding is that we will not be distributing, broadcasting, or displaying the presentation and that I should plan using the information here as talking points.

Comments welcome.

Jeff

Jeffrey B. Frithsen, Ph.D.
National Center for Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, SW (8623-P)
Washington, DC 20460
703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries
Two Potomac Yard (North Building), Room N-7741
2733 South Crystal Drive, Arlington, VA 22202

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
Cc: Zambrana, Jose[Zambrana.Jose@epa.gov]; Bueno, Michael[Bueno.Michael@epa.gov]
From: Matthews, Lisa
Sent: Wed 3/25/2015 1:08:35 PM
Subject: front matter for EPA HF reports
HF Reports_ Front Matter Template.docx

Hi Jeff,

Please review the text only. Ex. 5
Ex. 5

I noticed that for the FF report, OSP renamed the "Authors" page to "Authors and Contributors" (and added contractors). Is this what we want to follow?

We need to finalize and share with the LCO's.

Thank you,

Lisa

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Teichman, Kevin
Sent: Mon 3/9/2015 12:33:27 PM
Subject: See you tomorrow
KYT HFDWA Comments 03092015.docx
Worry List 03102015 0600.docx

Jeff:

Two attachments:

1. My overarching comments on the Assessment Report. It was hard to figure out what to include on this list. The more important items are highlighted, i.e., what I might say in my five minutes of fame tomorrow. Which comments to include was very subjective, so please don't discount the other comments indicated on my mark-ups of the chapters (not that you would). Some of these other comments are editorial at best (picky at worst), but some are important and almost made it to my overarching list. Of course, all of my comments are provided for your and the Assessment Team's consideration for potential revisions as deemed appropriate.

Non-Responsive

Thanks.

Kevin

Kevin Teichman

Senior Science Advisor

Office of Research and Development (8101R)

U.S. Environmental Protection Agency

1200 Pennsylvania Ave., NW

Washington, DC 20460

Phone: (301) 975-6421

Fax: (301) 975-4409

To: Bridget Scanlon[bridget.scanlon@beg.utexas.edu]
From: Frithsen, Jeff
Sent: Fri 7/10/2015 12:57:47 PM
Subject: RE: Excellent report

Bridget:

Thanks for your kind words. Completing the HF Study and the draft assessment was a monumental effort involving many agency staff. I am proud of what we have accomplished and how we have advanced understanding of the topic. Stay in touch and let me know should you have any comments or suggestions concerning the assessment. I'm looking forward to the peer review by the SAB.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Bridget Scanlon [mailto:bridget.scanlon@beg.utexas.edu]
Sent: Friday, June 12, 2015 5:30 PM
To: Frithsen, Jeff
Subject: Excellent report

Hi Jeff

It was great to see you in Aspen. I very much appreciate all the time and effort you put into the report related to hydraulic fracturing. I am very impressed. Thank you and your team for working so hard on this.

Warm regards

Bridget

Bridget R. Scanlon
Senior Research Scientist
Bureau of Economic Geology
Jackson School of Geosciences
Univ. of Texas at Austin
J.J. Pickle Research Campus, Bldg. 130
10100 Burnet Rd.
Austin, TX 78758-4445

Center for Sustainable Water Resources:
http://www.beg.utexas.edu/cswr

Ph. 512 471 8241; Fax 512 471 0140

To: Bohn, Brent[bohn.brent@epa.gov]
From: Frithsen, Jeff
Sent: Wed 7/8/2015 11:28:29 PM
Subject: FW: fracking FOIAs from Union of Concerned Scientists
FOIA Request 008265- UCS.pdf
FOIA Request 008372 - UCS.pdf
FOIA Request 008592 - UCS.pdf

Sharing as FYI….

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Mackay, Cheryl
Sent: Wednesday, July 08, 2015 5:01 PM
To: Flattery, Priscilla; Frithsen, Jeff; Berkley, Bruce; Malloy, Marilyn; Evanko, Peter; Lintner, Colby; Briskin, Jeanne
Subject: RE: fracking FOIAs from Union of Concerned Scientists

Hi all,

Ex. 5

I've also attached the incoming FOIA requests to this email, for your reference.

Please let me know if you have questions.

Thanks,

Cheryl

Cheryl A. Mackay

Office of General Counsel

U.S. Environmental Protection Agency

(202) 564-2023

From: Mackay, Cheryl
Sent: Tuesday, July 07, 2015 11:55 AM
To: Flattery, Priscilla; Frithsen, Jeff; Berkley, Bruce; Malloy, Marilyn; Evanko, Peter
Subject: fracking FOIAs from Union of Concerned Scientists

Hi all,

I hope everyone had a nice long weekend. I am sending this to folks in ORD and OPPT who are in some way involved in the 3 fracking-related FOIA requests we recently received from UCS:

EPA-HQ-2015-008592 (currently assigned to ORD)

EPA-HQ-2015-008265 (currently assigned to ORD)

EPA-HQ-2015-008372 (currently assigned to OPPT)

All of these FOIAs are identical, except that they ask us to search the files of different people. I have been assigned these FOIAs for the FEAT/OGC. These FOIAs will all be managed together, and we'll have to have a discussion about whether they are assigned correctly (the

current assignment was done by OEI). I plan to send a clarification letter to UCS soon, which will officially stop the clock on this FOIA. In the meantime, please hold off on doing any work until we can coordinate. I'll send out a meeting request later today.

Thanks!

Cheryl

Cheryl A. Mackay

Office of General Counsel

U.S. Environmental Protection Agency

(202) 564-2023

To: D'Amico, Louis[DAmico.Louis@epa.gov]; Cogliano, Vincent[cogliano.vincent@epa.gov]; Flowers, Lynn[Flowers.Lynn@epa.gov]; Vandenberg, John[Vandenberg.John@epa.gov]; Ross, Mary[Ross.Mary@epa.gov]
From: Frithsen, Jeff
Sent: Tue 6/30/2015 2:06:07 PM
Subject: RE: NCEA Communications Opportunities - June-Dec 2015

Lou:

Not sure is appropriate for your list. The SAB review of the draft hydraulic fracturing drinking water assessment is scheduled for **Ex. 5** That will likely generate a bit of public interest and inquiry.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: D'Amico, Louis
Sent: Monday, June 29, 2015 2:43 PM
To: Cogliano, Vincent; Flowers, Lynn; Vandenberg, John; Ross, Mary; Frithsen, Jeff
Subject: NCEA Communications Opportunities - June-Dec 2015

Hi all,

Attached are a list of the activities that I'm going to point out to the IOAA may trigger more significant external interest. **Non-Responsive**

Non-Responsive

Non-Responsive

Is there anything missing from this list? If so, please let me know as soon as possible.

-Lou

Louis D'Amico, Ph.D.

Acting Communications Director

National Center for Environmental Assessment | U.S. EPA - Office of Research and Development

Mail Code 8601P | 1200 Pennsylvania Ave, NW | Washington, DC 20460

Physical/Overnight Delivery Address: U.S. EPA | Two Potomac Yard (North Building), N-7651 | 2733 S. Crystal Drive| Arlington, VA 22202

Office: 703-347-0344 | Mobile: Ex. 6 Fax: 703-347-8689 | email: damico.louis@epa.gov

To: Claros, Carlos D.[claroscd@cdmsmith.com]
From: Frithsen, Jeff
Sent: Wed 6/24/2015 12:09:44 PM
Subject: RE: Draft Report on Hydraulic fracturing Impacts on Drinking Water

Carlos:

Thank you for your interest in the EPA's work on hydraulic fracturing.

All comments on the draft assessment, including comments concerning technical discrepancies and data gaps, should be submitted to the public docket for the assessment. Instructions on submitting comments may be found in the following web link: https://www.federalregister.gov/articles/2015/06/05/2015-13674/notification-of-teleconferences-and-a-public-meeting-of-the-science-advisory-board-hydraulic.

Thanks again.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Claros, Carlos D. [mailto:claroscd@cdmsmith.com]
Sent: Tuesday, June 23, 2015 6:20 PM
To: Frithsen, Jeff
Subject: Draft Report on Hydraulic fracturing Impacts on Drinking Water

Hi Jeff,

Regarding comments on technical discrepancies, data gaps etc, do we also report them in the comment section of the website?

Please advise.

Thanks

Carlos

Carlos D. Claros, P.E.

Senior Process Engineer

CDM Smith Inc.

3050 Post Oak Blvd

Houston, TX 77056

Phone: (713) 423-7323

Cell: (832) 205-4613

To: Gibbons, Dayna[Gibbons.Dayna@epa.gov]; Matthews, Lisa[Matthews.Lisa@epa.gov]
From: Frithsen, Jeff
Sent: Tue 6/23/2015 4:17:32 PM
Subject: RE: PROTRAC Comment added for: Hydraulic Fracturing Study Draft Assessment Training Video

Ex. 5

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Gibbons, Dayna
Sent: Friday, June 19, 2015 12:58 PM
To: Matthews, Lisa; Frithsen, Jeff
Subject: RE: PROTRAC Comment added for: Hydraulic Fracturing Study Draft Assessment Training Video

Do you think it would be helpful to have a video of jeff giving the presentation on the hf draft assessment for the groups that we are not going to be able to visit with? If not I will cancel it.

From: Hubbard, Carolyn
Sent: Friday, June 19, 2015 9:40 AM
To: Gibbons, Dayna
Subject: FW: PROTRAC Comment added for: Hydraulic Fracturing Study Draft Assessment Training Video

Not doing this right?

Carolyn Hubbard

Science Communications

EPA Office of Research and Development

202-564-2189

hubbard.carolyn@epa.gov

From: DCAOESO1/DC/USEPA/US [mailto:DCAOESO1/DC/USEPA/US@epamail.epa.gov]
Sent: Friday, June 19, 2015 12:12 AM
To: Slotkin, Ron; Ryan, Jini; Flores, Ray; Hubbard, Carolyn
Cc: Gibbons, Dayna; Perry, Dale; Slotkin, Ron
Subject: PROTRAC Comment added for: Hydraulic Fracturing Study Draft Assessment Training Video

Hello,
The project -- Hydraulic Fracturing Study Draft Assessment Training Video -- has had a comment added.
Please contact me if you have questions.

Regards,
Ron

LINK --->

Comment :

From OM: Can we close this entry or is there something more to do?

To: Vandenberg, John[Vandenberg.John@epa.gov]
From: Frithsen, Jeff
Sent: Thur 6/4/2015 10:19:31 PM
Subject: RE: ORD News Release: EPA Releases Draft Assessment on the Potential Impacts to Drinking Water Resources from Hydraulic Fracturing Activities

Thanks John. Much appreciated. The launch of nine final reports and one assessment of almost 1000 pages is indeed a big event! This is good stuff.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Vandenberg, John
Sent: Thursday, June 04, 2015 4:46 PM
To: Frithsen, Jeff
Subject: Fwd: ORD News Release: EPA Releases Draft Assessment on the Potential Impacts to Drinking Water Resources from Hydraulic Fracturing Activities

Congratulations!

Hope you can enjoy the moment - it is a Big one!

John

Sent from my iPhone

Begin forwarded message:

> **From:** "Maguire, Megan" <Maguire.Megan@epa.gov>
> **Date:** June 4, 2015 at 2:59:57 PM EDT
> **To:** "Anley-Mills, Melissa" <Anley-Mills.Melissa@epa.gov>, "Araujo, Rochelle" <Araujo.Rochelle@epa.gov>, "Bahadori, Tina" <Bahadori.Tina@epa.gov>, "Battaglia,

Amy" <Battaglia.Amy@epa.gov>, "Benforado, Jay" <Benforado.Jay@epa.gov>, "Benson, William" <Benson.William@epa.gov>, "Blackburn, Elizabeth" <Blackburn.Elizabeth@epa.gov>, "Blancato, Jerry" <Blancato.Jerry@epa.gov>, "Bouchard, Dermont" <Bouchard.Dermont@epa.gov>, "Costa, Dan" <Costa.Dan@epa.gov>, "Crofton, Kevin" <Crofton.Kevin@epa.gov>, "Daniels, Alva" <daniels.alva@epa.gov>, "Darney, Sally" <Darney.Sally@epa.gov>, "Dewey, Amy" <Dewey.Amy@epa.gov>, "Ernst, Hiba" <Ernst.Hiba@epa.gov>, "Fegley, Robert" <Fegley.Robert@epa.gov>, "Foley, Gary" <Foley.Gary@epa.gov>, "Gamble, Janet" <Gamble.Janet@epa.gov>, "Garcia, Val" <Garcia.Val@epa.gov>, "Gatchett, Annette" <Gatchett.Annette@epa.gov>, "Geller, Andrew" <Geller.Andrew@epa.gov>, "Gibbons, Dayna" <Gibbons.Dayna@epa.gov>, "Greene, Mary" <greene.mary@epa.gov>, "Gutierrez, Sally" <Gutierrez.Sally@epa.gov>, "Hauchman, Fred" <hauchman.fred@epa.gov>, "Hecht, Alan" <Hecht.Alan@epa.gov>, "Heckman, Deborah" <Heckman.Deborah@epa.gov>, "Hernandez, Alicia" <hernandez.alicia@epa.gov>, "Hetes, Bob" <Hetes.Bob@epa.gov>, "Johnson, Jim" <Johnson.Jim@epa.gov>, "Kadeli, Lek" <Kadeli.Lek@epa.gov>, "Kapuscinski, Jacques" <Kapuscinski.Jacques@epa.gov>, "Kavlock, Robert" <Kavlock.Robert@epa.gov>, "Klieforth, Barbara" <Klieforth.Barbara@epa.gov>, "Knudsen, Thomas" <Knudsen.Thomas@epa.gov>, "Kryak, DavidD" <Kryak.Davidd@epa.gov>, "Linkins, Samantha" <Linkins.Samantha@epa.gov>, "Margolies, Jennifer" <Margolies.Jennifer@epa.gov>, "Mattas-Curry, Lahne" <Mattas-Curry.Lahne@epa.gov>, "Matthews, Lisa" <Matthews.Lisa@epa.gov>, "Mayes, Desmond" <Mayes.Desmond@epa.gov>, "McGuinness, Moira" <McGuinness.Moira@epa.gov>, "McKinney, Doug" <Mckinney.Douglas@epa.gov>, "McQueen, Jacqueline" <McQueen.Jacqueline@epa.gov>, "Mintz, Bruce" <Mintz.Bruce@epa.gov>, "Olden, Kenneth" <Olden.Kenneth@epa.gov>, ORD Science Communication <ORD_Science_Communication@epa.gov>, "Orme-Zavaleta, Jennifer" <Orme-Zavaleta.Jennifer@epa.gov>, "Piantanida, David" <Piantanida.David@epa.gov>, "Preston, Julian" <Preston.Julian@epa.gov>, "Preuss, Peter" <Preuss.Peter@epa.gov>, "Radzikowski, Mary Ellen" <Radzikowski.Maryellen@epa.gov>, "Ramsey, Jayne" <Ramsey.Jayne@epa.gov>, Regional Science Liaisons to ORD <Regional_Science_Liaisons_to_ORD@epa.gov>, "Routt, Christiane" <Routt.Christiane@epa.gov>, "Russo, Bill" <Russo.Bill@epa.gov>, "Sabatini, Alice" <Sabatini.Alice@epa.gov>, "Sayles, Gregory" <Sayles.Gregory@epa.gov>, "Sayre, Philip" <Sayre.Phil@epa.gov>, "Shaw, Denice" <Shaw.Denice@epa.gov>, "Sikdar, Subhas" <sikdar.subhas@epa.gov>, "Sjogren, Mya" <Sjogren.Mya@epa.gov>, "Slimak, Michael" <Slimak.Michael@epa.gov>, "Smith, Emily J." <Smith.Emily@epa.gov>, "Sonich-Mullin, Cynthia" <Sonich-Mullin.Cynthia@epa.gov>, "Summers, Kevin" <Summers.Kevin@epa.gov>, "Teichman, Kevin" <Teichman.Kevin@epa.gov>, "Tychsen, Lisa" <Tychsen.Lisa@epa.gov>, "Vandenberg, John" <Vandenberg.John@epa.gov>, "vanDrunick, Suzanne" <vanDrunick.Suzanne@epa.gov>, "Walsh, Debra" <Walsh.Debra@epa.gov>, "Washburn, Edward" <Washburn.Edward@epa.gov>, "Watkins, Tim" <Watkins.Tim@epa.gov>, "Widener, Kelly" <Widener.Kelly@epa.gov>, "Wigginton, Mary" <Wigginton.Mary@epa.gov>, "Winchester, Erik" <Winchester.Erik@epa.gov>, "Younes, Lina" <Younes.Lina@epa.gov>, "Benson, William" <Benson.William@epa.gov>, ORD-NPD <ORDNPD@epa.gov>, "Robbins, Chris" <Robbins.Chris@epa.gov>, "Burke, Thomas" <Burke.Thomas@epa.gov>, "Smith,

Kelley" <Smith.Kelley@epa.gov>, "Gwinn, Maureen" <gwinn.maureen@epa.gov>, "Corona, Elizabeth" <Corona.Elizabeth@epa.gov>, "Thomas, Russell" <Thomas.Russell@epa.gov>

Subject: ORD News Release: EPA Releases Draft Assessment on the Potential Impacts to Drinking Water Resources from Hydraulic Fracturing Activities

Good afternoon everyone, the following press release was issued today. Please let me know if you have any questions.

Thanks!

Megan

Megan Maguire

US EPA, Office of Research and Development

RRB 41261

O: (202)564-6636

Ex. 6

Release Date: 06/04/2015
Contact Information: Cathy Milbourn, milbourn.cathy@epa.gov, (202) 564-7849, (202) 564-4355

Assessment shows hydraulic fracturing activities have not led to widespread, systemic impacts to drinking water resources and identifies important vulnerabilities to drinking water resources.

WASHINGTON—The Environmental Protection Agency (EPA) is releasing a draft assessment today on the potential impacts of hydraulic fracturing activities on drinking water resources in the United States. The assessment, done at the request of Congress, shows that while hydraulic fracturing activities in the U.S. are carried out in a way that have not led to widespread, systemic impacts on drinking water resources, there are potential vulnerabilities in the water lifecycle that could impact drinking water. The assessment follows the water used for hydraulic fracturing from water acquisition, chemical mixing at the well pad site, well injection of fracking fluids, the collection of hydraulic fracturing wastewater (including flowback and produced water), and wastewater treatment and disposal [http://www2.epa.gov/hfstudy/hydraulic-fracturing-water-cycle].

"EPA's draft assessment will give state regulators, tribes and local communities and industry around the country a critical resource to identify how best to protect public health and their drinking water resources," said Dr. Thomas A. Burke, EPA's Science Advisor and Deputy Assistant Administrator of EPA's Office of Research and Development. "It is the most complete compilation of scientific data to date, including over 950 sources of information, published papers, numerous technical reports, information from stakeholders and peer-reviewed

EPA scientific reports."

EPA's review of data sources available to the agency found specific instances where well integrity and waste water management related to hydraulic fracturing activities impacted drinking water resources, but they were small compared to the large number of hydraulically fractured wells across the country. The report provides valuable information about potential vulnerabilities, some of which are not unique to hydraulic fracturing, to drinking water resources, but was not designed to be a list of documented impacts.

These vulnerabilities to drinking water resources include:

water withdrawals in areas with low water availability;

hydraulic fracturing conducted directly into formations containing drinking water resources;

inadequately cased or cemented wells resulting in below ground migration of gases and liquids;

inadequately treated wastewater discharged into drinking water resources;

and spills of hydraulic fluids and hydraulic fracturing wastewater, including flowback and produced water.

Also released today were nine peer-reviewed EPA scientific reports (www.epa.gov/hfstudy). These reports were a part of EPA's overall hydraulic fracturing drinking water study and contributed to the findings outlined in the draft assessment. Over 20 peer-reviewed articles or reports were published as part of this study [http://www2.epa.gov/hfstudy/published-scientific-papers].

States play a primary role in regulating most natural gas and oil development. EPA's authority is limited by statutory or regulatory exemptions under the Clean Water Act, Safe Drinking Water Act, the Comprehensive Environmental Response, Compensation and Liability Act, and the Resource Conservation and Recovery Act. Where EPA's exemptions exist, states may have authority to regulate unconventional oil and gas extraction activities under their own state laws.

EPA's draft assessment benefited from extensive stakeholder engagement conducted across the country with states, tribes, industry, non-governmental organizations, the scientific community and the public to ensure that the draft assessment reflects current practices in hydraulic fracturing and utilizes all data and information available to the agency.

The study will be finalized after review by the Science Advisory Board and public review and comment. The Federal Register Notice with information on the SAB review and how to comment on the draft assessment will be published on Friday June 5, 2015.

For a copy of the study, visit www.epa.gov/hfstudy.

To submit comments on the report, see
http://yosemite.epa.gov/sab/sabproduct.nsf/fedrgstr_activites/HF%20Drinking%20Water%20Assessment?OpenDocument

http://yosemite.epa.gov/opa/admpress.nsf/bd4379a92ceceeac8525735900400c27/b542d827055a839585257e5

To: D'Amico, Louis[DAmico.Louis@epa.gov]
From: Frithsen, Jeff
Sent: Fri 5/15/2015 2:33:07 AM
Subject: RE: NCEA Weekly Report: 5/11-5/22

The team is holding together. WE are now done with 8 of the 9 HF Study reports. **Ex. 5**

Ex. 5

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: D'Amico, Louis
Sent: Thursday, May 14, 2015 10:31 PM
To: Frithsen, Jeff
Subject: Re: NCEA Weekly Report: 5/11-5/22

fuuunnnyyyy. hope you're hanging in there!

I'll be in the office tomorrow if you need anything.

-Lou

From: Frithsen, Jeff
Sent: Thursday, May 14, 2015 10:28 PM
To: D'Amico, Louis
Subject: RE: NCEA Weekly Report: 5/11-5/22

Glad to see someone else working late!

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: D'Amico, Louis
Sent: Thursday, May 14, 2015 10:28 PM
To: Burke, Thomas; Kadeli, Lek; Kavlock, Robert; Robbins, Chris
Cc: Blackburn, Elizabeth; Hubbard, Carolyn; Smith, Kelley; Corona, Elizabeth; Gwinn, Maureen; Piantanida, David
Subject: NCEA Weekly Report: 5/11-5/22

National Center for Environmental Assessment
Weekly Report: May 11 – May 22

Non-Responsive

Non-Responsive

To: Gray, David[gray.david@epa.gov]
From: Frithsen, Jeff
Sent: Wed 5/13/2015 2:18:07 PM
Subject: HF: Request from Rob Lawrence
HFDWA Briefing_Regions-States 20150511v3.pptx

Please print the attached. Thanks.

Jeff

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries

Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

To: Matthews, Lisa[Matthews.Lisa@epa.gov]
Cc: Gibbons, Dayna[Gibbons.Dayna@epa.gov]; Smith, Kelley[Smith.Kelley@epa.gov]
From: Frithsen, Jeff
Sent: Mon 5/4/2015 11:17:13 PM
Subject: HF: Outreach with states

Lisa:

The briefing with EOP folks went very well today. One issue that will require follow-up is that we were asked to provide briefing/talking points to the EOP before we meet with state folks.

Ex. 5

Concerning the meeting with the states, we have agreement on the videoconferencing plan with the states. However, there is still unease about teleconferencing. Ex. 5

Ex. 5

Jeff

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries

Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

To: Walsh, Debra[Walsh.Debra@epa.gov]
From: Frithsen, Jeff
Sent: Mon 5/4/2015 2:15:07 PM
Subject: RE: Hey

Yes, by COB today.

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Walsh, Debra
Sent: Monday, May 04, 2015 10:15 AM
To: Frithsen, Jeff
Subject: RE: Hey

I have been thinking about you – will John Stanek be getting comments for the chapter – I understand they are due back on Wednesday – he is a little nervous.

From: Frithsen, Jeff
Sent: Monday, May 04, 2015 10:13 AM
To: Walsh, Debra
Subject: RE: Hey

Non-Responsive

Today at Potomac Yards until about 1:00 then off to brief EOP on HF.

This is getting a bit nuts!

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Walsh, Debra
Sent: Monday, May 04, 2015 10:02 AM
To: Frithsen, Jeff
Subject: Hey

Non-Responsive

Non-Responsive

To: Smith, Kelley[Smith.Kelley@epa.gov]
From: Frithsen, Jeff
Sent: Mon 3/30/2015 6:15:03 PM
Subject: Fwd: new Fig 9-4 // revised Chapter 9
ATT00001.htm
ATT00002.htm
ATT00003.htm
ATT00004.htm
HFDWA - Chapter 9.pdf
ATT00005.htm

Use this version of chapter 9 for tom's review Thanks. Sorry for any confusion. Lots moving quickly!

Sent from Jeff Frithsen's iPhone
Office phone: 703-347-8623
Cell phone: Ex. 6

Begin forwarded message:

From: "Ridley, Caroline" <Ridley.Caroline@epa.gov>
To: "Frithsen, Jeff" <Frithsen.Jeff@epa.gov>
Subject: FW: new Fig 9-4 // revised Chapter 9

Jeff,

Here is a nice clean PDF of what Tom received on Friday.

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6
~~~~~~

From: Jonathan Koplos [mailto:J Ex. 4
Sent: Monday, March 30, 2015 12:57 PM
To: Yost, Erin; Stanek, John
Cc: Ridley, Caroline; Anna Weber
Subject: RE: new Fig 9-4 // revised Chapter 9

Thank you for the replies regarding Figure 9-4, Erin and (earlier) John.

Please find attached the PDF of your revised chapter that you sent us last Friday. (The PDF does include the new Fig 9-4.)

One (minor) note: we did update the references, but the citation ordering is specified by the EndNote style (not manually set by us) so although we updated there are some places where the ordering within a year (eg, 2015a, b, or c) might be slightly off.

Please let us know if you have any questions or would like us to make any changes. (If not, this PDF of Chapter 9 is otherwise ready for forwarding for Tom's review.)

Jonathan

From: Yost, Erin [mailto:Yost.Erin@epa.gov]
Sent: Monday, March 30, 2015 12:41 PM
To: Jonathan Koplos; John Stanek
Cc: Ridley, Caroline
Subject: RE: new Fig 9-4

This looks fine to me! Thanks, Jonathan.

-Erin

From: Jonathan Koplos [mailto:J Ex. 4
Sent: Monday, March 30, 2015 10:55 AM
To: John Stanek; Yost, Erin
Cc: Ridley, Caroline
Subject: new Fig 9-4

Good morning John and Erin,

How does this look? If ok, we'll get it into the revised chapter.

Jonathan

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Friday, March 27, 2015 12:08 PM
To: Jonathan Koplos
Cc: LeDuc, Stephen; Reinhart, Donna; Parrotta, Nancy; Stanek, John
Subject: FW: HFDWA NEW Chapter 9 - post ORD management review - draft for Cadmus (plus new Figure) and Tom Burke
Importance: High

Jonathan,

This is a TD to produce a clean, formatted Word version of chapter 9 for review by the Science Advisor. Please focus on creation and inclusion of the new figure, figure ordering, and general formatting issues. Ex. 5

Ex. 5

Ex. 5 Let me know if this isn't clear.

Also, I don't think we have time to update numbers in the figures between now and Tuesday, but maybe put a note in each caption *Numbers to be updated. For the section on Actor, please put a note in the header *Placeholder text. Data under development. Also,

create a placeholder figure and caption where John indicates that says *Figure under development.

Please do this work under WA 7-83, Task 4 and deliver no later than COB Monday March 30.

If you have any questions today, John is available until 1pm. I am around until 5pm.

Thanks,

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6

From: Stanek, John
Sent: Friday, March 27, 2015 11:41 AM
To: Ridley, Caroline; Frithsen, Jeff
Cc: Yost, Erin; Burgoon, Lyle; Vandenberg, John; Walsh, Debra
Subject: HFDWA NEW Chapter 9 - post ORD management review - draft for Cadmus (plus new Figure) and Tom Burke
Importance: High

Hi All,

Okay here it is. 2 copies (one contains some bubble comments on things we are still waiting to respond to 1 or 2 of our remaining "big" issues –if you are curious - and the other is the cleaner copy with some notes for Cadmus for the one going to Tom on the 31st) plus a new figure for Cadmus to incorporate (we will have one more hopefully soon).
~~~~~~

As far as addressing the comments from the ORD review – we have addressed/incorporated all of the major ones identified for us completely or have started (see below) plus some of the more minor relevant ones. Some were “absorbed” in the fairly significant rewrite of the chapter.

Specifically:

Ex. 5

Ex. 5

Those are the big ones. Hopefully we can get some clarity next week on some of the outstanding pieces.

Big thanks to Erin for working on anything and everything in keeping our 16 versions of track changes going in the right direction.

Best regards,

John

To: D'Amico, Louis[DAmico.Louis@epa.gov]
From: Frithsen, Jeff
Sent: Fri 2/27/2015 8:02:08 PM
Subject: RE: congrats on the SAB transmittal for the ROE

Sigh….. yes, my to do list grows!

But the good news is that we will deliver a preliminary external review draft of the hydraulic fracturing drinking water assessment early next week!!

Have a great weekend.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: D'Amico, Louis
Sent: Friday, February 27, 2015 2:50 PM
To: Frithsen, Jeff
Subject: congrats on the SAB transmittal for the ROE

You realize of course this means the correspondence you're on the hook for goes up to 3, right?

Congrats…onward to April 22nd!

Louis D'Amico, Ph.D.

Acting Communications Director

National Center for Environmental Assessment | U.S. EPA - Office of Research and Development

Mail Code 8601P | 1200 Pennsylvania Ave, NW | Washington, DC 20460

Physical/Overnight Delivery Address: U.S. EPA | Two Potomac Yard (North Building), N-7651 | 2733 S. Crystal Drive| Arlington, VA 22202

Office: 703-347-0344 | Mobile: Ex. 6 | Fax: 703-347-8689 | email: damico.louis@epa.gov

To: Teichman, Kevin[Teichman.Kevin@epa.gov]
From: Frithsen, Jeff
Sent: Fri 2/27/2015 7:24:43 PM
Subject: RE: ACToR data index for HF chemicals

So I can tell Maureen that her first project with be HF!!!!! Great!

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Teichman, Kevin
Sent: Friday, February 27, 2015 2:13 PM
To: Frithsen, Jeff
Subject: Fw: ACToR data index for HF chemicals

Fyi.

Kevin Teichman

Senior Science Advisor

Office of Research and Development (8101R)

U.S. Environmental Protection Agency

1200 Pennsylvania Ave., NW

Washington, DC 20460

Phone: (301) 975-6421

Fax: (301) 975-4409

From: Kavlock, Robert
Sent: Friday, February 27, 2015 1:52 PM
To: Teichman, Kevin
Subject: Re: ACToR data index for HF chemicals

Non-Responsive I can't open the file on my iPad. I think it is too large. You can always hide columns and only display what you want. I will be rtp Wednesday and will meet with Richard. We can connect you and Jeff by phone. Not sure what time will work.

Ex. 5

On Feb 27, 2015, at 1:36 PM, Teichman, Kevin <Teichman.Kevin@epa.gov> wrote:

AGREED!

Ex. 5

Am I making any sense?

Non-Responsive

Kevin Teichman

Senior Science Advisor

Office of Research and Development (8101R)

U.S. Environmental Protection Agency

1200 Pennsylvania Ave., NW

Washington, DC 20460

Phone: (301) 975-6421

Fax: (301) 975-4409

From: Kavlock, Robert
Sent: Friday, February 27, 2015 12:21 PM
To: Teichman, Kevin
Subject: Fwd: ACToR data index for HF chemicals

Richard is a true gem.

Begin forwarded message:

From: "Judson, Richard" <Judson.Richard@epa.gov>
To: "Kavlock, Robert" <Kavlock.Robert@epa.gov>, "Frithsen, Jeff" <Frithsen.Jeff@epa.gov>
Subject: ACToR data index for HF chemicals

Hi Bob, Jeff

Ex. 5

Richard

From: Kavlock, Robert
Sent: Thursday, February 26, 2015 6:19 PM
To: Judson, Richard
Subject: FW: HF pChem & Tox datasets - DRAFT 4Feb2015

Richard – in case this format is useful.

I will be in RTP on the 4th and hope to have a little time with you.

Bob

From: Frithsen, Jeff
Sent: Thursday, February 26, 2015 5:40 PM
To: Kavlock, Robert
Cc: Teichman, Kevin
Subject: FW: HF pChem & Tox datasets - DRAFT 4Feb2015

Bob:

FYI.....

To the best of my knowledge, this is all the tox data we have on HF chemicals. Not sure if you have seen it in this form. Enjoy!

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Ridley, Caroline
Sent: Thursday, February 26, 2015 5:07 PM
To: Frithsen, Jeff
Subject: FW: HF pChem & Tox datasets - DRAFT 4Feb2015

I have not opened this document, but it should have pchem data and tox data. Becky has scheduled a meeting next week to discuss how the eDatabase of properties is

coming along.

C

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6

From: Jonathan Koplos Ex. 4
Sent: Wednesday, February 04, 2015 1:19 PM
To: Daiss, Rebecca; Ridley, Caroline
Cc: LeDuc, Stephen; John Martin
Subject: HF pChem & Tox datasets - DRAFT 4Feb2015

Hi Becky and Caroline,

Please find attached the compilation of the pCHem and toxicological datasets including glossaries. The attached file includes 18 tabs which present the compilation of all the data you provided to us plus glossaries and definitions we've developed working with you over the last few weeks. Hopefully the name of each tab is fairly self-explanatory. This is a draft for your consideration; we look forward to your comments and suggestions.

Ex. 5
~~~~~~

Ex. 5

Ex. 5

Please let us know if you would like revisions, additions, etc.

Jonathan and John

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

Ex. 4

Follow us on social media:

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]; Briskin, Jeanne[Briskin.Jeanne@epa.gov]; Teichman, Kevin[Teichman.Kevin@epa.gov]; Zambrana, Jose[Zambrana.Jose@epa.gov]; Gibbons, Dayna[Gibbons.Dayna@epa.gov]; Matthews, Lisa[Matthews.Lisa@epa.gov]
Cc: Smith, Kelley[Smith.Kelley@epa.gov]

Rescheduling for this week. **Non-Responsive**

To: Weiner, Janet[Weiner.Janet@epa.gov]; Lewis, Paul[Lewis.Paul@epa.gov]; Vendinello, Lynn[Vendinello.Lynn@epa.gov]; Lobar, Bryan[Lobar.Bryan@epa.gov]; Hanley, Mary[Hanley.Mary@epa.gov]; Latham, John[Latham.John@epa.gov]; Doa, Maria[Doa.Maria@epa.gov]; Walker, Khadija[walker.khadija@epa.gov]; Ross, Johnny[Ross.Johnny@epa.gov]; Tesch, Danielle[Tesch.Danielle@epa.gov]; Banks, Stacey[Banks.Stacey@epa.gov]; Stewart, Andrew[Stewart.Andrew@epa.gov]; Ramos, Marilyn[Ramos.Marilyn@epa.gov]; Bergman, Ronald[Bergman.Ronald@epa.gov]; Bates, William[bates.william@epa.gov]; Carey, Kyle[Carey.Kyle@epa.gov]; Kelley, Rosemarie[Kelley.Rosemarie@epa.gov]; Spriggs, Gwendolyn[Spriggs.Gwendolyn@epa.gov]
Cc: Green, Holly[Green.Holly@epa.gov]
From: Engelberg, Dan
Sent: Tue 6/9/2015 7:57:22 PM
Subject: RE: OIG/OCSPP/OW/OECA mtg to discuss Agency Response to Fracking Review (OPE-FY14-0040) -- call in number Ex. 6

Hello Mary,

These are our basic questions for tomorrow's meeting. Answers to them will help us reach an evaluation in the final report of whether the agency's responses to the draft meet the intent of the recommendations:

Ex. 5

Ex. 5

I look forward to tomorrow's discussion,

Dan

-----Original Appointment-----
From: Weiner, Janet
Sent: Thursday, June 04, 2015 2:59 PM
To: Lewis, Paul; Vendinello, Lynn; Lobar, Bryan; Hanley, Mary; Latham, John; Doa, Maria; Engelberg, Dan; Walker, Khadija; Ross, Johnny; Tesch, Danielle; Banks, Stacey; Stewart, Andrew; Ramos, Marilyn; Bergman, Ronald; Bates, William; Carey, Kyle; Kelley, Rosemarie; Spriggs, Gwendolyn
Cc: Green, Holly
Subject: OIG/OCSPP/OW/OECA mtg to discuss Agency Response to Fracking Review (OPE-FY14-0040) -- call in number Ex. 6
When: Wednesday, June 10, 2015 11:00 AM-12:00 PM (UTC-05:00) Eastern Time (US & Canada).
Where: DCRoomEast3156/DC-EPA-EAST-OCSPP

Update 3 pm 6/4/15:
Per emails from OECA and OW, I am adding their staff to this meeting invite. Ex. 6

Ex. 6

Original message:
After reviewing the Agency's 5/28/15 response to the 4/28/15 Draft Report, the OIG team feels it necessary to meet to gain clarification on some of the corrective actions proposed.

The OIG would like to meet next week. I am tentatively scheduling this meeting date/time because it appears free for at least most of the OCSPP staff who may need to attend. Ex. 5 all or some subset of the staff that I've invited need to attend. If you are needed at the mtg, please accept the meeting notice to hold the time on your calendar. I will confirm the meeting once a decision is made on whether OCSPP and OECA will combine their meetings with OIG, or conduct them separately as I've scheduled it.

Any questions, please call me at 202-564-2309.
Thanks,
Janet Weiner

To: LeDuc, Stephen[LeDuc.Stephen@epa.gov]
From: Johnson, Craig
Sent: Wed 7/15/2015 11:40:44 AM
Subject: RE: Contractor to manage federal register material

Great. I am tied up 10:30 -12:30 and 3:00 – 4:00 in meetings.

From: LeDuc, Stephen
Sent: Tuesday, July 14, 2015 9:19 PM
To: Johnson, Craig
Subject: RE: Contractor to manage federal register material

Hi Craig,

No worries. I'm working from home and will call you tomorrow. I'm also reachable on my cell.
Best, Steve

Stephen D LeDuc, PhD

National Center for Environmental Assessment

US Environmental Protection Agency

Arlington, VA 22202

703-347-8962 (office)

Ex. 6

From: Johnson, Craig
Sent: Tuesday, July 14, 2015 5:35 PM
To: LeDuc, Stephen
Subject: RE: Contractor to manage federal register material

Steve,

As soon as I hung up we lost our power… twice.

Let's get together as soon as able, tomorrow… if that works with your schedule.

Thank you,

Craig

I'll be in the office tomorrow.

From: LeDuc, Stephen
Sent: Tuesday, July 14, 2015 3:38 PM
To: Johnson, Craig
Subject: RE: Contractor to manage federal register material

Hi Craig,

I just want to make sure I'm at my desk when you call. What time do you want to chat? Best, Steve

From: Johnson, Craig

Sent: Tuesday, July 14, 2015 10:33 AM
To: LeDuc, Stephen
Subject: RE: Contractor to manage federal register material

Cool. I'll call you at the office this afternoon, well after 2:00.

From: LeDuc, Stephen
Sent: Tuesday, July 14, 2015 9:56 AM
To: Johnson, Craig
Subject: RE: Contractor to manage federal register material

Hi Craig,

Glad to hear things are sort of OK at least. In the office today, I'm available from 2pm up until I leave the office at 5pm. Best, Steve

Stephen D LeDuc, PhD

US EPA, Office of Research and Development

National Center for Environmental Assessment

Arlington, VA

Phone: 703-347-8962

Ex. 6

From: Johnson, Craig
Sent: Tuesday, July 14, 2015 9:42 AM
To: LeDuc, Stephen
Subject: RE: Contractor to manage federal register material

Hey Steve,

Let's regroup this afternoon.

Thanks for your patience.

Everything turned out to be OK… sort of.

Craig

From: LeDuc, Stephen
Sent: Monday, July 13, 2015 2:05 PM
To: Johnson, Craig
Subject: RE: Contractor to manage federal register material

Of course, no worries. Hope everything is OK!

From: Johnson, Craig
Sent: Monday, July 13, 2015 2:04 PM
To: LeDuc, Stephen

Subject: RE: Contractor to manage federal register material

Ex. 5

From: LeDuc, Stephen
Sent: Monday, July 13, 2015 1:08 PM
To: Johnson, Craig
Cc: Kelley, Dave; Ridley, Caroline
Subject: Contractor to manage federal register material

Hi Craig,

I need a contractor to help us manage material/comments that comes in via the federal register notice for the draft hydraulic fracturing assessment we released in early June. Can you assist?

Ex. 5

Stephen D LeDuc, PhD

National Center for Environmental Assessment

US Environmental Protection Agency

Arlington, VA 22202

703-347-8962 (office)

Ex. 6

To: LeDuc, Stephen[LeDuc.Stephen@epa.gov]
From: Frithsen, Jeff
Sent: Mon 7/13/2015 4:41:22 PM
Subject: Re: Contractor for Public Comments

Ex. 5

Sent from Jeff Frithsen's iPhone
Office phone: 703-347-8623

Ex. 6

On Jul 13, 2015, at 12:27 PM, LeDuc, Stephen <LeDuc.Stephen@epa.gov> wrote:

Jeff,

Ex. 5

Best,

Steve

From: Frithsen, Jeff
Sent: Monday, July 13, 2015 10:48 AM
To: Schofield, Kate; LeDuc, Stephen; Alexander, Laurie
Cc: Ridley, Caroline
Subject: RE: Contractor for Public Comments

Ex. 5 Good feedback overall.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Schofield, Kate
Sent: Friday, July 10, 2015 12:12 PM
To: LeDuc, Stephen; Alexander, Laurie
Cc: Ridley, Caroline; Frithsen, Jeff
Subject: RE: Contractor for Public Comments

Hi Steve,

OW handled the Bristol Bay comment management Ex. 5

Ex. 5

Just let me know if you have any questions.

Kate

Kate Schofield | 703-347-8533 | schofield.kate@epa.gov

Mailing Address: USEPA (8623-P), 1200 PA Ave. NW, Washington DC 20460
FedEx and Ground Deliveries: Two Potomac Yard (North Building), 2733 S. Crystal Drive, Arlington VA 22202

From: LeDuc, Stephen
Sent: Friday, July 10, 2015 11:47 AM
To: Schofield, Kate; Alexander, Laurie
Cc: Ridley, Caroline; Frithsen, Jeff
Subject: Contractor for Public Comments

Hi Kate and Laurie,

We are considering getting a contractor to help us organize public comments for the hydraulic fracturing assessment. Ex. 5

Ex. 5

Stephen D LeDuc, PhD

National Center for Environmental Assessment

US Environmental Protection Agency

Arlington, VA 22202

703-347-8962 (office)

Ex. 6

To: Jonathan.Koplos[Ex. 4] William Jobs[Ex. 4] LeDuc, Stephen[LeDuc.Stephen@epa.gov]
Cc: Anna Weber[Ex. 4] Marc Morandi[Ex. 4] Daniel Mahr[Ex. 4]
From: Fleming, Megan
Sent: Thur 5/14/2015 5:36:30 PM
Subject: RE: Final QA on Appendix B Tables B-1 and B-7

Some answers/comments/questions below…

Thanks,
Megan

Megan Fleming
Office of Science Policy

U.S. EPA Office of Research and Development

1200 Pennsylvania Avenue, N.W.

Washington, D.C. 20460

(202)-564-6604

From: Jonathan Koplos[Ex. 4]
Sent: Thursday, May 14, 2015 12:52 PM
To: William Jobs; Fleming, Megan; LeDuc, Stephen
Cc: Anna Weber; Marc Morandi; Daniel Mahr
Subject: RE: Final QA on Appendix B Tables B-1 and B-7

We can treat this as the appendix master.

And, Megan, do you have the master on the chapter?

- Yes, I have the Chapter 4 master, and Steve has the Appendix B master.

Ex. 5

Thanks!

From: William Jobs
Sent: Thursday, May 14, 2015 12:23 PM
To: Megan Fleming; Stephen LeDuc (leduc.stephen@epa.gov)
Cc: Anna Weber; Jonathan Koplos; Marc Morandi
Subject: RE: Final QA on Appendix B Tables B-1 and B-7

Hi Megan and Steve,

Jonathan asked me to send along our up-to-date Appendix B Word document with the updated tables B-1 and B-7 included. The Excel file Jonathan just sent is a little cryptic as it came from our QA so it may be

easier to use the final version in this document (the numbers match those in the Excel file, however).

Thank you,

Will

Telephone: 617.673.7105

Fax: 617.673.7305

From: Jonathan Koplos
Sent: Thursday, May 14, 2015 11:38 AM
To: Megan Fleming; Stephen LeDuc (leduc.stephen@epa.gov)
Cc: Anna Weber; William Jobs
Subject: Final QA on Appendix B Tables B-1 and B-7

Hi Megan and Steve,

Here are the final QA'd versions of Appendix Tables B-1 (below) and B-7 attached.

Ex. 5

Jonathan

Ex. 5

Telephone: 617.673.7105

Fax: 617.673.7305

From: Jonathan Koplos
Sent: Friday, May 08, 2015 4:06 PM
To: William Jobs; Marc Morandi

Cc: Anna Weber
Subject: RE: Appendix B Tables - QA'd and edited

I now do remember that this was a formidable task the first time around for Marc.

I don't expect/want you putting in a long one today, Will. I'll let the client know that we're just not able to get this today.

Ex. 5

From: William Jobs
Sent: Friday, May 08, 2015 3:57 PM
To: Jonathan Koplos; Marc Morandi
Cc: Anna Weber
Subject: RE: Appendix B Tables - QA'd and edited

Not well – I've got to pull the data out of the raw USGS state level data and then work that into my code. Marc's writing an email to describe where he pulled the columns from, but I suspect this may take some time.

- Will

Telephone: 617.673.7105

Fax: 617.673.7305

From: Jonathan Koplos
Sent: Friday, May 08, 2015 3:55 PM
To: William Jobs; Marc Morandi
Cc: Anna Weber
Subject: RE: Appendix B Tables - QA'd and edited

How goes it?

From: William Jobs
Sent: Friday, May 08, 2015 2:47 PM
To: Marc Morandi; Jonathan Koplos
Cc: Anna Weber
Subject: RE: Appendix B Tables - QA'd and edited

Hold up, the final column isn't QA'd yet. Jonathan, I'll email you when it's ready.

- Will

Telephone: 617.673.7105

Fax: 617.673.7305

From: Marc Morandi
Sent: Friday, May 08, 2015 2:39 PM
To: William Jobs; Jonathan Koplos
Cc: Anna Weber
Subject: RE: Appendix B Tables - QA'd and edited

This is the table that I came up with, cells with discrepancies to the table Steve sent out this morning are highlighted in red:

Ex. 5

From: William Jobs
Sent: Friday, May 08, 2015 1:28 PM
To: Jonathan Koplos; Marc Morandi
Cc: Anna Weber
Subject: RE: Appendix B Tables - QA'd and edited

Jonathan and Marc,

Ex. 5

Thanks!

- Will

Telephone: 617.673.7105

Fax: 617.673.7305

From: Jonathan Koplos
Sent: Friday, May 08, 2015 1:00 PM
To: LeDuc, Stephen; Fleming, Megan; Ridley, Caroline
Cc: Anna Weber; Marc Morandi; William Jobs
Subject: RE: Appendix B Tables - QA'd and edited

Working on this now; think we can get it done this afternoon.

Will keep you posted.

From: LeDuc, Stephen [mailto:LeDuc.Stephen@epa.gov]
Sent: Friday, May 08, 2015 12:14 PM
To: Jonathan Koplos; Fleming, Megan; Ridley, Caroline
Cc: Anna Weber; Marc Morandi; William Jobs
Subject: RE: Appendix B Tables - QA'd and edited

Hi Jonathan,

Can someone QA this table B-1 this afternoon—see attached—based on the state values for the USGS water census? This would include getting the right Alaska value in. Best, Steve

From: Jonathan Koplos [mailto:Jonathan.Koplos@cadmusgroup.com]
Sent: Friday, May 08, 2015 11:04 AM
To: LeDuc, Stephen; Fleming, Megan; Ridley, Caroline
Cc: Anna Weber; Marc Morandi; William Jobs
Subject: RE: Appendix B Tables - QA'd and edited

Yes, that was a very last minute change for the FF report that I hadn't translated to Marc.

Ex. 5

I'll check with Marc and Will (our FF database expert).

Thanks, Steve.

Jonathan

From: LeDuc, Stephen [mailto:LeDuc.Stephen@epa.gov]
Sent: Friday, May 08, 2015 9:52 AM
To: Jonathan Koplos; Fleming, Megan; Ridley, Caroline
Cc: Anna Weber; Marc Morandi
Subject: RE: Appendix B Tables - QA'd and edited

Hi Jonathan,

Ex. 5

From: Jonathan Koplos Ex. 4
Sent: Thursday, May 07, 2015 5:23 PM
To: LeDuc, Stephen; Fleming, Megan; Ridley, Caroline
Cc: Anna Weber; Marc Morandi
Subject: RE: Appendix B Tables - QA'd and edited

And here is the info from Marc on Table B-1. Looks like your own thought on state vs county level date explains the difference you saw.

Note from Marc:

Ex. 5

Ex. 5

Ex. 5

From: LeDuc, Stephen [mailto:LeDuc.Stephen@epa.gov]
Sent: Thursday, May 07, 2015 4:37 PM
To: Jonathan Koplos; Fleming, Megan; Ridley, Caroline
Cc: Anna Weber
Subject: RE: Appendix B Tables - QA'd and edited

Good news: spot checked the 2nd table (B-2) and it appears correct.

From: Jonathan Koplos [mailto:Jonathan.Koplos@cadmusgroup.com]
Sent: Thursday, May 07, 2015 3:51 PM
To: LeDuc, Stephen; Fleming, Megan; Ridley, Caroline
Cc: Anna Weber
Subject: RE: Appendix B Tables - QA'd and edited

A meeting from 4-430 pm, then here until 5.

I'll call you now (office or cell)?

From: LeDuc, Stephen [mailto:LeDuc.Stephen@epa.gov]
Sent: Thursday, May 07, 2015 3:49 PM
To: Jonathan Koplos; Fleming, Megan; Ridley, Caroline
Cc: Anna Weber
Subject: RE: Appendix B Tables - QA'd and edited

Hi Jonathan,

I just started in on the Appendix and the first table doesn't appear correct. Are you around for a quick chat on the phone? Best, Steve

Stephen D LeDuc, PhD

US EPA, Office of Research and Development

National Center for Environmental Assessment

Arlington, VA

Phone: 703-347-8962

Ex. 6

From: Jonathan Koplos Ex. 4
Sent: Thursday, May 07, 2015 12:33 PM
To: LeDuc, Stephen; Fleming, Megan; Ridley, Caroline
Cc: Anna Weber
Subject: Appendix B Tables - QA'd and edited

Steve and Megan,

Lots of tracked changes, but mainly fairly small quantity changes.

A bit messy to look at, but we've kept the in for you for you to review/accept. All changes here have been transcribed to the Chapter, so the chapter and this appendix are consistent with the most updated and QA'd FF-related analyses.

The technical editing on this has a few questions for you in some comment bubbles.

Please let me know if you have any questions.

Jonathan

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

100 5th Avenue, Suite 100

Waltham, MA 02451

Ph. 617-673-7184

Ex. 4

www.cadmusgroup.com

Follow us on social media:

To: Johnson, Maureen[Johnson.Maureen@epa.gov]
Cc: LeDuc, Stephen[LeDuc.Stephen@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Ridley, Caroline
Sent: Tue 5/5/2015 7:18:44 PM
Subject: RE: Request for web site text

Here are some answers in red below.

JEFF- please weigh in if we need to reword something for the website. Almost all of the text comes directly from chapter 1 of the assessment.

-Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and Ex. 6

From: Johnson, Maureen
Sent: Tuesday, April 21, 2015 8:00 AM
To: Ridley, Caroline
Subject: Request for web site text

Hi Caroline,

In order to post your documents by the Scout date which is coming up very soon, I'll need the **final edited report** (in Word) 1 week before the Scout date to ensure the document is 508 compliant (for accessibility, this time varies depending on the size and complexity of your document) Ex. 5 Ex. 5 please remind me, will not be 508 at that time, will be 508 a couple weeks later). Could you please send the report cover and for the NCEA website (Developing this now with Vicki Soto), I'll need the following information per guidance from EPA's Office of Public Affairs (OPA).
~~~~~~

1. **Notice information and/or recent additions text:** (just a couple sentences or if this is an update from a previous version) I also need to know if NCEA will be posting a **Federal Register Notice** for your report. Ex. 5

Ex. 5

2. **Introductory Sentence:** Please provide an additional sentence or 2 that describes the document (this can be taken from the Introduction of the report). Ex. 5

Ex. 5

3. **Background information:** Please provide some additional Background information about the subject matter briefly touching on the purpose the document was written (this should be in plain English for the general public)

Ex. 5

4. **Contact:** if this isn't you let me know who it should be. Ex. 5

5. **History:** Please provide Year and/or Month that significant events related to the document(s) occurred: such as workshops, product reviews, draft releases, and prior releases. *Ex. 5

Ex. 5

6. **Next Steps:** For example, "Concluding this review, there will be a revised assessment in 2016

to be published on the NCEA or IRIS web site..... Ex. 5

Ex. 5

7. **Downloads:** Your document(s) plus anything else related to it, peer review charges, presentations, etc.. can be attached here. * Ex. 5

Ex. 5

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Ex. 5

Here is a sample: http://cfpub.epa.gov/ncea/bristolbay/recordisplay.cfm?deid=241743

Let me know if you have any questions, email usually works best for me.

Maureen Johnson

email: johnson.maureen@epa.gov / Ph: 703-347-8611 (M-T) / Ph: 202-641-7876 (W-F)/ Ex. 6
NCEA Webmaster, NCEA, ORD, USEPA

To: LeDuc, Stephen[LeDuc.Stephen@epa.gov]
From: Ridley, Caroline
Sent: Fri 5/1/2015 1:16:55 PM
Subject: FW: Freak out

I sent a text last night to Jeff about our team starting to reach freak out stage about the comments. Here's the reply ...
C

~~~~~~

Caroline E. Ridley, PhD
Ecologist
US Environmental Protection Agency
Office of Research and Development
National Center for Environmental Assessment
Office: (703) 347-8506 and AWL (Ex. 6

-----Original Message-----
From: Frithsen, Jeff
Sent: Thursday, April 30, 2015 10:17 PM
To: Ridley, Caroline
Subject: Freak out

I've been tied in knots this week with hydraulic fracturing stuff. Now have closure on 6 more reports.

Next up are the comments on the chapters and ES.

Non-Responsive

Jeff

Sent from Jeff Frithsen's iPhone
Office phone: 703-347-8623
Ex. 6
~~~~~~

To: Jonathan.Koplos[Ex. 4] Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: John Stanek[Ex. 6]; Anna Weber[Ex. 4]; LeDuc, Stephen[LeDuc.Stephen@epa.gov]
From: Fleming, Megan
Sent: Thur 3/26/2015 7:51:13 PM
Subject: RE: any new references in revised Chapter 4 or 9?
Scanlon_etal_2014_ERL_water-scarcity-semiarid-regions-HF-shale-plays.pdf

Hi Jonathan,

Attached is a new reference we're adding into Chapter 4 now. It's probably not in HERO yet.

Thanks,

Megan

Megan Fleming
Office of Science Policy

U.S. EPA Office of Research and Development

1200 Pennsylvania Avenue, N.W.

Washington, D.C. 20460

(202)-564-6604

From: Jonathan Koplos[Ex. 4]
Sent: Thursday, March 26, 2015 3:46 PM
To: Ridley, Caroline
Cc: John Stanek; Fleming, Megan; Anna Weber
Subject: any new references in revised Chapter 4 or 9?

If so, could you let us (or Caroline) know so we can get them into the HERO queue? (I'm guessing not, but just checking.)

Thanks!

Jonathan Koplos, Ph.D.

Ex. 4

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Will water scarcity in semiarid regions limit hydraulic fracturing of shale plays?

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doi:10.1088/1748-9326/9/12/124011

Will water scarcity in semiarid regions limit hydraulic fracturing of shale plays?

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Received 10 July 2014, revised 27 October 2014
Accepted for publication 29 October 2014
Published 8 December 2014

Abstract

There is increasing concern about water constraints limiting oil and gas production using hydraulic fracturing (HF) in shale plays, particularly in semiarid regions and during droughts. Here we evaluate HF vulnerability by comparing HF water demand with supply in the semiarid Texas Eagle Ford play, the largest shale oil producer globally. Current HF water demand (18 billion gallons, bgal; 68 billion liters, bL in 2013) equates to ~16% of total water consumption in the play area. Projected HF water demand of ~330 bgal with ~62 000 additional wells over the next 20 years equates to ~10% of historic groundwater depletion from regional irrigation. Estimated potential freshwater supplies include ~1000 bgal over 20 yr from recharge and ~10 000 bgal from aquifer storage, with land-owner lease agreements often stipulating purchase of freshwater. However, pumpage has resulted in excessive drawdown locally with estimated declines of ~100–200 ft in ~6% of the western play area since HF began in 2009–2013. Non-freshwater sources include initial flowback water, which is ⊔5% of HF water demand, limiting reuse/recycling. Operators report shifting to brackish groundwater with estimated groundwater storage of 80 000 bgal. Comparison with other semiarid plays indicates increasing brackish groundwater and produced water use in the Permian Basin and large surface water inputs from the Missouri River in the Bakken play. The variety of water sources in semiarid regions, with projected HF water demand representing ~3% of fresh and ~1% of brackish water storage in the Eagle Ford footprint indicates that, with appropriate management, water availability should not physically limit future shale energy production.

S Online supplementary data available from stacks.iop.org/ERL/9/124011/mmedia

Keywords: hydraulic fracturing, water scarcity, shale gas, brackish water, groundwater, unconventional energy, water energy nexus

1. Introduction

With increasing energy production from unconventional shale plays requiring large amounts of water to support hydraulic fracturing (HF), there is concern about limited water supplies. A recent global analysis of water resources relative to shale plays indicates that an estimated ~40% of shale resources are in arid areas or in areas of high–extremely high water stress, including China, Mexico, and S Africa, ranked 1st, 6th, and 8th in terms of shale gas production, respectively [1–3]. Extreme droughts exacerbate water shortages, with an estimated 15% of global shale resources in areas exposed to high–extremely high drought stress [1]. The USA is the global leader in unconventional oil and gas (O&G) production with initial development of the technology for producing O&G from low permeability shales in the Barnett shale play in Texas using HF and horizontal drilling [4]. In addition, private ownership of mineral rights has incentivized rapid expansion of production in the USA in contrast to government ownership in most other countries. The USA ranks 5th globally in terms of technically recoverable shale gas and 2nd

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in terms of shale oil resources and was classified as medium to high water stress in the global analysis [1]. An earlier report on USA resources indicates that ~50% of the 39 000 wells hydraulically fractured (January 2011–May 2013), that consumed ~100 billion gallons (bgal, ~380 billion liters, bL) of water, are in high or extremely high water stress areas [5]. The highest shale oil producing plays are in semiarid regions or in regions with low precipitation (Eagle Ford, 34% of USA production in 2013; Bakken, 29%; and Permian Basin, 23%).

Water scarcity is often defined as water demand exceeding water supply. Water demand for HF can be estimated fairly accurately in the USA from commercial and public databases (e.g. IHS Enerdeq database, FracFocus) [4–6]. However, there is considerable uncertainty in future demands based on projected O&G production in these plays (estimated ultimate recovery, EUR). Previous studies indicate that ~10 000 more wells will be drilled throughout the 20–30 yr life of the Barnett play [7], ~40 000 more wells in the Bakken [5], and 50 000 in the Eagle Ford [6, 8].

HF water supply is more difficult to assess than HF water demand because the reporting requirements for water sources used for HF in the USA are limited to some states (Pennsylvania, W Virginia, supporting information, SI, section 4, available at stacks.iop.org/ERL/9/124011/mmedia). Surface water supplies are more readily estimated from monitoring data; however, groundwater supplies depend in part on how they are defined. Many studies restrict groundwater supplies for HF to the water flux into the aquifer or recharge, often based on coarse resolution (0.5–1 degree) global models, such as PCR-GLOBWB in the Aqueduct water scarcity product [1, 5, 9]. Others define groundwater supplies based on water storage in aquifers [10]. Water supplies for HF are also impacted by water use in other sectors, particularly irrigation in semiarid regions [11].

Various strategies have been proposed to enhance resilience of HF to water constraints, including trading water among sectors and shifting to non-freshwater sources. Similar approaches are being considered for power generation [12]. Some studies emphasize the potential for trading with irrigated agriculture, considering that this sector is often the largest water consumer in semiarid regions [13, 14]. To date, most HF water has been derived from freshwater resources [5]; however, recent advances in HF technology allow use of more saline water, even as high as 285 000 mg L^{-1} total dissolved solids (TDS) [15]. While there is much emphasis on reuse (little or no treatment) or recycling (with treatment) of flowback/produced (FP) water, some studies show that flowback water (typically produced within 1–2 weeks after well completion) or water produced from the formation along with O&G (produced water), both referred to generically as FP water, represent a small percentage of HF water demand [4, 16]. Even in the Marcellus Shale, where almost 100% of the water is recycled, recycling accounts for □10–30% of the required HF water based on volumes of typical flowback (mean 0.44×10^6 gal/well, 1.7×10^6 L/well) and produced water (0.74×10^6 gal/well, 2.8×10^6 L/well) from wells in Pennsylvania [17] relative to mean HF water use throughout the play (4.4×10^6 gal/well 16.7×10^6 L/well) [5]. Brackish groundwater provides another alternative to freshwater with some referring to the 'sea of brackish water' in the subsurface; however, characterization of this resource is limited in terms of quantity and quality of water that can be recovered [18].

The objectives of this study were to address the following questions:

(1) How does water use for HF compare with that for other sectors?
(2) What is the projected demand for HF water for O&G production?
(3) Is HF in semiarid regions vulnerable to water constraints, i.e. does water demand exceed supply?
(4) What impacts does HF water use have on water resources?
(5) What strategies can O&G operators adopt to enhance resilience of HF to water constraints?

This study focused on water use for HF in the Eagle Ford shale play, the top ranked shale-oil producer and 4th ranked shale-gas producer in the USA in 2013 [19, 20]. It builds on a previous analysis that quantified water demand to date for HF in the Eagle Ford play [6]. Water use for HF was considered relative to that for irrigation and municipal sectors. Future HF water demand was projected for the next 20 yr. Water constraints were assessed by comparing HF water demand with estimated freshwater supplies from groundwater recharge and storage from groundwater models [21, 22]. Impacts of HF water use on water resources were evaluated by considering HF water use to date and also the life cycle of shale gas. Adaptive strategies to enhancing resilience of HF water supplies evaluated include use of brackish groundwater, reuse/recycling of FP water, and use of municipal waste water. Results from the Eagle Ford play were compared with those in other semiarid regions, including the Permian Basin play in Texas and Bakken play in N Dakota/Montana. This comprehensive analysis is designed to answer the question of whether HF in semiarid regions will be limited because of water constraints.

2. Materials and methods

2.1. Eagle Ford Shale Play

Unconventional O&G production in the Eagle Ford Play (~9500 mi^2, 24 600 km^2 area) began in 2008 (figure 1). Water use for HF in the play totaled 40 bgal (150 bL) for 8301 wells (2009–2013) [6].

Precipitation in the Eagle Ford play ranges from 19.5 inches/yr (495 mm yr^{-1}) in the west to 38.6 inches/yr (980 mm yr^{-1}) in the east (figure S1). Total population in the play area was ~0.2 million in 2010 in the mostly rural 16 county area. Nearby major cities include San Antonio (population 2.2 million) and Laredo (population 236 000) (figure S2). Land use/land cover consists of shrubland (45%), pasture (25%), grassland (8%), forest (7%), and cropland (5%) (figure S2). Most cropland and some pasture are irrigated. Major rivers include, from west to east, the Rio Grande, Nueces, Frio, Atascosa, San Antonio, and Guadalupe rivers. Major aquifers

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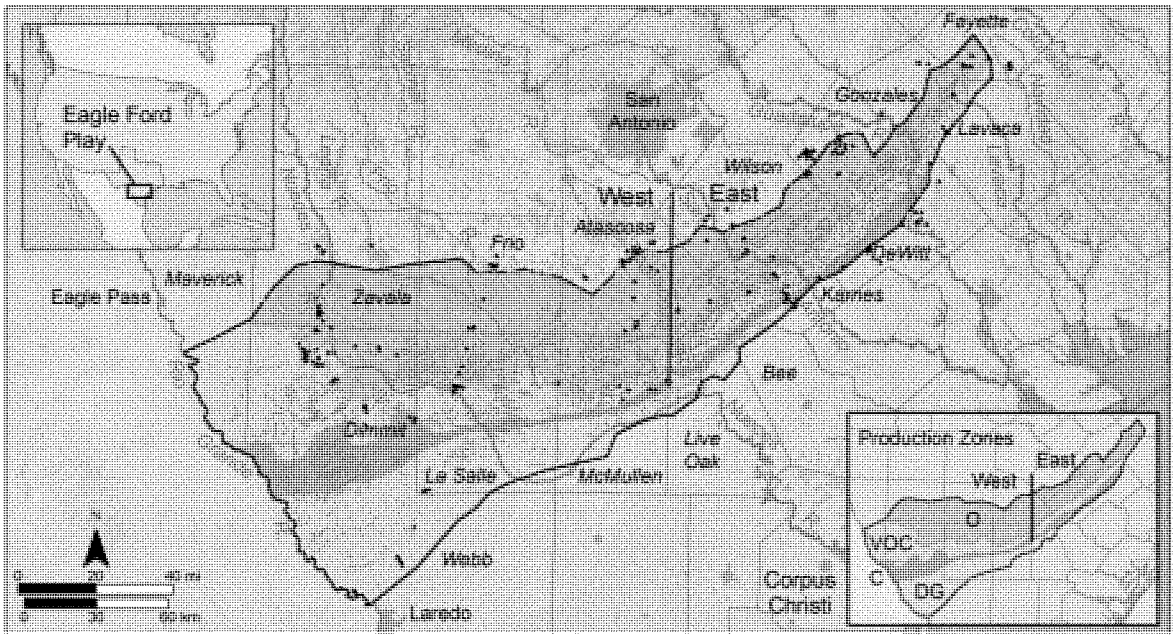

Figure 1. Location of the Eagle Ford Shale play in south-central Texas, USA. The study area (black outline), includes 99% of recently completed (2009–2013) Eagle Ford play area wells. The inset shows the different production zones, including the updip black oil zone (O, green), volatile oil-condensate (VOC, yellow), condensate (C, mustard), and dry gas (DG, rose) [6]. The O, VOC, and C zones were further subdivided into west and east zones. The gray points represent the locations of horizontal oil and gas wells that were completed using hydraulic fracturing (HF) techniques from January 2009 through December 2013 (8301 wells). The black points represent public water supply wells that serve community populations up to ~10 000 people. The blue points represent irrigation wells, with the highest density upgradient from the HF wells, mostly in the Winter Garden irrigation region. Mean depth of HF wells is ~2 miles (3.2 km) and the length of horizontals or laterals averages ~1 mile (1.6 km) [6]. Average HF water use is similar across production zones from oil, through volatile oil, gas condensate (liquid condensed from wet gas at the well head or natural gas plant), and dry gas, on a per well basis (4.7–4.9 × 10^6 gal/well, 17.8-18.5 × 10^6 L/well) and per unit length of lateral (930–1020 gal ft^{-1}, 11 500–12 700 m L^{-1} of lateral). However, HF water use varies spatially and is 17–29% higher in the west relative to the east within each production zone. Oil and gas has been produced in this region since the early 1900s from units such as the Austin Chalk and Edwards Limestone with horizontal drilling used in the relatively tight Austin Chalk for several decades [53]. Conventional oil and gas wells are not shown.

in the region include the Carrizo–Wilcox aquifer and the Gulf Coast aquifer system, and minor aquifers include the Queen City, Sparta and Yegua-Jackson aquifers (figures 2, S3) [23]. Groundwater Conservation Districts (8 GCDs) manage regional groundwater according to Texas Senate Bill 1, an omnibus water bill passed in 1997 (figure S4).

2.2. Data sources and analyses

HF water demand was compared with water supplies at the play and county and square mile grid levels while also considering water use in other sectors to assess vulnerability to water constraints (figure 3). Additional details on data sources are available in SI, section 6. HF water demand or use was based on water use to date (2009–2013) in the Eagle Ford [6]. Information on wells used to supply water for HF was obtained from the Texas Dept. of Licensing and Regulation. HF water use was compared with that for other sectors based on the most recent data from the Texas Water Development Board [24]. Future HF water use was estimated by assuming that the highest established well density (HEWD) for HF wells in each of the seven production zones (2 oil, 2 volatile oil condensate, 2 condensate, and 1 dry gas) or county/production zone intersections (40) would apply to the entire play (SI, section 6, tables S1, S2).

Primary sources of HF water include surface water and groundwater from aquifer recharge, aquifer storage, and cross-formational flow from adjacent aquifers; however, the latter was neglected in this analysis. Data on water diversions from the Rio Grande for mining were obtained from the Rio Grande Water Master. Renewable groundwater supplies for HF were estimated from aquifer recharge rates using a global model (PCR GLOBWB) as used in recent studies [1, 5, 25], regional recharge rates from groundwater chloride data [26], and groundwater availability models (GAMs) [27–29]. Groundwater supplies from aquifer storage were estimated from GAMs [22, 27, 28] and include drainable storage (water that would be drained under gravity, aquifer thickness × specific yield) in aquifer outcrop zones and compressible storage (water released from compressible storage: storativity × head decline) in downdip confined sections of aquifers (figure 2, SI, section 9, figure S11).

Impacts of HF on groundwater resources were evaluated using groundwater level monitoring data from 131 wells from the Texas Water Development Board (TWDB) database. Flow duration curves and baseflow were estimated for 20 streamflow gages using the length of record to determine which streams are perennial and could be impacted by HF groundwater pumpage. Net impact of HF on water resources was examined

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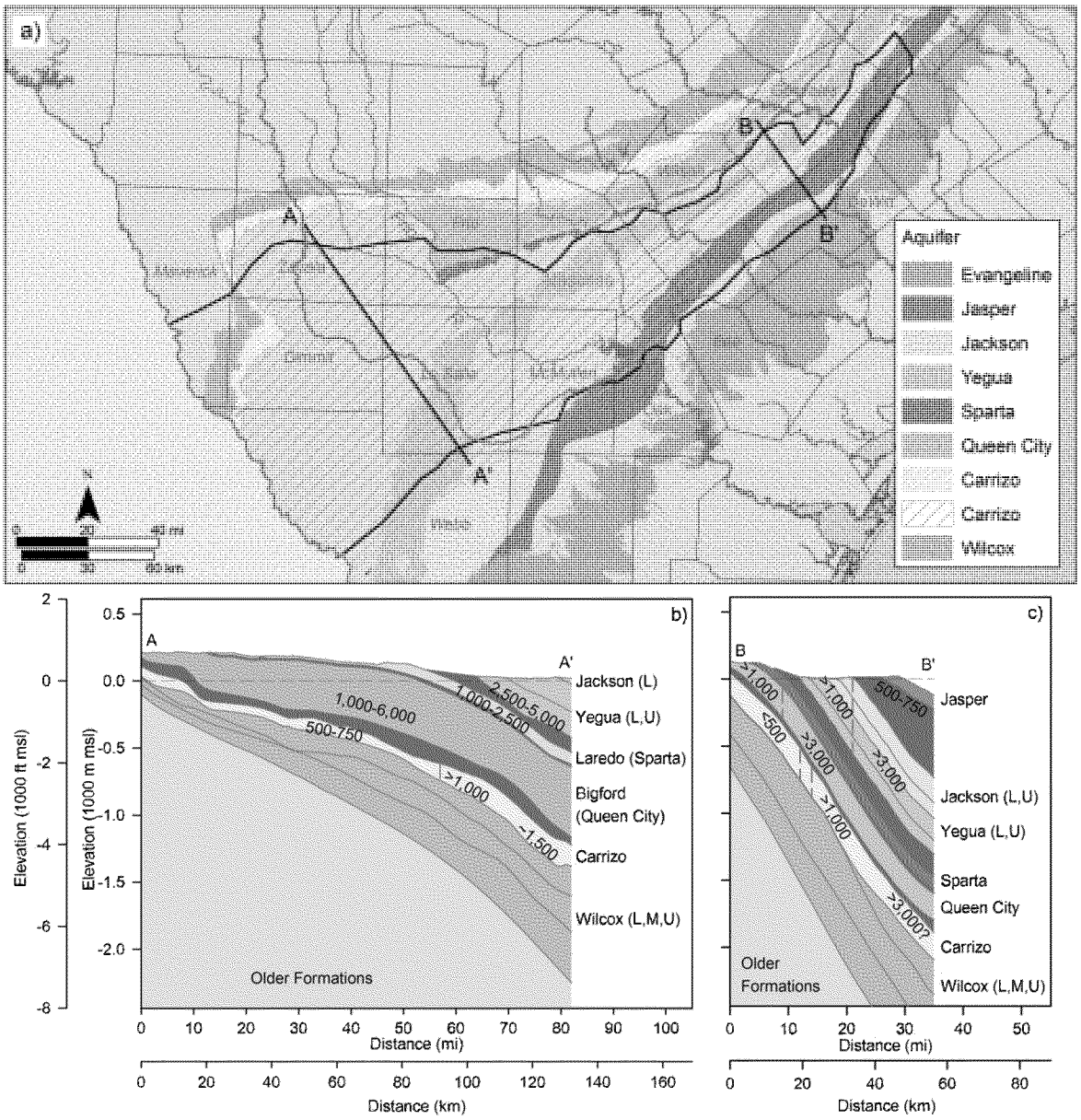

Figure 2. (a) Outcrop and recharge areas for aquifers in the Eagle Ford play area. Major aquifers include the Carrizo–Wilcox and the Gulf Coast (Jasper and Evangeline) and minor aquifers include the Queen City, Sparta, and the Yegua-Jackson. The primary water source in the western region of the Eagle Ford play is the confined section of the Carrizo Sand, represented by the cross-hatched area. Except for the outcrop area lying mostly to the northwest of the Eagle Ford play area, little information regarding water quality is available for the Wilcox units. The Queen City and Sparta aquifers also have equivalent water-bearing units west of the Frio River, although these units are not designated as aquifers in the west because of poor water quality (figure S3) [22]. We did not include water supplies for HF from these units. (b) Cross sections A-A' and (c) B-B'. Values shown in the cross section aquifer units represent approximate groundwater total dissolved solids (TDS) concentrations and dashed vertical lines represent approximate locations of transitional areas between different TDS concentration zones.

by comparing water use for shale gas extraction with water use for cooling in natural gas power plants [30].

Alternatives to freshwater sources for HF were evaluated, including flowback/produced (FP) water (SI, section 11), brackish groundwater, and municipal waste water. FP water volumes were estimated for individual wells from 2009–2013. The ratio of FP to HF water was calculated to evaluate what percentage of HF water would be available for reuse or recycling. Brackish groundwater was estimated by integrating groundwater quality (TDS) data from TWDB with groundwater storage data from the GAMs. Availability of municipal waste water was evaluated by contacting the 20 largest municipalities in the play area. We contacted O&G operators to determine trends in HF water sourcing through the South Texas Energy and Economic Roundtable (STEER.com) and through conferences. Analyses of water demand versus supply in the Eagle Ford play were compared with water demand from literature-based estimates for the semiarid Permian Basin play in west Texas [5] and from previous analysis for the semiarid Bakken play in N Dakota and Montana [6]. Water demand in the

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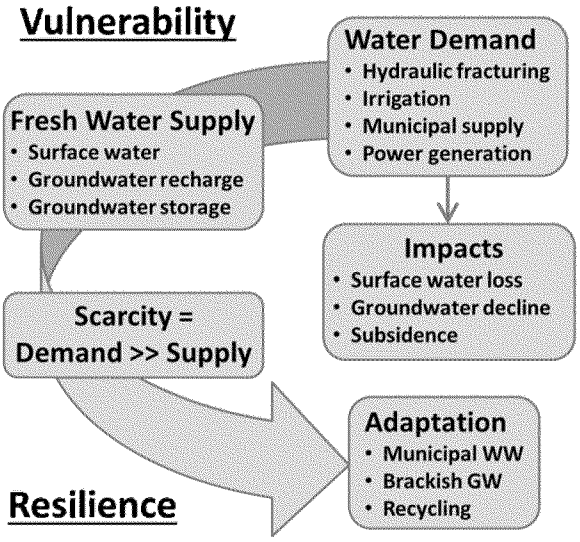

Figure 3. Water demand for HF is based on data on HF water use to date (2009–2013) from IHS and FracFocus databases [6]. Projected HF water demand assumes that additional HF wells will be drilled to achieve the current highest established well density (HEWD) in each of the seven production zones (east and west oil, VOC, and condensate zones, and dry gas zone). Projected HF water demand was calculated by multiplying the number of wells to be drilled in each production zone by the 2013 average HF water use per well in each zone. Water supplies were estimated from surface water (SW) based on data from Water Masters. Recharge rates were determined from a global model (PCR-GLOBWB (PCR-GLOBWB) [25], regional recharge estimates from groundwater chloride [26] and from Groundwater Availability Models (GAMs). Groundwater (GW) supplies from aquifer storage were estimated from GAMs, using water-level data in unconfined aquifers and potentiometric surface data in confined aquifers, aquifer tops and bottoms, and gridded storage coefficients (supporting information, SI, section 9). Total water storage was subdivided into freshwater (FW) and brackish water (BW, total dissolved solids, TDS □ 1000 mg L) using water quality data from the Texas Water Development Board. Data on flowback and produced water (FP) were obtained from IHS. Information on municipal waste water (WW) was obtained from municipalities. Impacts of HF on surface water (SW) were estimated by determining which streams are perennial and could be affected by pumpage from unconfined aquifers. Impacts of HF on groundwater were based on groundwater level data from TWDB wells in the region. Net impact of HF on water resources considered use of natural gas in power generation.

Permian Basin was compared with water supplies from groundwater storage, including brackish water from the GAMs and discussions with operators through the Permian Basin Petroleum Association. Water demand in the Bakken was compared with reservoir storage in the Missouri River [31].

3. Results and discussion

A schematic (figure 4) shows the main components of the Eagle Ford play area, including the Eagle Ford Shale unit at depth, a typical HF well (~2 miles deep and 1 mile lateral), an injection well for disposal of FP water, a shallow dipping confined aquifer typical of the Gulf Coast aquifers, and various sources of water, including recharge in the aquifer outcrop and fresh and brackish groundwater storage. HF water

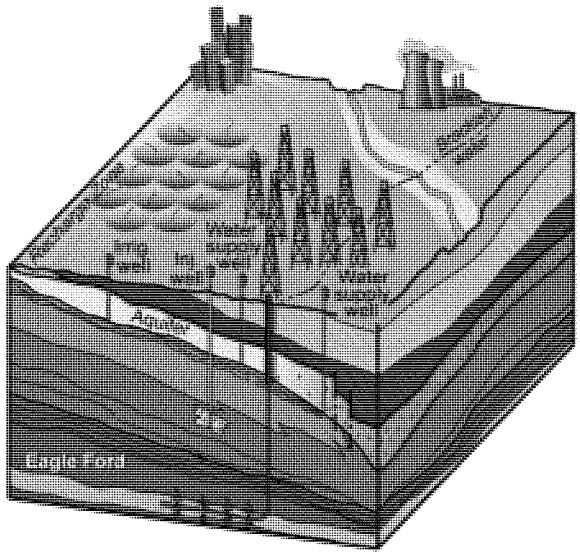

Figure 4. Schematic of Eagle Ford play area. Only one aquifer is shown for clarity and includes an up-dip recharge zone where the aquifer outcrops and downdip confined section including brackish water shown in red. A representative hydraulically fractured well is shown with mean depth of ~2 miles (3.2 km) and mean lateral length of ~1 mi (1.6 km). A nearby injection well is shown where flowback-produced water can be disposed. The various water sources are schematized to include groundwater recharge and storage (freshwater and brackish water), reused or recycled FP water from HF wells, municipal waste water, surface water (e.g. Rio Grande), and transfer from the irrigation sector. Irrigation is mostly up-gradient from the Eagle Ford HF and is represented by center pivot irrigation circles representative of the Winter Garden irrigation region. A power generation station is included to represent net impacts of natural gas on water resources including water cooling through power generation and water creation from natural gas combustion.

demand was compared with water supplies based on production to date (2009–2013) and projected production throughout the play life (~20 yr) at the play level, county level, and where feasible at the one square mile grid level to assess water scarcity.

3.1. How does water demand for hydraulic fracturing compare with that for other sectors?

Water demand or use for HF in the Eagle Ford in 2013 (17.8 bgal, 67 bL) is assumed to be mostly consumptive because of limited recycling as discussed later. At the state level, HF water demand in the Eagle Ford in 2013 represents 0.3% of statewide water withdrawal (5200 bgal, 20 000 bL, 2012) and 0.5% of statewide water consumption (3900 bgal, 15 000 bL, 2012), assuming 85% of irrigation and 40% of municipal water use is consumptive [32]. The latest year with reported state water use data is 2012. At the play level, HF water consumption represents 4–9% of water withdrawal in 2011 and 2012 and 5–11% of water consumption (figure 5, table S2). However, using 2013 HF water use with 2012 water use data results in HF representing 13% of water withdrawal and 16% of water consumption. The dominant water user in the play is irrigation, accounting for 62–65% of

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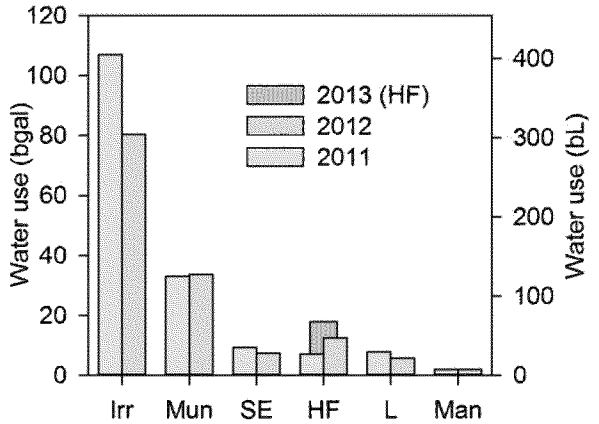

Figure 5. HF water use for 2011–2013 relative to total water use by other sectors in the Eagle Ford play area for 2011 and 2012 (most recent years with complete data) (table S1). Total non-HF water use was 168 bgal (636 bL) for 2011 related to dry conditions associated with most extreme drought on record and 129 bgal (490 bL) for 2012, related to normal conditions. HF water use during the period was 7.0 bgal (36 bL; 2011), 12.5 bgal (47 bL, 2012), and 17.8 bgal (67 bL, 2013).

Table 1. Summary of past and projected HF water demand and future HF water supply sources in the Eagle Ford play region.

		HF demand and storage		
Category		bgal	bL	Demand % of source
HF Water demand				
2009–2013		40	150	—
20-Year projection		330	1250	—
HF Water sources				
Fresh storage	Unconfined	6000	22 700	5
	Confined	3800	14 400	8
Brackish storage	Unconfined	34 800	132 000	1
	Confined	45 600	173 000	1
Other[a]	Recharge	1200	4540	26
	MWW	36	136	860

[a] Annual values (recharge: 60 bgal yr^{-1}, municipal waste water (MWW) 1.8 bgal yr^{-1}) multiplied by 20 yrs.

water consumption (2011–2012), followed by municipal (10–12%), and steam electric power (7–13%) (figure 5).

3.2. What is the projected water demand for hydraulic fracturing?

Total HF drilling during the remaining life of the play (~20 years) was estimated based on the current highest established well density (HEWD) to be 50 700–70 400 wells, resulting in ~42 000–62 000 wells remaining after subtracting the 8300 wells drilled to date [6] (table S3; figure S6), bounding the previous estimate of 50 000 wells [8]. Multiplying 2013 drilling (3512 wells) by 20 and subtracting 8300 would result in a similar estimate (62 000 wells). These projections would result in ~223–333 bgal (844–1260 bL) of additional HF water based on average 2013 HF water use/well in each production zone (oil, volatile oil, condensate, and dry gas) (table S3), representing ~6–8 times HF water use to date (~40 bgal, 150 bL, 2009–2013) [6]. To assess water constraints for HF, we used the upper bound for HF water demand (~330 bgal, 1250 bL) as a conservative estimate (table 1).

3.3. How does water demand for hydraulic fraction compare to freshwater supplies?

The dominant HF water supplies in the Eagle Ford play include aquifer recharge and freshwater storage (table 1). The focus on freshwater derives in part from reports that many landowners stipulate use of their fresh groundwater as part of lease agreements to generate an additional revenue stream to land owners and the sole revenue stream to landowners with severed mineral rights. Long-term (1960–2000) mean recharge rates from simulated drainage below the root zone in the PCR-GLOBWB model totaled 49 bgal yr^{-1} (185 bL yr^{-1}) for the Eagle Ford play area (table S5), ~170% greater than HF water demand in 2013 (18 bgal, 68 bL) but 65–72% less than total water withdrawal in the play area in 2011 (175 bgal, 662 bL) and 2012 (142 bgal, 538 bL) (table S3). Regional recharge rates from groundwater chloride data in the Carrizo–Wilcox aquifer totaled 43 bgal yr^{-1} (163 bL yr^{-1}) [26]. Sources of recharge include diffuse recharge from percolation below the root zone and focused recharge beneath losing streams (e.g. Leona, Nueces, and Frio rivers) [33, 34]. Simulated recharge in regional GAMs in outcrop areas in the play totaled ~60 bgal yr^{-1} (227 bL yr^{-1}; table S5). All of these recharge estimates refer to aquifer outcrop zones; however, most O&G water supply wells in the western part of the play are in the deeper confined parts of the aquifers (1000–7000 ft deep, 300–2000 m) (figure S5). Net flow to the downdip confined aquifer was estimated to be ~34% of the outcrop recharge for the Carrizo–Wilcox aquifer, the dominant aquifer in the west, based on the GAM [26]. Applying the percentage of deep recharge in the Carrizo aquifer (34%) to other confined aquifers in the play as an estimate results in net recharge of ~20 bgal yr^{-1} (76 bL yr^{-1}), which is similar to HF water use in 2013 (17.8 bgal) but is ~86–89% less than total water withdrawal in 2011 and 2012 in the play area. Therefore, relying on recharge alone for HF is inadequate because recharge is not uniformly distributed in the play (figure S10) and most of the HF water supply wells are in the deep confined aquifers with very low recharge rates.

