REVISED DRAFT
Remedial Investigation Report

Kerr-McGee Chemical Corporation Superfund Site
Navassa, North Carolina

EPA ID #NCD980557805

Prepared for:

Greenfield Environmental Multistate Trust, LLC
Trustee of the Multistate Environmental Response Trust

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List of Acronyms

AECOM	AECOM Technical Services of North Carolina, Inc.
ASTM	American Society for Testing and Materials
BERA	Baseline Ecological Risk Assessment
bgs	Below Ground Surface
Catlin	Catlin Engineers and Scientists
CCA	Chromated Copper Arsenate
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
cm/sec	Centimeter per Second
COC	Chemical of Concern
COPC	Chemical of Potential Concern
CPT/ROST™	Cone Penetrometer Testing Rapid Optical Screening Tool
CSM	Conceptual Site Model
CSEM	Conceptual Site Exposure Model
°C	Degrees Celsius
DNAPL	Dense Non-Aqueous Phase Liquid
DPT	Direct Push Technology
DO	Dissolved Oxygen
DU	Decision Unit
EarthCon	EarthCon Consultants of North Carolina, P.C.
ED	Exposure Duration
EF	Exposure Frequency
ELS	Early Life Stages
ENSR	ENSR Corporation of North Carolina
EqP	Equilibrium Partitioning
ESI	Expanded Site Inspection
FS	Feasibility Study
g/cm^3	Gram per Cubic Centimeter
HHRA	Human Health Risk Assessment
HI	Hazard Index
HMW	High Molecular Weight
HQ	Hazard Quotient
HRS	Hazard Ranking System
I.D.	Inner Diameter
in/yr.	Inch per Year
IS	Interstitial
ISM	Incremental Sampling Methodology
J&E	Johnson & Ettinger
K	Hydraulic Conductivity
KMCC	Kerr-McGee Chemical Corporation
K_{oc}	Organic Carbon-Water Partition Coefficient

K_{ow}	Octanol-Water Partition Coefficient
LIF	Laser-Induced Fluorescence
LMW	Low Molecular Weight
LOAEL	Lowest Observed Adverse Effect Level
LOE	Line of Evidence
MDL	Method Detection Limit
mg/kg	Milligram per Kilogram
mg/L	Milligram per Liter
MSL	Mean Sea Level
Multistate Trust	Multistate Environmental Response Trust
NAVD	North American Vertical Datum
NCAC	North Carolina Administrative Code
NCDENR	North Carolina Department of Environment and Natural Resources
NCDEHNR	North Carolina Department of Environment, Health, and Natural Resources
NC DEQ	North Carolina Department of Environmental Quality
NCDHHS	North Carolina Department of Health and Human Services
NCDHS	North Carolina Division of Health Services
NCDOT	North Carolina Department of Transportation
NCHWS	North Carolina Hazardous Waste Section
NCP	National Contingency Plan
NOAEL	No Observed Adverse Effect Level
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
NRCS	Natural Resources Conservation Service
NRWQC	National Recommended Water Quality Criteria
NTU	Nephelometric Turbidity Unit
ORP	Oxidation-Reduction Potential
PA	Preliminary Assessment
PAH	Polycyclic Aromatic Hydrocarbon
PCBs	Polychlorinated Biphenyls
PFS	Problem Formulation Statement
PSA	Preliminary Site Assessment
PVC	Polyvinyl Chloride
RCRA	Resource Conservation Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RLS	Registered Land Surveyor
RSLs	USEPA Regional Screening Levels for Chemical Contaminants at Superfund Sites
SAA	Superfund Alternative Approach
SARA	Superfund Amendments and Reauthorization Act of 1986
SC	Specific Conductance
SI	Site Inspection