The largest water source for HF is groundwater storage in the play area. A previous study of water sources for irrigation pumpage in the confined portion of the Carrizo–Wilcox aquifer indicates that ~60% of the pumped water was derived from aquifer storage, which is not sustainable and has resulted in groundwater depletion [21]. Freshwater extends far downdip in the Carrizo aquifer in the western part of the play, reflecting high permeability sands but is much more limited in the east [35] (figures 2(b), (c), S9). Drainable freshwater

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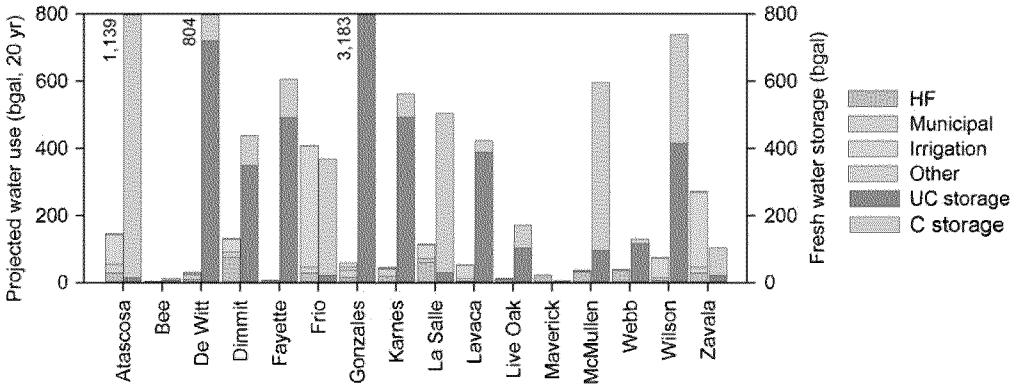

Figure 6. Comparison of estimated 20 yr water demand by sector relative to estimated total fresh water storage in the Eagle Ford play area. 'Other' category includes manufacturing, electrical power generation, and livestock sectors combined. HF demand based on highest established well density for seven production zones from this study and the remaining sector demands estimated as 20 times the respective 2000–2012 annual sector mean values (TWDB). Unconfined (UC) and confined (C) fresh water storage values based on the groundwater availability models (GAMs).

storage in the unconfined portions of the aquifers, estimated from integration of TDS data (figures S19–S23) with storage from the GAMs, totaled ~6000 bgal (22 700 bL, tables 1 and S6); however, most HF water supply wells are completed in the confined portions of the aquifers, with compressible freshwater storage of ~3800 bgal (14 400 bL) in the play area (table S6). Projected total HF water demand (330 bgal, 1200 bL) represents ~3% of freshwater storage (9800 bgal, 37 000 bL) at the play level (table S4). The projected 20 yr water demand from all sectors (~1400 bgal based on average 2000–2012 withdrawals) is mostly irrigation (62%) and municipal (12%) use, and represents ~14% of total freshwater storage in the play (table S4). Projected HF water demand at the county level ranges from <1–27% of total freshwater storage (figure 6, table S4). Projected water withdrawal for all sectors at the county level represents 1–36% of total freshwater storage for all counties except Frio (111%) and Zavala (262%) counties which are dominated by irrigation (90–95% of county water use).

A secondary source of water for HF is the Rio Grande for counties adjacent to the river, mostly Webb County. Diversions from the Rio Grande for mining in 2011–2013 ranged from 1.1 to 2.3 bgal yr^{-1} (4.2–8.8 bL yr^{-1}; table S8). Assuming this water is available for HF, it could provide HF water for ~230–500 wells/yr assuming an average water use of 4.8×10^6 gal/well, 18.2×10^6 L/well [6] (figure S12). However, there is limited drilling near the Rio Grande and operators do not normally transport water more than ~5–10 miles.

3.4. How vulnerable is water use for hydraulic fracturing to drought?

The 2011 drought was the most extreme on record for Texas, with precipitation in the play only 42% of the long-term mean (12.3/29.3 inches, www.prism.oregonstate.edu). Droughts generally have a much greater impact on surface water than groundwater; however, reported diversions from the Rio Grande for mining for 2011 were similar to those in 2012 and 2013 (table S8). Drought should not markedly impact water demand for HF or groundwater supply, particularly for the confined aquifers which have been recharging for several thousand years [36]. The main impact of the 2011 drought was related to increased water demand for irrigation (figure 5, table S2). The increase in water withdrawal related to irrigation from 2010 to 2011 (33 bgal, 125 bL) due to the 2011 extreme drought is similar to total HF water use for 2012 and 2013 combined (30 bgal, 114 bL). However, the main irrigation region, the Winter Garden region, is mostly north of the Eagle Ford play area and generally does not compete with HF water use (figures 1 and 4).

3.5. What legal issues impact hydraulic fracturing water use?

In addition to physical availability of water, legal access to water and regulations governing water resources need to be considered. Legal challenges relate to groundwater ownership in Texas, with current law providing that landowners have a 'vested property right' to groundwater in place [37]. Therefore, regulations, including reduced permits by Groundwater Conservation Districts that would restrict landowners' access to groundwater, may constitute 'a taking' and would have to be compensated [38]. These recent rulings call into question the scope and authority of GCDs. In addition, because of confusing language in the Texas Water Code (SI, section 9), it is not clear whether groundwater produced for HF activities is exempt from GCD regulation. While groundwater use for O&G exploration in Texas is exempt from regulation, confusion results from whether to consider HF part of exploration or production.

Groundwater management by the GCDs is based on estimates of desired future conditions (DFCs) for aquifers within groundwater management areas that result from joint-planning efforts by multiple GCDs (Texas Water Code §36.108). In Groundwater Management Area 13, covering most of the Eagle Ford play (figure S4), the desired future condition is a not-to-exceed area-average drawdown of 23 ft (7 m) across the GCD by 2060. However, localized

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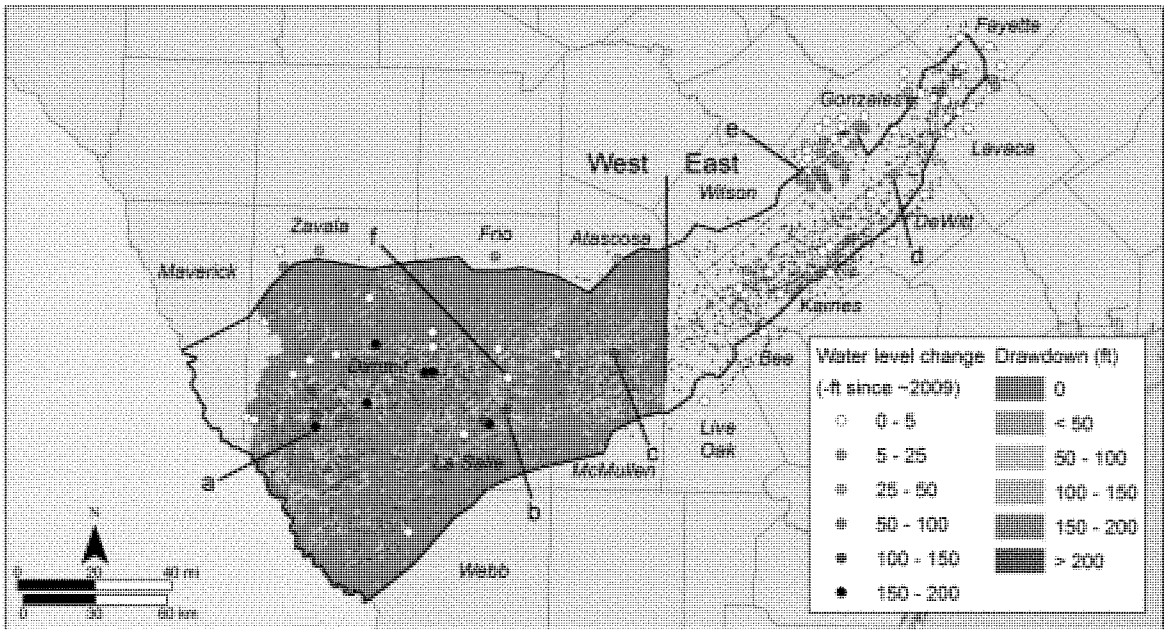

Figure 7. Monitored water level changes (large circular symbols) and estimated drawdown (1 square mile grid cells in west) in the Eagle Ford play. Monitored data are based on groundwater wells from TWDB database showing changes since 2009 when hydraulic fracturing began in the Eagle Ford play. Small gray points represent locations of oil and gas water supply wells. The gridded drawdown map in the western region represents estimated water level changes in the Carrizo–Wilcox aquifer resulting from pumping of water for hydraulic fracturing (HF) from 2009–2013. The analysis was restricted to the west because most water is derived from the Carrizo–Wilcox aquifer in this region. Water for HF is assumed to be derived entirely from compressible aquifer storage in the Carrizo–Wilcox aquifer, neglecting any water derived from recharge or cross-formational flow. Water declines >100 ft occur in 6.2% of the area, >150 ft in 3.7% of the area, and >200 ft in 2.3% of the area. There is general correspondence between the estimated water-level declines and those recorded in monitoring wells with large declines generally coinciding with areas of dense drilling to support HF.

drawdown in pumping centers will likely exceed this amount. This desired future condition translates to modeled available groundwater of ~150 bgal yr^{-1} (570 bL yr^{-1}) from the GAMs to honor the drawdown limitation and planning horizon. The 2013 HF water use (18 bgal, 68 bL) corresponds to ~12% whereas total withdrawal from all sectors (142 bgal, 538 bL) represents ~95% of the annual modeled available groundwater in this region. These desired future conditions will be revised in 2016 and should reflect groundwater pumpage for HF in the region.

3.6. What impacts does hydraulic fracturing water use have on water resources?

Groundwater level monitoring data from 131 wells in the play area indicate that water levels have declined to a maximum depth of ~200 ft (~60 m) in the west and mostly □50 ft (15 m) in the east (figures 7, 8, and S13). Greater declines in the west may be related to the deeper O&G water supply wells completed mostly in confined aquifers relative to shallower wells in the east, many of which may be completed in unconfined aquifers (figure S5). The specific yield for most of the unconfined aquifers is ~0.15 whereas the average storativity of the confined Carrizo–Wilcox aquifer in the west is 0.0012 (table S7). The ratio of the volumetric extent of cones of depression in confined versus unconfined aquifers is equivalent to the ratio of specific yield to storativity, about a factor of 1000 in many cases [39] (SI, section 9). A crude estimate of the impacts of HF water use to date (2009–2013) on groundwater levels in the confined Carrizo–Wilcox aquifer in the west was based on the assumption that all HF water was sourced from compressible aquifer storage within a mile of HF wells (figure 7). While water-level declines are small in much of the region, with 69% of western play area having no declines, 74% □25 ft (7.6 m) decline, and 81% □50 ft (15 m) decline, large declines (mostly 100–200 ft, 30–60 m) were found in 6% of the land area (figure 7). These estimates of water-level declines are generally consistent with the limited water-level monitoring data and coincident with high density of HF wells.

Impacts of past irrigation pumpage can be used as an extreme example of potential impacts of future HF water use in the region. Irrigation in the Winter Garden district lowered groundwater levels by up to 330 ft (100 m) regionally during the past century, decreasing water storage by ~4000 bgal (15 000 bL) in the Carrizo–Wilcox aquifer (figure S14). Irrigation pumpage reversed groundwater discharge in much of the region and changed some rivers (Atascosa, Frio, and San Antonio rivers) from gaining to losing [21]. No land subsidence has been recorded in this region in response to groundwater depletion, most likely because the sediments are generally indurated. Projected HF water use over the 20 yr life of the play is ~10% of groundwater depletion from past irrigation. The lack of subsidence from past depletion suggests that HF pumpage should not cause subsidence. HF pumpage may not impact rivers in the west, which are already

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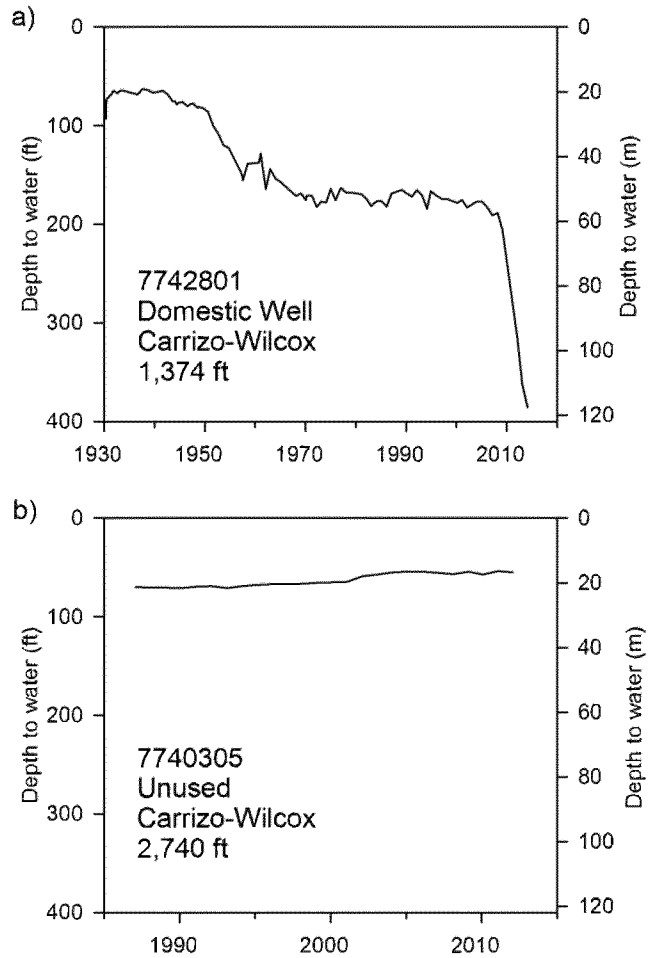

Figure 8. Water level hydrographs for '(a) groundwater well location 'a' and (b) groundwater well location 'f' in figure 7. Well 'a' shows long term water level declines resulting from irrigation withdrawals followed by recent rapid water level declines resulting from water withdrawal for hydraulic fracturing. Well 'f' shows slight increases in water levels during the period of record and no discernable water level impacts resulting from HF withdrawal. Analysis of water demand for HF indicates that these large water level declines are restricted to ~6% of the play area in the west (figure 7).

losing, but could impact river flow in the east which are mostly perennial (figure S15, table S9).

3.7. What is the net impact of hydraulic fracturing water use considering life cycle assessment (LCA)?

Previous studies emphasize the net impact of HF water use on water resources using a LCA of gas production [16, 40, 41]. The primary market for natural gas is thermoelectric power generation, with natural gas representing ~50% of power generation in Texas in 2012 (SI, section 10, figure S16). Most natural gas power plants in Texas have combined cycle generators (NGCC, 170 out of 215 TWh, 80%) with consumptive cooling water requirements totaling ~32 bgal (121 bL) in 2012 (~0.19 gal kWh^{-1}) [30]. Power generation at NGCC plants in Texas in 2012 (170×10^{12} Wh) corresponds to 580×10^{12} Btu of energy (3.412 Btu Wh^{-1} of electricity) requiring 1318×10^{12} Btu of natural gas assuming 44% fuel efficiency of NGCC power plants in Texas (i.e. 44% of the energy goes to electricity with the remaining 56% to waste heat). The amount of water required to extract Eagle Ford shale gas is estimated to be 1.5 gal/10^6 Btu [6]. If the natural gas required to power all Texas NGCC power plants during 2012 had been produced entirely from the Eagle Ford, this would represent ~2 bgal (7.6 bL) of water to extract the gas (1318×10^{12} Btu × 1.5 gal/10^6 Btu = ~2.0 bgal of water). Therefore, water consumption for extracting the gas represents ~6% of the cooling water consumed at the NGCC power plants (2.0 bgal/32 bgal), similar to the estimate of 6% for the Marcellus shale gas in Pennsylvania [40]. In addition, recent replacements of retiring coal steam turbine plants with NGCC plants, which have 1/3rd of the cooling water requirements, result in a net savings of water in the state [32, 42]. However, this water savings does not occur where the gas is produced in the west but where the power in generated, mostly in the central and eastern parts of the state.

Many suggest that the net impact of HF water use on water resources and the hydrologic cycle is much greater than that of other sectors, such as irrigation, because FP water in Texas is mostly disposed of in deep injection wells and removed from the hydrologic cycle (figure S5). However, in the Eagle Ford play, most of the water used for HF is not part of the active hydrologic cycle to begin with as it is mostly derived from deep confined aquifers that have been recharging for several thousand years [36]. In addition, previous studies indicate that methane combustion from natural gas in the Marcellus Shale play puts water vapor back into the hydrologic cycle (5.7×10^6 gal/well, 22×10^6 L/well) that more than compensates for HF water use (3.6 mgal/well, 14×10^6 L/well) [40]. Similar calculations for the Eagle Ford indicate that water vapor from methane combustion alone based on methane production to date is equivalent to ~90% of HF water use in the play (SI, section 10), ignoring water vapor generated by combustion of other hydrocarbons produced in the play.

3.8. What strategies can O&G operators adopt to increase resilience of hydraulic fracturing to water constraints?

Operators are considering various approaches to reduce vulnerability of HF to water constraints and reduce impacts of HF on water resources. The basic approaches include reducing water demand, increasing water supplies (particularly non-freshwater supplies), and intersectoral transfers (primarily from irrigation to HF). Water demand can be reduced by changing HF fluid types as shown by a recent analysis indicating ~55–110% higher water demands associated with slickwater HF relative to cross-link gel HF; however, these changes in HF fluid types generally occurred in the early stages of Eagle Ford play development [6]. Water demand can also be reduced through reuse-recycling of FP water. Non-freshwater sources include brackish water and municipal waste water.

3.8.1. Flowback/produced water. Small FP water volumes generally do not support reuse/recycling requirements. FP/HF

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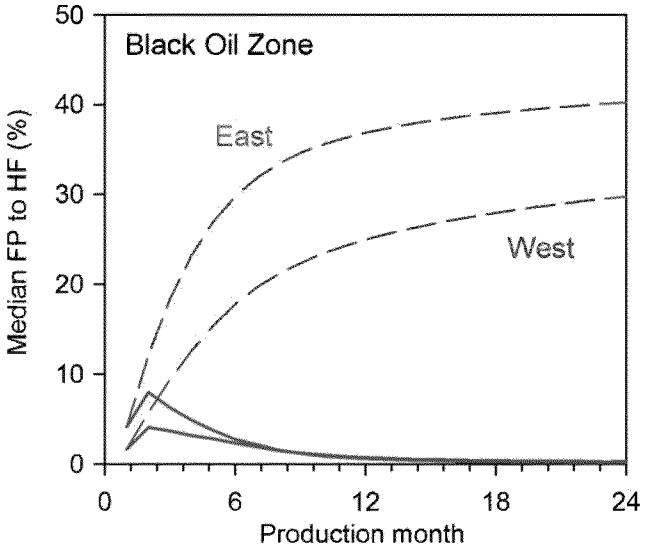

Figure 9. Monthly (solid lines) and cumulative (dashed lines) median FP to HF ratio in the east and west regions of the Black Oil production zone.

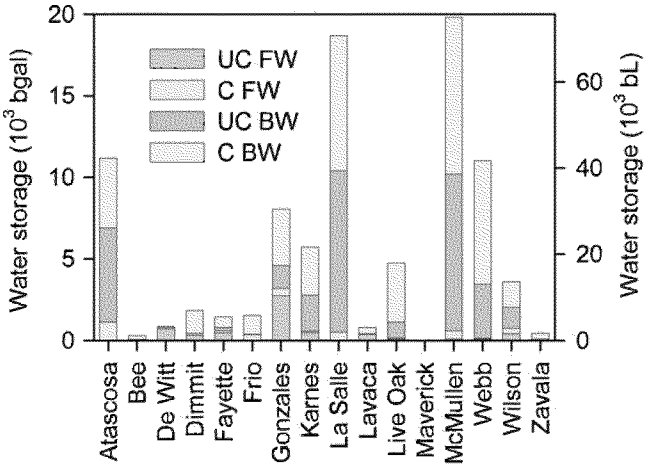

Figure 10. Estimated total fresh water (FW) and brackish water (BW) storage under unconfined (UC) and confined (C) aquifer conditions by county in the Eagle Ford play based on groundwater availability models (GAMs) and water quality data.

ratios are generally <5% within the first month of well completion in all production zones, making it difficult to collect sufficient water to support recycling for HF (figures 9, S18). Most FP water is disposed of in the ~700 active UIC Class II injection wells in the 18 county area, including and extending beyond the 16 counties in the Eagle Ford play (figure S5). The quality of the FP water is not highly saline, with reported values of ~40 000 mg L^{-1} TDS. Some operators are doing a limited amount of recycling; however, there is no formal reporting of these volumes. Portable treatment units are used to treat the FP water, particularly for reducing boron levels, which must be managed for the cross-link gel HF fluid additives. The logistics of recycling is complicated because of the low FP volumes. The economics of recycling is also generally not favorable with relatively low injection well disposal costs.

To promote reuse/recycling of FP water the Texas Railroad Commission modified their rules in March 2013. The new rules allow operators to recycle FP fluids on their own leases or they can transfer those fluids for recycling to another operator without the need for a permit [43]. Some operators report that these new rules promote increased reuse/recycling of water.

3.8.2. Brackish groundwater resources. There is an estimated ~35 000 bgal (130 000 bL) of brackish water in unconfined sections of aquifers and ~45 000 bgal (170 000 bL) of compressible brackish groundwater storage in the confined sections of the aquifers in the Eagle Ford play area, totaling 80 000 bgal (300 000 bL, figure 10, tables 1, S4, S10). Projected 20 yr HF water demand represents 0.4% of brackish groundwater storage, suggesting sufficient water at a play level. At the county level, projected HF water use is ⩽16% of total brackish water storage (table S4). Projected total water demand by all sectors represents ~2% of brackish water storage at the play level and ranges from 0–13% of brackish water storage, with the exception of Frio (35%) and Zavala (78%) counties where irrigation is dominant and DeWitt county (62%) where brackish water is limited.

A previous survey of operators in 2010 indicated that ~20% of the HF water use throughout the play was brackish [44]; however, HF water use has expanded greatly since that time. To avoid impacting shallower domestic wells, many operators report drilling into deeper units to limit the potential for competition for shallow groundwater. Some operators indicate that 60–80% of their water use is brackish (e.g. Marathon Oil Company reported 85% of their water use in 2012 was non-freshwater, [45]); however, there is no formal reporting of this water source. Another operator reported flowing artesian production from a 6000 ft (1800 m) deep well in the eastern part of the play (Dewitt County) with TDS of ~36 000 mg L^{-1}. Water treatment is often required to make the water compatible with HF fluid additives. To incentivize use of brackish groundwater, the Pecan Valley GCD recently revised their regulations to allow up to 20 times more groundwater pumpage if brackish water is withdrawn from the aquifer (SI, section 9).

3.8.3. Municipal waste water. Some municipalities are selling their waste water to intermediary companies to provide water to operators (SI, section 11). For example, Laredo Utilities Department contracted 5×10^6 gal d^{-1} (19×10^6 L) which could be used to HF 380 wells/yr (4.8 mgal/well) or could supply ~50% of HF water in Webb county based on 2012 HF water use (table 1). However, infrastructure needs to be built to transport this water to HF sites. Most municipal waste water was previously disposed of in surface water bodies using a National Pollution Discharge Elimination System permit. The Texas state water plan projects continually increasing municipal water demand in the future; therefore, municipalities may require this waste water to meet their own future water demands.

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3.8.4. Purchasing water from irrigation. Intersectoral water transfers have been proposed in semiarid regions, primarily purchasing water from the irrigation sector [13, 14]. However, the dominant irrigation region in the Eagle Ford play (Winter Garden region) is generally not collocated with the highest density of HF wells (figures 1 and 4), reducing the feasibility of intersectoral water transfers within the play. However, another study suggested that increasing irrigation efficiency in the Lower Rio Grande Valley, downstream of the Eagle Ford play, could provide ~250–500 bgal water/yr for HF, though infrastructure development would be required to transport the water to HF sites [46].

3.9. Overall water supply versus demand and related uncertainties for the Eagle Ford Play

The previous discussions of water demand versus supply focused on fresh and brackish water separately. However, projected HF water demand is a small percentage of total water resources at both the play (0.4%) and the county (0.1–6%) levels. Projected total water demand for all sectors (HF, irrigation, municipal and other) is also a small percentage of total available water at the play level (1.6%) as well as at the county level for most counties (0.2–7%), excluding two counties with high irrigation demands (Frio: 27%, Zavala: 60%), and one county (Maverick) that has essentially no modeled available groundwater resources in the play (table S4). Mapping the relationship between demand and supply indicates that there should not be problems with available water throughout much of the play, with the highest demands relative to supplies focused where irrigation demand is currently high in the northwest (figure 11).

Uncertainties in water demand to date (2009–2013) are considered relatively low because of the reporting requirements and availability of multiple databases [6]. The analysis of water demand in the Eagle Ford play is hindered by lack of reporting requirements for the source of water used for HF (e.g. surface water, groundwater, recycled FP water) or the quality of the water used (fresh versus brackish). Uncertainties in projected HF water demands are considered high because they are based on the assumption that the HEWD to date will apply to entire O&G production zones. A much more granular analysis based on square mile productivity and considering production economics, such as that available for the Barnett play [7], is required to improve estimates of projected HF water demand. This level of analysis is currently being conducted for a project funded by the Sloan Foundation [47]. Uncertainties in water demand for other sectors also need to be considered and are considered high for irrigation. Current studies funded by TWDB are evaluating remote sensing approaches to improve these estimates [48].

Data on water supplies in the Eagle Ford rely heavily on GAMs for the region. These models were designed to assess mostly freshwater resources in aquifers; however, the Bigford and Laredo Fms. which are stratigraphically equivalent to the Queen City and Sparta, respectively, west of the Frio River are not considered aquifers and recharge and storage estimates are considered less reliable west of the Frio River. The emphasis of these models is on fresh water and estimates of brackish water are not as reliable because of limited data availability. Future models should be developed that focus on brackish water resources and integrate data being collected by industry in these regions. A recent analysis of geophysical logs in the Eagle Ford play supports the estimated volumes of brackish water in these regions [49] (figure S24). While comparisons of water demand versus supply in this study have been limited, future modeling would provide more comprehensive comparisons that would include all the water sources, including groundwater from recharge and fresh and brackish water storage, and leakage from adjacent geologic units. More detailed models may be required for assessing water demand versus supply at the level of municipalities. The impact of pressure loss in confined aquifers on well yields is not known in detail. In particular, how many water wells would be required to produce similar water volumes and would water production be economical?

While the current water level monitoring network has been invaluable in documenting impacts of water use in the play on groundwater depletion, this network should be expanded and should be designed to provide detailed information in critical areas, such as those in the vicinity of municipal well fields.

4. Comparison with shale plays in other semiarid regions

The semiarid Permian Basin in west Texas includes conventional and unconventional production, with HF water use totaling 10.4 bgal (39 bL) from 9308 wells for 2.5 years (2011–mid-2013) [5]. Water use for conventional production has shifted from predominantly fresh (85%) in 1995 to brackish and produced water (80%) in 2010 based on a survey of operators in 2010 [44]. HF water use may follow a similar trend, with many current lease agreements stipulating freshwater use to provide revenue streams to landowners. Some use the term 'water play' to refer to the water markets in this region. A reconnaissance analysis from GAMs indicates large volumes of brackish groundwater resources in the underlying aquifers (figure S25), totaling an estimated 360 bgal (1360 bL) in compressible storage (table S11) [50]. Uncertainties in the location and accessibility of these brackish resources should decrease with increased exploration and production. Collocated unconventional and conventional energy production means that the large volume of produced water with conventional oil production (volumetric produced water to oil ratio of ~8 from 2009–2012, table S12, similar to that in the USA [51]), may provide additional water for HF in the region, if it is not used for water flooding for conventional oil production. Presentations in a recent symposium sponsored by the Railroad Commission of Texas on reuse/recycling of water indicated increasing trends in some companies to use brackish and FP water and discontinue use of freshwater [52] (SI, section 12).

The Bakken play is the second largest shale oil producer in the USA with HF water use of 16 bgal (60 bL) for 7868 wells from 2005 through 2013 [6]. Low precipitation rates in the Bakken play in North Dakota and Montana (mean 14.6

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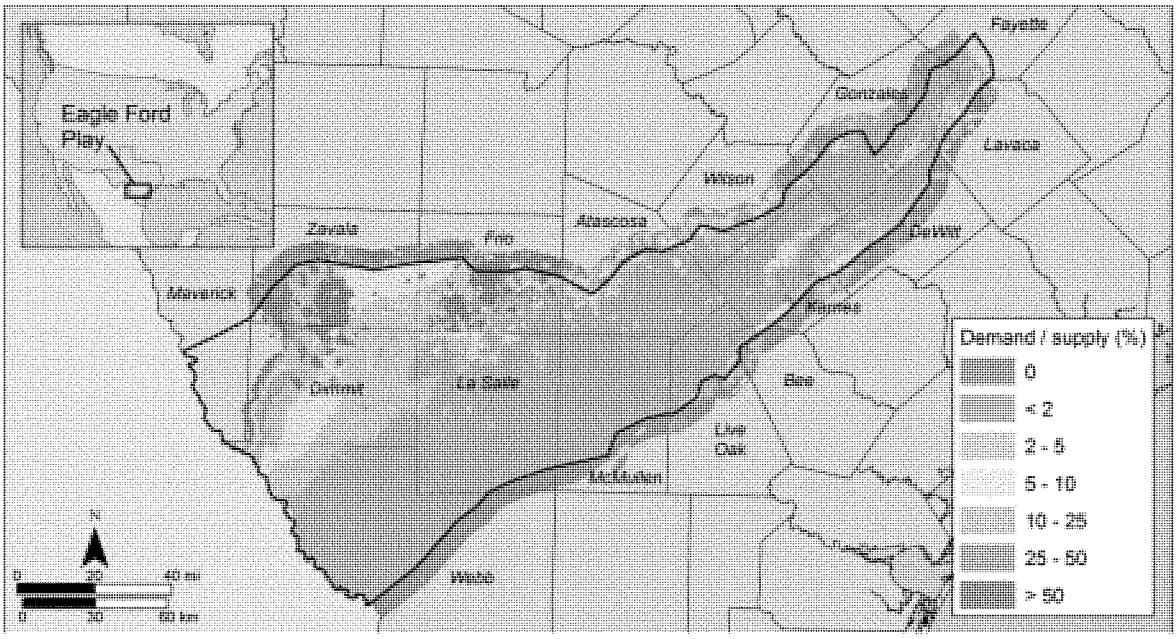

Figure 11. Distribution of the projected total 20 yr water demand for the HF, irrigation, and municipal sectors expressed as a percentage of available total groundwater storage per square mile, including freshwater and brackish water. HF demand assumes that the Eagle Ford play matures to the current seven-zone highest established well density in each production zone (figure S7) and that irrigation and municipal demands equal the average annual sector demands for the period 2000–2012 multiplied by 20 yr (projected life of the play) (figure S8). Note this depiction does not account for distribution or transport of water demand or supply across cell boundaries and assumes the current land use footprint remains static. Higher percentage of demand versus supply areas located along the southeastern play boundary in Lavaca, DeWitt, Karnes, and Bee counties reflect the Carrizo–Wilcox, Queen City-Sparta, and Yegua-Jackson GAM model limitations in regions with high groundwater TDS.

inches/yr (370 mm yr^{-1}), 1981–2010, PRISM precipitation, figure S26) might suggest that HF production could be vulnerable to water constraints. However, the Missouri River provides a major source of water in the region, with the Sakakawea Reservoir (7800 bgal (30 000 bL) storage capacity, figure S27) located in the middle of the Bakken play, though regulatory issues currently limit access to this water source, which is controlled by the USA Army Corps of Engineers. Additional water is provided by groundwater with water depots in different regions of the play. In addition, low population density and limited irrigation, particularly in the North Dakota region of the play, reduces water stress in the region (table S13).

5. Conclusions

(1) Water demand for HF in the Eagle Ford (18 bgal in 2013) represents 16% of consumptive water use in the play area. Maximum projected HF water use over the next 20 yr is 330 bgal from 62 000 additional wells, representing ~8 times HF water use to date. Projected HF water use represents ~10% of historic groundwater depletion resulting from irrigation in the adjacent Winter Garden region over the last century.

(2) Water supplies for HF include groundwater recharge, estimated to be ~60 bgal yr^{-1} in the aquifer outcrop area and ~20 bgal yr^{-1} in the deep confined aquifers.

(3) Additional water supplies are provided by fresh groundwater storage, with projected HF water use (330 bgal) representing ~3% of groundwater storage in the play.

(4) While regional impacts of water pumpage to support HF are small, localized impacts can be large with estimated water level declines of ~100–200 ft in ~6% of the western play area.

(5) The net impact of HF water use based on life cycle of natural gas is low, with HF water use for gas extraction representing ~6% of water consumed at the power plants.

(6) Brackish groundwater may provide a viable alternative to freshwater with projected HF water use representing 0.4% of the estimated 80 000 bgal of brackish groundwater storage.

(7) There is limited potential for reuse or recycling of flowback or produced water because of small volumes (□5% of HF water requirements in the first month) in the Eagle Ford play.

(8) Evaluation of HF water use in the semiarid Permian Basin play in Texas indicates increasing use of brackish groundwater and recycling of produced water, which benefits from large volumes of produced water from collocated conventional oil production (volumetric water: oil ratio of ~8). In the Bakken play in N Dakota and Montana, water inputs from outside this dry basin through the Missouri River provide a large potential

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resource for HF, although currently limited because by regulatory restrictions.

(9) The comprehensive analysis of Eagle Ford water issues and comparison with other semiarid plays indicates that, with proper management, water should not constrain HF in these semiarid regions.

Acknowledgments

We would like to acknowledge the Jackson School of Geosciences, the Shell University of Texas Unconventional Research (SUTUR) program, BP, and the Mitchell Foundation for funding this study. We would also like to acknowledge free access to the Enerdeq database provided by IHS. We are very grateful to Dr Yun Huang for input to model parameters for the southern Carrizo–Wilcox aquifer. We appreciate communications with various O&G operators in the Eagle Ford play and discussions with members of the South Texas Energy and Economics Roundtable. We appreciate input on groundwater modeling from Shirley Wade and groundwater monitoring from Janie Hopkins, both at TWDB. We are grateful for reviews by Walt Ayers (Texas A&M Univ.), Jim Bradbury (James D Bradbury PLLC), Ron Green (Southwest Research Institute), Robert Mace (TWDB), William Mullican (Mullican & Associates), and two anonymous reviewers.

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To: Ridley, Caroline[Ridley.Caroline@epa.gov]; LeDuc, Stephen[LeDuc.Stephen@epa.gov]
From: Shari Ring
Sent: Thur 3/19/2015 3:40:50 PM
Subject: RE: HFDWA management review comments and responses
Chapter 6 comments and responses on HFDWA for Tom_20150317.docx

Attached are brief responses to the comments on Chapter 6.

Ex. 5

Shari Ring

The Cadmus Group, Inc.

Ex. 4

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Tuesday, March 17, 2015 1:52 PM
To: Jonathan Koplos; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari Ring; Weaver, Jim; Cluff, Maryam; Mary Ellen Tuccillo; Stanek, John; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen
Subject: HFDWA management review comments and responses

Hi, team,

Your quick help is needed.

Attached is a distilled set of comments received during the ORD management review. Ex. 5

Ex. 5

Ex. 5

We need your **responses by COB Thursday March 19**.

Thank you!!!