SIP	Site Inspection Prioritization
SLERA	Screening Level Ecological Risk Assessment
SPME	Solid Phase Microextraction
SPT	Soil Penetration Test
SRI	Supplemental Remedial Investigation
SSI	Screening Site Investigation
SVOC	Semi-Volatile Organic Compound
SWQS	Surface Water Quality Standard
Tronox	Tronox, LLC
TAL	Target Analyte List
TarGOST®	Tar-Specific Green Optical Screening Tool
TCL	Target Compound List
TCL/TAL	Target Compound List/Target Analyte List
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TRV	Toxicity Reference Value
TU	Toxic Unit
UCL	Upper Confidence Limit
USACE	United States Army Corps of Engineers
USCS	Unified Soils Classification System
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USF&WS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VOC	Volatile Organic Compound
VISL	Vapor Intrusion Screening Level
µg/kg	Microgram per Kilogram
µg/L	Microgram per Liter

Executive Summary

EarthCon Consultants of North Carolina, P.C. (EarthCon) has prepared this Remedial Investigation (RI) Report for the Greenfield Environmental Multistate Trust, LLC, not individually but solely in its representative capacity as Trustee of the Multistate Environmental Response Trust (the Multistate Trust) as a component of the effort to complete the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) characterization of the Kerr-McGee Chemical Corporation (KMCC) - Navassa Site [United States Environmental Protection Agency (USEPA) ID# NCD980557805], located in Navassa, North Carolina (Figure 1-1).

The RI Report documents the site characteristics, identifies the chemicals of concern (COCs) and describes the extent of impacts and fate and transport of COCs in impacted media at the Site. The RI Report summarizes investigative activities performed by KMCC and the Multistate Trust. It also provides a summary of the Human Health Risk Assessment (HHRA) and the Baseline Ecological Risk Assessment (BERA).

According to USEPA guidance, an NPL "site" is best defined as that portion of a facility that includes the location of a release (or releases) of hazardous substances and wherever hazardous substances have come to be located. As such, the extent of a site is not limited by property boundaries and does not include clean areas within a facility's property boundaries. In this document, the former KMCC property will be referred to as "the property", the former wood treating areas will be referred to as "the former facility" and the areas of known impact will be referred to as "the Site".

Background

The Site is a former wood treating facility located within the limits of the Town of Navassa, in Brunswick County, North Carolina (Figure 1-1). The property is bounded to the north by Quality Drive and the former Rampage Boat Company, to the east by the Brunswick River, to the south by Sturgeon Creek, and to the west by Navassa Road followed by residential property (Figure 1-2).

The property consists of approximately 244 acres, 152 acres of upland areas and 92 acres of marsh. The upland areas are owned by the Multistate Trust. The marsh is owned by the State of North Carolina. The eastern two-thirds of the property (Eastern Upland) is undeveloped and wooded and bounded to the east by a marsh. Two 1-acre residential parcels (the Residential Parcels) are located within the east central portion of the property. Access to the Residential Parcels is via Canal Drive from Quality Drive. Canal Drive is an unpaved road approximately one half-mile long. Historically, the western third of the property, consisting of approximately 58 acres, was used for the wood treating operations and is generally referred to as the Site. The northern and eastern portions of the Site were used primarily for storage of treated and untreated wood (Treated and Untreated Wood Storage Areas). The southern portion of the Site (Process Area and Pond Area) was used in the wood treating process. Areas of the tidal marsh south of the former wood treating facility that have been impacted by wood treating process releases are also included in the Site (Figure 1-2).

Currently, most of the Site is overgrown with trees and underbrush with little evidence of the former structures as shown on Figure 1-3. A fence is located on the north and west boundaries of the Process Area. A fenced area is located within the western area of the property and is currently used as a staging area for the RI field activities. A field office is located on the northern property boundary near Quality Drive and Canal Drive.

From 1936 to 1974, a wood treating plant operated on the southwestern and western area of the property to treat wood used for railroad ties, utility poles, and pilings. The plant was originally constructed by Gulf States Creosoting Company in 1936. American Creosoting purchased the facility in 1958 and sold it to KMCC in 1965. KMCC reportedly used only creosote as a preservative in their wood treating process. Historical operations prior to KMCC are unknown; however, there are no records that document the use of pentachlorophenol or chromated copper arsenate (CCA) at the facility. KMCC discontinued site operations in 1974. The plant was decommissioned and dismantled in late 1979 to early 1980. Plant equipment, treatment cylinders, buildings, and tanks were reportedly demolished and/or sold as scrap during the dismantling/closure process.