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): **Ex. 6**
~~~~~~

To: LeDuc, Stephen[LeDuc.Stephen@epa.gov]; Fleming, Megan[Fleming.Megan@epa.gov]
From: Clark, Christopher
Sent: Wed 3/18/2015 6:59:23 PM
Subject: RE: Options paper for Kevin
Options for Kevin_20150317_sdl_cmc.docx

Hi all,

Here are my comments/edits to the doc, feel free to use or not. Talk to ya soon! (I'll call in)

Chris

Christopher Michael Clark, Ph.D.
Research Scientist
U.S. Environmental Protection Agency
Office of Research and Development
National Center for Environmental Assessment
Global Change Assessment Staff

Phone: (703) 347-8665

Mailing Address:

US EPA (8601-P);1200 Pennsylvania Ave NW; Washington DC, 20460

Physical Address:

US EPA Potomac Yards; 2733 South Crystal Drive; N-7834; Arlington, VA 22202

From: LeDuc, Stephen
Sent: Tuesday, March 17, 2015 4:07 PM
To: Fleming, Megan; Clark, Christopher
Subject: RE: Options paper for Kevin

Hi Megan,

Here are my edits. And yes, we should send this to Jeff and Kevin tomorrow. I'll ask Jeff right now how he'd like us to proceed, and cc' you.

Ex. 5

Best,

Steve

From: Fleming, Megan
Sent: Tuesday, March 17, 2015 2:11 PM
To: LeDuc, Stephen; Clark, Christopher
Subject: Options paper for Kevin

Hi Steve and Chris,

Please take a look at this Options paper I mocked up Ex. 5 Ex. 5 Please make any edits or suggestions you see fit.

Steve – should we send this to Jeff/Kevin sometime tomorrow maybe?

Thanks,

Megan

Megan Fleming
Office of Science Policy

U.S. EPA Office of Research and Development

1200 Pennsylvania Avenue, N.W.

Washington, D.C. 20460

(202)-564-6604

To: LeDuc, Stephen[LeDuc.Stephen@epa.gov]
From: Penalva-Arana, Carolina
Sent: Tue 3/17/2015 7:43:53 PM
Subject: HF - Human and animal health reference
Bamberger&Oswald_DrillingHuman&AnimalHealth_2012.pdf

Here is the reference Sue mentioned I had found that talks about the effects seen on household pets.

Enjoy!

Carolina

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NEW SOLUTIONS, Vol. 22(1) 51-77, 2012

Scientific Solutions

IMPACTS OF GAS DRILLING ON HUMAN AND ANIMAL HEALTH

MICHELLE BAMBERGER
ROBERT E. OSWALD

ABSTRACT

Environmental concerns surrounding drilling for gas are intense due to expansion of shale gas drilling operations. Controversy surrounding the impact of drilling on air and water quality has pitted industry and leaseholders against individuals and groups concerned with environmental protection and public health. Because animals often are exposed continually to air, soil, and groundwater and have more frequent reproductive cycles, animals can be used as sentinels to monitor impacts to human health. This study involved interviews with animal owners who live near gas drilling operations. The findings illustrate which aspects of the drilling process may lead to health problems and suggest modifications that would lessen but not eliminate impacts. Complete evidence regarding health impacts of gas drilling cannot be obtained due to incomplete testing and disclosure of chemicals, and nondisclosure agreements. Without rigorous scientific studies, the gas drilling boom sweeping the world will remain an uncontrolled health experiment on an enormous scale.

Keywords: hydraulic fracturing, shale gas drilling, veterinary medicine, environmental toxicology

> At what point does preliminary evidence of harm become definitive evidence of harm? When someone says, "We were not aware of the dangers of these chemicals back then," whom do they mean by *we*?
>
> —Sandra Steingraber, *Living Downstream* (Da Capo Press, 2010)

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doi: http://dx.doi.org/10.2190/NS.22.1.e
http://baywood.com

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Communities living near hydrocarbon gas drilling operations have become de facto laboratories for the study of environmental toxicology. The close proximity of these operations to small communities has created a variety of potential hazards to humans, companion animals, livestock and wildlife. These hazards have become amplified over the last 20 years, due in part to the large-scale development of shale gas drilling (horizontal drilling with high-volume hydraulic fracturing), encouraged by the support of increased drilling and exploration by U.S. government agencies [1]. Yet this large-scale industrialization of populated areas is moving forward without benefit of carefully controlled studies of its impact on public health. As part of an effort to obtain public health data, we believe that particular attention must be paid to companion animals, livestock, and wildlife, as they may serve as sentinels for human exposures, with shorter lifetimes and more opportunity for data collection from necropsies.

All phases of hydrocarbon gas production involve complex mixtures of chemical substances. For example, in hydraulic fracturing fluids, chemical substances other than water make up approximately 0.5 to 1 percent of the total volume; however, the very large volumes used require correspondingly large volumes of a variety of compounds. These substances range from the relatively benign to the highly toxic. Some of these are reported to the public and others are not, but the quantities and proportions used are largely considered trade secrets. In addition to these added chemicals, naturally occurring toxicants such as heavy metals, volatile organics, and radioactive compounds are mobilized during gas extraction and return to the surface with the gas/chemical mix (wastewater); of the 5.5 million gallons of water, on average, used to hydraulically fracture a shale gas well one time [2], less than 30 percent to more than 70 percent may remain underground [3]. Hydraulic fracturing takes place over 2 to 5 days and may be repeated multiple times on the same well over the course of the potential 25- to 40-year lifetime of a well [4]. Many of these chemicals are toxic and have known adverse health effects, which may be apparent only in the long term. A discussion of these compounds and their health effects is beyond the scope of this article; however, Colborn et al. [5] have analyzed this topic in depth.

The large-scale use of chemicals with significant toxicity has given rise to a great deal of public concern, and an important aspect of the debate concerns the level of proof required to associate an environmental change with activities associated with gas drilling. Environmental groups typically invoke the precautionary principle [6]. That is, if an action is suspected of causing harm to the environment, then in the absence of a scientific consensus, the burden of proof falls on the individual or organization taking the action. The oil and gas industry has typically rejected this analysis and has approached the issue in a manner similar to the tobacco industry that for many years rejected the link between smoking and cancer. That is, if one cannot prove beyond a shadow of doubt that an environmental impact is due to drilling, then a link is rejected. This approach

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by the tobacco companies had a devastating and long-lasting effect on public health from which we have still not recovered [7], and we believe that a similar approach to the impacts of gas drilling may have equally negative consequences.

Although reports of petroleum hydrocarbon exposure in humans [8-14], primates [15], and several other species, including ruminants [16-26], horses [27], wildlife [28], and a dog [29], have been cited in the literature, there are few reports on exposure of animals to gas operations, and to our knowledge, no case reports on exposure of humans to hydrocarbon gas operations [30]. Adler et al. [31] observed aspiration pneumonia in sheep following exposure to gas condensate. In another study, Waldner et al. [32] found no association between the productivity of cattle and exposure to a sour gas pipeline leak; while in a longer-term study [33] in cattle, the same group reported associations between sour-gas flaring and increased risk of stillbirth across three of the four years studied, as well as increased risk of calf mortality in one of the years studied. In a study of habitat selection, Sawyer et al. [34] found that mule deer tended to move away from areas of gas development, and in a recent report [35] from the same author, the deer population dropped by 45 percent in one year, and the survival rate decreased.

Just as epidemiologic studies linked smoking to human health impacts, such studies could be used to assess the health impacts of gas drilling operations on human beings. Studies in laboratory animals have also been a powerful tool for linking components of tobacco smoke to cancer, not only because controlled studies can be done but also because breeding cycles are short and the age at which cancer develops is within a range accessible to laboratory studies. Though such controlled animal studies of the effects of gas drilling are not feasible, animals can nevertheless serve as sentinels for human health impacts. Animals, particularly livestock, remain in a confined area and, in some cases, are continually exposed to an environmental threat. Further, effects on reproduction can be more readily assessed in a herd of cattle than in a human population, simply due to the higher rates of reproduction.

For the past year, we have been documenting cases of animal and owner health problems with potential links to gas drilling. Many cases are currently in litigation. To protect individuals' privacy and due to ongoing legal action, the discussion will not include personal identifying information. We summarize the results of our investigation, provide several case studies, and conclude with recommendations for minimizing or preventing similar problems in the future. This study is not an epidemiologic analysis of the health effects of gas drilling, which could proceed to some extent without knowledge of the details of the complex mixtures of toxicants involved. It is also not a study of the health impacts of specific chemical exposures related to gas drilling, since the necessary information cannot be obtained due to the lack of testing, lack of full disclosure of the International Union of Pure and Applied Chemistry (IUPAC) names and Chemical Abstracts Service (CAS) numbers of the chemicals used, and the

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industry's use of nondisclosure agreements. Nevertheless, the value of this study is twofold. First, clear health risks are present in gas drilling operations. These cannot be eliminated but can be decreased by commonsense reforms. Second, our study illustrates not only several possible links between gas drilling and negative health effects, but also the difficulties associated with conducting careful studies of such a link. Again, simple commonsense policy reforms could facilitate the collection of data that would lead to a careful assessment of the health consequences of gas drilling on both humans and animals.

SUMMARY OF THE EFFECTS OF GAS DRILLING ON PRODUCTION AND COMPANION ANIMALS AND ANIMAL OWNERS

To describe how exposures may occur, and to report health effects, we conducted interviews with animal owners in six states (Colorado, Louisiana, New York, Ohio, Pennsylvania, Texas) affected by gas drilling. In all but one case, we spoke directly with animal owners. The exception was a case that had previously been documented by the state environmental regulatory agency [36]. When possible, we interviewed the owners' veterinarians. Where available, we have obtained the results of water, soil, and air testing as well as the results of laboratory tests on affected animals and their owners. Documentation was obtained from the animal owners, the veterinarians (with permission of the owners), drilling company representatives, state regulatory agencies, and a Freedom of Information Act (FOIA) request from the Pennsylvania Department of Agriculture. Cases were identified by requesting referrals from environmental groups and individuals actively involved in influencing shale gas policy and studying its effects. For each case, a standard series of questions was asked, including the exact location of each owner's property; details on wells in the area (subsequently verified by crosschecking with state records and, using software developed for this project, mapping the wells relative to the owner's property); details of seismic testing and well flaring; location of wastewater impoundments; results of water, soil, and air testing; details of animal husbandry and medical records preceding, during and following drilling, depending upon the individual case; a list of animals (species, breed, age, sex, use (e.g., livestock)), sorted into those healthy and those unhealthy; health history for all animals; observations of wildlife in the area; and health histories of the humans living in the household. As each case is different, the standard form was used as a starting point, with additional information invariably supplied by individuals being interviewed.

More than one-third of the cases involved conventional wells (shallow or deep vertical wells), with the remainder comprising horizontal wells subjected to high-volume hydraulic fracturing. Because of the scale of the horizontal well drilling operations, such wells were more commonly associated with animal health problems. However, conventional wells have also had problems

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associated with faulty well casings and failure of blowout preventers; in our study, wastewater dumping and leakage, failure of a blowout preventer, and affected well water involving conventional gas wells were associated with both animal and human health problems.

By the standards of a controlled experiment, this is an imperfect study, as one variable could not be changed while holding all others constant. It also is not a systematic study that will provide the percentage of farms with problems associated with gas drilling, but the design is such that the study can illustrate what can happen in areas experiencing extensive gas drilling. It is also possible to observe temporal correlations between events such as well flaring and air quality, or hydraulic fracturing and water quality leading to toxicity. In two cases, spatial differences (cows in a single herd, with some allowed access to a creek or pond and others not allowed access) could be used to compare outcomes.

Table 1 summarizes the types of wells involved and the sources of exposure, and Table 2 describes the details of each individual case. In some cases, exposure was due to accidents or negligence, but at other times, it was a consequence of normal operations. Direct exposure to hydraulic fracturing fluid occurred in two cases: in one, a worker shut down a chemical blender during the fracturing

Table 1. Number of Cases, by Type of Gas Well and Source of Exposure[a]

Type of gas well	
Shallow vertical wells	4
Deep vertical wells	3
Horizontal high-volume hydraulically fractured wells	18
Source of exposure	
Hydraulic fracturing fluid spill from holding tank	2
Drilling fluids overran well pad during blow out	1
Storm water run-off from well pad to property	3
Wastewater impoundment leak	1
Wastewater impoundment allegedly compromised	1
Wastewater spread on road	2
Wastewater dumped on property	1
Wastewater dumped into creek	3
Wastewater impoundment not contained	3
Well/spring water	17
Pond/creek water	8
Pipeline leak	1
Compressor station malfunction	2
Flaring of well	3

[a]Total number of cases is 24; one case has two types of wells.

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Table 2. Summary of Individual Cases

Case	Type of gas well[a]	Source	Animal	Health impact
1	SV	Wastewater dumped on property and into creek	White-tailed deer	Body condition
2	SV	Well/spring water	Bovine	Reproduction, milk production
3	SV	Well/spring water Pond/creek water Drilling fluids overran well pad during blowout	Bovine	Reproduction
4	SV	Well/spring water Pond/creek water Wastewater impoundment allegedly compromised	Bovine Fish	Reproduction, growth Sudden death
5	DV	Well/spring water Pond/creek water	Equine Canine Human	Neurological Urological, gastrointestinal, dermatological Upper respiratory, burning of eyes, headache, gastrointestinal, dermatological
6	DV	Pond/creek water	Bovine	Reproduction
7	DV, HHV	Well/spring water	Canine Poultry Human	Reproduction, dermatological Sudden death, musculoskeletal, dermatological Upper respiratory, burning of eyes, neurological, gastrointestinal, headache
8	HHV	Well/spring water Pond/creek water Wastewater impoundment not contained Wastewater dumped into creek	Song birds Human	Sudden death Neurological, immunological
9	HHV	Pond/creek water Storm water runoff from well pad	Fish	Sudden death

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Table 2. (Cont'd.)

Case	Type of gas well[a]	Source	Animal	Health impact
10	HHV	Well/spring water Wastewater impoundment not contained	Ovine Canine Human	Reproduction Sudden death Gastrointestinal, neurological, upper respiratory, burning of eyes, dermatological, vascular, sensory, headache
11	HHV	Wastewater impoundment leak	Bovine	Reproduction
12	HHV	Storm water runoff from well pad	Canine Human	Neurological Gastrointestinal, headache, dermatological
13	HHV	Well/spring water Pond/creek water Pipeline leak	Equine	Neurological, gastrointestinal, musculoskeletal, upper respiratory
			Canine	Urological, gastrointestinal, musculoskeletal, neurological
			Amphibian	Sudden death
			Human	Upper respiratory, burning of eyes, bone marrow
14	HHV	Well/spring water Wastewater spread on road Wastewater impoundment not contained	Canine Human	Reproduction Neurological
15	HHV	Well/spring water	Canine	Gastrointestinal, dermatological
			Feline	Dermatological
			Human	Gastrointestinal, upper respiratory, burning of eyes, vascular, headache

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Table 2. (Cont'd.)

Case	Type of gas well[a]	Source	Animal	Health impact
16	HHV	Well/spring water	Llama	Reproduction, upper respiratory
			Human	Endocrine, upper respiratory, burning of eyes, vascular, dermatological, sensory
17	HHV	Well/spring water Flaring of well	Canine Feline	Urological Gastrointestinal, dermatological
			Human	Upper respiratory, burning of eyes, urological, dermatological, headache
18	HHV	Well/spring water	Ovine Poultry	Sudden death Sudden death
		Storm water runoff from well pad Flaring of well	Human	Vascular, gastrointestinal, headache
19	HHV	Well/spring water Hydraulic fracturing fluid spill from tank Wastewater dumped into creek	Equine Ovine Human	Reproduction Reproduction Neurological
20	HHV	Compressor station malfunction Flaring of well	Canine	Upper respiratory
			Human	Upper respiratory, burning of eyes
21	HHV	Well/spring water	Bovine	Neurological, reproduction
		Pond/creek water	Equine Poultry	Neurological Sudden death
		Compressor station malfunction	Human	Vascular, immunological
22	HHV	Well/spring water	Ovine Fish Human	Neurological Dermatological Dermatological, gastrointestinal

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Table 2. (Cont'd.)

Case	Type of gas well[a]	Source	Animal	Health impact
23	HHV	Well/spring water Wastewater spread on road	Equine Canine Human	Neurological Reproduction, gastrointestinal Reproduction, upper respiratory, burning of eyes, vascular, sensory, headache
24	HHV	Hydraulic fracturing fluid spill from tank	Bovine	Gastrointestinal, neurological, respiratory, sudden death

[a]SV = shallow vertical well, DV = deep vertical well, HHV = horizontal high-volume hydraulically fractured well.

process, allowing the release of fracturing fluids into an adjacent cow pasture, killing 17 cows in one hour; the other was a result of a defective valve on a fracturing fluid tank, which caused hundreds of barrels of hydraulic fracturing fluid to leak into a pasture where goats were exposed and suffered from reproductive problems over the following two years. Exposure to drilling chemicals occurred during a blowout when liquids ran into a pasture and pond where bred cows were grazing; most of the cows later produced stillborn calves with congenital defects. Exposure to wastewater occurred through leakage or improper fencing of impoundments, alleged compromise of a liner in an impoundment to drain fluid, direct application of the wastewater to roads, and dumping of the wastewater on creeks and land. The most common exposure by far was to affected water wells and/or springs; the next most common exposure was to affected ponds or creeks. Finally, exposures also were associated with compressor station malfunction, pipeline leaks, and well flaring. In addition to humans, the animals affected were: cows, horses, goats, llamas, chickens, dogs, cats, and koi. Other than photographing and recording the presence of dead and dying wildlife (deer, songbirds, fish, salamanders, and frogs) in the vicinity of affected pastures, creeks and ponds, the effect on wildlife has not been well documented.

Because production animals were exposed to the environment for longer periods and in greater numbers than companion animals, and because most of the farms we documented raised beef cattle, cows were represented to a greater extent than other animals. Exposures through well water, ponds, springs, dumping of

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wastewater into creeks, and spills or leakage of wastewater from impoundments were believed by farmers to result in deaths over time periods typically ranging from one to three days, with cows going down and unable to rise despite symptomatic treatment. The most commonly reported symptoms were associated with reproduction. Cattle that have been exposed to wastewater (flowback and/or produced water) or affected well or pond water may have trouble breeding. When bred cows were likewise exposed, farmers reported an increased incidence of stillborn calves with and without congenital abnormalities (cleft palate, white and blue eyes). In each case, farmers reported that in previous years stillborn calves were rare (fewer than one per year). In most cases where diagnostics were pursued, no final diagnosis was made; in other cases, acute liver or kidney failure was most commonly found. Of the seven cattle farms studied in the most detail, 50 percent of the herd, on average, was affected by death and failure of survivors to breed. In one case, exposure to drilling wastewater led to a quarantine of beef cattle and significant uncompensated economic loss to the farmers.

The most dramatic case was the death of 17 cows within one hour from direct exposure to hydraulic fracturing fluid. The final necropsy report listed the most likely cause of death as respiratory failure with circulatory collapse. The hydraulic fracturing fluid contained, among other toxicants, petroleum hydrocarbons and quaternary ammonium compounds (tetramethylammonium and hexamethylenetetramine). Although petroleum hydrocarbons were reported to be found in the small intestine, lesions in the lung, trachea, liver and kidneys suggested exposure to other toxicants as well, and quaternary ammonium compounds have been described as producing similar lesions [37].

Two cases involving beef cattle farms inadvertently provided control and experimental groups. In one case, a creek into which wastewater was allegedly dumped was the source of water for 60 head, with the remaining 36 head in the herd kept in other pastures without access to the creek. Of the 60 head that were exposed to the creek water, 21 died and 16 failed to produce calves the following spring. Of the 36 that were not exposed, no health problems were observed, and only one cow failed to breed. At another farm, 140 head were exposed when the liner of a wastewater impoundment was allegedly slit, as reported by the farmer, and the fluid drained into the pasture and the pond used as a source of water for the cows. Of those 140 head exposed to the wastewater, approximately 70 died and there was a high incidence of stillborn and stunted calves. The remainder of the herd (60 head) was held in another pasture and did not have access to the wastewater; they showed no health or growth problems. These cases approach the design of a controlled experiment, and strongly implicate wastewater exposure in the death, failure to breed, and reduced growth rate of cattle.

Companion animals were defined as those animals that were kept as pets, and included horses, dogs, cats, llamas, goats, and koi. Companion animal exposures typically occurred when animals ingested affected water from a well,

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spring, creek or pond. Reproductive problems (irregular cycles, failure to breed, abortions, and stillbirths) and neurological problems (seizures, incoordination, ataxia) were the most commonly reported. Other commonly reported symptoms included those of gastrointestinal (vomiting, diarrhea) and dermatological (hair and feather loss, rashes) origin.

In the majority of cases, owners of animals were exposed upon using their well or spring water for drinking, cooking, showering and bathing. Upper respiratory symptoms (including burning of the nose and throat) and burning of the eyes were the most commonly reported. Headaches and symptoms associated with the gastrointestinal (vomiting, diarrhea), dermatological (rashes), and vascular (nosebleeds) systems were commonly reported.

CASES ILLUSTRATING THE EFFECTS OF GAS DRILLING ON PRODUCTION AND COMPANION ANIMALS AND THEIR OWNERS

Case 1

Two homes (A and B) are located within two miles of approximately 25 shale gas wells. The closest pad, drilling muds pit, and wastewater impoundment are within one mile of both homes; the impoundment is approximately 4.5 acres in area and is at a higher elevation than either home. Two compressor stations are located within one mile of both homes. The owners have a variety of companion and farm animals, and reported no unusual pet morbidity or mortality preceding drilling operations. Predrilling tests on water sources were not done for either home. Soon after drilling began, the owner of Home B noted that her well water had an odor and black sediment, and the owners of Home A observed a decreased quantity of their water sources (a well and a spring). Once the wastewater impoundment was constructed, the owners of Home A noted a dramatic decrease in quantity, as well as poor quality, of both the well and spring water. The spring served as the sole source of water for the owners' farm animals. Approximately nine months after drilling began, the owners of Home A began hauling water from a nearby creek, to supplement the spring water.

Since drilling operations began, both owners have observed wastewater being spread on the roads during all weather conditions, and noted that cats and dogs in their neighborhood licked their paws after walking on the road, and also drank from wastewater puddles; some of these animals became severely ill and died over a period of one to three days following these exposures. According to the owner of Home B, the wastewater impoundment was not initially fenced and animals had direct access to the wastewater. An accident involving the wastewater impoundment was noted by both owners; after filling, a truck carrying wastewater drove away from the impoundment site with an open valve, releasing approximately 20 gallons of wastewater onto the impoundment access

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road and onto the road near the property of Home A. Most recently, both the drilling company and the state environmental regulatory agency were notified of a spill from the wastewater impoundment that flowed past temporary barriers and into a creek; based on soil erosion patterns, the owners of Homes A and B reported that this spill had been ongoing for months. Soon after this accident, a malfunction occurred in the wastewater impoundment aeration system, producing a raw sewage smell that persisted in the air around Homes A and B for days and sickened the families in both homes. When the owner of Home A complained, the drilling company offered to pay motel expenses for her and her family; this offer was declined because the owner refused to leave her animals.

Approximately a year after drilling began, an 18-year-old intact female American Quarter Horse in Home A had an acute onset of anorexia, malaise, rapid weight loss, and mild incoordination after testing normal on a physical examination a few weeks earlier. The horse was treated symptomatically with an antibiotic, steroid, and antihistamine. A few days later, the horse had become ataxic, and was treated for equine protozoal myeloencephalitis, although no diagnosis was made. The horse did not improve after three to four days and was treated again. Within a few days, the horse's neurological symptoms had progressed such that the horse was unable to rise. Blood and clinical chemistry parameters indicated acute liver failure due to toxicity. The veterinarian suspected heavy metal poisoning as a cause of the horse's sudden illness; this was not confirmed, as toxicology tests were not done. The horse was euthanized two weeks after onset due to poor prognosis and failure to respond. Similar neurologic signs were reported in another case in this study that involved two horses living adjacent to a deep, vertical gas well operation.

In addition, both homeowners were caring for animals that were bred at this time: the owner of Home B had a three-year-old intact female Boer goat that aborted two kids in the second trimester, and the owners of Home A had a five-year-old intact female Boxer that experienced dystocia with a fourth litter (after previously whelping three normal litters), producing one stillborn pup and one pup with cleft palate that died soon after birth. This same dog subsequently whelped a fifth litter of 15 pups in which seven pups were stillborn and eight pups died within 24 hours. All the pups were afflicted with congenital hypotrichosis; that is, they were born with the complete or partial absence of normal hair.

Soon after drilling and hydraulic fracturing began for the first well, a child living in Home B began showing signs of fatigue, severe abdominal pain, sore throat, and backache. Six months later, the child was hospitalized with confusion and delirium and was given morphine for abdominal pain. After the deaths of several animals as cited above, the child's physician suspected that the child's symptoms were of toxicological origin. A toxicology test revealed arsenic poisoning as the cause of the child's sickness. The family stopped using their well water despite test results indicating that the water was safe to drink, and the child gradually recovered after losing one year of school.

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During high-volume hydraulic fracturing, substances that occur naturally in the shale, including arsenic, come to the surface in wastewater. In this case, the wastewater was stored in the impoundment, where aerators misted the chemicals into the air, increasing the chances of inhalation by animals and people; also, surface spillage of wastewater, as noted above, could have contaminated the ground water. Tests on well water from both Homes A and B, and the spring from Home A, did not show elevated levels of arsenic; however, it is possible that, given fluctuations in the water table and water quality, high levels of arsenic may have initiated symptoms in the child in Home B and then dropped to low levels before water testing was done more than one year later. Also, reported arsenic levels may be deceptively low because arsenic can be converted to arsine-a toxic gas that dissipates rapidly [38]. In people, both acute and chronic oral exposure to inorganic arsenic causes gastrointestinal effects as well as effects on the nervous system: short-term effects include headaches, weakness, and delirium, while long-term effects include peripheral neuropathy [39]. Acute exposure of people to arsine can produce many effects including abdominal pain and headaches [39]. Animals exposed acutely to inorganic arsenic may show many symptoms including staggering gait, extreme lethargy, and intense abdominal pain, while animals exposed over a longer period of time may manifest signs including anorexia, depression, and partial paralysis of the rear limbs [40]. Animal studies show that arsenic can also cause fetal malformations and fetal death [41].

As the family in Home B continued to be screened for toxicants, random urine tests on all family members were positive for phenol, a metabolite of benzene, with dramatic increases over a period of a few months. Based on occupational health studies [e.g., 42], the testing laboratory judged these results to be consistent with chronic exposure to 0.5 to 4.0 ppm benzene in the air. The most recent symptoms observed by families in both homes include extreme fatigue, headaches, nosebleeds, rashes, and sensory deficits (smell and hearing). The child in Home B also had difficulty breathing, and again had to be taken out of school. Doctors of the families in both homes warned them to leave their homes for at least 30 days or suffer more severe health consequences. The owner of Home B followed her doctor's advice, and moved her children out of her home, returning each day to care for her animals; the owners of Home A elected to remain at their home to care for their animals. After one month of being away, the phenol levels as well as the symptoms of the children in Home B decreased, while the owner of Home B, who returns to the home for a few hours each day, has increased phenol levels and worsening of symptoms. One of the owners in Home A, who works at home, has experienced worsening of symptoms.

This case illustrates the importance of considering both animal and human health. Animals live among us and are exposed to the same environmental influences; however, they tend to suffer more direct exposure and have shorter life and reproductive cycles. If it were not for the numerous deaths of animals

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soon after shale gas operations began in this neighborhood, the child's doctor might not have ordered toxicology tests, as arsenic poisoning is not a common diagnosis.

Case 2

In this case, a beef cattle farmer had a herd of 96 cattle (Angus Limousine cross) that was divided among three pastures. The farm is located in an area of intensive gas drilling, with two active shallow vertical gas wells on the farmer's property and approximately 190 active gas wells within five miles of the property; of these, approximately 11 are shale gas wells and approximately 26 are deep vertical gas wells. In one pasture, 60 cows (a mixed herd, mostly 5- to 10-year-old bred cows) had access to a creek as a source of water. In a second pasture, 20 cows (bred yearlings) obtained water from hillside runoff, and in a third pasture, 14 feeder calves (8 to 14 months old) and two bulls had access to a pond. Over a three-month period, 21 head from the creek-side pasture died (17 adult bred cows and 4 calves). All the cattle were healthy before this episode. Despite symptomatic treatment, deaths occurred 1 to 3 days after the cows went down and were unable to rise. Basic diagnostics were done, but no cause of death was determined. On rendering, 16 of the 17 adults were found to have dead fetuses, nearly doubling this farmer's losses. Of the 39 cows on the creek-side pasture that survived, 16 failed to breed and several cows produced stillborn calves with white and blue eyes. The health of the cattle on the other two pastures was unaffected; on the second pasture, only one cow failed to breed. Historically, the health of the herd was good, the farmer reporting average losses of 1-2 cows a year in his herd of nearly 100 cattle.

This is an interesting case because it has a natural control group. That is, the cattle that were kept along the creek suffered severe problems while the cattle in pastures at a higher elevation and away from the creek experienced no morbidity or mortality. As discussed below, the contamination of the creek may have been caused by illegal dumping of wastewater. Fortunately, these cows were not taken to slaughter, as they died on the farm. However, they still may have entered our food chain as well as that of our pets: rendering plants produce feed for many non-ruminants including chickens, pigs, cats, dogs and horses, so it is possible that chickens, raised for egg production or meat, and pigs were fed the flesh from these cattle.

Case 3

This case concerns farmers that have raised beef cattle (Herford Simmental cross) for the past 21 years. Before drilling operations began the farmers lost one or two animals out of a closed herd of 33 (yearlings, heifers, mature cows, two bulls) every few years to illness or accident. There is one active shale gas well on the farmers' 530-acre property, and approximately six active shale gas wells within two miles of their property. A private well provides water for the family's

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use; the water for the herd comes from a creek that originates from springs above and below the well pad, and spillover from a pond below the well pad. The gas wellhead is 300 feet from the farmers' house and 250 feet from their water well. The well pad is 75 feet from their barn at higher elevation, and slopes directly down to the door. A one-acre impoundment, used to collect wastewater from the high-volume hydraulic fracturing operations, and a 1/3-acre drilling muds pit, used to collect the chemicals and fluids brought to the surface during drilling operations, were both within 350 feet of the farmers' water well, and within 200 feet of the creek and the pond where the cattle drink.

Soon after hydraulic fracturing operations concluded, the farmers noticed that on the far bank of the wastewater impoundment, two dark spots could be seen adjacent to a 20-acre cow pasture. According to the farmers, these two spots were a concern as they grew in size from day to day; approximately one month after first observing these spots, the farmers found ankle-deep water in one-third of an acre of the pasture with the wet area extending another one-quarter of an acre into the pasture; the pasture grass in these areas appeared to be burned. Fearing their herd drank the wastewater, they voluntarily quarantined their farm and notified the state environmental regulatory agency.

According to the farmers, drilling company workers informed them that the liners of both the wastewater impoundment and the drilling muds pit had two-foot tears, and that the tear in the liner of the wastewater impoundment had caused the leak into the cow pasture. Except for the two bulls, the entire herd was exposed to the wastewater leakage.

Four notices of violations were issued to the drilling company by the state environmental regulatory agency: failure to notify the agency, improperly lined impoundment (pressure testing of liner revealed a failed patch), pollution of a spring and farm pond due to leakage of the impoundment, and mismanagement of residual waste (wastewater leaked from the impoundment onto the ground and surfaced in an adjacent pasture).

Testing of the wastewater in the impoundment indicated the presence of calcium, iron, magnesium, manganese, potassium, sodium, strontium, fluoride, chloride, sulfate, and bromide; there was no reported testing for any organic compounds. Strontium was of most concern: it can be toxic to both animals and people because it replaces calcium in bone, especially in the young, and because it may take years to be eliminated from the body [43]. The state environmental regulatory agency placed a quarantine on the herd such that mature cows would be held from slaughter for six months, yearlings would be held for nine months, calves exposed in utero would be held for eight months, and growing calves would be held for two years. Six of the exposed cows eventually went on to slaughter, and, according to the farmers, there was no testing before or after slaughter.

Pre-drilling tests were not done on any of the cattle's sources of water; post-drilling tests were done and revealed no significant findings. Soil tests done

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on the cow pasture contaminated by the leaked wastewater revealed high levels of chloride, sulfate, sodium, and strontium when compared to background samples. The liners from both the wastewater impoundment and drilling-muds pit were removed, the affected soil removed, and areas remediated; sulfate concentrations remained at high levels in the cow pasture despite remediation.

During the spring of the first calving season following the leakage of wastewater into their cow pasture, the farmers lost two calves: one calf was aborted late-term, and the other calf lived for approximately seven days before dying [44]; both calves were exposed in utero to the wastewater. In the second calving season post-drilling, the farmers lost 11 out of 17 calves: seven were stillborn, three died a few months after birth and one was born alive but severely ill; the dams of all the calves had previously been exposed to the wastewater. The severely ill calf and a stillborn calf were sent for necropsy: the ill calf was diagnosed with *E. coli* septicemia, and the stillborn calf was diagnosed with goiter (diffuse thyroid hyperplasia); both calves were also diagnosed with low liver vitamin E and selenium.

This case illustrates several important points. First, the testing was not complete. According to the farmers, they were not informed of the chemicals used during either drilling or hydraulic fracturing operations. Testing of the water well and cattle's sources of water excluded organic compounds except for a pasture spring; the wastewater analysis also excluded organic compounds. No toxicology tests were done on live cattle, and the tests at necropsy omitted volatile organic compounds, endocrine disruptors, and many minerals present in the wastewater. The cattle's sources of water were tested only after the farmers lost many calves. Soil tests were not done in the area affected by the leakage of the drilling-muds pit. Second, the cattle were exposed to sulfate in the wastewater for at least one month and to elevated sulfate in the grass and soil [45, 46] for over a year. Studies show that increasing dietary sulfur decreases the bioavailability of selenium [47-50], and that Vitamin E and selenium deficiency is associated with reproductive failure in cattle [51, 52]. Third, the liner tear and subsequent leakage of drilling fluids onto the farmers' land were not considered a potential problem and not officially recorded as a violation by the state environmental regulatory agency. Due to gas drilling operations on their property, the farmers now have 26 head of cattle instead of 33, and have lost 40 to 50 acres of hayfields. These farmers received no compensation from the drilling company for the loss of their animals, damage to their land, or the treatment of the animal health problems they have encountered since gas drilling began.

DISCUSSION

The most striking finding of our investigations was the difficulty in obtaining definitive information on the link between hydrocarbon gas drilling and health effects. However, the results point to a number of ways policies can

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be changed to facilitate better data collection and to avoid obvious risks to animal and human health.

Practices for Providing Better Assessment of Health Impacts

Nondisclosure Agreements

Nondisclosure agreements between injured parties and corporations make it difficult to document incidents of contamination. Compensation in the form of cash, payment for all settlement expenses, an offer to buy the property and/or payment for medical expenses in exchange for a nondisclosure agreement prevents information on contamination episodes and health effects from being documented and analyzed. Nondisclosure agreements are common in all areas of business and are often essential to protect intellectual property. However, when documentation of health problems associated with gas operations is shielded from public scrutiny by a nondisclosure agreement, this is clearly a misuse of this important business tool and should be prohibited. Likewise the lack of prior testing of air and water, and of follow-up testing during drilling and after incidents of suspected contamination, impedes the analysis of health impacts. Even when testing is done, the results are being withheld from interested parties either by government agencies (e.g., by incomplete responses to FOIA requests) or by the industry. If the industry, government agencies, and the public truly want the facts, then appropriate testing must be done, and full disclosure of all data associated with both baseline and incidents of suspected contamination must be made. Without full disclosure of all facts, scientific studies cannot properly be done. Science should drive decisions on whether or not to use a practice such as shale gas drilling, and until scientific studies can proceed unimpeded, then an accurate assessment cannot be made.

Food Safety

A major problem is the lack of federal funding for food safety research. We documented cases where food-producing animals exposed to chemical contaminants have not been tested before slaughter and where farms in areas testing positive for air and/or water contamination are still producing dairy and meat products for human consumption without testing of the animals or the products. Some of these chemicals could appear in milk and meat products made from these animals. In Case 3, a quarantine was instituted after cattle were exposed to wastewater. However, basic knowledge, such as hold times for animals exposed to chemical contaminants as a result of gas operations, is lacking, and research in this area is desperately needed to maintain an adequate level of food safety in our country [53]. Without this information, contaminants in the water, soil and air from gas drilling operations could taint meat products made from these animals, thus compromising the safety of the food supply.

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Routes of Exposure

The major route of exposure in the cases documented here is through water contamination. This is perhaps the most obvious problem (seen in all three case studies), but other routes of exposure are of serious concern. Soil contamination can be significant in situations such as that described in Case 3. Although the cases we have documented thus far include only a handful of exposures through affected air, the actual incidence of health effects may be underestimated due to a lack of air sampling. In Case 1, toxicological testing suggested high levels of ambient benzene due to a nearby impoundment pond, but air canister tests were not done at the time. Neither drilling companies nor state environmental regulatory agencies routinely offer air canister tests as a part of testing protocols, and due to the expense, many property owners are reluctant to pursue them on their own. Nevertheless, the effects of air pollution on cardiovascular and respiratory health have been well documented [54], and we believe that exposure to contaminated air may contribute significantly to the health problems of both people and animals living near gas drilling operations. In several cases where air monitoring was done, the results confirmed the presence of carcinogens commonly known to originate from gas industrial processes such as exploration, drilling, flaring, and compression. Thus, the Environmental Protection Agency (EPA) must include a study of air in its congressionally mandated hydraulic fracturing study [55] if it is to be complete.

Testing

The most important requirement for an assessment of the impact of gas drilling on animal and human health is complete testing of air and water prior to drilling and at regular intervals after drilling has commenced. This includes chemicals used in the drilling muds, fracturing fluid and wastewater (the latter contains heavy metals and radioactive compounds normally found in a particular shale [56]). Currently, the extent of testing (particularly for organic compounds) is frequently inadequate and limited by lack of information on what substances were used during the drilling process. In a number of the cases that we have studied, drinking water is clearly unsuitable for human and animal consumption, based not only on the smell and turbidity, but also on pathological reactions to drinking the water. Nevertheless, because of inadequate testing, the water is deemed fit for consumption and use, and neither bottled water nor the large plastic containers known as "water buffaloes" are typically provided for the affected individuals-and even less commonly for animals living on those farms. In Case 1, water was reluctantly provided for the humans (after considerable effort) but not to the animals living on the farm. Even when identified, the health effects of chemicals associated with the drilling process are unknown in many cases. No Maximum Contaminant Levels (MCLs) have been set by the EPA for many of the compounds used, and those that have been set are based on older data that does not

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take into consideration effects at significantly lower concentrations (e.g., endocrine disruption [5]). Furthermore, the disclosure of all chemicals involved in the drilling and hydraulic fracturing processes is not required if a component can be justified as a "trade secret." In order to be complete, air, soil and all sources of potable water used for humans and animals in the vicinity of a well site (at least within 3,000 feet for soil and water tests [57], and five miles for air monitoring, based on dispersion modeling of emissions from compressor stations [58]) must be tested for all components that are involved in drilling and are likely to be found in wastewater, before any work on the site commences. Sampling must then be repeated at intervals following the commencement of drilling as well as upon suspicion of adverse effects. The following practices must be part of a testing protocol:

1. The sampling must be done by a disinterested third party with a clear chain of custody between sampling and testing. A certified independent laboratory must do the testing, and the results must be available to all interested parties.
2. All chemicals (with IUPAC names and CAS numbers) used in the hydraulic fracturing fluid at any concentration for each well must be disclosed to the property owners within a five-mile radius, testing laboratories, local governments, and state agencies. Material Safety Data Sheets (MSDSs) for each chemical and chemical mixture must accompany this disclosure. Following this procedure will allow prior testing to be targeted to specific chemicals to be used in the drilling process for a specific well, as well as providing valuable information to first responders and hospital personnel in the case of an accident.
3. Upon suspicion of adverse health effects, testing must include air, soil, wastewater, all sources of drinking water, and blood, urine and tissue samples from affected animals and humans. If methane is present in drinking water, isotopic analysis to determine the origin (thermogenic vs. biogenic) must be done.
4. As illustrated by several cases we documented, air canister tests are essential. This must be done as a baseline before drilling begins and during and after well flaring. It must also be done after a wastewater impoundment and a compressor station have been established.
5. Any fracturing fluid chemicals and chemicals released from the shale that are known or possible human carcinogens, are regulated under the Safe Drinking Water Act, or are listed as hazardous air pollutants under the Clean Air Act must have MCLs, which are set by the EPA. Many of the chemicals to which both people and animals are exposed as a result of high-volume hydraulic fracturing are not listed as primary contaminants, and thus have no enforceable MCL. More than half of the chemicals listed as toxic chemicals in a recently released U.S. House of Representatives report [59] have no MCL.

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6. All testing expenses must be a part of the cost of doing business for gas drilling companies.

Testing before and during drilling operations is an important part of documenting health effects. If health effects are related to a chemical pre-existing in a pond or well, this would prevent a false association between drilling and water contamination. Alternatively, if a change in chemical composition is correlated to health changes, then a strong justification for compensation is provided. In numerous cases that we documented, compensation was not provided because adequate prior testing had not been done. By doing complete testing, at the proper times, a clear scientific justification can be made for providing or denying compensation. Beyond that, a better understanding of what practices lead to water contamination can be obtained. This will be a benefit to people living in the midst of shale gas drilling and will, in fact, benefit the industry by providing consistent and useful data to guide operations. The current practice of under-testing and denying any link between drilling and water, air, or soil contamination is beneficial to neither the public nor the industry.

Practices for Avoiding Animal and Human Exposure to Environmental Toxicants

As shale gas drilling expands across the northeastern United States, exposure of animals and humans to environmental toxicants can result from negligence, illegal actions, catastrophic accidents (at drilling pads or compressor stations), or normal operations. Negligence and illegal actions are difficult to prevent and may have contributed to the health problems we documented. Suspected illegal dumping of wastewater and the alleged compromise of the liner of a wastewater impoundment were most likely responsible for cattle deaths in two instances that we studied. Cases of alleged wrongdoing [60] illustrate the vulnerability of agricultural operations in the midst of large volumes of toxic waste. Dumping and other intentional violations are difficult to prevent or regulate given the large numbers of small companies involved in servicing drilling operations and the lack of willingness and funding on the part of state environmental regulatory agencies to investigate and fine the gas industry. The prevalence of small subcontractors increases the possibility that best practices will not be followed due to inadequate training and supervision.

Although accidents might be minimized with strict safety standards and careful inspection, regulatory agencies would require sufficient staff to monitor operations. This is obviously not the case in Pennsylvania, where 666 environmental health and safety violations have been reported in 2011 as of June [61]. With a staff of 37 inspectors [62] and 64,939 active wells (as of December, 2010), regulatory oversight is essentially impossible. The situation is even worse in New York State, where only 16 inspectors are currently on the staff of the Department of Environmental Conservation. Although the number of staff

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positions required to police this industry adequately would necessarily be very large, hiring of new inspectors is essential if environmental and health damages are to be minimized. New York, Pennsylvania, and Iowa are the only active drilling states that have no severance tax for drilling operations. A severance tax could fund additional inspectors and help insure compliance with existing regulations, although this will require the political will to levy a tax sufficient to fund the required number of inspectors. Given the high probability that accidents will happen [63], increasing setbacks between homes, barns, schools, ponds, and streams would provide some additional security. The current regulation in Pennsylvania is a setback of 200 feet from water supply springs and wells, 100 feet from surface water bodies, and 200 feet from wetlands. The revised draft supplemental generic environmental impact statement in New York indicates a 500-foot setback from private water wells. Increasing these setbacks 5- to 10-fold would decrease but not eliminate the impacts of accidents such as the April 20, 2011 spill in Bradford County, PA [64]. Contamination of the air by compressor station blowouts and contamination of streams leave an imprint that cannot be easily mitigated by even the most stringent setbacks.

Normal practices can be modified to reduce but not eliminate exposure of humans and animals to toxicants associated with gas drilling. One of the important problems associated with shale gas drilling is the huge volume of wastewater generated. This wastewater, which includes flowback and produced water, contains at different times in the process the chemicals used in the hydraulic fracturing fluid as well as compounds and minerals extracted in the fluid flowing back with hydrocarbon gas. The materials extracted from underground can be equally or more toxic than the hydraulic fracturing fluid, and include radioactive material (e.g., radium-226, radon-222, and uranium-238), arsenic, lead, strontium, barium, benzene, chromium and 4-nitroquinoline-1-oxide [56]. However, despite the actual toxicity of this material, according to the EPA, "drilling fluids, produced waters, and other wastes associated with the exploration, development, or production of . . . natural gas" are considered "solid wastes which are not hazardous wastes" [65]. This allows the substances to be spread on roads as deicing solutions and as solutions to minimize dust and sets up a potentially lethal threat, particularly to companion animals, wildlife, and children. Typically these solutions contain high salt concentrations and attract dogs and cats, as was illustrated in Case 1. This hazard can be easily mitigated by not allowing wastewater to be spread or sprayed on roads.

Before wastewater is removed from a drilling site, it is often stored in large impoundments (sometimes serving multiple well pads) where the volume is decreased by evaporation. This increases the concentration of some toxic substances in the impoundment (salts, heavy metals) and also introduces other toxicants into the atmosphere (e.g., volatile organics such as benzene and toluene). In addition, impoundments are associated with a number of deaths of both cattle and wildlife [66]. These effects raise the question of whether

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wastewater should be stored in open impoundments. Whereas this may be economically advantageous to the drilling company, the environmental and agricultural impacts are too great to allow this practice to continue. In Pennsylvania, some progress has been made in recycling increasing fractions of the wastewater. This decreases the total volume of wastewater but increases its toxicity due to the successive increase in the concentrations of total dissolved solids. The alternative is to store wastewater in metal containers at the drilling site before it is removed for disposal.

Finally, the disposal of wastewater presents significant environmental risks. Cases of alleged dumping of untreated wastewater in streams have been documented in the press (e.g., [60]). In the southwestern United States, wastewater is disposed of in injection wells; however, the prevalence of nonporous sandstones and shales in Pennsylvania and New York State largely precludes the use of disposal wells. An earthquake of magnitude 3.2 was associated with injection into a hydraulically fractured vertical well on February 3, 2001 near Avoca, New York [67], suggesting that seismic considerations may further limit the development of injection wells in New York State. Similar seismic occurrences in other parts of the country, most recently in Ohio [68], may mean that New York and Pennsylvania will have fewer options for disposal of wastewater due to shale gas drilling. In May 2011, a voluntary moratorium was placed on the acceptance of hydraulic fracturing wastewater at sewage treatment plants in Pennsylvania. These plants are not equipped to handle either the radioactive and toxic compounds or the high salt content of this waste, and the increased use of recycling has magnified the problem. Discharge of water treatment plants into the Monongahela River led to the contamination of drinking water in Pittsburgh in 2010 [63]. Sewage treatment plants clearly are not a viable option for disposal of wastewater, and despite the industry's progress in recycling, suitable injection wells are unlikely to be located to support the scale of drilling planned in Pennsylvania and possibly New York State.

CONCLUSION

Animals, especially livestock, are sensitive to the contaminants released into the environment by drilling and by its cumulative impacts. Documentation of cases in six states strongly implicates exposure to gas drilling operations in serious health effects on humans, companion animals, livestock, horses, and wildlife. Although the lack of complete testing of water, air, soil and animal tissues hampers thorough analysis of the connection between gas drilling and health, policy changes could assist in the collection of more complete data sets and also partially mitigate the risk to humans and animals. Without complete studies, given the many apparent adverse impacts on human and animal health, a ban on shale gas drilling is essential for the protection of public health. In states that nevertheless allow this process, the use of commonsense measures

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to reduce the impact on human and animals must be required in addition to full disclosure and testing of air, water, soil, animals, and humans.

ACKNOWLEDGMENTS

We would like to thank Sandra Podulka (Cornell University) and Dr. Sandra Steingraber (Ithaca College) for comments on an early draft of the manuscript.

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Subject: Synthesis comments
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Hi guys,

I made some edits/comments to the Synthesis of Ch. 4, I hope they help. I didn't edit anywhere else. Ex. 5
Ex. 5
Ex. 5. Hope it helps. I'll try to get to the ES tomorrow.

Take care!

Chris

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20150311_Compilation HFDWA and Ch3 comments (LY).docx

Hi all,

Here are the assessment-wide and chapter 3 comments I picked up on from the meeting yesterday and the hard copy comments (below and attached). Working with Jeanne to synthesize her concerns about Ch3. Plan to have approval on the agenda to set up a meeting tomorrow.

Thanks,

Lia

Assessment-wide comments

Ex. 5

Ex. 5

Chapter 3 main comments:

Ex. 5

Ex. 5

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Subject: couple good peer reviewed HF articles
Malone et al 2015.pdf
Alawattegama et al 2015.pdf

Peer reviewed articles on **Data inconsistencies from states with unconventional oil and gas activity** and **Well water contamination in a rural community in southwestern Pennsylvania near unconventional shale gas extraction.** Some good supplemental citations in at least the intro chapters.

(Anna came across these doing some other lit search.)

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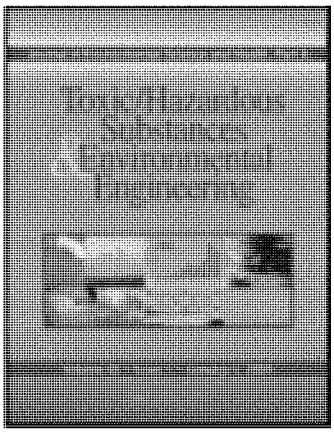

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Well water contamination in a rural community in southwestern Pennsylvania near unconventional shale gas extraction

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Published online: 03 Mar 2015.

To cite this article: Shyama K. Alawattegama, Tetiana Kondratyuk, Renee Krynock, Matthew Bricker, Jennifer K. Rutter, Daniel J. Bain & John F. Stolz (2015) Well water contamination in a rural community in southwestern Pennsylvania near unconventional shale gas extraction, Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering, 50:5, 516-528, DOI: 10.1080/10934529.2015.992684

To link to this article: http://dx.doi.org/10.1080/10934529.2015.992684

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Journal of Environmental Science and Health, Part A (2015) 50, 516–528
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ISSN: 1093-4529 (Print); 1532-4117 (Online)
DOI: 10.1080/10934529.2015.992684

Well water contamination in a rural community in southwestern Pennsylvania near unconventional shale gas extraction

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Reports of ground water contamination in a southwestern Pennsylvania community coincided with unconventional shale gas extraction activities that started late 2009. Residents participated in a survey and well water samples were collected and analyzed. Available pre-drill and post-drill water test results and legacy operations (e.g., gas and oil wells, coal mining) were reviewed. Fifty-six of the 143 respondents indicated changes in water quality or quantity while 63 respondents reported no issues. Color change (brown, black, or orange) was the most common (27 households). Well type, when known, was rotary or cable tool, and depths ranged from 19 to 274 m. Chloride, sulfate, nitrate, sodium, calcium, magnesium, iron, manganese and strontium were commonly found, with 25 households exceeding the secondary maximum contaminate level (SMCL) for manganese. Methane was detected in 14 of the 18 houses tested. The 26 wells tested for total coliforms (2 positives) and E. coli (1 positive) indicated that septic contamination was not a factor. Repeated sampling of two wells in close proximity (204 m) but drawing from different depths (32 m and 54 m), revealed temporal variability. Since 2009, 65 horizontal wells were drilled within a 4 km (2.5 mile) radius of the community, each well was stimulated on average with 3.5 million gal of fluids and 3.2 million lbs of proppant. PA DEP cited violations included an improperly plugged well and at least one failed well casing. This study underscores the need for thorough analyses of data, documentation of legacy activity, pre-drill testing, and long term monitoring.

Keywords: Marcellus shale, gas wells, water quality, hydraulic fracturing.

Introduction

Groundwater serves as a major source of drinking water for many Pennsylvania residents with an estimated 3 million Pennsylvanians relying on private wells for their water needs.[1] Pennsylvania has over 1 million water wells and around 20,000 new water wells are drilled each year.[1] Unlike public water supplies, Pennsylvania does not regulate residential groundwater use and there have been very few studies on general water well quality.[1–4]

The rise in unconventional shale gas extraction using hydraulic fracturing and the consistent claims of groundwater contamination associated with this practice has raised concerns about groundwater quality.[5–10] Freshwater aquifers may be contaminated by brines or hydrocarbons from underlying formations, chemicals used in the drilling or fracturing processes, waste water, and the natural gas itself through a number of pathways.[11–18] These include but are not limited to surface contamination from leaky impoundments and spills, poor well construction resulting in failed cement and improper casing, a pressurized annulus, as well as pre-existing faults and legacy issues from previous mining and drilling operations.[11,12,19] Well construction issues involving casing and cementing failures of the gas wells account for most contamination incidents.[19] They result in the creation of vertical migration pathways for fluids to migrate from the surface downward or from deep formations under extreme pressure upwards. In addition, hydraulic fracturing can increase the permeability of the targeted deep formations by creating new fractures or propagating existing fractures thereby creating flow pathways for the upward migration of gases and fluids.[11,14,17,18]

Establishing a definitive link between hydraulic fracturing itself and groundwater contamination has been

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challenging. The Energy Policy Act of 2005, Section 322 Hydraulic Fracturing amends the Safe Drinking Water Act to exclude "(i) the underground injection of natural gas for purposes of storage and (ii) the underground injection of fluids or propping agents (other than diesel fuels) pursuant to hydraulic fracturing operations related to oil, gas, or geothermal production activities." Additionally, the large distances (hundreds of meters) separating the deep gas rich formations and the shallower groundwater sources, the multitude of surface and subsurface contaminant sources and the lack of comprehensive scientific baseline study data are all factors that contribute to the challenge.[2-4,20] The main objective of this study was to determine if recent the changes in well water (quality and quantity) of a small rural community in southwestern Pennsylvania could be related to the current unconventional shale gas extraction activities of drilling and/or fracturing.

The community chosen for this study comprises a development that began as hunting camps with most eventually converted to year round residences. It covers a total area of around 2.5 km^2 (1 km £ 2.5 km or 0.62 £ 1.5 miles) and has about 190 households. All have been dependent on wells for their source of drinking water as there is no connection to municipal supply. Although there had been previous oil and gas drilling and coal mining activity in the area,[21,22] considerable new activity in unconventional shale gas extraction (USGE) now surrounds the community. The first reported unconventional extraction of shale gas according to the Pennsylvania Department of Environmental Protection (PA DEP) began in this area in early 2007 and 2008 with the drilling of the Steven Lensey 1 and Reedy D2 vertical wells, respectively. Drilling activity increased with 20 wells spudded between March 2010 and November 2011.

Coinciding with the increased USGE activity, several residents of the community reported groundwater contamination with changes in water quality and quantity.[23] As drilling continued more residents filed complaints and alternative water was provided.[24,25] After a PA DEP investigation found no connection between the change in water quality and the drilling, the alternative water was removed and a volunteer water bank was established.[24,25] The current study was conducted between the fall of 2011 through the spring of 2014. The goal was to determine how many wells in the community had been affected as well as those that had not, and to determine types and possible sources of contamination. An initial door-to-door survey of the residents was carried out in the fall of 2011.

Residents were asked six questions regarding water supply, well location, well construction and water issues. Subsequently, well water samples were collected and analyzed and additional surveys were completed. Water analysis included on site measurements (temperature, dissolved oxygen, pH, and conductivity) and lab analyses for selected anions (chloride, bromide, fluoride, sulfate, phosphate, nitrate, nitrite) using ion chromatography and selected metals using ICP-MS (EPA method 200.8). A subset of wells was tested for light hydrocarbons and the presence of coliforms and E. coli. Base maps of the study area were created identifying the location of current horizontal wells, legacy operations (e.g., gas and oil wells, coal mining), and topography. Where available pre-drill and post-drill water analyses, done either by the drilling company, Pennsylvania Department of Environmental Protection (PA DEP), or independent certified water testing lab, were reviewed in addition to a comprehensive PA DEP file review of permits and well completion reports.

Methods and materials

Community survey

The study was conducted with full Institutional Review Board (IRB) approval with the principle investigator (JFS) completing basic IRB training. The survey consisted of six questions relating to well location, water quality and quantity and testing.

1. Do you have well water and where is your well located?
2. What kind of well is it (e.g. artesian, rotary, cable tool)?
3. Do you know how deep the well is and have you noticed a change in your well depth?
4. Have you noticed any change in water quality (taste, smell, color) and if so when?
5. Have you noticed any change in the water flow or quantity?
6. Have you had the water tested and would you be willing to share those results?

Sample collection and analysis

Water samples were collected in sterile 1L French square glass bottles and 100 ml glass bottles containing 10M nitric acid (trace metal grade, Fisher Scientific, Pittsburgh, PA, USA). Samples were collected upstream of any water treatment and filtration devices, after purging the source, usually an outside spigot, for 10–20 min. Purge times were reduced to between 2–5 min when running the well dry was an issue. Collected samples were stored in the dark and on ice and transported back to the lab and stored at 4ffC until analyses. On site field measurements of temperature, dissolved oxygen, pH, and conductivity were made with a YSI-Pro Plus multimeter (YSI Incorporated, Yellow Springs, OH, USA). Lab concentrations of selected anions (chloride, bromide, fluoride, sulfate, phosphate, nitrate, nitrite) were measured using a ThermoFisher Dionex ICS-1100 Ion Chromatography System equipped with a conductivity cell and UV/VIS detector (Dionex, Sunnyvale, CA, USA) using EPA Method 300.0[26] with

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modifications as reported in Kondratyuk et al.[27] Five-point calibrations, in triplicate, were done with standards for each anion. Analysis for selected cations was done with a Perkin-Elmer NexION 300X ICP-MS (Waltham, MA, USA) at the University of Pittsburgh using the EPA Method 200.8[28] with modifications as reported in Kondratyuk et al.[27]

Light hydrocarbon analyses

For light hydrocarbon analyses (methane, ethane, ethene, propane, propylene, butane), samples were collected in 100-ml amber septum sealed vials without headspace. The bottles were kept in the dark on ice, and hand delivered to VaporTech Analytical Laboratory and Sampling Services (Valencia, PA, USA) where the analyses were completed.

Total coliform and E. coli testing

Total coliforms were determined using EPA Method 9222 B and Method 9222 G was used to detect the presence of E. coli.[29] First, 100-mL samples were collected in triplicate using six 50-mL sterile polypropylene tubes. The water was collected from either an outside spigot or other inside faucet prior to any water treatment system (i.e., water softeners, UV treatment, or filtration). The samples were kept on ice packs in the dark after collection and processed within 48 h.

Data mapping and file review

Base maps of the study area were created using the ArcGIS software package (ESRI, Redlands, CA, USA). Pre-existing base maps, topography, digital elevation data (LiDAR), coal mining operations, and abandoned mine land, were retrieved from the Pennsylvania Spatial Data Access (PASDA) and Pennsylvania Geospatial Data Clearinghouse.[30] Gas field locations were obtained from the Pennsylvania Department of Conservation and Natural Resources (PA DCNR).[31] Abandoned oil and gas well data, where available, came from the PA DEP.[32] A comprehensive PA DEP file review was conducted in January of 2013 that included permits and well completion reports for the study area. Violations were accessed through the PA DEP website.[32] In addition, pre-drill and post-drill water analyses, done either by the drilling company and/or PA DEP and provided by study participants were reviewed and compiled.

Results

Community survey

In the initial survey, a total of 143 households participated. Survey results showed that majority of survey respondents (61%) did not know the type of well construction. When well type was known, it was either cable tool (27% of respondents) or rotary (12% of respondents). The average and median well depths were 63.7 m (209ft) and 54.3 m (178 ft) respectively, with the shallowest well at a depth of 19.8m (65 ft) and the deepest well at 274.3 m (900 ft). Fifty-six (56) households (39%) reported changes in water quality or quantity since 2010, 63 households (44%) reported no issues and the remaining 24 households (17%) were unsure.

Out of the 56 households reporting issues, 50 indicated changes in quality based on taste and/or smell, 23 households had quantity issues and 18 reported both quality and quantity issues (Fig. 1). Color was the most common change, with 27 households reporting brown, black, or orange water. Twenty-five households noticed odors and 6 households a change in taste (Fig. 1). Change in the water level of the well was not readily discernable as 78 of the respondents (55%) indicated they did not know. Six households stated loss of water during normal use. Ninety-five households (66%) indicated that they had their water tested at some time. Among these, only 42 had their water tested by the drilling company as part of predrill testing. Although most households had received their test results, 9 households said they had not.

Water chemistry

Initially, 57 water samples from 33 wells were collected and analyzed over an 18-month period for this study. Anion analysis of these samples revealed the presence of all analytes (e.g., bromide, chloride, fluoride, nitrate, phosphate, sulfate) except nitrite (Table 1). ICP-MS analysis looked at 31 analytes consisting of a combination of major ions, minor ions (trace metals), inorganic chemicals and radionuclides (e.g., uranium) (Table 2). Only cadmium and uranium were not detected. Although their concentrations varied in amount from well to well, the most common contaminates were sodium, calcium, magnesium,

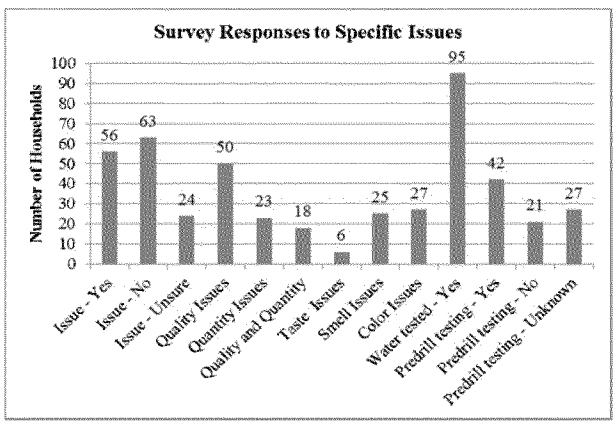

Fig. 1. Results showing the number of respondents for each question out of the 143 that participated in the survey.

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Table 1. Summary of anion analysis of water samples.

Anion	Presence (Households %)	Highest Conc. (ppm)	Lowest Conc. (ppm)	Method Detection Limits (ppm)
Chloride	100	222.69	0.8	0.0033
Bromide	41	1.39	0.05	0.0084
Fluoride	71	5.28	0.03	0.0064
Sulfate	98	134.82	5.34	0.0068
Phosphate	30	10.76	0.15	0.0169
Nitrate	88	26.81	0.05	0.0073
Nitrite	0	—	—	0.0054

iron, manganese, and strontium (Table 2). Twenty-five households had levels of manganese above the maximum contaminate level (MCL) (Table 2). Plotting of the Cl/Br mass ratios for all water samples having both anions show a broad distribution of values (Fig. 2). However, most lie below the mixing line for seawater (Fig. 2).

Regular monitoring of the water wells from two households (Household 1 and Household 2) that were close to each other (204 m), had similar well construction (cable tool), but well depths that differed (32 m and 54 m), in order to determine changes in water quality over time and whether they were affected similarly (Figs. 3 and 4). Field analysis showed that the water temperature and pH of these two wells were similar and remained steady with average temperatures of 11ffC and 14ffC, respectively, and pH of 7 in both. Dissolved oxygen (DO) readings showed

Table 2. Summary of cation analysis of water samples collected in this study.

Cation	(S) MCL (mg/L)	Samples Exceeding (S) MCL	Min. (mg/L)	Med. (mg/L)	Max. (mg/L)	MDL (ppb)
Aluminum	0.05–0.2	1	0.007	0.01	0.13	2.571
Antimony	0.006	0	<0.001	<0.001	0.002	0.024
Arsenic	0.01	0	<0.001	0.002	0.009	0.239
Barium	2	0	0.02	0.08	0.42	0.521
Boron	*	0	<0.001	0.02	0.149	2.533
Cadmium	0.005	0	<0.001	<0.001	<0.001	0.021
Calcium	*	—	2.1	36.1	126.24	2.464
Chromium	0.1	0	<0.001	0.003	0.038	0.097
Cobalt	*		<0.001	0.001	0.008	0.133
Copper	1.3	0	<0.001	0.012	0.339	2.272
Iron	0.3	2	0.04	0.135	0.415	1.509
Lead	0.015	0	<0.001	0.005	0.014	0.028
Lithium	*	—	0.001	0.007	0.021	0.088
Magnesium	*	—	0.3	6.562	20.98	3.504
Manganese	0.05	25	0.002	0.067	2.627	0.897
Molybdenum	*	—	<0.001	<0.001	0.003	0.096
Nickel	*	—	0.001	0.003	0.019	0.140
Phosphorus	*	—	0.001	0.027	0.318	2.098
Potassium	*	—	0.041	0.81	2.67	2.051
Rubidium	*	—	<0.001	0.001	0.003	0.002
Selenium	0.05	0	<0.001	0.002	0.013	0.566
Silicon	*	—	0.4	8.84	14.7	29.5
Silver	0.1	0	<0.001	0.002	0.003	7.996
Sodium	*	—	5.279	10.4	217.03	0.527
Strontium	*	—	0.03	0.16	0.62	0.100
Tin	*	—	<0.001	<0.001	0.002	0.243
Titanium	*	—	<0.001	0.001	0.01	0.171
Tungsten	*	—	<0.0001	0.001	0.002	0.004
Uranium	0.03	0	<0.0001	<0.0001	<0.0001	0.05
Vanadium	*	—	<0.001	<0.001	0.003	2.182
Zinc (Zn)	5	0	<0.001	0.033	0.392	1.202

(S)MCL – (Secondary) Maximum Contaminant Level (US EPA 2009),
* No MCL has been set. MDL – method detection limit.

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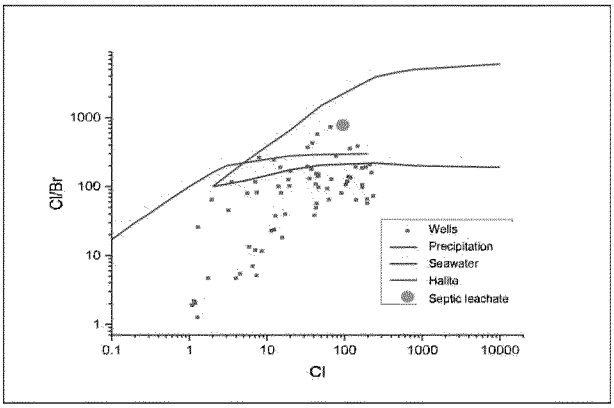

Fig. 2. The mass ratios of Cl-Br to Cl for all well water samples having both anions present collected during the study. The halite and seawater mixing curves and septic leachate field are from Katz et al.[48] The precipitation mixing curve is from Davis et al.[44]

seasonal fluctuations, increasing in the colder months, with Household 1 exhibiting more variation in DO. The specific conductance readings of the well from Household 2 mirrored the laboratory chloride readings, indicating that chloride was the major source of dissolved solids.

In contrast, Household 1 specific conductance readings were inversely related, with higher conductance readings

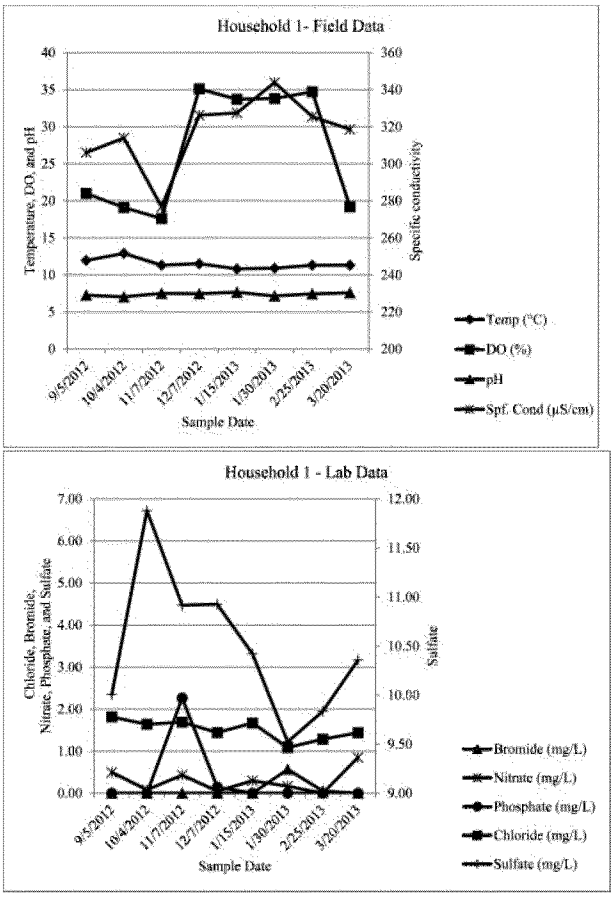

Fig. 3. Monthly field and lab data for household 1.

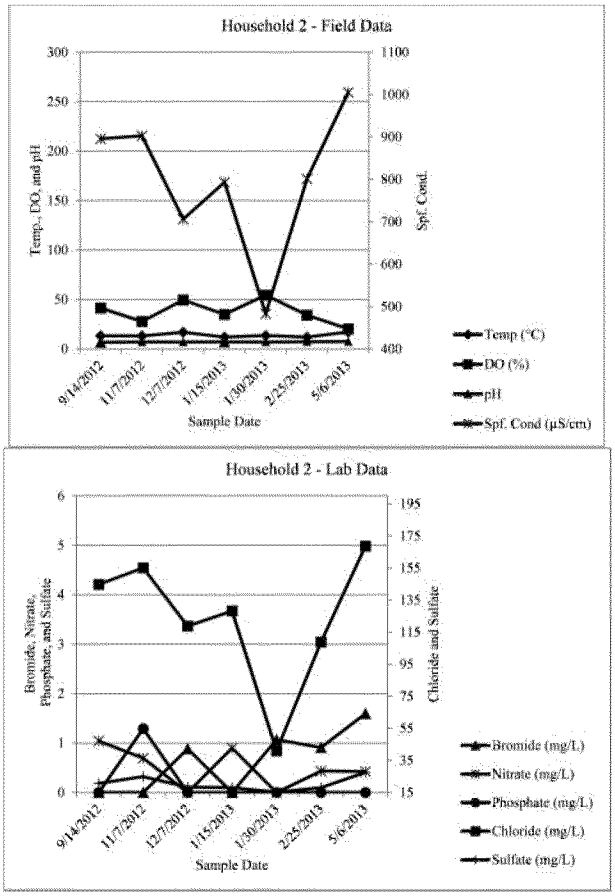

Fig. 4. Monthly field and lab data for household 2.

corresponding to lower chloride levels. Here the increase in conductivity appears to be due to an increase in sulfate. Review of laboratory results for Household 1 and Household 2 showed that except for phosphate, all readings were higher for Household 2 compared to Household 1. ICP-MS analysis for these two households showed the presence of iron and manganese. The varying results of both field and lab analyses indicates that while the two wells share similar physical properties (i.e. location, construction), they draw water from two different sources.

Household 1 and 2 (the same as above) had pre-drill water testing data performed by the industry as well as PA DEP (Tables 3 and 4). Review of this data showed increased levels of all analytes except for barium in Household 1 between pre-drill and post-drill. Analyses of industry pre-drill and three PA DEP post-drill testing data for Household 1 appear to indicate the increases in iron, manganese and strontium coincided with drilling activities. However the levels decrease in subsequent sampling (Table 4). Determination letters from the PA DEP reviewed in this study, although negative, indicate contamination (e.g., chloride, iron, and manganese) at levels above secondary MCL (Table 4). We were also able to obtain the results of the water analyses carried out by the

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Table 3. Industry water testing results.

Analyte	Household 1[a] Sample date 6/29/2010	Household 2[a] Sample date 6/30/2010	Household 3[a] Sample date 5/3/2010	Household 4[a] Sample date 6/28/2010	Household 5[b] Sample date 6/29/2011
Barium (mg/L)	0.155	0.389	0.227	0.113	0.13
Chloride (mg/L)	2.4	173.7	11.5	21.2	25.5
Iron (mg/L)	0.149	0.173	1.7	0.31	2.952
Manganese (mg/L)	0.049	0.143	0.353	0.047	0.622
Spc. conductance (mS/cm)	339	861	212	825	456
Total dissolved solids (mg/L)	183	581	179	420	291
E. coli	Absent	Absent	Absent	Absent	Absent
Total Coliform	Absent	Absent	Absent	Present	Present
Methane (mg/L)	ND	ND	ND	8.53	2.66
Strontium	Not tested	Not tested	Not tested	Not tested	0.089

[a]Pre-drill testing,
[b]Post-drilling test.

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drilling company and PA DEP for a total of five households (including Households 1 and 2). Four of these reports were pre-drill test results, while the fifth was conducted after the drilling had commenced (Table 3). Three of the 5 households also had their water tested by the PA DEP (Households 1, 2, and 5) following complaints filed by the homeowners subsequent to noticing changes to their well water quality (Table 4). The data show a change in water quality from pre-drill to post-drilling.

Light hydrocarbons

Eighteen wells were tested for the presence of light hydrocarbons (methane, ethane, ethylene, propane, propylene, and butane) between January, 2013 and April, 2014 (Table 5). Those that were tested multiple times during the study showed that both the concentrations of methane as well as the presence and concentration of other light hydrocarbons varied (data not shown). Ethane was detected in 5 of the wells, and one also had traces of propane and propylene (Table 5).

Total coliforms and E. coli

A total of 26 wells were tested for total coliforms and E. coli as part of this study during 2013. Of these only one well was positive for total coliforms, and one tested positive for both coliforms and E. coli. These results indicate no source of pathogens, or that flow paths large enough to allow bacteria to be transported to the wells are absent.

Base mapping

Base mapping of the study findings and data gathered from public databases were used to locate the presence of

Table 4. DEP water testing results.

Analyte	Household 1 Sample Date 2/10/2011	Household 1 Sample Date 2/14/2011	Household 1 Sample Date 4/4/2011	Household 2 Sample Date 11/14/2012	Household 5 Sample Date 8/11/2011
Barium (mg/L)	0.142	0.495	0.143	0.61	0.132
Chloride (mg/L)	3.9	2.2	2.5	252.4	11.2
Iron (mg/L)	1.175	36.6	0.113	2.059	1.968
Manganese (mg/L)	0.194	5.617	0.081	0.287	0.69
Strontium (mg/L)	0.163	0.224	0.189	0.591	0.123
Spc. conductance (mS/cm)	381	366	299	1072	300
Total dissolved solids (mg/L)	244	172	164	872	226
E. coli	Absent	Not tested	Not tested	Not tested	Not tested
Total Coliform	Absent	Not tested	Not tested	Not tested	Not tested
Toluene (mg/L)	ND	0.000372	Not tested	Not tested	Not tested
Other VOC's	ND	ND	Not tested	Not tested	Not tested
Methane (mg/L)	Not tested	Not tested	Not tested	0.0153	0.0241
Ethene (mg/L)	Not tested	Not tested	Not tested	Not tested	0.0198
Ethane (mg/L)	Not tested	Not tested	Not tested	0.0124	0.0198
Propane (mg/L)	Not tested	Not tested	Not tested	0.0142	0.0142

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Table 5. Light hydrocarbons (in mg/L).

Household	Methane	Ethane	Ethylene	Propane	Propylene	Butane
LV1	42.32	0.58	ND	ND	ND	ND
BS1	ND	ND	ND	ND	ND	ND
RA1	0.37	ND	ND	ND	ND	ND
PH1	0.56	ND	ND	ND	ND	ND
HK1	9.93	ND	0.03	ND	ND	0.08
CH2	ND	ND	ND	ND	ND	ND
WO1	0.33	ND	ND	ND	ND	ND
CO1	ND	ND	ND	ND	ND	ND
CB1	1.09	0.02	ND	ND	ND	ND
CB2	1.37	ND	0.02	ND	ND	ND
SV1	1557	1.43	ND	0.05	0.07	ND
SV2	ND	ND	ND	ND	ND	ND
HT1	4.21	ND	ND	ND	ND	ND
HT2	0.42	0.01	ND	ND	ND	ND
HT3	0.55	ND	ND	ND	ND	ND
HT4	0.52	ND	ND	ND	ND	ND
HT5	1.83	0.28	ND	0.02	0.05	ND
HT6	3.6	ND	0.04	ND	ND	ND

historic and current oil and gas and mining activity surrounding the community. The Little Creek Oil Field, which has had previous drilling activity, lies at about 1,300' below the community (Fig. 5). The main petroleum-bearing section is the Hundred Foot sandstone, and the Snee sandstone lies even deeper at around 1,600 ft.[21] Mapping of legacy oil and gas wells, abandoned and/or orphaned wells, coal mines and abandoned mines data confirms the existence of previous oil and gas and mining activity surrounding the community (Fig. 6), however pinpointing these has been difficult. Lytle's review of oil field exploration in Butler County, indicates 500 abandoned oil wells with 250' spacing drilled into the Hundred Foot and Snee sands within Connequenessing and Forward Townships.[33] No specific locations, however, were provided. The USGS Topo map obtained through the US Fish and Wildlife Service indicate at least three oil wells within the confines of the community.[34] The same cannot be said for gas wells as, unfortunately, these same maps use the identical symbol for buildings and gas wells. PA DEP file review data indicate at least a dozen gas wells were drilled in the area between 1961 and 1985; however, their coordinates (longitude, latitude) appear to have been added later and only plot to the general area, down to minutes rather than seconds (e.g., N40°50' W 80°00').

PA DEP file reviews

PA DEP file reviews of permits and well completion records provided the locations, lengths, and directions of USGE wells in Connequenessing and Lancaster Townships. Analysis of this data shows that by late 2012 the community was surrounded by 15 well pads and a total of 65 laterals (horizontal gas wells) (Fig. 7). Table 6 summarizes the review of unconventional shale gas drilling records obtained from the PA DEP. Each well was stimulated with varying amounts of fluids and proppant, on average 3.5 million gal and 3.2 million lbs, respectively.

A list of violations for oil and gas activity in the township from September 2010 through September 2012 was obtained from the PA DEP website (Table 7).[32] Violations ranged from simple administrative issues such as failure to post proper documentation to more direct environmental impacts such as improper discharges, and compromised well casings and inadequate plugging of a well.

Discussion

The results of the survey indicate that a significant number of families (56 out of 143) saw noticeable changes in quality and/or quantity to their private well water supply since 2009 (Fig. 1). Although the recent USGE activities began in 2009 the respondents began noticing the changes at different times after that. This delay might be attributed the location within the community of each household relative to the well pads, the substantial difference in depth of the water wells, (that varied in depth from 19 to 274 m), as well as the form of contamination. Most respondents saw changes in secondary water standards, namely color, taste or smell. It is not surprising that no one surveyed had equipment to routinely monitor or test their well water quality. The study by the Center for Rural Pennsylvania indicated that about half of the participants in their study had not had proper water testing done, thus many did not know if they had issues.[1] In contrast, more than 66% of the households in this study (95 out of the 143) indicated they had had their water tested at some time. However, only 42 households had had their water tested by the gas drilling company as part of predrill testing. The survey results suggest that more comprehensive (e.g., greater distances from the well pad) pre-drill testing should be required as recommended by the Citizens Marcellus Shale Commission.[35]

Typical contaminants seen in Pennsylvania domestic wells include bacteria from septic or runoff, chloride from road salt, nitrate and phosphate from agriculture, iron and sulfate from mining, brines from oil and gas wells, and methane.[1–3] The brine and produced water associated with unconventional gas extraction in the Marcellus Shale is reported to contain high levels of total dissolved solids, halides (e.g., chloride, bromide), strontium, barium, and naturally occurring radionuclides.[36–41] Water analyses conducted during this study indicated elevated levels of chloride, manganese, iron, and specific conductance as compared to good quality groundwater.[1] Chloride was found in all of the wells sampled, however, none exceeded

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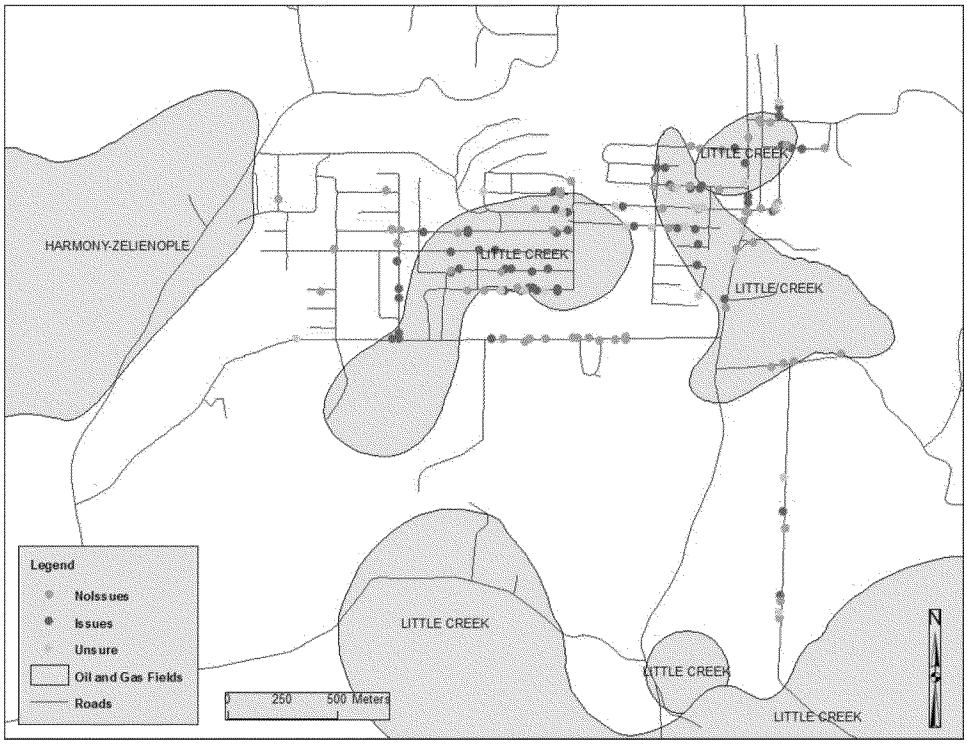

Fig. 5. Survey results plotted over the Little Creek Oil Field that underlies the community.

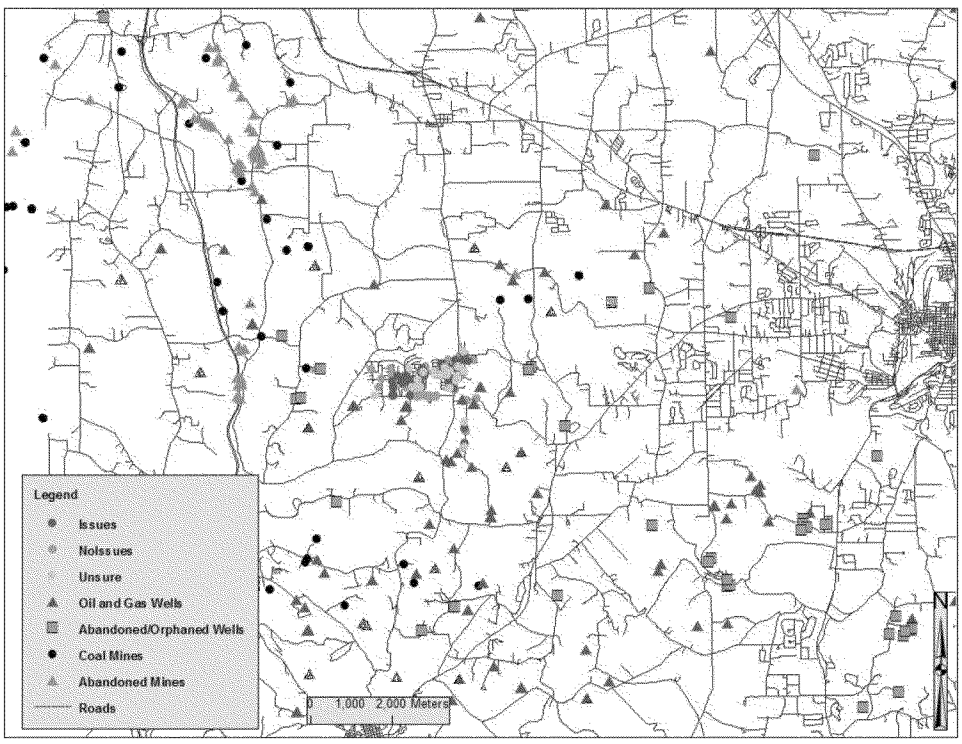

Fig. 6. Current and historic oil and gas and mining activity surrounding the community as could be determined from state sources (e.g., PASDA, PA DEP).

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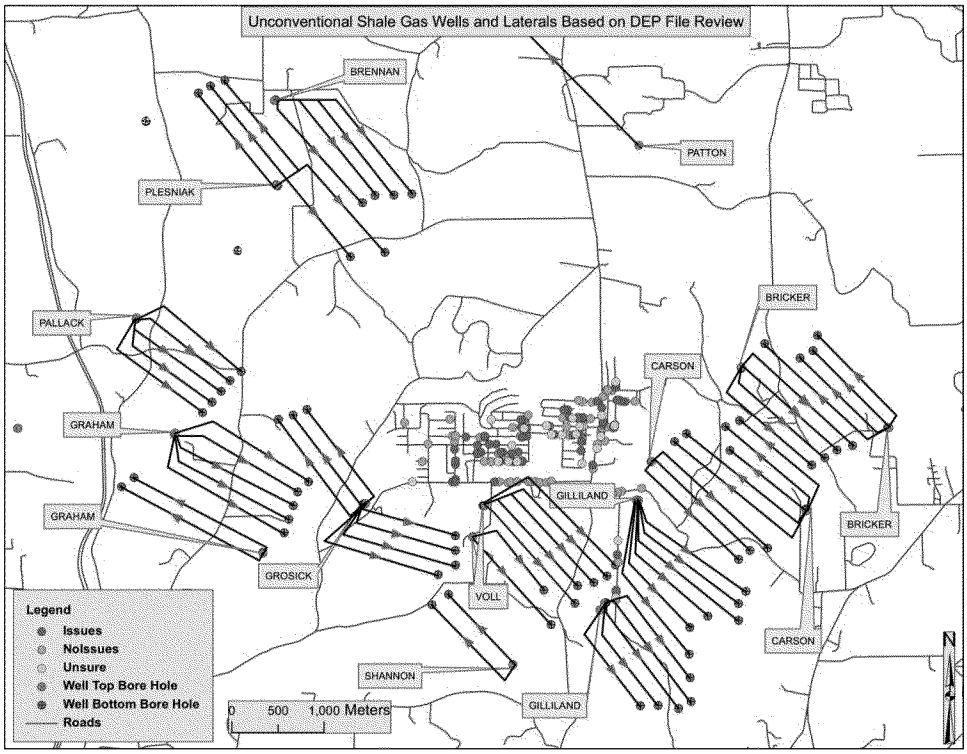

Fig. 7. Locations, lengths, and directions of lateral wells surrounding the community. Data compiled from DEP file review of location plats.

the secondary drinking water limit of 250 mg L^{-1} (Table 1). The presence of chloride in Pennsylvania groundwater is common, however, concentrations are typically less than 25 mg L^{-1}.[1,42]

The results from the total coliform and E. coli testing as well as the mass ratio analyses for chloride and bromide, indicate that septic leachate may be ruled out as a source.[43] Other potential sources of contaminants include precipitation, road salt (e.g., halite), and brines associated with coal, oil, and gas fields. Here, the use of Cl/Br mass ratios can be used to assess potential sources of chloride.[44–48] Reported values for Cl/Br mass ratios range from 50–150 for precipitation, 100–200 for shallow groundwater, 300–600 for septic leachate, and 1,000–10,000 for halite.[44,48] Produced water from unconventional shale gas extraction may have concentrations of chloride in excess of 100,000 mg L^{-1}, but the Cl/Br mass ratios are indicative of evaporated seawater.[49] Our analyses revealed that the majority of the well samples fell below the primary mixing line for seawater (Fig. 2). This suggests that brine may be the primary source of elevated chloride mixing with groundwater.[48,49]

Similar to chloride, iron and manganese have limits set under the secondary standards for drinking water.[50] These two analytes were elevated in a number of

Table 6. Summary of DEP file reviewa findings showing well name, dates of stimulation (e.g., fracking), volume of fluids, amount of proppant and length of the lateral.

Well Name	Dates Fracked	Volume of Fluid (gal)	Proppant (lb.)	Length Fracked (ft)
Steven Lesney 1	2/12/2007	11,839	4,154	118
Reedy 2	6/10/2008	1,066,700	1,004,920	62
Shannon 1H	10/5/2010 – 10/9/2010	3,572,208	3,766,100	3,000
Shannon 2H	12/10/2010 – 12/19/2010	3,179,278	2,461,050	2,660
Voll 1H	1/7/2011 – 1/21/2011	3,159,184	2,634,500	3,240
Voll 2H	1/7/2011 – 1/22/2011	4,215,810	3,800,400	4,200
Ragan 11	4/20/2011	37,500	25,000	216
Grosick 1H	11/4/2011 – 11/12/2011	4,744,446	No data	3,575
Grosick 2H	1/10/2012 – 1/13/2012	3,924,774	No data	2,965

[a]Data gathered from DEP file reviews of well record and completion reports.

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Table 7. PA DEP reported USGE violations for the township issued between September 2010 to 2012.

Site Name	Violation ID	Violation Date	Violation Description
Edward Gilliland 0 OG Well	594808	9/8/2010	Failure to plug a well upon abandonment
Voll Unit 1H OG Well	595298	9/14/2010	Failure to maintain 2' freeboard in an impoundment
Voll Unit 1H OG Well	595299	9/14/2010	Failure to report defective, insufficient, or improperly cemented casing w/in 24 h or submit plan to correct w/in 30 days
Voll Unit 3H OG Well	599948	11/16/2010	Stream discharge of IW, includes drill cuttings, oil, brine and/or silt
Gilliland Unit 4H OG Well	599859	11/20/2010	Failure to properly store, transport, process or dispose of a residual waste.
Bricker Unit 1H OG Well	619173	8/31/2011	Failure to notify DEP, landowner, political subdivision, or coal owner 24 h prior to commencement of drilling
Bricker Unit 1H OG Well	619174	8/31/2011	Failure to post permit number, operator name, address, telephone number in a conspicuous manner at the site during drilling
Grosick Gilliland Carson Pipeline ESX	629497	1/17/2012	Discharge of industrial waste to waters of Commonwealth without a permit
Grosick Gilliland Carson Pipeline ESX	630037	1/23/2012	Discharge of industrial waste to waters of Commonwealth without a permit.
Bricker Pipeline ESX	641921	6/18/2012	Discharge of industrial waste to waters of Commonwealth without a permit.
Patton Unit 1H OG Well	650294	9/28/2012	Conservation well located less than 330' from lease or unit line without waiver.

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samples with iron found above the 0.3 mg $L^{i\,1}$ standard limit in 3.5% of samples, and manganese was above the 0.05 mg $L^{i\,1}$ standard limit in 44% of samples (Table 2). The ubiquitous presence of manganese in these wells, with 25 households above the maximum contaminate level (MCL), is a serious health concern (Table 2).[50] Manganese is an essential element required for many biological enzymes, however, it is also a known neurotoxin.[51] Long-term exposure can lead to manganism and Parkinson's Disease.[52] Recent studies have shown that manganese concentrations in drinking water between 300-400 ppb can lead to lower IQ in children.[53,54] The presence of iron and manganese is a common occurrence in western Pennsylvania waters, especially around coal mining areas.[1] Although the PA DEP base map for abandoned coal mines does not show the presence of such mines underneath the confines of the community, strip mines are in close proximity (Fig. 6) and the watershed is under a TMDL monitoring program.[55] Thus mine drainage may be another important source of contamination to the wells.

Methane was found in 14 of the 18 wells tested, and while most were in low microgram amounts, at least one well had mg $L^{i\,1}$ quantities (Table 5). Methane can be either biogenic or thermogenic origin. Methanogens, microorganisms belonging to the domain Archaea, generate methane from carbon dioxide, acetate, or simple organic compounds (e.g., formate).[56] Thermogenic methane, on the other hand, is formed through the "cracking" or catagensis of fossil organic carbon (e.g., kerogen), and is usually found with other light hydrocarbons.[14,17] In addition, biogenic methane is depleted in ^{13}C, and has $d^{13}C$ values ranging from ¡ 60 to ¡ 120 o/oo.[17] Thus biogenic sources may be distinguished from thermogenic sources through isotopic (e.g., $d^{13}C$-CH_4 and $d^{2}H$-CH_4) and geochemical analyses (e.g., propane/methane ratios).[9,14,17,56-58] The presence of associated hydrocarbons (e.g., ethane, propane, propylene, butane) may then be an indication that the source of methane is thermogenic in at least six wells (Table 5). Definitive determination of the thermogenicity, however, will require isotopic analyses, but may not indicate the exact source (i.e., both Little Creek Field and deeper deposits are thermogenic).[57,58]

Mapping of survey results shows the spatial extent of groundwater issues experienced by the residents. No pattern of contamination is apparent as the households indicating changes in water quality are not clustered together (Fig. 7). Overlay of the survey results with underlying oil and gas reserves shows that the affected homes sit atop the Little Creek Oil Field (Fig. 5). Both the Hundred Foot sandstone and the Snee sandstone of the Little Creek were developed in the late 1800's and early 1900's, with at least one well reaching over 4,000 ft.[21,33] The PA DEP file review also included permits for at least a dozen conventional wells in the area that were drilled between 1961 and 1985 with several on current USGE sites (e.g., Graham,

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Gilliland pads). Thus the region has had significant legacy oil, gas, and mining operations (Fig. 6).

More telling is the location of the new unconventional wells as there are 15 well pads with 65 horizontal wells within a -m radius of the community (Fig. 7). The laterals follow a north-north west or south-south-east drilling direction to take advantage of the enhanced permeability of the J_1 joint of the Marcellus shale, maximizing yields.[59] The large volumes of fluids and proppant used in the slick water hydraulic fracturing of the new wells (on average 3.2 million gal. and 3 million lbs, respectively) (Table 6) could also affect the local hydrology and contribute to subsurface disturbance resulting in well water contamination.[11] While the depth of the Marcellus in this part of the state is around 5,000 ft, the violations cited in late 2010 (Table 7), especially the failed casing/cement job, could provide conductive pathways for the migration of legacy mining as well as deep formations fluids.[11,19] Although the PA DEP eventually determined that there was no connection between the new drilling and the changes in water quality, their own data indicate that at least for Household 1, there was a dramatic and contemporaneous increase in concentrations of barium, strontium, iron and manganese (Table 4) as well as contamination in other wells (e.g., chloride, iron, and manganese) at levels above secondary MCL (Table 4).

Conclusions

We have used a variety of methods to determine whether there is a correlation between the changes in well water quality in water wells with surrounding USGE in this community in Southwest Pennsylvania. The survey results indicate that there has been an increase in well water issues in the community since 2010. Water chemistry results show elevated cations and anions including manganese, iron, bromide and chloride. Different wells had different contaminants although the majority had manganese above the MCL. Light hydrocarbon analyses suggested a thermogenic source for the methane in some wells. Analysis of mapping results revealed the community lies over the Little Creek Oil Field, and locations of previous mining and oil and gas activities.

DEP file review indicates several violations that could result in groundwater contamination. The proximity and location of USGE well sites to the community provide shorter pathways for the transport of surface and subsurface contamination. The number of lateral wells (65) within 4 km of the community could have contributed to subsurface disturbance ultimately resulting in well water contamination. Further in-depth study of the local geology and hydrology, in addition to access to all pre-drill tests and well completion records would allow for a more definitive assessment. This study demonstrates the challenges faced in making a positive determination (e.g., relating contamination to drilling activity) and the need for thorough investigation including legacy activity, pre-drill testing, and long term monitoring.

Acknowledgments

The authors would like to thank the community for their willingness to participate in the study. We also thank S. Mayes, C. Nolan, C. Brown, and T. Umstead for additional sample collection and analyses as well as W.M. Griffin, R.S. Oremland, and A. Ingraffea for helpful comments.

Funding

This work was supported in part by the Heinz Endowments and Colcom Foundation.

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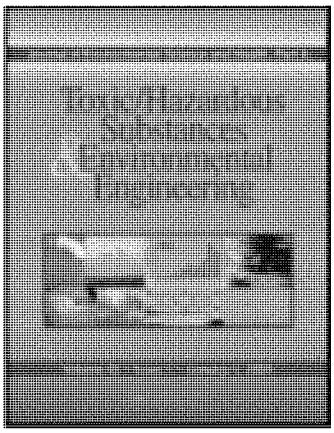

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Data inconsistencies from states with unconventional oil and gas activity

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Published online: 03 Mar 2015.

To cite this article: Samantha Malone, Matthew Kelso, Ted Auch, Karen Edelstein, Kyle Ferrar & Kirk Jalbert (2015) Data inconsistencies from states with unconventional oil and gas activity, Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering, 50:5, 501-510, DOI: 10.1080/10934529.2015.992678

To link to this article: http://dx.doi.org/10.1080/10934529.2015.992678

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Journal of Environmental Science and Health, Part A (2015) 50, 501–510
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ISSN: 1093-4529 (Print); 1532-4117 (Online)
DOI: 10.1080/10934529.2015.992678

Data inconsistencies from states with unconventional oil and gas activity

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The quality and availability of unconventional oil and gas (O&G) data in the United States have never been compared methodically state-to-state. By conducting such an assessment, this study seeks to better understand private and publicly sourced data variability and to identify data availability gaps. We developed an exploratory data-grading tool - Data Accessibility and Usability Index (DAUI) - to guide the review of O&G data quality. Between July and October 2013, we requested, collected, and assessed 5 categories of unconventional O&G data (wells drilled, violations, production, waste, and Class II disposal wells) from 10 states with active drilling activity. We based our assessment on eight data quality parameters (accessibility, usability, point location, completeness, metadata, agency responsiveness, accuracy, and cost). Using the DAUI, two authors graded the 10 states and then averaged their scores. The average score received across all states, data categories, and parameters was 67.1 out of 100, largely insufficient for proper data transparency. By state, Pennsylvania received the highest average ($\bar{x}$ D 93.5) and ranked first in all but one data category. The lowest scoring state was Texas ($\bar{x}$ D 44) largely due to its policy of charging for certain data. This article discusses the various reasons for scores received, as well as methodological limitations of the assessment metrics. We argue that the significant variability of unconventional O&G data—and its availability to the public—is a barrier to regulatory and industry transparency. The lack of transparency also impacts public education and broader participation in industry governance. This study supports the need to develop a set of data best management practices (BMPs) for state regulatory agencies and the O&G industry, and suggests potential BMPs for this purpose.

Keywords: Data transparency, environmental governance, oil and gas extraction, public participation, unconventional drilling.

Introduction

Energy extraction has been a topic of contentious debate in recent years in both the United States and internationally.[1–3] The process of extracting natural gas and other hydrocarbons from difficult-to-access formations in the ground, herein referred to as "unconventional drilling," embodies this controversy due to its potential costs and benefits,[4] which are not discussed in detail here. Advances in hydraulic fracturing and horizontal drilling technologies made formerly difficult hydrocarbon extraction more feasible, but the generation, cataloging, and sharing of quality data about the industry have not kept up with such innovations or the related permitting process. Although some unconventional drilling data are available that provide basic information (e.g., the location of wells drilled), the availability and quality of these datasets are not consistent across states.

For the purposes of this article, we define data transparency as the standardization and consistent publication of various types of unconventional oil and gas (O&G) data by state regulatory agencies. Some state regulatory agencies have improved O&G data transparency in recent years by releasing information and datasets on their websites. Ohio, for example, switched from reporting production data annually to quarterly as of January 2014. Unfortunately, many states have caught up with neither the pace of O&G activities nor the public's interest in accessing data.

O&G data transparency is made complex for many reasons. Increasingly scarce resources within environmental regulatory agencies limit personnel capacity to manage data and build appropriate technical infrastructure such as

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databases, websites, and other public information portals. Data accessibility also suffers due to the sheer number of entities responsible for collecting and sharing O&G data, as well as the rate at which unconventional drilling wells are permitted. Historical studies show that diffusion of responsibilities across agencies causes data to be aggregated using different standards, with specific parameters to suit the needs of particular regulatory agencies and/or administrative codes, in addition to the laws on which such efforts are designed to reflect.[5] Although such data may eventually become public, many data portals and variable standards, rather than a state-wide or nationally standardized approach, poses a persistent problem that results in poor data-sharing arrangements among agencies, ultimately creating barriers to public accessibility.[6–8]

Inadequacies in data sharing and quality can significantly affect the degree of public trust in the regulation of the O&G industry. Arguments for data transparency go well beyond the obvious need for better public understanding, however. Data transparency promotes broader participation in the democratic governance of the environmental "commons."[9–11] Access to state regulatory data also empowers local communities in mitigating potential industry impacts and allows non-governmental organizations (NGOs) to fill gaps in economic, social, health, and environmental knowledge created by lagging and/or incomplete regulatory oversight.

Furthermore, utilization of data provided by respected regulatory agencies allows academic and non-profit researchers to improve the accuracy of their findings and add credibility to their efforts when participating in scientific and political debates about the impacts of the O&G industry.[12] In addition to opening doors to broader public participation, data transparency also benefits local government and other state governments that are seeking information to inform their own regulatory policies.[13]

Some states have approached the issue of data transparency by requiring the O&G industry to share data through projects like FracFocus.org, a site designed to disclose chemicals used in unconventional drilling.[14] The logic of this method is derived from success stories of similar industry databases, such as the Toxic Release Inventory, and projects like "Scorecard" that build on those inventories to make data more readable for non-expert audiences.[15,16] Some argue, however, that the reporting of O&G data to third parties has diverted attention away from the responsibilities of regulatory agencies tasked with managing environmental resources and public health.[17] Reporting data to non-regulatory entities also offers few assurances that data are accurate and complete.[18] In light of this issue, we believe that in the case of O&G data, the states themselves need to undertake the tasks necessary to ensure data transparency and make possible cross-state data comparisons.

In recognition of the data gaps in the O&G industry, several NGOs and websites, including the FracTracker Alliance (www.FracTracker.org), were launched to better collect and share unconventional drilling data with the public.[19] Over the last three years FracTracker has developed a series of parameters to quantitatively measure data transparency and data quality within the field. FracTracker's position outside of industry and government allows it to better understand and approximate the experience of the general public when obtaining and working with O&G data. Data tools and meaningful pathways between raw data and refined information promote increased public understanding and engagement.

This study documents and quantifies the variability we see in data provided by state regulatory agencies across the United States where active unconventional drilling activity is occurring as a way to estimate the barriers faced by the general public when trying to access this information. This article also provides initial recommendations regarding the data gaps identified during this process so as to improve O&G data transparency. Closing these access gaps will enable the public to participate more meaningfully in important scientific and political debates that determine how O&G extraction will be regulated in their communities.

Methods

Between July and October 2013, five different categories of data were sought from 10 U.S. states. These data were reviewed using an internally developed Data Accessibility and Usability Index (DAUI).

Data categories reviewed

The five data categories assessed in this article are wells drilled, violations, production (of profitable hydrocarbons), waste (non-profitable returns), and U.S. Environmental Protection Agency (EPA)-defined Class II disposal wells. Disposal wells do not include those that are used for enhanced oil recovery, hydrocarbon storage, annular disposal, or salt-solution mining injection. Permit data were not reviewed because many states release these combined with drilled wells in a single dataset. Information about the nature and location of compressor stations from state regulatory agencies is difficult to obtain. (Only in January 2014 did it become possible to obtain dated locations of compressor stations in the United States from the U.S. Energy Information Administration.)

Although disclosure of data about this aspect of the industry is critically important, it was not the primary focus of this study, which aimed to test the DAUI in situations where data availability was relatively robust. Data on current and proposed pipelines were also not reviewed, as their locations are difficult to obtain in the United States due to the contention that releasing on-shore pipeline location information could be a national security risk. (Pipeline incidents data are available from the U.S. Department

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of Transportation's Pipeline and Hazardous Materials Safety Administration. Offshore pipelines are available from the Bureau of Ocean Energy Management. Of note, the government of British Columbia does release pipeline right-of-way data to the public.) Sand mining datasets were also not assessed in this study, but could feasibly be included in future reviews.

Data quality criteria

Eight data qualities were assessed using the DAUI for each of the categories of data: accessibility, usability, point location, completeness, metadata, agency responsiveness, cost, accuracy (on varying scales of 1–20, 1–15, or 1–10, depending on the importance of the metric). Inclusion of latitude and longitude information in the data is a key parameter; without this information, data cannot be easily mapped or statistically analyzed for research purposes. From the viewpoint of effective public information, raw—or tabular–data have far less power to inform or educate compared to data that can be mapped or visualized.[5] (Table 1 describes the discrete scoring categories). Using this system, each of the five categories of data may earn up to 100 points. Each state can score a maximum of 500 points.

States included in the assessment

States were chosen for this study based on three factors: 1) degree of unconventional O&G activity along a gradient from somewhat active to very active, 2) geographic location to capture distribution across the United States, and 3) whether violations data are available. Experience in working with unconventional O&G data to-date shows that datasets about violations are rarely released. While not all of the states considered in the DAUI maintain datasets on violations, all states with known violation data as of the inception of the project were included in the index. These criteria resulted in our choice of the following states for this review: Arkansas (AR), California (CA), Colorado (CO), Nebraska (NE), New York (NY), North Dakota (ND), Ohio (OH), Oklahoma (OK), Pennsylvania (PA), and Texas (TX). Figure I presents selected states and U.S. shale plays.

Obtaining the data

Free data from the selected states were reviewed between July and October 2013 in order to provide a snapshot of data over that time period. ND data were later purchased in order to determine how much of ND's original score had been affected by its policy of charging for violation information. Scores presented in the results section for ND represent the original results from our review, not the assessment of this purchased data. Datasets were collected by several of the study's authors, but all data were reviewed and graded by the same two authors in order to maintain scoring consistency. The final results presented comprise the average scores derived by these two authors.

The first step in the data gathering process involved visiting each regulatory agency's website. If datasets were provided free of charge and online, data review could begin. When data could not be assessed in this fashion, the agencies were contacted by email and phone to request the data. All unanswered requests were repeated a second time. If data could not be obtained after this point, a state received a score of zero in most, if not all, of the data quality categories. (Even if no data were available for review, a state could receive up to 10 points in the responsiveness category if the agency responded to our request in some way.)

Results

Scores received in each data category are shown alphabetically by state in Table 2. The combined average across all 10 states and categories is 67.1. By state, PA received the highest overall mean score ($\bar{x}$ D 93.5) and the highest in all data categories except drilled wells. The lowest scoring state was TX ($\bar{x}$ D 44), which is largely the result of its charging for certain data. ND was also docked for access to violations data. By data category, drilled wells ($\bar{x}$ D 87.8), Class II disposal wells ($\bar{x}$ D 85.3), and production data ($\bar{x}$ D 81.3) received much higher averages state-to-state because of their wide availability than did violations and waste, at 33.8 and 47.5, respectively.

Discussion

The variability of O&G data regarding wells drilled, permitting and waste produced variability is substantial. This appears to be due to variation in corporate and regulatory structures from state-to-state. The structure of data provided to the public; however, need not be so varied. Some degree of consistency is required to discern even the most basic trends, as well as for making meaningful comparisons between states and between various shale plays.

Scores by data category

Below, two states' scores from each data category are reviewed, both to highlight variability in the data and to demonstrate how the DAUI captures such differences.

For the category of drilled wells with a mean of 87.8 points, 10 out of 10 states provided accessible data. OK scored a perfect 100 points and ranked first among the states in this data category. Compared to OK, AR scored 75 points and ranked 9th overall. In the DAUI scoring system, AR lost points because of limitations in

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Table 1. Data Accessibility and Usability Index, a grading index with (scores) for each data category based on eight criteria.

Accessibility (20)	Usability (10)	Point Location (15)	Completeness (15)	Metadata (10)	Responsiveness (10)	Accuracy (10)	Cost (10)
Data not in digital form (0)	Agency only releases pre-packaged data (ex: .pdf, .jpg, or can only use their map interface; no download options) (0)	Point location not provided (0)	Data missing several important columns, such as date or operator, or only a portion of the records are available (0)	No metadata available (0)	Agency is unhelpful or obstructive (e.g., requiring a FOIA request for non-critical data) (0)	Major accuracy issues call reliability of dataset into question (0)	Data costs money (0)
Data is in digital form, but not available to public (5)		Point location provided, but in alternate system, such as State Plane or PLSS (5)	Data missing one important column, such as date or operator (5)	Metadata present, but incomplete (5)	Emails or calls are sometimes not returned (5)	Minor accuracy issues noted (5)	
Downloadable digital data available upon request (15)			Some minor data missing, but basic analysis is still possible (10)				
Downloadable digital data published on web (20)	Agency releases data that can be analyzed with free software (ex: .shp, .csv) (10)	Point location provided in decimal degree (15)	Data very complete (15)	Metadata very complete (10)	Agency is cooperative with data request (separate issue from whether or not they have the data in the first place) (10)	No known accuracy issues (10)*	All data free (10)

*Where data exists, the default score is 10. Points are deducted if we notice accuracy problems when the data are mapped.
Abbreviations: FOIA, Freedom of Information Act; PLSS, Public Land Survey System.

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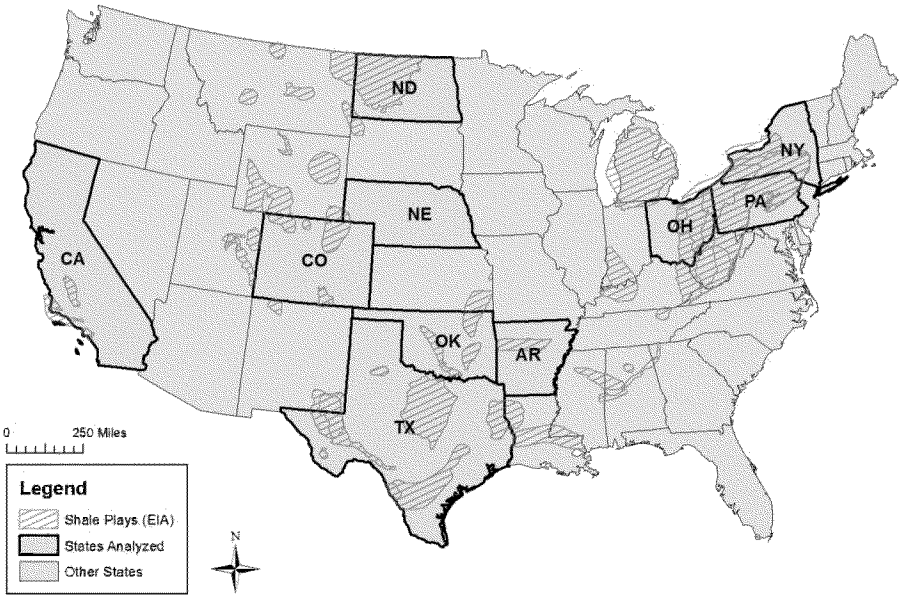

Fig. 1. States analyzed with the Data Accessibility and Usability Index in this study overlaid on continental U.S. shale plays (shapefile source U.S. Energy Information Administration).

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its online data management system; AR allowed access to only the first 1,000 records. Full data were provided upon request in Microsoft Access form. Microsoft Access requires that users have more sophisticated computer skills compared to those needed for working with a simple spreadsheet. Therefore, some points were deducted because data were provided in a challenging file format.

Datasets for disposal wells were also commonly available, obtained from 10 out of 10 states. Among the states in this study, the mean score for disposal wells data was 85.3. CO scored 73 points and ranked 9th, due to usability issues with data released in HTML tables. CO's disposal well dataset was also missing point locations and metadata. NE received 80 points and tied for a rank of 6th due an issue similar to the one described above for AR – requiring Microsoft Access to work with the data – and also because metadata were missing.

All 10 states provided production data, with an average score of 81.3 points. CA scored 95 points and ranked 3rd in this data category, while TX scored only 60 points and ranked last (10th) among the states. CA was docked for usability because it, too, released data in Microsoft Access format. Although TX does publish production data for wells, the information is solely available in online tables that cannot be downloaded and viewable only 15 records at a time. For this reason, TX scored poorly in both accessibility and usability. Additionally, the free TX data lacked location coordinates.

Table 2. Summary of scores on the FracTracker data index by state and data category.

	State Scores											
Data Categories	AR	CA	CO	ND*	NE	NY	OH	OK	PA	TX	State $\bar{x}$	State s
Wells Drilled	75	85	90	95	90	92.5	90	100	95	65	87.8	10.4
Violations	75	10	65	15	10	55	10	0	77.5	20	33.8	30.6
Production	75	95	75	62.5	85	80	80	100	100	60	81.3	14.1
Waste	70	10	67.5	62.5	85	0	75	0	95	10	47.5	37.8
Class II Disposal	75	100	72.5	95	80	85	80	100	100	65	85.3	12.8
Category $\bar{x}$	74	60	74	66	70	62.5	67	60	93.5	44	67.1	12.7
Category s	2.2	46	9.8	32.8	33.7	37.7	32.3	54.8	9.3	26.8	24.8	

*The format of ND's datasets and website navigation initially prevented us from finding the state's unconventional drilling waste and production data. When these data were located, however, we reevaluated ND on the DAUI in December 2013. ND's up-to-date scores for waste and production data are presented here.

Abbreviations: AR, Arkansas; CA, California; CO, Colorado; ND, North Dakota; NE, Nebraska; NY, New York; OH, Ohio; OK, Oklahoma; PA, Pennsylvania; TX, Texas; $\bar{x}$, Sample Mean; s, Standard Deviation from the Mean.

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Waste data could be acquired only from 6 of the 10 states that we analyzed in the DAUI, making the mean score 47.5 for all datasets and 75.8 for procured datasets. Immediately prior to submission of this article, the NY Department of Conservation responded to a Freedom of Information Law (FOIL) request for data on the disposition of drilling waste generated in NY. The data are not available in spreadsheet format. We were directed to an FTP site where the following information is catalogued: permit documentation (for general operation, not specific waste products), and annual reports in PDF form for incinerators (MWC), landfills, construction and demolition, household hazardous waste, vehicle dismantling facilities, and recyclables. In order to find O&G data, it is necessary to go through each folder manually. Documents are not searchable by keyword as they are scanned as images. Due to the long time it took for NY to respond (>3 months) and the poor format of the data when a response was received, the NY score was not amended on the DAUI. NY scored 0 points, thus tying for 9th in their management of waste data. OH scored 75 out of 100 and ranked 3rd. OH was docked for missing point location information regarding the nature and origin of the waste being reported. Metadata were insufficient, and some data seemed to be missing from brine totals.

Violations data were available from 4 out of 10 states at the time of our assessment, averaging 33.8 points per dataset, and 68.1 for those datasets that we could obtain. (OH has since released a violations dataset.) PA ranked 1st with a score of 78 for violations data, with point reductions due to insufficient metadata and missing location information. For the public to determine the location of an issued violation such as a spill, in PA, the user must link the violation report to a separate dataset that contains location data (e.g., drilled wells), using a unique API number. There were also some concerns regarding accuracy of the data. For example, in the past, several nearby wells were commonly assigned a single violation ID number.

In recent years, the ID coding methodology seems to have been improved by the PA Department of Environmental Protection (PA DEP). Nevertheless, there is a legacy of this older record-keeping practice manifesting itself in confusion over the number of violations for unconventional wells in the state. PA DEP appears to count violations by the number of unique violation ID numbers issued rather than actual incidents themselves. CO scored 65 points and ranked 3rd in quality and availability of their violations data. Problems with CO data included inconsistencies between dataset entries, spills, and Notices of Alleged Violations, as well as missing point locations and metadata. Data were accessible online in HTML table format only, with results limited to 2,500 records at a time. Compared to PA's system, where complete datasets can be downloaded from the website with one click, downloading data from CO in aggregate, and subsequently analyzing the datasets, is very difficult. CO's Notices of Alleged Violations lacked not only location data but often API numbers, as well.

Reflections on methodology

State scores on the DAUI should be considered only in terms of the data and states that were reviewed because not all states with active unconventional drilling activity in the United States were reviewed, and only in terms of a sample of potential data categories. Among the states assessed, PA stands out due to its consistently high scores. Despite its faults as discussed previously, data provided by the PA DEP ranked 1st in every data category except for drilled wells, for which it tied for 2nd place. In addition, PA datasets did not vary much from one data category to the other, as indicated by a fairly low category standard deviation (s D 9.3).

Several reasons may account for the relatively high scores of PA on the DAUI. First, FracTracker originated in PA, and reviewers were most conversant with the characteristics and sources of PA data. Familiarity with and expectations of O&G data likely shaped how the DAUI was structured and the data categories selected. A similar group in CO, for example, might have prioritized other data categories, therefore yielding different results. CO publishes data about impoundments, which are not readily available from the PA DEP website (although they do make some impoundment data available on the Pennsylvania Geospatial Data Clearing House).

Choosing to include impoundments as a data category in the analysis would have helped to weigh the results more highly for CO than for PA. Similarly, if providing a shapefile of the lateral portion of horizontal wells had been one of our criteria, PA would have scored poorly for not providing that data category, whereas ND and CO would have earned relatively higher marks. Under such circumstances, scores for specific states could be significantly different than those presented here. The DAUI's ability to highlight variances in the data, however, would be retained. Future versions of the DAUI and other data assessments would benefit from including additional data categories.

It might also be posited that the existing familiarity between FracTracker and the PA DEP gave PA a scoring advantage. This review included not only a search for data online, but also involved asking regulatory agencies for this information. Existing knowledge of PA's website and data availability could have helped to bolster the rating we applied in the "accessibility" category of the DAUI. However, it did not significantly aid PA's score in any of the other fields. Another scoring advantage for PA could have been that the PA DEP is more familiar with data requests from FracTracker, whereas other states might not have received as many requests in recent years from like groups for data that is appropriately geo-referenced.

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It must be emphasized that these scores represent data acquisition in a singular point assessment at a moment in time. In general, the trend in PA over the last two years toward better data accessibility and quality points to the possibility that, when citizen groups and NGOs apply repeated pressure to regulators, state agency reporting practices improve. At the time of the launch of FracTracker in 2010, for example, comprehensive PA violation data were unavailable. Data on drilled wells were released only once per month. These datasets were incomplete, lacked location data, and were generally fraught with errors. In contrast, a current DAUI snapshot of Tennessee (TN) would have likely scored more poorly today than it would have several years ago. Personal correspondence from the TN Department of Environment and Conservation with FracTracker has verified our observation that O&G data for the state are altogether unavailable on the TN website. TN previously offered such data, however, and plans to reinstate this service in the future.

In situations where the exact data being collected are not already available online, there is a social aspect to data collection. In other words, the manner in which data requests are delivered could have significant impacts on the DAUI score beyond what is captured in the "responsiveness" category. For example, a regulatory worker whose function it is to help with the dissemination of data might respond in differing ways depending on whether he or she perceived particular requests as polite, demanding, or aggressive. This tendency could, in theory, cause overworked regulatory agencies to selectively prioritize other requests if they felt that requests were rude, ill informed, or unimportant.

Of the 50 datasets analyzed in the DAUI, 3 returned scores of 0 because data were not available and our inquiries went unanswered. One of these is the aforementioned waste dataset from NY, while the other two are the waste and violation datasets from OK. Two different officials at the OK Corporation Commission Oil and Gas Division failed to reply to email requests that were sent to them. Inadequate staff resources and differing our approaches to data requests could have impacted these, and other, scores on the DAUI. OK should review its public inquiry process to ensure requests like ours are answered in the future.

The lowest scoring state on the DAUI was TX, with an average of 44 points across the data categories. These low scores were strongly impacted TX's policy of charging for certain data, such as location information. Originally, the DAUI was designed to demerit states 10 points if they charged for data. Because paying for the data was not part of the initial study design, however, the two states that charged for data, ND for violations data and TX for most of its data, scored poorly in some data categories on the DAUI. Simply put, data quality could not be assessed if not procured. The overall impact of charging for data created a cascade effect—reducing scores by more than the intended 10-point demerit—even though some points could still be obtained in the Responsiveness and Metadata categories. This effect should be addressed in future versions of the DAUI.

A related shortcoming of the matrix was that there was no mechanism in the DAUI to account for the relative price of data. For example, a basic one-year subscription to ND's data costs a relatively modest $50 and provides the user with several types of valuable data. In contrast, one would have to purchase several datasets from TX to do a similar analysis, with estimated costs exceeding $1,000. For the general public and small non-profit organizations, the financial burden of acquiring data from TX is much higher than for data from ND.

Although data purchases were not part of the original study design, ND's violations data were purchased post hoc in order to determine how much the purchase would affect ND's score in that category. Access to these new data improved ND's violation score from 15 points to 55, considerably enhancing the state's mean and standard deviation from 66.0 and 32.8 to 74.0 and 19.4, respectively. TX's DAUI scores would also likely benefit from purchasing the data.

Best data management practices

Next, we list recommended data best management practices to improve O&G data transparency.

A universal data management system. Due to the nature of O&G data being processed and distributed at the state level of government, attempts to make assessments at the national scale are inherently difficult due to inconsistency. A recent Associated Press analysis of violations datasets [20] concluded that it is very difficult to conduct cross-state comparisons because of the wide variability in the data collection process and in what determines a 'violation'—if violations data are even available. The implementation of a national O&G data management system is one way to reduce these inconsistencies.

Such a system could be structured similarly to the U.S. EPA Toxic Release Inventory (TRI), which requires companies in every state to report emissions of certain toxic chemicals to TRI databases and then publishes the data online in a publicly accessible and downloadable format. FracFocus.org is a website originally designed to improve the transparency of unconventional drilling data. The site design has some inherent barriers to transparency, however; data are not available for download in aggregate formats, and reporting requirements are uneven across states. Additionally, the TRI is government-run, while the Groundwater Protection Council and Interstate Oil and Gas Compact Commission run FracFocus.[21] These characteristics would severely limit the extent of compulsory disclosures by the states; hence the current FracFocus model is insufficient.

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More stringent data and metadata. Even with a system like TRI in place, O&G data accuracy, transparency, and access issues could still arise because the data are often self-reported by industry. This issue makes clear the need for reporting requirements to carry threat of prosecution for deliberate false reporting or failing to report. Separately, due to resource limitations, the state regulatory agency might not be able to verify all of the incoming data, increasing the possibility for errors. For example, when a biannual waste report was released in PA in August 2012, the total waste amounts were greatly over reported by several operators who had reported amounts in gallons rather than the required unit of barrels.[22] In addition to improving data quality, it is important to maintain basic metadata standards.

At a minimum, these standards should include descriptions of codes used in the various datasets that are maintained by a regulatory agency. Other information about the data is also important. For example, personal correspondence with the CA Department of Conservation Division of Oil, Gas, and Geothermal Resources (DOGGR) has verified that the regulatory agency was in the process of retroactively applying a new data column to old wells, in order to indicate whether they had been hydraulically fractured or not. As the process was incomplete, not knowing this crucial metadata could potentially lead those analyzing the data to reach faulty conclusions.

States can improve the quality and accessibility of existing O&G datasets by merely including latitude and longitude in each dataset. Consistently applied and comprehensive location information would help ensure data quality, especially over time, when wells and facilities will need to be located in order for reclamation to take place. Had there been proper record keeping and location information for historical O&G wells in PA, for example, PA would have been able to locate thousands of abandoned and orphaned traditional wells.[23]

Augmenting cost of data management. Limited funding to support data management by state agencies remains a major hurdle to greater accessibility. Regulatory agencies must look to increase their funding in order to be able to ground-truth incoming industry data. Charging indiscriminately for access to the data reduces overall transparency, especially for smaller NGOs, academic institutions, and individuals that may not be able to afford the high cost. These funding models amount to asking citizens to "pay twice" for services they should rightly expect public institutions would offer.[24] This barrier could be reduced if regulatory agencies charged companies a fee for data collection and cataloguing as a part of the permitting process, provided a tiered payment system for citizens or small groups that request data, or incorporated management costs into severance/ad valorem taxation.

Accessible technologies and standards

Many of the issues described here demonstrate the need for states to recognize that they are serving multiple audiences – not just government agencies and industry. Complicated and obtuse website navigation posed a serious impediment to obtaining data for this study. For example, while one author was looking for NE disposal well data and was not able to find it through the direct route recommended by the state's web page, another author was later able to locate it while looking for data about wells that have been drilled. In light of this experience in regularly working with unconventional drilling data it is reasonable to conclude that the process of accessing these data would be only more difficult for a member of the general public. To improve user access to data on these sites, states should adopt search and navigation recommendations set forth by web-based user-interface research.[25] Data and metadata, such as geolocation, should also be available for download in multiple formats, including CSV or Microsoft Excel spreadsheets, rather than sharing data through tedious HTML tables or intricate relational databases (such as Microsoft Access).

Conclusion

This review of unconventional O&G regulatory data highlights the need for more consistent data management practices across affected states. Answers to seemingly simple questions such as "How many unconventional oil and gas wells are there in the United States?" and "How often are these wells issued violations?" remain elusive due to inconsistent standards and data reporting among the states.

The DAUI was designed as a tool to identify the variability in data issued by differing regulatory agencies, as well as to provide a means to compare resulting datasets. By applying the index to 5 distinct data categories from 10 states, the former goal was met. Cross-state comparisons, while possible, must account for the variability outlined in the "Reflections of Methodology" section. Future analyses would benefit from some minor adjustments in the scoring mechanism, most notably with respect to data that is provided for a fee. This result is reasonably expected; much in the way that the index serves to highlight weaknesses in the data, applying real-world data to the DAUI provides an opportunity to further optimize the DAUI.

The best practices for data management outlined here, such as more stringent data standards, technologies designed to be accessible to multiple audiences, and alternative methods for augmenting the costs of data management, can help to improve data transparency issues revealed in the application of the DAUI. Furthermore, while there are certainly state-specific characteristics that show promise in how data is shared, data pertaining to

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particular issues or geographies should not be compartmentalized. Waste disposal[26] and hydraulic fracturing sand networks,[27] for example, can often encompass industrial sites operating across state lines. The simplest solution to this problem is to adopt a universal, mandatory, and federal government system that supplements state-managed data systems.

Whether it be through practices suggested here, or by some other means, ultimately it is critical to find solutions to data accessibility and usability gaps that have been identified. Unconventional O&G extraction incites many criticisms, as well as support. Proponents argue that developing a greater capacity for O&G extraction across the US creates jobs in local economies and offers a viable way out of dependency on global energy markets. Many others, however, voice concerns about the possible impacts of unchecked development on transportation infrastructures, ecological habitats, public health, air quality, and water quality. Precedents set by states with existing O&G development may have lasting impacts on how we expect public institutions to respond to demands for transparency in the future. Without access to consistent and comprehensive O&G data, these debates will only continue to be muddied by a lack of adequate public knowledge about industry activities.

Acknowledgments

The research was originally presented at the 2013 Facing the Challenges: Research on Shale Gas Extraction Symposium hosted by the Center for Environmental Research and Education at Duquesne University.

Funding

This work was supported by the FracTracker Alliance and our various funders (see www.fractracker.org/about-us/#Funders).

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To: Ex. 4 Ridley, Caroline[Ridley.Caroline@epa.gov]; LeDuc, Stephen[LeDuc.Stephen@epa.gov]
Cc: Ex. 4
From: Anna Weber
Sent: Mon 3/2/2015 10:05:19 PM
Subject: RE: Complete Draft HFDWA 3-2-2015 Two parts (Part A)
HFDWA 3-2-15 Part B.pdf

Here's a revised version of Part B, with the item on page 8-15 fixed.

From: Jonathan Koplos
Sent: Monday, March 02, 2015 4:58 PM
To: Anna Weber; Ridley, Caroline; LeDuc, Stephen
Cc: Shari Ring
Subject: RE: Complete Draft HFDWA 3-2-2015 Two parts (Part A)

Which I should have in a few minutes

From: Jonathan Koplos
Sent: Monday, March 02, 2015 4:57 PM
To: Anna Weber; Ridley, Caroline; LeDuc, Stephen
Cc: Shari Ring
Subject: RE: Complete Draft HFDWA 3-2-2015 Two parts (Part A)

But *after* I send you the new version of Figures 2a and 2b for the ES.

From: Anna Weber
Sent: Monday, March 02, 2015 4:54 PM
To: Jonathan Koplos; Ridley, Caroline; LeDuc, Stephen
Cc: Shari Ring
Subject: RE: Complete Draft HFDWA 3-2-2015 Two parts (Part A)

I'm here! I'll send a new version of Part B with the 8-15 item fixed shortly.

From: Jonathan Koplos

Sent: Monday, March 02, 2015 4:45 PM
To: Ridley, Caroline; LeDuc, Stephen
Cc: Anna Weber; Shari Ring
Subject: RE: Complete Draft HFDWA 3-2-2015 Two parts (Part A)

I'll see if figures can be changed yet today.

Anna might have left (but I can possibly find someone else to help with the PDF'ing and other changes).

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Monday, March 02, 2015 4:42 PM
To: LeDuc, Stephen; Jonathan Koplos
Subject: RE: Complete Draft HFDWA 3-2-2015 Two parts (Part A)

Ex. 5

I'm ok with no ES in the TOC for now.

The one thing I noticed (that we should try to fix today) was a little hiccup on pg 8-15 ln 20-23. Looks like some text is missing. I opened the word file of the chapter that you sent today, Jonathan, and the problem is there, too.

Otherwise, the minor issues I found can be overlooked for now. Good note about references. I will ask Jeff to put a sentence in the transmission email about that.

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6

From: LeDuc, Stephen
Sent: Monday, March 02, 2015 4:32 PM
To: Ex. 4 Ridley, Caroline
Subject: Re: Complete Draft HFDWA 3-2-2015 Two parts (Part A)

Hi Jonathan,

Just flipped through the ES, and I'm going to keep going. A few things:

1) is it standard not to list the ES in the TOC? probably, but I just don't know

2) On the water budget figures:

Ex. 5

Ex. 5

Ex. 5 Best, Steve
~~~~~~

Stephen D. LeDuc, PhD

US Environmental Protection Agency

National Center for Environmental Assessment, Arlington, VA 22202

Office Phone: (703) 347-8962; AWL Phone (Mon & Fri): Ex. 6

From: Jonathan Koplos < Ex. 4
Sent: Monday, March 2, 2015 4:07 PM
To: Ridley, Caroline
Cc: LeDuc, Stephen; Anna Weber; Ex. 4
Ex. 4
Subject: RE: Complete Draft HFDWA 3-2-2015 Two parts (Part A)

Letting you know I just sent Part A (8MBs) and Part B (12MBs).

Let me know if you haven't received them.

Jonathan

From: Jonathan Koplos
Sent: Monday, March 02, 2015 3:57 PM
To: Caroline Ridley (ridley.caroline@epa.gov)
Cc: Stephen LeDuc (leduc.stephen@epa.gov) ; Anna Weber; Shari Ring; Mary Ellen Tuccillo
Ex. 4
Subject: Complete Draft HFDWA 3-2-2015 Two parts (Part A)

Caroline,

Please find attached the first part (Part A) of the HFDWA; this Part A includes the Front Matter, List of Tables, List of Figures, the Executive Summary, and Chapters 1, 2, 3, and 4. This totals 190 pages.

The second part, in a following separate email, includes Chapters 5, 6, 7, 8, 9, and 10.

Please let us know if you have any questions.

Jonathan

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

Ex. 4

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: LeDuc, Stephen[LeDuc.Stephen@epa.gov]; Anna Weber[Ex. 4

Ex. 4

From: Jonathan Koplos
Sent: Mon 3/2/2015 8:59:44 PM
Subject: Complete Draft HFDWA 3-2-2015 Two parts (Part B)
HFDWA 3-2-15 Part B.pdf

Caroline,

Please find attached the second part (Part B) of the HFDWA; this Part B includes Chapters 5, 6, 7, 8, 9, and 10. This totals 376 pages.

Please let us know if you have any questions.

Jonathan

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

Ex. 4

Ex. 4

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: LeDuc, Stephen[LeDuc.Stephen@epa.gov];
MaryEllen.Tuccillo Ex. 4
From: Jonathan Koplos
Sent: Mon 3/2/2015 3:33:54 PM
Subject: Chap 8 draft final
Ch_8_Draft_Feb27_for_March_PDF.docx

Just an FYI.

Mary Ellen finished this up Friday night. (Sorry I didn't send sooner.)

It's just too long, otherwise hopefully getting in decent shape.

(Most remaining comments in the chapter are about references, HERO, etc.)

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

Ex. 4

Ex. 4

To: LeDuc, Stephen[LeDuc.Stephen@epa.gov]
From: Fleming, Megan
Sent: Thur 2/26/2015 5:31:27 PM
Subject: RE: HFDWA: Chapter 4 - FracFocus

Yes sure.

Megan Fleming
Office of Science Policy

U.S. EPA Office of Research and Development

1200 Pennsylvania Avenue, N.W.

Washington, D.C. 20460

(202)-564-6604

From: LeDuc, Stephen
Sent: Thursday, February 26, 2015 12:30 PM
To: Fleming, Megan
Subject: Re: HFDWA: Chapter 4 - FracFocus

Hi Megan,

You got some time if I call you in a few minutes? Steve

Stephen D. LeDuc, PhD

US Environmental Protection Agency

National Center for Environmental Assessment, Arlington, VA 22202

Office Phone: (703) 347-8962; AWL Phone (Mon & Fri): Ex. 6

From: Fleming, Megan
Sent: Thursday, February 26, 2015 10:39 AM
To: Frithsen, Jeff; Dean, Jill; Burden, Susan; LeDuc, Stephen
Subject: RE: HFDWA: Chapter 4 - FracFocus

Will do.

Thanks, Jill for your input. I'll take a look and get back to you with any questions.

Thanks,

Megan

Megan Fleming
Office of Science Policy

U.S. EPA Office of Research and Development

1200 Pennsylvania Avenue, N.W.

Washington, D.C. 20460

(202)-564-6604

From: Frithsen, Jeff
Sent: Thursday, February 26, 2015 10:38 AM
To: Dean, Jill; Burden, Susan; Fleming, Megan; LeDuc, Stephen
Subject: RE: HFDWA: Chapter 4 - FracFocus

Wow – all those colors!

Thanks Jill.

Megan – please take the lead on reviewing and editing the box in Chapter 4. Thanks.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Dean, Jill
Sent: Thursday, February 26, 2015 10:36 AM
To: Burden, Susan; Frithsen, Jeff; Fleming, Megan; LeDuc, Stephen
Subject: RE: HFDWA: Chapter 4 - FracFocus

Ex. 5

Ex. 5

Ex. 5

Ex. 5

Jill Dean

Office of Science Policy

US EPA Office of Research and Development

office: 202-564-8241

email: dean.jill@epa.gov

From: Frithsen, Jeff
Sent: Wednesday, February 25, 2015 9:06 PM
To: Burden, Susan; Dean, Jill

Cc: LeDuc, Stephen; Fleming, Megan
Subject: HFDWA: Chapter 4 - FracFocus

Susan and Jill:

Given recent revisions to the FracFocus report, I wanted to cycle back and make sure that the HFDWA is consistent with those revisions. Please take a look at the following and provide feedback concerning the assessment of how complete fracfocus is for water use estimations. Thanks.

Jeff

Ex. 5

Ex. 5

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

703-347-8623 (office phone)

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2733 South Crystal Drive, Arlington, VA 22202

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
Cc: LeDuc, Stephen[LeDuc.Stephen@epa.gov]
From: Clark, Christopher
Sent: Thur 2/26/2015 5:05:39 AM
Subject: RE: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 2

Sounds good Jeff thanks!

Chris

Christopher Michael Clark, Ph.D.
Research Scientist
U.S. Environmental Protection Agency
Office of Research and Development
National Center for Environmental Assessment
Global Change Assessment Staff

Phone: (703) 347-8665

Mailing Address:

US EPA (8601-P);1200 Pennsylvania Ave NW; Washington DC, 20460

Physical Address:

US EPA Potomac Yards; 2733 South Crystal Drive; N-7834; Arlington, VA 22202

From: Frithsen, Jeff
Sent: Tuesday, February 24, 2015 5:48 PM
To: Clark, Christopher
Cc: LeDuc, Stephen
Subject: RE: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 2

Chris:

My suggestion is that you wait and read the version that will be distributed next week. That will be a better use of your time. Thanks.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Clark, Christopher
Sent: Tuesday, February 24, 2015 3:05 PM
To: Frithsen, Jeff
Cc: LeDuc, Stephen
Subject: RE: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 2

Hi Jeff,

I'm at a workshop this week so can't turn this around in 2 days. My apologies! If you are accepting comments after that point I'll read it on the plane on my way home Friday.

Take care and good luck!

Chris

Christopher Michael Clark, Ph.D.
Research Scientist
U.S. Environmental Protection Agency
Office of Research and Development
National Center for Environmental Assessment
Global Change Assessment Staff

Phone: (703) 347-8665

Mailing Address:

US EPA (8601-P);1200 Pennsylvania Ave NW; Washington DC, 20460

Physical Address:

US EPA Potomac Yards; 2733 South Crystal Drive; N-7834; Arlington, VA 22202

From: Frithsen, Jeff
Sent: Monday, February 23, 2015 9:55 PM
To: Anna Weber; Bates, William; Brent Ranalli; Burden, Susan; Burgoon, Lyle; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca; Dean, Jill; Deniz (Inci) Demirkanli; Fleming, Megan; Glen Boyd [Ex. 4] Impellitteri, Christopher; Jonathan.Koplos[Ex. 4]; Ken Klewicki ([Ex. 4] Knightes, Chris; LeDuc, Stephen; MaryEllen.Tuccillo[Ex. 4]m; Ridley, Caroline; Sandie Koenig; Shari.Ring[Ex. 4] Singer, Alison; Stanek, John; Todd, Jason; Weaver, Jim; Williams, Larke; Yohannes, Lia; Yost, Erin
Subject: RE: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 2

HFDWA Preliminary External Review Draft, 2/23/2015 – Part 2 – Chapters 5 through 10.

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Frithsen, Jeff
Sent: Monday, February 23, 2015 9:48 PM
To: 'Anna Weber'; Bates, William; 'Brent Ranalli'; Burden, Susan; Burgoon, Lyle; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca; Dean, Jill; 'Deniz (Inci) Demirkanli'; Fleming, Megan; Frithsen, Jeff; 'Glen Boyd [Ex. 4]'; Impellitteri, Christopher; 'Jonathan Koplos'; 'Ken Klewicki ([Ex. 4])'; Knightes, Chris; LeDuc, Stephen; 'Mary Ellen Tuccillo'; Ridley, Caroline; 'Sandie Koenig'; Shari.Ring[Ex. 4]; Singer, Alison; Stanek, John; Todd, Jason; Weaver, Jim; Williams, Larke; Yohannes, Lia; Yost, Erin
Subject: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 1

Team:

We now have a near complete version of the preliminary external review draft of the hydraulic fracturing drinking water assessment report. I know much hard work and thought has gone into getting us this far. Congratulations for a job well done!

We still have a way to go before we can turn over the final external review draft to the SAB. We have promised the Administrator that we will do that on May 14. Here's what we need to do this week to move us along towards that goal.

With this email, I am passing along a PDF file with the draft report frontmatter, executive summary and Chapters 1 through 4. In a separate email, I will be sending a second PDF file with Chapters 5 through 10. Everyone receiving this email is listed as an author of the assessment report, which means that we are all jointly responsible for its content. **Please block out the next two days and read through the two PDF files.** Don't just read the chapter on which you worked. We want your comments on the entire assessment.

The draft report has gone through at least two rounds of editing so I'm not very concerned about typographical errors and spelling at this point. Instead, focus on the big picture. Are the main results and conclusions of the draft assessment clear stated and fully supported by the data and information presented in the chapters? Have we done what we can to address the questions outlined in the HF Study Plan? Have we brought into the assessment the appropriate results and conclusions from ORD's HF study reports and journal publications? Have we missed something significant?

Please pass along your comments on this draft to the appropriate Chapter lead no later than start of business day (Eastern Time) Thursday, February 26. Just to remind everyone, our chapter leads are as follows:

Executive Summary – Steve LeDuc;

Chapter 1 – Caroline Ridley;

Chapter 2 – Caroline Ridley;

Chapter 3 – Lia Yohannes;

Chapter 4 – Megan Fleming;

Chapter 5 – Chris Knightes;

Chapter 6 – Shari Ring (Cadmus);

Chapter 7 – Jim Weaver;

Chapter 8 – Mary Ellen Tuccillo (Cadmus);

Chapter 9 – John Stanek;

Chapter 10 – Steve LeDuc.

Chapter leads will use Thursday to consolidate and evaluate comments and revise their chapters as appropriate. Chapter leads will be able to access their Chapters in MS Word format on a SharePoint site. Caroline will send out additional information about the SharePoint site. **Chapter leads should return their revised chapters to Jonathan Koplos (Cadmus) with a copy to Caroline as soon as possible, hopefully by noon Thursday, but no later than COB Thursday.** Chapter leads should focus on text changes and not be concerned with formatting.

Our Cadmus team will work to complete revisions and turn around the revised preliminary external review draft on **Monday, March 2**. It will be this next draft that we will use to complete ORD review and clearance.

I draw your attention to the following notes concerning this draft. First, the references are not yet finalized, so reviewers can ignore odd-looking citations (including parentheses with no spaces in between them and "ENREF" errors). Second, in the Word files, some of the internal comments are just FYI-types notes or notes that are for internal Cadmus needs only. Third, some Chapter 8 formatting (e.g., table formatting, text box placement) is still in progress.

Should you have any concerns about this draft, or you are unable to review, please contact me immediately to discuss.

Thanks again for all the hard work. We are getting closer to being able to deliver a completed external review draft that will make a difference.

Jeff

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries

Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

To: LeDuc, Stephen[LeDuc.Stephen@epa.gov]
Cc: Fleming, Megan[Fleming.Megan@epa.gov]; Jonathan.Koplos@cadmusgroup.com Ex. 4
From: Mary Ellen Tuccillo
Sent: Wed 2/25/2015 5:40:15 PM
Subject: RE: Chapter 8 comment: TX reuse #s

Yes, thanks!

Ex. 5 Ex. 5

From: LeDuc, Stephen [mailto:LeDuc.Stephen@epa.gov]
Sent: Wednesday, February 25, 2015 9:59 AM
To: Mary Ellen Tuccillo
Cc: Fleming, Megan; Jonathan Koplos
Subject: Re: Chapter 8 comment: TX reuse #s

It is Table 8-5 in the pdf version. Does that help?

Stephen D. LeDuc, PhD

US Environmental Protection Agency

National Center for Environmental Assessment, Arlington, VA 22202

Office Phone: (703) 347-8962; Ex. 6

From: Mary Ellen Tuccillo Ex. 4
Sent: Wednesday, February 25, 2015 9:52 AM
To: LeDuc, Stephen
Cc: Fleming, Megan; Jonathan.Koplos Ex. 4
Subject: RE: Chapter 8 comment: TX reuse #s

Hi Steve,

Thanks. I will take a second look at those sources. But can you be a bit more specific about exactly which section you are referring to? Page 31 for me is in the CWTs section, not reuse.

Thanks!

Mary Ellen

Mary Ellen Tuccillo, Ph.D.

The Cadmus Group

100 5th Ave., Suite 100

Waltham, MA 02451

Ex. 4

Ex. 4

Water is the driving force of all nature. Leonardo da Vinci

From: LeDuc, Stephen [mailto:LeDuc.Stephen@epa.gov]
Sent: Wednesday, February 25, 2015 9:38 AM
To: Mary Ellen Tuccillo
Cc: Fleming, Megan; Jonathan Koplos
Subject: Chapter 8 comment: TX reuse #s

Hi Mary Ellen,

I'm not reading your chapter in detail so I won't be giving formal comments, b Ex. 5

Ex. 5

Ex. 5

Ex. 5 I'm cc'ing Megan on this because she has worked closely with those #s. Best, Steve

---

Stephen D. LeDuc, PhD

US Environmental Protection Agency

National Center for Environmental Assessment, Arlington, VA 22202

Office Phone: (703) 347-8962; Ex. 6

To: MaryEllen.Tuccillo Ex. 4
Cc: Jonathan.Koplos Ex. 4 LeDuc, Stephen[LeDuc.Stephen@epa.gov]
From: Ridley, Caroline
Sent: Mon 2/23/2015 11:50:53 PM
Subject: Few details to add to chapter 10
Chapter 10 DRAFT_20150222.docx

Mary Ellen,

Could you take a look at our current version of ch 10 and help us answer some questions related to the WW section? And put the additions into tracked changes?

Ex. 5

Could we get this from you by early on Thursday?

Thanks,

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): (703) 362-5955
~~~~~~

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: Jonathan.Koplos Ex. 4 LeDuc, Stephen[LeDuc.Stephen@epa.gov]
From: Frithsen, Jeff
Sent: Mon 2/23/2015 4:03:44 PM
Subject: RE: Status of HFDWA extraneous bits- front matter and appendices

See comments in red font below. For discussion.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Ridley, Caroline
Sent: Monday, February 23, 2015 10:41 AM
To: Frithsen, Jeff
Cc: Jonathan.Koplos Ex. 4 LeDuc, Stephen
Subject: RE: Status of HFDWA extraneous bits- front matter and appendices

Jeff- I know our time is short to talk this morning, but I think it would be helpful to identify which of the pieces below we need to include in the March 2 draft and in what state.

Thanks,

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist
~~~~~~

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6

From: Ridley, Caroline
Sent: Friday, February 13, 2015 4:49 PM
To: Burden, Susan; Frithsen, Jeff; LeDuc, Stephen
Cc: Jonathan Koplos
Subject: Status of HFDWA extraneous bits- front matter and appendices

All,

Probably stupid to send right before a holiday weekend, but I need to put a marker down so I don't forget. Here are some pieces of the HFDWA that we haven't really had a chance to discuss and their status. If there are things we CANNOT leave out of the draft on March 2, please identify them. We can talk more next week.

Have a good long weekend!

Caroline

Front matter

- Disclaimer- needs to be edited, right now says it's an internal copy – Needed for March draft – use standard disclaimer for internal review draft.

- Abstract- blank Not needed for March draft

- TOC- will be auto-generated with penultimate PDF – Complete TOC not needed for March draft – Useful to have major sections if possible

- List of tables- will be auto-generated with penultimate PDF – Not needed for March draft

- List of figures- will be auto-generated with penultimate PDF Not needed for March draft

- List of abbreviations- blank – Not needed for March draft

- Preface- blank Not needed for March draft

- Foreword- blank Not needed for March draft

- Authors and contributors list- needs to be looked at again and agreed upon by everyone -- Needed for March draft – want to make sure everyone is onboard. I want to see before it goes it.

- Reviewers- blank -- Needed for March draft – need to identify EPA staff involved in the review of the September 2014 draft.

- Acknowledgements- blank

Ex. 5

Ex. 5

- ES- in development Needed for March draft

For appendices, I think we should plan to have these ready April 1.

Ex. 5

Ex. 5

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6

To: Jonathan.Koplos@cadmusgroup.com[Ex. 5 LeDuc, Stephen[LeDuc.Stephen@epa.gov]; Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: MaryEllen.Tuccillo[Ex. 4 Stephen LeDuc[Ex. 6
From: Shari Ring
Sent: Thur 2/19/2015 12:16:49 PM
Subject: RE: Chapter 10 edits
HFDWA ES Draft Text_20150213-Cadmus comments.docx

I got to read the front part of the Exec Summary last evening, and had 2 comments on p. 3, which are in the attached and copied below, in case that's easier.

Also, I forwarded Jonathan's email to Steve's gmail account, in case email problems still persist.

Ex. 5

Ex. 5

Shari Ring

The Cadmus Group, Inc.

Ex. 4

From: Jonathan Koplos
Sent: Wednesday, February 18, 2015 6:49 PM
To: Stephen LeDuc (leduc.stephen@epa.gov) ; Caroline Ridley (ridley.caroline@epa.gov)
Cc: Shari Ring; Mary Ellen Tuccillo
Subject: Chapter 10 edits

Steve,

Shari got through well injection, and Mary Ellen got through the first two pages of wastewater. We'll get you the remaining edits on wastewater tomorrow before noon.

Jonathan

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

100 5th Avenue, Suite 100

Waltham, MA 02451

Ex. 4

www.cadmusgroup.com

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]; LeDuc, Stephen[LeDuc.Stephen@epa.gov]
Cc: Ridley, Caroline[Ridley.Caroline@epa.gov]; Ex. 6
From: Fleming, Megan
Sent: Wed 2/18/2015 2:38:28 PM
Subject: RE: HFDWA: Initial Feedback on draft Chapters

Hi Jeff,

Thanks for passing along the feedback. We'll consider these comments going forward.

Thanks,

Megan

Megan Fleming
Office of Science Policy

U.S. EPA Office of Research and Development

1200 Pennsylvania Avenue, N.W.

Washington, D.C. 20460

(202)-564-6604

From: Frithsen, Jeff
Sent: Tuesday, February 17, 2015 11:07 PM
To: LeDuc, Stephen; Fleming, Megan
Cc: Ridley, Caroline
Subject: FW: HFDWA: Initial Feedback on draft Chapters

Following-up on the email below. Kevin and I talked this afternoon about the chapters he read. Concerning Chapter 4, he did have a few specific comments. I will do my best to characterize those general comments.

Ex. 5

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Frithsen, Jeff
Sent: Tuesday, February 17, 2015 10:54 PM
To: Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Ridley, Caroline; Burgoon, Lyle; Cluff, Maryam; Fleming, Megan; Impellitteri, Christopher; Jonathan.Koplos Ex. 4 Knightes, Chris; MaryEllen Tuccillo; Shari.Ring@ Ex. 4 ; Stanek, John; Weaver, Jim; Yohannes, Lia

Subject: HFDWA: Initial Feedback on draft Chapters

I shared drafts of Chapters 1, 2, 3, and 4 with Kevin Teichman and he read through those chapters over the weekend. He thought all four chapters were very well done, especially Chapter 1 and 2. He sends along his appreciation and thanks for all the hard work put in by the team.

Kevin is sending me marked up chapters. I suspect I will be sharing minor comments with the appropriate chapter leads.

Thanks all. The assessment is coming together nicely.

Jeff

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

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1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

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2733 South Crystal Drive, Arlington, VA 22202

To: Jackson, Joe-A[Jackson.Joe-A@epa.gov]
From: LeDuc, Stephen
Sent: Wed 7/15/2015 2:23:10 PM
Subject: Hydraulic Fracturing Drinking Water Assessment: Peer Review Assistance

Dear Joe Jackson,

I'm a research scientist over in ORD/NCEA, Ex. 5

Ex. 5

Ex. 5 Any assistance on this would be most appreciated. Thank you for your time and consideration. Best, Steve

Stephen D LeDuc, PhD

National Center for Environmental Assessment

US Environmental Protection Agency

Arlington, VA 22202

703-347-8962 (office)

Ex. 6

From: LeDuc, Stephen
Location: DCRoomPYN7100-River/ORD-NCEA-DC
Importance: Normal
Subject: NCEA Presentation on Draft Hydraulic Fracturing Assessment
Start Date/Time: Tue 6/16/2015 5:00:00 PM
End Date/Time: Tue 6/16/2015 6:00:00 PM
HFDWA Release Briefing 20150616.pdf

For those interested,

Caroline Ridley and I are providing an overview presentation on the Draft Hydraulic Fracturing Drinking Water Assessment. We released this assessment on June 4th and it covers the potential impacts of hydraulic fracturing activities on drinking water resources. This was a cross-ORD effort, with NCEA authors playing a prominent role. The presentation will last ca. 30-40 minutes with time for Q&A afterwards. Slides and call-in information are below.

Best,

Steve

****We would like to keep this presentation to NCEA personnel so please do not forward on this invite without permission****

Ex. 6

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]; Ridley, Caroline[Ridley.Caroline@epa.gov]
From: LeDuc, Stephen
Sent: Mon 6/8/2015 4:15:20 PM
Subject: RE: HFDWA: Presentation with notes
HFDWA Release Briefing 20150608.pptx

Caroline,

I touched this up a little—changed the date on the opening slide, and noted that the reports/assessment came out last week. I'm sending to you in case I missed anything—once you think it is OK, can you send on to Kelsey and cc' me? Best, Steve

From: Frithsen, Jeff
Sent: Monday, June 08, 2015 12:11 PM
To: LeDuc, Stephen; Ridley, Caroline
Subject: RE: HFDWA: Presentation with notes

Thanks Steve and Caroline.

I plan to be over at RRB Hurd Hall for the presentation, but just as backup. I have full confidence in you and Caroline!

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: LeDuc, Stephen
Sent: Monday, June 08, 2015 12:05 PM
To: Frithsen, Jeff; Ridley, Caroline
Subject: RE: HFDWA: Presentation with notes

Thanks Jeff. Caroline, I'm making a few very minor updates (the date and getting rid of the word today) per our conversation, and then will send them along to you for your review, before sending to Kelsey. Best, Steve

From: Frithsen, Jeff
Sent: Monday, June 08, 2015 11:49 AM
To: Ridley, Caroline; LeDuc, Stephen
Subject: HFDWA: Presentation with notes

Caroline and Steve:

Attached is a version of the presentation with notes.

Ex. 5

Ex. 5

Thanks.

Jeff

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries

Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

To: Ridley, Caroline[Ridley.Caroline@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: LeDuc, Stephen
Sent: Mon 6/8/2015 1:35:42 PM
Subject: RE: Additional slide comments

Sounds good! Steve

From: Ridley, Caroline
Sent: Monday, June 08, 2015 9:32 AM
To: LeDuc, Stephen; Frithsen, Jeff
Subject: RE: Additional slide comments

Non-Responsive I grabbed the slides off the HF study page.

Talk to you in a bit.

C

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6

From: LeDuc, Stephen
Sent: Monday, June 08, 2015 9:28 AM
To: Ridley, Caroline; Frithsen, Jeff
~~~~~~

Subject: RE: Additional slide comments

Caroline,

Let's talk after our 11am call today. I'm working AWL today.

Jeff, do you have the slides for us? Best, Steve

Stephen D LeDuc, PhD

National Center for Environmental Assessment

US Environmental Protection Agency

Arlington, VA 22202

703-347-8962 (office)

Ex. 6

From: Ridley, Caroline
Sent: Friday, June 05, 2015 3:19 PM

To: LeDuc, Stephen; Frithsen, Jeff
Subject: RE: Additional slide comments

Let's save it until Monday. I'm brain dead.

C

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6

From: LeDuc, Stephen
Sent: Friday, June 05, 2015 11:42 AM
To: Ridley, Caroline; Frithsen, Jeff
Subject: RE: Additional slide comments

Caroline,

I'm in the office today—do you want to talk logistics for Tuesday's presentation?

Jeff, I assume we are using the same slide deck that you used for the states? And, is there a script for that? Best, Steve
~~~~~~

From: Ridley, Caroline
Sent: Friday, June 05, 2015 10:50 AM
To: Frithsen, Jeff
Cc: LeDuc, Stephen
Subject: Additional slide comments

Ex. 5

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6

To: Solomon, Sarah[Solomon.Sarah@epa.gov]
From: LeDuc, Stephen
Sent: Tue 5/19/2015 4:00:54 PM
Subject: FW: HFDWA: Revised Executive Summary
HFDWA - Executive Summary_20150510 jbf WISER clean.docx
ATT00001.htm

Can you bring in these comments from Nathan—don't make any of the changes just bring them in. Some might not be applicable anymore b/c they were on an earlier draft.

From: Frithsen, Jeff
Sent: Monday, May 18, 2015 1:34 PM
To: Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Ridley, Caroline
Subject: FW: HFDWA: Revised Executive Summary

Note – additional comments on the ES from Nathan. This is on our previous version.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Briskin, Jeanne
Sent: Monday, May 11, 2015 4:53 PM
To: Frithsen, Jeff
Subject: Fwd: HFDWA: Revised Executive Summary

pls include these edits/comments too
Begin forwarded message:

From: "Wiser, Nathan" <Wiser.Nathan@epa.gov>
To: "Briskin, Jeanne" <Briskin.Jeanne@epa.gov>
Subject: RE: HFDWA: Revised Executive Summary

Hi Jeanne,

I made some additional comments/suggestions.

Nathan Wiser, Environmental Scientist
Office of Research and Development, Office of Science Policy
303-312-6211 office
wiser.nathan@epa.gov

mailing address:
EPA Region 8 (8ENF-UFO)
1595 Wynkoop Street
Denver, CO 80202

From: Briskin, Jeanne
Sent: Monday, May 11, 2015 5:33 AM
To: Wiser, Nathan
Subject: Fwd: HFDWA: Revised Executive Summary

Please let me know if there is anything not true or otherwise intolerable in here. Thanks!

Begin forwarded message:
From: "Frithsen, Jeff" <Frithsen.Jeff@epa.gov<mailto:Frithsen.Jeff@epa.gov>>
Date: May 10, 2015 at 9:03:34 PM EDT
To: "Burke, Thomas" <Burke.Thomas@epa.gov<mailto:Burke.Thomas@epa.gov>>,
"Kavlock, Robert" <Kavlock.Robert@epa.gov<mailto:Kavlock.Robert@epa.gov>>,
"Kadeli, Lek" <Kadeli.Lek@epa.gov<mailto:Kadeli.Lek@epa.gov>>
Cc: "Briskin, Jeanne" <Briskin.Jeanne@epa.gov<mailto:Briskin.Jeanne@epa.gov>>,
"Gibbons, Dayna" <Gibbons.Dayna@epa.gov<mailto:Gibbons.Dayna@epa.gov>>,
"Matthews, Lisa" <Matthews.Lisa@epa.gov<mailto:Matthews.Lisa@epa.gov>>,
"Teichman, Kevin" <Teichman.Kevin@epa.gov<mailto:Teichman.Kevin@epa.gov>>,
"Zambrana, Jose" <Zambrana.Jose@epa.gov<mailto:Zambrana.Jose@epa.gov>>
Subject: HFDWA: Revised Executive Summary
Tom:

The latest version of the executive summary is attached. With your approval, we can pass it along to the administrator and others in the AO tomorrow morning.

We didn't get to everything on our tick list for the executive summary and will be working on further refinements during the week. However, it is coming along well.

Enjoy – all comments welcome!

Jeff

Jeffrey B. Frithsen, Ph.D.
National Center for Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency
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Washington, DC 20460
703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries
Two Potomac Yard (North Building), Room N-7741
2733 South Crystal Drive, Arlington, VA 22202

To: Solomon, Sarah[Solomon.Sarah@epa.gov]
From: LeDuc, Stephen
Sent: Tue 5/19/2015 3:49:43 PM
Subject: FW: HFDWA: Executive Summary - Page ES-14

Can you bring these comments into the ES. See my note. Thanks! Steve

From: LeDuc, Stephen
Sent: Tuesday, May 19, 2015 11:49 AM
To: 'Shari Ring'; Frithsen, Jeff; Burden, Susan; Ridley, Caroline
Subject: RE: HFDWA: Executive Summary - Page ES-14

Hi all,

I agree with Shari's edits, except Ex. 5
Ex. 5 Other than that I'm OK with these. Best, Steve

From: Shari Ring [mailto:Shari.Ring@cadmusgroup.com]
Sent: Tuesday, May 19, 2015 7:14 AM
To: Frithsen, Jeff; Burden, Susan; LeDuc, Stephen; Ridley, Caroline
Subject: RE: HFDWA: Executive Summary - Page ES-14

My 2 cents below:

Ex. 5

Ex. 5

Shari Ring

The Cadmus Group, Inc.

703.247.6159

From: Frithsen, Jeff [mailto:Frithsen.Jeff@epa.gov]
Sent: Monday, May 18, 2015 11:21 PM
To: Shari Ring; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Ridley, Caroline
Subject: HFDWA: Executive Summary - Page ES-14

We continue to get comments on how we refer to our example cases. This paragraph from the ES (page ES-14) received some comment from Jose. Ex. 5

Ex. 5

Ex. 5

Ex. 5

Ex. 5

Jeff

Ex. 5

Jeffrey B. Frithsen, Ph.D.

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2733 South Crystal Drive, Arlington, VA 22202

To: Solomon, Sarah[Solomon.Sarah@epa.gov]
From: LeDuc, Stephen
Sent: Fri 5/15/2015 2:09:05 PM
Subject: FW: Comments on ES and ch 10

Can you bring into ES? Feel to free address changes. Best, Steve

From: Ridley, Caroline
Sent: Thursday, May 14, 2015 4:11 PM
To: LeDuc, Stephen
Cc: Burden, Susan; Frithsen, Jeff
Subject: Comments on ES and ch 10

Generally, the HF water cycle paragraphs in the ES are now reading much better than the synthesis sections and answers to the research questions at the end of chapters. Sometimes they don't have exactly the same info anymore either. This might be ok, or we might encourage the chapter leads to translate some of the ES writing to the ends of their chapters.

~~~~~~~~~~~~~~~~~~~~~~~~~~`

Ex. 5
~~~~~~~~~~~~~~~~~~~~~~~~~~

Ex. 5

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): (703) 362-5955

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: LeDuc, Stephen
Sent: Fri 5/1/2015 2:28:41 PM
Subject: RE: Freak out

Ugh. OK, thanks for sharing. I'm working on and off today. Best, Steve

-----Original Message-----
From: Ridley, Caroline
Sent: Friday, May 01, 2015 9:17 AM
To: LeDuc, Stephen
Subject: FW: Freak out

I sent a text last night to Jeff about our team starting to reach freak out stage about the comments. Here's the reply ...
C

~~~
~~~

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: Jonathan Koplos Ex. 4
From: LeDuc, Stephen
Sent: Mon 3/30/2015 9:01:03 PM
Subject: Louisiana State Report
12.Final.GW.Report.pdf

Ex. 5

Stephen D LeDuc, PhD

National Center for Environmental Assessment

US Environmental Protection Agency

Arlington, VA 22202

703-347-8962 (office)

Ex. 6

Louisiana Ground Water Resources Commission

Managing Louisiana's groundwater resources

with supplemental information on surface water resources

An Interim report to the Louisiana Legislature

March 15, 2012

Managing Louisiana's Groundwater Resources

with supplemental information on surface water Resources

An Interim Report to the Louisiana Legislature

Published
March 15, 2012

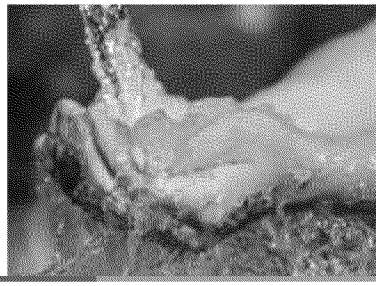
Louisiana Ground Water Resources Commission

617 North Third Street
Baton Rouge, Louisiana 70802
(225) 342-8244
dnr.louisiana.gov

This interim report and all appendices may be viewed online:

http://dnr.louisiana.gov/index.cfm?md=pagebuilder&tmp=home&pid=907

To the Distinguished Members of the Louisiana Legislature and the People of the Great State of Louisiana



March 15, 2012

From its beginning in 1682 when La Salle claimed all of the territory drained by the Mississippi River in the name of King Louis XIV of France and called it "Louisiana," water has been at the center of many significantmilestones in Louisiana's history. Communities and economies have developed and thrived along our rivers and coastal regions, while residents have faced the challenges of historic river floodsand devastating tropical storm events that tested our state's strength and stability. As a result, much of the focus over the past 200 years since Louisiana's statehood has prudently been on reducing the risk of rising water and encroaching saltwater. Consequently, our leaders have wisely invested in critical infrastructure designed to manage floodwatersand fightcoastal erosion, protecting people and property. State laws and rules have also been adopted to protect water quality and regulate discharges into surface water bodies like streams, rivers, lakes, and bayous.

Water is a conundrum, being the only natural substance that can be found in all three physical states (solid, liquid and gas) at normally occurring temperatures. It is equally enigmatic as it pertains to regulatory classification in that water is simultaneously a precious life-giving necessity, a commodity with universal utility in industry, and a nuisance to be disposed of, diverted, and controlled. As such, a hodgepodge of laws, rules, regulations, and regulatory authorities have evolved to address the complicated management of this resource. Currently in Louisiana, there are at least four federal agencies, eight state agencies, two ground water conservation districts and more than 700 local entities such as watershed districts, surface water conservation districts, reservoir districts, drainage basins, waterway commissions, lake commissions, water and sewerage districts, waterworks and recreation districts with management or regulatory authority over the resource.

In addition to the complexity with regard to the agencies that manage our water resources, our laws governing water are also complex. Historically, our state has applied various and sometimes conflictinglegal concepts such as absolute ownership, rule of capture, and riparian rights. This has resulted in a situation where the running surface waters of the state are recognized as public resources, owned by the state, and generally subject to a charge for consumption, excepting riparian landowners and where used for agriculture, aquaculture, and municipal purposes. Conversely, groundwater, when reduced to possession, is treated as privately owned and free of charge. This paradox results in the state charging for surface water resources that are normally in abundance, while allowing uncompensated withdrawal of groundwater resources that are often in limited supply. While we embrace the right of capture for landowners, in order to address this quandry, legal scholars should research, debate, and explore the potential non-compensated consumption of surface water when used as an alternative to groundwater and as an aid to economic development, job creation, and job retention.

It wasn't until 2001 that Louisiana took major steps to manage a vital, yet often overlooked, asset —the groundwater provided by this state's eleven principal aquifer systems. In response to an extreme drought period in 1999-2000, the Louisiana Legislature approved Act 446, which established the Louisiana Ground Water Resources Commission, the Ground Water Management Advisory Task Force, and the Ground Water Resources Program. Ensuring the sustainability of this critical resource is the ongoing goal of these entities, placed within the Louisiana Department of Natural Resources (LDNR), Office of Conservation, by the legislature in 2003.

Since then, important steps have been made in regulating and managing groundwater use and promoting conservation, with nearly 190,000 entries in the Office of Conservation database and a list of 154 certified water well drilling contractors. From 2001 to 2007, the agency processed 980 new water well installation notices submitted as required by 2001 and 2003 legislation. Following administrative changes initiated in the fall of 2007, passage of enforcement legislation in 2008, aggressive compliance auditing and enforcement activity implemented in January 2008, and ongoing education and outreach efforts, agency staff received and processed over 5,000 new well installation notices from 2008 through February 2012, an increase of 500 percent. The primary causative force driving this improvement is the diligence in implementing compliance auditing procedures and enforcement actions. Since January 2009 to present, nearly 3,000 enforcement actions have been issued to owners of water wells that were installed without providing the agency proper notification for groundwater withdrawal sustainability evaluation. Clearly, this effort has resulted in necessary improvements, bringing into play a more comprehensive implementation of the legislature's intent for the agency to fulfilla proactive, well-specific role in the state's management of aquifer sustainability and groundwater use.

The Office of Conservation has responded to aquifer-specific groundwater supply issues by designating three Areas of Ground Water Concern in the Sparta aquifer system in 2005. More recently, due to persistent exceptional drought conditions, increased dependence on groundwater resources in two population centers in southern Caddo Parish caused some domestic well owners to experience well pumping problems, many losing the ability to withdraw groundwater from their wells. To manage groundwater availability and aquifer sustainability, the agency issued an order in August 2011 declaring portions of the Carrizo-Wilcox and Upland Terrace aquifers a groundwater emergency, thus invoking its statutory authority to curtail groundwater production and require conservation measures. Although, at the time of this interim report, aquifer conditions for these situations continue to require extraordinary management and oversight, monitoring results show that prudent application of these management techniques have had a positive impact on recovery toward sustainability.

According to the U.S. Geological Survey (USGS), total withdrawals from Louisiana groundwater and surface water sources in 2010 were approximately 8,500 million gallons per day, a decrease of about 17 percent since 2005. However, while surface water withdrawals decreased by approxinately 20 percent during this period, groundwater withdrawals increased by two percent (diagram page 51).

Today, population and economic growth are placing added pressure on strained aquifers, while severe drought conditions reveal the fragility of our aquifer systems and the interdependence of our groundwater and surface water resources. Water as a natural resource of Louisiana has been thought of as a limitless commodity. One,

that, from time to time, has been more conspicuous in its overabundance (floods) than in its absence (drought). This impression has been changed in recent times. Louisiana's water is now recognized as tremendously valuable. Evidence of this can be seen by the market's interest in the 2011 effort of the Sabine River Authority of Louisiana (SRA-LA) to sell raw water from the Toledo Bend Reservoir (Appendix A). For a variety of reasons, the SRA-LA recently elected to suspend this effort, but it is clear that we have come to a time in Louisiana's history when the State of Texas is interested in our water resources. The consequences of such a consideration, whether intended or unintended, long or short term, should be well researched by experts and fully debated through a transparent public process.

Current challenges require a renewed effort by both government and citizens to manage all of our water resources in ways that meet current and future water use demands. Clearly, the authors of our State Constitution understood the value of water resources, as expressed in Article IX, Section 1, which states, "The natural resources of the state, including air and water, and the healthful, scenic, historic, and esthetic quality of the environment shall be protected, conserved, and replenished insofar as possible and consistent with the health, safety, and welfare of the people."

It is well accepted that the ability to manage resources is only as good as the capacity to monitor the resources. Groundwater and surface water data collection has been ongoing in Louisiana by agencies, such as the USGS and the U.S. Army Corps of Engineers, for over 90 years. The USGS has had a cooperative monitoring program with the State since the early 1950's. Peak monitoring occurred in the early 1980's, at which point the cooperative network included a groundwater network of 739 wells and a surface water network of 184 gaging stations. Due to budget reductions in the mid-1980's, these networks have been reduced to the present 164 wells and 59 gaging stations, a 78 percent and 68 percent reduction respectively. Recognizing it is paramount that the State's groundwater monitoring networks be robust enough to timely identify areas of concern and enable scientifically based management decisions, the Fiscal Year 2012-2013 Executive Budget includes an appropriation, from a decade-old fund comprised of federal fines, to expand and enhance the groundwater monitoring network, reporting frequency, and aquifer evaluations, all as per a USGS recommendation. For this specific reason, this document is an interim report to be updated annually as this robust monitoring program is implemented. We are hopeful that additional funding to expand and enhance surface water monitoring can be secured in the near future.

Furthermore, we recognize that no two aquifers are the same, and a one-size-fits-all management approach is inappropriate. This interim report recommends a management strategy implemented through a centralized state governance model complemented by the establishment of regional advisory panels composed of local governments, user groups, and interested stakeholders, all as previously authorized by Act 49 of 2003. In the cases where the legislature has already established regional commissions, specifically, the Capital Area Ground Water Conservation Commission and the Sparta Aquifer Ground Water Conservation Commission, these entities should concurrently serve as their regional advisory panel. Additionally, we recognize investing in conservation education and outreach is the best value proposition to promote the long-term sustainability of the resource. We have been advised that LDNR is in the process of reallocating personnel to provide this service, in conjunction with other resource agencies, and we are very encouraged by this progress.

This interim report is a culmination of discussions with public and private water users and stakeholders, other state and federal agencies, and elected officials over the past two years, and follows a recent study of our groundwater resources and water policy. In addition to an overview of water resources and governance of these resources, we have compiled information requested by House Concurrent Resolution 1 of 2010, including recommendations for enhancing water management. This interim report also demonstrates that the management of groundwater and surface water are inextricable, and that a comprehensive approach to water sustainability in Louisiana should be considered. As a result, this interim report recommends that the appropriate public policy is for the legislature to consider adding surface water fact-gathering responsibilities, without management or regulatory authority, to the mission of the Ground Water Resources Commission, expanding its membership, and amending its name to the Water Resources Commission.

As members of the current Ground Water Resources Commission, we take our responsibilities seriously. While records indicate that the previous Ground Water Commission did not meet their statutory requirement to convene twice annually, this Commission exceeded that requirement by meeting a total of 13 times in 41 months beginning in October 2008. Prior to 2008, all Commission meetings were held in Baton Rouge; however, since that time, to foster greater public participation, meetings have also been held in Minden, Ruston, Eunice, Mandeville, Alexandria, Crowley, and Shreveport.

There are so many people throughout Louisiana who play important roles in water management, protection, and distribution. We particularly recognize the licensed water well drillers throughout Louisiana who help bring our valuable groundwater resource to the surface and enable it to be used by residents and businesses throughout our state. Additionally, we are thankful to the thousands of stakeholders, contractors, and employees, both public and private, throughout the state who are dedicated to the safe withdrawal, treatment, and distribution of this life-sustaining resource.

The members of the Louisiana Ground Water Resources Commission are appreciative of the opportunity to work with all of you to protect, conserve, and sustain our vital water resources. When reviewing this interim report, we encourage you to refer to the appendices, which provide supporting and additional information for the water sustainability issues discussed. Please be advised, as previously communicated to the Louisiana Legislature on February 23, 2012, this interim report was delayed for two weeks to allow us to include comments from a March 8 public meeting in Baton Rouge on the matter of saltwater encroachment in the 1,500-foot and 2,000-foot sands of the Southern Hills aquifer system. Finally, this report is not an ending, but rather, a continuation of the state's efforts to manage its water resources.

Respectfully submitted,

Members of the LA Ground Water Resources Commission

LA Ground Water Resources Commission

Secretary Scott A. Angelle, *Chairman*
LA Dept. of Natural Resources

Brad Spicer, *Vice Chairman*
LA Dept. of Agriculture & Forestry

Hal Leggett
James Burland (2008-2012)
LA Chemical Assoc., LA Mid-Continent Oil & Gas Assoc.,
LA Assoc. of Business & Industry, LA Pulp & Paper Assoc.

Elliot Colvin
LA Farm Bureau

VACANT
William Downs (2008-2012)
Ground Water Resource Management Professional

Paul Frey
LA Landowners Association

Dan Hollingsworth
LA Municipal Association

James B. "Jimmy" Johnston
LA Wildlife Federation, Coalition to Restore Coastal LA,
League of Women Voters

Charles Killebrew
Garret Graves (2008-2010)
Governor's Office of Coastal Activities

Paul "Jackie" Loewer
Chicot Aquifer Representative

Mickey Mays
Police Jury Association of LA

Ted McKinney
Gene Coleman (2006-2010)
Spirit Ground Water Conservation District

Eugene Owen
Capital Area Ground Water Conservation District

Kyle Balkum, *Ex-Officio*
LA Dept. of Wildlife And Fisheries

Zahir "Bo" Bolourchi, *Ex-Officio*
LA Dept. of Transportation & Development

Jonathan "Jake" Causey, *Ex-Officio*
Glenn Cambre (2009-2012), *Ex-Officio*
LA Dept. of Health & Hospitals

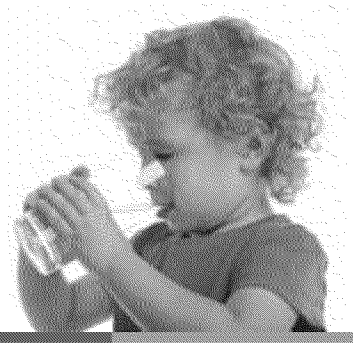
Vince Sagnibene, *Ex-Officio*
Paul Miller (2009-2012), *Ex-Officio*
LA Dept. of Environmental Quality

Kelsey Short, *Ex-Officio*
LA Dept. of Economic Development

James Welsh, *Ex-Officio*
LA Commissioner of Conservation

LA Ground Water Management Advisory Task Force

Jim Pratt, *Chairman* - Sabine River Authority of Louisiana
Sen. Jody Amedee
Larry Ardoin - LDOTD
Jesse Barr - LA Cotton Producers Association
Andrea Bourgeois-Calvin - Lake Pontchartrain Basin Foundation
Herschel Bourque - LA Groundwater Association
Joseph Breaux - Office of Soil & Water Conservation
Gifford Briggs - LA Oil & Gas Association
Charles Cannatella - LA Soybean Association
Chacko John - LA Geological Survey
Cloyce Clark, III - Office of the Governor
Danny Cole - LA Cattlemen's Association
Patrick Credeur - LA Rural Water Association
Rep. Gordon Dove
Timothy Duex - ULL Dept. of Geology
Anthony Dupiechin - Capital Area Groundwater Conservation District
Jim Ferguson - LA Engineering Society
Ernest Girouard - LSU Ag Center
Marshall "Mike" Goree - Irrigation Association
Henry Graham - LA Chemical Association
Adam Haddox - LA Pulp & Paper Association
Gary Hanson - LSU-S Watershed Management Institute
William Herke - Citizens for A Clean Environment
Robert Jackson - New Orleans Sewerage & Water Board
Nancy Lanctot - LA Wildlife Federation
John Lovelace - U.S. Geological Survey
R. Michael Lyons - LA Mid-Continent Oil & Gas Association
Kyle McCann - LA Farm Bureau
Olivia McDonald - Spirit Groundwater Conservation District
Stephen Minvielle - LA Crawfish Farmers Association
Sen. Jean-Paul Morrell
Rep. James Morris
Fulbert Namwamba - Southern University
Britt Paul, U.S. Dept. of Agriculture/Natural Resources Conservation Service
Kerry St. Pe - Barataria-Terrebonne National Estuary Program
Sen. Francis Thompson
C.A. "Buck" Vandersteen - LA Forestry Association
Jennifer Vidrine - League of Women Voters
Herman Waguespack - American Sugar Cane League
Kathy Wascom - Coalition to Restore Coastal LA
Carol Wicks - LSU Dept. of Geology & Geophysics
James "Dennie" Williams - Association of Public Utilities
Fred Zaunbrecher - LA Rice Growers Association



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Why This Report Is Important

Sustainability is Non-Optional - Louisiana's water budget – our total withdrawal and recharge capacities for groundwater and surface water – is not infinite. Just as families, businesses, and governments must act and plan responsibly to ensure that withdrawals do not exceed deposits, so must our state proactively address the sustainability of our aquifers and all water sources. Water is not an option for life. As such, we have no choice but to sustain our critical water supply.

Our Constitution Mandates It - Article IX of the Louisiana Constitution is considered by many to be the ultimate directive with regard to the public trust empowered to the government in the management of our natural resources and environment. According to Article IX, Section 1 (Natural Resources and Environment; Public Policy) of the Louisiana Constitution, "The natural resources of the state, including air and water, and the healthful, scenic, historic, and esthetic quality of the environment shall be protected, conserved, and replenished insofar as possible and consistent with the health, safety and welfare of the people." This constitutional mandate drives every law, rule, and regulation implemented to manage or preserve water quality and quantity. Article IX also impacts the way the state manages activities and assets that rely on water, such as agriculture, wildlife, fisheries, coastal restoration and protection, exploration and mining, and industrial development.

Louisiana Constitution Article IX. Natural Resources

§1. Natural Resources and Environment; Public Policy

Section 1. The natural resources of the state, including air and water, and the healthful, scenic, historic, and esthetic quality of the environment shall be protected, conserved, and replenished insofar as possible and consistent with the health, safety, and welfare of the people.

The legislature shall enact laws to implement this policy.

Consistency With and Implementation of Coastal Master Plan - Recognizing the need to "coordinate and focus the functions of all state agencies as they relate to coastal protection, including hurricane protection and wetlands conservation and restoration," Governor Bobby Jindal issued an Executive Order on January 28, 2008 (Appendix B). The order requires all state agencies to administer regulatory practices, programs, contracts, grants, and all other functions vested in them in a manner consistent with Louisiana's Master Plan for Coastal Restoration and Protection. Complying with Governor Jindal's Executive Order and maintaining consistency with the Coastal Master Plan are critical in the management of the state's water resources. The 2012 Draft Coastal Master Plan relies heavily upon the availability of fresh water to achieve its anticipated outcomes over the 50-year vision of the plan. The Plan relies on fresh water to enhance freshwater fisheries and habitat, combat high salinities that infiltrate our basins, and uses freshwater and sediment diversions as a restoration tool. A reliable supply of fresh water is critically important to the long-term success of the Plan. The 2012 Draft Plan has undergone public review and comment, and the Final Plan will be submitted to the Louisiana Legislature in early April 2012.

Preserving "Sportsman's Paradise" - Groundwater resources are intrinsically connected to surface water resources. Groundwater discharges to stream, bayous, marshes, coastal wetlands, and rivers, as well as many other ecologically important wildlife habitats. Louisiana is known to be the "The Sportsman's Paradise," and in many cases, this heaven for fishermen, fowl hunters, bird watchers, canoeists, boaters and general outdoorspersons heavily depends on a reliable and clean groundwater influx. During the drier months of the year, as well as during droughts, the sole source of life-giving water for many of those sensitive environments comes from the ground, as water that has travelled through aquifers discharges and becomes surface water, sustaining swamps like the Atchafalaya, our coastal marshes, and Louisiana's overall tourism and recreation industry.

Economic Development - According to the World Bank's *2006 water for Growth and Development* report, water is a key driver of sustainable growth and poverty alleviation. Many key industry sectors in Louisiana, including traditional and emerging industries, are especially sensitive to water supply, such as agriculture, oil and gas, chemical manufacturing, power generation, food and beverage production, and construction. As indicated by GrowingBlue.com, an online resource for water issues, "many companies already consider water resources when making decisions about where to invest or locate facilities... These businesses understand what policymakers are now coming to realize: When water resources are unhealthy or unreliable, businesses cannot grow and cannot hire or sustain a workforce. Local commerce suffers, incomes decline, tax revenues fall. The effects are very real and they are felt immediately and acutely."

Power Generation, Industry, and Mineral Extraction - A dependable supply of fresh water is critical to Louisiana's industrial sector, including power generation, petrochemical, pulp and paper, mineral extraction, and other industries that are extremely important to Louisiana's economy. Many of these industries have located in this state due to the abundance and quality of this resource and have thrived because of its availability. Louisiana ranks first amongst all of the states in uses of water for industrial purposes, using about 2,680 million gallons per day, or about 17 percent of the U.S. total, according to USGS. Louisiana's oil refineries represent over 18 percent of America's refining capacity and almost four percent of the world's refining capacity. Sixteen percent of the 2011-2012 Louisiana State General Fund is derived directly from mineral income. Louisiana is also home to numerous chemical manufacturing and pulp and paper industries that are key components of this state's and nation's economy. Both industry and our residents rely upon a dependable source of power from our power generation industry, which accounts for 63 percent of surface water withdrawals and five percent of groundwater withdrawals.

Agriculture & Aquaculture - Crops, pastures, forests, livestock, and aquaculture ponds all require water to remain productive. Agriculture accounts for 54 percent of the groundwater and 5.4 percent of the surface water used in Louisiana (USGS, 2011). Agricultural production represented approximately two percent and agri-businesses 20 percent of the state's gross domestic product in 2009, and farmland is approximately 29 percent of the land area of Louisiana, according to the LSU AgCenter. Of the farmland, 60 percent is cropland and 12 percent is irrigated. Agriculture, including aquaculture, is extremely important to Louisiana's culture and employment. Agriculture employs nearly ten percent of Louisiana's workforce and represents a significant portion of the economies of 55 percent of Louisiana parishes. A large segment of Louisiana's agriculture, including rice farming, and crawfish and catfish aquaculture, would not be possible without the availability of reliable and sustainable sources of groundwater and surface water.

Tourism - Water covers almost one fifth of Louisiana's land area, contributing greatly to this state's unique geography. From the many attractive water sports in numerous state parks to world class fishing and hunting in our rivers, streams, and marshes, Louisiana's water resources have been instrumental in making this beautiful state one of America's top leisure destinations. According to the LA Department of Culture, Recreation, and Tourism, in 2010, 24.6 million domestic and international travelers spent $9.3 billion in Louisiana, an average of $24.7 million per day. The travel and tourism industry is the seventh highest employer in the State of Louisiana, with one out of ten jobs directly dependent on the industry.

Navigation - Louisiana must maintain adequate surface water flows to support navigation and waterborne commerce. Our ports are number one among the 50 states, according to the U.S. Army Corps of Engineers (USACE), which maintains 2,800 miles of Louisiana's 5,000 miles of navigable rivers, bayous, creeks, and canals. The Congressional Research Service (CRS) found in its October 14, 2005 Report to Congress that "the ports of South Louisiana, New Orleans and Baton Rouge rank third, fourth and fifteenth, respectively in total trade by port to all world ports." The CRS also pointed out that 55 to 70 percent of all corn, soy, and wheat being exported from the U.S. passes through these three ports, with the Port of New Orleans handling about 6,000 vessels annually. Among the states, Louisiana has five of the top fifteen ports, with Lake Charles and Plaquemines joining South Louisiana, New Orleans, and Baton Rouge on the list. With Louisiana's ports serving as a gateway between the inland states and the rest of the world, they play a substantial role in the state's economy, supporting about 92,566 primary and secondary jobs generating $1.95 billion in income and earnings for Louisiana's residents, according to *the economic impacts of the ports of louisiana and the maritime industry* by Timothy P. Ryan (University of New Orleans, 2001). Additionally, Louisiana's abundant navigable waterways provide opportunities for numerous recreational activities such as fishing, boating, hunting, canoeing, bird watching, and other water sports. For the Atchafalaya River Basin alone, the value of recreational related resources has been estimated at about $97 million annually, based on a survey by the Louisiana Department of Wildlife and Fisheries and the USACE.

Report Development

The report you hold in your hands today has its beginnings in 2001 with the creation of the Louisiana Ground Water Resources Commission (LGWRC) and Louisiana Ground Water Advisory Task Force (LGWATF). One of the duties of the LGWRC and LGWATF was to develop and implement a management plan. In 2002, *assistance in Developing the statewide Groundwater management plan* was published. It was designed to serve as a "road map for developing and implementing water regulations for Louisiana" and to "lay the foundation for water management planning in Louisiana." (C.H. Fenstermaker and Associates, Inc., 2002) The findings of that report provided support for Act 49 of 2003 and helped to launch the present groundwater authority and activities of the LDNR.

This legislation authorized the Office of Conservation to develop a groundwater emergency contingency plan and implement regulations to govern the sustainability of the state's groundwater resources. The agency subsequently developed a groundwater emergency contingency plan focused on addressing drought conditions and groundwater use, created a well-owner notification database management and tracking system, and promulgated regulations for the proper application and procedures for establishing Areas of Ground Water Concern and Critical Areas of Ground Water Concern. Regulations also included proper procedures for water well owners to comply with pre- and post-installation water well notification requirements, and provisions for agency actions to prevent well installation and groundwater withdrawal from posing adverse impacts to the aquifer or nearby water well owners. Agency staff participated and continues to participate in groundwater conservation public education and outreach efforts statewide. Adding to this responsibility in 2008 and 2009 were robust enforcement authorities and regulatory oversight of all water well driller and well construction requirements formerly under LDOTD authority. All of this collectively, along with the continued advisory roles of the Ground Water Resources Commission and Ground Water Management Advisory Task Force, served and continues to function as the management plan for groundwater resource sustainability.

Over the years, lessons have been learned and opportunities for improvement recognized. In May 2009, the LGWRC identified the need for enhanced management of our state's groundwater to address aquifer-specific concerns such as those experienced in the Sparta, Carrizo-Wilcox, Southern Hills (Baton Rouge area), and Chicot aquifer systems. The LGWRC adopted a resolution requesting LDNR to seek funding to support the development of the next generation of groundwater management in Louisiana. An interagency agreement with the Louisiana Department of Health and Hospitals was approved, setting in motion a planning process that began in March 2010. LGWRC members were interviewed in March and May 2010 to compile their ideas for addressing groundwater concerns and suggestions for future resource management. Two public workshops were conducted in September 2010 to allow all stakeholders and interested parties an opportunity to contribute their ideas and concerns, and public comments were also received electronically.

A draft report titled *Recommendations for a statewide Groundwater management plan* was completed in October 2011. Five public meetings on the draft report were held in November 2011 in Ruston, Alexandria, Crowley, Shreveport, and Baton Rouge, and oral and written comments were received. The final *Recommendations for a statewide Groundwater management plan* incorporated relevant comments and was released by the LDNR Office of Conservation on December 7, 2011. It includes recommendations for nine key components of groundwater management. The LGWRC hosted a two-day public meeting January 19-20, 2012 to further discuss and seek input on these recommendations. Following robust discussion and interaction, one additional component was added to the list of recommendations.

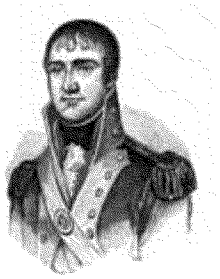
The work described above has contributed to the March 15, 2012 publication of this LGWRC interim report, *managing louisiana's Groundwater Resources,* the first modern publication of its kind produced by a Louisiana government agency on groundwater resource sustainability. In addition to a complete list and description of groundwater management recommendations, this document also provides readers with a description of our water resources, users and uses, agencies with authority over these resources, state law and regulatory framework for water management, current water management activities and accomplishments, and other key facts that help us understand the tremendous value of sustaining our groundwater and surface water resources in Louisiana. Additionally, specific information requested by the Louisiana Legislature in House Concurrent Resolution 1 from the 2010 Regular Legislative Session is included in this report.

According to "A Defining Resource: Louisiana's Place in the Emerging Water Economy" by Mark Davis and James Wilkins (Loyola Law Review, 2011), "The state is facing a future in which water, even in Louisiana, will be a scarce resource that will demand a well-thought-out and integrated approach to stewardship…The need to purposefully balance navigation, flood control, environmental, agricultural, industrial, and drinking water supplies is already pressing and becoming more so." (273)

History of Ground Water

1682 LaSalle claims Louisiana for France.

1812 Louisiana becomes a state.



Gov. William Claiborne

160 Years of Statehood without Groundwater Management

1972 Act 535 of the LA Legislature places the Dept. of Transportation and Development (LDOTD) in charge of water well drillers licensing, construction, and registration requirements. *(1972)*

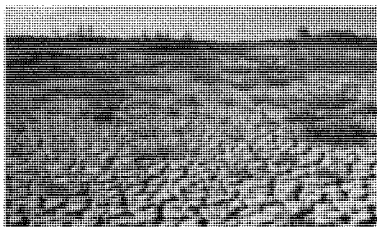
1974 Act 678 of the LA Legislature creates the Capital Area Ground Water Conservation District with permitting and funding authority over five parishes centered on East Baton Rouge. *(1974)*

1975 LDOTD implements rules for certain wells in accordance with Act 535 of 1972. (LAC Title 56) *(1975)*

1985 LDOTD implements rules for all water wells. *(1985)*

1999 LA Legislature establishes Sparta Ground Water Conservation District. *(1999)*

1999-2000 Louisiana experiences severe drought conditions, impacting groundwater and surface water supplies. *(1999-2000)*



2001 Act 446 of the LA Legislature establishes the Ground Water Resources Commission (LGWRC), Ground Water Management Advisory Task Force (LGWMATF), and current legal structure for groundwater management.*(2001)*

2003 Act 49 of the LA Legislature places the LGWRC and LGWMATF under the Office of Conservation. *(2003)*

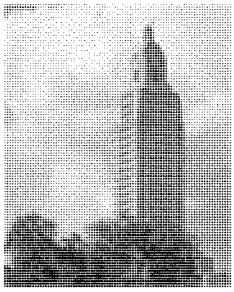
Management in Louisiana

2005

Commissioner of Conservation designates three areas in the Sparta aquifer system as Areas of Ground Water Concern. *(2005)*

2007

Act 471 of the LA Legislature provides sales tax exemptions for water conservation equipment used in the Sparta Ground Water Conservation District. *(2007)*



2008

Act 581 of the LA Legislature provides for the imposition of civil penalties for violations of groundwater regulations. *(2008)*

2009

Act 437 of the LA Legislature transfers duties relative to groundwater resources, water wells, and drillers from LDOTD to Office of Conservation. *(2009)*

2010

House Concurrent Resolution 1 instructs LGWRC to report on LA groundwater and surface water resources. *(2010)*

Act 955 establishes policy for withdrawals of "running waters of the state" by nonriparian landowners. *(2010)*

Act 301 changes quorum requirements for LGWMATF. *(2011)*

2011

Due to drought conditions, Commissioner of Conservation declares a temporary Ground Water Emergency for two areas south of Shreveport in Caddo Parish. The prolonged drought also allowed saltwater to encroach on rice farms in coastal southwest Louisiana and greatly reduced flow in the Ouachita River, impacting nearby industries. *(2011)*

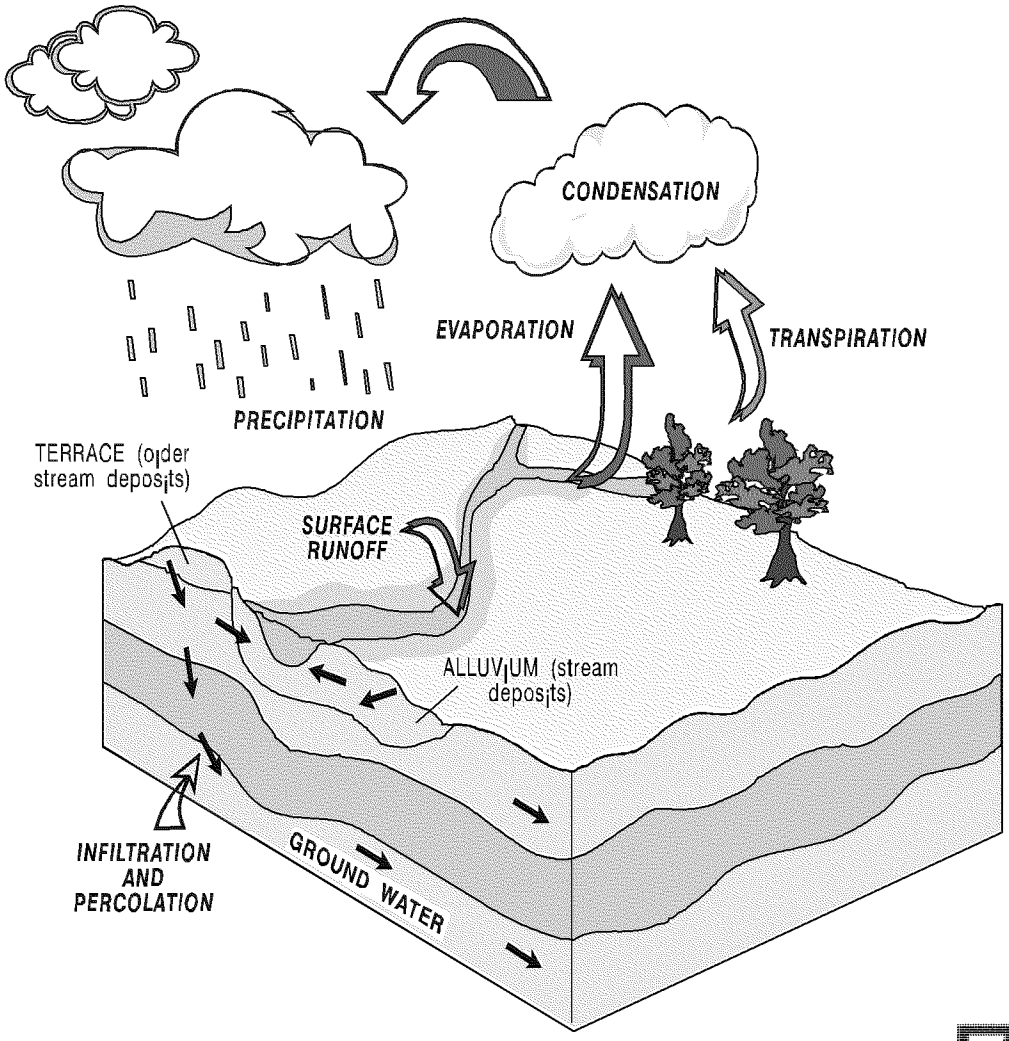
2012

Office of Conservation holds a public meeting on saltwater encroachment in the Southern Hills Aquifer (Baton Rouge). *(2012)*

LGWRC submits report, *managing louisiana's Groundwater Resources,* to the Louisiana Legislature with recommendations for ensuring water sustainability. *(2012)*

Groundwater Withdrawal and Recharge Cycle

THE HYDROLOGIC CYCLE



Source: Stuart, C.G., Knochenmus, D., and McGee, B.D., 1994, Guide to Louisiana's ground-water resources: U.S. Geological Survey Water-Resources Investigations Report 94-4085, 55 p.

Our Water Cycle

All of the water that we use in our homes comes from either a groundwater source, such as a well, or from a surface water source, such a river, lake, or reservoir. When more than half of Lousiana's 4.5 million residents turn on their faucets, groundwater flows from their tap. Public water supplies, rural wells, agriculture irrigation systems, livestock watering, industry processes, and power generation all rely on groundwater from our states's eleven principal aquifer systems.

Groundwater is one of the Earth's most valuable resources, providing drinking water to more than 50 percent of the population of the United States. (USGS, 2011). It often begins as precipitation that infiltrates into the ground where it moves and becomes stored in geological strata. Some of this water recharges saturated strata of permeable sediment and rock called aquifers. Within these aquifers, groundwater moves away from areas of recharge toward areas of discharge, such as springs, streams, lakes, oceans, and water supply wells. The groundwater flow rate in porous aquifers is slow, in the order of tens of feet per day to a few feet per year. The movement follows a tortuous path created by pores, voids, crevices, and other apertures present in the aquifers. Aquifers can be quite extensive, possibly stretching for hundreds of miles, providing for thousands of ground-water supply wells, as well as naturally feeding springs, bayous, streams, rivers, lakes, wetlands, and coastal marshes.

Water removed from the ground has the potential to be constantly replenished or "recharged" by precipitation. However, the rate of recharge is not the same for all aquifers. Adequate time is often needed for this replenish-ment process since the deeper the aquifer, the longer it takes for rainfall to get there. This makes conservation of our water resources important every day of the year.

Stress placed on aquifers by extreme drought conditions and significantly increased water withdrawals can greatly impact the sustainability of our aquifers and our groundwater supply. To recover from a drought, an extended period of rain is needed to make up for water deficits, fill our surface water reservoirs, and recharge our aquifers. During hot summers, recharge is additionally diminished when rainwater evaporates before having the opportunity to replenish our water supplies. Pumping too much water too fast also draws down the water in the aquifer and might eventually cause a well to yield less water or run dry. Pumping a well too fast or too often might also cause a neighbor's well to run dry if both are pumping from the same aquifer.

Background

> *"whiskey is for drinking. water is for fighting."*
> - attributed to Mark Twain

Rarely have Louisianans had to worry about not having enough water. With rivers and bayous criss-crossing our state, freshwater swamps and brackish marshes spanning our coastal region, and the Gulf of Mexico at our front doorstep, our biggest concerns have usually focused on keeping our communities dry as we enjoy all of the benefits that our surface water resources offer. Therefore, beginning with statehood in 1812 and continuing for the next 190 years, state law and programs related to water resources management exclusively concentrated on implementing flood protection, providing navigation, and preventing contamination of our water supply. Absent from these early initiatives was the sustainable management of a critical resource in the state's water portfolio that is literally hidden beneath our feet.

Louisiana has been blessed with an abundance of high quality groundwater in eleven principal aquifer systems that provide drinking water to nearly 50 percent of our state's residents through public water supplies and domestic water wells. Surface water from rivers, lakes, and bayous is the drinking water source for the remaining 50 percent (USGS,2011). Together, groundwater withdrawn from aquifers by public and private water wells, and surface water withdrawn from our state's water bodies make up our state's total available water resources for household, agricultural, commercial, and industrial use.

Like rivers and bayous, no two aquifers are the same and a one-size-fits-all management approach is not effective. What works in one aquifer may not be appropriate in another. Sustainability of groundwater resources is best achieved by an aquifer-by-aquifer management strategy implemented through a centralized state governance model complemented by aquifer-specific advisory panels composed of local governments, user groups, and interested stakeholders.

In 1974, the Louisiana Legislature passed Act 446, which enacted Louisiana Revised Statute 38:3071 et seq., establishing the Capital Area Ground Water Conservation District. The purpose of the district is to provide for the efficient administration, conservation, and orderly development and supplementation of groundwater resources for the parishes of East Baton Rouge, East Feliciana, Pointe Coupee, West Baton Rouge, and West Feliciana. By limiting the district to five specific parishes, the legislature recognized the need for management of ground water resources on a regional basis prior to the establishment of any statewide management authority.

In 1975, the LA Department of Transportation and Development (LDOTD) began to implement regulations related to water well driller registration, well construction, inspection, and plugging and abandonment of water wells (LAC Title 56, 1975). The scope of these regulations was and remains predominantly focused on groundwater and environmental protection, including the prevention of adverse impacts to groundwater from surface contaminant migration from abandoned or improperly constructed boreholes. Simply put, the goal of these regulations is groundwater quality protection rather than maintaining groundwater quantity.

A severe drought in 1999-2000, along with a growing population and economy that increased water demand, brought needed attention to the fragility of Louisiana's aquifer systems and available groundwater supply. As a result, the Louisiana Legislature took the first step to comprehensively manage the use and sustainability of this water resource in 2001. Act 446 of 2001 called for the regulation of groundwater withdrawals and implementation of aquifer sustainability policies, and established the Louisiana Ground Water Resources Commission (LGWRC) and the Louisiana Ground Water Management Advisory Task Force (LGWMATF). Act 49 of 2003 placed the LGWRC and the LGWMATF under the authority of the Louisiana Department of Natural Resources, Office of Conservation, and the current Louisiana Ground Water Resources Program was born.

For the first time, prospective owners of water wells statewide that were to be used for industrial, irrigation, and public supply purposes were required to provide notification for review and evaluation prior to construction. Through enabling laws and regulations, the Office of Conservation is responsible for the protection, conservation, preservation, and overall sustainability of Louisiana's aquifer systems, including the management of groundwater withdrawals, monitoring and designation of Areas of Ground Water Concern, and groundwater education and conservation initiatives. The authorities granted exclusively to the Commissioner of Conservation within these Acts, combined with the previous restrictions of Louisiana Revised Statute 36:806 (which prevents the LDNR Secretary, Deputy Secretary, and Undersecretary from exercising, reviewing, administering, or implementing the quasi-judicial, licensing, permitting, regulatory, rulemaking, or enforcement powers or decisions of the Commissioner) clearly establish the Commissioner as the state's chief groundwater sustainabiilty manager.

As depicted on page 45, stakeholders in Louisiana's water mangement efforts are numerous and varied. The Office of Conservation is the lead agency in the management of groundwater sustainability assessment and production in Louisiana. Working in cooperation with the Departments of Natural Resources, Environmental Quality, Health and Hospitals, Agriculture and Forestry, Transportation and Development, and Wildlife and Fisheries, and the Office of Coastal Restoration and Protection, the Office of Conservation is responsible for managing the evaluation, construction and installation of water wells; well registration; and a database of nearly 190,000 entries. Of these entries, approximately 130,000 water wells are registered for groundwater withdrawal; more than 106,000 are listed as active or available for groundwater withdrawal; and approximately 80,000 registered wells are domestic and public supply wells providing drinking water to households. In addition, the Office of Conservation now manages driller licensing in Louisiana. There are presently 249 active drilling contractors licensed in Louisiana, of which 154 hold water well drilling contractor certification.

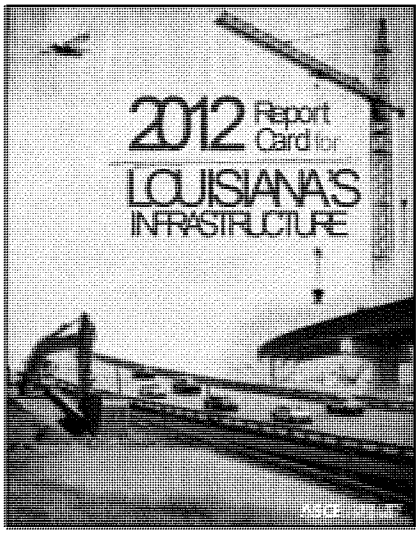
Management authority granted to the Office of Conservation over ten years ago was an effective first step toward achieving ground water sustainability. However, severe drought periods in the last decade, along with continued increases in demand for ground and surface water, have stressed our aquifer systems in recent years, prompting a renewed interest in this resource.

Pursuant to authority granted by the Louisiana Legislature in 2003 and responding to continual groundwater level decline in historic pumping centers, the Commissioner of Conservation designated Areas of Ground Water Concern in the Sparta aquifer system in August 2005. In August 2011, the Office of Conservation declared a temporary groundwater emergency for two areas of southern Caddo Parish due to a 15-month drought that resulted in higher than normal withdrawal of groundwater without sufficient aquifer recharge. The declaration calls for conservation and groundwater use restrictions and remains in effect as of the publication date of this interim report.

The prolonged 2011 drought also had significant impacts on Ouachita River levels in northeast Louisiana and rice farms in the southwest, particularly in Vermilion Parish. Ouachita River flows fell below those used in the establishment of authorized wastewater discharge limits, which are protective of water quality. In order for certain facilities to remain compliant with their permits and for water quality to remain protected, operations at these facilities had to slow or cease to reduce wastewater contributions. Had this condition endured for longer periods, impacts to local economies may have resulted. Rice farmers along the coastal southwest Louisiana were faced with limited irrigation water sources as the drought allowed salt water to move into traditional surface water sources.

In 2011, it was estimated that 40,000 to 80,000 acres of irrigated rice field in Vermilion Parish may be at risk if the intrusion of saltwater within canals could not be stopped. Saltwater intrusion in coastal Louisiana is a constant battle that has now been exacerbated by drought, and damaged levees, spoil banks and water-control structures. Diversion of 138 billion gallons of Atchafalaya River water by the Teche-Vermilion Freshwater District eased the saltwater problem for some in east Vermilion Parish, but the lack of freshwater influx and / or the presence of saltwater remained an issue for many Vermilion rice farmers. A breach in levees and spoil banks, damaged locks and the lack of freshwater inflow were identified as the main culprit. Although some of the issues are being remediated by the U.S. Army Corps of Engineers, which controls and maintains the locks, this is a repeat of a situation first observed in 1999-2000, in 2003, in 2005 in the aftermath of Hurricane Rita, and in 2007.

More recently, the issue of movement of a naturally occurring saltwater wedge across a well-documented fault line, and its potential impacts to groundwater resources in the Greater Baton Rouge Area, has received renewed attention. The Office of Conservation hosted a public meeting on this concern on March 8, 2012, and the comments from this meeting are summarized on page 78. Additionally, a public hearing on this issue has been scheduled for April 12, 2012.



The condition of our water resources and water delivery infrastructure, among other issues, has recently been evaluated by the American Society of Civil Engineers (2012). In *2012 Report Card for louisiana's infrastructure*, the organization notes, "The aging and deteriorating water supply and treatment and distribution systems are not capable of providing potable water for future, and in some cases, current demands. Better planning and more funding are key elements to providing Louisiana with a safe supply of drinking water in the future." (41)

While the State initiated its management of groundwater only within the last decade and has made advancements in that time, these findings provide further evidence of the need for the state's current water management efforts to evolve into a more robust, comprehensive plan. This interim report includes recommendations for achieving that goal, beginning on page 101. However, prior to that discussion, the following sections provide more details on the condition of our groundwater resources today and current management efforts.

Key Terms

> *"water is the driving force of nature."*
> -Leonardo da Vinci

Groundwater - water percolating below the earth's surface.

Aquifer - a fresh groundwater-bearing stratum of permeable rock, sand, or gravel.

Surface Water - an open body of water such as a lake, river, stream, etc.

Sustainability - the development and use of a resource in a manner that can be maintained for the present and future time without causing unacceptable environmental, economic, social, or health consequences.

Sustainability of Groundwater Resources - a situation in which water demand generally does not exceed supply. It is the State's intent to implement strategies that will help make impacted aquifers sustainable.

Conservation - the careful utilization of a natural resource in order to prevent depletion. (dictionary.reference.com, 2012)

Water Use - water withdrawn or diverted from a groundwater or surface water source and used for public supply, industry, power generation, rural domestic, livestock, irrigation, or aquaculture purposes. (USGS, 2011)

Area of Ground Water Concern - an area in which, under current usage and normal environmental conditions, sustainability of an aquifer is not being maintained due to either movement of a salt water front, water level decline, or subsidence, resulting in unacceptable environmental, economic, social, or health impacts, or causing a serious adverse impact to an aquifer, considering the areal and temporal extent of all such impacts.

Critical Area of Ground Water Concern - an Area of Ground Water Concern, in which the Commissioner of Conservation finds that the sustainability of the aquifer cannot be maintained without withdrawal restrictions.

Ground Water Emergency - an unanticipated occurrence as a result of a natural force or a man-made act which causes a groundwater source to become immediately unavailable for beneficial use for the foreseeable future or drought conditions determined by the commissioner to warrant the temporary use of drought relief wells to assure the sustained production of agricultural products in the state.

The definitions of the terms listed above are provided for the purposes of this report only.

State Agencies with Primary Regulatory Authority for Water Management*

Office of Conservation – Administers and gathers groundwater data; registers wells and groundwater users; establishes construction standards for water wells; oversees groundwater conservation and sustainability; protects groundwater from contamination through the underground injection control program; regulates oil and gas well casing and cementing; requires proper well plugging and abandonment; regulates pit construction and closure; manages offsite exploration and production waste; administers the oilfield site restoration program; and regulates storage of hydrocarbons in salt dome caverns.

Department of Natural Resources — Administers surface water cooperative endeavor agreements pursuant to Act 955 of 2010.

Department of Environmental Quality — Enforces the Clean Water Act and protects groundwater and surface water resources from contamination.

Department of Health & Hospitals — Enforces the Safe Drinking Water Act and protects groundwater and surface drinking water supplies.

Department of Transportation & Development — Administers construction requirements for surface water impoundments including reservoirs and dams. Manages state-owned water control structures.

Department of Wildlife & Fisheries — Enforces the Endangered Species Act, which prohibits the use of surface water to the extent that the habitat of threatened or endangered species is adversely modified, as well as administers Natural and Scenic River Systems.

Department of Agriculture & Forestry — Regulates the use and application of pesticides through the Office of Agriculture and Environmental Sciences. Advises and assists state soil and water conservation districts with implementing water and soil conservation activities and projects through the Office of Soil and Water Conservation.

Office of Coastal Protection & Restoration - Responsible for integrating hurricane protection, storm damage reduction, flood control, coastal protection and restoration efforts, and associated infrastructure construction and maintenance.

* There are at least 735 other entities with local, municipal, regional, or state authority for specific water resource oversight, including 51 conservation districts, seven recreation districts, seven reservoir districts, eight watershed districts, two waterway districts, two freshwater districts, 651 municipal/local water districts & systems, and seven others (Appendix C).

Our Current Governance System

Regulatory authority over our water resources is as varied as the water sources themselves.

Our laws governing water are also complex. Historically, we have used various and sometimes conflicting legal concepts such as Absolute Ownership, Rule of Capture, and Riparian Rights. Louisiana water law originated in the traditional thinking that usable water would be available forever in unlimited quantities. However, we have recognized in recent times that we must take a different approach to governance of water resources and have made significant changes to our laws.

Our Constitution Mandates It

Louisiana's responsible and effective management of the state's water resources is rooted in our State Constitution. This exemplifies the high priority that our leaders have placed on the protection and conservation of both groundwater and surface water. This priority is evidenced by the fact that the word "water" appears a total of 24 times in the 1974 Louisiana Constitution. It is used in 12 of the Constitution's 332 articles. The most notable is:

> *Article IX, Section 1, (Natural Resources and Environment; Public Policy)*
> The natural resources of the state, including air and water, and the healthful, scenic, historic, and esthetic quality of the environment shall be protected, conserved, and replenished insofar as possible and consistent with the health, safety, and welfare of the people. The legislature shall enact laws to implement this policy.

To put this into perspective, the Constitution references other natural resources such as oil (18 times), gas (32 times), fish (17 times), wildlife (13 times), sulfur (13 times), timber (12 times), lignite (8 times), and soil (once). Our state's constitution then unequivocally articulates that water has a value to the public that goes beyond its value to the individuals that have access to it by virtue of their land ownership. In addition, the people have clearly charged the legislature to enact laws which fulfill this policy.

A Look at Our Key Legal Traditions, Civil and Mineral Codes

Traditional Groundwater Law - Absolute Ownership and the Rule of Capture

Civil Code Article 490. Accession above and below the surface.

> *unless otherwise provided by law, the ownership of a tract of land carries with it the ownership of everything that is directly above or under it. the owner may make works on, above, or below the land as he pleases, and draw all the advantages that accrue from them, unless he is restrained by law or by rights of others. acts 1979, no. 180, §1.*

This ancient civil code article states the traditional absolute ownership concept of property, simply stated, "whoever owns the soil, it is theirs all the way up to Heaven and down to Hell." This has been part of Louisiana's written laws since 1808.

Louisiana's Supreme Court concluded in the 1963 case of Adams v. Grigsby that the absolute ownership theory was not wholly sufficient to govern subterranean liquid mineral substances like oil, gas, and groundwater. The court applied what is known as the "Rule of Capture" to groundwater ownership.

Louisiana's "Rule of Capture" is a legal theory that helps determine ownership of natural resources such as water, wildlife, and petroleum. The general rule is that the landowner captures or obtains possession of the resource in order to own that resource. This approach was originally based on the belief that these resources may move from one parcel of property to another.

This theory is written into Section 8 of our Mineral Code:

Mineral Code, §8. Landowner's right of enjoyment for mineral extraction

> *a landowner may use and enjoy his property in the most unlimited manner for the purpose of discovering and producing minerals, provided it is not prohibited by law. he may reduce to possession and ownership all of the minerals occurring naturally in a liquid or gaseous state th be obtained by operations on or beneath his land even though his operations may cause their mi from beneath the land of another. acts 1974, no. 50, §1, eff. Jan. 1, 1975.*

Traditional Surface Water Law in Louisiana – Riparian Rights

Traditional surface water law in Louisiana can be found in three Civil Code Articles: 657, 658 and 667.

Civil Code Article 657. Estate bordering on running water.

> *the owner of an estate bordering on running water may use it as it runs for the purpose of wat*
> *estate or for other purposes. acts 1977, no. 514, §1.*

Civil Code Article 658. Estate through which water runs.

> *the owner of an estate through which water runs, whether it originates there or passes from la*
> *above, may make use of it while it runs over his lands. he cannot stop it or give it another directi*
> *and is bound to return it to its ordinary channel where it leaves his estate. acts 1977, no. 514,*

In addition to the above two articles, Article 667 limits the owner's uses to those that that do not "deprive his neighbor of the liberty of enjoying his own, or which may be the cause of any damage to him."

The rights of the owner are referred to as "Riparian Rights." These rights are limited and can only be exercised by an owner whose property is next to the water.

In contrast to the traditional Absolute Ownership and Rule of Capture theories that allowed virtually unlimited access by landowners to groundwater, traditional Louisiana law has not treated running surface water as privately owned, even when captured. A riparian owner (the owner of land next to a stream, river, or lake) has a traditional right to use the adjacent water for his own domestic purposes, but he never has legal title to the water.

Key State Groundwater Laws and Acts 994 and 955 of 2010

To fulfill the objectives of Article IX, Section 1 of the Louisiana Constitution, the legislature has, through the years, adopted a variety of laws, regulations, and rules intended to protect our groundwater and surface water, and to maintain sustainability of these resources.

In spite of the traditions of Absolute Ownership and the Rule of Capture, the legislature recognized some management and regulation of these resources were necessary to protect sustainability. It gave specific authority to the Commissioner of Conservation to evaluate notifications to drill, require water well registration, construction, plugging and abandonment standards; establish Areas of Ground Water Concern, and Critical Areas of Ground Water Concern. Additionally, the authority of the Commissioner of Conservation to limit withdrawals to respond to sustainability challenges was also granted.

Notably, through Revised Statutes 38:3091, et seq., for the first time in Louisiana's history, all well owners, with the exception of domestic, replacement, drilling rig supply (not fracking supply), and drought relief wells, are required to provide a notice of intent to drill at least 60 days prior to drilling. Upon review of this notice and where applicable, the Commissioner may 1) issue an order placing restrictions on the well, 2) request further reasonable information, or 3) take no action, allowing the drilling to proceed as noticed. The process of evaluating the proposed well to determine any potential adverse impact on the aquifer or surrounding water wells is the key determining factor for the Commissioner's decision. For proposed large volume wells (greater than 1,500 gallons per minute or greater than eight inches in diameter) not otherwise exempted, the Commissioner may restrict production or impose spacing requirements as deemed necessary.

When an Area of Ground Water Concern is established, the Commissioner may require metering, monitoring, and reporting for new and existing wells. For new wells in an Area of Ground Water Concern, the Commissioner may also impose spacing requirements. However, the Commissioner's authority to impose withdrawal restrictions is limited to 1) areas within a *Critical* Area of Ground Water Concern, an area by definition of which sustainability is challenged and 2) proposed large volume wells (greater than 1,500 gallons per minute or greater than eight inches in diameter) not otherwise exempted, regardless of location, as determined necessary.

While this authority treads on traditional ownership theories, the legislature has made it clear that this authority is necessary to achieve sustainability and to comply with Article IX, Section 1 of the Louisiana Constitution.

Mindful of Louisiana's Riparian Rights for surface water, and various Attorney General opinions (see page 30) related to the state's ownership of running water and the fair market sale of running water, the Louisiana Legislature adopted Act 955 in 2010 (found in Title 30 of Louisiana's Revised Statutes, Chapter 9-B, sections 961, 962 and 963). The law directs the Department of Natural Resources to serve in a stewardship role in the management, preservation, conservation, and protection of the state's surface water resources. It authorizes the Secretary of LDNR to develop an application for and to enter into Cooperative Endeavor Agreements (CEA's) for the withdrawal of running surface water. The statute applies to a person or entity that seeks to withdraw water from the running surface waters of the state.

As of this publication, LDNR has entered into approximately 40 CEA's with primarily industrial companies who have requested the use of surface water for production processes. (A complete list of current CEA's subject to Act 955 is included as Appendix D.) Act 955 sunsets on December 31, 2012, and legislation is being requested to extend its authorization through 2014.

Following the adoption of Act 955, the Louisiana Legislature approved Act 994 of the 2010 legislative session, (Louisiana Revised Statute 9:1103). Act 994 expanded riparian rights for agricultural and aquaculture uses. The legislature recognized the beneficial use of surface water for agricultural and aquacultural purposes by riparian owners. The legislature decided that "waters used in agricultural or aquacultural pursuits are not consumed, rather they are merely used" and that no prohibited donation was created by their use free of charge.

What is Act 955 of 2010?

"the louisiana legislature recently enacted act 955 during the 2010 Regular session to address the precise issue of the proper mechanism for the sale of running surface waters. this law implements a procedure to allow the Department of natural Resources to enter into cooperative endeavor agreements for the withdrawal of running surface water from bodies of water in louisiana."

AG Opinion 10-0173 (November 23, 2010)

While Act 955 successfully established a procedure for the sale of running surface waters, an unintended consequence has been a greater reliance by commercial users on groundwater, for which withdrawals do not incur any usage fees. Surface waters are recognized as public resources, owned by the state and subject to a charge for use, whereas groundwater is being treated as wholly private and free of charge. This legal disparity is noted in Louisiana Attorney General opinions (see page 30) in recent years. It is recommended that legal scholars be engaged to research and explore the potential non-compensated consumption of surface water when used as an alternative to groundwater and as an aid to economic development, job creation, and job retention.

Legislative Authority Divided Among State Agencies

To enact the policies of Article IX, our legislature set up various agencies with differing, but complementary, regulatory authority for water management.

The Office of Conservation administers and gathers groundwater data; registers wells and groundwater users; establishes construction standards for water wells; oversees groundwater conservation and sustainability; protects groundwater from contamination through the underground injection control program; regulates oil and gas well casing and cementing; requires proper well plugging and abandonment; regulates pit construction and closure; manages offsite exploration and production waste; administers the oilfield site restoration program; and regulates storage of hydrocarbons in salt dome caverns.

The Department of Natural Resources administers surface water cooperative endeavor agreements pursuant to Act 955 of 2010. The Department of Environmental Quality enforces the Clean Water Act and protects groundwater and surface water resources from contamination. The Department of Health and Hospitals enforces the Safe Drinking Water Act and protects groundwater and surface drinking water supplies. The Department of Transportation and Development administers construction requirements for surface water impoundments, including reservoirs and dams, and manages state-owned water control structures. The Department of Wildlife and Fisheries enforces the Endangered Species Act, prohibiting the use of surface water to the extent that the habitat of threatened or endangered species is adversely modified, and administers the Natural and Scenic River Systems. The Department of Agriculture and Forestry regulates the use and application of pesticides through the Office of Agriculture and Environmental Sciences, and assists state soil and water conservation districts with implementing water and soil conservation activities and projects through the Office of Soil and Water Conservation. The Office of Coastal Protection and Restoration is responsible for integrating hurricane protection, storm damage reduction, flood control, coastal protection and restoration efforts, and associated infrastructure construction and maintenance.

Louisiana Attorney General Opinions

Since 2008, the Office of the Louisiana Attorney General has issued seven key opinions interpreting Louisiana water law.

these opinions include:

Year	Opinion	Summary
2008	(08-0176)	There is no right to private ownership of running waters in Louisiana.
2009	(09-0028)	If a lake's water is considered "running water," it is owned by the State.
2009	(09-0066)	Any sales of water must be for fair market value.
2009	(09-0291)	Political subdivisions of the State may only sell running waters with specific legislative authority.
2010	(10-0173)	A riparian owner may access and "use" running water for his estate, but the water remains a public thing owned by the State.
2010	(10-0289)	Statutory language that authorizes a political subdivision to "regulate the use of water" establishes regulatory control over the waters, but does not grant any rights with regard to selling the waters at issue.
2010	(10-0297)	The Sabine River Authority has a special statutory exemption from the limitations set in Opinion 10-0173.

The following pages (31-42) illustrate the governance of the various state agencies involved in water resource management.

Groundwater Sustainability Governance

Office of Conservation

- Education
- Implements Regulations
- Requires Notification
- Performs Evaluation
- Requires Registration
- Manages Data
- Orders Restrictions
  - Limiting Production
  - Establishing Spacing
  - Requiring Information
- Establishes Area of Ground Water Concern
- Establishes Critical Area of Ground Water Concern
- Declares a Ground Water Emergency
- Issues Civil Penalties for Violation

Ground Water Resource Commission
- Advisory Role
- Considers Conservation Order Appeals

Ground Water Management Advisory Taskforce
- Advisory Role

Sparta Ground Water Commission
Capital Area Ground Water Commission
- Regional Aquifer-Specific Management Authority

Surface Water Withdrawal Process

Act 955 of 2010

LDNR
- Implement the voluntary process
- Draft and update application and uniform forms
- Develop and maintain online application process
- Review applications
- Coordinate technical review
- Enter in Cooperative Endeavor Agreements

Mineral and Energy Board
- Review and approve uniform forms

Attorney General
- Review and approve uniform forms
- Address citizen concern

Office of Conservation
- Review Plan of Water Use
- Assist in inspecting and confirming water withdrawals

OCPR
- Review Plans of Water Use for consistency with the Master Plan

LDEQ & LDWF
- Review the Plans of Water Use
- Provide advice

LSU-Center for Energy Studies
- Review the Economic Impact Reports

Surface Water Quality Governance At DEQ

State Agencies
- DHH
- DWLF
- DAF
- DNR
-CPRA
-DOTD
-SHPO
-NRCS
•Coordination of Surface Water Program Activities
•Participate in Public Use Advisories

Non Government Organizations and Trade Groups
•Advisory Role

DEPARTMENT OF ENVIRONMENTAL QUALITY
- Implement CWA programs delegated to DEQ
- education and outreach
- implement regulations
- WQ monitoring and assessment
- develop water quality standards
- manages water quality data
- establishes areas of water quality impairment
- assists in water quality advisories
-Early Warning Organic Compound Detection System (EWOCS)
-Implement State Revolving Loan Program
- Inspection and enforcement
-criminal enforcement
-Issue water quality permits and certifications
-Development and Implementation of Total Maximum Daily Loads (TMDL)

Federal Agencies
- USEPA
- USDA
- USFWS
- USGS
-USACOE
-FERC
-BOEMRE
-NMFS
-USCG
-NASA
•Coordinate Surface Water Programs under CWA

Local Government
•Advisory Role
•Provide funding for infrastructure upgrades

Groundwater Quality Governance At DEQ

DEPARTMENT OF ENVIRONMENTAL QUALITY
- Implementation of Federal Programs delegated to DEQ
- education and outreach
- notification
- perform evaluation
- manages data
- establishes remediation standards
- oversees remediation activities
- establishes wellhead protection areas
- implements regulations
- conducts compliance activities
- issues permits to monitor groundwater near solid waste and hazardous waste sites

State Agencies
DHH and DNR
•Coordinate Groundwater Protection Activities

Federal Agencies
EPA and USGS
•Site Evaluation and Remediation under RCRA, CERCLA, UST, Brownfields

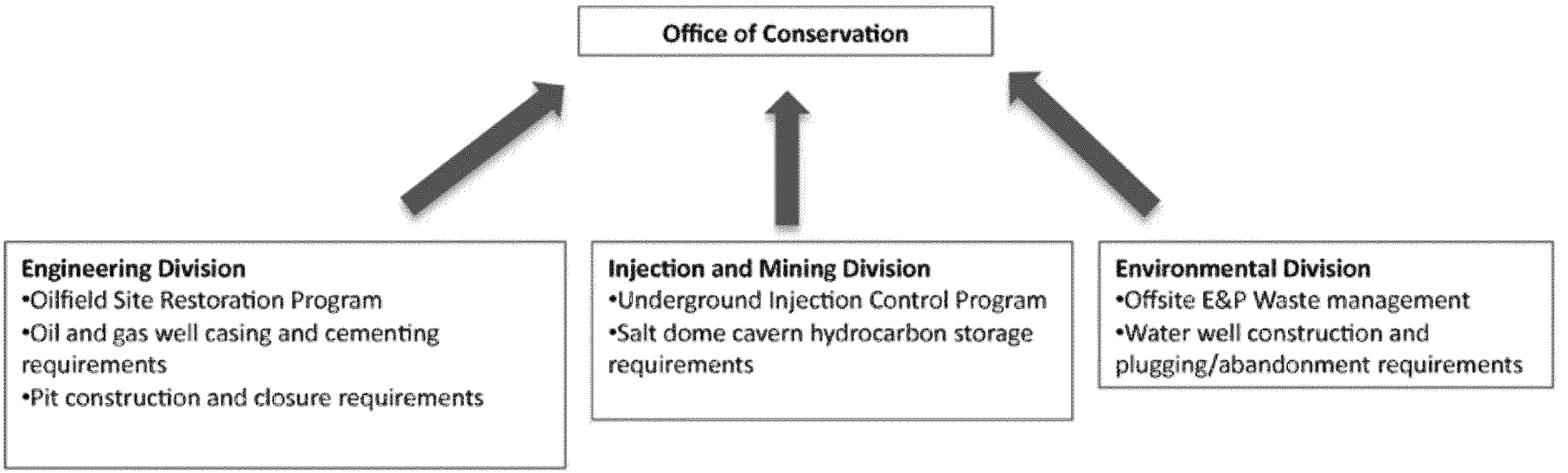
Non Government Organizations
•Advisory Role
•Coordinate Groundwater Protection Activities

Local Government
•Advisory Role

GW Resource Commission
•Advisory Role

Office of Conservation

Groundwater Protection Measures



CPRA Implementation Office

CPRA
Coastal Protection and Restoration Authority of Louisiana

Directs development and implementation of efforts to achieve comprehensive "integrated coastal protection" through the state's comprehensive Master Plan for a Sustainable Coast.