During plant operations, untreated wood was cut, dried, and stored in the Untreated Wood Storage Area shown on Figure 1-2. Creosote storage and application occurred in the Process Area. Wood treatment cylinders, a boiler house, product storage tanks, and drip tracks were located in this area. The Process Area, including the drip tracks, was approximately 5.8 acres in size. The wood treating process involved placing pre-cut timber in a treatment cylinder. The cylinder was then filled with the creosote solution and pressurized, forcing the creosote into pore spaces within the cut timber. Treatment occurred in either of two 140-foot long by 8-foot diameter cylinders. The creosote was stored in steel, aboveground tanks situated within a diked containment area, located in the south-central end of the Process Area, just north of the Fire Protection Pond. The pressure cylinders and boiler house were located in the central portion of the Process Area. The boiler house and treatment cylinder foundations remain on the Site. Treated wood was removed from the cylinders and transported via railcar. The railcar was temporarily staged in the drip tracks area north of the cylinders. Excess creosote would drip from the treated wood onto the land surface. Treated wood was then transferred via rail car from the Process Area to the north where it was unloaded and staged in the Treated Wood Storage Area (Figure 1-2).

The wood treating process generated wastewater which was collected and discharged into two unlined earthen surface impoundments referred to as "process water treatment ponds" in 1984 and now referred to as the Wastewater Ponds. Creosote was separated and reclaimed for reuse in the Wastewater Ponds. The effluent from the Wastewater Ponds was reportedly recycled to a condenser as make-up cooling water. After 1966, excess wastewater was discharged to an evaporation pond installed by KMCC. Five other earthen, unlined surface impoundments were used at various times during facility operations, including: a Fire Protection Pond, two Boiler Ponds, and two Evaporation Ponds (Figure 1-2). Dikes used to contain liquids are still visible.

In 1980, the wood treating plant was decommissioned. As part of the decommissioning process, wastewater in the Wastewater Ponds was pumped to the Evaporation Pond(s). Creosote in the Wastewater Ponds was reported to be reclaimed, but creosote sludge from the Wastewater Ponds and the bottom of the creosote storage tanks was reportedly mixed with clean soil, consolidated and compacted in the bottom of the Wastewater Ponds. The upper portions of the ponds were then backfilled with clean soil and covered with a vegetative clay cap. The Boiler Ponds were reportedly drained and filled and the Fire Protection Pond dike was breached and drained.

The property has not been redeveloped or used for industrial activity since the facility was decommissioned in 1980. Beginning in the 1980s, multiple parties performed pre-CERCLA environmental investigations at the Site and surrounding areas. Beginning in 2006, RI activities were performed by ENSR Corporation of North Carolina and AECOM Technical Services of North Carolina, Inc. (under contract to Tronox), by USEPA, and by CH2M Hill and EarthCon

(under contract to the Multistate Trust). The activities conducted included dense non-aqueous phase liquid (DNAPL) investigations and soil (background, surface soil, terrestrial sediment and subsurface), groundwater, marsh sediment, surface water and vapor intrusion assessments. Sampling locations for the CERCLA-related investigations [including the Expanded Site Inspection (ESI) and RI sampling events] are highlighted on the Comprehensive Sample Locations Map provided as Figure 1-4.

Physical Characteristics

The former KMCC property is in the northeast portion of Brunswick County in the Coastal Plain Physiographic Province. The sedimentary soils in this province consist of thickly bedded sand, silts and clays, shells, sandstone and limestone that are more than 1,000 feet thick and overlie igneous and metamorphic basement bedrock. Locally, the property is underlain by surficial soils that consist of a pale yellow to gray, medium to fine sand with intermittent zones of silty to clayey sands with some natural organic materials. The uppermost surficial soils are underlain by pale yellow to light brown to gray predominantly finer grain material referred to locally as the Gumbo clay. The surficial soils, the Gumbo clay and the soils below the clay are considered to represent the Surficial Aquifer. The Peedee Formation underlies the Surficial Aquifer. The contact with the Peedee Formation is characterized by a distinct color change from yellowish brown to dark gray. The lithology of the Peedee Formation consists of silty medium sands with traces of mica and fine shell fragments with thin layers of calcareous cemented sands.

The major aquifers in Brunswick County include the Surficial, Castle Hayne, Peedee, Black Creek, Upper Cape Fear and Lower Cape Fear Aquifers. The Surficial Aquifer and upper part of the Peedee Aquifer are an important source of groundwater supply for domestic and commercial use in Brunswick County. The Black Creek and Cape Fear Formations are not used for potable water supplies in Brunswick County, as they contain brackish water. The Castle Hayne Aquifer, which is the most productive aquifer in Brunswick County, is absent in the Navassa area.

The direction of groundwater flow in the Surficial Aquifer and the Peedee Aquifer is to the south-southeast towards the southern marsh and Sturgeon Creek. Where the Gumbo clay is present, localized perched groundwater conditions exist. Vertical groundwater data based on groundwater elevation data from monitoring well clusters suggest a negligible vertical gradient between the Surficial and Peedee Aquifers. Using the geometric mean hydraulic conductivity value, the calculated hydraulic gradient, and an effective porosity of 30 percent, the horizontal groundwater flow velocity in the Surficial Aquifer is calculated at 0.33 feet per day or 120 feet per year. The estimated horizontal groundwater flow velocity in the Peedee Aquifer is calculated at 0.007 feet per day or 2.6 feet per year.

Generally, the rivers in Brunswick County are under tidal influence and approximately one-fifth of Brunswick County consists of swampy or poorly drained land subject to seasonal flooding. The property is bounded to the east by a tidal marsh and the Brunswick River and to the south by a tidal marsh and Sturgeon Creek. Sturgeon Creek drains wetland areas and a tidal marsh on the north side of the Town of Leland and to the west and south of the Town of Navassa. The eastern marsh is hydraulically connected to the Brunswick River. Sturgeon Creek flows into the Brunswick River at the southeastern point of the property

The property has limited areas of standing water. Surface water found on the property is primarily localized and intermittent storm water typically associated with heavy or prolonged rainfall events. There are remnants of several drainage swales that cut across portions of the property, but these do not consistently contain standing water. None of the available data suggest that surface water on the property affects groundwater flow dynamics beneath the

property. Tidal studies indicated that tidal fluctuations influence groundwater elevations in monitoring wells installed in the Surficial Aquifer as far as 1,300 feet from Sturgeon Creek or more than 600 feet from the southern tidal marsh. Tidal fluctuations influence groundwater elevations as much as 0.4 feet in monitoring wells installed near the tidal marsh.

The three major ecological habitats found at the property include forested terrestrial, tidal marsh and riverine habitats. Habitat on the property is generally homogeneous throughout the terrestrial areas with approximately 90 to 100 percent wooded with Loblolly pine. Vegetation at the edge of the marsh consists of water oak, wax myrtle, sweetbay magnolia, red maple, southern arrowwood, willow oak, dogwood, and black cherry. The southern marsh and Sturgeon Creek were selected for baseline ecological evaluation of potential risks to aquatic and benthic receptors. These areas are located adjacent to the suspected area of release and may contain creosote-related contaminants. The tidal marsh is controlled by semidiurnal tides and fluctuates from fresh to brackish, depending on the season (i.e. average rainfall). Sturgeon Creek is a tidal creek that borders the southern end of the property, is approximately 80 feet wide, 13 feet deep with a tidal range of approximately 4 to 4.5 feet. The tidal marshes located adjacent to the property along the south and east sides and the water bodies are Surface Water Target Sensitive Environments because many wildlife receptors are expected to be present in the wetland and Sturgeon Creek.

Nature and Extent of Contamination

Limited available historical records indicate that creosote was the only wood treating chemical used at the Site. Releases of wood treating chemicals have resulted in the presence of DNAPL, creosote constituents, and fuel-related constituents in surface soil and terrestrial sediment, subsurface soil, groundwater, and marsh sediment.