(Currently OCPR)

Plans, projects, policies, and programs intended to provide hurricane protection or coastal conservation or restoration, and shall include but not be limited to coastal restoration; coastal protection; infrastructure; storm damage reduction; flood control; water resources development; erosion control measures; marsh management; diversions; saltwater intrusion prevention; wetlands and central wetlands conservation, enhancement, and restoration; barrier island and shoreline stabilization and preservation; coastal passes stabilization and restoration; mitigation; storm surge reduction; or beneficial use projects.

Levee/Conservation Districts

State Agencies

Parishes/Political Subdivisions

Office of Public Health

Center for Environmental Health

Engineering Services

- Implements and enforces the Safe Drinking Water Act
- Conducts regular inspections of public water supplies
- Reviews plans and issues permits for public water supplies
- Reviews plans and issues permits for community sewage collection and treatment facilities
- Conducts sewage inspections in response to sewage complaints
- Collects raw and finished water chemical samples such as radiological, nitrites, arsenic, and lead for public water supplies
- Evaluates chemical, bacteriological, and radiological test results for compliance with the Safe Drinking Water Act
- Provides technical assistance to water and sewer systems
- Issues compliance orders and civil penalties for Sanitary Code violations
- Monitors boil advisories and requests boil orders
- Regulates activities in or near Drinking Water designated reservoirs
- Reviews projects in coastal zone for impacts to surface water quality affecting public water supplies
- Conducts training and outreach for water and wastewater (sewer) system operators
- Certifies public water and wastewater (sewer) system operators
- Maintains/conducts Lower Mississippi Waterworks Warning Network in emergency events
- Lead agency for statewide water and wastewater emergency response in ESF-12 (Infrastructure Branch)

State Health Officer (DHH)

- Exclusive jurisdiction, control and authority of state's Sanitary Code
- Issues health advisories
- Issues boil orders
- Issues compliance orders

Dept. of Environmental Quality

Source Water Assessment Program,

Well Head Protection Program, Drinking Water Protection Program, & Early Warning Organic Compound Detection System

Commissions/Committees/Councils

Operator Certification Committee, Ground Water Resource Commission, Advisory Committee for Regulation and Control of Water Well Drillers, & Louisiana Aquatic Invasive Species Council

Office of Public Health

Center for Environmental Health

Sanitarian Services

- Reviews plans and issues permits for onsite sewage treatment systems
- Conducts sewage inspections in response to sewage complaints
- Conducts inspections of existing onsite wastewater systems
- Reviews plans and issues permits for domestic wells
- Conducts inspections and sampling of existing domestic wells
- Collects Bacteriological samples for public water supplies
- Provides technical assistance to water and sewer systems
- Issues compliance orders and civil penalties for Sanitary Code violations
- Beach water monitoring – water sampling between April 1 – October 31
- Provide and monitor public awareness signage as dictated by beach water sample results
- Reviews plans and issue permits for bottled water manufacturing and distribution facilities
- Hydrogeological review of springs and artesian wells used for bottled water production
- Monitors the source and finish water for contaminants for bottled water manufacturing facilities
- Conducts inspections of bottled water manufacturing and distribution sites
- Reviews plans and issues permits for water and ice vending units
- Monitors the source and finish water for bacteriological contaminants used in water and ice vending units

Office of Public Health

Center for Preventive and Community Health

OPH Laboratory

- Analyzes chemical, bacteriological, and radiological samples in accordance with the Safe Drinking Water Act
- Analyze Oyster growing waters for harmful bacteria.
- Inspect and Certify both in state and out of state Laboratories to perform chemical analysis of drinking water in Louisiana as a National Environmental Laboratory. Accreditation Authority certified by NELAC.
- Limited certification of Drinking water laboratories that perform microbiological testing of drinking water.
- Analyzed bacteriological water samples for the Beach Program

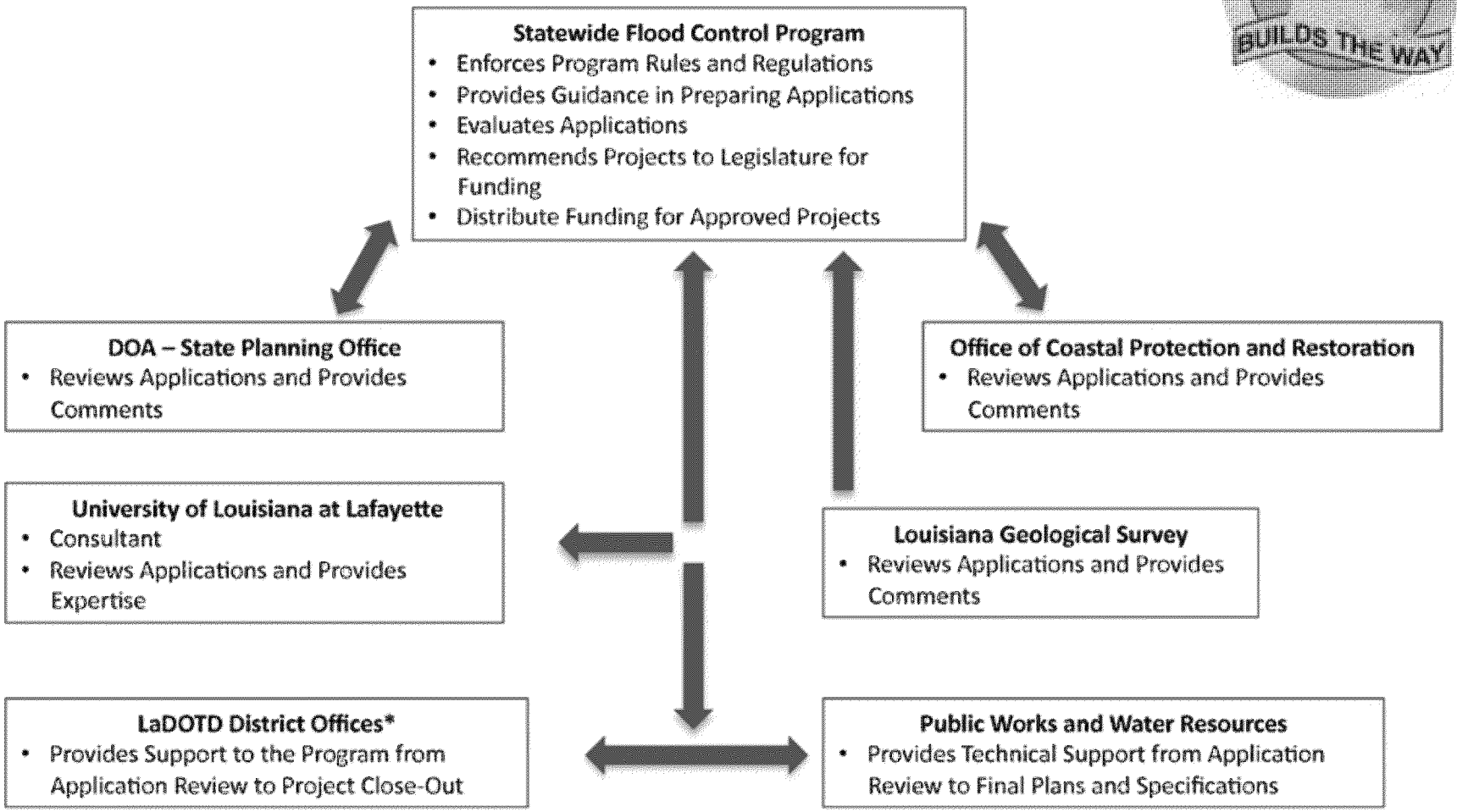
Environmental Epidemiology and Toxicology

- Assesses water quality to determine impact on human health
- Issues environmental health advisories related to water and seafood quality
- Distributes information on contaminants effecting water quality
- Develops and tracks environmental public health indicators related to water quality

Infectious Epidemiology

- Evaluate outbreaks and unusual infections related to water.

Flood Control Governance



*See Appendix E for additional details.

Wildlife & Fisheries Surface and Ground Water Authority

LDWF & LWF Commission

Office of Fisheries

- Administer functions of the state relating to freshwater fisheries
- Manage resources within game and fish preserves

Office of Wildlife

- Administer Scenic Rivers Act
- Maintain, operate Wildlife Management Areas & Refuges
- Manage resources within game and fish preserves
- Fish & Wildlife Coordination Act consultation
- Member of Ground Water Resources Commission

Louisiana Department of Agriculture and Forestry

Office of Agricultural & Environmental Sciences
(R.S. 3:3201 et seq.)

Pesticide Enforcement
- Licensing and training pesticide applicators
- Implements Regulations
  - Pesticide Registration
  - Conduct Inspections
  - Surface water and groundwater sampling
  - Manages Data
  - State lead agency for federal pesticide enforcement

Advisory Commission on Pesticides

Office of Soil & Water Conservation
(R.S. 3:1201 et seq.)

- Education
- Agricultural Nonpoint Source Pollution Abatement
- Irrigation Water Management
- Flood Control and Prevention
- Watershed Management
- Agricultural Solid Waste Management
- Private Lands Conservation Planning
- Water Conservation
- Water Quality Protection
- Member of Groundwater Resources Commission

State Soil & Water Conservation Commission

Soil & Water Conservation Districts

Memorandum of Understanding Between State Agencies

A Guidance Memorandum issued by the Office of the Louisiana Attorney General and the Secretary of the Louisiana Department of Natural Resources on February 5, 2010, addressed the removal for private use of running water and water in naturally navigable water bodies owned by the state. In some cases, the removal of surface water was a result of negotiated agreements between private entities and the public entities statutorily charged with the management of a water body. In other cases, however, the removal of state surface water was occurring without the knowledge or consent of the appropriate public entity (Appendix F).

As the memorandum states, "Under Louisiana Law persons, with the possible exception of riparian landowners, are not authorized to remove State owned surface water without obtaining the prior written approval of the State and without paying fair value." The memorandum continues with instructions to state agencies and state political subdivisions for responding to requests for the transfer or sale of state-owned surface waters.

Following this memorandum, the Office of the Attorney General issued opinions 10-0173, 10-0289, 10-0297 to further clarify restrictions on surface water use. In addition, the Secretaries of the Louisiana Department of Natural Resources, Louisiana Department of Environmental Quality, and Louisiana Department of Wildlife and Fisheries signed a Memorandum of Understanding on April 22, 2010 (Appendix G), confirming that LDNR shall act as the coordinating agency for requests for withdrawal of surface waters. LDNR shall, in turn, distribute requests and coordinate comments and responses from other agencies. According to the MOU, "The parties recognize the value of working together to protect and preserve Louisiana's valuable natural resources."

Many Other Stakeholders

The issues discussed in this report are critically important to our state. They touch each and every citizen in a daily, almost invisible, way that if not addressed with a balance of care and vigor, could result in much loss. Fortunately, the people of Louisiana realize this and have formed many diverse and talented groups and organizations to address water-related issues.

The following organizations carry out the management and distribution of this crucial resource as it exists today:

- state agencies
- federal agencies
- soil and water conservation districts
- local governments
- academic institutions
- trade associations
- user groups,
- non-profits
- recreation districts
- reservoir districts
- watershed and waterway districts
- river and lake authorities
- municipal water districts and systems in addition to numerous other private and corporate water systems. The Environmental Protection Agency (EPA) lists over 1,000 community water systems in Louisiana that report to them under the Safe Drinking Water Act. In addition, there are systems not on the EPA list since they serve less than 25 people.

The vast number of stakeholders that are involved is a testament to how important this resource is to our state.

STAKEHOLDERS

Federal Agencies
USGS USDA
USACOE USFWS

Louisiana State Agencies
DNR OOC DEQ DOTD
DWLF LDAF DHH OCPR

Ground Water Commission

Ground Water Management Taskforce

Louisiana Ground Water Association (Drillers)

Soil and Water Conservation Districts

Sabine River Authority

Academic Institutions
Louisiana Geological Survey
UL System
LSU System
LSU AgCenter
Southern University System
Tulane University

Groundwater Conservation Commissions
Sparta Capital Area

Water Resources

Red River Watershed Institute

Local Government
Police Jury Association
Louisiana Municipal Association
New Orleans Sewer & Water Board
City Governments
Parish Governments

Lake Commissions
Conservation Districts
Recreation Districts
Watershed Districts
Municipal/Local Water Districts

Users
Public Supply Business
Agriculture Industry
Recreation Fisheries
Navigation Power Generation
Coastal Restoration
Mineral Extraction

NGO's
Louisiana Rural Water Association
Louisiana Engineering Society
Lake Pontchartrain Basin Association
Barataria-Terrebonne National Estuary Program
Citizens for a Cleaner Environment
Louisiana Wildlife Federation
Coalition to Restore Coastal Louisiana
League of Women Voters
Louisiana Environmental Action Network
Sierra Club
Audubon Institute
The Nature Conservancy

Trade Associations
LOGA LMOGA Paper Farm Bureau
Cotton Soybeans Cattle Irrigation
Crawfish Forestry Rice Sugar Cane
Electric Utilities

Water Research

Colleges and universities in Louisiana have partnered with federal and state agencies and local water districts over the years to provide unique and valuable studies about water quality and availability. Important research currently being conducted on campuses around the state will greatly contribute to our understanding of water resources and prudent water management.

A sample of this research conducted by universities such as UNO, LSU, LSU-S, UL-L, LA Tech, McNeese State University, Tulane University, Loyola University, and Southern University are listed below:

Groundwater

- Groundwater flow modeling studies
  (Sparta, Chicot, Carrizo-Wilcox and Southern Hills aquifer systems)
- Groundwater contaminant transport modeling studies
  (Southern Hills, Chicot and Mississippi River Alluvial aquifer systems)
- Saltwater intrusion studies and evaluation of remediation techniques for groundwater systems
  (Chicot, Mississippi River Alluvial and Southern Hills aquifer systems)
- Baseline groundwater quality (organic, inorganic and toxicologic) and natural gas (methane) occurrence studies of regional groundwater systems (Carrizo-Wilcox and Sparta aquifer systems)
- Geospatial analyses of aquifer recharge areas (Chicot Aquifer System) and orphan water wells locations
- Induced land subsidence
- Groundwater use conservation education

Surface Water

- Hydrodynamics, transport and circulation in estuaries, lakes, rivers, tidal inlets, and the Gulf
- Geospatial analysis of watersheds
- Surface water quality and implication for bioaccumulation in aquatic life
- Coastal and marsh hydrology and restoration
- Saltwater intrusion impact on riverine and marsh systems
- Wetland and aquatic ecology and Invasive aquatic species and vegetation
- Impact of climatic change on coastal hydrology and ecology

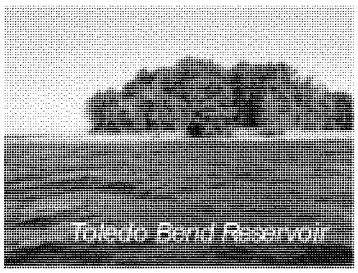
Louisiana Water by the Numbers

Groundwater

- Louisiana has 11 principal freshwater aquifers. If you live in a home that uses its own water well, you are likely using groundwater from one of these aquifers.
- Louisiana uses a total of 1.6 billion gallons of groundwater every day. About 421 million gallons a day of that total is derived from home water wells and public water supply. (USGS, 2011)
- Approximately 3.9 million out of LA's 4.5 million residents use water from public suppliers. Of this number, approximately half of these residents (1.95 million) rely on groundwater-fed public supplies and the other half rely on surface water-fed public supplies.The remaining 587,507 of state residents, or 13 percent of the Louisiana population, use groundwater-fed privately owned domestic wells. (USGS, 2011)
- Estimated groundwater used for drinking water in 2010: approximately 420 million gallons per day (USGS, 2011).
- Estimated number of active public water supply wells: approximately 2,700 wells (LDHH).
- Estimated number of domestic water supply wells in 2010: approximately 75,000 wells (USGS,2011)
- Aquifer with the greatest number of water supply wells: Chicot aquifer system.
- Total number of active drilling contractors in Louisiana as of March 1, 2012: 249
  Of that total, 154 are licensed water well drillers (121) and licensed water well and environmental drillers (33) (Office of Conservation).
- Nearly 190,000 entries are in the Office of Conservation water well database.

Surface Water

- Water from 41 percent of continental United States land areas flows through Louisiana.
- Water covers 17.5 percent of Louisiana's territorial area, or 9,174 square miles out of a state total of 43,204 square miles. (U.S. Census, 2010)
- Eleven percent of that water is coastal in nature, including the Gulf of Mexico and bays. Four percent includes lakes and two percent includes rivers (Louisiana GIS CD, 1999).
- The state's largest metropolitan area relies primarily on surface water resources rather than groundwater.



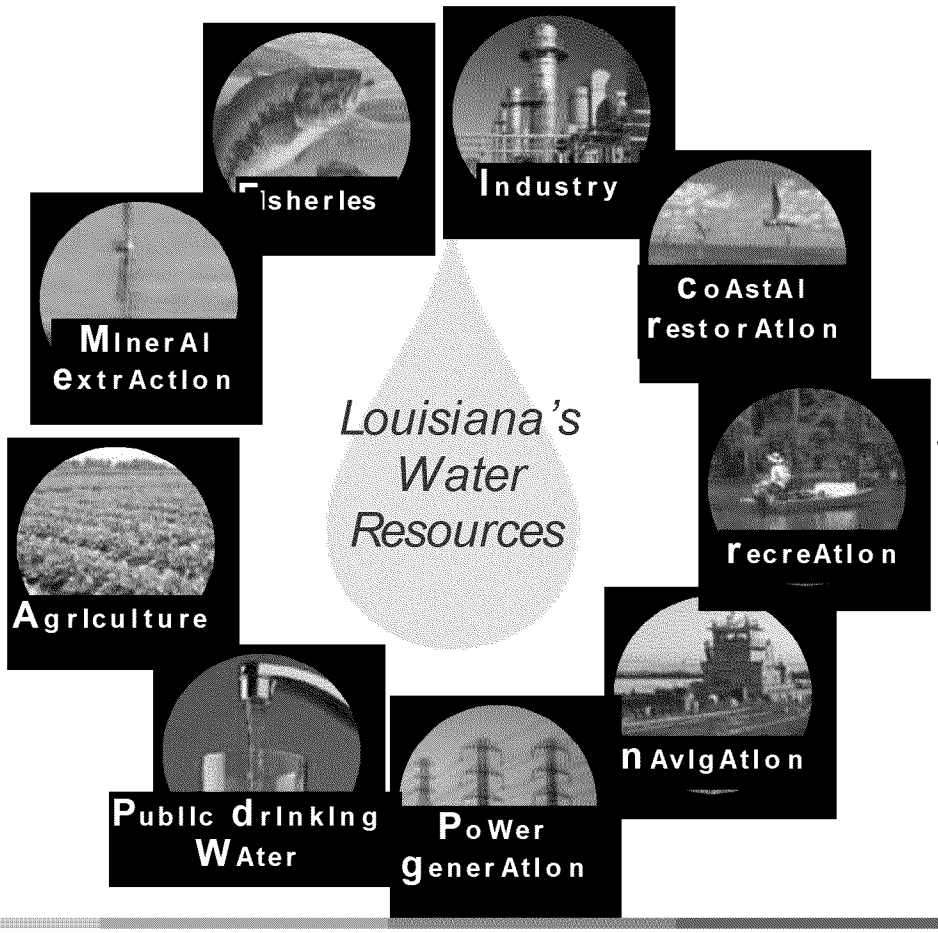
- The state's largest freshwater lake is Toledo Bend Reservoir.

water works for us

According to preliminary results compiled by the U.S. Geological Survey (USGS, 2011) for *water use in louisiana, 2010,* total withdrawals from groundwater and surface water sources in Louisiana in 2010 were approximately 8,500 million gallons per day. Of this total, about 1,600 million gallons per day (19 percent) was from groundwater and about 6,900 million gallons per day (81 percent) was from surface water.

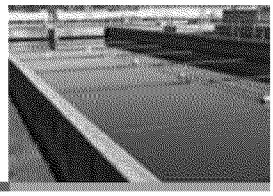
Following are descriptions of water use categories identified by the LDOTD and USGS:

- ***Aquaculture*** **-** Water is used in the fishing and crawfishing industries, and in alligator farming.
- ***Industry*** **-** Water is used in / for process and production, boiler feed, air conditioning, cooling, sanitation, washing, and steam generation.
- ***Irrigation*** **-** Water is applied to the land to promote vegetation growth, including field crops, fruit crops, nurseries, and nonagricultural applications such as golf courses and sporting fields.
- ***Livestock*** **-** Water is used in the production of cattle, horses, sheep, swine, poultry, and other animals.
- ***Power Generation*** **-** Water is used in thermo-electric power generation such as for cooling, sanitation, washing, and steam generation.
- ***Public supply*** **-** Water is delivered to a group of users by public or private suppliers.
- ***Rural Domestic*** **-** Water is used by individuals or families for personal home use in rural areas where public supplies are unavailable.

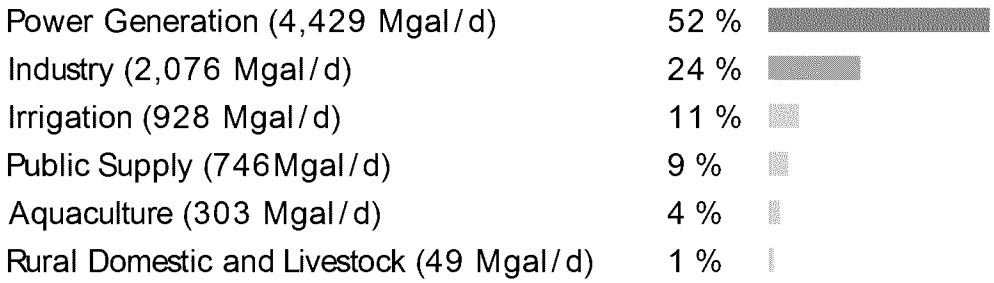


The information described herein is for illustrative purposes only and shall not be considered in the context of compliance with the Clean Water Act, EPA, or LDEQ jurisdiction.

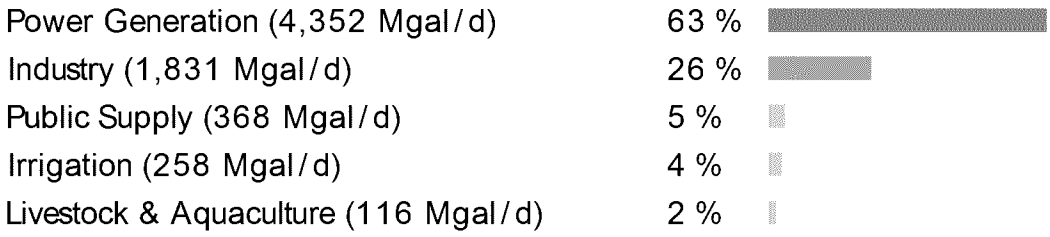
How We Use Our Water



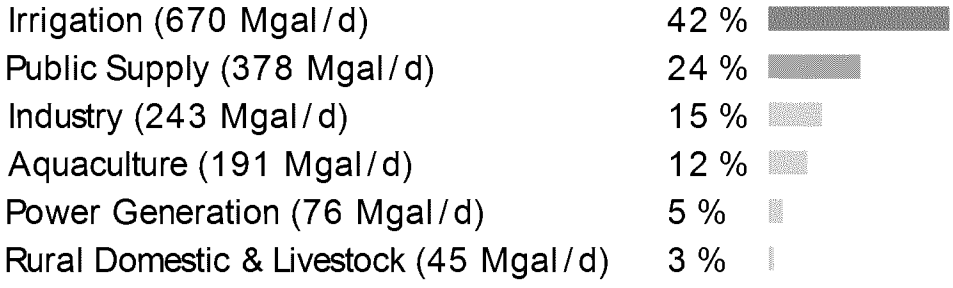
Louisiana Total Water Withdrawals by Use Category, 2010
(usGs, 2011)



Louisiana Surface Water Withdrawals by Use Category, 2010
(usGs, 2011)



Louisiana Groundwater Withdrawals by Use Category, 2010
(usGs, 2011)

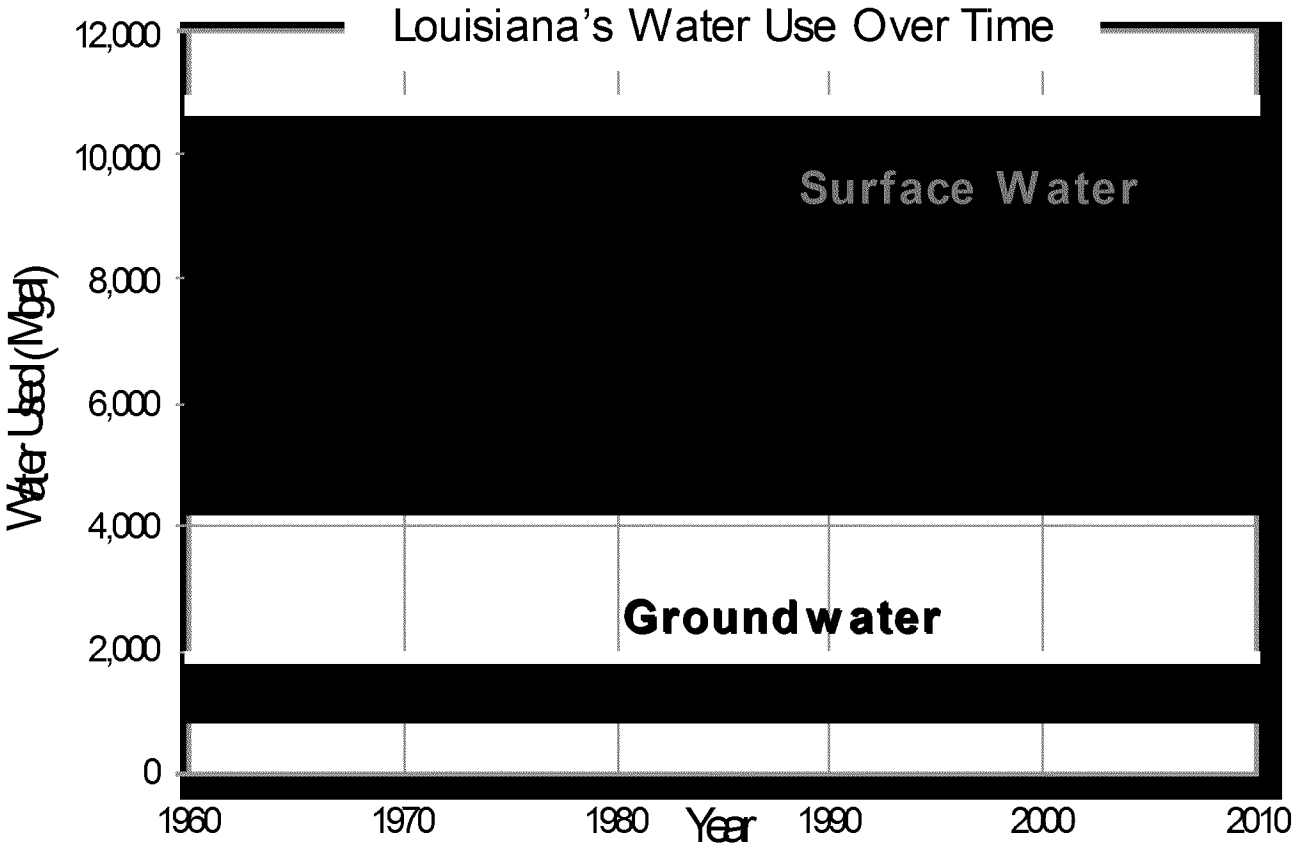


mgal/d = million gallons per day

Water Use in Louisiana - 2010

(Millions of gallons per day)

Total:
8,500 Mgal/day

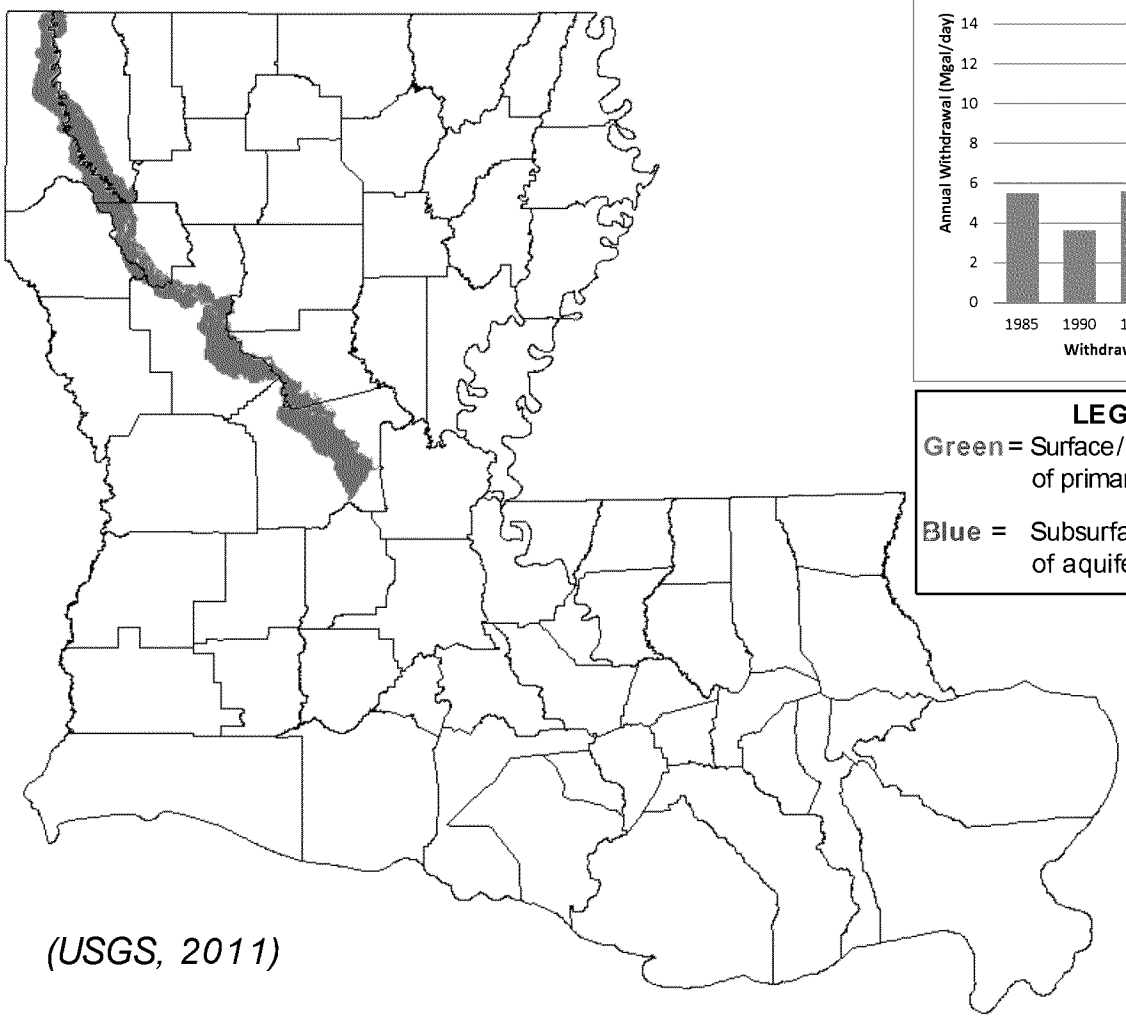


According to *water use in louisiana, 2005* and *water use in louisiana, 2010* by the LDOTD and USGS, total withdrawals from groundwater and surface water sources in 2010 were approximately 8,500 million gallons per day, a decrease of about 17 percent since 2005. Surface water withdrawals decreased by approxinately 20 percent during this period (8661.96 Mgal /d in 2005 versus 6926.19 Mgal/d in 2010), while groundwater withdrawals increased by two percent (571.91 Mgal/d versus 1603.51 Mgal/d in 2010).

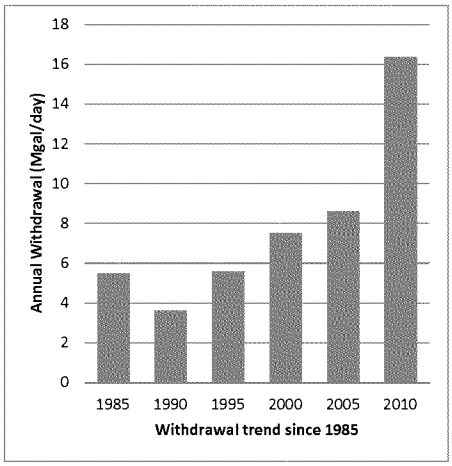
Our Aquifer Systems

louisiana has eleven principal fresh water aquifers systems that are used for pub domestic, industrial and agricultural water supplies. they also feed into streams, lakes, and other surface water reservoirs.

Red River Alluvial Aquifer



(USGS, 2011)



LEGEND

Green = Surface/unconfinedareas of primary aquifer recharge

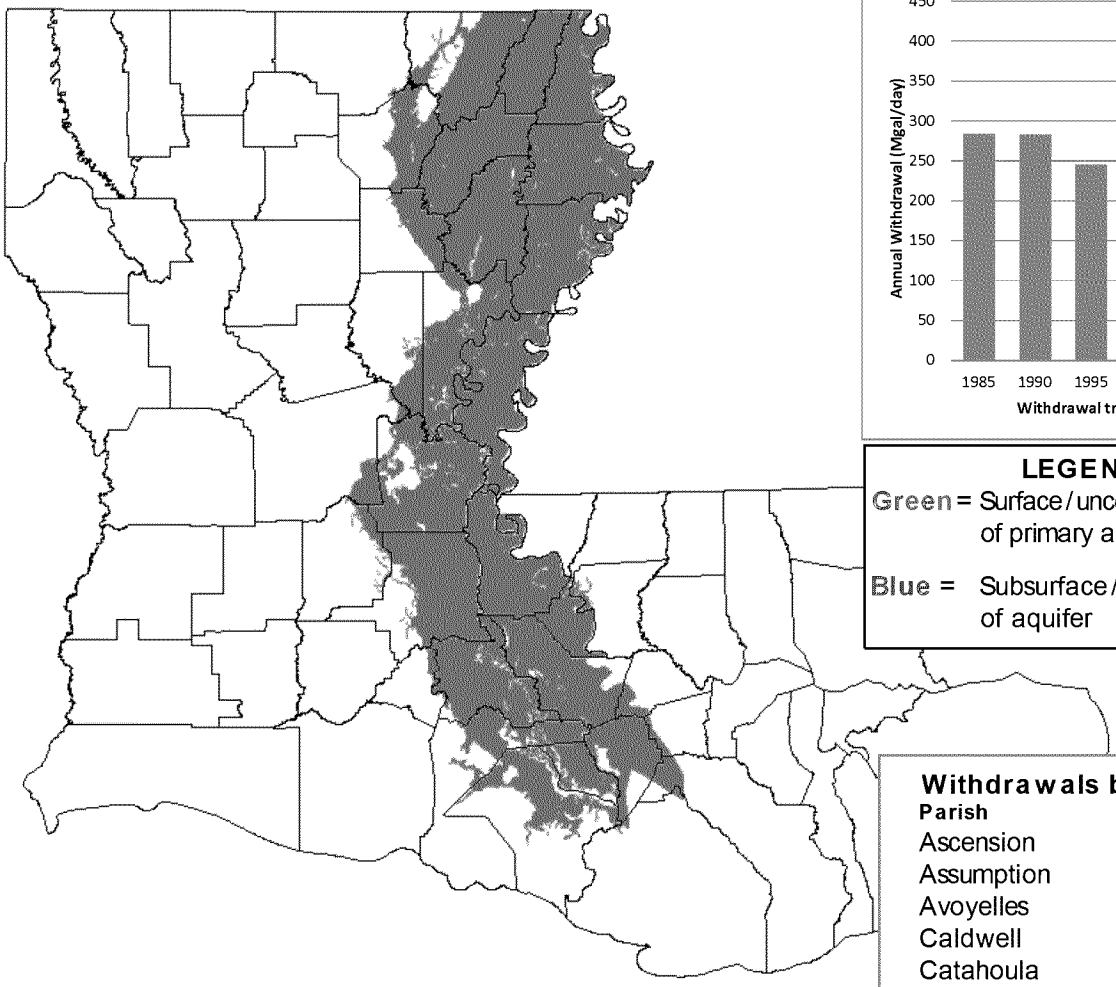
Blue = Subsurface/confined areas of aquifer

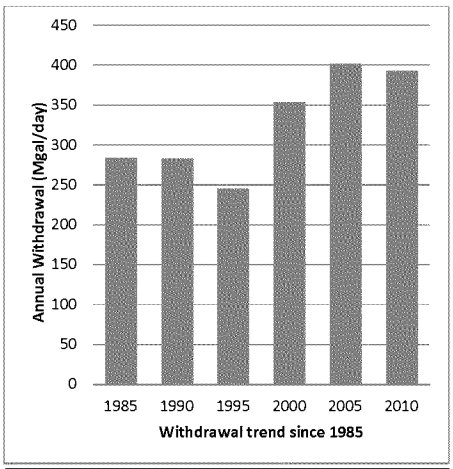
Withdrawals, in millions gallons per day (Mgal/d)	
Public supply	0.12
Industry	0.27
Power generation	0.00
Rural domestic	0.15
Livestock	0.29
Rice Irrigation	3.43
General irrigation	5.31
Aquaculture	6.80
Total	**16.37**

Withdrawals by Parish

Parish	Mgal/d
Avoyelles	6.47
Bossier	0.24
Caddo	3.09
Catahoula	0.21
DeSoto	0.15
Grant	0.02
Natchitoches	2.99
Rapides	1.92
Red River	1.26

Mississippi River Alluvial Aquifer





LEGEND

Green = Surface/unconfinedareas of primary aquifer recharge

Blue = Subsurface/confined areas of aquifer

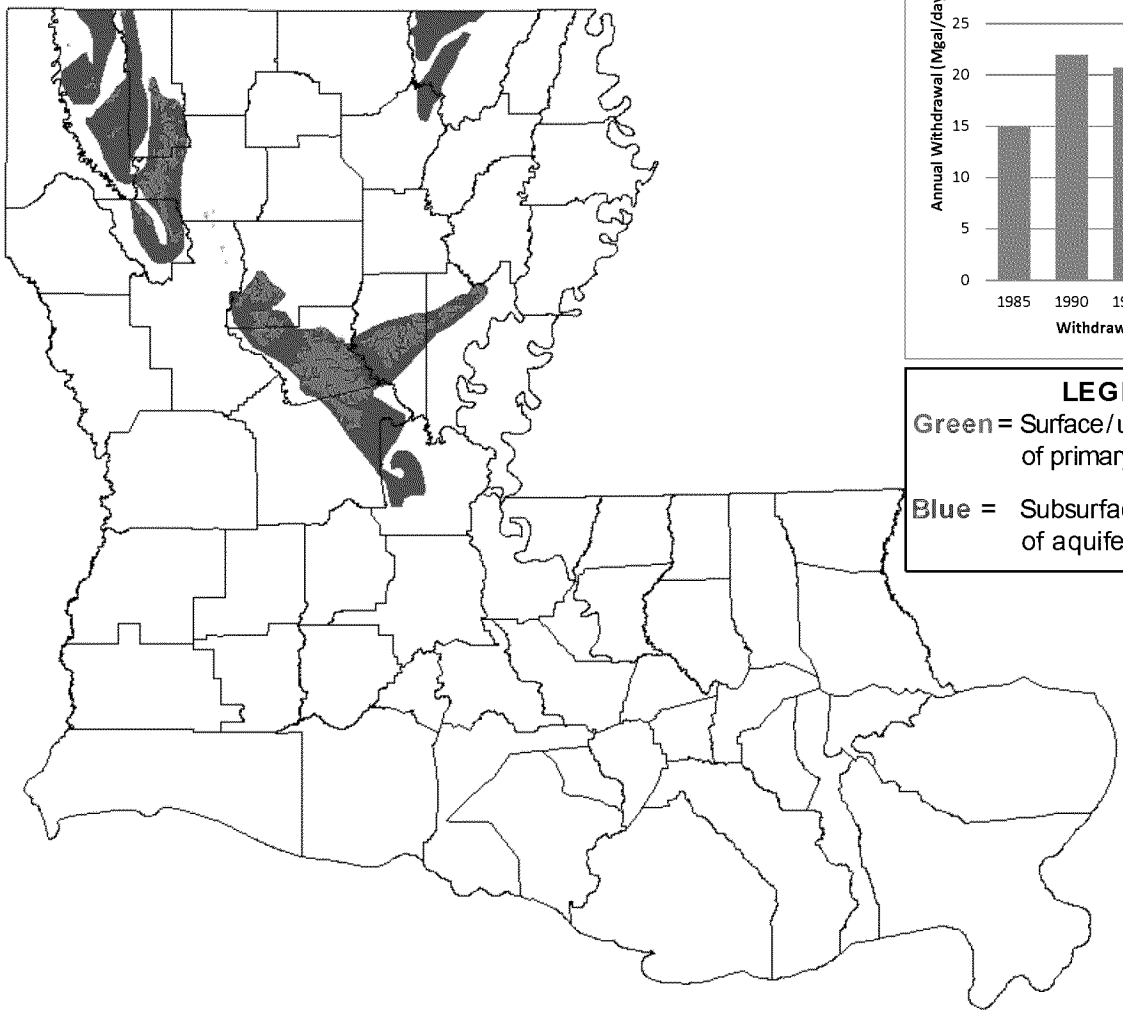
Withdrawals, in millions gallons per day (Mgal/d)	
Public supply	10.04
Industry	28.49
Power generation	0.82
Rural domestic	3.41
Livestock	1.12
Rice Irrigation	132.3
General irrigation	155.13
Aquaculture	62.26
Total	**393.57**

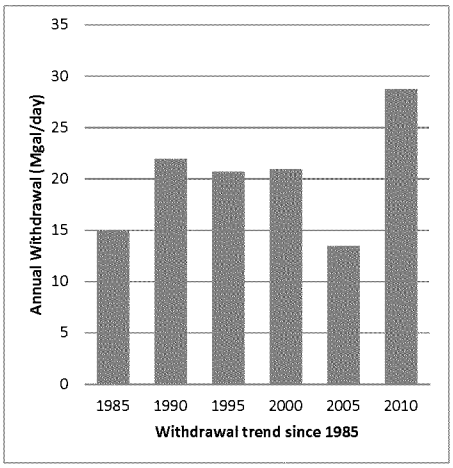
Withdrawals by Parish

Parish	Mgal/d
Ascension	0.15
Assumption	6.81
Avoyelles	24.96
Caldwell	0.61
Catahoula	20.49
Concordia	26.16
East Baton Rouge	0.09
East Carroll	19.91
Franklin	35.18
Iberia	0.17
Iberville	20.41
Lafayette	0.29
Lafourche	4.09
Madison	38.83
Morehouse	67.5
Ouachita	0.88
Pointe Coupee	17.64
Richland	20.37
St. James	0.01
St. Landry	19.77
St. Martin	25.08
St. Mary	0.03
Tensas	28.62
Terrebonne	0.61
West Baton Rouge	2.88
West Carroll	11.98
West Feliciana	0.04

(USGS, 2011)

Upland Terrace Aquifer





LEGEND

Green = Surface/unconfined areas of primary aquifer recharge

Blue = Subsurface/confined areas of aquifer

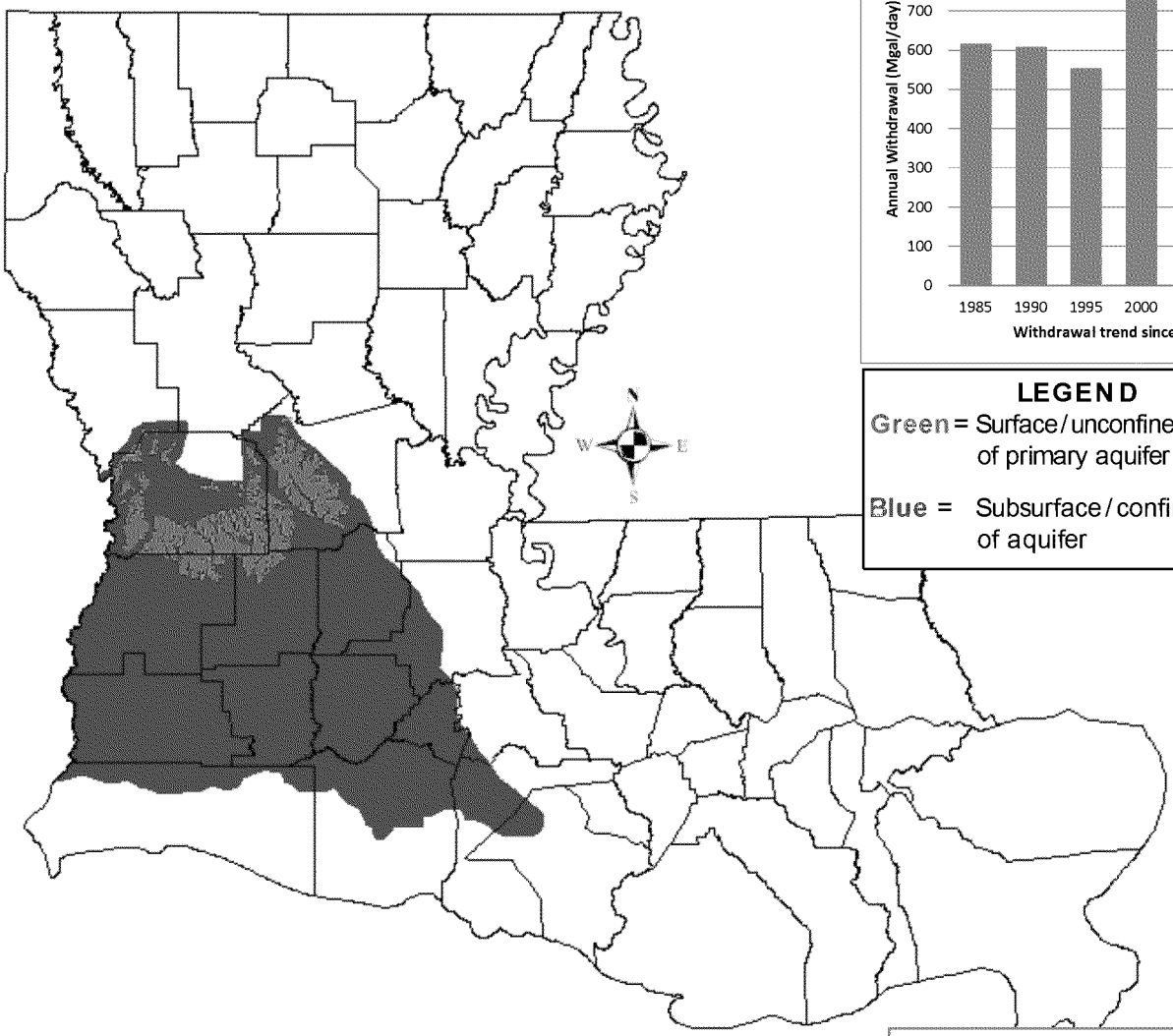
Withdrawals, in millions gallons per day (Mgal/d)	
Public supply	13.24
Industry	0.62
Power generation	0.00
Rural domestic	0.99
Livestock	0.09
Rice Irrigation	4.64
General irrigation	4.47
Aquaculture	4.71
Total	**28.76**

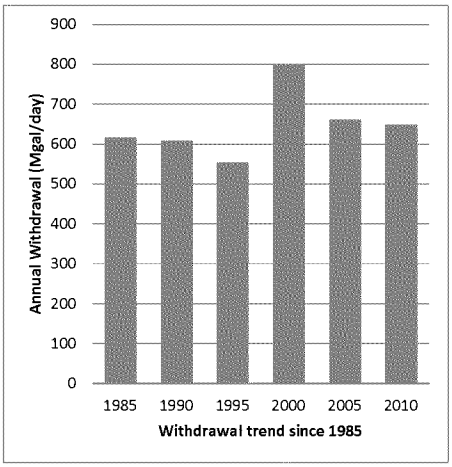
Withdrawals by Parish

Parish	Mgal/d
Avoyelles	5.35
Bienville	0.03
Bossier	1.40
Caddo	0.58
DeSoto	0.49
Grant	0.98
LaSalle	1.28
Morehouse	7.08
Natchitoches	0.20
Ouachita	0.07
Rapides	10.45
Red River	0.25
Sabine	0.03
Union	0.01
Vernon	0.06
Webster	0.43
Winn	0.05

(USGS, 2011)

Chicot Aquifer System





LEGEND

Green = Surface/unconfinedareas of primary aquifer recharge

Blue = Subsurface/confined areas of aquifer

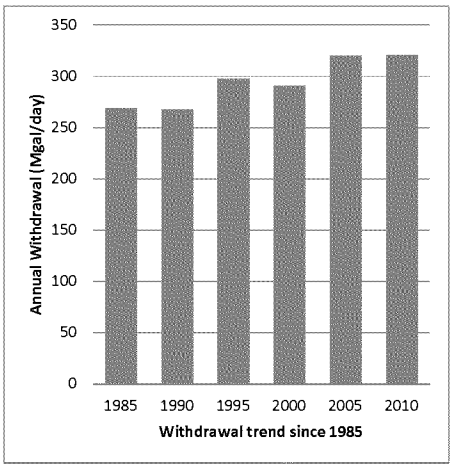
Withdrawals, in millions gallons per day (Mgal/d)	
Public supply	97.35
Industry	57.86
Power generation	14.74
Rural domestic	11.84
Livestock	1.20
Rice Irrigation	341.9
General irrigation	10.55
Aquaculture	113.89
Total	**649.33**

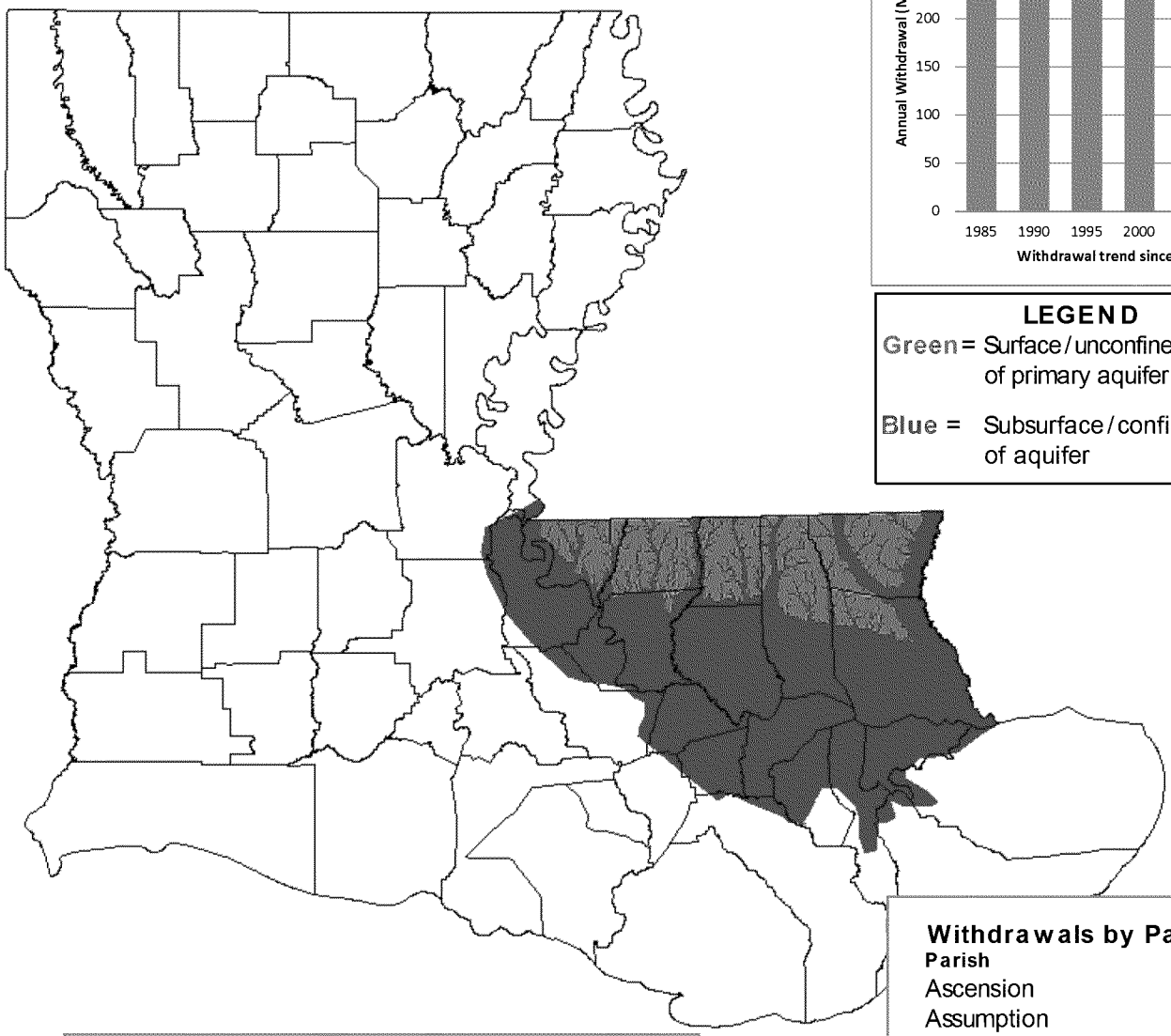
Withdrawals by Parish

Parish	**Mgal/d**
Acadia	183.25
Allen	17.77
Beauregard	11.74
Calcasieu	85.86
Cameron	7.74
Evangeline	65.69
Iberia	16.29
Jefferson Davis	140.46
Lafayette	38.24
Rapides	1.15
St. Landry	36.49
St. Martin	4.11
St. Mary	8.28
Vermilion	31.75
Vernon	0.53

(USGS, 2011)

Southern Hills Aquifer System





LEGEND

Green = Surface/unconfined areas of primary aquifer recharge

Blue = Subsurface/confined areas of aquifer

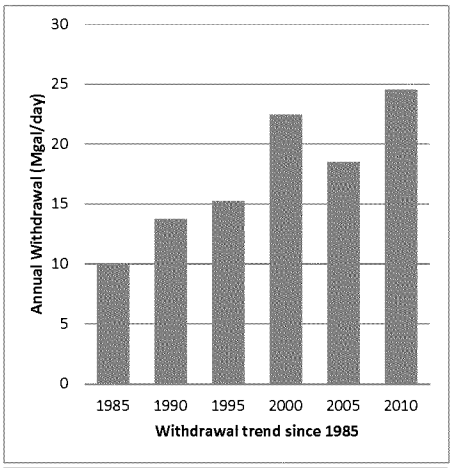
Withdrawals, in millions gallons per day (Mgal/d)	
Public supply	162.79
Industry	112.64
Power generation	25.35
Rural domestic	16.66
Livestock	0.89
Rice Irrigation	0.24
General irrigation	1.83
Aquaculture	0.36
Total	**320.76**

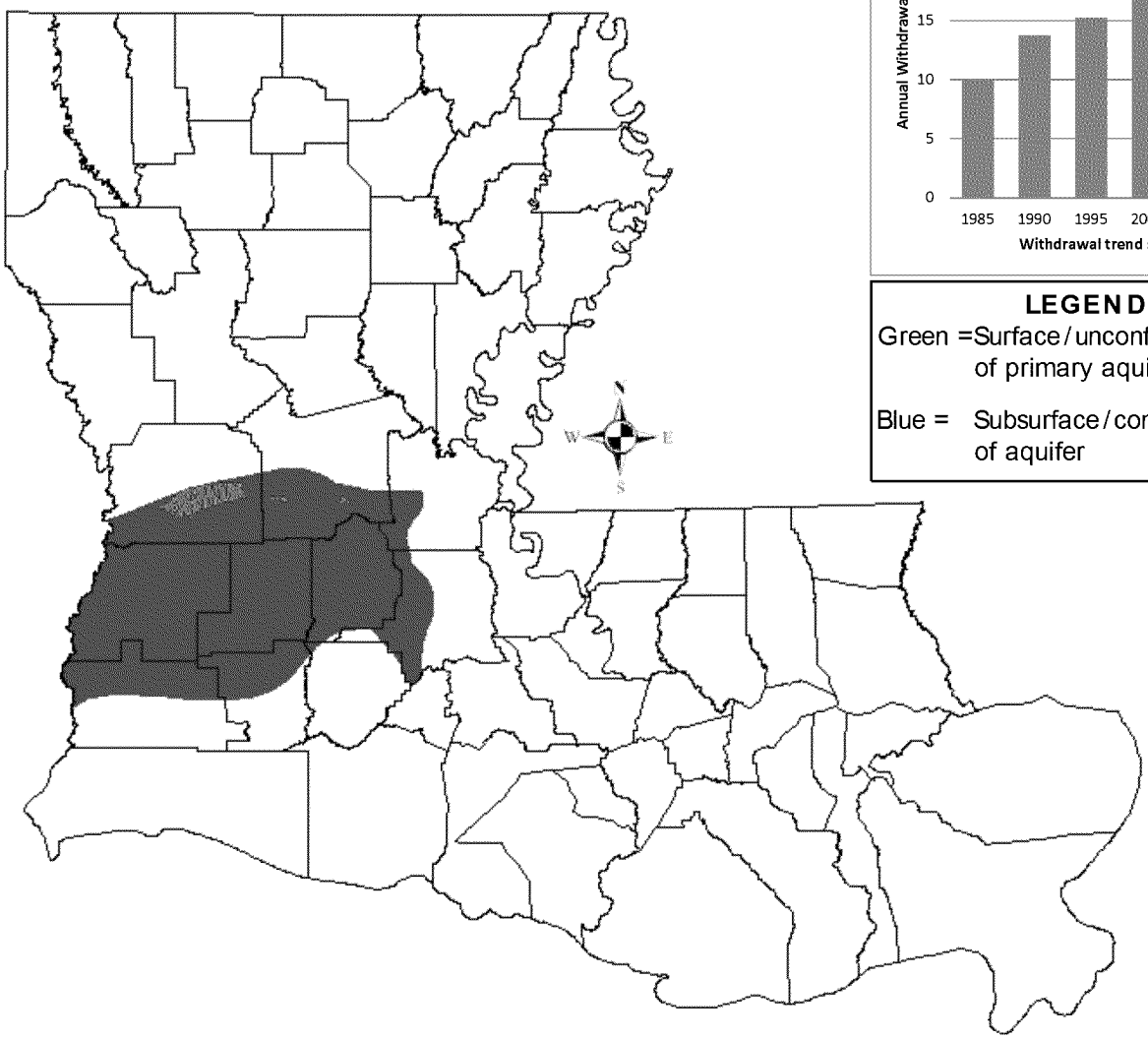
Withdrawals by Parish

Parish	Mgal/d
Ascension	11.80
Assumption	2.22
East Baton Rouge	149.81
East Feliciana	3.45
Iberville	0.47
Jefferson	7.16
Livingston	13.55
Orleans	12.94
Plaquemines	0.04
Pointe Coupee	9.87
St. Bernard	0.02
St. Charles	4.23
St. Helena	1.05
St. James	2.85
St. John the Baptist	13.51
St. Tammany	27.84
Tangipahoa	19.90
Washington	28.11
West Baton Rouge	7.33
West Feliciana	4.64

(USGS, 2011)

Evangeline Aquifer





LEGEND

Green = Surface / unconfined areas of primary aquifer recharge

Blue = Subsurface / confined areas of aquifer

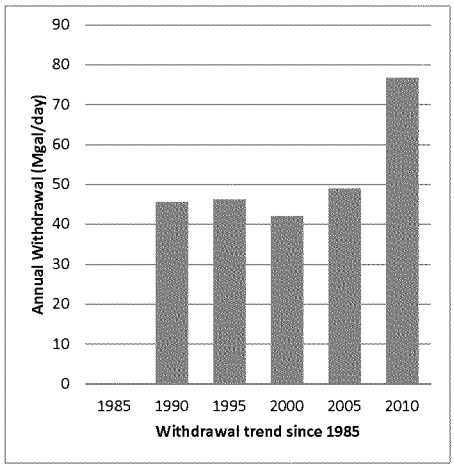
Withdrawals, in millions gallons per day (Mgal/d)	
Public supply	17.66
Industry	2.71
Power generation	0.00
Rural domestic	0.30
Livestock	0.07
Rice Irrigation	2.89
General irrigation	0.68
Aquaculture	0.27
Total	**24.58**

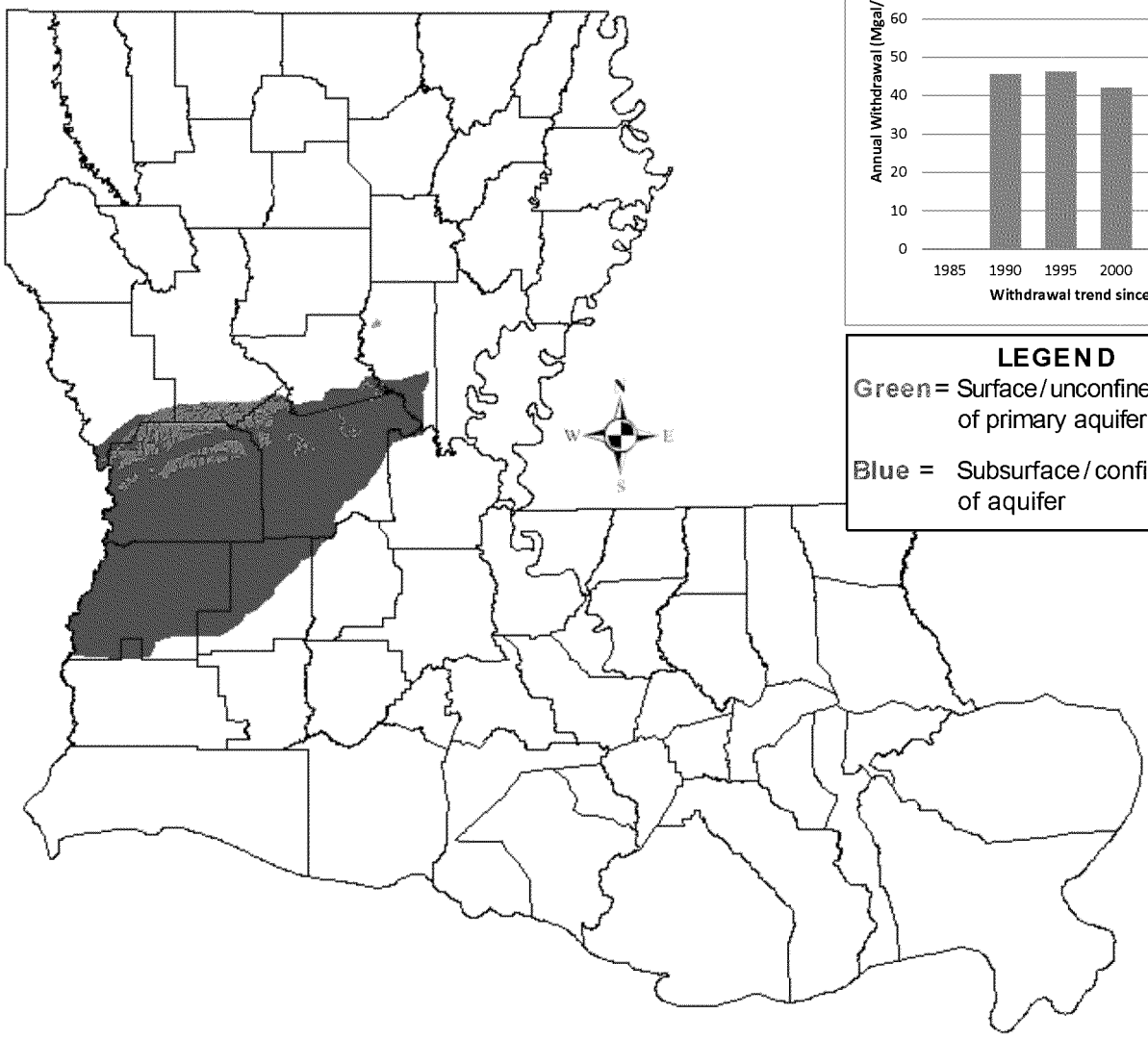
Withdrawals by Parish

Parish	**Mgal/d**
Allen	4.25
Avoyelles	3.36
Beauregard	3.22
Calcasieu	0.79
Evangeline	6.99
Rapides	3.40
St. Landry	2.42
Vernon	0.15

(USGS, 2011)

Jasper Aquifer System





LEGEND

Green = Surface/unconfined areas of primary aquifer recharge

Blue = Subsurface/confined areas of aquifer

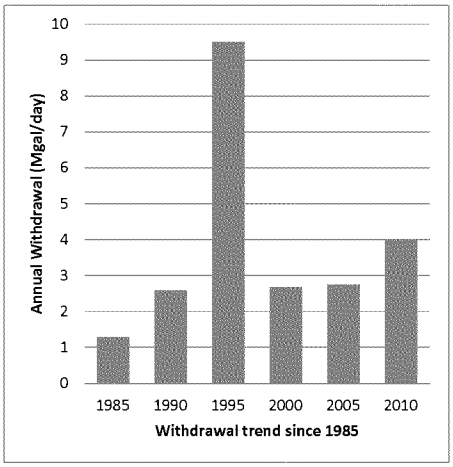
Withdrawals, in millions gallons per day (Mgal/d)	
Public supply	25.01
Industry	12.80
Power generation	34.72
Rural domestic	1.06
Livestock	0.04
Rice Irrigation	0.96
General irrigation	0.65
Aquaculture	1.52
Total	**76.76**

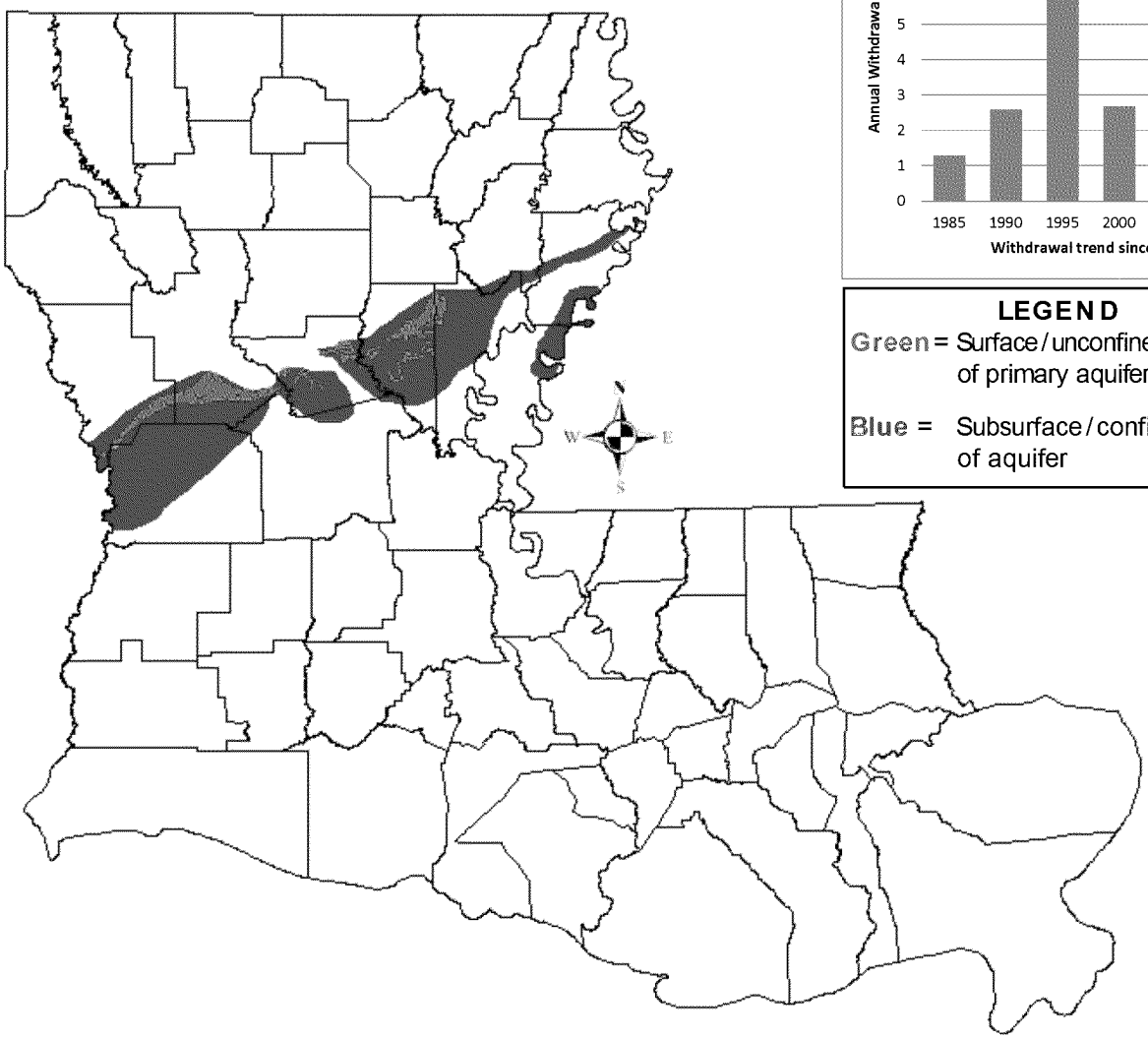
Withdrawals by Parish

Parish	Mgal/d
Avoyelles	0.01
Beauregard	12.40
Concordia	2.17
Grant	0.50
Rapides	54.52
Vernon	7.17

(USGS, 2011)

Catahoula Aquifer





LEGEND

Green = Surface/unconfined areas of primary aquifer recharge

Blue = Subsurface/confined areas of aquifer

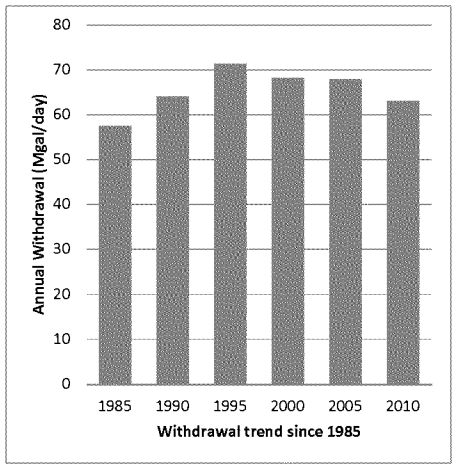
Withdrawals, in millions gallons per day (Mgal/d)	
Public supply	3.51
Industry	0.06
Power generation	0.00
Rural domestic	0.20
Livestock	0.03
Rice Irrigation	0.00
General irrigation	0.15
Aquaculture	0.06
Total	**4.01**

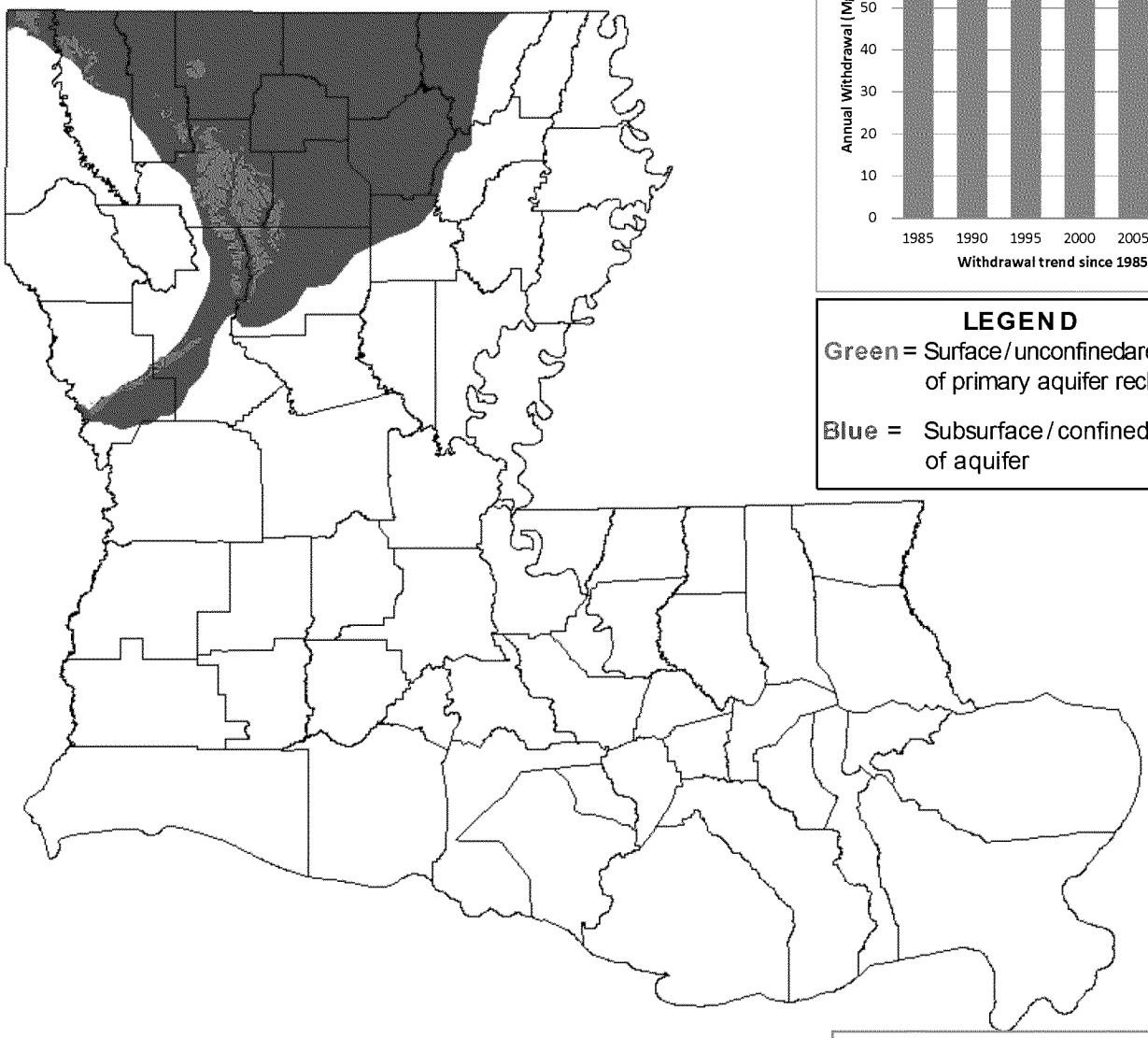
Withdrawals by Parish

Parish	Mgal/d
Catahoula	1.93
Concordia	0.41
East Feliciana	0.06
Grant	0.61
LaSalle	0.16
Natchitoches	0.03
Rapides	0.59
Sabine	0.05
Vernon	0.18

(USGS, 2011)

Sparta Aquifer System





LEGEND

Green = Surface/unconfinedareas of primary aquifer recharge

Blue = Subsurface/confined areas of aquifer

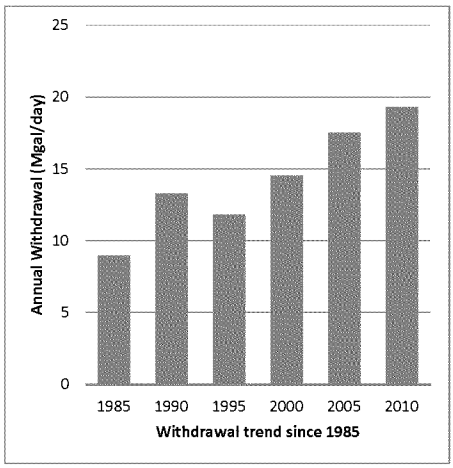
Withdrawals, in millions gallons per day (Mgal/d)	
Public supply	34.61
Industry	25.60
Power generation	0.00
Rural domestic	1.50
Livestock	0.14
Rice Irrigation	0.22
General irrigation	0.98
Aquaculture	0.06
Total	**63.11**

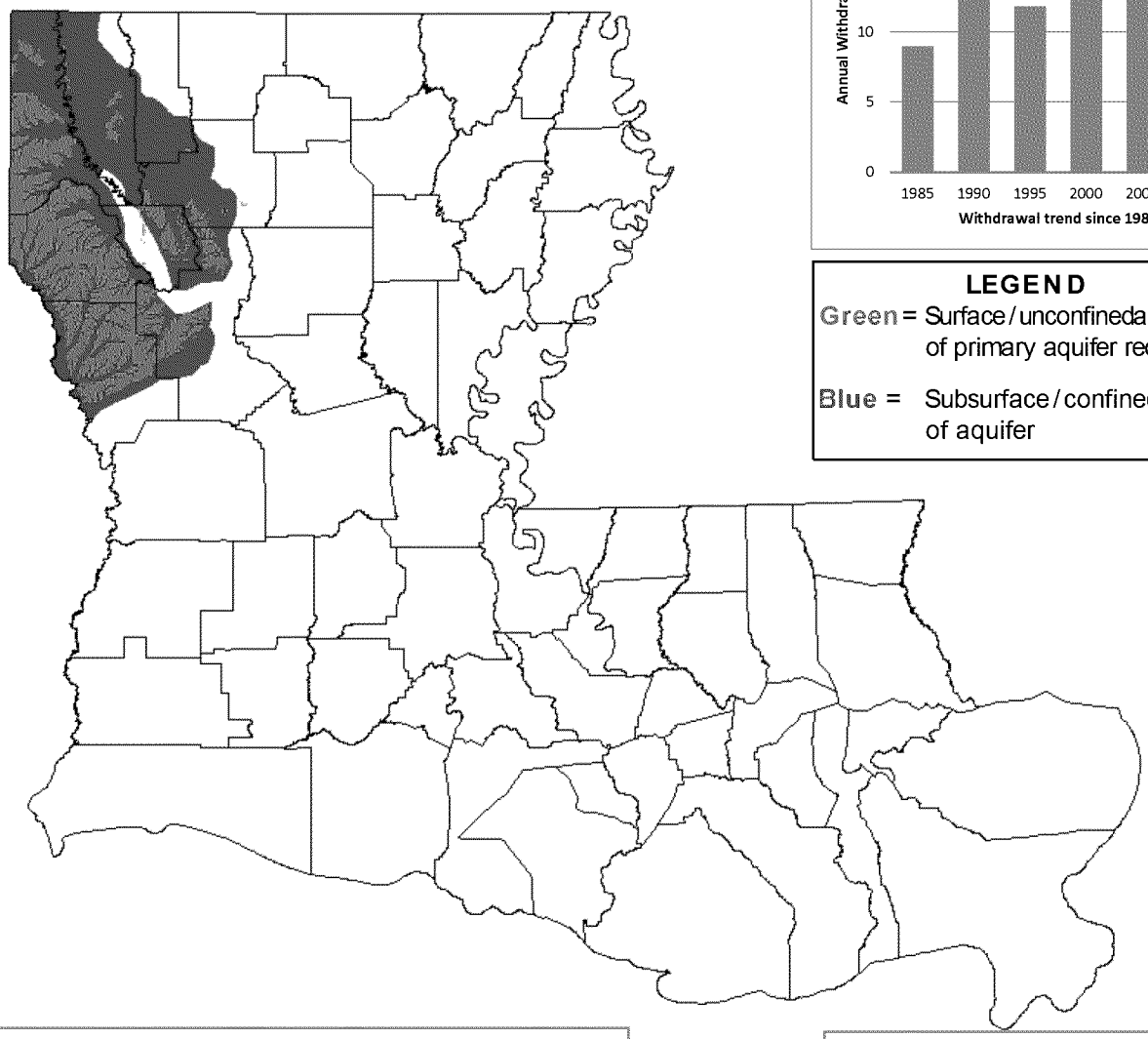
Withdrawals by Parish

Parish	Mgal/d
Bienville	12.00
Bossier	0.19
Caddo	0.13
Caldwell	0.02
Claiborne	2.41
Jackson	3.88
Lincoln	8.71
Morehouse	0.38
Natchitoches	1.21
Ouachita	22.27
Sabine	0.13
Union	3.84
Webster	5.89
Winn	2.05

(USGS, 2011)

Carrizo-Wilcox Aquifer





LEGEND

Green = Surface/unconfined areas of primary aquifer recharge

Blue = Subsurface/confined areas of aquifer

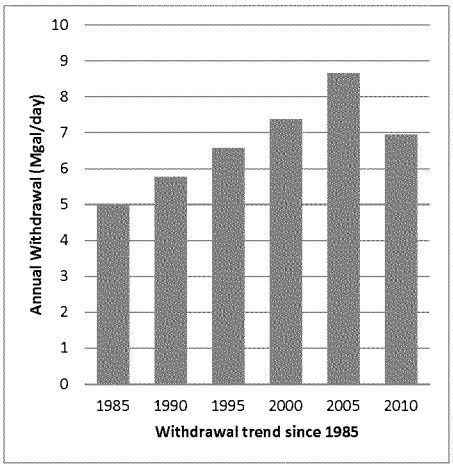
Withdrawals, in millions gallons per day (Mgal/d)	
Public supply	7.55
Industry	3.03
Power generation	0.00
Rural domestic	4.46
Livestock	0.28
Rice Irrigation	0.15
General irrigation	3.05
Aquaculture	0.79
Total	**19.31**

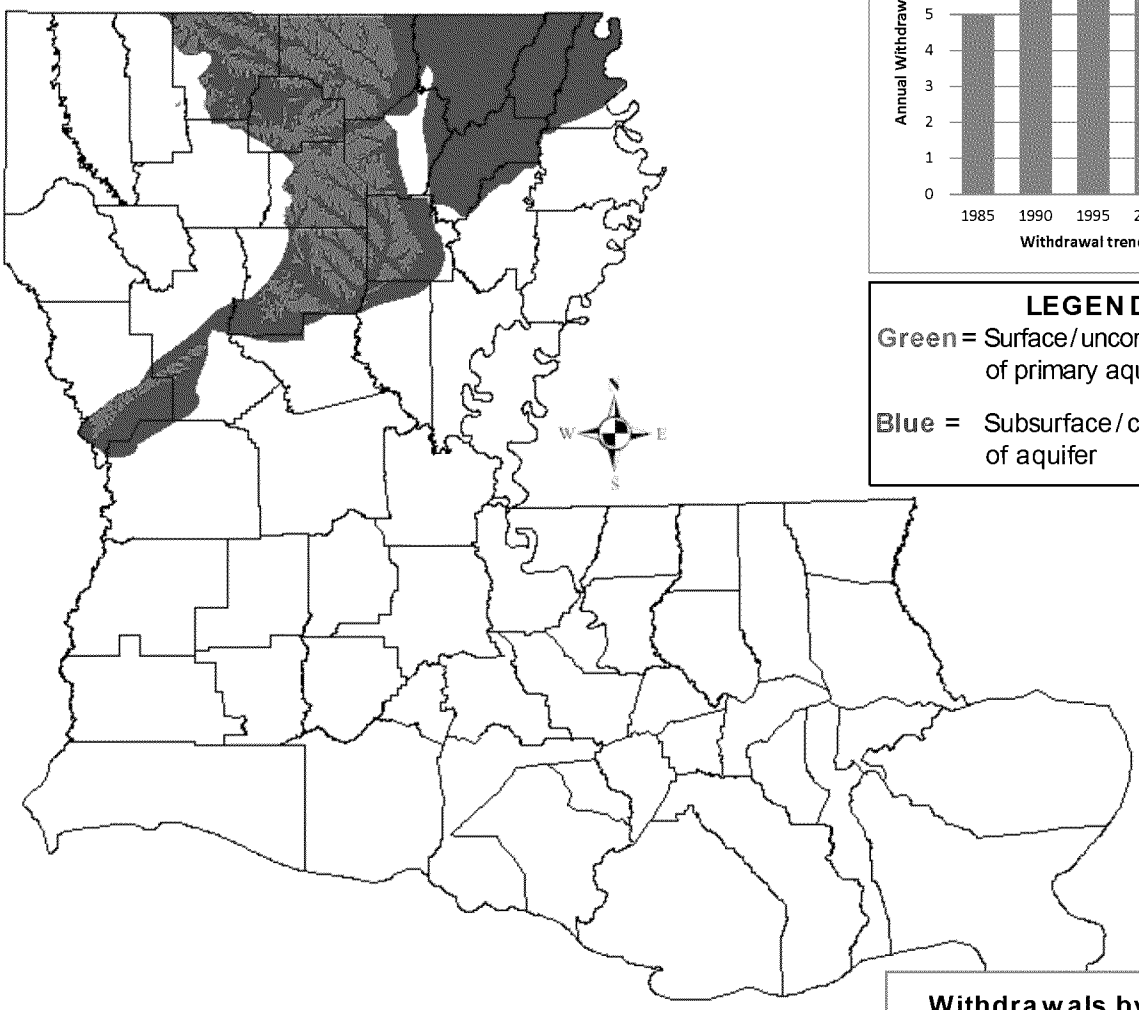
Withdrawals by Parish

Parish	Mgal/d
Bienville	0.99
Bossier	2.39
Caddo	6.78
DeSoto	4.11
Natchitoches	1.03
Red River	1.19
Sabine	1.81
Webster	1.03

(USGS, 2011)

Cockfield Aquifer





LEGEND

Green = Surface/unconfined areas of primary aquifer recharge

Blue = Subsurface/confined areas of aquifer

Withdrawals, in millions gallons per day (Mgal/d)	
Public supply	6.40
Industry	0.00
Power generation	0.00
Rural domestic	0.44
Livestock	0.01
Rice Irrigation	0.11
General irrigation	0.00
Aquaculture	0.00
Total	**6.96**

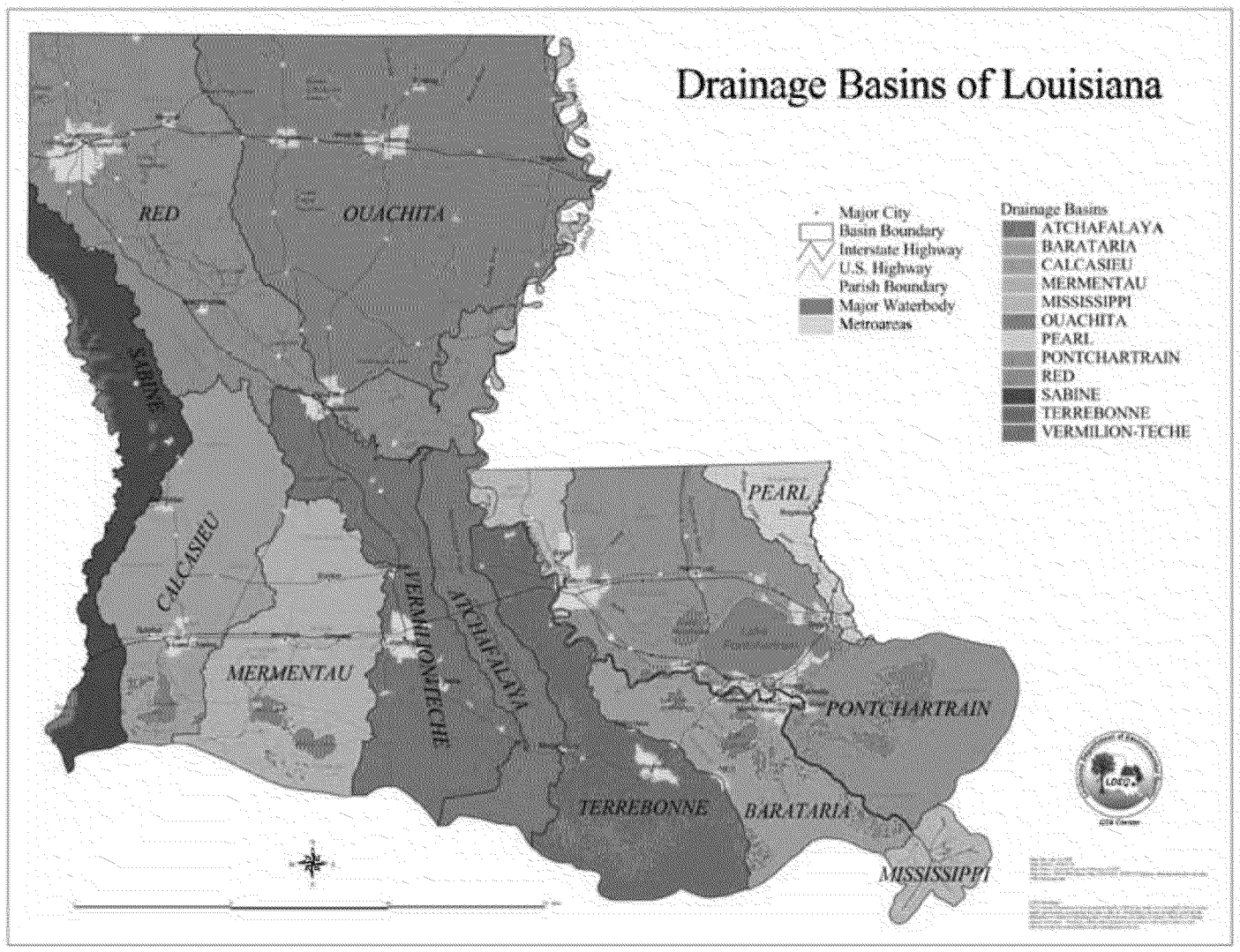
Withdrawals by Parish

Parish	Mgal/d
Caldwell	1.09
Claiborne	0.01
East Carroll	1.29
Grant	0.20
Jackson	0.06
LaSalle	0.86
Lincoln	0.01
Morehouse	0.34
Natchitoches	0.07
Ouachita	0.11
Richland	1.46
Sabine	0.07
Union	0.06
Vernon	0.06
West Carroll	1.08
Winn	0.19

(USGS, 2011)

Principal Drainage Basins in Louisiana

Comprehensive water management integrates both groundwater and surface water resources to achieve resource sustainability. In addition to eleven aquifers, Louisiana has ten recognized surface watersheds, depicted in the map below.



map produced by la Department of environmental Quality.