The semi-volatile organic compounds (SVOCs) considered to be the primary indicators of creosote include polycyclic aromatic hydrocarbons (PAHs), phenols, and 3 compounds closely associated with the PAHs (1,1-biphenyl, carbazole and dibenzofuran). For purposes of this RI Report, the SVOCs most commonly detected at concentrations greater than USEPA's residential Regional Screening Levels (RSLs) will be referred to as "creosote-related SVOCs" which will include the following constituents:

- 1,1-Biphenyl
- Carbazole
- Dibenzofuran
- 1-Methylnaphthalene
- 2-Methylnaphthalene
- Acenaphthene
- Acenaphthylene
- Anthracene
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(g,h,i)perylene
- Benzo(k)fluoranthene
- Chrysene
- Dibenz(a,h)anthracene
- Fluoranthene
- Fluorene
- Indeno(1,2,3-cd)pyrene
- Naphthalene
- Phenanthrene
- Pyrene

Volatile organic compounds (VOCs) are often present at creosote wood treating sites due to their presence in carrier oil, fuel for machinery and vehicles, and their associated use in equipment maintenance. Petroleum products are sometimes added to dilute or "cut" the creosote. The VOCs most commonly detected at concentrations greater than residential RSLs at the Site include:

- Benzene
- Ethylbenzene
- Total xylenes
- 1,2,4-Trimethylbenzene
- 1,3,5-Trimethylbenzene

DNAPL

DNAPL is present in thin layers or "stringers" in subsurface soils in the Process Area, downgradient of the Wastewater Ponds and beneath the Evaporation Ponds. None of the data indicate a large, continuous plume of DNAPL. DNAPL stringers were identified in the Process Area at depths from the ground surface to 25 feet below ground surface (bgs). DNAPL stringers were also observed at depths ranging from the ground surface to 100 feet near the Wastewater Ponds extending to the southern marsh. DNAPL was also present beneath the Boiler Ponds, the Operations Evaporation Pond, the Decommissioning Evaporation Pond and the marsh sediments.

Surface Soil and Terrestrial Sediment

Creosote-related SVOCs were detected above residential RSLs throughout the Process Area, Treated Wood Storage Area, Untreated Wood Storage Area, and Pond Area. Creosote-related SVOCs were detected in the Eastern Upland Area primarily in drainage swales. Arsenic was also detected in 26 of the 83 surface soil samples throughout the property. The arsenic concentrations that exceed background values were detected sporadically throughout the areas used for wood treating and the Eastern Upland Area. Because there is no record of CCA (an alternative wood preservative) use at this Site, the presence of arsenic may be related to historical agricultural uses on the property.

Subsurface Soil

VOCs were detected in subsurface soil samples in the Pond and Process Areas. Creosote-related SVOCs were detected in subsurface soils in the Treated and Untreated Wood Storage Areas, the Process Area, and the Pond Area. SVOCs were not detected above residential RSLs in subsurface soil from the Eastern Upland Area. Concentrations of SVOCs in subsurface soil from the Treated Wood Storage Area were lower than the concentrations in the surface soil indicating surface releases of creosote consistent with the use of this area. The occurrence of SVOCs above residential RSLs in the subsurface soil in the Untreated Wood Storage Area was limited to two samples. Subsurface soil data combined with DNAPL observations indicate that soil in the Process Area is impacted from the ground surface to 25 feet bgs. Subsurface soil data and DNAPL observations in the Pond Area indicate impacts from ground surface to 100 feet at the Wastewater Pond extending to the southern marsh.

Groundwater

VOCs are present in groundwater in the Surficial Aquifer extending from the Process Area southwest across Navassa Road, and from the Evaporation Ponds extending southwest to the marsh. Groundwater in the Peedee Aquifer is impacted west of Navassa Road, near the Operations Evaporation Pond, south of the Fire Protection Pond and south of the Wastewater Ponds.