Current Major Issues

Discussed in this section are major issues having either a direct or indirect impact on groundwater sustainability management, in no particular order. These include inadequate monitoring network, coastal restoration and saltwater intrusion, Sparta aquifer system Areas of Ground Water Concern, saltwater encroachment in Capital Area aquifers, high water use in southwest Louisiana, southern Caddo Parish temporary groundwater emergency, Toledo Bend Reservoir, surface water withdrawal management, energy exploration / emerging technologies, surface water quality management, safe drinking water supply, and conservation education / public outreach. An aquifer-by-aquifer summary of all known or potential adverse impacts affecting groundwater quality or availability are identified on page 82.

Inadequate Monitoring Network

This recommendation is derived from the December 7, 2011 report by Ecology and Environment, Inc. (E&E) for LDNR titled *Recommendations for a statewide Groundwater management plan* and extensively discussed by members of the Ground Water Resources Commission at a public meeting on January 19-20, 2012.

The E&E Executive Summary notes, "In conclusion, the single most significant and fundamental groundwater resource management issue that Louisiana should focus its immediate attention and efforts for improvement is the timely and periodic acquisition and dissemination of comprehensive aquifer-wide groundwater level measurements, water well production and ground-water quality data. Although the state has implemented various methods of obtaining such information, it is clear that these current methods fall short of producing a sufficient volume of data in a coordinated manner available in a time frame necessary for implementing a more efficient and effective means of managing the state's groundwater resources to ensure both short and long term aquifer sustainability. Establishing improvements in data acquisition and dissemination must be adequately addressed in order for the state to develop and implement any successful groundwater management strategy and therefore should be addressed as a matter of priority."

Groundwater and surface water data collection has been ongoing in Louisiana by agencies such as the USGS and the U.S. Army Corps of Engineers for over 90 years. The USGS has had a cooperative monitoring program with the state since the early 1950's. Peak monitoring occurred in the early 1980's, at which point the cooperative network included a groundwater network of 739 wells and a surface water network of 184 gaging stations. Due to budget reductions in the mid-1980's, these networks have been reduced to the present 164 wells and 59 gaging stations, a 78 percent and 68 percent reduction respectively.

Recognizing it is paramount that the state's groundwater monitoring networks be robust enough to timely identify areas of concern and enable scientifically based management decisions, the Fiscal Year 2012-2013 Executive Budget includes an appropriation, from a decade-old fund comprised of federal fines, to expand and enhance the groundwater monitoring network, reporting frequency, and aquifer evaluations, all as per a USGS recommendation. See Appendix H for details of the enhanced monitoring well network proposal.

The data gathered from any increased monitoring project may be used to determine if more frequent or extensive water withdrawal reporting may need to be required for certain users and / or in certain areas. Considering that all aquifers are not the same, the monitoring program should not be "one size fits all." For example, the challenges of the lenticuler nature of the Carrizo-Wilcox aquifer, the deficit issues of the Sparta aquifer, the high use of the Chicot aquifer, and the Baton Rouge area Southern Hills aquifer saltwater encroachment issue all require aggressive, yet different, monitoring strategies.

For the above reason, this document is called an interim report. It will be updated annually as this robust monitoring program is implemented. In addition, we are hopeful that additional funding to expand and enhance surface water monitoring can be secured in the near future.

Coastal Restoration and Saltwater Intrusion

Louisiana's coastal ecosystem and wetland habitats are in peril due to the continued loss of coastal wetlands. Currently, Louisiana has 30 percent of the total coastal marsh and accounts for 90 percent of the coastal marsh loss in the lower 48 states. In the last 80 years 1,883 square miles have been lost and it is projected that 1,756 square miles of additional land are at risk of being lost in the next 50 years. In 2004, the United States Geological Survey (USGS) projected that, between 1956 and 2050, Louisiana will have lost more than 2,000 square miles of coastal wetlands. Naturally occurring deltaic processes, exacerbated by human activities, have been identified as key contributors to this coastal land loss crisis. It has been well documented that a reduction of sediments and the lack of fresh water that is being input into the coastal ecosystem are two of the major reasons for continued coastal wetland decline. Due to the importance to the state and to nation of the assets that are located in this fragile area – our ports, energy infrastructure, seafood, wetlands, natural resources, etc. – this land loss crisis is nothing short of a national emergency.

The State of Louisiana is making significant efforts to reverse this land loss trend, having restored more land and invested more dollars since the release of the 2007 State Master Plan for a Sustainable Coast than any time in the state's history. Since 2007 the Coastal Protection and Restoration Authority (CPRA) has built or improved 159 miles of levees, benefited 19,405 acres of coastal habitat, secured approximately $17 billion in state and federal coastal funding, constructed 32 miles of barrier islands and berms, moved 150 projects into design and construction, and constructed projects in 20 parishes.Therefore, as the state moves forward to implement its aggressive coastal restoration and protection effort, in accordance with the 2012 draft State of Louisiana's Comprehensive Master Plan for a Sustainable Coast (Plan), water must play a key role in reversing the trend of coastal land loss.

Yearly changes in the availability of fresh water and sediment, as well as other long-term trends that may be associated with climate change, reinforce the need to explore aggressive ecosystem restoration measures to include management of freshwater resources. Salt water is destroying fragile marsh and impinging on freshwater lakes and marshes. Fresh water needed for agriculture is also increasingly compromised by this saltwater intrusion, a trend that endangers the region's tradition of rice, cattle, and crawfish farming. These conditions have been further exacerbated by recent drought conditions. It is critical that the state maintains the integrity of freshwater reservoirs in both the Chenier and Deltaic Plains of the coastal area. Inland lakes and freshwater marshes are at continued risk from encroaching saltwater. Without an adequate supply of fresh water, these coastal wetland habitats will not receive the wetland-sustaining fresh water that is required to sustain these critical habitats.

Current major issues (cont.)

The 2012 draft Plan relies heavily upon the availability of fresh water to achieve its anticipated outcomes over the 50-year vision of the plan. The Plan also relies on fresh water to enhance freshwater fisheries and habitat, combat higher salinities which infiltrate our basins and uses freshwater and sediment diversions as a restoration tool. A reliable supply of fresh water is critically important to the long-term success of the Plan. In order to maintain the supply envisioned by the plan as well as sustain surface water resources for drinking water, agriculture, municipal, and industrial needs, and recreation and aquatic habitat ecosystem demands throughout the state, a management plan that addresses water allotment should be developed to ensure the sustainable use of this valuable resource for coastal restoration and other purposes. In order to reduce the impacts of periodic salt-water intrusion, the Plan suggests managing fresh water supplies to allow better maintenance of water resources throughout the year. Such management will also permit the delivery of fresh water to areas that may be exposed to saltwater stress.

Images of Freshwater-Starved Marsh in Coastal Louisiana

Area of Ground Water Concern: Sparta Aquifer System

After due process, including public notice and public hearing, and based on good management practices and scientifically sound data, the Commissioner of Conservation can establish an Area of Ground Water Concern. Louisiana Revised Statute 38:3097.2.(1) states that an area of ground water concern shall mean an area in which, under current usage and normal environmental conditions, sustainability of an aquifer is not being maintained due to either movement of a saltwater front, water level decline, or subsidence, resulting in unacceptable environmental, economic, social, or health impact, or causing serious adverse impact to an aquifer, considering the areal and temporal extent of all such impacts.

In 2003, the Sparta Ground Water Conservation Commission submitted an application to LDNR to have areas of the Sparta aquifer system evaluated based on aquifer studies that showed long term declining water level trends in the aquifer. The Office of Conservation reviewed, evaluated, and documented water usage and water levels. After careful consideration of the facts available before, during and after public hearings, three Areas of Ground Water Concern were established in 2005 under Office of Conservation Order No. AGC-1-05 (Order) in areas experiencing continual ground water level decline in historic pumping centers.

These areas include Ruston (Lincoln Parish), Jonesboro-Hodge (Jackson and Bienville Parishes), and Monroe-West Monroe (Ouachita Parish). Management actions such as water conservation education, monthly groundwater production reporting, and Sparta user pursuit of alternative water resources were implemented.

Since 2005, water level data collected from USGS observation wells located in the Sparta aquifer system in north Louisiana generally show improving water level conditions (see maps on pages 70-71). However, while water level conditions and trends have clearly improved in some areas of the Sparta aquifer system, water level decline, in the three established Areas of Ground Water Concern warrants continued close observation and management actions.

Letter from Union County (Arkansas) Water Conservation Board to LDNR - June 24, 2010

"On behalf of the Union County Water Conservation Board, our public and private partners, and particularly the citizens of Union County, thank you (to) the Louisiana Office of Conservation for your support of the Board's Sparta Aquifer Recovery Initiative in South Arkansas and North Louisiana."

- uCwCB president Robert Reynolds

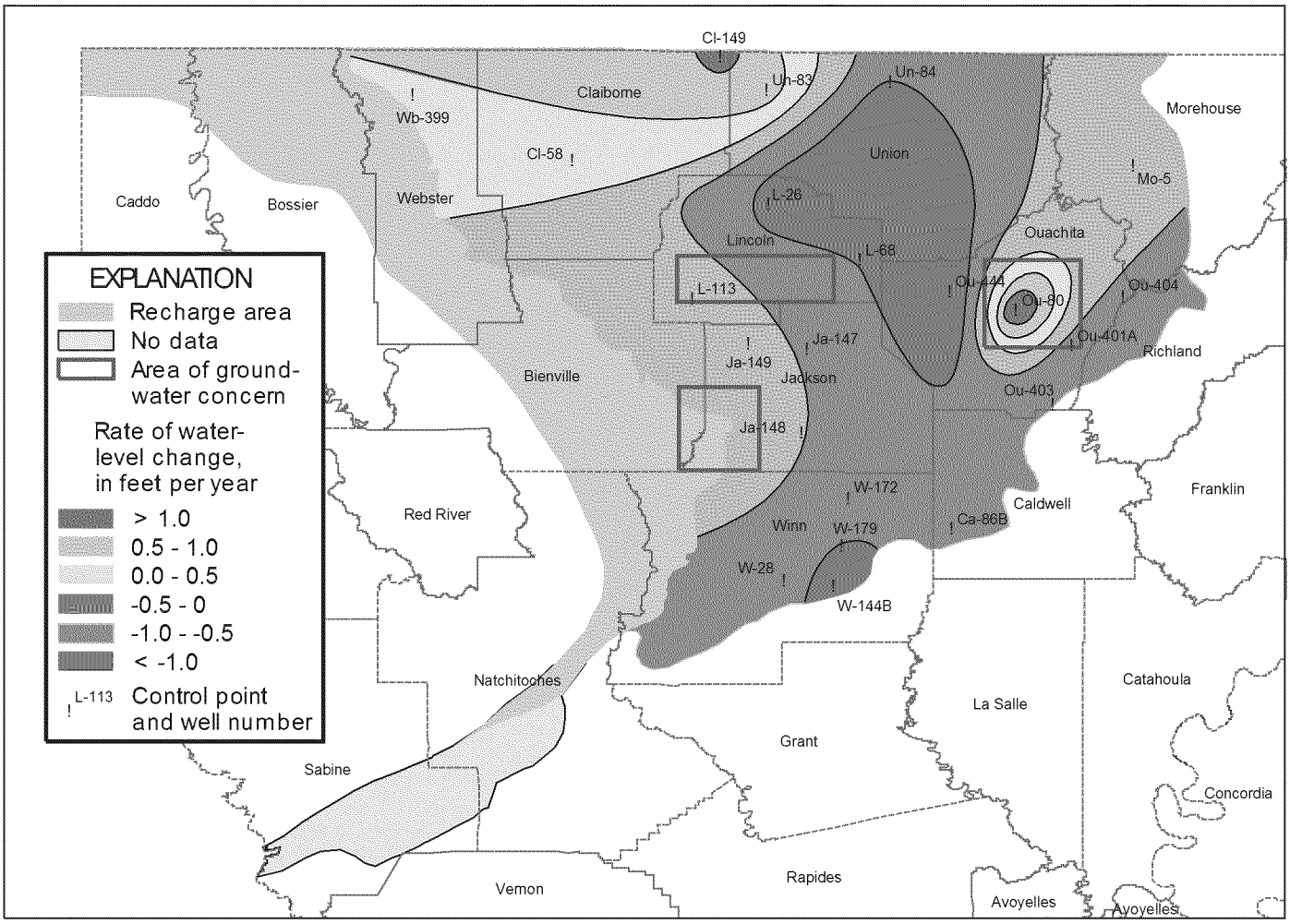
Current major issues (cont.)

Funding for Outside Groups Associated with Groundwater Monitoring of the Sparta

- On October 1, 2007, LDNR entered into a contract with United States Geological Survey in the amount of $47,950 to determine water level data from the Sparta aquifer system in northern Louisiana.
- On October 1, 2008, LDNR entered into a contract with United States Geological Survey in the amount of $23,250 to determine water level data from the Sparta aquifer system in northern Louisiana.
- On July 1, 2008, LDNR entered into a contract with United States Geological Survey in the amount of $32,000 to determine water quality data from the Sparta aquifer system in northern Louisiana.
- On January 1, 2008, LDNR entered into a contract with United States Geological Survey in the amount of $16,000 to determine water quality data from the Sparta aquifer system in northern Louisiana.
- On July 1, 2009, LDNR entered into a contract with United States Geological Survey in the amount of $31,000 to determine water quality data from the Sparta aquifer system in northern Louisiana.
- On July 1, 2009, LDNR entered into a contract with Union County Arkansas in the amount of $32,746 to monitor the North Louisiana Sparta Aquifer Recovery.
- On July 1, 2011, LDNR entered into a contract with Union County Arkansas in the amount of $35,375 to collect and analyze water samples from seven Sparta Aquifer Recovery MW'S located in Northern Louisiana.

Current major issues (cont.)

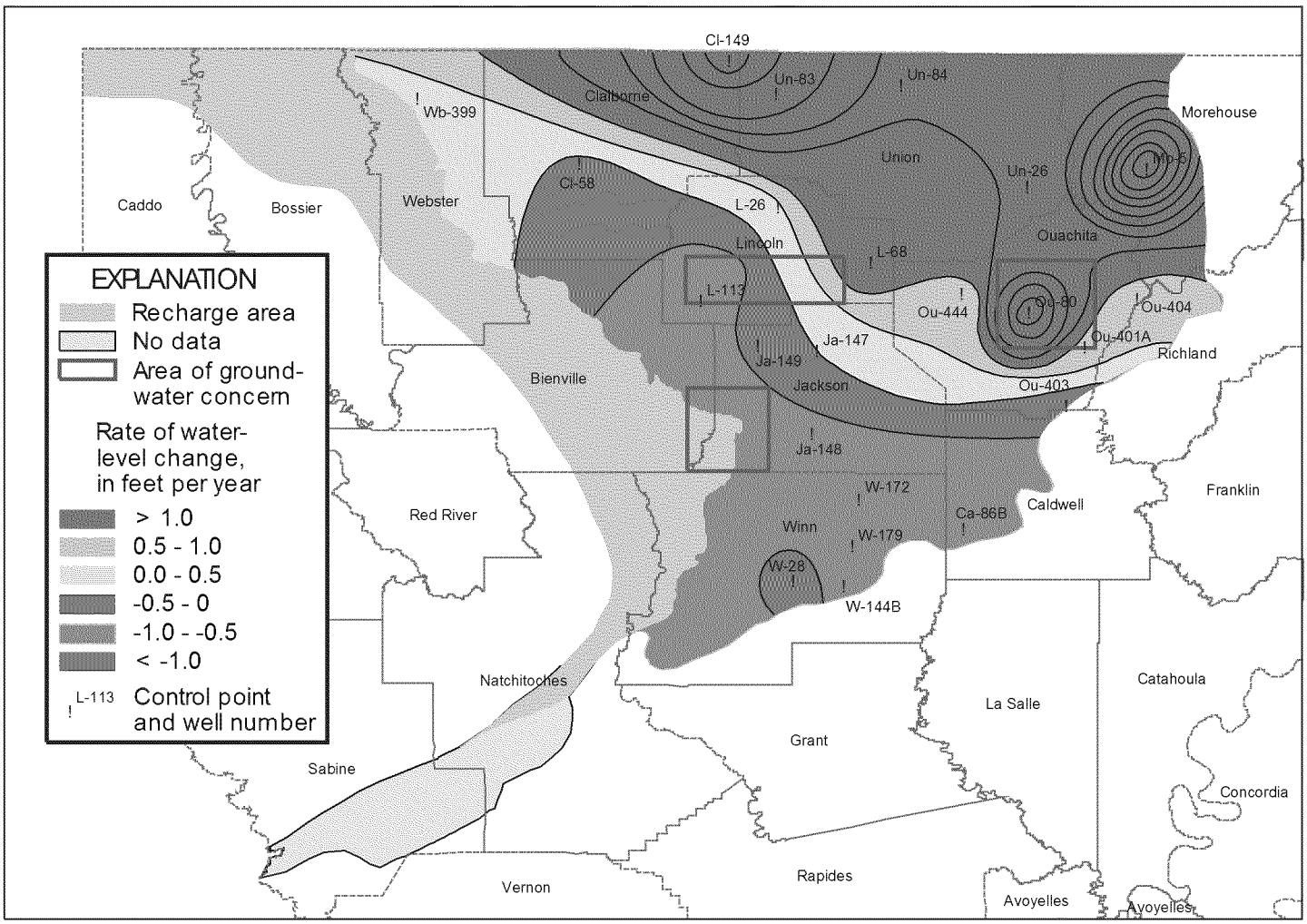
Water-level changes in the Sparta aquifer, 2000-05



This 2000-2005 map from the USGS shows most of the Sparta aquifer system is still in long-term decline during this period, although water levels are starting to rise in northern Claiborne Parish and northwestern Union Parish due to changes in pumping at El Dorado, Arkansas. Water levels have also started to rise at West Monroe, presumably due to decreased pumping there. Much of the area between northwestern Union Parish and West Monroe are not yet affected by these changes and still reflect the long-term decline. Also notable is the continued decline in central Winn Parish.

Current major issues (cont.)

Water-level changes in the Sparta aquifer, 2006-11



Unpublished data, subject to revision

The 2006-2011 map produced by the USGS shows water levels rising across much of the northern extent of the Sparta aquifer system in this period due to decreased pumping at El Dorado, West Monroe, and Bastrop. Water levels continue to decline in Winn Parish.

Saltwater Encroachment in Capital Area Aquifers

At the request of the Capital Region Legislative Delegation and East Baton Rouge Parish Metro Council, a public meeting was held on March 8, 2012 on the issue of saltwater encroachment in the aquifer system underlying the Baton Rouge area. The purpose of the meeting was two-fold: 1) to provide information on the issue of saltwater encroachment in the 1,500-foot and 2,000- foot sands of the Southern Hills aquifer system in the Baton Rouge area, and 2) to provide an opportunity for all stakeholders, interested parties and the general public to deliver information on this issue for the Office of Conservation and other governing authorities to consider as they proceed with evaluating, determining, and implementing the next steps to take toward managing aquifer sustainability in Baton Rouge and surrounding areas affected by saltwater encroachment. Comments from this public meeting are summarized on page 78.

A subsequent public hearing has been scheduled for April 12, 2012 to create a record, including the information obtained during and after the March 8, 2012 public meeting, all for consideration by the Commissioner of Conservation in determining what action should be undertaken to manage the sustainability of the Southern Hills aquifer system, particularly as it concerns saltwater encroachment in the 1,500-foot and 2,000-foot sands in the Baton Rouge area. At that hearing, the Commissioner will take testimony, receive evidence, and hear public comments in order to determine if the water levels in the aquifers under East Baton Rouge Parish are being lowered because of excessive pumping of groundwater, and whether the lowering of the water levels in these aquifers is causing the acceleration of the intrusion of saltwater in the 1,500-foot and 2,000-foot sands of the Southern Hills aquifer system from the saltwater aquifers south of the Baton Rouge Fault into the fresh water north of the Baton Rouge Fault.

The Issue Defined:

According to scientific publications from the United States Geological Survey (USGS), two major groundwater supply aquifers of the Baton Rouge area,namely the 1,500-foot and 2,000-foot sands of the Southern Hills aquifer system, have undergone historic high water use dating back to the 1940's and continue to be relied upon to provide large volumes of water supply. Historical observation well data indicate that water levels have declined as much as 175 feet for the 1,500-foot sand – approximately 150 feet from 1945 to 1975, and an additional 25 feet from 1975 to the present. More recent well data indicates that water levels continue to decline, and a large cone of depression in the 1,500-foot sand is centered over the Lula Street, central Baton Rouge public supply pumping station consisting of six 1,500-foot sand wells. Historic observation well data show that water levels of the 2,000-foot sand declined as much as 275 feet from 1945 to 1970, then rose 25 to 50 feet after 1975. However, more recent well data show that water levels of the 2000-foot sand have been mostly stable since 1985. A large cone of depression in the 2,000-foot sand is centered over the Baton Rouge industrial area.

Current major issues (cont.)

The USGS published information during 1970's reporting that large withdrawals of groundwater from the 1,500-foot sand and 2,000-foot sand aquifers in the Baton Rouge area have caused groundwater flow patterns to change from their former north-to-south orientation toward the pumping centers such that saltwater now flows north across the Baton Rouge Fault System and encroaches into these formerly freshwater areas. Samples collected semi-annually from 13 public supply wells screened in the 1,500-foot sand in 2004 and following years indicate that saltwater encroachment is presently continuing and increasing in this aquifer beneath the Baton Rouge area. Similarly, samples collected semi-annually from 22 wells screened in the 2,000-foot sand in 2004 and following years indicate that saltwater encroachment is presently continuing and increasing in the 2,000-foot sand aquifer beneath the Baton Rouge area.

Legal Framework Established:

Recognizing the issues described above, the state passed legislation in 1974 creating the Capital Area Ground Water Conservation District (District), comprised of the parishes of East Baton Rouge, East Feliciana, Pointe Coupee, West Baton Rouge, and West Feliciana. The legislature also created a board of commissioners to administer the affairs of the district. The Capital Area Ground Water Conservation Commission consists of 15 members including representation from state government, district parishes, and groundwater users and stakeholders. The law provided the Commission with broad authority to manage groundwater resource sustainability in the District which includes, among other things, specific provisions to address saltwater intrusion.

In 2003, the Capital Area Ground Water Conservation Commission (Capital Area Commission) law was amended to recognize the newly established statewide governing authority granted to the Office of Conservation for groundwater resources management. Thus, since 2003, the Capital Area Commission continues to hold all previous authority to manage groundwater sustainability issues within their District with the added measure that they broadly "shall work with" the Office of Conservation as it exercises its groundwater management authority within the district, and more specifically shall have the authority to manage groundwater resources within their District "in conjunction with" the Commissioner of Conservation.

Current major issues (cont.)

Resource Management Actions:

From its inception in 1974 to present, the Capitol Area Ground Water Conservation Commission has developed and implemented strategies to address groundwater issues within its District including the issues of water level decline and saltwater encroachment in the 1,500-foot and 2000-foot foot sands in the Baton Rouge area. Details of those actions are found in Appendix I. The latest effort will be delivery of a regional groundwater flow and solute-transport model to simulate past, current and a variety of possible future conditions in the 2000-foot sand in the Baton Rouge area, with similar evaluation capabilities for the 1,500-foot sand. The model and simulation results are expected to be delivered and available to the public within nine months, with a target delivery date of October 2012.

Next Steps:

The Office of Conservation will continue to work with the Capital Area Ground Water Conservation Commission, providing the necessary guidance, governance and action, as needed, within our statutory authority to manage the sustainability of the aquifers in the Baton Rouge area. The knowledge gained from the USGS model, in addition to relevant findings of the hearing record, will be considered by the Commissioner in determining what future actions may be necessary to address saltwater encroachment and sustainability of the 1500-foot and 2000-foot sands of the Southern Hills aquifer system.

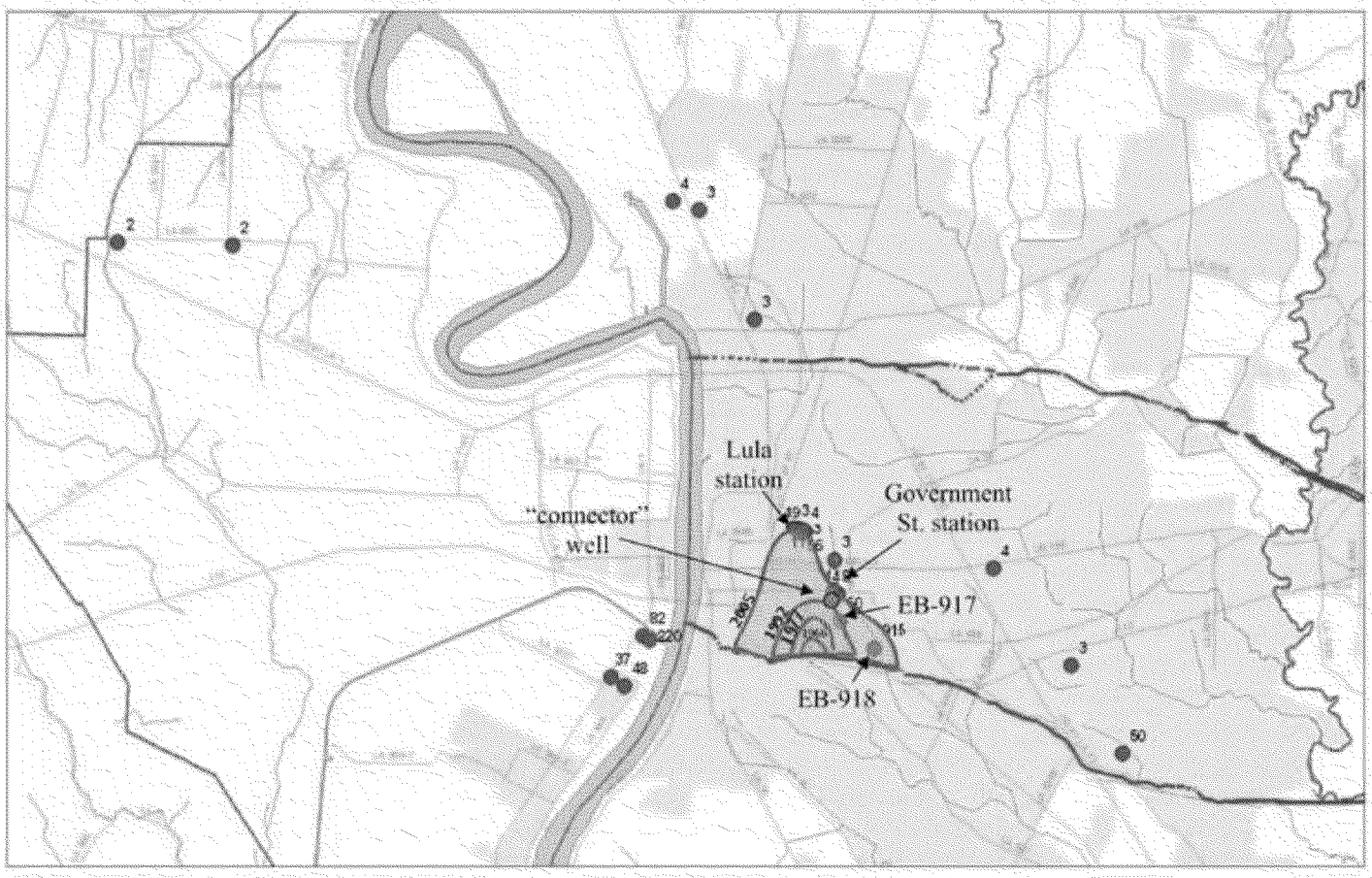
"we do not know the value of water until we go dry."

- Irish proVerb

Current major issues (cont.)

Saltwater Encroachment in the Capital Area

Images provided by USGS



Location of saltwater and chloride concentrations at sampled wells and in the "1,500-foot" sand. (Note: The location of the saltwater interface in 2005 is unpublished and subject to revision.)

Current major issues (cont.)

Saltwater Encroachment in the Capital Area

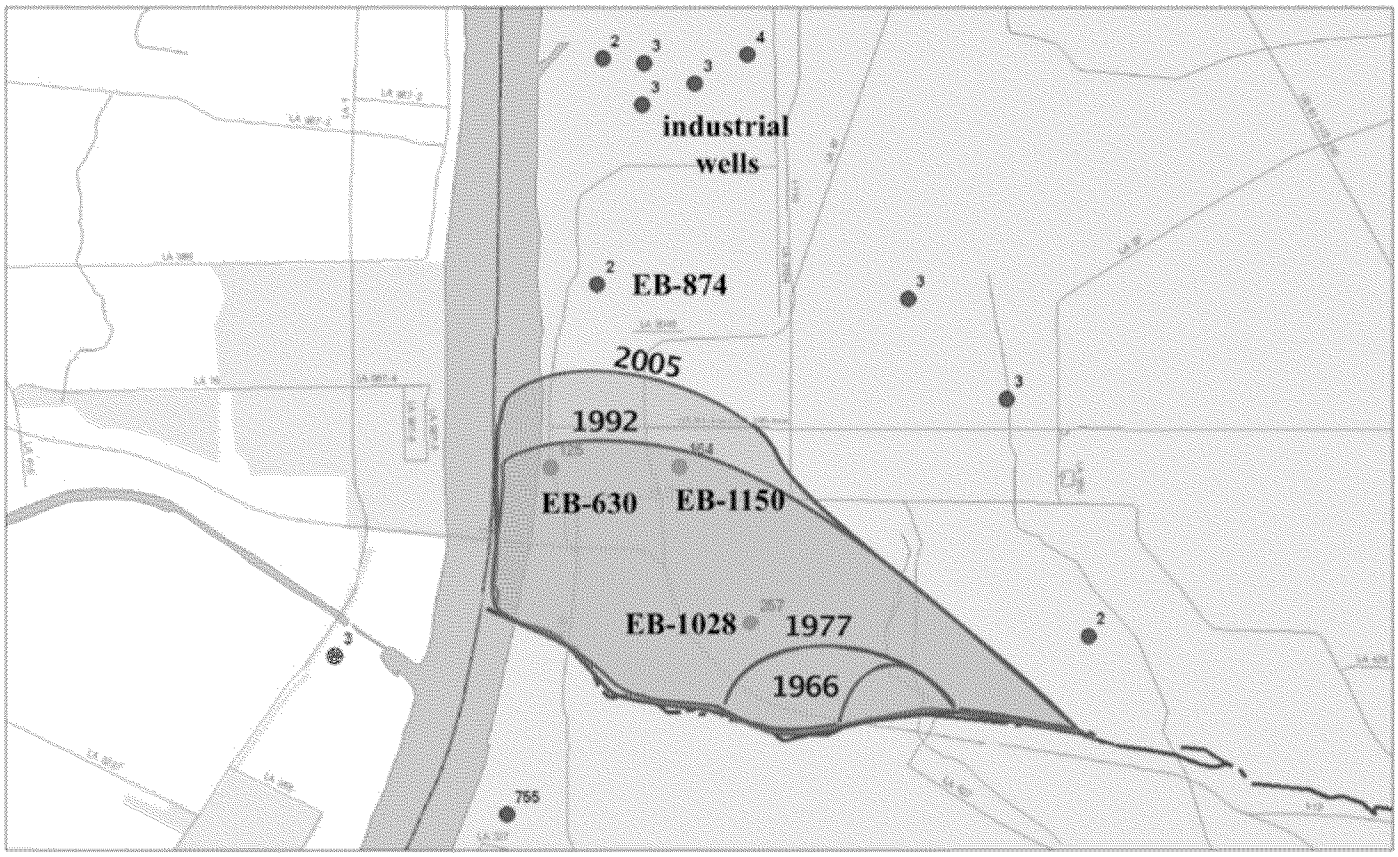
Images provided by USGS

Location of saltwater and chloride concentrations at sampled wells and in the "2,000-foot" sand. (Note: The location of the saltwater interface in 2005 is unpublished and subject to revision.)

Current major issues (cont.)

Saltwater Encroachment in the Capital Area

Images provided by USGS



Location of saltwater and chloride concentrations at sampled wells and in the "2,000-foot" sand. (Note: The location of the saltwater interface in 2005 is unpublished and subject to revision.)

Comments from March 8, 2012 Capital Area Public Meeting

A public meeting was held on March 8, 2012 on the issue of saltwater encroachment in the aquifer system underlying the Baton Rouge area. Approximately 70 people attended the meeting including local and state officials, state agency and legislative staff, industry and public water supply representatives, media representatives, other interested parties, stakeholders, and members of the general public.

The meeting opened with assurances from the Commissioner of Conservation that the issue of saltwater encroachment and aquifer sustainability in the Baton Rouge area is taken very seriously and will be addressed as necessary within the Office's legal jurisdiction based on sound, objective science. Office of Conservation, Capital Area Ground Water Conservation Commission, and United States Geological Survey (USGS) staff then proceeded with providing information on: 1) the history of saltwater encroachment in the Baton Rouge area dating back to the 1940's, 2) legislative action taken in the 1970's establishing a groundwater resource management governing body, i.e., the Capital Area Ground Water Conservation Commission (Capital Area), 3) legislative action taken in 2003 for statewide groundwater management under the Office of Conservation, 4) actions implemented by the Capital Area from 1974 to present including development of an aquifer sand-specific groundwater flow and saltwater transport model by the USGS, and 5) specific use of the model as a management tool to aid in the management of saltwater encroachment in the Baton Rouge area.

Eight persons in attendance elected to speak during the public meeting, which was being transcribed by a court reporter. Although no specific aquifer remediation plans were discussed in detail, timely action was urged by a majority of speakers. The hearing officer announced that the transcript of the March 8 public meeting would be placed into the official record, and that the information contained in this transcript would assist Conservation staff in preparing for its public hearing on April 12, 2012.

Current major issues (cont.)

High Water Use in Southwest Louisiana

Southwest Louisiana is a vital part of Louisiana's agricultural and industrial base. According to census data, this area is home to 20 percent of the population of the state. It produces 65 percent of the rice grown in the state, generates 42 percent of the aquaculture and fisheries output, and grows 34 percent of the state's sugar cane crop (LSU AgCenter).

The Chicot aquifer aystem of southwest Louisiana is referred to by the U.S. Environmental Protection Agency as a "sole-source aquifer." In this part of Louisiana, an alternative reliable source of freshwater to groundwater is not readily available. Surface water diversions from both the Toledo Bend Reservoir to the Sabine River and onward to the Sabine River Diversion Canal provide some supply to industries to the west around the Lake Charles area, and from the Atchafalaya River to Bayou Teche to farmers to the east. SRA-LA is currently under contract with 12 industries and two public utilities from the Lake Charles area to divert over 79 million gallons of Toledo Bend Reservoir water down the Sabine River Diversion Canal. But the water levels of the Chicot aquifer system, the primary source of water for southwest Louisiana and the largest provider of groundwater of the state (40 percent) (USGS, 2011), have declined as much as 50 feet or more in Calcasieu, Jefferson Davis, and Acadia Parishes since major industrial pumping began. The rate of decline in these areas is due primarily to industrial use in the Lake Charles area and rice irrigation. The observed decline has been as much as one to two feet per year (USGS, 2011). However, water level declines in the rice-growing areas are seasonal, and the water levels fluctuate as much as 20 feet each year, recovering to their pre-pumping levels. Saltwater migration / intrusion from deeper sands has occurred in wells in the high water use Lake Charles area. Others areas with saltwater concerns are the vicinities of Iowa and Opelousas, as well as areas along the eastern edge of the Chicot Aquifer System, which are affected by the presence of salt domes and / or relic saltwater.

In 2011, it was estimated that 40,000 to 80,000 acres of irrigated rice field in southwest Louisiana, primarily in Vermilion Parish, might be at risk if intrusion of saltwater from the Gulf of Mexico within canals used for irrigation could not be stopped. Saltwater intrusion in coastal Louisiana is a constant battle that has now been exacerbated by drought causing decreased freshwater influx, damaged levees and old spoil banks, and damaged water control structures. Diversion of 138 billion gallons of Atchafalaya River water by the Teche-Vermilion Freshwater District eased the saltwater problem for some in eastern Vermilion Parish, but the current lack of freshwater influx and / or the presence of saltwater has remained an issue for many rice farmers. Some of the issues are being remediated by the U.S. Army Corps of Engineers, which controls and maintains the locks. This is a repeat of the situation first observed in Southwest Louisiana in 1999-2000, in 2003, in 2005 in the aftermath of Hurricane Rita, and in 2007.

Temporary Ground Water Emergency: Southern Caddo Parish

Extreme drought conditions in north Louisiana triggered a temporary groundwater emergency declaration by the Office of Conservation on August 19, 2011 for two areas of southern Caddo Parish. Higher than normal withdrawals of groundwater without sufficient offsetting aquifer recharge caused water levels in the Carrizo-Wilcox and Upland Terrace aquifers to drop, resulting in several water wells in the area going dry in July 2011.

To prevent further water level decline and reduce stress on the aquifers in these two areas, the Office of Conservation ordered water conservation measures and ground water use restrictions.

Since issuance of the emergency order, Conservation staff has continued to monitor hydrologic data in the region provided to our agency courtesy of the LSU Shreveport Red River Watershed Management Institute. Review of the groundwater level data received on February 6, 2012 collected from the LSU Shreveport monitoring wells located in the areas of interest indicate that water levels from November 2012 to present continue to show a gradual upward trend. Water level data reported during January and February 2012 indicate that water levels at all four monitored locations have risen above water levels reported on June 28, 2011 (see page 81).

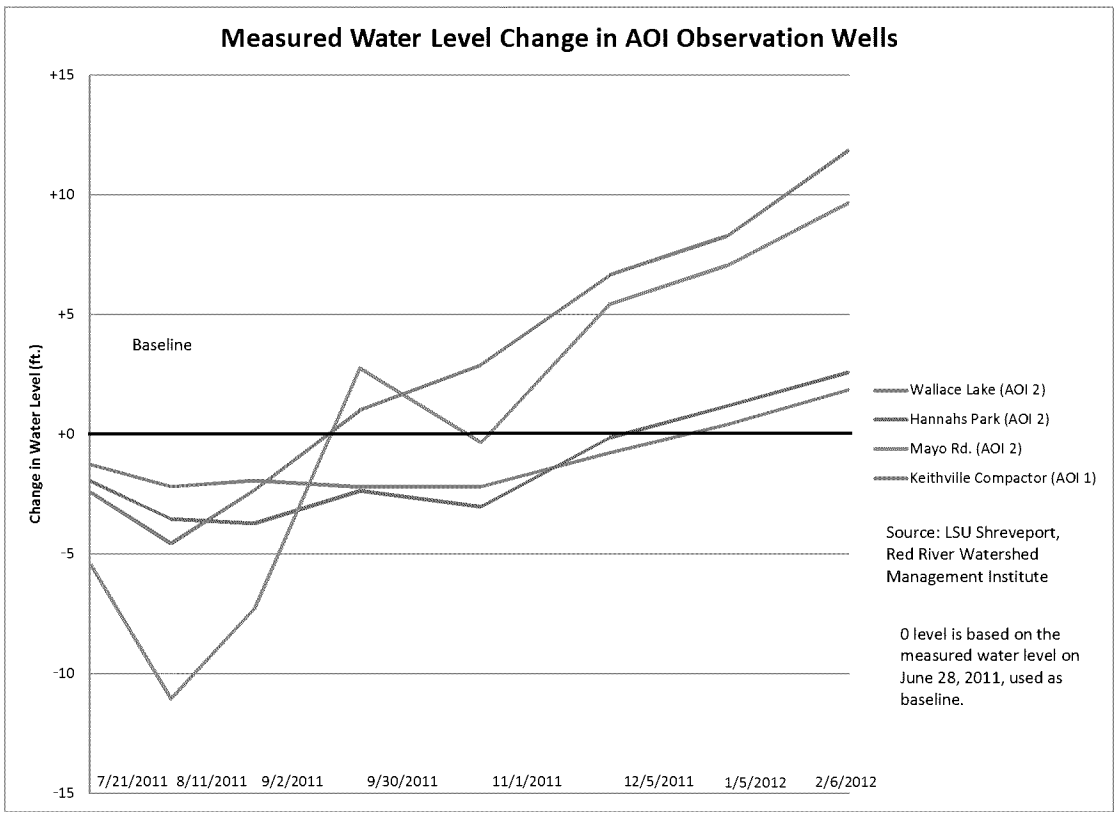
The most recent U. S. Drought Monitor Report for Louisiana dated February 22, 2012 indicates drought conditions continue to improve in the areas of interest having been upgraded from “extreme” to “severe.”

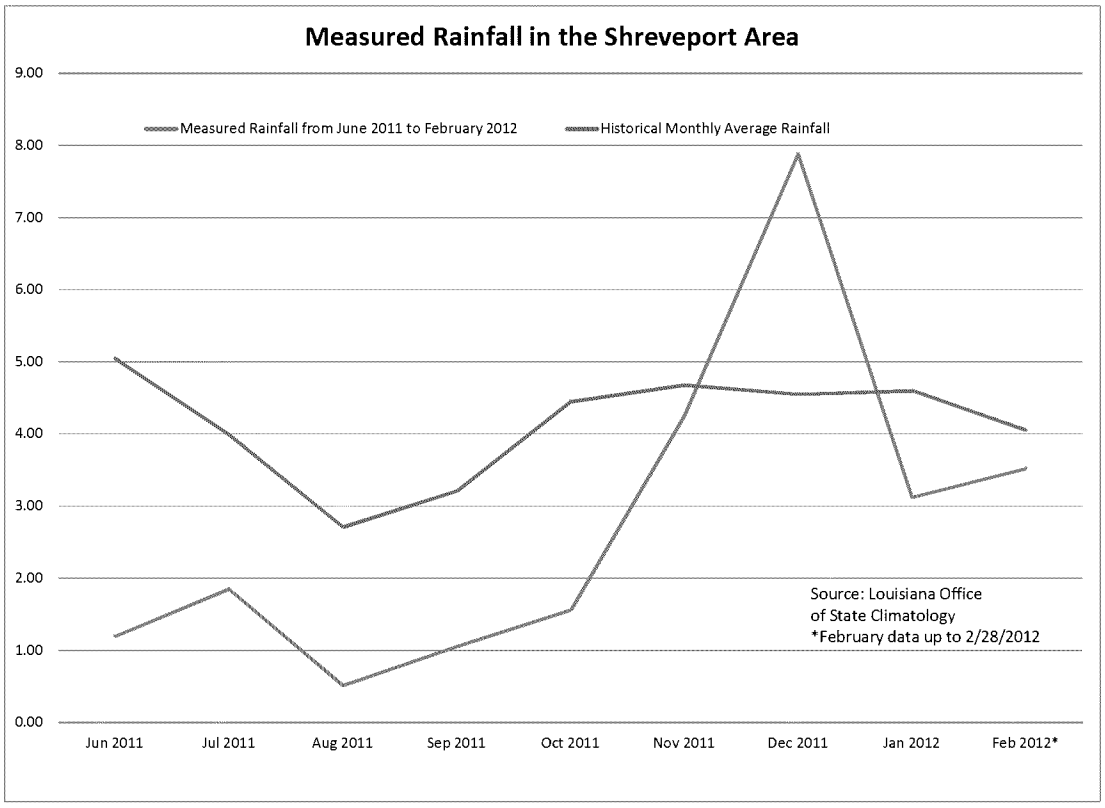
The Louisiana Office of State Climatology rainfall data for the area south of Shreveport indicates monthly rainfall totals for June through October 2011 to be well below respective average monthly rainfall with the month of October 2011 reported to be 65 percent below the monthly average. The rainfall total for the month of November is reported to be within nine percent of the monthly average and continued improvement is noted for December with a 73 percent increase of rainfall above the normal average. Although rainfall in the area continues to show marked improvement from summer and fall 2011 rainfall totals, rainfall reported for January 2012 fell 32 percent below the monthly average and February totals to date are reported to be 13 percent below the monthly average (see page 81).

In summary, although aquifer water levels and measurable rainfall data continue to show signs of improvement, severe drought conditions are expected to continue to place high groundwater demands on the aquifer systems underlying the areas of interest. The Office of Conservation will continue to closely monitor hydrologic conditions in the areas of interest and periodically provide updates on the same. All restrictions and conditions set forth in the Emergency Order shall remain in full effect at this time and until further notice.

Recognizing that additional monitoring was needed to fully evaluate water levels in the two areas of interest, on November 1, 2011, LDNR entered into a contract with United States Geological Survey in the amount of $10,400 adding four more observation well locations to the existing network thus providing the agency a more comprehensive assessment of conditions in these areas to manage regional aquifer sustainability.

Current major issues (cont.)





Current major issues (cont.)

Other Aquifer Issues

In its report, *Recommendations for a statewide Groundwater management plan*, December 7, 2011, Ecology and Environment, Inc. provides a summary of known or potential adverse impacts to groundwater quality or availability in the major aquifer systems in Louisiana. The chart below includes an aquifer-by-aquifer reference of major aquifer issues such as those noted in the Sparta, Southern Hills (Capital Area) and Carrizo-Wilcox aquifer systems are discussed in greater detail in prior text in this chapter.

Summary of Impacts to Major Aquifer Systems in Louisiana

Aquifers	Location	Impacts
Mississippi River Alluvial Aquifer	Aquifer wide	Water quality (total dissolved solids [TDS], metals)
	Franklin Parish, SE Ouachita Parish	Naturally-occurring chlorides
	Coastal Parishes	Saltwater intrusion from Gulf of Mexico and potential upward migration of saltwater
	Sporadic throughout	Occurrence of methane in shallow sands
	Aquifer wide	Agricultural applications (pesticides / herbicides, fertilizers) Water quality (TDS, metals) Naturally-occurring chlorides
Chicot Aquifer	Iowa, LA	Shallow saltwater, possibly from Iowa Salt Dome
	Lake Charles	200 ' and 500' sand have been impacted by water level decline from industrial activity / over pumping and increased TDS impact
	Lake Charles	200 ' and 500' sands exhibit the presence of methane 700' sand is being impacted by saltwater intrusion
	Opelousas	Possible saltwater intrusion from naturally-occurring chlorides, salt domes in the area
	Coastal Zone	Saltwater intrusion from Gulf of Mexico, subsidence, and land loss
	Eastern edge of Chicot	Contact with Atchafalaya Aquifer provides potential increased TDS impact
Jasper Aquifer	Leesville	Water level decline and increased TDS impact
	Alexandria	Water level decline and increased TDS impact
Cockfield Aquifer	Southern Winn / Northern Grant Parishes	Water level decline and increased TDS impact
Sparta Aquifer	Monroe	Water level decline and increased chlorides
	Ruston	Water level decline and increased chlorides
	Minden	Water level decline and increased TDS impact
	Jonesboro Hodge	Water level decline and increased TDS impact
	Winnfield	Water level decline and increased chlorides
Carrizo- Wilcox Aquifer	Sporadic Throughout	Water level decline and increased TDS / chlorides
	South of Shreveport	Water level decline and increased TDS impact
Southern Hills Aquifer	Baton Rouge	Water level decline and saltwater intrusion
	Bogalusa	Water level decline and increased TDS impact

Toledo Bend Reservoir

In 1950, the legislature of the State of Louisiana created the Sabine River Authority, State of Louisiana, by Act 261 of 1950, amended by Act 432 of 1956, and shown as Louisiana Revised Statutes Title 38, Section 2321, et. Seq., as amended. The voters of the State of Louisiana, on November 8, 1960, passed Amendment Number 8 to the 1921 Constitution of the State of Louisiana, (Article 14, Section 45), which ratified the creation of the Sabine River Authority and gave it constitutional status. These provisions were subsequently transferred to La. R.S. 38:2321, et. Seq., after adoption of a new constitution in 1974.

The Toledo Bend Reservoir Project was funded, constructed, and managed by the Sabine River Authority of Louisiana (SRA-LA) jointly with the Sabine River Authority of Texas (SRA Texas). A feasibility report was done on the project by Forrest & Cotton, Inc. in 1958. Thereafter, the Federal Energy Regulatory Commission issued a License on October 14, 1963 for 50 years. That license is set to expire in 2013. Construction of the dam was complete and operations began in 1969.

Toledo Bend Project Joint Operations (TBPJO) are controlled by the Basic Contract between Louisiana and Texas. Administration of the operations is handled by SRA Texas whereas the engineering is done by SRA-LA. There is a TBPJO Operating Board with two Board members from each respective Authority and an Executive Director / General Manager from each Authority. The TBPJO Technical Committee includes staff from each Authority.
The Sabine River Diversion System was created by Act's 90 and 117 of the 1970 legislature as part of the program for utilization of the waters impounded in Toledo Bend Reservoir. The Sabine River Diversion Canal was constructed by the Department of Public Works and completed in 1981. Act 898 of 1985 transferred responsibility for maintenance and operations to SRA-LA. The Diversion System is a water conveyance system consisting of more than 35 miles of unlined, open channel canals, nearly four and a half miles of underground pipelines, three pumping stations, and five automatic level control gates. The system diverts surface water from the Sabine River to supply agricultural, municipal, and industrial water needs in southwest Louisiana and reduce dependence on the Chicot Aquifer. Approximately 20 billion gallons are diverted annually.

SRA-LA currently has about 43 active water sales contracts in effect (Appendix J). About eight of those are long-term contracts to municipal or utility customers. About 14 are intermediate-term to industrial customers, and the rest are short-term contracts.

Current major issues (cont.)

The stated mission of the SRA-LA is, "to provide for economic utilization and preservation of the waters of the Sabine River and its tributaries by promoting economic development, irrigation, navigation, improved water supply, drainage, public recreation, and hydroelectric power for the citizens of Louisiana."

One of the goals of the SRA-LA is, "to strengthen SRA's financial ability to service debt obligations, support existing programs, and implement new programs." A stated objective and strategy to achieve this goal include:

- Developing Water Supply as the primary source of revenue to support the Toledo Bend Project in lieu of Hydro electric Power Production by 2018.
- Identifying and developing markets to utilize the water of the Sabine River Basin, its tributaries and reservoirs, for municipal, industrial, and agricultural purposes.

Consistent with this goal, objective and strategy, out-of-state water sales have been considered by SRA-LA for a number of years. However, recently there was an effort of SRA-LA to sell raw water from the Toledo Bend Reservoir (Appendix A). For a variety of reasons, the SRA-LA elected to suspend this effort.

Here is a timeline of those recent actions taken by the Board of Commissioners of SRA-LA:

- January, 2011: The board's water sales committee considered a proposal received by staff from Toledo Bend Partners, LLC. A negotiating team was named, a law firm approved for hiring, and the executive director authorized to execute the necessary documents.
- August, 2011: Upon recommendation of the water sales committee, the Board approved the out-of-state water sales Contract with Toledo Bend Partners, authorized the director to execute the contract and send it to Governor for his approval.
- September, 2011: A letter was received from the governor's office with written directions that SRA-LA put together a request for proposal for the out-of-state water sales contract. The board authorized the board chairman, water sales committee chairman, executive director and SRA-LA staff to prepare an RFP for out-of-state water sales contract, to let for bids, and to report back to the board to make a recommendation to accept or reject the bids.
- November, 2011: As recommended by the governor's office, staff prepared an RFP specific to out-of-state water sales contract. The deadline to return proposals was November 9, 2011, at which time bids were opened for the RFP. Only one proposal was received, that being from Toledo Bend Partners, LP.
- December, 2011: Board discussed the drought contingency plan, length of the contract, the state's water needs, as well as spending the revenue from the sale of water. Board moved to delay accepting the proposal from Toledo Bend Partners, LP until the public had time to review and make comments.
- January, 2012: Upon recommendation of the executive director, the board suspended the consideration of an out-of-state water sales contract until the State of Louisiana develops a statewide comprehensive water plan.

Other states are likely to be interested in Louisiana's water resources. The recent effort of the SRA-LA to sell raw water from the Toledo Bend Reservoir evidences that there is valuable, marketable interest in our water. Before taking steps to act on this situation, we should consider the long-term effects on our state, let experts research the issue, and let it be fully debated through a transparent process.

Act 955 of 2010: Procedure for Authorizing Withdrawals from Running Waters of the State for Non-Riparian Owners

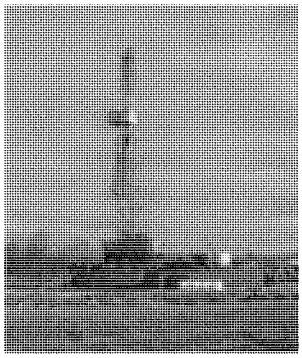
With Act 955 of 2010, the Louisiana Legislature has directed the LDNR to serve in a stewardship role in the management, preservation, conservation, and protection of the running surface water of the state. The statute authorized the secretary of LDNR to develop a voluntary application process and to enter into cooperative endeavor agreements (CEAs) with prospective consumptive water users for the withdrawal of surface water from state-owned water bodies

The content of the application includes a plan of water use, any supporting documents, and an economic impact report from users seeking to compensate Louisiana for the value of the water taken with credit for the values of their project in-lieu of cash payment. After the water user's plan of water use is reviewed by a hydrologist in the LDNR, comments are solicited from the Departments of Environmental Quality and Wildlife and Fisheries. When applicable, the Departments of Health and Hospitals and Transportation and Development are also asked to provide comments to ensure that the plan does not present any adverse impacts to the resource, users, or the environment. All agreements are presented to the Office of Coastal Protection and Restoration for a review of the plan of water use for consistency with Louisiana's Comprehensive Master Plan for a Sustainable Coast. Each agreement is confected on a form that was developed by the Mineral and Energy Board and approved by the Attorney General. Almost immediately after the program began, an online electronic submittal and tracking process was established to streamline the process for users and commenting agencies. To date the state has reviewed more than 40 applications and entered into more than 30 agreements (Appendix D).

For the applicants that select to submit cash payments for their use of running surface water of the state, LDNR is using the fee charged by SRA-LA ($0.15 per 1,000 gallons). In an attempt to assess the economic value of raw surface water in Louisiana, LDNR, in July, 2011, proposed to the Mineral and Energy Board that a survey of water purchasers and sellers be completed. The online survey showed that a broad range of fees were being practiced in the state (Appendix K), however, the number of positive responses was too small to statistically evaluate the results.

Act 955 sunsets on December 31, 2012. HB-532 has been submitted to the 2012 regular session of the legislature requesting to extend its authorization until December 31, 2014.

Emerging Technologies for Energy Exploration



Over the last several years, Louisiana, and indeed the U.S., has witnessed an exponential increase in the application of horizontal drilling and hydraulic fracturing stimulation technologies to access oil and natural gas deposits once thought impossible to recover, giving rise to the term "unconventional resources." In Louisiana alone, the use of these technologies at their 2010 peak in the state was nearly 30 times what it was in 2007.

This has contributed to a marked increase in domestic energy production and has, in fact, reversed a decades-long decline in our nation's oil production. The application of this technology, commonly referred to as "fracking," has allowed the Haynesville Shale in northwestern Louisiana and east Texas to become the nation's largest natural gas shale producer in only four years. Although Haynesville Shale wells made up only nine percent of Louisiana's active gas well count in 2011, they accounted for an astounding 68 percent of our state's 2011 natural gas production.

All of this has contributed to the economy in a big way. In a 2010 economic impact study, economist Loren Scott noted that Haynesville Shale activity benefited the state through $16.9 billion in business sales, $4.3 billion in new household earnings, and more than 111,000 jobs tied directly or indirectly to the activity. And in fact, expansion in the oil and natural gas industry sector alone contributed nine percent of all jobs created in the U.S. in 2011.

In addition to creating jobs, this increased production has sparked a new debate on the possibility of the U.S. gaining the long-sought-after goal of energy independence and ushering in a new world order for national security. That's a big statement, but experts agree that discovering and producing more domestic energy will help inoculate us against the spreading impacts of the many world events that lead to spiraling fuel costs, while at the same time slowing down the transfer of U.S. wealth to unstable areas of the globe.

Here in Louisiana, the use of these technologies, in only a few short years, has transformed the natural gas supply chain. In 2003, then-Federal Reserve Chairman Allen Greenspan testified to the U.S. Congress that we, as a nation, didn't have enough natural gas to fuel our economy, and that we needed to embrace construction of natural gas import facilities and the subsequent importation of foreign natural gas. Due to supply challenges, in the summer of 2008, natural gas prices spiked to $13 per thousand cubic feet. While having a positive impact on drilling investment, this unsustainable commodity pricing sent the chemical and petrochemical industry, a huge user of natural gas, reeling with cutbacks, closures, and layoffs. Yet by 2009, the wider use of horizontal drilling and hydraulic fracturing stimulation in unconventional resources led to a claim that the U.S. was now sitting on a 100-year supply of natural gas. Commodity pricing begin to fall and is now currently trading around $2.50 per

Current major issues (cont.)

thousand cubic feet. The result is a boom in chemical and petrochemical expansion, employment, and investment.

Some of the activity directly credited to natural gas price and availability includes:

- Dow Chemical re-opening its St. Charles Parish ethylene plant
- Nucor's announced investment of up to $750 million in a new St. James Parish iron-making facility
- Williams chemical company's announced 44-percent expansion of its ethylene plant in Ascension Parish
- Sapa's announced expansion of its Richland Parish aluminum products manufacturing facility
- Union Pacific's $200-million expansion of rail capacity along the Mississippi River to support increased petrochemical activity
- Sasol's announced investment of $4.5 billion for an ethylene plant in Calcasieu Parish
- Sasol's consideration of Calcasieu Parish as the site of an up-to-$10-billion new facility to convert natural gas to liquid fuel
- Cheniere Energy's moving forward with plan to invest more than $4 billion in expanding its Sabine Pass Liquefied Natural Gas (LNG) import facility in Cameron Parish to allow for liquefaction and export of domestic natural gas as LNG
- The Port of New Orleans' announced 34-percent increase in chemical exports in 2010

Simply put, this has been good for Louisiana. But why is this being mentioned in a report on water resources? Because the unlocking of these unconventional resources requires water, and lots of it. It requires the consumption of one natural resource, water, to make available another natural resource, natural gas. The average hydraulic fracking job in Louisiana uses five millions of gallons, as reported to the Office of Conservation from 2009 to 2012. The charts on page 92 show that energy industry has been very cooperative in seeking the use of abundant surface water rather than ground water.

At present, the only area of the state that has experienced significant increased water usage associated with hydraulic fracturing for shale-gas production purposes is in the northwestern portion of the state – where Haynesville Shale development has been focused in the parishes of Bienville, Bossier, Caddo, DeSoto, Natchitoches, Red River, Sabine, and Webster.

At the onset of development in summer and early fall of 2008, operators were relying primarily on local groundwater resources to supply water for drilling (referred to as rig supply water) and hydraulic fracturing (referred to as "frack water"), withdrawing large volumes of water from the Carrizo-Wilcox, Upland Terrace, and Red River Alluvial aquifer systems. In order to protect and preserve the sustainability of the Carrizo-Wilcox, which is a low-yielding, high-quality aquifer system used predominantly for public supply and domestic purposes throughout the Haynesville Shale development area, the Commissioner of Conservation issued an October 2008 water use advisory to the oil and gas industry (Appendix L).

Current major issues (cont.)

Haynesville Shale operators were advised to seek frack water supply alternatives to groundwater from the Carrizo-Wilcox aquifer system, and encouraged to draw water from the more prolific, lesser-quality Red River Alluvial aquifer, or from abundant surface water sources such as the Toledo Bend Reservoir or the Red River.

Subsequent to issuance of the advisory, in October 2009, the agency began requiring oil and gas operators to report water use source and volume information for every work permit issued for hydraulic fracture stimulation operations.

Based on data obtained from this reporting requirement following issuance of the water use advisory, we know that approximately 75 percent of all water used at Haynesville Shale well locations reporting from October 2009 to present originated from surface water resources.

Other areas of the state hold promise for additional unconventional resources; specifically the Tuscaloosa Marine Shale and the Lower Smackover / Brown Dense (map page 93). The Tuscaloosa Marine Shale, estimated to contain as much as seven billion barrels of oil, is believed to underlie much of central Louisiana, with potential productive areas currently being explored from Vernon and Sabine parishes to Tangipahoa Parish.
The potential "Brown Dense" productive area spans portions of northern Louisiana and southern Arkansas – including the parishes of Claiborne, Morehouse, Union and East and West Carroll – is believed to lie at the base of the Smackover, a well-known formation that has long been a source for traditionally produced oil and natural gas in northern Louisiana. Industry estimates of oil contained in the formation have ranged as high as 3 billion barrels.

As the energy industry focuses more on the opportunities represented by these unconventional resources, and consequently requires more water, it is important that Louisiana likewise remains focused on water issues to avoid injuring one resource to take advantage of another. It is critical that we ensure the appropriate balance of the Three E's-Energy, Environment, and Economy.

What is Hydraulic Fracture Stimulation?

The practice of hydraulic fracture stimulation in the oil and natural gas exploration industry involves using water pressure to create hairline fractures in dense geologic formations, creating a path for oil and natural gas to flow to wells through otherwise-impermeable rock. Hydraulic fracture stimulation is not a new technique – exploration companies began common implementation of the practice in the 1940's, and the national Interstate Oil and Gas Compact Commission (IOGCC) has noted that more than one million wells across the U.S. have been fractured since that time.

The IOGCC and U.S. Environmental Protection Agency (EPA) estimate that about 35,000 wells in the U.S. are stimulated with hydraulic fracture stimulation each year. Operators have hydraulically fractured approximately 40,000 wells in Louisiana since the practice began to take hold in the state in the 1960's.

EPA Director Lisa Jackson has spoken several times in recent months to the track record of fracture stimulation practices and regulation, including her statement in May 2011 testimony to the U.S. House of Representatives Committee on Oversight and Government Reform, that "I'm not aware of any proven case where the fracking process itself has affected water."

In a November media interview, Jackson noted indicated that states were doing a "good job" in regulating fracturing and that additional federal regulation of the practice may not be necessary in the future.
At a recent energy symposium in New Jersey, Jackson said, "I think that fracking as a technology is perfectly capable of being clean. I do. But it requires people who are doing it and innovators who use the technology to take some time to make sure that it's done right. And it requires smart regulation, smart rules of the road."

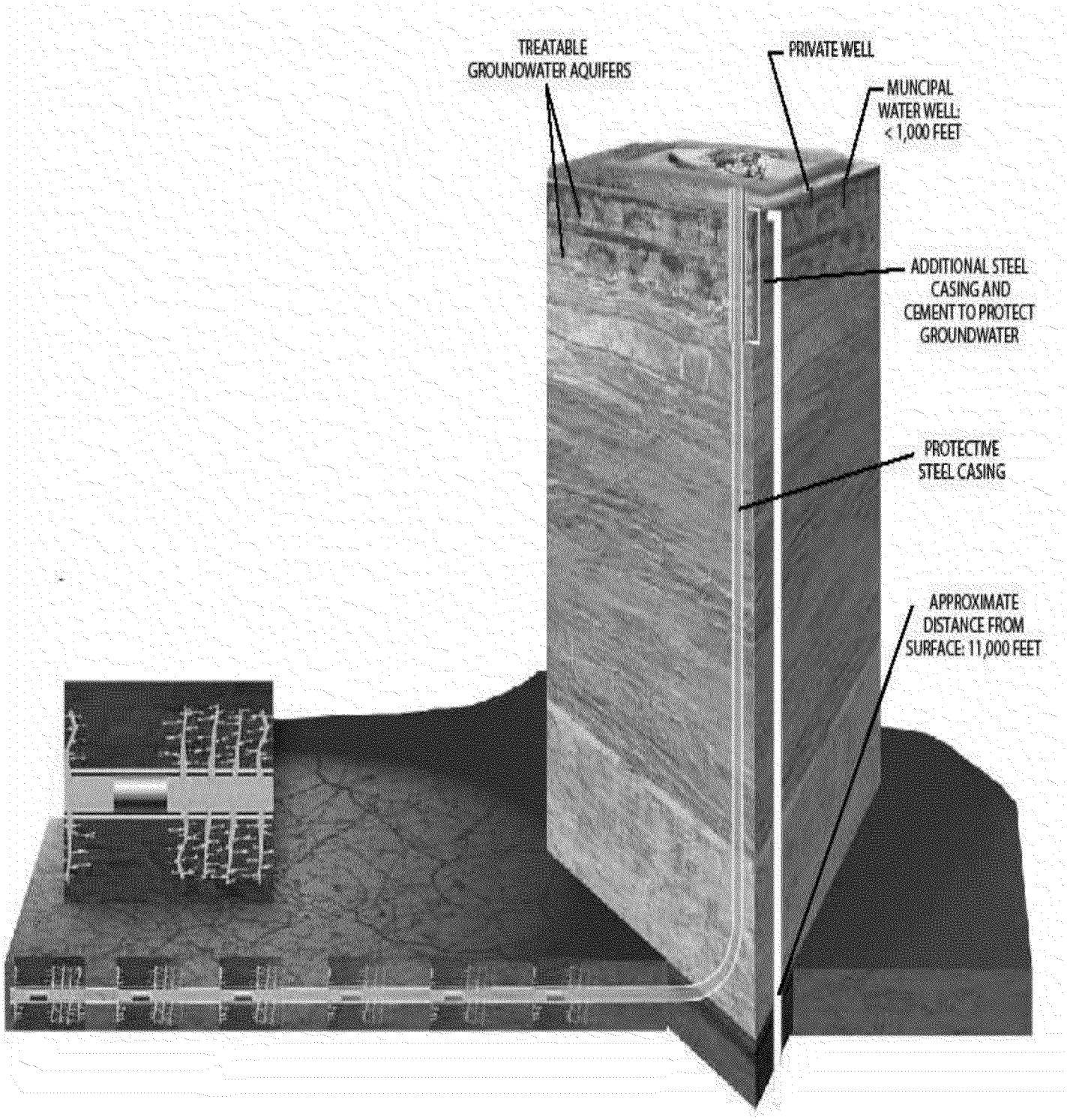
How is It Regulated?

The Louisiana hydraulic fracturing disclosure regulation requires operators to report all additives used in hydraulic fracturing fluids and the names and concentrations of chemicals which are subject to Occupational Safety and Health Administration (OSHA) Hazard Communication requirements (29 CFR 1910.1200) and are not deemed trade secret. Disclosure can be made by reporting directly to the Office of Conservation or via the Frac Focus website. The Louisiana regulation has no effect on rules or laws mandating disclosure of trade secret information to health care providers. The requirements are effective for wells with drilling permits issued on or after October 20, 2011.

The disclosure rule was developed following a recommendation in the March 2011 report made by the non-profit, multi-stakeholder organization, STRONGER, Inc. (State Review of Oil and Natural Gas Environmental Regulations), summarizing the results of their review of Office of Conservation policies and regulations associated with the hydraulic fracturing. To draft the rule, the Office of Conservation consulted with operators and used portions of the hydraulic fracturing regulations recently promulgated in the State of Arkansas and statutes recently passed in Texas as models. A summary of other states regulations can be found as Appendix M.

Current major issues (cont.)

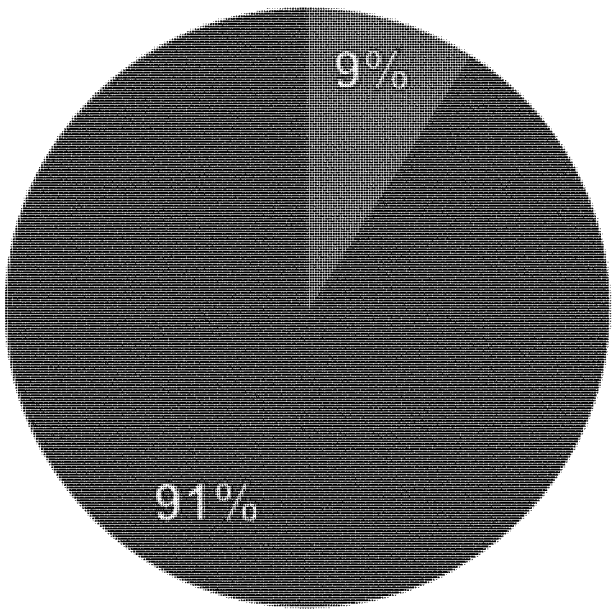
Horizontal Wells and Hydraulic Fracturing



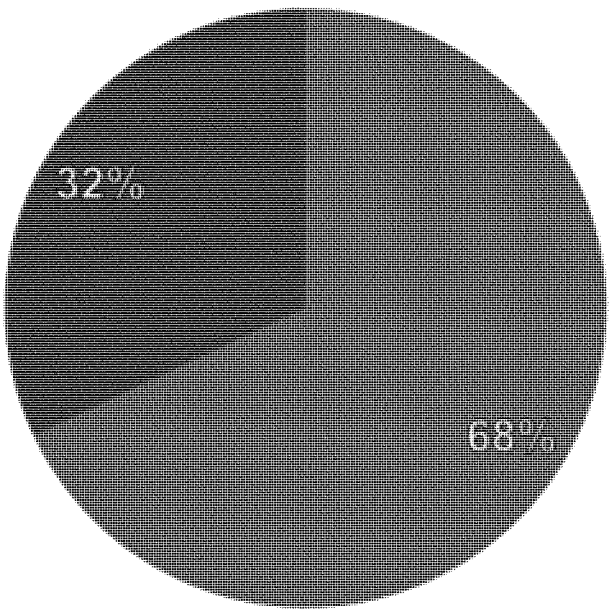
Current major issues (cont.)

Haynesville Shale vs. All Other Louisiana Natural Gas 2011 Wells & Production

Percentage of Total Natural Gas Wells



Percentage of Total Natural Gas Produced

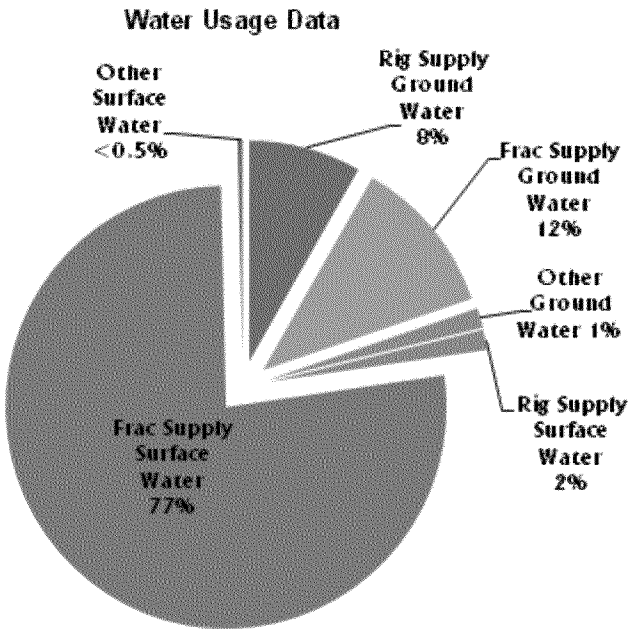


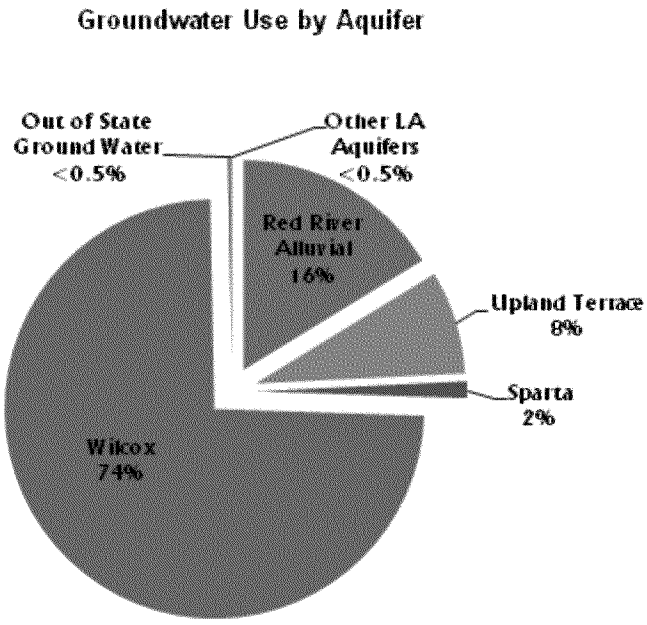
■ **Haynesville Wells** ■ **Other Wells**

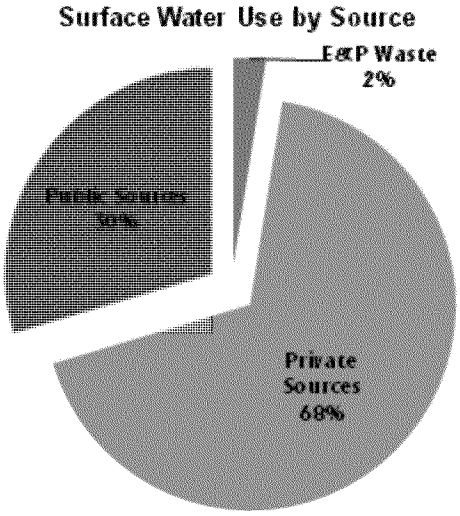
Current major issues (cont.)

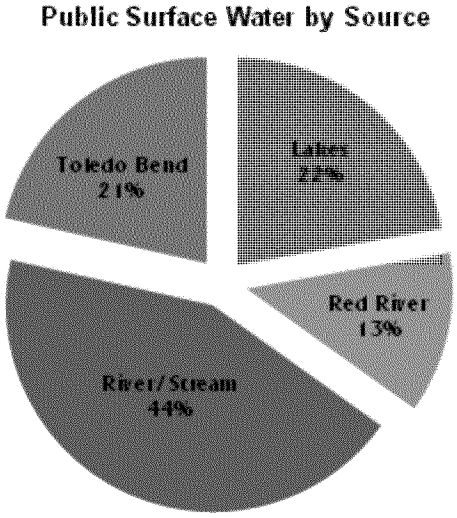
Haynesville Shale Natural Gas Well Development Drilling and Stimulation Operations

Reported Usage from 10/1/2009 to 2/23/2012 - 1959 Wells



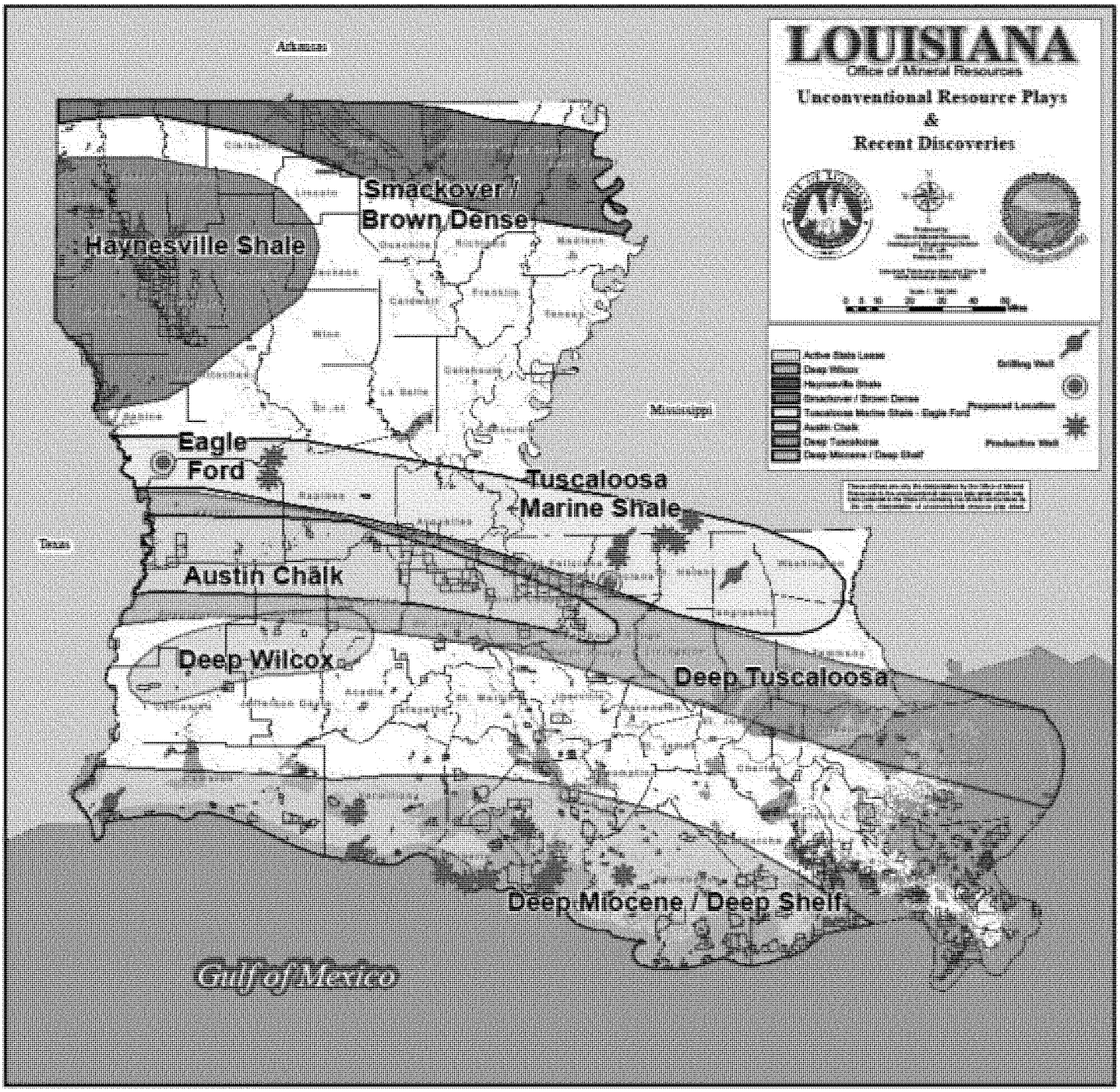






Current major issues (cont.)

Louisiana's New Energy Map



Surface Water Quality Impairment Management

In 2011 extreme drought conditions on the Ouachita River led the U.S. Army Corps of Engineers to reduce the flow through the Felsenthal Lock and Dam. The reduction in flow reduced the assimilative capacity of the river, potentially impacting 67 permitted water discharge facilities. The Graphic Packaging paper mill in West Monroe was forced to limit its discharge to the river and impound the remaining effluent. This facility employs in excess of 1,000 people and spends approximately $100-$125 million per year on purchases from Louisiana-based industries.

The City of West Monroe's wastewater treatment plant was forced to reduce its discharge, typically about seven million gallons per day, to three million gallons per day. Additional reductions of the river's flow would have forced the plant to impound its effluent in two 50-acre ponds. These ponds would have reached capacity in about three days. Any additionally effluent would have overflowed into the river, potentially causing unsanitary conditions.

Having reliable and suitable surface water resources for use where needed as an alternative to groundwater resources is a vital sustainability management tool that is fortunately often available to resource planners and managers as an option in Louisiana. However, should our surface water features not be adequately regulated with regard to water quality, their availability as potential alternatives to groundwater may be diminished or simply rendered unsuitable.

The Louisiana Department of Environmental Quality (LDEQ) has assumed delegation of certain aspects of the Clean Water Act, including those associated with monitoring and assessing state surface water quality (Ambient Water Quality Monitoring Network, AWQMN) and with issuing water discharge permits that are protective of existing and designated water uses (Louisiana Pollutant Discharge Elimination System, LPDES). When water quality is not sufficient to meet these uses, the waters are listed as "impaired." Impaired water bodies are surveyed for Total Maximum Daily Load (TMDL) development to further restrict pollutants allowed by existing permits and potentially restrict the issuance of new waste water permits in watersheds of the impaired water bodies.

LPDES permits, as well as the calculations associated with TMDL development, are dependent upon knowing the "low flow critical condition" of the subject water body so as to be protective of that water body at all times. If natural stream "low flows" are less, such as through excessive removal for "out-of-stream" uses or through excessive drought conditions, waste loads authorized by LPDES permits may no longer be adequately protective of stream health. Also, lack of adequate flow in a stream may require existing discharges to pay for costly treatment add-ons or limit new discharges, potentially hampering economic development.

This situation can occur in streams where TMDLs have been developed or where LPDES permitted discharges are predicated on in-stream flows. However, in any flowing water, should flows be reduced to the point of creating an "effluent dominated stream," then all LPDES water discharge permits may have to be re-issued with more stringent treatment requirements, potentially contributing economic impact to both public and private assets within an affected watershed.

Louisiana's water quality is assessed and reported every two years in the "Louisiana Water Quality Integrated Report" (WQIR) and includes the status of the state's surface waters, such as impairment listings when compared to state surface water quality standards. The 2010 draft WQIR and previously published reports are found at the LDEQ website.

Safe Drinking Water Supply

Low water levels expose water intakes and can result in sanitary issues for treatment facilities. During the recent drought, the water level in Caddo Lake dropped to its lowest level since 1921, the first year data are available for the USGS gaging station located at Caddo Lake Dam near Mooringsport. Caddo Lake is the water supply source for seven Louisiana utilities, and the bayou to which it discharges is a backup source of water supply for the City of Shreveport. In 2011, of the seven utilities using this water resource, one had their water intake completely exposed and had to install a bypass line; another had its water intake partially exposed. Overall, three out of the seven utilities had to move their intakes as a result of the drought.

Similar to issues associated with low water levels, high water level events can affect public and private water supply systems. During the Mississippi River flood of 2011, 46 public water supply wells and at least 281 domestic water supply wells were located in the path of or near the rising floodwater. Systems which were submerged may be exposed to potential pathogens that require special disinfection treatments of the wells, as well as the distribution / delivery system.

Should situations such as these persist, increased reliance on groundwater resources to offset loss of surface water availability could adversely impact, or further impact, aquifer systems serving to fulfill the water budget demand.

Current major issues (cont.)

The Department of Health and Hospital's (LDHH's) role in statewide water quality begins with the enabling legislation found in R.S. 40:4(8)(a) that states in part, "In order to protect the public against disease from water supplied for drinking, culinary, and ablutionary purposes, the state health officer shall prepare and promulgate all rules and regulations necessary to ensure that water supplied to the public by public water supplies is obtained from safe and sanitary sources and that such sources are properly protected; is treated, stored, and conveyed in a safe and sanitary manner; and is safe and potable for human use."

Subsequently, LDHH is the primacy agency for the federal Safe Drinking Water Act in Louisiana, and as such, supervises and ensures compliance of Louisiana's approximately 1,400 public water systems with the requirements of the Safe Drinking Water Act.

In light of these responsibilities, LDHH currently has the most extensive active groundwater sampling network of any entity operating in the state. From Louisiana's 1,400 public water systems, the LDHH has nearly 2,700 active water wells that are sampled at regular three-year intervals for approximately 125 distinct chemical and physical analytical parameters.

When groundwater monitoring reveals that any drinking water source is contaminated at concentrations above the established maximum contaminant levels (MCLs), LDHH works with the affected water system to identify options including alternate water supply sources or water treatment strategies that would provide safe drinking water to the citizens connected to the affected system. In cases where contamination of the groundwater appears to have occurred due to human influence, LDHH reports such findings to LDEQ, as they have authority and jurisdiction over groundwater contamination, and LDHH works with LDEQ to identify a reasonable and safe solution for any affected public water system.

Additionally, LDHH works with LDEQ to support the Source Water Protection Program they administer that works with local governments to identify potential sources of contamination near their public water supply wells and establish local ordinances to safeguard and protect these water wells from future potential sources of contamination.

Conservation Education and Public Outreach

Each year, there has been a statewide Governor's Proclamation issued during the month of March, acknowledging Ground Water Awareness Week nationally and across our state. As part of the LA Department of Natural Resources' awareness campaigns during March, educators and students have been the primary focus, and LDNR provides materials, lesson plans, and information on the department's website that encourage the protection and importance of groundwater resources in our daily lives. Activities have included the development, creation and posting of the "Teacher's Portal to Ground Water Lesson Plans" on the LDNR website, and others listed below:

- LDNR Geaux Team, Executive staff, and Science/PIO staff visited elementary and middle school classrooms to teach and provide instruction about the environment.
- Produced and distributed an award-winning DVD, called "Our Lives…Our Water" video in 2008 with over 3,000 copies in circulation to date.
- Distributed water video to youth groups and institutions such as YMCAs, daycare programs, and at community Fairs and Festivals all across the state.
- Declared Sept. 14, 2010 as "Protect Your Ground Water Day", and prepared fliers and conservation "tips" push cards.
- Organized and traveled for "WATER Teaching Tour" in 2010 with Sparta Ground Water Educator and participated in several school presentations during the week.
- Participated in other community events such as LSU's Ocean Commotion, annual Earth Day and Earth Walk, Water Fest in Claiborne Parish, Home and Garden Shows.
- Teamed with other organization for exhibits and presentations such as the Boy Scouts, LA Resources Center for Educators, LA Environmental Education Commission, LA Dept. of Environmental Quality, LSU Center for Energy Studies, LSU AgCenter and Cooperative Extension Service, LA Farm Bureau, Sparta Ground Water Commission, and Home Builders Association.

Recognizing investing in conservation education and outreach is the best value proposition to promote the long-term sustainability of the resource, at the January 19-20, 2012 public meeting, members of the Louisiana Ground Water Resources Commission discussed the great value of groundwater conservation education in achieving the goal of resource sustainability. As a result of this discussion, the LDNR is in the process of reallocating personnel to coordinate conservation education for the state, in conjunction with other resource agencies. LDNR will work with other Louisiana agencies such as Wildlife and Fisheries, Transportation and Development, Environmental Quality, Agriculture and Forestry, and Health and Hospitals, as well as the Office of Coastal Protection and Restoration, to develop a robust education program.

An Example of What Integrated State Policy Can Do

One promising strategy for promoting sound water management in specific aquifers is the use of capital outlay investments to promote conservation and alternative, beneficial use of water sources and streams. The Sparta Reuse Demonstration Project in Ouachita Parish's City of West Monroe is a strong example of how use of state capital outlay funding can support sound water action and policy.

The Sparta Aquifer provides groundwater for 16 northern Louisiana parishes, including nearly all the freshwater needed by homes, businesses, and industry for the majority of parishes in north-central Louisiana. Parish and community leaders throughout the area recognized more than a decade ago that the rate of use of the water, or "draw," from the aquifer was far outstripping the aquifer's natural rate of replenishment, or "recharge," with the total draw on the aquifer as a whole estimated at about 18 million gallons a day greater than the rate of recharge. In seeking opportunities to relieve this stress on groundwater supplies, area leaders identified a single industrial user, Graphic Packaging, as a potential focus of an effort to take a significant step in water conservation for the Sparta aquifer system.

Graphic Packaging draws approximately ten million gallons of groundwater a day to support operations involving its core business of manufacturing cardboard for packaging. Threats to the the company's ability to access water present very real risks to the viability of its facilities in West Monroe, which in turn provide employment for more than 1,000 workers.

Recognizing that opportunity, area leaders developed the "Sparta Reuse Demonstration Project." This involved construction of treatment facilities and pipelines to process up to ten million gallons a day of West Monroe wastewater to clean it up to federal drinking water standards and direct it to Graphic Packaging, supplanting an equal amount of the company's draw on the Sparta aquifer system. If the full ten million gallons a day could be provided to the treatment facility by West Monroe's wastewater system, it would mean a reduction of more than half the estimated overdraw on the entirety of the Sparta aquifer system in Louisiana.

In 2008 and 2009, the administration of Gov. Bobby Jindal worked with legislators in providing more than half of the funding for construction of the project. Much of the balance of the cost was covered by a $4.7 million grant awarded by the LA Department of Environmental Quality, drawn from federal American Recovery and Reinvestment Act funding. The project is expected to be complete in the first half of 2012.

Beyond the direct and immediate relief of stress on the aquifer, the project is expected to demonstrate environmental benefits as well. City wastewater will be directed to manufacturing instead of to the Ouachita River,

allowing the city to consolidate older, more inefficient wastewater facilities. Another key benefit of the Sparta Reuse project is its potential to be applied in other areas where industries draw heavily on water sources shared with providers of public supply.

The Sparta Reuse Demonstration Project is an example of how water use and the availability impacts economic growth of a community, and how wise capital outlay investments tied to sound water management policy can provide benefits not only to our water supplies themselves, but to the overall environmental and economic health of a region as well.

Community Water Enrichment Fund

The Community Water Enrichment Fund was established in FY 08/09. Its purpose is to fund rehabilitation, improvement and construction projects for community water systems. Funds were to be divided equally among 63 parishes (Orleans Parish was excluded due to direct funding) with some funding held in an Emergency Set-Aside fund. The cities of Alexandria, Baton Rouge, Bossier City, Kenner, Lafayette, Lake Charles, Monroe, New Orleans and Shreveport are excluded due to being HUD entitlement cities.

The following is a summary of the Community Water Enrichment Fund to date.

	FY 08/09	FY 09/10	FY 10/11	FY 11/12 *
Programmatic Funding	$10,000,000	$0	$10,000,000	$10,000,000
Total Project Value	$9,327,758	$0	$8,745,135	$10,000,000
# of Projects	261	-	268	TBD
# of Parishes Participating	63	-	57	TBD

* FY 11/12 project awards are currently being reviewed

Commodity of the 21st Century: Where Do We Go From Here?

Throughout the 20th century, issues such as available land, workforce, infrastructure, and energy sources were driving forces of economic development in our state and nation. These issues remain critical today, but could something as basic as water become the "commodity of the 21st century?" More and more researchers and economic development professionals believe so.

In the article, "A Defining Resource: Louisiana's Place in the Emerging Water Economy," published in Loyola Law Review (2011), Mark Davis and James Wilkins write, "…it is clear that the availability of dependable supplies of fresh water is already transforming our economic and cultural landscapes. As the state's and the nation's growth, energy, and environmental priorities evolve, water is often the common denominator." (273)

Clearly, if Louisiana intends to continue to attract new business and industry to every region of our state, comprehensive water management is required to ensure that this commodity of the 21st century is sustained for all public and private water users.

Key Components of Groundwater Sustainability Management

1. Monitoring
2. Auditing
3. Public Education, Conservation & Outreach
4. Registration
5. Evaluation
6. Incentives
7. Enforcement
8. Emergencies
9. Collaboration
10. Governance

Groundwater Sustainability Management Recommendations

Based on recommendations provided in the E&E report, robust meeting discussions and input from LGWRC, LGWMATF, stakeholders, interested parties, etc. and agency staff experienced in implementing water management laws and regulations, this section details resource management changes and recommendations that, at this time, are considered necessary to improve efficiency and provide for a more comprehensive regulatory strategy. The management changes and recommendations are categorized by key groundwater resource management plan components that are currently under development as we continue our progression toward finalizing a statewide groundwater resource management plan.

1. Monitoring (Resource Metrics)

Action Required	Recommendation	Start Date
Legislative	Appropriate funding as necessary to establish an adequate statewide aquifer monitoring network, as recommeded by USGS, including monitoring of domestic wells. *	2012
Legislative	Appropriate funding as necessary to establish an adequate statewide surface water availability gaging network in areas where surface water alternatives may be necessary to obtain or maintain groundwater resource sustainability. *	2012
Administrative	Establish, where supported by objective, sound science, periodic groundwater production reporting requirements for non-domestic water well owners in areas within aquifer systems where metrics demonstrate that resource sustainability is not improving. *	7/1/13
Administrative	As supported by statewide monitoring network improvements, develop and implement an aquifer sustainability grading and prioritization ranking system. *	1/31/14

* Assumes legislative funding approved and available for monitoring network enhancement implementation in 2012.

2. Auditing (Regulatory Compliance and Program Effectiveness)

Action Required	Recommendation	Start Date
Administrative	Continue to improve aggressive implementation of statewide water well notification compliance audit procedures.	Ongoing
Administrative	Focus resources on consolidating existing and future water well registration and notification database information under one uniform database system and establish one unique well identifier for each well in the system.	7 / 1 / 12

3. Education (Resource Conservation and Regulatory Compliance)

Action Required	Recommendation	Start Date
Administrative	Through the Louisiana Department of Education, seek to establish a mandatory statewide groundwater and surface water education and water conservation curriculum at elementary and higher grade levels. Partner with the LDEQ, through its Drinking Water Protection Program, LDWF, LDHH, LDAF, OCPR, and LDOTD to leverage existing conservation and protection education activities currently presented to most grade levels.	7 / 1 / 12
Administrative	Seek to partner with other established web-based education programs, implement improvements to LDNR's and LDEQ's existing web-based education and outreach efforts, and develop social media opportunities for the same.	7 / 1 / 12
Administrative	Request local governments, where groundwater resources are in demand for public drinking water supplies, to establish groundwater and surface water education and conservation outreach measures.	7 / 1 / 12
Administrative	Pursue partnerships with each parish to establish a single point of contact to serve as the champion of the respective parish's groundwater and surface water education and conservation efforts in coordination with statewide efforts for the same.	7 / 1 / 12

4. Registration (Water Well Driller and Owner/User Responsibilities)

Action Required	Recommendation	Start Date
Administrative	In an effort to achieve 100 percent compliance with water well registration (notification) and agency evaluation requirements for proposed well installation for non-exempt well use purposes, such as irrigation, public supply, industrial, etc., the agency intends to aggressively pursue amending regulations under groundwater resources management law for water well drillers to ensure that water well pre-installation notification evaluation has been performed and an appropriate agency response has been issued to the well owner prior to engaging in well construction operations.	4/1/12
Administrative	Focus resources to implement integration of water well driller registration and well owner notification database management systems into one consolidated system, improve SONRIS and GIS output capacity, and develop and implement online document review opportunities for easier access to agency well notification, evaluation and response correspondence.	7/1/12
Administrative	Pursue innovative ideas to encourage well owner registration of any water well still in existence (not plugged and abandoned or destroyed) but previously not required to be registered with the state under Louisiana Administrative Code Title 56.	7/1/12

5. Evaluation (Assessing Resource Sustainability)

Action Required	Recommendation	Start Date
Administrative	Update the water well notification evaluation procedure to clearly document that water level drawdown assessments are performed, taking into account multiple well withdrawal effects within established areas of review, where applicable. The current evaluation procedure can be viewed at: http://dnr.louisiana.gov/assets/docs/conservation/documents/WellEvalation Checklist.pdf and as Appendix N in this report.	5/1/12
Administrative	Investigate revising the water well notification form (Form GWR-01) to include identification of and disclosure of efforts to use surface water alternatives for certain well uses (irrigation, public supply, industrial, etc., but excluding domestic use) in certain areas of aquifers such as areas of ground water concern, etc. Form GWR-01 can be viewed at: http://dnr.louisiana.gov/assets/docs/conservation/documents/GWR-01.pdf.	5/1/12
Administrative	Focus resources to improve and increase the use of USGS observation well and other state agency groundwater level/quality data through the DNR SONRIS and GIS systems.	7/1/12

6. Incentives (Resource Conservation)

Action Required	Recommendation	Start Date
Administrative	Continue to investigate feasible and effective ways to provide incentives such as conservation stewardship recognition plans, etc.	7 / 1 / 12
Legislative	Evaluate capital outlay policies & procedures to promote beneficial use of alternative water sources where sustainability is challenged.	2012
Legislative	Evaluate requirements for local governments and water districts' eligibility to participate in the Community Water Enrichment Fund program, including master meter installation, conservation education, public outreach, water production reporting, and unaccounted for water loss abatement.	2012
Legislative	Evaluate linking tax credit and abatement policy to conservation participation, water loss prevention, and alternative water use.	2012
Legislative	Evaluate fiscal policy to reward high volume groundwater users to switch to surface water, recognizing the public benefits.	2012

7. Enforcement (Regulatory Compliance)

Action Required	Recommendation	Start Date
Administrative	Investigate possibilities of implementing progressive enforcement techniques to aid in beneficial projects such as conservation education assistance, etc., similar to LDEQ's program.	7 / 1 / 12

8. Emergencies (Response Coordination)

Action Required	Recommendation	Start Date
Administrative	Investigate the extent to which groundwater emergencies are covered through GOHSEP, consider any additional needs to establish a multi-agency committee for emergencies, and amend or revise the agency's Ground Water Emergency Response Contingency Plan as necessary.	7 / 1 / 12

9. Collaboration (Concerted Multi-Agency Resource Management)

Action Required	Recommendation	Start Date
Administrative	Implement an annual multi-agency stakeholders conference, including legislators, state agencies, federal agencies, local governments, conservation commissions, soil and water districts, academic institutions, non-governmental organizations, trade associations, lake commissions, drillers, agriculture and aquiculture farmers, industry representatives, environmental organizations, power generators, navigation interests, coastal restoration advocates, fisheries interests, oil and gas representatives, tourism industry, economic developers, and other users, all designed to seek best management practices for the sustainability and protection of our water resources.	2012
Administrative	Require the regional conservation commissions and the soon-to-be-established regional advisory bodies to file annual reports with the Ground Water Commission on the vital statistics and concerns for the groundwater of their region.	2012
Administrative	Engage legal scholars to research and explore the potential non-compensated consumption of surface water when used as an alternative to groundwater.	2012
Administrative	Engage experts to research and explore the consequences of out-of-state sales of water resources.	2012

10. Governance

Action Required	Recommendation	Start Date
Administrative	Draft and implement regulations for the establishment of a statewide regional network of advisory panels composed of local governments, user groups, and interested stakeholders, all as previously authorized by Act 49 of 2003. In cases where the legislature has already established regional commissions, specifically the Capital Area Ground Water Conservation Commission and the Sparta Aquifer Ground Water Conservation Commission, these entities should concurrently serve as their regional advisory panel.	2012
Legislative	By legislation or resolution, affirm the authority of local governments to adopt ordinances to protect the quality of public groundwater supply wells.	2012
Administrative	Explore the possibility of drafting new regulations to improve upon recent on-site and off-site E&P waste fluids recovery, remediation, recyclying, and reuse regulatory amendments, encouraging greater use of these fluids as an alternative to groundwater and surface water resources in hydraulic fracture stimulation operations.	2012
Administrative	Engage legal scholars to research and explore the potential non-compensated consumption of surface water when used as an alternative to groundwater, and as an aid to economic development, job creation, and job retention.	2012
Administrative	Engage experts to research and explore the consequences of out-of-state sales of water resources.	2012
Legislative	Extend the sunset of Act 955 of 2010 through December 2014, continuing state agency oversight and management of surface water resource use under the cooperative endeavor agreement procedure consistent with the Attorney General's surface water use opinions.	7/1/12
Legislative	Add surface water fact-gathering responsibilities, without management or regulatory authority, to the mission of the Ground Water Resources Commission, expanding its membership, and amending its name to the Water Resources Commission.	7/1/12
Administrative	Investigate possibilities of developing new, or improving upon existing, agency aquifer recharge area protective measures.	2012

Conclusion

For the first 190 years of statehood, Louisiana's efforts to manage water predominantly focused on keeping it out of our communities, namely flood waters and the encroaching Gulf of Mexico. However, since 2001 and following extreme drought conditions, Louisiana has recognized the critical need to manage the sustainability of our ground and surface water resources. Laws and regulations through the past decade have been passed and implemented, and policies and procedures have been developed to ensure the appropriate use and continued availability of Louisiana water.

As population and industry growth continue to place increased demands on our water resources, and weather conditions continue to impact the natural replenishment of those resources, a renewed focus on comprehensive water management in Louisiana is required. The Louisiana Ground Water Resources Commission and the Louisiana Department of Natural Resources have produced this report and compiled legislative and regulatory recommendations aimed at enhancing and strengthening current management practices. Much of the recommendations concern ground water resources, but this report also acknowledges that ground water and surface water are inextricable and effective management must consider the sustainability of both.

Recognizing that each aquifer represents a unique environment with its own individual challenges, state regulators continue to assess water quality and availability and make management decisions as needed on an aquifer-by-aquifer basis when risk is determined. LDNR expects that greater monitoring capabilities now planned will increase the amount and frequency of reliable data gathered in the most stressed aquifer systems. In addition, the Ground Water Resources Commission is proposing to move forward with suggested legislative and administrative actions contained in this report (beginning on page 101) that focus on monitoring, auditing, conservation education and public outreach, well registration, evaluation, incentives, enforcement, emergencies, collaboration, and governance. These recommendations will positively benefit not only stressed aquifers, but our state's total water budget. No single law, regulation, or recommendation will be a quick-fix; rather, the wise prioritization and implementation of these recommendations, covering all components and more, will help Louisiana sustain its precious water resources for centuries to come.

This report is only a first step in what will be a continuous, vigorous effort to effectively manage what we believe is the "commodity of the 21st Century," and develop a comprehensive water resources management plan. Ultimately, the goal is to "protect, conserve, and replenish" all water resources, as entrusted to state government by the people of Louisiana in Article IX, Section 1 of the State Constitution.

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Online Resources

View the Executive Summary of *Recommendations for a statewide Groundwater management plan* at:
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View the *Recommendations for a statewide Groundwater management plan* Technical Report and Appendices at:
http://dnr.louisiana.gov/assets/OC/env_div/gw_res/20111206_GWPLAN_FINALTECHAPP.pdf

Appendices

Appendix A: Sabine River Authority RFP for sale of raw water and Response to RFP

Appendix B: Executive Order Relative to Coastal Master Plan

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Appendix D: List of existing CEA's relative to Act 955

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Appendix F: Guidance Memorandum, Office of the Attorney General

Appendix G: Memorandum of Understanding April 2010

Appendix H: USGS Monitoring Proposal

Appendix I: Capital Area Ground Water Conservation Commission Actions

Appendix J: Toledo Bend Current Water Sales

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Appendix L: Haynesville Shale Water Use Advisory

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Appendix N: Water Well Evaluation Procedure

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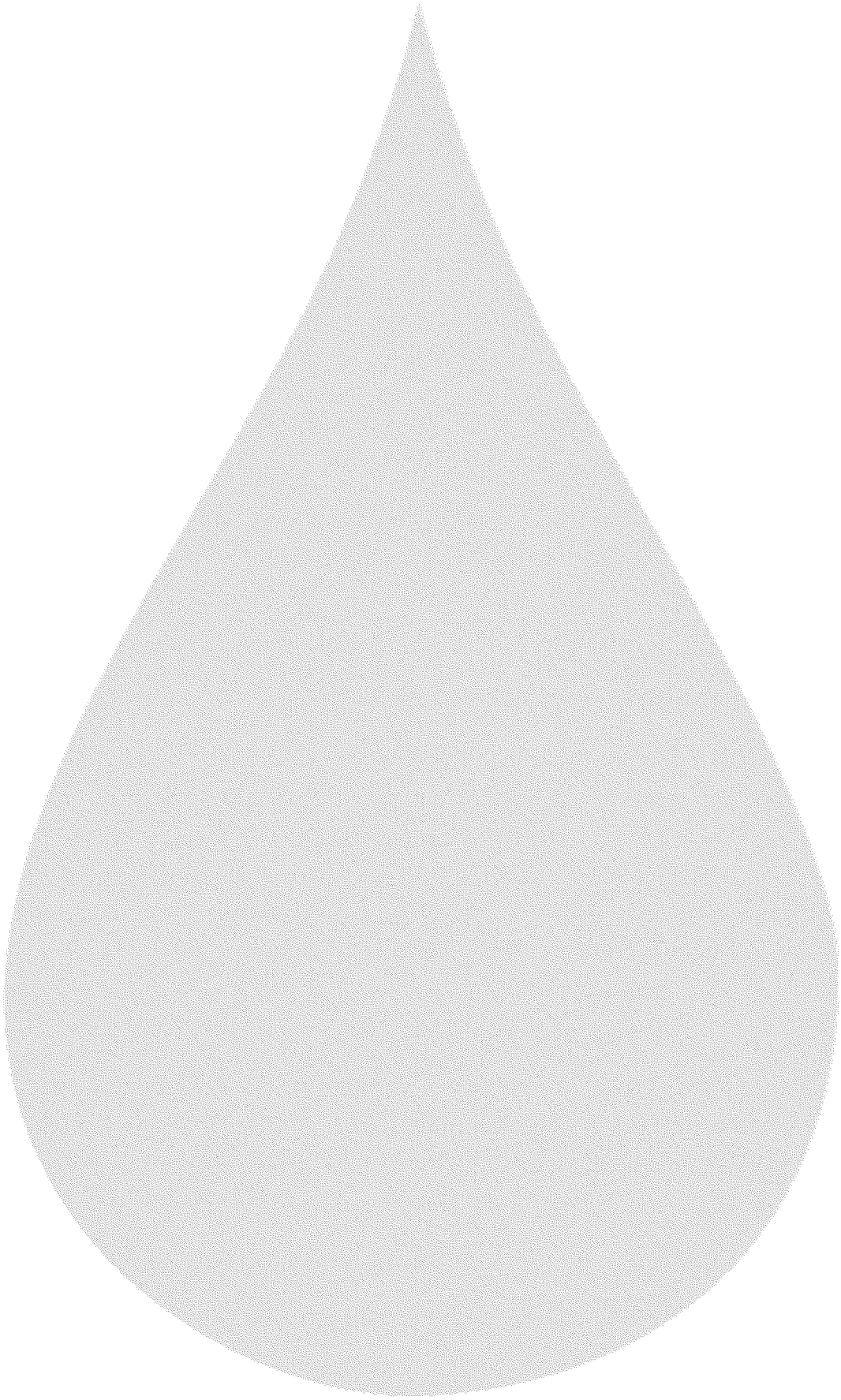

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This public document was published at a total cost of $3,619.65. Two hundred (200) copies of this document were published in this firstprinting at a cost of $3,619.65. This document was published by the Louisiana Department of Natural Resources, Office of Conservation, Environmental Division to comply with HCR1 of the 2010 Regular Session of the Louisiana Legislature. This material was printed in accordance with standards for printing by State Agencies established in R.S. 43:31.

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doi:10.1088/1748-9326/9/12/124011

Will water scarcity in semiarid regions limit hydraulic fracturing of shale plays?

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Received 10 July 2014, revised 27 October 2014
Accepted for publication 29 October 2014
Published 8 December 2014

Abstract
There is increasing concern about water constraints limiting oil and gas production using hydraulic fracturing (HF) in shale plays, particularly in semiarid regions and during droughts. Here we evaluate HF vulnerability by comparing HF water demand with supply in the semiarid Texas Eagle Ford play, the largest shale oil producer globally. Current HF water demand (18 billion gallons, bgal; 68 billion liters, bL in 2013) equates to ~16% of total water consumption in the play area. Projected HF water demand of ~330 bgal with ~62 000 additional wells over the next 20 years equates to ~10% of historic groundwater depletion from regional irrigation. Estimated potential freshwater supplies include ~1000 bgal over 20 yr from recharge and ~10 000 bgal from aquifer storage, with land-owner lease agreements often stipulating purchase of freshwater. However, pumpage has resulted in excessive drawdown locally with estimated declines of ~100–200 ft in ~6% of the western play area since HF began in 2009–2013. Non-freshwater sources include initial flowback water, which is ⊔5% of HF water demand, limiting reuse/recycling. Operators report shifting to brackish groundwater with estimated groundwater storage of 80 000 bgal. Comparison with other semiarid plays indicates increasing brackish groundwater and produced water use in the Permian Basin and large surface water inputs from the Missouri River in the Bakken play. The variety of water sources in semiarid regions, with projected HF water demand representing ~3% of fresh and ~1% of brackish water storage in the Eagle Ford footprint indicates that, with appropriate management, water availability should not physically limit future shale energy production.

Online supplementary data available from stacks.iop.org/ERL/9/124011/mmedia

Keywords: hydraulic fracturing, water scarcity, shale gas, brackish water, groundwater, unconventional energy, water energy nexus

1. Introduction

With increasing energy production from unconventional shale plays requiring large amounts of water to support hydraulic fracturing (HF), there is concern about limited water supplies. A recent global analysis of water resources relative to shale plays indicates that an estimated ~40% of shale resources are in arid areas or in areas of high–extremely high water stress, including China, Mexico, and S Africa, ranked 1st, 6th, and 8th in terms of shale gas production, respectively [1–3]. Extreme droughts exacerbate water shortages, with an estimated 15% of global shale resources in areas exposed to high–extremely high drought stress [1]. The USA is the global leader in unconventional oil and gas (O&G) production with initial development of the technology for producing O&G from low permeability shales in the Barnett shale play in Texas using HF and horizontal drilling [4]. In addition, private ownership of mineral rights has incentivized rapid expansion of production in the USA in contrast to government ownership in most other countries. The USA ranks 5th globally in terms of technically recoverable shale gas and 2nd

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in terms of shale oil resources and was classified as medium to high water stress in the global analysis [1]. An earlier report on USA resources indicates that ~50% of the 39 000 wells hydraulically fractured (January 2011–May 2013), that consumed ~100 billion gallons (bgal, ~380 billion liters, bL) of water, are in high or extremely high water stress areas [5]. The highest shale oil producing plays are in semiarid regions or in regions with low precipitation (Eagle Ford, 34% of USA production in 2013; Bakken, 29%; and Permian Basin, 23%).

Water scarcity is often defined as water demand exceeding water supply. Water demand for HF can be estimated fairly accurately in the USA from commercial and public databases (e.g. IHS Enerdeq database, FracFocus) [4–6]. However, there is considerable uncertainty in future demands based on projected O&G production in these plays (estimated ultimate recovery, EUR). Previous studies indicate that ~10 000 more wells will be drilled throughout the 20–30 yr life of the Barnett play [7], ~40 000 more wells in the Bakken [5], and 50 000 in the Eagle Ford [6, 8].

HF water supply is more difficult to assess than HF water demand because the reporting requirements for water sources used for HF in the USA are limited to some states (Pennsylvania, W Virginia, supporting information, SI, section 4, available at stacks.iop.org/ERL/9/124011/mmedia). Surface water supplies are more readily estimated from monitoring data; however, groundwater supplies depend in part on how they are defined. Many studies restrict groundwater supplies for HF to the water flux into the aquifer or recharge, often based on coarse resolution (0.5–1 degree) global models, such as PCR-GLOBWB in the Aqueduct water scarcity product [1, 5, 9]. Others define groundwater supplies based on water storage in aquifers [10]. Water supplies for HF are also impacted by water use in other sectors, particularly irrigation in semiarid regions [11].

Various strategies have been proposed to enhance resilience of HF to water constraints, including trading water among sectors and shifting to non-freshwater sources. Similar approaches are being considered for power generation [12]. Some studies emphasize the potential for trading with irrigated agriculture, considering that this sector is often the largest water consumer in semiarid regions [13, 14]. To date, most HF water has been derived from freshwater resources [5]; however, recent advances in HF technology allow use of more saline water, even as high as 285 000 mg L^{-1} total dissolved solids (TDS) [15]. While there is much emphasis on reuse (little or no treatment) or recycling (with treatment) of flowback/produced (FP) water, some studies show that flowback water (typically produced within 1–2 weeks after well completion) or water produced from the formation along with O&G (produced water), both referred to generically as FP water, represent a small percentage of HF water demand [4, 16]. Even in the Marcellus Shale, where almost 100% of the water is recycled, recycling accounts for □10–30% of the required HF water based on volumes of typical flowback (mean 0.44×10^6 gal/well, 1.7×10^6 L/well) and produced water (0.74×10^6 gal/well, 2.8×10^6 L/well) from wells in Pennsylvania [17] relative to mean HF water use throughout the play (4.4×10^6 gal/well 16.7×10^6 L/well) [5]. Brackish groundwater provides another alternative to freshwater with some referring to the 'sea of brackish water' in the subsurface; however, characterization of this resource is limited in terms of quantity and quality of water that can be recovered [18].

The objectives of this study were to address the following questions:

(1) How does water use for HF compare with that for other sectors?
(2) What is the projected demand for HF water for O&G production?
(3) Is HF in semiarid regions vulnerable to water constraints, i.e. does water demand exceed supply?
(4) What impacts does HF water use have on water resources?
(5) What strategies can O&G operators adopt to enhance resilience of HF to water constraints?

This study focused on water use for HF in the Eagle Ford shale play, the top ranked shale-oil producer and 4th ranked shale-gas producer in the USA in 2013 [19, 20]. It builds on a previous analysis that quantified water demand to date for HF in the Eagle Ford play [6]. Water use for HF was considered relative to that for irrigation and municipal sectors. Future HF water demand was projected for the next 20 yr. Water constraints were assessed by comparing HF water demand with estimated freshwater supplies from groundwater recharge and storage from groundwater models [21, 22]. Impacts of HF water use on water resources were evaluated by considering HF water use to date and also the life cycle of shale gas. Adaptive strategies to enhancing resilience of HF water supplies evaluated include use of brackish groundwater, reuse/recycling of FP water, and use of municipal waste water. Results from the Eagle Ford play were compared with those in other semiarid regions, including the Permian Basin play in Texas and Bakken play in N Dakota/Montana. This comprehensive analysis is designed to answer the question of whether HF in semiarid regions will be limited because of water constraints.

2. Materials and methods

2.1. Eagle Ford Shale Play

Unconventional O&G production in the Eagle Ford Play (~9500 mi^2, 24 600 km^2 area) began in 2008 (figure 1). Water use for HF in the play totaled 40 bgal (150 bL) for 8301 wells (2009–2013) [6].

Precipitation in the Eagle Ford play ranges from 19.5 inches/yr (495 mm yr^{-1}) in the west to 38.6 inches/yr (980 mm yr^{-1}) in the east (figure S1). Total population in the play area was ~0.2 million in 2010 in the mostly rural 16 county area. Nearby major cities include San Antonio (population 2.2 million) and Laredo (population 236 000) (figure S2). Land use/land cover consists of shrubland (45%), pasture (25%), grassland (8%), forest (7%), and cropland (5%) (figure S2). Most cropland and some pasture are irrigated. Major rivers include, from west to east, the Rio Grande, Nueces, Frio, Atascosa, San Antonio, and Guadalupe rivers. Major aquifers

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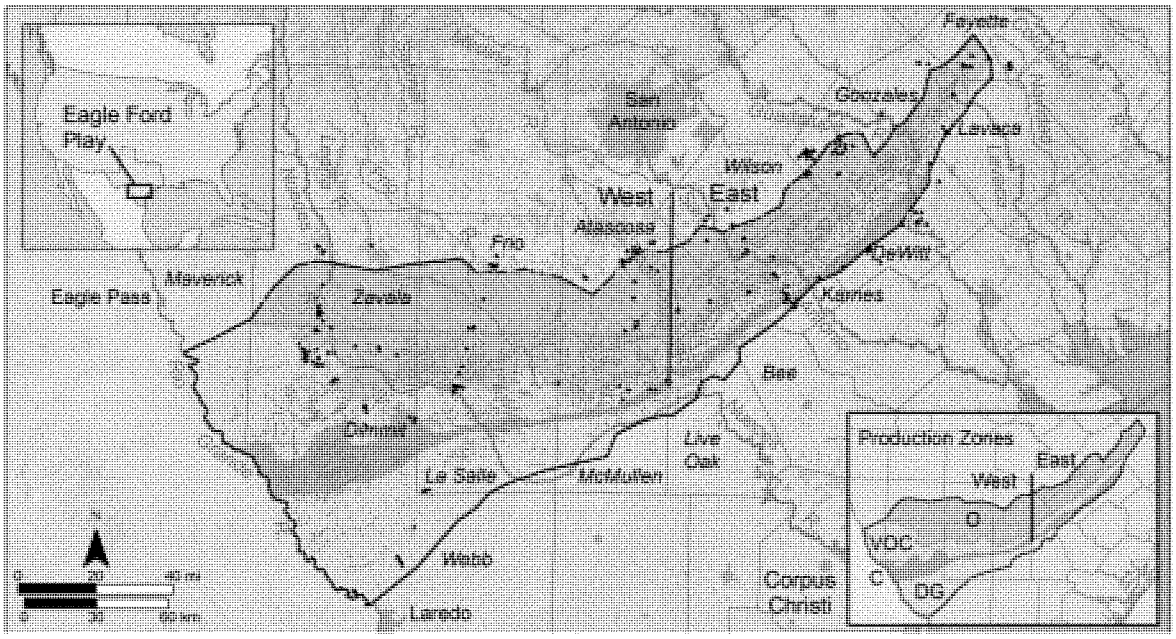

Figure 1. Location of the Eagle Ford Shale play in south-central Texas, USA. The study area (black outline), includes 99% of recently completed (2009–2013) Eagle Ford play area wells. The inset shows the different production zones, including the updip black oil zone (O, green), volatile oil-condensate (VOC, yellow), condensate (C, mustard), and dry gas (DG, rose) [6]. The O, VOC, and C zones were further subdivided into west and east zones. The gray points represent the locations of horizontal oil and gas wells that were completed using hydraulic fracturing (HF) techniques from January 2009 through December 2013 (8301 wells). The black points represent public water supply wells that serve community populations up to ~10 000 people. The blue points represent irrigation wells, with the highest density upgradient from the HF wells, mostly in the Winter Garden irrigation region. Mean depth of HF wells is ~2 miles (3.2 km) and the length of horizontals or laterals averages ~1 mile (1.6 km) [6]. Average HF water use is similar across production zones from oil, through volatile oil, gas condensate (liquid condensed from wet gas at the well head or natural gas plant), and dry gas, on a per well basis (4.7–4.9 × 10^6 gal/well, 17.8-18.5 × 10^6 L/well) and per unit length of lateral (930–1020 gal ft^{-1}, 11 500–12 700 m L^{-1} of lateral). However, HF water use varies spatially and is 17–29% higher in the west relative to the east within each production zone. Oil and gas has been produced in this region since the early 1900s from units such as the Austin Chalk and Edwards Limestone with horizontal drilling used in the relatively tight Austin Chalk for several decades [53]. Conventional oil and gas wells are not shown.

in the region include the Carrizo–Wilcox aquifer and the Gulf Coast aquifer system, and minor aquifers include the Queen City, Sparta and Yegua-Jackson aquifers (figures 2, S3) [23]. Groundwater Conservation Districts (8 GCDs) manage regional groundwater according to Texas Senate Bill 1, an omnibus water bill passed in 1997 (figure S4).

2.2. Data sources and analyses

HF water demand was compared with water supplies at the play and county and square mile grid levels while also considering water use in other sectors to assess vulnerability to water constraints (figure 3). Additional details on data sources are available in SI, section 6. HF water demand or use was based on water use to date (2009–2013) in the Eagle Ford [6]. Information on wells used to supply water for HF was obtained from the Texas Dept. of Licensing and Regulation. HF water use was compared with that for other sectors based on the most recent data from the Texas Water Development Board [24]. Future HF water use was estimated by assuming that the highest established well density (HEWD) for HF wells in each of the seven production zones (2 oil, 2 volatile oil condensate, 2 condensate, and 1 dry gas) or county/production zone intersections (40) would apply to the entire play (SI, section 6, tables S1, S2).

Primary sources of HF water include surface water and groundwater from aquifer recharge, aquifer storage, and cross-formational flow from adjacent aquifers; however, the latter was neglected in this analysis. Data on water diversions from the Rio Grande for mining were obtained from the Rio Grande Water Master. Renewable groundwater supplies for HF were estimated from aquifer recharge rates using a global model (PCR GLOBWB) as used in recent studies [1, 5, 25], regional recharge rates from groundwater chloride data [26], and groundwater availability models (GAMs) [27–29]. Groundwater supplies from aquifer storage were estimated from GAMs [22, 27, 28] and include drainable storage (water that would be drained under gravity, aquifer thickness × specific yield) in aquifer outcrop zones and compressible storage (water released from compressible storage: storativity × head decline) in downdip confined sections of aquifers (figure 2, SI, section 9, figure S11).

Impacts of HF on groundwater resources were evaluated using groundwater level monitoring data from 131 wells from the Texas Water Development Board (TWDB) database. Flow duration curves and baseflow were estimated for 20 streamflow gages using the length of record to determine which streams are perennial and could be impacted by HF groundwater pumpage. Net impact of HF on water resources was examined

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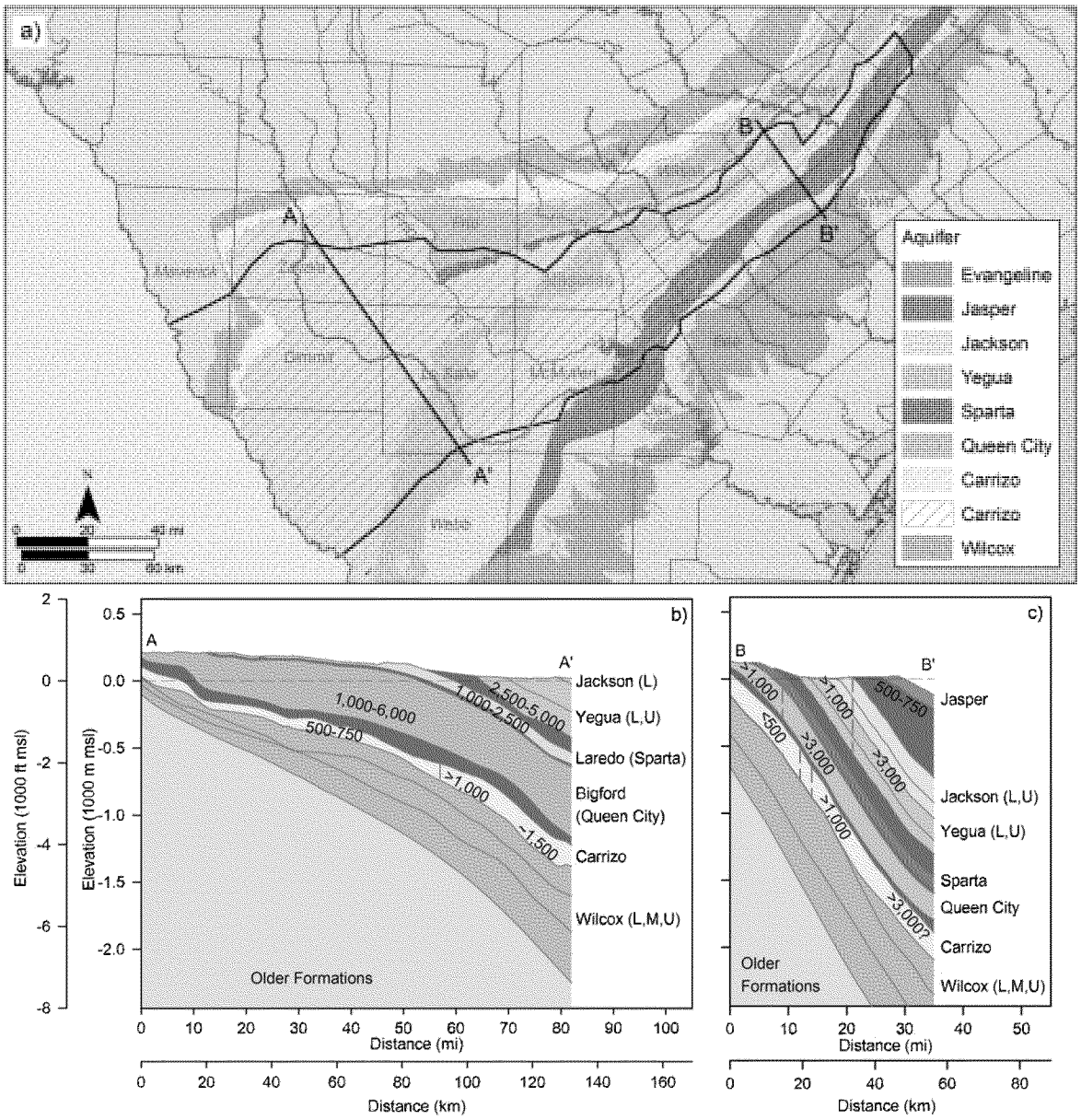

Figure 2. (a) Outcrop and recharge areas for aquifers in the Eagle Ford play area. Major aquifers include the Carrizo–Wilcox and the Gulf Coast (Jasper and Evangeline) and minor aquifers include the Queen City, Sparta, and the Yegua-Jackson. The primary water source in the western region of the Eagle Ford play is the confined section of the Carrizo Sand, represented by the cross-hatched area. Except for the outcrop area lying mostly to the northwest of the Eagle Ford play area, little information regarding water quality is available for the Wilcox units. The Queen City and Sparta aquifers also have equivalent water-bearing units west of the Frio River, although these units are not designated as aquifers in the west because of poor water quality (figure S3) [22]. We did not include water supplies for HF from these units. (b) Cross sections A-A' and (c) B-B'. Values shown in the cross section aquifer units represent approximate groundwater total dissolved solids (TDS) concentrations and dashed vertical lines represent approximate locations of transitional areas between different TDS concentration zones.

by comparing water use for shale gas extraction with water use for cooling in natural gas power plants [30].

Alternatives to freshwater sources for HF were evaluated, including flowback/produced (FP) water (SI, section 11), brackish groundwater, and municipal waste water. FP water volumes were estimated for individual wells from 2009–2013. The ratio of FP to HF water was calculated to evaluate what percentage of HF water would be available for reuse or recycling. Brackish groundwater was estimated by integrating groundwater quality (TDS) data from TWDB with groundwater storage data from the GAMs. Availability of municipal waste water was evaluated by contacting the 20 largest municipalities in the play area. We contacted O&G operators to determine trends in HF water sourcing through the South Texas Energy and Economic Roundtable (STEER.com) and through conferences. Analyses of water demand versus supply in the Eagle Ford play were compared with water demand from literature-based estimates for the semiarid Permian Basin play in west Texas [5] and from previous analysis for the semiarid Bakken play in N Dakota and Montana [6]. Water demand in the

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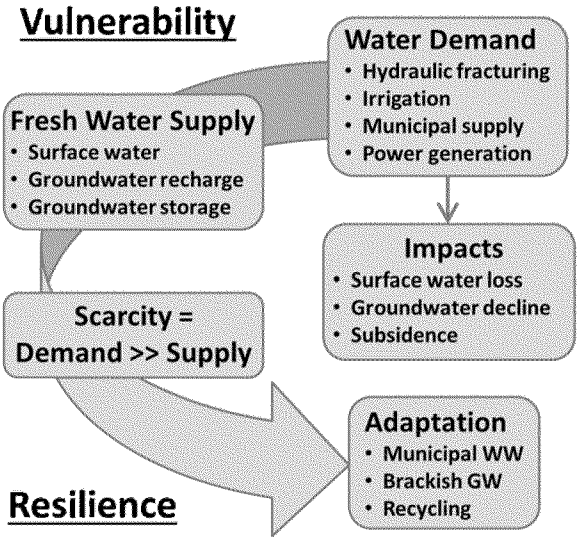

Figure 3. Water demand for HF is based on data on HF water use to date (2009–2013) from IHS and FracFocus databases [6]. Projected HF water demand assumes that additional HF wells will be drilled to achieve the current highest established well density (HEWD) in each of the seven production zones (east and west oil, VOC, and condensate zones, and dry gas zone). Projected HF water demand was calculated by multiplying the number of wells to be drilled in each production zone by the 2013 average HF water use per well in each zone. Water supplies were estimated from surface water (SW) based on data from Water Masters. Recharge rates were determined from a global model (PCR-GLOBWB (PCR-GLOBWB) [25], regional recharge estimates from groundwater chloride [26] and from Groundwater Availability Models (GAMs). Groundwater (GW) supplies from aquifer storage were estimated from GAMs, using water-level data in unconfined aquifers and potentiometric surface data in confined aquifers, aquifer tops and bottoms, and gridded storage coefficients (supporting information, SI, section 9). Total water storage was subdivided into freshwater (FW) and brackish water (BW, total dissolved solids, TDS □ 1000 mg L) using water quality data from the Texas Water Development Board. Data on flowback and produced water (FP) were obtained from IHS. Information on municipal waste water (WW) was obtained from municipalities. Impacts of HF on surface water (SW) were estimated by determining which streams are perennial and could be affected by pumpage from unconfined aquifers. Impacts of HF on groundwater were based on groundwater level data from TWDB wells in the region. Net impact of HF on water resources considered use of natural gas in power generation.

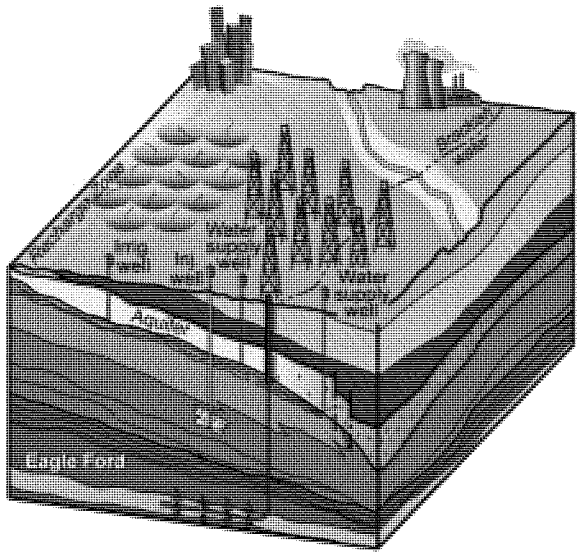

Figure 4. Schematic of Eagle Ford play area. Only one aquifer is shown for clarity and includes an up-dip recharge zone where the aquifer outcrops and downdip confined section including brackish water shown in red. A representative hydraulically fractured well is shown with mean depth of ~2 miles (3.2 km) and mean lateral length of ~1 mi (1.6 km). A nearby injection well is shown where flowback-produced water can be disposed. The various water sources are schematized to include groundwater recharge and storage (freshwater and brackish water), reused or recycled FP water from HF wells, municipal waste water, surface water (e.g. Rio Grande), and transfer from the irrigation sector. Irrigation is mostly up-gradient from the Eagle Ford HF and is represented by center pivot irrigation circles representative of the Winter Garden irrigation region. A power generation station is included to represent net impacts of natural gas on water resources including water cooling through power generation and water creation from natural gas combustion.

Permian Basin was compared with water supplies from groundwater storage, including brackish water from the GAMs and discussions with operators through the Permian Basin Petroleum Association. Water demand in the Bakken was compared with reservoir storage in the Missouri River [31].

3. Results and discussion

A schematic (figure 4) shows the main components of the Eagle Ford play area, including the Eagle Ford Shale unit at depth, a typical HF well (~2 miles deep and 1 mile lateral), an injection well for disposal of FP water, a shallow dipping confined aquifer typical of the Gulf Coast aquifers, and various sources of water, including recharge in the aquifer outcrop and fresh and brackish groundwater storage. HF water demand was compared with water supplies based on production to date (2009–2013) and projected production throughout the play life (~20 yr) at the play level, county level, and where feasible at the one square mile grid level to assess water scarcity.

3.1. How does water demand for hydraulic fracturing compare with that for other sectors?

Water demand or use for HF in the Eagle Ford in 2013 (17.8 bgal, 67 bL) is assumed to be mostly consumptive because of limited recycling as discussed later. At the state level, HF water demand in the Eagle Ford in 2013 represents 0.3% of statewide water withdrawal (5200 bgal, 20 000 bL, 2012) and 0.5% of statewide water consumption (3900 bgal, 15 000 bL, 2012), assuming 85% of irrigation and 40% of municipal water use is consumptive [32]. The latest year with reported state water use data is 2012. At the play level, HF water consumption represents 4–9% of water withdrawal in 2011 and 2012 and 5–11% of water consumption (figure 5, table S2). However, using 2013 HF water use with 2012 water use data results in HF representing 13% of water withdrawal and 16% of water consumption. The dominant water user in the play is irrigation, accounting for 62–65% of

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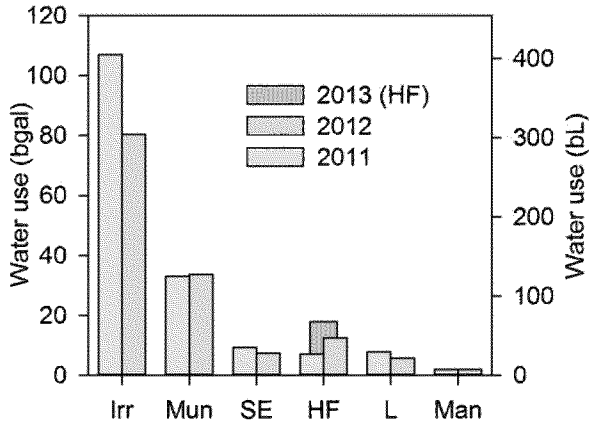

Figure 5. HF water use for 2011–2013 relative to total water use by other sectors in the Eagle Ford play area for 2011 and 2012 (most recent years with complete data) (table S1). Total non-HF water use was 168 bgal (636 bL) for 2011 related to dry conditions associated with most extreme drought on record and 129 bgal (490 bL) for 2012, related to normal conditions. HF water use during the period was 7.0 bgal (36 bL; 2011), 12.5 bgal (47 bL, 2012), and 17.8 bgal (67 bL, 2013).

Table 1. Summary of past and projected HF water demand and future HF water supply sources in the Eagle Ford play region.

		HF demand and storage		
Category		bgal	bL	Demand % of source
HF Water demand				
2009–2013		40	150	—
20-Year projection		330	1250	—
HF Water sources				
Fresh storage	Unconfined	6000	22 700	5
	Confined	3800	14 400	8
Brackish storage	Unconfined	34 800	132 000	1
	Confined	45 600	173 000	1
Other[a]	Recharge	1200	4540	26
	MWW	36	136	860

[a] Annual values (recharge: 60 bgal yr^{-1}, municipal waste water (MWW) 1.8 bgal yr^{-1}) multiplied by 20 yrs.

water consumption (2011–2012), followed by municipal (10–12%), and steam electric power (7–13%) (figure 5).

3.2. What is the projected water demand for hydraulic fracturing?

Total HF drilling during the remaining life of the play (~20 years) was estimated based on the current highest established well density (HEWD) to be 50 700–70 400 wells, resulting in ~42 000–62 000 wells remaining after subtracting the 8300 wells drilled to date [6] (table S3; figure S6), bounding the previous estimate of 50 000 wells [8]. Multiplying 2013 drilling (3512 wells) by 20 and subtracting 8300 would result in a similar estimate (62 000 wells). These projections would result in ~223–333 bgal (844–1260 bL) of additional HF water based on average 2013 HF water use/well in each production zone (oil, volatile oil, condensate, and dry gas) (table S3), representing ~6–8 times HF water use to date (~40 bgal, 150 bL, 2009–2013) [6]. To assess water constraints for HF, we used the upper bound for HF water demand (~330 bgal, 1250 bL) as a conservative estimate (table 1).

3.3. How does water demand for hydraulic fraction compare to freshwater supplies?

The dominant HF water supplies in the Eagle Ford play include aquifer recharge and freshwater storage (table 1). The focus on freshwater derives in part from reports that many landowners stipulate use of their fresh groundwater as part of lease agreements to generate an additional revenue stream to land owners and the sole revenue stream to landowners with severed mineral rights. Long-term (1960–2000) mean recharge rates from simulated drainage below the root zone in the PCR-GLOBWB model totaled 49 bgal yr^{-1} (185 bL yr^{-1}) for the Eagle Ford play area (table S5), ~170% greater than HF water demand in 2013 (18 bgal, 68 bL) but 65–72% less than total water withdrawal in the play area in 2011 (175 bgal, 662 bL) and 2012 (142 bgal, 538 bL) (table S3). Regional recharge rates from groundwater chloride data in the Carrizo–Wilcox aquifer totaled 43 bgal yr^{-1} (163 bL yr^{-1}) [26]. Sources of recharge include diffuse recharge from percolation below the root zone and focused recharge beneath losing streams (e.g. Leona, Nueces, and Frio rivers) [33, 34]. Simulated recharge in regional GAMs in outcrop areas in the play totaled ~60 bgal yr^{-1} (227 bL yr^{-1}; table S5). All of these recharge estimates refer to aquifer outcrop zones; however, most O&G water supply wells in the western part of the play are in the deeper confined parts of the aquifers (1000–7000 ft deep, 300–2000 m) (figure S5). Net flow to the downdip confined aquifer was estimated to be ~34% of the outcrop recharge for the Carrizo–Wilcox aquifer, the dominant aquifer in the west, based on the GAM [26]. Applying the percentage of deep recharge in the Carrizo aquifer (34%) to other confined aquifers in the play as an estimate results in net recharge of ~20 bgal yr^{-1} (76 bL yr^{-1}), which is similar to HF water use in 2013 (17.8 bgal) but is ~86–89% less than total water withdrawal in 2011 and 2012 in the play area. Therefore, relying on recharge alone for HF is inadequate because recharge is not uniformly distributed in the play (figure S10) and most of the HF water supply wells are in the deep confined aquifers with very low recharge rates.

The largest water source for HF is groundwater storage in the play area. A previous study of water sources for irrigation pumpage in the confined portion of the Carrizo–Wilcox aquifer indicates that ~60% of the pumped water was derived from aquifer storage, which is not sustainable and has resulted in groundwater depletion [21]. Freshwater extends far downdip in the Carrizo aquifer in the western part of the play, reflecting high permeability sands but is much more limited in the east [35] (figures 2(b), (c), S9). Drainable freshwater

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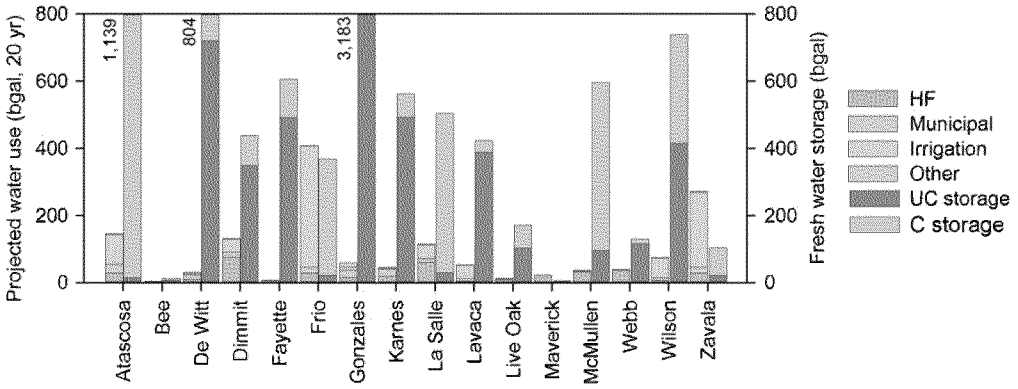

Figure 6. Comparison of estimated 20 yr water demand by sector relative to estimated total fresh water storage in the Eagle Ford play area. 'Other' category includes manufacturing, electrical power generation, and livestock sectors combined. HF demand based on highest established well density for seven production zones from this study and the remaining sector demands estimated as 20 times the respective 2000–2012 annual sector mean values (TWDB). Unconfined (UC) and confined (C) fresh water storage values based on the groundwater availability models (GAMs).

storage in the unconfined portions of the aquifers, estimated from integration of TDS data (figures S19–S23) with storage from the GAMs, totaled ~6000 bgal (22 700 bL, tables 1 and S6); however, most HF water supply wells are completed in the confined portions of the aquifers, with compressible freshwater storage of ~3800 bgal (14 400 bL) in the play area (table S6). Projected total HF water demand (330 bgal, 1200 bL) represents ~3% of freshwater storage (9800 bgal, 37 000 bL) at the play level (table S4). The projected 20 yr water demand from all sectors (~1400 bgal based on average 2000–2012 withdrawals) is mostly irrigation (62%) and municipal (12%) use, and represents ~14% of total freshwater storage in the play (table S4). Projected HF water demand at the county level ranges from <1–27% of total freshwater storage (figure 6, table S4). Projected water withdrawal for all sectors at the county level represents 1–36% of total freshwater storage for all counties except Frio (111%) and Zavala (262%) counties which are dominated by irrigation (90–95% of county water use).

A secondary source of water for HF is the Rio Grande for counties adjacent to the river, mostly Webb County. Diversions from the Rio Grande for mining in 2011–2013 ranged from 1.1 to 2.3 bgal yr^{-1} (4.2–8.8 bL yr^{-1}; table S8). Assuming this water is available for HF, it could provide HF water for ~230–500 wells/yr assuming an average water use of 4.8×10^6 gal/well, 18.2×10^6 L/well [6] (figure S12). However, there is limited drilling near the Rio Grande and operators do not normally transport water more than ~5–10 miles.

3.4. How vulnerable is water use for hydraulic fracturing to drought?

The 2011 drought was the most extreme on record for Texas, with precipitation in the play only 42% of the long-term mean (12.3/29.3 inches, www.prism.oregonstate.edu). Droughts generally have a much greater impact on surface water than groundwater; however, reported diversions from the Rio Grande for mining for 2011 were similar to those in 2012 and 2013 (table S8). Drought should not markedly impact water demand for HF or groundwater supply, particularly for the confined aquifers which have been recharging for several thousand years [36]. The main impact of the 2011 drought was related to increased water demand for irrigation (figure 5, table S2). The increase in water withdrawal related to irrigation from 2010 to 2011 (33 bgal, 125 bL) due to the 2011 extreme drought is similar to total HF water use for 2012 and 2013 combined (30 bgal, 114 bL). However, the main irrigation region, the Winter Garden region, is mostly north of the Eagle Ford play area and generally does not compete with HF water use (figures 1 and 4).

3.5. What legal issues impact hydraulic fracturing water use?

In addition to physical availability of water, legal access to water and regulations governing water resources need to be considered. Legal challenges relate to groundwater ownership in Texas, with current law providing that landowners have a 'vested property right' to groundwater in place [37]. Therefore, regulations, including reduced permits by Groundwater Conservation Districts that would restrict landowners' access to groundwater, may constitute 'a taking' and would have to be compensated [38]. These recent rulings call into question the scope and authority of GCDs. In addition, because of confusing language in the Texas Water Code (SI, section 9), it is not clear whether groundwater produced for HF activities is exempt from GCD regulation. While groundwater use for O&G exploration in Texas is exempt from regulation, confusion results from whether to consider HF part of exploration or production.

Groundwater management by the GCDs is based on estimates of desired future conditions (DFCs) for aquifers within groundwater management areas that result from joint-planning efforts by multiple GCDs (Texas Water Code §36.108). In Groundwater Management Area 13, covering most of the Eagle Ford play (figure S4), the desired future condition is a not-to-exceed area-average drawdown of 23 ft (7 m) across the GCD by 2060. However, localized

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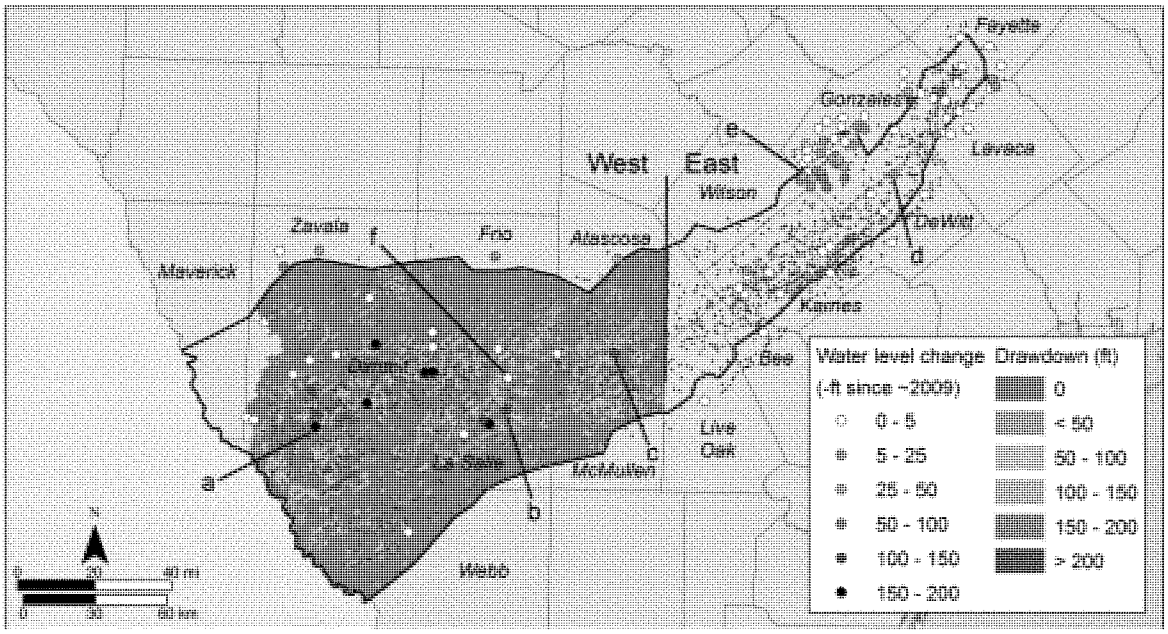

Figure 7. Monitored water level changes (large circular symbols) and estimated drawdown (1 square mile grid cells in west) in the Eagle Ford play. Monitored data are based on groundwater wells from TWDB database showing changes since 2009 when hydraulic fracturing began in the Eagle Ford play. Small gray points represent locations of oil and gas water supply wells. The gridded drawdown map in the western region represents estimated water level changes in the Carrizo–Wilcox aquifer resulting from pumping of water for hydraulic fracturing (HF) from 2009–2013. The analysis was restricted to the west because most water is derived from the Carrizo–Wilcox aquifer in this region. Water for HF is assumed to be derived entirely from compressible aquifer storage in the Carrizo–Wilcox aquifer, neglecting any water derived from recharge or cross-formational flow. Water declines >100 ft occur in 6.2% of the area, >150 ft in 3.7% of the area, and >200 ft in 2.3% of the area. There is general correspondence between the estimated water-level declines and those recorded in monitoring wells with large declines generally coinciding with areas of dense drilling to support HF.

drawdown in pumping centers will likely exceed this amount. This desired future condition translates to modeled available groundwater of ~150 bgal yr^{-1} (570 bL yr^{-1}) from the GAMs to honor the drawdown limitation and planning horizon. The 2013 HF water use (18 bgal, 68 bL) corresponds to ~12% whereas total withdrawal from all sectors (142 bgal, 538 bL) represents ~95% of the annual modeled available groundwater in this region. These desired future conditions will be revised in 2016 and should reflect groundwater pumpage for HF in the region.

3.6. What impacts does hydraulic fracturing water use have on water resources?

Groundwater level monitoring data from 131 wells in the play area indicate that water levels have declined to a maximum depth of ~200 ft (~60 m) in the west and mostly <50 ft (15 m) in the east (figures 7, 8, and S13). Greater declines in the west may be related to the deeper O&G water supply wells completed mostly in confined aquifers relative to shallower wells in the east, many of which may be completed in unconfined aquifers (figure S5). The specific yield for most of the unconfined aquifers is ~0.15 whereas the average storativity of the confined Carrizo–Wilcox aquifer in the west is 0.0012 (table S7). The ratio of the volumetric extent of cones of depression in confined versus unconfined aquifers is equivalent to the ratio of specific yield to storativity, about a factor of 1000 in many cases [39] (SI, section 9). A crude estimate of the impacts of HF water use to date (2009–2013) on groundwater levels in the confined Carrizo–Wilcox aquifer in the west was based on the assumption that all HF water was sourced from compressible aquifer storage within a mile of HF wells (figure 7). While water-level declines are small in much of the region, with 69% of western play area having no declines, 74% <25 ft (7.6 m) decline, and 81% <50 ft (15 m) decline, large declines (mostly 100–200 ft, 30–60 m) were found in 6% of the land area (figure 7). These estimates of water-level declines are generally consistent with the limited water-level monitoring data and coincident with high density of HF wells.

Impacts of past irrigation pumpage can be used as an extreme example of potential impacts of future HF water use in the region. Irrigation in the Winter Garden district lowered groundwater levels by up to 330 ft (100 m) regionally during the past century, decreasing water storage by ~4000 bgal (15 000 bL) in the Carrizo–Wilcox aquifer (figure S14). Irrigation pumpage reversed groundwater discharge in much of the region and changed some rivers (Atascosa, Frio, and San Antonio rivers) from gaining to losing [21]. No land subsidence has been recorded in this region in response to groundwater depletion, most likely because the sediments are generally indurated. Projected HF water use over the 20 yr life of the play is ~10% of groundwater depletion from past irrigation. The lack of subsidence from past depletion suggests that HF pumpage should not cause subsidence. HF pumpage may not impact rivers in the west, which are already

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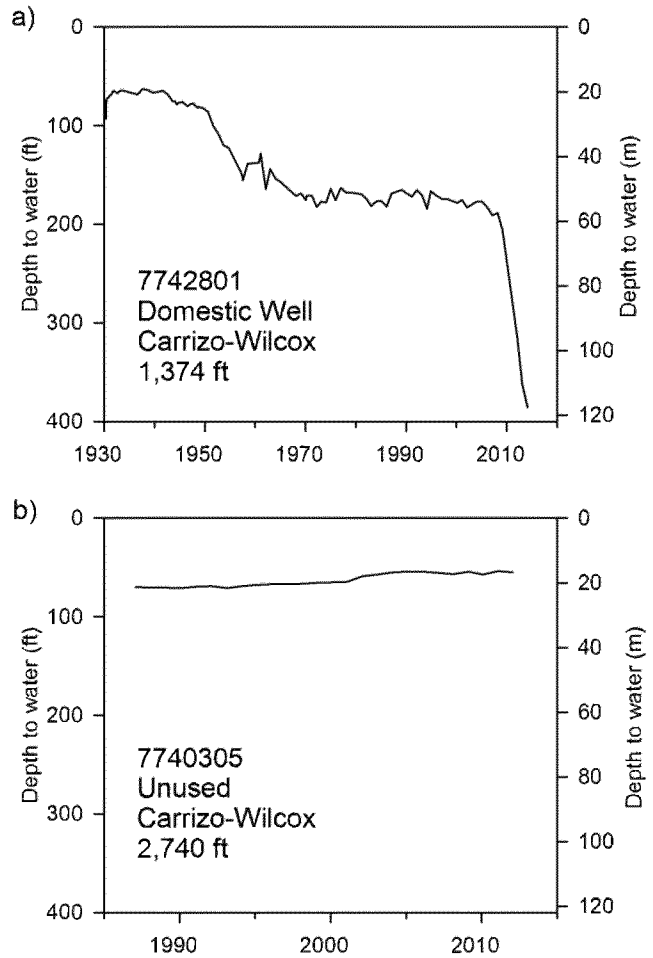

Figure 8. Water level hydrographs for '(a) groundwater well location 'a' and (b) groundwater well location 'f' in figure 7. Well 'a' shows long term water level declines resulting from irrigation withdrawals followed by recent rapid water level declines resulting from water withdrawal for hydraulic fracturing. Well 'f' shows slight increases in water levels during the period of record and no discernable water level impacts resulting from HF withdrawal. Analysis of water demand for HF indicates that these large water level declines are restricted to ~6% of the play area in the west (figure 7).

losing, but could impact river flow in the east which are mostly perennial (figure S15, table S9).

3.7. What is the net impact of hydraulic fracturing water use considering life cycle assessment (LCA)?

Previous studies emphasize the net impact of HF water use on water resources using a LCA of gas production [16, 40, 41]. The primary market for natural gas is thermoelectric power generation, with natural gas representing ~50% of power generation in Texas in 2012 (SI, section 10, figure S16). Most natural gas power plants in Texas have combined cycle generators (NGCC, 170 out of 215 TWh, 80%) with consumptive cooling water requirements totaling ~32 bgal (121 bL) in 2012 (~0.19 gal kWh^{-1}) [30]. Power generation at NGCC plants in Texas in 2012 (170×10^{12} Wh) corresponds to 580×10^{12} Btu of energy (3.412 Btu Wh^{-1} of electricity) requiring 1318×10^{12} Btu of natural gas assuming 44% fuel efficiency of NGCC power plants in Texas (i.e. 44% of the energy goes to electricity with the remaining 56% to waste heat). The amount of water required to extract Eagle Ford shale gas is estimated to be 1.5 gal/10^6 Btu [6]. If the natural gas required to power all Texas NGCC power plants during 2012 had been produced entirely from the Eagle Ford, this would represent ~2 bgal (7.6 bL) of water to extract the gas (1318×10^{12} Btu × 1.5 gal/10^6 Btu = ~2.0 bgal of water). Therefore, water consumption for extracting the gas represents ~6% of the cooling water consumed at the NGCC power plants (2.0 bgal/32 bgal), similar to the estimate of 6% for the Marcellus shale gas in Pennsylvania [40]. In addition, recent replacements of retiring coal steam turbine plants with NGCC plants, which have 1/3rd of the cooling water requirements, result in a net savings of water in the state [32, 42]. However, this water savings does not occur where the gas is produced in the west but where the power in generated, mostly in the central and eastern parts of the state.

Many suggest that the net impact of HF water use on water resources and the hydrologic cycle is much greater than that of other sectors, such as irrigation, because FP water in Texas is mostly disposed of in deep injection wells and removed from the hydrologic cycle (figure S5). However, in the Eagle Ford play, most of the water used for HF is not part of the active hydrologic cycle to begin with as it is mostly derived from deep confined aquifers that have been recharging for several thousand years [36]. In addition, previous studies indicate that methane combustion from natural gas in the Marcellus Shale play puts water vapor back into the hydrologic cycle (5.7×10^6 gal/well, 22×10^6 L/well) that more than compensates for HF water use (3.6 mgal/well, 14×10^6 L/well) [40]. Similar calculations for the Eagle Ford indicate that water vapor from methane combustion alone based on methane production to date is equivalent to ~90% of HF water use in the play (SI, section 10), ignoring water vapor generated by combustion of other hydrocarbons produced in the play.

3.8. What strategies can O&G operators adopt to increase resilience of hydraulic fracturing to water constraints?

Operators are considering various approaches to reduce vulnerability of HF to water constraints and reduce impacts of HF on water resources. The basic approaches include reducing water demand, increasing water supplies (particularly non-freshwater supplies), and intersectoral transfers (primarily from irrigation to HF). Water demand can be reduced by changing HF fluid types as shown by a recent analysis indicating ~55–110% higher water demands associated with slickwater HF relative to cross-link gel HF; however, these changes in HF fluid types generally occurred in the early stages of Eagle Ford play development [6]. Water demand can also be reduced through reuse-recycling of FP water. Non-freshwater sources include brackish water and municipal waste water.

3.8.1. Flowback/produced water. Small FP water volumes generally do not support reuse/recycling requirements. FP/HF

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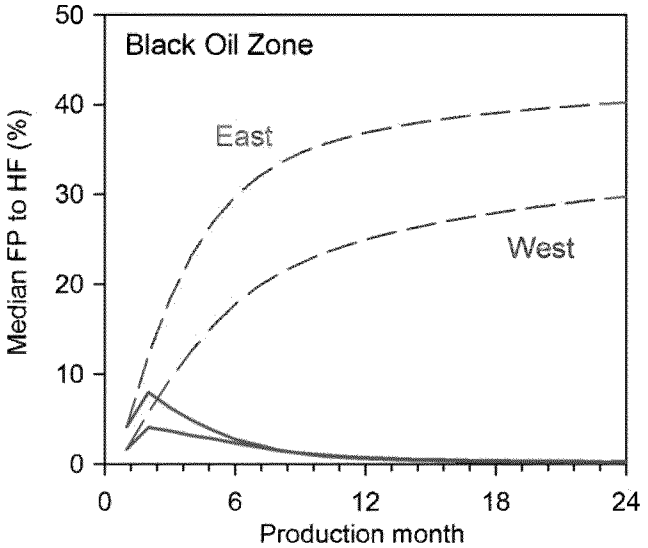

Figure 9. Monthly (solid lines) and cumulative (dashed lines) median FP to HF ratio in the east and west regions of the Black Oil production zone.

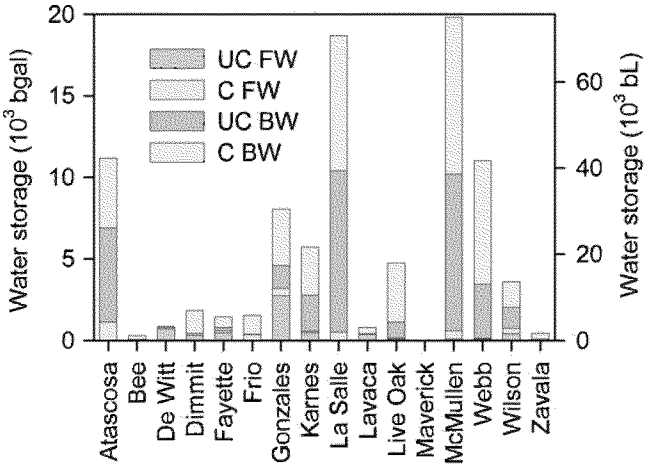

Figure 10. Estimated total fresh water (FW) and brackish water (BW) storage under unconfined (UC) and confined (C) aquifer conditions by county in the Eagle Ford play based on groundwater availability models (GAMs) and water quality data.

ratios are generally <5% within the first month of well completion in all production zones, making it difficult to collect sufficient water to support recycling for HF (figures 9, S18). Most FP water is disposed of in the ~700 active UIC Class II injection wells in the 18 county area, including and extending beyond the 16 counties in the Eagle Ford play (figure S5). The quality of the FP water is not highly saline, with reported values of ~40 000 mg L^{-1} TDS. Some operators are doing a limited amount of recycling; however, there is no formal reporting of these volumes. Portable treatment units are used to treat the FP water, particularly for reducing boron levels, which must be managed for the cross-link gel HF fluid additives. The logistics of recycling is complicated because of the low FP volumes. The economics of recycling is also generally not favorable with relatively low injection well disposal costs.

To promote reuse/recycling of FP water the Texas Railroad Commission modified their rules in March 2013. The new rules allow operators to recycle FP fluids on their own leases or they can transfer those fluids for recycling to another operator without the need for a permit [43]. Some operators report that these new rules promote increased reuse/recycling of water.

3.8.2. Brackish groundwater resources. There is an estimated ~35 000 bgal (130 000 bL) of brackish water in unconfined sections of aquifers and ~45 000 bgal (170 000 bL) of compressible brackish groundwater storage in the confined sections of the aquifers in the Eagle Ford play area, totaling 80 000 bgal (300 000 bL, figure 10, tables 1, S4, S10). Projected 20 yr HF water demand represents 0.4% of brackish groundwater storage, suggesting sufficient water at a play level. At the county level, projected HF water use is ⩽16% of total brackish water storage (table S4). Projected total water demand by all sectors represents ~2% of brackish water storage at the play level and ranges from 0–13% of brackish water storage, with the exception of Frio (35%) and Zavala (78%) counties where irrigation is dominant and DeWitt county (62%) where brackish water is limited.

A previous survey of operators in 2010 indicated that ~20% of the HF water use throughout the play was brackish [44]; however, HF water use has expanded greatly since that time. To avoid impacting shallower domestic wells, many operators report drilling into deeper units to limit the potential for competition for shallow groundwater. Some operators indicate that 60–80% of their water use is brackish (e.g. Marathon Oil Company reported 85% of their water use in 2012 was non-freshwater, [45]); however, there is no formal reporting of this water source. Another operator reported flowing artesian production from a 6000 ft (1800 m) deep well in the eastern part of the play (Dewitt County) with TDS of ~36 000 mg L^{-1}. Water treatment is often required to make the water compatible with HF fluid additives. To incentivize use of brackish groundwater, the Pecan Valley GCD recently revised their regulations to allow up to 20 times more groundwater pumpage if brackish water is withdrawn from the aquifer (SI, section 9).

3.8.3. Municipal waste water. Some municipalities are selling their waste water to intermediary companies to provide water to operators (SI, section 11). For example, Laredo Utilities Department contracted 5×10^6 gal d^{-1} (19×10^6 L) which could be used to HF 380 wells/yr (4.8 mgal/well) or could supply ~50% of HF water in Webb county based on 2012 HF water use (table 1). However, infrastructure needs to be built to transport this water to HF sites. Most municipal waste water was previously disposed of in surface water bodies using a National Pollution Discharge Elimination System permit. The Texas state water plan projects continually increasing municipal water demand in the future; therefore, municipalities may require this waste water to meet their own future water demands.

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3.8.4. Purchasing water from irrigation. Intersectoral water transfers have been proposed in semiarid regions, primarily purchasing water from the irrigation sector [13, 14]. However, the dominant irrigation region in the Eagle Ford play (Winter Garden region) is generally not collocated with the highest density of HF wells (figures 1 and 4), reducing the feasibility of intersectoral water transfers within the play. However, another study suggested that increasing irrigation efficiency in the Lower Rio Grande Valley, downstream of the Eagle Ford play, could provide ~250–500 bgal water/yr for HF, though infrastructure development would be required to transport the water to HF sites [46].

3.9. Overall water supply versus demand and related uncertainties for the Eagle Ford Play

The previous discussions of water demand versus supply focused on fresh and brackish water separately. However, projected HF water demand is a small percentage of total water resources at both the play (0.4%) and the county (0.1–6%) levels. Projected total water demand for all sectors (HF, irrigation, municipal and other) is also a small percentage of total available water at the play level (1.6%) as well as at the county level for most counties (0.2–7%), excluding two counties with high irrigation demands (Frio: 27%, Zavala: 60%), and one county (Maverick) that has essentially no modeled available groundwater resources in the play (table S4). Mapping the relationship between demand and supply indicates that there should not be problems with available water throughout much of the play, with the highest demands relative to supplies focused where irrigation demand is currently high in the northwest (figure 11).

Uncertainties in water demand to date (2009–2013) are considered relatively low because of the reporting requirements and availability of multiple databases [6]. The analysis of water demand in the Eagle Ford play is hindered by lack of reporting requirements for the source of water used for HF (e.g. surface water, groundwater, recycled FP water) or the quality of the water used (fresh versus brackish). Uncertainties in projected HF water demands are considered high because they are based on the assumption that the HEWD to date will apply to entire O&G production zones. A much more granular analysis based on square mile productivity and considering production economics, such as that available for the Barnett play [7], is required to improve estimates of projected HF water demand. This level of analysis is currently being conducted for a project funded by the Sloan Foundation [47]. Uncertainties in water demand for other sectors also need to be considered and are considered high for irrigation. Current studies funded by TWDB are evaluating remote sensing approaches to improve these estimates [48].

Data on water supplies in the Eagle Ford rely heavily on GAMs for the region. These models were designed to assess mostly freshwater resources in aquifers; however, the Bigford and Laredo Fms. which are stratigraphically equivalent to the Queen City and Sparta, respectively, west of the Frio River are not considered aquifers and recharge and storage estimates are considered less reliable west of the Frio River. The emphasis of these models is on fresh water and estimates of brackish water are not as reliable because of limited data availability. Future models should be developed that focus on brackish water resources and integrate data being collected by industry in these regions. A recent analysis of geophysical logs in the Eagle Ford play supports the estimated volumes of brackish water in these regions [49] (figure S24). While comparisons of water demand versus supply in this study have been limited, future modeling would provide more comprehensive comparisons that would include all the water sources, including groundwater from recharge and fresh and brackish water storage, and leakage from adjacent geologic units. More detailed models may be required for assessing water demand versus supply at the level of municipalities. The impact of pressure loss in confined aquifers on well yields is not known in detail. In particular, how many water wells would be required to produce similar water volumes and would water production be economical?

While the current water level monitoring network has been invaluable in documenting impacts of water use in the play on groundwater depletion, this network should be expanded and should be designed to provide detailed information in critical areas, such as those in the vicinity of municipal well fields.

4. Comparison with shale plays in other semiarid regions

The semiarid Permian Basin in west Texas includes conventional and unconventional production, with HF water use totaling 10.4 bgal (39 bL) from 9308 wells for 2.5 years (2011–mid-2013) [5]. Water use for conventional production has shifted from predominantly fresh (85%) in 1995 to brackish and produced water (80%) in 2010 based on a survey of operators in 2010 [44]. HF water use may follow a similar trend, with many current lease agreements stipulating freshwater use to provide revenue streams to landowners. Some use the term 'water play' to refer to the water markets in this region. A reconnaissance analysis from GAMs indicates large volumes of brackish groundwater resources in the underlying aquifers (figure S25), totaling an estimated 360 bgal (1360 bL) in compressible storage (table S11) [50]. Uncertainties in the location and accessibility of these brackish resources should decrease with increased exploration and production. Collocated unconventional and conventional energy production means that the large volume of produced water with conventional oil production (volumetric produced water to oil ratio of ~8 from 2009–2012, table S12, similar to that in the USA [51]), may provide additional water for HF in the region, if it is not used for water flooding for conventional oil production. Presentations in a recent symposium sponsored by the Railroad Commission of Texas on reuse/recycling of water indicated increasing trends in some companies to use brackish and FP water and discontinue use of freshwater [52] (SI, section 12).

The Bakken play is the second largest shale oil producer in the USA with HF water use of 16 bgal (60 bL) for 7868 wells from 2005 through 2013 [6]. Low precipitation rates in the Bakken play in North Dakota and Montana (mean 14.6

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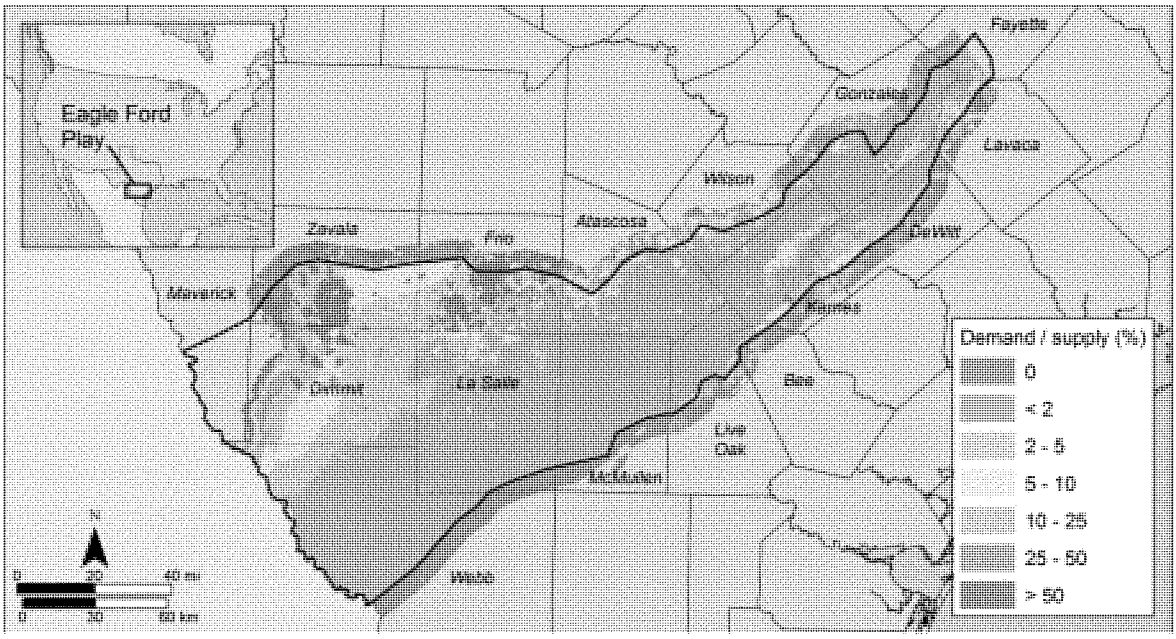

Figure 11. Distribution of the projected total 20 yr water demand for the HF, irrigation, and municipal sectors expressed as a percentage of available total groundwater storage per square mile, including freshwater and brackish water. HF demand assumes that the Eagle Ford play matures to the current seven-zone highest established well density in each production zone (figure S7) and that irrigation and municipal demands equal the average annual sector demands for the period 2000–2012 multiplied by 20 yr (projected life of the play) (figure S8). Note this depiction does not account for distribution or transport of water demand or supply across cell boundaries and assumes the current land use footprint remains static. Higher percentage of demand versus supply areas located along the southeastern play boundary in Lavaca, DeWitt, Karnes, and Bee counties reflect the Carrizo–Wilcox, Queen City-Sparta, and Yegua-Jackson GAM model limitations in regions with high groundwater TDS.

inches/yr (370 mm yr^{-1}), 1981–2010, PRISM precipitation, figure S26) might suggest that HF production could be vulnerable to water constraints. However, the Missouri River provides a major source of water in the region, with the Sakakawea Reservoir (7800 bgal (30 000 bL) storage capacity, figure S27) located in the middle of the Bakken play, though regulatory issues currently limit access to this water source, which is controlled by the USA Army Corps of Engineers. Additional water is provided by groundwater with water depots in different regions of the play. In addition, low population density and limited irrigation, particularly in the North Dakota region of the play, reduces water stress in the region (table S13).

5. Conclusions

(1) Water demand for HF in the Eagle Ford (18 bgal in 2013) represents 16% of consumptive water use in the play area. Maximum projected HF water use over the next 20 yr is 330 bgal from 62 000 additional wells, representing ~8 times HF water use to date. Projected HF water use represents ~10% of historic groundwater depletion resulting from irrigation in the adjacent Winter Garden region over the last century.

(2) Water supplies for HF include groundwater recharge, estimated to be ~60 bgal yr^{-1} in the aquifer outcrop area and ~20 bgal yr^{-1} in the deep confined aquifers.

(3) Additional water supplies are provided by fresh groundwater storage, with projected HF water use (330 bgal) representing ~3% of groundwater storage in the play.

(4) While regional impacts of water pumpage to support HF are small, localized impacts can be large with estimated water level declines of ~100–200 ft in ~6% of the western play area.

(5) The net impact of HF water use based on life cycle of natural gas is low, with HF water use for gas extraction representing ~6% of water consumed at the power plants.

(6) Brackish groundwater may provide a viable alternative to freshwater with projected HF water use representing 0.4% of the estimated 80 000 bgal of brackish groundwater storage.

(7) There is limited potential for reuse or recycling of flowback or produced water because of small volumes (□5% of HF water requirements in the first month) in the Eagle Ford play.

(8) Evaluation of HF water use in the semiarid Permian Basin play in Texas indicates increasing use of brackish groundwater and recycling of produced water, which benefits from large volumes of produced water from collocated conventional oil production (volumetric water: oil ratio of ~8). In the Bakken play in N Dakota and Montana, water inputs from outside this dry basin through the Missouri River provide a large potential

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resource for HF, although currently limited because by regulatory restrictions.

(9) The comprehensive analysis of Eagle Ford water issues and comparison with other semiarid plays indicates that, with proper management, water should not constrain HF in these semiarid regions.

Acknowledgments

We would like to acknowledge the Jackson School of Geosciences, the Shell University of Texas Unconventional Research (SUTUR) program, BP, and the Mitchell Foundation for funding this study. We would also like to acknowledge free access to the Enerdeq database provided by IHS. We are very grateful to Dr Yun Huang for input to model parameters for the southern Carrizo–Wilcox aquifer. We appreciate communications with various O&G operators in the Eagle Ford play and discussions with members of the South Texas Energy and Economics Roundtable. We appreciate input on groundwater modeling from Shirley Wade and groundwater monitoring from Janie Hopkins, both at TWDB. We are grateful for reviews by Walt Ayers (Texas A&M Univ.), Jim Bradbury (James D Bradbury PLLC), Ron Green (Southwest Research Institute), Robert Mace (TWDB), William Mullican (Mullican & Associates), and two anonymous reviewers.

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Cc: Fleming, Megan[Fleming.Megan@epa.gov]; Jonathan.Koplos[Ex. 4]Ridley, Caroline[Ridley.Caroline@epa.gov]
To: MaryEllen.Tuccillo[Ex. 4]
From: LeDuc, Stephen
Sent: Wed 2/25/2015 8:46:44 PM
Subject: Re: Chapter 8 comment: TX reuse #s
Nicot et al. 2014 ES&T.pdf

Hi Mary Ellen,

I'm sure you have this article, but just in case I thought I'd send it along. It is really detailed about reuse and disposal in the Barnett, beyond earlier Nicot articles. Ex. 5

Ex. 5

Best, Steve

Stephen D. LeDuc, PhD

US Environmental Protection Agency

National Center for Environmental Assessment, Arlington, VA 22202

Office Phone: (703) 347-8962; AWL Phone Ex. 6

From: Mary Ellen Tuccillo[Ex. 4]
Sent: Wednesday, February 25, 2015 12:40 PM
To: LeDuc, Stephen
Cc: Fleming, Megan; Jonathan.Koplos[Ex. 4]
Subject: RE: Chapter 8 comment: TX reuse #s

Ex. 5

From: LeDuc, Stephen [mailto:LeDuc.Stephen@epa.gov]
Sent: Wednesday, February 25, 2015 9:59 AM
To: Mary Ellen Tuccillo
Cc: Fleming, Megan; Jonathan Koplos

Subject: Re: Chapter 8 comment: TX reuse #s

It is Table 8-5 in the pdf version. Does that help?

Stephen D. LeDuc, PhD

US Environmental Protection Agency

National Center for Environmental Assessment, Arlington, VA 22202

Office Phone: (703) 347-8962; AWL Phone (Mon & Fri): (301) 957-8390

From: Mary Ellen Tuccillo <maryellen.tuccillo@cadmusgroup.com>
Sent: Wednesday, February 25, 2015 9:52 AM
To: LeDuc, Stephen
Cc: Fleming, Megan; Jonathan.Koplos Ex. 4
Subject: RE: Chapter 8 comment: TX reuse #s

Hi Steve,

Thanks. I will take a second look at those sources Ex. 5

Ex. 5

Thanks!

Mary Ellen

Mary Ellen Tuccillo, Ph.D.

The Cadmus Group

100 5th Ave., Suite 100

Waltham, MA 02451

Ex. 4

Water is the driving force of all nature. Leonardo da Vinci

From: LeDuc, Stephen [mailto:LeDuc.Stephen@epa.gov]
Sent: Wednesday, February 25, 2015 9:38 AM
To: Mary Ellen Tuccillo
Cc: Fleming, Megan; Jonathan Koplos
Subject: Chapter 8 comment: TX reuse #s

Hi Mary Ellen,

Ex. 5

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Environmental Science & Technology

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Source and Fate of Hydraulic Fracturing Water in the Barnett Shale: A Historical Perspective

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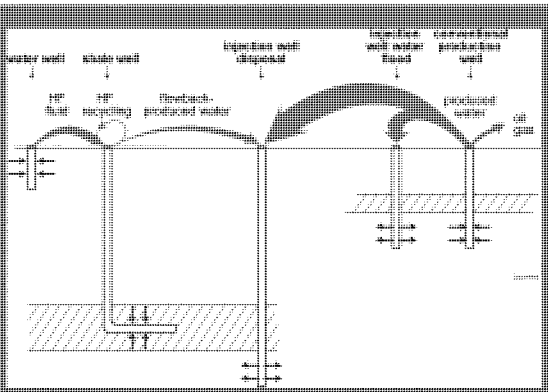
* Supporting Information

Considerable controversy continues about water availability for and potential impacts of hydraulic fracturing (HF) of hydrocarbon assets on water resources. Our objective was to quantify HF water volume in terms of source, reuse, and disposal, using the Barnett Shale in Texas as a case study. Data were obtained from commercial and state databases, river authorities, groundwater conservation districts, and operators. Cumulative water use from ~18 000 (mostly horizontal) wells since 1981 through 2012 totaled ~170 000 AF (210 Mm^3), ~26 000 AF (32 Mm^3) in 2011, representing 32% of Texas HF water use and ~0.2% of 2011 state water consumption. Increase in water use per well by 60% (from 3 to 5 Mgal/well; 0.011−0.019 Mm^3) since the mid-2000s reflects the near-doubling of horizontal-well lengths (2000−3800 ft), offset by a reduction in water-use intensity by 40% (2000−1200 gal/ft; 2.5−1.5 m^3/m). Water sources include fresh surface water and groundwater in approximately equal amounts. Produced water amount is inversely related to gas production, exceeds HF water volume, and is mostly disposed in injection wells. Understanding the historical evolution of water use in the longest-producing shale play is invaluable for assessing its water footprint for energy production.



INTRODUCTION

Hydraulic fracturing (HF) has become a hotly debated topic, particularly in regard to the volume of water used and the potential for aquifer contamination.[1,2] Although HF and horizontal drilling has been practiced for decades, the combination of the two resulted in the exponential increase in gas production from <1% of U.S. gas production in the early 2000s to 40% in 2012[3] (9.6 Tcf; 9.6×10^{12} standard cubic feet; 272 Gm^3). With expansion of HF into more water-scarce regions in the western U.S. and potential expansion into semiarid regions globally, understanding the volume of water required for HF is particularly important. Even in more humid settings, water availability can be an issue during droughts. Previous studies estimated HF water use for Texas [2011: 81.5 thousand AF (kAF), 100.2 million m^3 (Mm^3), including shales and tight formations, SI section] and in Colorado (2011: 15 kAF/yr, 18.5 Mm^3/yr).[4,5] An estimated 13.2 kAF (16.3 Mm^3) was used for HF in Oklahoma in 2011.[6] Although these water-use estimates represent a small fraction of water used in each state (~0.1% in Colorado, ~0.5% in Texas, and <0.5% in Oklahoma), the volumes may be significant locally, depending on competition with other sectors. Additional water-use estimates are available for the Marcellus Shale, totaling 32 kAF (39 Mm^3) consumed between June 2008 and the end of 2012 in the Susquehanna River Basin, mostly in 2011−2012 (15−20 kAF/yr; 18−25 Mm^3/yr)[7] and 23.5 kAF (29 Mm^3) within the 2008−2012 period in the Upper Ohio River Basin, mostly in 2011−2012 (8.4 kAF/yr; 10.4 Mm^3/yr).[8] Water demand in the Bakken area is estimated to be ~22 kAF/yr (~27 Mm^3/yr).[9,10]

Understanding the source of the water used for HF is important to assess the impact on water resources. To date, much of the water used has been fresh water from surface water or groundwater sources. Plays in more humid regions generally rely on surface water, whereas limited surface water availability in more semiarid regions may result in more groundwater use. The Marcellus Shale play uses predominantly surface water controlled by different river basins, e.g., the Susquehanna and Delaware basins.[11] In contrast, the Eagle Ford play lies mostly in a semiarid region and relies heavily on groundwater from the Carrizo-Wilcox aquifer because of limited surface water availability.[4]

The amount of HF water that flows back to the surface, commingled with water from the formation (produced water), termed flowback-produced (FP) water (see SI), is important because it controls the absolute volume that can be reused or recycled or the volume that must be disposed.[12,13] Reuse is generally understood as requiring little treatment, whereas recycling suggests more involved treatment.[12] Shale formations (Marcellus[14] and Eagle Ford[15]) traditionally have been described as having small volumes of FP water.

Received: September 11, 2013
Revised: January 22, 2014
Accepted: January 27, 2014
Published: January 27, 2014

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Disposal approaches vary by play. Piping and trucking to centralized facilities for treatment and reuse is dominant in the Marcellus Shale with some on-site operations,[14,16,17] but injection wells (see SI) are preferred in the Barnett,[4] Eagle Ford,[15] and Bakken[10,18] areas, despite improving technological capabilities in using high-salinity waters (50 000 mg/L and higher total dissolved solid (TDS)).[19]

The Barnett Shale play provides an ideal case for assessment of issues related to production of unconventional resources such as shale gas or shale oil. The Barnett Shale area (~26 000 mi^2, 68 000 km^2) occupies ~45 counties in Central and North Texas, extending from suburban to rural settings (Figure S2). This study focuses on a ~10 000 mi^2 (~26 000 km^2) area in ~15 counties in the eastern area of the shale footprint with hydrocarbon production potential.[20−23] It includes the core area (Figure 1) and most of the development activity. It was the first shale play in the world to be fully developed with HF[23,24] and be subjected to intense HF. After a start in 1981 and through the 1990's with vertical wells, the combined use of horizontal drilling and HF that originated in the play in the early 2000s has allowed economical recovery of gas from shales. Operational details related to HF as applied to the Barnett Shale have been described.[19−23] The Barnett Shale produced an average of 1.9 Tcf/yr in the 2008−2012 5-year period (2.1 Tcf in 2011), to be compared to a total U.S. gas production of 28.5 Tcf in 2011, including 8.5 Tcf from shale gas wells.[3] Cumulative production since 1993 totals 14.9 Tcf as of April 2013.[25] Total production, including past and projected production, has been estimated at 45.1 Tcf.[26]

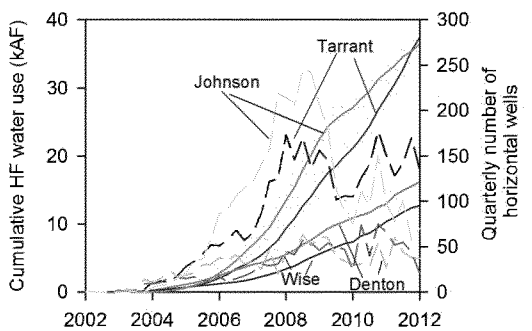

Figure 1. Cumulative water use for horizontal wells and their quarterly well count in the four counties of the core area (Denton, Johnson, Tarrant, and Wise; see SI).

Gas production began in the mid-1990s using vertical wells and transitioned in 2003−2005 to mostly horizontal wells. Following a period of strong growth in the mid-2000s (>2000 wells/yr), drilling declined in the late 2000s because of reduced demand following an economic slump toward the end of the decade and decreasing natural gas prices. Although drilling activity has abated at the edges of the play core, it is still vigorous in the core itself[26,27] and has increased in the so-called combo play (combined oil and gas production) in the northern portion of the play, in Cooke and Montague counties where HF-enhanced oil production has increased sharply since mid-2010.

The objective of this study was to assess the amount of water used for HF and the sources of that water, followed by an analysis of FP water and of its fate, including evaluation of disposal through injection and recycling (Figure S1). This study builds on previous work[4] that quantified HF water use in all Texas shale plays up to mid-2011 by increasing spatial resolution, increasing temporal resolution from annual to quarterly, extending analysis from water use to disposal and reuse, and assessing reliability of results by interviewing operators.

MATERIALS AND METHODS

Water Use for Hydraulic Fracturing. Data on water use were obtained from the commercial IHS database,[28] which, in turn, is based on water use that is self-reported by operators to the Railroad Commission (RRC), the state regulatory agency for oil and gas activities in Texas. Building on Nicot and Scanlon,[4] the analysis time period extends through December 2012. The analysis focuses on 2000 and the following years, as pre-2000 water use is <1 kAF (<1 Mm^3). Data reporting from Barnett Shale operators is high, with >90% of wells reporting water volume, proppant amount, and lateral length of wells providing multiple checks on the reported water-use data. Water-use intensity (water volume used per unit length of lateral), proppant loading (proppant mass per unit water volume), and mean and median values were used to detect reporting errors.[4,29] Similar information is available from the Web site FracFocus (http://fracfocus.org), but, as of August 2013, not in a format that can be readily queried and, more importantly, FracFocus only includes data from 2010, precluding retrospective analysis.

Source of Water for Hydraulic Fracturing. The source of water for HF is more difficult to access than amount of water used, because no regulation requires reporting of water sources. Therefore, we relied on a mix of hard data and soft data such as interviews to provide estimates. The industry generally uses water sources that are most readily available and economic for a given time and location. Sources can be classified into unequivocal (1) surface water and (2) groundwater, with several other minor categories of either ultimate origin and in decreasing importance: (1) municipal water from either urban reservoirs or water hydrants; (2) recycling/reuse of HF water, of treated industrial or municipal wastewater; and (3) small, distributed sources such as farm ponds. The information can be obtained from either the users (industry) or the water suppliers. We interviewed several major operators in the play about their practices relative to water sourcing in 2012[30] and again in 2013.

Water suppliers include self-suppliers, local landowners, municipalities, larger water districts, and river authorities with various levels of reporting and data accessibility. The first two groups (self-suppliers and landowners) rely mostly on groundwater, whereas the last two groups use surface water mostly. Information on groundwater use is generally obtained from groundwater conservation districts (GCDs, see SI). The study area contains five multicounty GCDs (Figure S2) out of ~100 in the state, all but one created within 2007−2009 (Table S1); therefore, only very recent data are potentially available. Whereas groundwater is owned by the landowner and withdrawals are controlled by the rule of capture with some restrictions posed by GCDs, surface water use follows a prior appropriation doctrine ("first in time, first in right") and is owned and strictly regulated by the state, which grants permits and regulates the resource. As such, volumes of surface water withdrawn are well-known but their ultimate use is not, because several uses are bundled into larger categories, e.g., in the case of HF, "mining." River authorities are state entities that manage their respective river basins and operate reservoirs and treatment plants. They also hold some water rights. Four

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river authorities (Figure S2) could potentially provide water to the oil and gas industry. We contacted GCDs, river authorities, water districts, and several municipalities (Fort Worth, Arlington) in the course of this study.

Hydraulic Fracturing Water Quality. Overall, public-domain information on ionic composition of HF water is qualitative at best. Water quality is not reported to the RRC. Some companies report TDS, but not the ionic makeup of HF fluids, to FracFocus. Operator interviews provided additional information. Water quality can be inferred from some sources, e.g., surface water and wastewater treated to state standards being fresh.

Flowback-Produced Water Characteristics. RRC regulations require that operators report oil, gas, and water production on a monthly basis. Although operators perform routine chemical analyses on an as-needed basis, TDS and ionic makeup of FP water are not recorded systematically and very few data sets are available in the public domain. Production water volumes were compiled from the IHS database.[28] About 10% of the wells do not have production water data, most likely because of lack of reporting, and is consistent with the fraction of wells with no reported HF water use. We examined a total of 12 228 horizontal wells.

Injection of FP Water for Disposal. Information about injection volumes is accessible through both the IHS database[28] and the RRC Web site. The RRC has the apparent benefit of singling out disposal from HF operations, whereas IHS provides information about individual wells but not the source of the injected water. The RRC regulates U.S. EPA Class II wells and has for many years been tracking water injected for disposal and water used for waterflooding and reservoir pressure maintenance. Injection can be done by commercial entities, which manage wells disposing of oil and gas waste and salt water into nonproducing intervals, or by oil and gas companies, which operate the vast majority of Class II wells.

In Texas, most FP water is disposed of into injection wells · information that has recently (end of 2011) become specifically available from the RRC.[31] In the past, reporting of Class II injection from HF operations was combined with conventional (not HF) salt-water disposal. The Texas Class II injection well count is ~50 000; ~20% of these are disposal wells · i.e., injecting into nonproducing formations. A query of the IHS database for Class II wells in the 15-county area yielded ~2000 wells. Fluid injection into 1383 wells was reported during the period from 2001 through 2012. Unlike production, which must be reported on a monthly basis, injection volumes are reported to the RRC only annually; therefore, injection volumes in this study are accurate only if reported before and during summer 2012.

RESULTS AND DISCUSSION

Overall, hydrocarbon production is fragmented among ~250+ operators but dominated by a few companies. According to the IHS database, a total of 17 685 horizontal and vertical wells reported in the play at the beginning of 2013 were operated by 250+ companies (see SI).

Water Use. Historical Water Use and Consumption. Barnett Shale water use in 2011 totaled ~25.8 kAF, amounting to ~32% of the total HF water use in Texas in 2011, including HF in tight formations,[30] and down from a high of 28.8 kAF in 2008 (Figure S3). Until the end of 2002, wells were mostly vertical and restricted predominantly to Denton and Wise counties (with a cumulative total of ~3.8 and ~3.6 kAF), out of a cumulative total of 8.3 kAF. The estimated total amount of water used in the play to the end of 2012 is ~170 kAF, including ~152 kAF for horizontal wells (Figure S4a,b) and an additional ~18 kAF for vertical wells. Tarrant and Johnson counties are the largest water users (Figure 1). Water use increased outward from the core area until 2008, contracted back to the core area in 2009, and then shifted toward the combo play to the north and the liquid-rich area to the northwest (Figures S5 and S6).

Water use is currently almost exclusively related to HF of horizontal wells, which peaked in 2008 with fracturing of ~2750 horizontal wells. The peak year for HF of vertical wells occurred in 2002 with a total of ~750 wells. Horizontal wells account for the bulk of the water use and the length of the laterals has been slowly increasing in the past few years (median ~3800 ft in 2011), with a concomitant increase in water use per well (Figure 2a, Figure S4c; Figure S7). Water use is often

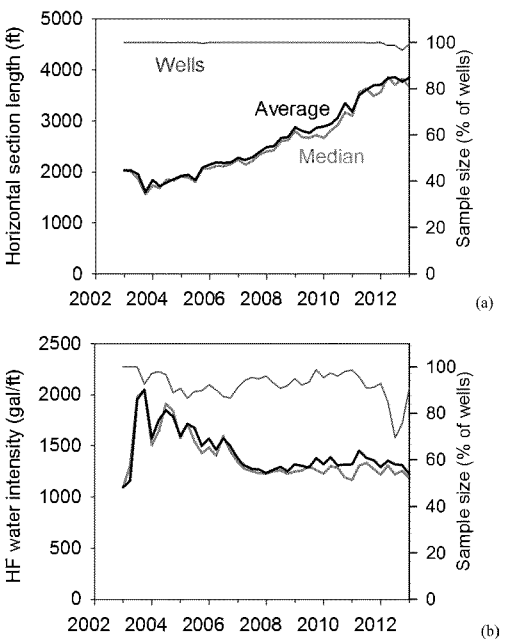

Figure 2. Data on Barnett Shale horizontal wells, including various historical parameters and coefficients for reported and estimated water use as a function of time: (a) average/median lateral length and fraction of wells for which it is reported; (b) average/median water-use intensity and fraction of wells for which both HF water use and lateral length are reported. Tick marks on the x-axis represent the beginning of the year. Other parameters are reported on Figure S4 (number of wells completed per quarter and cumulative count; cumulative water use; average/median water use per well; and average/median proppant loading).

reported on a per-well basis, and, in the case of the Barnett Shale, water use per well has increased from ~3 Mgal/well in mid 2000s to ~5 Mgal/well in 2011 (1 Mgal = 3.8 thousand m^3). However, increasing trends in water use per well are misleading because they reflect an almost doubling of the lengths of laterals during that time. A more useful indicator is normalized water use per length of lateral or water-use intensity, which has remained steady at ~1100−1200 gal/ft (1.4−1.5 m^3/m) since 2007 (Figure 2b). Note that, in the years 2003−2006, water-use intensity was generally much higher but was steadily decreasing, finally stabilizing when operators perfected the HF technology in horizontal wells; a total of

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~2300 horizontal wells were completed to the end of 2006 vs an estimated 10 500 wells from that point to the end of 2012. In contrast to water-use intensity, proppant loading has been increasing over time, from 0.2 lb/gal in 2002 to ~0.8 lb/gal in 2009 (25 to 100 kg/m^3), plateauing until the beginning of 2012, and slightly decreasing since then (Figure S4d).

Water consumption is different from water use. In this work, water use is defined as the amount of water required to perform HF stimulations, whatever the source of the water. Water consumption is defined as the amount of fresh water abstracted from surface water or groundwater. Most water used in the Barnett Shale is estimated to be consumed; operator interviews reveal that ~23.7 kAF (~92% of total water use) was consumed in 2011. Additional HF water (~5%) is derived from reuse/recycling of used-water streams. The remainder (~3%) consists of brackish water originating from mostly brackish water sections of aquifers.

The Barnett Shale water use represents a small fraction (0.14%) of total statewide water use (18.1 million AF in 2011) as reported by the Texas Water Development Board (TWDB). Water use in Texas is reported in terms of withdrawal for all categories and consumption for thermoelectric generation. Total water use has averaged 15.4 million AF/yr for 2005 through 2011, with interannual variations related mostly to irrigation needs. Statewide water consumption has been estimated at 10.2 million AF in 2010[32] and 11.4 million AF on average for the period 2005−2011 (13.4 million AF in 2011 translating into 0.18% for Barnett Shale water consumption). When analyzed at the county level, HF water use can represent a much higher fraction, especially in rural, sparsely populated counties (Figure 3). However, water may originate from outside the county, particularly in large population centers (see below). Water for auxiliary uses, e.g., for drilling, is relatively small and strongly operator-dependent. For example, some operators use oil-based muds requiring very little water, while others use water-based muds potentially requiring up to 0.5 Mgal/well but more often <0.25 Mgal/well.[29,33]

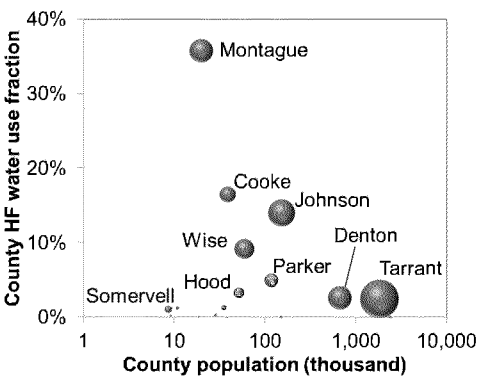

Figure 3. 2010 County population vs 2011 fraction of water use in the county for HF purposes. Bubble size is related to absolute HF water use (for example, 8.8 kAF in Tarrant County, 1.5 kAF in Cooke County, and 0.3 kAF in Somervell County).

Water-use intensity is higher in Denton County and in the eastern half of Wise County, where the Barnett Shale is deepest and also where many older horizontal wells are located (Figure S8). High water-use intensity in Montague County most likely reflects early production from the oil window. The cumulative length of laterals in a given area or county (Figure S9) can be used to estimate the average well density (Figure S10). Density of well laterals is fairly high in Johnson County and the southern half of Tarrant County. The county with the highest relative cumulative length of laterals (Johnson County) yields an average spacing between assumed parallel laterals of ~1700 ft (Table S2). This value is much greater than the operational distance between laterals of ~1000 ft or even 500 ft,[33,34] suggesting that Johnson County, despite its past HF activity, is still likely to see further significant drilling and HF activity, as illustrated by the coverage gaps (Figure S8). The decrease in well completion activity in Johnson County (Figure 1) is more related to gas prices than to true depletion of the resource.

Source and Quality of Water for Hydraulic Fracturing. Data on the source of HF water are sparse. The industry is fragmented, and within the same company, practices may differ from one lease to the next and through time. Water contracts are signed and expire in a very dynamic business environment, suggesting that collected information can only be considered semiquantitative. Available data suggest that the play as a whole relies roughly equally on both groundwater and surface water. At least three temporal phases are discernible, with the middle phase relying more on surface water but all relying strongly on fresh water. During the initial phase, up to 2006, groundwater was estimated at 50%+ of total water consumption.[35] Interviews suggest that, during the second phase, 2007−2010, operators used more surface water, estimated at 70−80% of water consumed during that period,[30] but with considerable variations among operators and locations. A plausible explanation for such a pattern resides in the typical approach followed by operators. Water-supply wells initially tap local groundwater unless the stimulated well is close to surface water. Then, after the initial period during which operators drill to hold leases (often 3 years) and explore for sweet spots (areas of high gas production), exploration and production become more predictable, and semipermanent water lines are installed from surface water reservoirs that can provide large amounts of water at relatively low cost. The third phase (from 2011) shows a renewed reliance on groundwater related to development of the combo play in Montague and Cooke counties. Montague County groundwater use increased from ~1 kAF in 2009 to 5.4 kAF in 2011.

Groundwater is derived mostly from the Trinity aquifer,[36] the only major aquifer underlying 76% of the 15-county area. A large fraction of Trinity aquifer withdrawals are for municipal use.[36,37] The aquifer is one of the most depleted aquifers in the state.[38,39] The underlying Paleozoic aquifer system[15] supplies some water in Montague County. GCDs provided volumes for some or all HF-related groundwater withdrawals for years 2011−2012 (Figure S11 and Table S3). They account for more than half (~15 kAF/yr) of the annual total HF water use.

Most of the 15-county area of interest is located in the Brazos (51%) and Trinity (46%) river basins. The combined reservoir conservation-pool storage capacity in the 15-county area is 2700 kAF. The Trinity River Authority does not supply water to oil and gas operators. The Brazos River Authority, with the largest watershed, has contracts with operators to provide HF water but data on water deliveries are only available for the broader mining category, which includes HF water use. The Brazos River Authority delivered an increasing water volume from 2001 (2.6 kAF) to 2008 (5.7 kAF), but has supplied 2.1 kAF/yr (in 2012) or less since then in the mining category, following the general trend of HF water use. On the basis of this pattern, it is logical to assume that most of the mining-category water use is for HF.

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HF water can also originate far from the Barnett Shale footprint. As is often the case in large urban centers, water is imported from distant reservoirs to provide water to municipal and industrial customers.[40] Such is the case in Tarrant County (which includes the City of Fort Worth), with the primary water supplier being the Tarrant Regional Water District (TRWD)[41] providing water to many municipalities in the county and operating large reservoirs southeast of Dallas (Figure S12). A significant fraction of the Tarrant County HF water use is provided directly by TRWD and was as high as 3.5 kAF in 2009, decreasing to 1.0 kAF in 2012. The remaining surface water sources include smaller water providers and unknown surface water right holders. Municipalities (Arlington, Fort Worth, Dallas) also provide water directly to operators, either through direct withdrawals from urban reservoirs before water is treated, or as treated water through hydrants (>4 kAF in 2011). In both cases, the ultimate water source is from the municipal supply. Tarrant County has the highest water use in the play, both annual and cumulative (Figure 1); however, HF water use is nevertheless a very small fraction of total water use (Figure 3).

Interviews with operators hinted that some use water from brackish aquifers,[30] estimated to be ~3% of HF water use and highest in the combo play in Montague County and on the western edges of the play. The Trinity aquifer[42] and the north-central Texas Paleozoic aquifers[15] contain slightly brackish horizons interspersed with fresher horizons. However, the largest source of salinity comes from blending fresh water with FP water. Some operators also use outflow from wastewater treatment plants. Texas Commission on Environmental Quality (TCEQ) has records, but no volumes, showing that some treated wastewater from large cities (Dallas, Fort Worth, Waco) and smaller towns (Bowie, Cisco, Keene, Weatherford) is used.

Overall, less recycling/reuse and brackish water use is currently occurring in the Barnett than in other Texas plays further west or south.[29,30] A large operator in 2005−2011 processed 2.24 kAF of FP water to generate 1.6 kAF of pure water to be used for stimulating new wells. Knowing that this particular operator manages ~21% of the wells and has had a more active recycling program than most operators, we extrapolated that the entire field used ~7.7 kAF of recycled water (1.6 kAF/21%); i.e., 5.5% of the total of 139 kAF of water used in that period. Interviews with operators are consistent with this estimate, suggesting that ~5% of HF water is from reuse/recycling for the past few years. Periodic droughts, characteristic of Texas climate, do not seem to control HF water use in the Barnett play, which is more sensitive to the price of gas and economic activity (Figure S13).

FP · Flowback/Produced Water. FP water flow decreases rapidly with time after wells are allowed to produce. Records from the IHS database show that percentiles (5th to 90th) of monthly water production steadily decline over time (Figure S14). Percentiles also show large variability, with a median for maximum monthly production <5000 bbl/month (0.64 AF/month; 1 bbl = 0.159 m^3) but a 90th percentile >20 000 bbl/month (2.58 AF/month) and a 5th percentile of ~0 bbl/month. However, cumulative production can still result in large volumes: median ~75 000 bbl (9.67 AF) after 4 years with a 90th percentile >300,000 bbl (38.7 AF) but a 5th percentile of 7000 bbl (0.90 AF) (Figure S15). A more interesting metric is the ratio of FP water to the amount used for HF, which we call the HF water balance ratio (WB ratio) (Figure 4). After one year, the median WB ratio is ~60%, but the mean is >100%

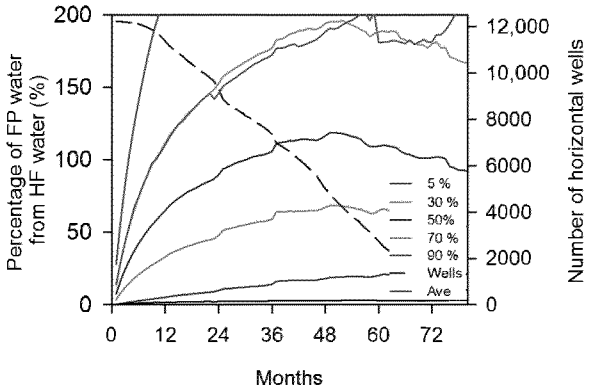

Figure 4. WB ratio; that is, ratio of FP water to HF water over time (5th, 30th, 50th, 70th, 90th percentiles, and average) and number of wells having data (dotted line). The base for the calculation includes only horizontal wells. The monthly records of each well were sequentially ordered from the first month where water was produced to the last month of record, specifically ignoring initial months with zero water production. For all wells for a given month, percentiles were then calculated. Logically, the number of wells with many months of production is much lower than the number of wells with a few months of production, because many wells were completed recently.

because of a few wells with exceptional water production. After several years, the median exceeds 100% of HF water. The variability of the ratio is large (Figure 4), ranging from 20% (5th percentile) to 350% (90th percentile) after 4 years. In interviews, operators tended to underestimate the amount of FP water as reported by IHS, likely focusing on the initial period during which some treatment and recycling can still take place. At later times, monthly volumes are small, but cumulatively they amount to a non-negligible fraction of the overall FP water.

The spatial distribution of the county-level medians of the WB ratios is not random but structured, with a minimum in the core area increasing outward (Figures S16 and S17), suggesting that the higher the amount of HF water retained in the shale, the higher the gas production. It is, however, premature to draw a direct causal relationship. Efforts are underway to relate this observation to various gas-production parameters, including the so-called maturing or soaking time, during which a well remains shut-in after HF, and geological parameters, e.g., porosity, pore-size distribution, and rock competence. A water-encroachment operational explanation, in which the underlying karstic Ellenburger Formation is systematically breached during HF, is unlikely; the Viola-Simpson Formation pinch-out[20,21] does not seem to control the WB ratio. A time-dependence of the WB ratio, suggesting possible operational improvements through time, is not clear: percentiles in Tarrant and Denton counties trend in opposite directions over time (Figure S18). The WB ratio does not appear to be related to operator skill level: comparing WB ratios from different large operators where leases are commingled shows no significant difference. Note that producing less water in the core area means that less water is available for reuse/recycling. Quality and chemical composition of the FP water are only known through anecdotal evidence.[43,44]

Injection Wells. Injection-well count (all vertical) has increased in the Barnett Shale play during the past decade. Until 2002, HF was confined to Denton and Tarrant counties and all injection activities outside of these counties were related to conventional hydrocarbon production (Figure S19, year

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2000). Injection activity in Cooke and Montague counties, the NW half of Wise County, Jack and Palo Pinto counties, and the western half of Parker County is clearly related to conventional oil production. All wells active in 2000 in this area with no change or decrease in injection volumes are assumed to be unrelated to FP water and other HF spent-fluid disposal. The Ellenburger Formation that underlies the Barnett Shale is the injection horizon of choice,[45] although FP water was also reinjected into shallower formations above the Barnett Shale in the early years.

Within the 15-county area, 8.8 kAF/yr of water was injected in 2000, representing the baseline in the NW corner of the area. In 2011, the injection rate had increased 5-fold in ~10 years to 45.7 kAF/yr; i.e., ~36.9 kAF/yr attributed to HF activities through ~150 currently active commercial injection wells.[46] A significant fraction of disposal occurs in Johnson County, which has the highest injection-well count (Figure S20) and receives more than twice the volume of water to be disposed than the county listed second (Parker County) (Figures 5, S21 and

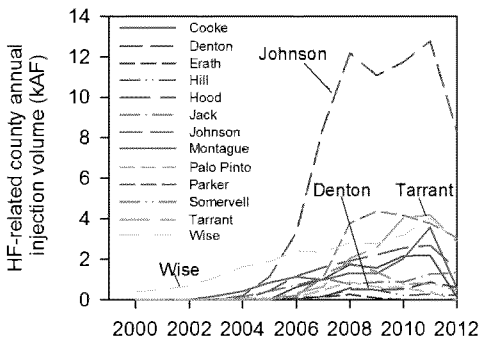

Figure 5. HF-related corrected yearly injection volumes per county in kAF (that is, pre-HF baseline subtracted, assuming that injection from conventional hydrocarbon production remains unchanged). Figure S21 displays uncorrected data, whereas Figure S22 focuses on all counties but Johnson County. No injection well in Dallas and Bosque Counties.

S22). A cumulative total of 170 kAF has been disposed of through injection wells from 2000 through 2011, whereas a total of 152 kAF was used in HF operations (Figure S23), although the latter number can be reduced by 5%, to 144 kAF, to account for recycled/reused water.[30] This result is consistent with the observation that many Barnett wells produce back >100% of the volume injected (Figure 4) and with the understanding that many wells have been fractured only recently and will produce significant amounts of water unless shut in. Natural evaporation from storage pits could also reduce the volume of fluids to be injected.[13]

Injection of FP water in the Barnett Shale area represents <4% of the wastewater volume injected in Texas each year. Statewide injection volume for a 12-month period (Oct. 2011 to Sept. 2012) was 924 kAF, similar to the previously reported value of 951 kAF for 2007.[47] Note that a small fraction of the injection wells are thought to have produced seismic events strong enough to be felt at the surface,[48,49] but the HF operation itself has not been documented as generating felt seismic events. As mentioned earlier, the RRC has recently started to report water disposal in a specific HF category. However, the statewide volume of 6.0 kAF for the same 12-month period used above shows that the current RRC data clearly underestimate the volume of HF fluids disposed in injection wells, most likely as a result of underreporting in the HF category and reporting to the salt-water general category instead.

IMPLICATIONS AND THE FUTURE

Drilling activity in the Barnett Shale play has been decreasing since a peak in 2008, despite periodic surges related to increased demand for natural gas following renewed economic activity or interest in condensates and oil. However, use of water for HF has remained relatively steady since 2009 because the mean lateral length has almost doubled. The price of gas, which steadily increased between 2002 and 2008 to ~$8/McfHH (thousand cubic feet Henry Hub; 1 Mcf = 28.3 m^3) and higher (Figure S13d) and then quickly dropped to $2−$4/McfHH, translated into a focus in the core area which is likely to continue. The current average well spacing and projection of drilling activity[26] suggest sustained drilling for several decades. Broadly, groundwater and surface water each account for half of the new HF water with periodic swings favoring one or the other. HF water needs in the core area will be met by local groundwater resources, in particular, the confined section of the Trinity aquifer, but also, very likely, by imported water. As the Dallas/Fort Worth area grows, it secures large contracts for water that originates from outside the metroplex. It then makes sense to project that operators in the core area will keep acquiring water from local surface water districts and will be able to meet HF water needs, especially when combined with recycling/reuse and use of brackish water. Currently, most of the FP water is disposed through deep well injection. Given that injected water volumes are larger, on average, than HF volumes, growth in recycling/reuse is possible.

A metric that has been proposed to assess competing water uses is known as the water intensity or the amount of water (gal or m^3) used to produce a unit volume of gas (Mcf or m^3) or unit of energy (MBtu or GJ). Because all water use is up front during well completion,[4] the ultimate water intensity depends on total gas production and the estimated ultimate recovery. With most wells still producing, this number is not yet accessible, although more and more data are in the public domain (Figure S24). The current water intensity can be computed from cumulative HF water use and gas production (Figure S25); at the end of 2012, it reached 4.37 gal/Mcf (15.7 L/GJ), which is clearly an upper bound. Extrapolating trends from older wells yields more accurate values (Figure S26) and suggests that, after 6 years of production, the water intensity is in the range of 2.5−3 gal/Mcf (9.0−10.8 L/GJ), consistent with findings by Clark et al.[50] This value would then evolve downward over time, to the range of 1−2 gal/Mcf (3.6−7.2 L/GJ).

ASSOCIATED CONTENT

* Supporting Information

Some definitions and Figures S1 to S26 and Tables S1 to S3. This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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ACKNOWLEDGMENTS

The work was performed with financial support from the University of Texas Energy Institute. We thank the database provider, IHS (http://www.ihs.com), for access to the Enerdeq database. We also gratefully acknowledge the oil and gas companies that are members of the Barnett Shale Water Conservation and Management Committee, Groundwater Conservation Districts, River Authorities, and Water Districts for their time and for providing data. Chris Parker edited the manuscript. Publication authorized by the Director, Bureau of Economic Geology, The University of Texas at Austin.

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ED_000496_00009145

To: Maloney, Kelsey[Maloney.Kelsey@epa.gov]; Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: LeDuc, Stephen
Sent: Mon 6/8/2015 4:02:07 PM
Subject: RE: EPA employee webinar availability

Hi Kelsey,

We just got the slide deck from Jeff for tomorrow's presentation and we will send those to you this afternoon—will you be able to upload them and have them ready for tomorrow?

Also, what will the format be for the Q&A—will there be a moderator and will questions come in via chatbox like in previous presentations? Best, Steve

Stephen D LeDuc, PhD

National Center for Environmental Assessment

US Environmental Protection Agency

Arlington, VA 22202

703-347-8962 (office)

Ex. 6

From: Maloney, Kelsey
Sent: Friday, June 05, 2015 11:54 AM

To: LeDuc, Stephen; Ridley, Caroline
Cc: Frithsen, Jeff
Subject: RE: EPA employee webinar availability

Steve,

Here is the link to register for the webinar: https://www.eventbrite.com/e/us-epa-epa-employee-webinar-draft-assessment-of-the-potential-impacts-of-hydraulic-fracturing-for-tickets-17229572114.

Once folks register, they are given the adobe connect webinar room link, and the conference line number.

I've booked Hurd Hall for the webinar on Tuesday in 41102 RRB.

Please let me know if you have other questions- Kelsey

From: LeDuc, Stephen
Sent: Friday, June 05, 2015 11:41 AM
To: Ridley, Caroline; Maloney, Kelsey
Cc: Frithsen, Jeff
Subject: RE: EPA employee webinar availability

Hi Kelsey,

I'm got some logistical questions from our division director (Dave Bussard) about this presentation. Has anything been circulated on this yet that I can send to him? I'm not familiar with the evenbrite system. Best, Steve

From: Ridley, Caroline
Sent: Wednesday, June 03, 2015 4:02 PM
To: Maloney, Kelsey; LeDuc, Stephen
Subject: RE: EPA employee webinar availability

Kelsey,

List both of us as presenters. We will likely divide the presentation in some way so that we both have speaking time.

Thanks,

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6

From: Maloney, Kelsey
Sent: Wednesday, June 03, 2015 2:00 PM
To: Ridley, Caroline; LeDuc, Stephen
Subject: RE: EPA employee webinar availability
~~~~~~

Hi Caroline and Steve,

Are you both planning on presenting at the EPA employee webinar? I'm listing the speaker(s) on the Evenbrite page, where we keep track of registration. As a reminder, the plan is to give a webinar on Tuesday, June 9th from 2-3pm, this includes time for questions (about 15 minutes).

Thank you,

Kelsey

From: Ridley, Caroline
Sent: Tuesday, June 02, 2015 12:28 PM
To: Maloney, Kelsey; LeDuc, Stephen
Cc: Gibbons, Dayna; Frithsen, Jeff
Subject: RE: EPA employee webinar availability

I think we would slightly prefer Tuesday June 9 at 2pm.

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6
~~~~~~

From: Maloney, Kelsey
Sent: Tuesday, June 02, 2015 12:20 PM
To: Ridley, Caroline; LeDuc, Stephen
Cc: Gibbons, Dayna; Frithsen, Jeff
Subject: EPA employee webinar availability

Caroline and Steve,

Are either of you available **Tuesday, June 9 or Wednesday, June 10 at 2 PM** to give an EPA employee webinar on the draft assessment?

Thanks!

Kelsey

Kelsey Maloney

Student Services Contractor

Science Communications

Office of Research and Development, US EPA

O: 202-564-4131

Maloney.kelsey@epa.gov

From: Frithsen, Jeff
Sent: Tuesday, June 02, 2015 12:09 PM
To: Gibbons, Dayna
Cc: Maloney, Kelsey
Subject: RE: Dates for EPA webinars next week

Dayna and Kelsey:

June 9 or June 10 at 10:00 is just fine by me for the EPA webinar. However, isn't that a bit early for folks in the western regions? Would it be better to try for a noon or afternoon time so that all of the regions might be able to participate?

For the EPA seminar, I suggest we have Caroline Ridley and/or Steve LeDuc make the presentation. I can introduce and backstop. However, it would be great to give a bit of exposure to the lead authors. Caroline especially has touched all of the chapters and Steve was responsible for pulling together our Executive Summary.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Gibbons, Dayna
Sent: Tuesday, June 02, 2015 12:01 PM
To: Frithsen, Jeff
Cc: Maloney, Kelsey
Subject: Dates for EPA webinars next week

Jeff—if you could look at your calendar quickly, we could check another thing off the box here. Does Tuesday or Wednesday @ 10am work best for you to give EPA employees the webinar on the draft assessment. We need to do some legwork—reserve rooms and lines, etc and need to get that done. I'm out on Thursday but that was a third option.

Thanks

202-564-7983

gibbons.dayna@epa.gov

Communications

Office of Research and Development

U.S. Environmental Protection Agency

To: Biddle, Lisa[Biddle.Lisa@epa.gov]; Maloney, Kelsey[Maloney.Kelsey@epa.gov]
From: Williams, Larke
Sent: Thur 6/4/2015 10:31:06 PM
Subject: RE: Register for the EPA's June 5th Webinar on the Draft Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources

Hi Lisa

Let me put you in touch with Kelsey that can answer the question below. She us with ORD Comms staff.

Sent from my Windows Phone

From: Biddle, Lisa
Sent: 6/4/2015 5:32 PM
To: Williams, Larke
Subject: FW: Register for the EPA's June 5th Webinar on the Draft Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources

Hey Larke,

Congrats on getting the study out!! What a great milestone!

I was wondering if you can help field this question below?

Thanks!

Lisa

Lisa A. Biddle
U.S. EPA, Office of Water
ph: (202) 566 0350
Biddle.Lisa@epa.gov

From: McFadden, Angela
Sent: Thursday, June 04, 2015 5:31 PM
To: Biddle, Lisa
Subject: RE: Register for the EPA's June 5th Webinar on the Draft Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources

If anyone has registered for the public webinar can they un-register?

From: Biddle, Lisa
Sent: Thursday, June 04, 2015 5:27 PM
To: Chadwick, Dan; Alvarez, Christine; Stewart, Andrew; McFadden, Angela; Bates, William; Benisek, Cher A.; Bergdale, Amy; Blanco-Gonzalez, Joel; BORSUK, FRANK; Campbell, Gwen; Johnston, Carey; Harsh, Chad; Vanlerberghe, Daren; Parker, David; DeJong, Stephanie; Deyoe, Jeremy; Elkins, Timothy; Garcia-Bakarich, Luis; Hildebrandt, Kurt; Davison, Jenny; Duggan, Jessica; Johnson, KarenD; Jollie, Jeff; Hykel, Judith; Kenney, James; Lapp, Jeffrey; Lischinsky, Robert; Lister, Chris; Lutte, Todd; Malone, Kathleen; Marquess, Scott; Marshall, Paul; Mathews, Kaye; Lukowich, Michael; Mikulak, Ron; Miller, Mamie; Moloney, Mark; Novak, Paul; Platt, Steve; Pritts, Jesse; Crane, Rebecca; Howland, Sanda; Segall, Martha; Shell, Karrie-Jo; Staples, Bridget; Sullivan, Tim; Thurmon, Clarke; Vincent, Anne Marie; Wang, Gary; Lane, Willie
Subject: RE: Register for the EPA's June 5th Webinar on the Draft Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources

Hello,

I wanted to pass along the request we received from ORD that EPA employees register for the webinar being offered for EPA (see details below, date is June 9) rather than the public webinar on June 5, so that the maximum spaces are available to the public for the June 5 webinar. Here is the email with the link to register for the EPA employee webinar.

Thanks,

Lisa

Greetings,

Today, the EPA's Office of Research and Development released the Draft Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources. The draft assessment has been posted online at http://www2.epa.gov/hfstudy.

We are offering an **EPA employee webinar on Tuesday, June 9th, 2015 at 2:00 PM ET**. This webinar will be identical to the public webinars on Friday, June 5th. We ask that all EPA employees participate in the June 9th webinar so that we can ensure the public can participate in the public webinars being offered on June 5th.

•□□□□□□□□ Register for the June 9th EPA employee webinar here.

Thank you for your interest in EPA's Study of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources.

Lisa A. Biddle
U.S. EPA, Office of Water
ph: (202) 566 0350
Biddle.Lisa@epa.gov

From: Chadwick, Dan
Sent: Thursday, June 04, 2015 5:15 PM
To: Alvarez, Christine; Stewart, Andrew; McFadden, Angela; Bates, William; Benisek, Cher A.; Bergdale, Amy; Biddle, Lisa; Blanco-Gonzalez, Joel; BORSUK, FRANK; Campbell, Gwen; Johnston, Carey; Harsh, Chad; Chadwick, Dan; Vanlerberghe, Daren; Parker, David; DeJong, Stephanie; Deyoe, Jeremy; Elkins, Timothy; Garcia-Bakarich, Luis; Hildebrandt, Kurt; Davison, Jenny; Duggan, Jessica; Johnson, KarenD; Jollie, Jeff; Hykel, Judith; Kenney, James; Lapp, Jeffrey; Lischinsky, Robert; Lister, Chris; Lutte, Todd; Malone, Kathleen; Marquess, Scott; Marshall, Paul; Mathews, Kaye; Lukowich, Michael; Mikulak, Ron; Miller, Mamie; Moloney, Mark; Novak, Paul; Platt, Steve; Pritts, Jesse; Crane, Rebecca; Howland, Sanda; Segall, Martha; Shell, Karrie-Jo; Staples, Bridget; Sullivan, Tim; Thurmon, Clarke; Vincent, Anne Marie; Wang, Gary; Lane, Willie
Subject: FW: Register for the EPA's June 5th Webinar on the Draft Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources

All,

Please see registration information about a webinar on the ORD fracking study.

From: U.S. Environmental Protection Agency [mailto:usaepa@service.govdelivery.com]
Sent: Thursday, June 04, 2015 2:01 PM
To: Chadwick, Dan
Subject: Register for the EPA's June 5th Webinar on the Draft Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources

Greetings,

Today, the EPA released its *Draft Assessment of the Potential Impacts of Hydraulic*

Fracturing for Oil and Gas on Drinking Water Resources for public comment and peer review, along with nine final peer-reviewed EPA technical reports completed as part of the study. The draft assessment provides the most complete compilation of scientific data to date on the potential impacts to drinking water resources from hydraulic fracturing activities. The draft assessment integrates a broad literature review, with results from EPA-led research projects and input from stakeholders through outreach efforts.

- Learn more about the Scientific Advisory Board's (SAB) peer review process for the draft assessment.

The EPA will be hosting two public webinars on **Friday, June 5, 2015 at 10AM EDT and 2PM EDT** to provide a brief overview of the draft assessment, the key findings, and the review process.

- To participate in the **10:00 AM EDT** webinar, please register here.
- To participate in the **2:00 PM EDT** webinar, please register here.

Webinar access and instructions will be sent upon registration.

Thank you for your interest in the EPA's Study of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources.

You can view or update your subscriptions or e-mail address at any time on your Subscriber Preferences Page. All you will need is your e-mail address. If you have any questions or problems e-mail subscriberhelp.govdelivery.com for assistance.

This service is provided to you at no charge by U.S. Environmental Protection Agency.

This email was sent to chadwick.dan@epa.gov using GovDelivery, on behalf of: U.S. EPA Office of Research and Development · 1200 Pennsylvania Avenue NW · Washington DC 20460 · 202-564-4355

To: Maguire, Megan[Maguire.Megan@epa.gov]
Cc: Milbourn, Cathy[Milbourn.Cathy@epa.gov]; Maloney, Kelsey[Maloney.Kelsey@epa.gov]; Hubbard, Carolyn[Hubbard.Carolyn@epa.gov]; Gibbons, Dayna[Gibbons.Dayna@epa.gov]; Daguillard, Robert[Daguillard.Robert@epa.gov]
From: Allen, Laura
Sent: Thur 6/4/2015 4:34:58 PM
Subject: Re: Final- HF Study News Release, 12 PM

Adding Robert.

Robert- can you send Megan the link?

Sent from my iPhone

On Jun 4, 2015, at 12:26 PM, Maguire, Megan <Maguire.Megan@epa.gov> wrote:

Hi- the press release is still not in the news room, can you please get it posted there ASAP? People are asking for the URL.

Thanks,
Megan

Megan Maguire

US EPA, Office of Research and Development

RRB 41261

O: (202)564-6636

Ex. 6

From: Allen, Laura
Sent: Thursday, June 04, 2015 11:34 AM
To: Daguillard, Robert; AO OPA OMR 60 Minute Warning
Subject: Final- HF Study News Release, 12 PM

Hi all- the final version of the press release is below and it will be sent at noon today. Thanks!

Laura Allen

Deputy Press Secretary
Office of the Administrator
U.S. Environmental Protection Agency

Email: Allen.Laura@epa.gov

Office: 202-564-1175

Ex. 6

Please consider the environment before printing this email.

Contact: (News Media Only)

Cathy Milbourn

(202) 564-7849

(202) 420-8648

milbourn.cathy@epa.gov

For Immediate Release

June 4th, 2015

EPA Releases Draft Assessment on the Potential Impacts to Drinking Water Resources from Hydraulic Fracturing Activities

Assessment shows hydraulic fracturing activities have not led to widespread, systemic impacts to drinking water resources and identifies important vulnerabilities to drinking water resources.

WASHINGTON—The Environmental Protection Agency (EPA) is releasing a draft assessment today on the potential impacts of hydraulic fracturing activities on drinking water resources in the United States. The assessment, done at the request of Congress, shows that while hydraulic fracturing activities in the U.S. are carried out in a way that have not led to widespread, systemic impacts on drinking water resources, there are potential vulnerabilities in the water lifecycle that could impact drinking water. The assessment follows the water used for hydraulic fracturing from water acquisition, chemical mixing at the well pad site, well injection of fracking fluids, the collection of hydraulic fracturing wastewater (including flowback and produced water), and wastewater treatment and disposal [http://www2.epa.gov/hfstudy/hydraulic-fracturing-water-cycle].

"EPA's draft assessment will give state regulators, tribes and local communities and industry around the country a critical resource to identify how best to protect public health and their drinking water resources," said **Dr. Thomas A. Burke, EPA's Science Advisor and Deputy Assistant Administrator of EPA's Office of Research and Development.** "It is the most complete compilation of scientific data to date, including over 950 sources of information, published papers, numerous technical reports, information from stakeholders and peer-reviewed EPA scientific reports."

EPA's review of data sources available to the agency found specific instances where well integrity and waste water management related to hydraulic fracturing activities impacted drinking water resources, but they were small compared to the large number of hydraulically fractured wells across the country. The report provides valuable information about potential vulnerabilities, some of which are not unique to hydraulic fracturing, to drinking water resources, but was not designed to be a list of documented impacts.

These vulnerabilities to drinking water resources include:

•□□□□□□□ water withdrawals in areas with low water availability;

•□□□□□□□ hydraulic fracturing conducted directly into formations containing drinking water resources;

•□□□□□□□ inadequately cased or cemented wells resulting in below ground migration of gases and liquids;

•□□□□□□□ inadequately treated wastewater discharged into drinking water resources;

•□□□□□□□ and spills of hydraulic fluids and hydraulic fracturing wastewater, including flowback and produced water.

Also released today were nine peer-reviewed EPA scientific reports (www.epa.gov/hfstudy). These reports were a part of EPA's overall hydraulic fracturing drinking water study and contributed to the findings outlined in the draft assessment. Over 20 peer-reviewed articles or reports were published as part of this study [http://www2.epa.gov/hfstudy/published-scientific-papers].

States play a primary role in regulating most natural gas and oil development. EPA's authority is limited by statutory or regulatory exemptions under the Clean Water Act, Safe Drinking Water Act, the Comprehensive Environmental Response, Compensation and Liability Act, and the Resource Conservation and Recovery Act. Where EPA's exemptions exist, states may have authority to regulate unconventional oil and gas extraction activities under their own state laws.

EPA's draft assessment benefited from extensive stakeholder engagement conducted across the country with states, tribes, industry, non-governmental organizations, the scientific community and the public to ensure that the draft assessment reflects current practices in hydraulic fracturing and utilizes all data and information available to the agency.

The study will be finalized after review by the Science Advisory Board and public review and comment. The Federal Register Notice with information on the SAB review and how to comment on the draft assessment will be published on Friday June 5, 2015.

For a copy of the study, visit www.epa.gov/hfstudy.

To submit comments on the report, see www.epa.gov/sab.

To: Gibbons, Dayna[Gibbons.Dayna@epa.gov]; Maloney, Kelsey[Maloney.Kelsey@epa.gov]
From: Bueno, Michael
Sent: Mon 6/1/2015 4:28:53 PM
Subject: Updated HFDWA comms materials
Draft Press Release 5.28.docx
draft script for tom 528.docx
HF in DW Resources QAs DRAFT 052815.docx
Press HF study QAs5.28.15.docx
Top Lines_HF_5 29 15 draft final (6).docx

Hi Dayna and Kelsey,

I've been asked to make briefing book for Lek as well. Have there been any major changes to the comms materials attached?

Thanks!

Michael

Michael Bueno

US EPA Office of Research and Development

p. (202) 564-5051

e. bueno.michael@epa.gov

To: HARPREET DINSA[hdinsa@shaw.ca]
Cc: Maloney, Kelsey[Maloney.Kelsey@epa.gov]
From: Frithsen, Jeff
Sent: Tue 6/30/2015 2:00:27 PM
Subject: RE: EPA's Hydraulic Fracturing Study (Want the real truth about alternatives to water fracturing methods?)

Thank you for your interest in EPA's hydraulic fracturing drinking water assessment. In our assessment (in Chapter 5), we did briefly describe non-aqueous fracking fluids, including energized fluids involving gases.

Your comments on the use of non-aqueous fracking fluids to reduce water consumption are interesting and I encourage you to submit comment to the public docket for the draft assessment. Instructions for how to submit comments to the docket may be found through the web link provided immediately below:

https://www.federalregister.gov/articles/2015/06/05/2015-13674/notification-of-teleconferences-and-a-public-meeting-of-the-science-advisory-board-hydraulic

Thanks again.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: HARPREET DINSA [mailto:hdinsa@shaw.ca]
Sent: Wednesday, June 17, 2015 2:20 PM
To: Frithsen, Jeff
Cc: Maloney, Kelsey
Subject: Re: EPA's Hydraulic Fracturing Study (Want the real truth about alternatives to water fracturing methods?)

Hi my name is Harpreet Dinsa, a graduate of Petroleum Engineering from the University of Alberta with a Professional Engineering (P. Eng.) received from my professional association APEGGA in 2000. Please read ...

The best way to reduce the impact of fracturing on drinking water resources is not to use water or limit its use. There are alternative methods of fracturing available such as foams and emulsions. A gas i.e.(nitrogen, carbon dioxide, methane, propane) foam generally requires only 10%-30% water, is great for proppant transport and provides an energized clean-up. A liquid/liquid emulsion i.e (hydrocarbon/carbon dioxide, hydrocarbon/propane, hydrocarbon/methane) does not use water at all and again is energized for better clean-up. These fracturing techniques are not new, but do cost more than a conventional water or hydrocarbon frac and proper laboratory testing equipment is not yet available.

Hydra Fracturing Laboratory Equipment Solutions Ltd. has a patent pending device for attachment to HPHT viscometers on the market and a method that allows viscosity testing with methane foams and emulsions (or similar). The cheap price and widespread availability of LNG cannot be ignored. The switch to these alternative types of fracturing methods is inevitable to reduce pressure on water reserves and also cannot be ignored. You just have to look at the predicament California is in presently. The solution already exists. The general public, including government agencies, are not completely informed.

Harpreet Dinsa P.Eng.

If you have any questions, email me at hdinsa@shaw.ca or look me up on linkedIn under Harpreet Dinsa. Thank you.

To: Piantanida, David[Piantanida.David@epa.gov]; Anley-Mills, Melissa[Anley-Mills.Melissa@epa.gov]; Ferster, Aaron[Ferster.Aaron@epa.gov]; McGuinness, Moira[McGuinness.Moira@epa.gov]; Brown, Ann[Brown.Ann@epa.gov]; Kapuscinski, Jacques[Kapuscinski.Jacques@epa.gov]; Margolies, Jennifer[Margolies.Jennifer@epa.gov]; Morse, Myles[Morse.Myles@epa.gov]; Smith, Emily J.[Smith.Emily@epa.gov]; Coberly, Dan[Coberly.Dan@epa.gov]; Nickel, Kathy[Nickel.Kathy@epa.gov]; McCall, Amelia[McCall.Amelia@epa.gov]; Doyle, Brendan[Doyle.Brendan@EPA.Gov]; Linnenbrink, Monica[Linnenbrink.Monica@epa.gov]; Dowd, Sean[Dowd.Sean@epa.gov]; Widener, Kelly[Widener.Kelly@epa.gov]; Gibbons, Dayna[Gibbons.Dayna@epa.gov]; Blackburn, Elizabeth[Blackburn.Elizabeth@epa.gov]; Bauer, Sarah[Bauer.Sarah@epa.gov]; Drumm, Heather[Drumm.Heather@epa.gov]; Deener, Kathleen[Deener.Kathleen@epa.gov]; Dearie, Jessica[Dearie.Jessica@epa.gov]; Ice, Jane[Ice.Jane@epa.gov]; Blank, Valerie[Blank.Valerie@epa.gov]; Williams, Ryann[Williams.Ryann@epa.gov]; Renwick, Dustin[Renwick.Dustin@epa.gov]; Chagolla, Armando[Chagolla.Armando@epa.gov]; Walling, Joyce[Walling.Joyce@epa.gov]; Dannel, Mimi[Dannel.Mimi@epa.gov]; Mattas-Curry, Lahne[Mattas-Curry.Lahne@epa.gov]; Milbourn, Cathy[Milbourn.Cathy@epa.gov]; Cassidy, Kristin[Cassidy.Kristin@epa.gov]; Perry, Dale[Perry.Dale@epa.gov]; Shams, Dahnish[Shams.Dahnish@epa.gov]; Styles, Lacresha[Styles.Lacresha@epa.gov]; Baghdikian, Christina[Baghdikian.Christina@epa.gov]; Hubbard, Carolyn[Hubbard.Carolyn@epa.gov]; Plotkin, Viktoriya[Plotkin.Viktoriya@epa.gov]; Simunek, Diane[Simunek.Diane@epa.gov]; Mebane, Sheryl[Mebane.Sheryl@epa.gov]; Allen, Laura[Allen.Laura@epa.gov]; schafer, joan[schafer.joan@epa.gov]; Corona, Elizabeth[Corona.Elizabeth@epa.gov]; Connair, Ryan[Connair.Ryan@epa.gov]; Bhandari, Pradnya[Bhandari.Pradnya@epa.gov]; Kocer, Alissa[Kocer.Alissa@epa.gov]; D'Amico, Louis[DAmico.Louis@epa.gov]; Mueller, Blake[Mueller.Blake@epa.gov]; Maloney, Kelsey[Maloney.Kelsey@epa.gov]; Jones, Marjorie[Jones.Marjorie@epa.gov]; Bowling, Charlena[Bowling.Charlena@epa.gov]; Fitzpatrick, Kacey[Fitzpatrick.Kacey@epa.gov]; Bland, Naseera[Bland.Naseera@epa.gov]; Linkins, Samantha[Linkins.Samantha@epa.gov]; Walton, Eli[Walton.Eli@epa.gov]; Carroll, Carly[Carroll.Carly@epa.gov]; Schulte, Kayla[Schulte.Kayla@epa.gov]; Johnson, Maureen[Johnson.Maureen@epa.gov]; Osaka, Anna[Osaka.Anna@epa.gov]; Specter, Matthew[Specter.Matthew@epa.gov]; Jones, Skylar[Jones.Skylar@epa.gov]; Moody, Christina[Moody.Christina@epa.gov]; Karp, Alison[Karp.Alison@epa.gov]; Dunn, Michael[dunn.michael@epa.gov]; Abdulhadi, Dina[Abdulhadi.Dina@epa.gov]; Noel, Glenda[Noel.Glenda@epa.gov]; Leinbach, Alan[Leinbach.Alan@epa.gov]; Gwinn, Maureen[gwinn.maureen@epa.gov]; White, Terri-A[White.Terri-A@epa.gov]; Linkins, Samantha[Linkins.Samantha@epa.gov]; Westerman, Debbie[Westerman.Debbie@epa.gov]; Heimbrock, Peggy[Heimbrock.Peggy@epa.gov]; Hartzell, Evelyn[hartzell.evelyn@epa.gov]
From: Maguire, Megan
Sent: Mon 5/18/2015 9:58:40 PM
Subject: Hurd on the Call: May 18, 2015

Hurd on the Call: Notes from ORD's Weekly Communication Meeting

May 18, 2015

Quick Notes and Reminders

Non-Responsive

Non-Responsive

Ex. 5

Non-Responsive

Non-Responsive

Non-Responsive

To: MaryEllen.Tuccillo Ex. 4
Cc: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: Solomon, Sarah
Sent: Tue 7/14/2015 7:56:43 PM
Subject: HERO Errors

Hi Mary Ellen,

My name is Sarah Solomon and I am Student Service Contractor working alongside Caroline Ridley on correcting errors in the HERO database for the HFDWA. I received the Reference Quality spreadsheet for Appendix F and have a question about the accompanying comments.

Ex. 5

Many thanks for the clarification and your help.

Sarah

Sarah Solomon

Student Service Contractor

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

Work: (703) 347-0490

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: Jonathan.Koplos Ex. 6
From: Mary Ellen Tuccillo
Sent: Fri 6/19/2015 8:03:20 PM
Subject: Wish list items for Chapter 8
Chapter8_Outstanding Work_6_19_15.docx

Hi Caroline,

Please find attached a list of work we might have done if we'd had more time. This does not include review of materials in key sources or web sites to address any comments we will be receiving, nor does it include review of any new literature that has been recently published.

Let me know if you have any questions.

Mary Ellen

Mary Ellen Tuccillo, Ph.D.

The Cadmus Group

100 5th Ave., Suite 100

Waltham, MA 02451

Ex. 6

Water is the driving force of all nature. Leonardo da Vinci

Follow us on social media:

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: Frithsen, Jeff
Sent: Mon 6/1/2015 4:51:50 PM
Subject: RE: Hydraulic Fracturing Drinking Water Assessment: Executive Summary

Thanks.

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Ridley, Caroline
Sent: Monday, June 01, 2015 10:03 AM
To: Frithsen, Jeff
Subject: RE: Hydraulic Fracturing Drinking Water Assessment: Executive Summary

This is from pg 8-20.

Ex. 5

Ex. 5

Caroline

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): (703) 362-5955

From: Frithsen, Jeff
Sent: Monday, June 01, 2015 9:49 AM
To: Ridley, Caroline
Subject: FW: Hydraulic Fracturing Drinking Water Assessment: Executive Summary

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Giles-AA, Cynthia
Sent: Monday, June 01, 2015 9:48 AM
To: Frithsen, Jeff
Cc: Kenney, James; Burke, Thomas; Hanley, Mary; Kadeli, Lek
Subject: RE: Hydraulic Fracturing Drinking Water Assessment: Executive Summary

Ex. 5

From: Frithsen, Jeff

Sent: Monday, June 01, 2015 9:43 AM
To: Giles-AA, Cynthia
Cc: Kenney, James; Burke, Thomas; Hanley, Mary; Kadeli, Lek
Subject: RE: Hydraulic Fracturing Drinking Water Assessment: Executive Summary

Cynthia:

Thanks for looking at this over the weekend.

Ex. 5

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Giles-AA, Cynthia
Sent: Monday, June 01, 2015 9:29 AM
To: Frithsen, Jeff
Cc: Kenney, James; Burke, Thomas; Hanley, Mary
Subject: RE: Hydraulic Fracturing Drinking Water Assessment: Executive Summary

Thanks for circulating this Jeff. It is looking good!

Ex. 5

Please let me know if you would like to discuss.

Thanks - Cynthia

From: Frithsen, Jeff
Sent: Friday, May 29, 2015 4:37 PM
To: Bloom, David; Brooks, Karl; Burke, Thomas; Dunkin, Ann; Garbow, Avi; Giles-AA, Cynthia; Jones, Jim; Kadeli, Lek; Kopocis, Ken; McCabe, Janet; Nishida, Jane; Stanislaus, Mathy; Wynn, Renee; Beauvais, Joel; Blumenfeld, Jared; Curry, Ron; Enck, Judith; Garvin, Shawn; Hague, Mark; Hedman, Susan; McGrath, Shaun; McLerran, Dennis; McTeerToney, Heather; Rupp, Mark; Spalding, Curt; Fritz, Matthew; Hanley, Mary; Perry, Dale; Purchia, Liz
Cc: Smith, Kelley; Briskin, Jeanne; Gibbons, Dayna; Matthews, Lisa; Teichman, Kevin; Zambrana, Jose
Subject: Hydraulic Fracturing Drinking Water Assessment: Executive Summary

On behalf of ORD, I am following-up on our April 29 briefing and update concerning the Hydraulic Fracturing Drinking Water Study.

On June 4, we will be releasing nine final reports from the HF Drinking Water Study. These reports present the results of various research projects focused on understanding the potential impacts of hydraulic fracturing on drinking water resources in the United States. We will also be releasing our draft report, "Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and gas on Drinking Water Resources". The draft assessment synthesizes ORD research results with information from over 950 publications to present the state-of-the-science concerning hydraulic fracturing and drinking water. When released, the draft assessment will be made

available for public comment and turned over to the Agency's Science Advisory Board for peer review.

Attached is the executive summary of the draft assessment report. The executive summary is being shared with you as FYI and as a heads-up concerning the major findings of the assessment. We anticipate being ready to share the entire draft assessment with you on Monday, June 1.

Just a reminder that this material is for internal use only and that the date for the release of the HF Study reports and draft assessment has not been announced.

Should you have any questions, please do not hesitate to contact me or Tom Burke

Have a great weekend.

Jeff

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries

Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: Knightes, Chris
Sent: Wed 5/20/2015 5:11:42 PM
Subject: RE: HFDWA: CBI Text box in Chapter 5
HFDWA - Chapter 5 May 20 2015.docx

If I could hug you through the screen, I would. Getting everyone and their brother to throw in their 2c at this stage of the game is getting a little ridiculous. Ex. 5 Ex. 5 Here is the updated chapter. I'm ready to pass the baton.

I'm not sure what OGC is. Ex. 5

From: Ridley, Caroline
Sent: Wednesday, May 20, 2015 1:04 PM
To: Knightes, Chris
Subject: RE: HFDWA: CBI Text box in Chapter 5

Ex. 5

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development
~~~~~~

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): (703) 362-5955

From: Knightes, Chris
Sent: Wednesday, May 20, 2015 12:34 PM
To: Sharkey, Susan; Briskin, Jeanne; Frithsen, Jeff; Burden, Susan; LeDuc, Stephen; Ridley, Caroline
Cc: Sherlock, Scott
Subject: RE: HFDWA: CBI Text box in Chapter 5

Ex. 5

Ex. 5

From: Sharkey, Susan
Sent: Wednesday, May 20, 2015 11:15 AM
To: Knightes, Chris; Briskin, Jeanne; Frithsen, Jeff; Burden, Susan; LeDuc, Stephen; Ridley, Caroline
Cc: Sherlock, Scott

Subject: RE: HFDWA: CBI Text box in Chapter 5

Adding Scott Sherlock for OPPT, who also weighed in on the text box language.

Ex. 5

Ex. 5

Ex. 5

From: Knightes, Chris
Sent: Wednesday, May 20, 2015 10:42 AM
To: Briskin, Jeanne; Frithsen, Jeff; Burden, Susan; LeDuc, Stephen; Ridley, Caroline
Cc: Sharkey, Susan
Subject: RE: HFDWA: CBI Text box in Chapter 5

Ex. 5

From: Briskin, Jeanne
Sent: Wednesday, May 20, 2015 10:37 AM
To: Frithsen, Jeff; Knightes, Chris; Burden, Susan; LeDuc, Stephen; Ridley, Caroline
Cc: Sharkey, Susan
Subject: RE: HFDWA: CBI Text box in Chapter 5

Ex. 5

From: Frithsen, Jeff
Sent: Wednesday, May 20, 2015 10:29 AM
To: Knightes, Chris; Briskin, Jeanne; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Ridley, Caroline
Subject: FW: HFDWA: CBI Text box in Chapter 5

One more small edit…..

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Auerbacher, Kevin
Sent: Wednesday, May 20, 2015 10:25 AM
To: Frithsen, Jeff
Subject: RE: HFDWA: CBI Text box in Chapter 5

Jeff,

Ex. 5

From: Frithsen, Jeff
Sent: Wednesday, May 20, 2015 10:12 AM
To: Auerbacher, Kevin; Hanley, Mary; Perry, Dale
Subject: RE: HFDWA: CBI Text box in Chapter 5

Thanks Kevin.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Auerbacher, Kevin
Sent: Wednesday, May 20, 2015 10:08 AM
To: Frithsen, Jeff; Hanley, Mary; Perry, Dale
Subject: RE: HFDWA: CBI Text box in Chapter 5

A suggested revision to the CBI discussion in the revised text box. Otherwise looks fine. Let me know if you have any questions.

Ex. 5

Ex. 5

From: Frithsen, Jeff
Sent: Wednesday, May 20, 2015 8:43 AM
To: Auerbacher, Kevin; Hanley, Mary; Perry, Dale
Subject: HFDWA: CBI Text box in Chapter 5

Below is the revised CBI text box.

Comments?

Clean revised text:

Ex. 5

Ex. 5

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

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2733 South Crystal Drive, Arlington, VA 22202

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: Daiss, Rebecca
Sent: Wed 5/13/2015 6:24:00 PM
Subject: FW: Internal review of draft electronic database of HF chemical properties

Meant to forward this…

From: Daiss, Rebecca
Sent: Tuesday, May 12, 2015 2:00 PM
To: Green, Holly
Cc: Moore, Keara; Bates, William
Subject: RE: Internal review of draft electronic database of HF chemical properties

Thanks Holly,

Your input is much appreciated.

Becky

From: Green, Holly
Sent: Tuesday, May 12, 2015 1:43 PM
To: Daiss, Rebecca
Cc: Moore, Keara; Bates, William
Subject: RE: Internal review of draft electronic database of HF chemical properties

Hi Rebecca,

My team leaders/experts looked at these files and in general think that they are pretty clear and user-friendly. We do have a few comments/suggestions:

Ex. 5

Ex. 5

Thanks,

Holly

Holly Sage Green

Acting Chief, Prevention Branch

EPA Office of Ground Water and Drinking Water

1200 Pennsylvania Ave. NW, Washington, DC 20460

(202) 566-0651

From: Daiss, Rebecca
Sent: Thursday, April 30, 2015 3:49 PM
To: Green, Holly
Subject: FW: Internal review of draft electronic database of HF chemical properties

Hi Holly,

Here's the database and the background info. Don't know why I didn't think to just forward it to you myself…

Becky

From: Ridley, Caroline
Sent: Thursday, April 30, 2015 2:37 PM

To: Lee, Wen-Hsiung; Scarano, Louis; Woodall, George; Knightes, Chris; Christ, Lisa
Cc: Daiss, Rebecca; Briskin, Jeanne; Frithsen, Jeff; Stanek, John
Subject: Internal review of draft electronic database of HF chemical properties

Dear EPA colleagues,

Attached for your review is series of 10 excel data files that contain lists of chemicals used in hydraulic fracturing and found in flowback and that provides physiochemical property data and toxicological values for those chemicals. Ex. 5

Ex. 5 h

Ex. 5 Please provide comments **no later than Wednesday May 13**. If you have questions during your review, please email or call Becky Daiss (daiss.rebecca@epa.gov, 202-564-7074).

Following is a brief description of each data file.

HFChems_File1_Background_Index_ChemList_April2015_IR.xlsx

This file provides background information on the list of hydraulic fracturing chemicals generated by ORD. It provides the list of hydraulic fracturing chemicals identified by Chemical Name and CASRN and identifies whether a chemical is a fracturing fluid additive or a chemical found flowback from fractured wells. It provides the references for the list of chemicals. It also provides a summary of physiochemical and toxicity data available in the other data files.

HFChems_File2_PhysiochemicalPropertyData_April-2015_IR.xlsx

This file provides physiochemical property data for chemicals for which such data is available from EPISuite, QikProp and LeadScope software programs. QikProp and LeadScope are commercial products designed primarily as drug development and screening tools. EPISuite is freely downloadable suite of physical/chemical property and environmental fate estimation programs. This file provides background information on the data sources and glossaries for the property data generated from each source.

HFChems_File3_ToxicityReferenceValues_April2015_IR.xlsx

This file provides toxicity reference values from seven sources; EPA Integrated Risk Information System (IRIS), EPA Provisional Peer Reviewed Toxicity Values (PPRTV), Agency for Toxic Substances & Disease Registry (ATSDR), California Office of Environmental Health Hazard Assessment (OEHHA), National Primary Drinking Water Regulations (NPDWR), Human Health Benchmarks for Pesticides (HHBP) and Concise International Chemical Assessment Documents (CICAD). The file provides background information on each of the sources and glossaries for the reference values from each source.

HFChems_Reaxys©File1_PropertyDataSummary_April2015_IR.xlsx

This file provides a summary of property data obtained from Reaxys© for six environmental parameters; biodegradation, hydrolysis, photolysis, stability in soil, bioaccumulation, and ecological toxicity. Reaxys© is a commercial product that provides a comprehensive database of chemical structure and property data. Reaxys© reports typically provide information on the type of study, methods used, experimental parameters, key outputs, and sources. Data on each of the six environmental parameters are provided in separate files.

HFChems_Reaxys©File2_BiodegradationData_April2015_IR.xlsx

HFChems_Reaxys©File3_HydrolysisData_April2015_IR.xlsx

HFChems_Reaxys©File4_PhotolysisData_April2015_IR.xlsx

HFChems_Reaxys©File5_SoilStabilityData_April2015_IR.xlsx

HFChems_Reaxys©File6_BioaccumulationData_April2015_IR.xlsx

HFChems_Reaxys©File7_EcologicalToxicityData_April2015_IR.xlsx

Ex. 5

Ex. 5

Thank you for taking this time to review this important produce of EPA's hydraulic fracturing study!

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays) Ex. 6
~~~~~~

To: MaryEllen.Tuccillo Ex. 4
Cc: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: Frithsen, Jeff
Sent: Wed 5/13/2015 2:18:13 PM
Subject: RE: Notes on States et al. and other information on bromide

Mary Ellen:

Ex. 5

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Mary Ellen Tuccillo Ex. 4
Sent: Wednesday, May 13, 2015 9:45 AM
To: Frithsen, Jeff
Cc: Ridley, Caroline
Subject: RE: Notes on States et al. and other information on bromide

Hi Jeff,

Ex. 5

Ex. 5

Mary Ellen

From: Frithsen, Jeff [mailto:Frithsen.Jeff@epa.gov]
Sent: Wednesday, May 13, 2015 8:54 AM
To: Mary Ellen Tuccillo
Cc: Ridley, Caroline
Subject: FW: Notes on States et al. and other information on bromide

Mary Ellen:

Ex. 5

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Briskin, Jeanne
Sent: Wednesday, May 13, 2015 8:32 AM
To: Frithsen, Jeff
Subject: RE: Notes on States et al. and other information on bromide

Ex. 5

From: Frithsen, Jeff
Sent: Wednesday, May 13, 2015 8:23 AM
To: Briskin, Jeanne
Subject: FW: Notes on States et al. and other information on bromide

Jeanne:

Sharing the recent re-evaluation of the States et al. paper.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Ridley, Caroline
Sent: Tuesday, May 12, 2015 4:26 PM
To: Frithsen, Jeff
Subject: FW: Notes on States et al. and other information on bromide

Jeff-

See information from Mary Ellen on the States et al. paper and other issues with bromide.

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6

From: Mary Ellen Tuccillo Ex. 4
Sent: Tuesday, May 12, 2015 3:35 PM
To: Ridley, Caroline
~~~~~~

Cc: Jonathan.Koplos@ Ex. 4 Linda Hills
Subject: Notes on States et al. and other information on bromide

Hello Jeff and Caroline,

Ex. 5

Ex. 5

Mary Ellen

Mary Ellen Tuccillo, Ph.D.

The Cadmus Group

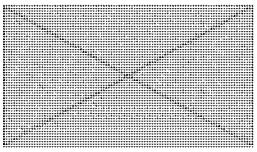
100 5th Ave., Suite 100

Waltham, MA 02451

Ex. 4

Ex. 4

Water is the driving force of all nature. Leonardo da Vinci



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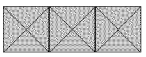

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: Frithsen, Jeff
Sent: Tue 5/12/2015 12:27:09 PM
Subject: HF: Monthly Status call with agency representatives

Caroline:

Thanks for jumping in and leading the monthly status call. Perhaps the notes below will help.

Jeff

Monthly status call on ORD's Hydraulic Fracturing Drinking Water Study

Major messages

Many of the products outlined in the HF Study Plan (USEPA 2011) are coming to completion.

Thus far, the study has produced: 3 EPA technical reports; 4 EPA authored journal publications; and 9 journal publications from colleagues at Lawrence Berkeley National laboratories

Products have been posted online at: www.epa.gov/hfstudy (Except for those journal articles accepted but not yet published.)

Within the month, we will be releasing several more products, including 9 final EPA technical reports and 1 draft assessment. The reports and draft assessment will be released together.

The 9 final EPA technical reports include the following:

- Study of water acquisition in the Susquehanna and Upper Colorado river basins.

- Study of sources of selected HF-related chemicals in the Allegheny river and streams in PA.
- Studies of possible impacts to drinking water resources (five retrospective case studies):
- Northeast, PA (Bradford County)
- Southwest, PA (Washington County)
- Killdeer, ND
- Raton Basin, CO
- Wise County, TX
- Description of well construction and design characteristics (Well file review report).
- Characterization of spills related to HF operations (Spills report).

When released, the draft assessment will be available for public comment and a public docket will be set up to receive public comments.

The draft assessment will also be reviewed by the agency's Science Advisory Board.

In answer to questions:

Will we share products prior to release? We have briefed the administrator, assistant administrators and regional administrators. EPA senior management is working with ORD to help us release the HF study reports and draft assessment as soon as possible. At this time, we are not planning on distributing products prior to release.

Questions: Call Jeff…..

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

703-347-8623 (office phone)

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Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: Weaver, Jim
Sent: Thur 5/7/2015 10:06:47 PM
Subject: more new references
GWBessentials.pdf
Rowan2015.pdf
Borrirukwisitsak 2012.pdf

Bethke, C.M., Yeakel, S., 2014,The Geochemist's Workbench, Release 10.0, GWB Essentials Guide, Aqueous Solutions, LLC, Champaign, Illinois (http://www.gwb.com/pdf/GWB10/GWBessentials.pdf), accessed 5-7-2015

Borrirukwisitsak, S., Keenan, H.E., Gauchotte-Lindsay, C., 2012, Effects of Salinity, pH and Temperature on the Octanol-Water Partition Coefficient of BisPhenol A, International Journal of Environmental Science and Development, 3(5), October, 460-464.

Ford, R.G., Wiklin, R.T, Puls, R.W., 2007, Monitored Natural Attenuation of Inorganic Contaminants in Ground Water: Volume 1 – Technical Basis for Assessment, US Environmental Protection Agency, EPA/600/R-07/139.

Schwarzenbach, RP; Gschwend, PM; Imboden, DM. (2002). Environmental Organic Chemistry. 2nd Edition. Hoboken, New Jersey: John Wiley & Sons, Inc.

Rowan, E.L., Engle, M.A., Kraemer, T.F., Schroeder, Hammakc, R.W., Doughten, M.W., 2015, Geochemical and isotopic evolution of water produced from Middle Devonian Marcellus shale gas wells, Applalchian basin, Pennsylvania, American Association of Petroleum Geologists Bulletin, 99(2), 181-206.

Šimůnek, J., M. Šejna, H. Saito, M. Sakai, and M. Th. van Genuchten, The Hydrus-1D Software Package for Simulating the Movement of Water, Heat, and Multiple Solutes in Variably Saturated Media, Version 4.17, HYDRUS Software Series 3, Department of Environmental Sciences, University of California Riverside, Riverside, California, USA, pp. 342, 2013.

Jim Weaver, Ph. D. | Research Hydrologist

U.S. Environmental Protection Agency | National Risk Management Research Laboratory | Ground Water and Ecosystems Restoration Division

919 Kerr Research Dr | Ada, Oklahoma 74820 | 580-436-8550 | weaver.jim@epa.gov

To: Ridley, Caroline[Ridley.Caroline@epa.gov]; Bates, William[bates.william@epa.gov]
From: Kobelski, Bruce
Sent: Thur 5/7/2015 3:18:04 PM
Subject: RE: HF assessment- OGWDW input on CBM?

Good deal, Caroline. I hope you all get a restful couple of days after it goes out to de-stress. Those studies are like a sword hanging over your heads!

From: Ridley, Caroline
Sent: Thursday, May 07, 2015 10:28 AM
To: Bates, William
Cc: Kobelski, Bruce
Subject: RE: HF assessment- OGWDW input on CBM?

Thank you so much for the quick response! We are ever-so close to wrapping this assessment up!

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): (703) 362-5955

From: Bates, William
Sent: Thursday, May 07, 2015 10:22 AM
To: Ridley, Caroline
Cc: Kobelski, Bruce
Subject: RE: HF assessment- OGWDW input on CBM?
~~~~~~

Good morning Caroline,

Attached are Bruce's comments. I did not have anything to add to his comments.

William J. L. Bates

Geologist

U.S. EPA

Office of Ground Water & Drinking Water: Prevention Branch

202-564-6165

From: Ridley, Caroline
Sent: Wednesday, May 06, 2015 1:15 PM
To: Bates, William
Subject: RE: HF assessment- OGWDW input on CBM?

Not since last September. Ex. 5 Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): (703) 362-5955
~~~~~~

From: Bates, William
Sent: Wednesday, May 06, 2015 1:11 PM
To: Ridley, Caroline
Subject: RE: HF assessment- OGWDW input on CBM?

Hey Caroline,

There seems some information related to CWA authority. Did Scott Wilson in OWM take a look at this?

William J. L. Bates

Geologist

U.S. EPA

Office of Ground Water & Drinking Water: Prevention Branch

202-564-6165

From: Ridley, Caroline
Sent: Wednesday, May 06, 2015 12:52 PM
To: Bates, William
Subject: FW: HF assessment- OGWDW input on CBM?

Hey, Bill,

Reeeeally quick favor. Lisa Biddle in OST suggested we run our section on CMB wastewater management by OGWDW. Know anyone that would care to take a look? Like by noon tomorrow?

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): (703) 362-5955

From: Mary Ellen Tuccillo Ex. 4
Sent: Wednesday, May 06, 2015 12:32 PM
To: Ridley, Caroline
Cc: Jonathan.Koplo Ex. 4
Subject: RE: HF assessment- OGWDW input on CBM?

Hi Caroline,

This is the current version. I've incorporated your comments.

Mary Ellen

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Wednesday, May 06, 2015 12:12 PM
To: Mary Ellen Tuccillo
Subject: RE: HF assessment- OGWDW input on CBM?
~~~~~~

Is there a version of this section with my comments incorporated that I could send to Bill today?

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): (703) 362-5955

From: Biddle, Lisa
Sent: Wednesday, May 06, 2015 12:02 PM
To: Ridley, Caroline; Pritts, Jesse
Subject: RE: HF assessment- OGWDW input on CBM?

Hi Caroline,

I think we were recommending they review pages 8-36 and 8-37 because there is a lot of discussion about managing CBM wastewater in ways that fall under OGWDW's SDWA authority (like aquifer recharge for example). This is not our area of expertise in OST but it is something they are careful about and we always run those types of write ups by them to make sure we are explaining everything correctly.

I work with Bill Bates at the staff level on hydraulic fracturing related things, so I would recommend starting there. Also, Holly Green is a branch chief who is also involved in a lot of HF related work. If you cannot get either of them, Jeff Jollie is another staff person who is generally in the loop on these topics and is helpful.

Thanks,
~~~~~~

Lisa

Lisa A. Biddle
U.S. EPA, Office of Water
ph: (202) 566 0350
Biddle.Lisa@epa.gov

From: Ridley, Caroline
Sent: Wednesday, May 06, 2015 11:39 AM
To: Biddle, Lisa; Pritts, Jesse
Subject: HF assessment- OGWDW input on CBM?

Hi, guys,

Ex. 5

Thanks,

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): **Ex. 6**
~~~~~~

To: Ridley, Caroline[Ridley.Caroline@epa.gov]; Jonathan.Koplos Ex. 4
From: Anna Weber
Sent: Tue 5/5/2015 3:43:32 PM
Subject: RE: May 4 version of Chapter 2

Ex. 5

Thanks,

Anna

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Tuesday, May 05, 2015 11:29 AM
To: Jonathan Koplos
Cc: Anna Weber
Subject: RE: May 4 version of Chapter 2

Jonathan,

Ex. 5

Thanks!

Caroline

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and Ex. 6

From: Jonathan Koplos Ex. 4
Sent: Monday, May 04, 2015 1:59 PM
To: Ridley, Caroline
Cc: Anna Weber
Subject: May 4 version of Chapter 2

Hi Caroline,

Ex. 5

Please let me know if you have any questions.

Jonathan

Ex. 5

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

100 5th Avenue, Suite 100

Waltham, MA 02451

Ex. 4

www.cadmusgroup.com

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