SVOCs are present in groundwater in the Surficial Aquifer from the Process Area southwest across Navassa Road and from the Evaporation Ponds extending south to the marsh. SVOCs are present in the Peedee Aquifer in the Process Area, west of Navassa Road and in the Pond Area. Results of groundwater samples collected by USEPA from residential irrigation wells located south of Sturgeon Creek do not indicate the presence of groundwater contamination south of Sturgeon Creek. Naphthalene was the only constituent detected in the monitoring

wells west of Navassa Road. While the extent of contamination to the west is not fully defined, the concentrations were relatively low. Continued monitoring will provide additional information regarding the extent of naphthalene west of Navassa Road.

The sources of groundwater contamination include DNAPL and creosote impacted soil primarily located in the Pond and Process Areas. Based on the similarity of shape and the extent of the groundwater plume with the DNAPL configuration, the primary source of groundwater contamination appears to be DNAPL.

The lateral extent of VOCs and SVOCs in Peedee groundwater is less than the lateral extent in Surficial groundwater. However, DNAPL was measured in three deep monitoring wells (MW-06D, MW-27D, and MW-32D). Deeper wells were not installed because boring log descriptions from nearby soil borings SB-E, SB-D, SB-D-01 and the boring log for monitoring well MW-06D do not indicate the presence of DNAPL or creosote odors below 88 feet bgs. In addition, based on geotechnical laboratory data, the soil becomes progressively less permeable at depth as demonstrated in SB-D-01 where permeability at 130 feet is 6.5×10^{-7} and SB-E, where permeability is 8.1×10^{-7} at 100 feet bgs and 5.2×10^{-6} at 110 feet bgs. Based on field observations and soil permeability, the vertical extent of contamination in groundwater can be inferred.

Arsenic concentrations in surficial groundwater above tapwater RSLs correlate with high concentrations of PAHs and low oxidation reduction potentials. Because there is no record of CCA use at this Site, the presence of arsenic may be due to changes in groundwater chemistry due to the presence of DNAPL or high concentrations of dissolved phase creosote constituents.

Marsh Sediment

Creosote-related SVOCs were detected in marsh sediments at concentrations exceeding residential RSLs, Ecological Screening Levels, and/or background concentrations. The constituents detected consist primarily of PAHs, carbazole and dibenzofuran. The most frequently detected PAHs were benzo(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene, fluoranthene, and pyrene. The highest concentrations of creosote-related SVOCs were observed in the disturbed area in the southern marsh. The SVOC concentrations in this area generally decrease with increasing depth. The lateral extent of contamination ranges from west of Navassa Road to southeast of the Pond Area to approximately 500 feet south of the marsh edge.

Arsenic was detected in each of the sediment samples collected including the background samples. Arsenic concentrations in the samples from the marsh sediment were in the same range as the background samples and may be indicative of natural conditions in the marsh and/or anthropogenic conditions.

Fate and Transport

Creosote was released during the wood treating process near several process units including the drip tracks, the treatment vessels, and the product tanks located in the Process Area as well as the Wastewater Ponds and Evaporation Ponds. To some extent, process water and overland precipitation run-off containing dissolved-phase creosote constituents were also released from the Process Area.

DNAPL

Creosote in the free phase (DNAPL) will continue to migrate vertically downward until migration is impeded by less permeable zones (e.g. a clay or silt layer), where it may spread horizontally. Vertical migration continues when a zone of higher permeability is encountered. If the volume

of DNAPL is sufficient, it will continue to migrate into the saturated zone until the volume is eventually exhausted by the residual saturation process or until it is intercepted by a low permeable formation where it begins to migrate laterally. The DNAPL will continue to migrate vertically and horizontally until it reaches a less permeable boundary.

Substantial future migration of DNAPL in the free phase is not likely to occur as wood treating activities have not been conducted since 1974 and there is no longer a continuing source of creosote. Natural processes, including fluctuation of groundwater elevations and the presence of naturally occurring organic carbon, will help control the plume size and stability but are not expected to completely attenuate the DNAPL source zones or dissolved phase plume. Therefore, DNAPL will continue to be an ongoing source of dissolved phase groundwater contamination.

Soil

Surface and subsurface soils and sediments in the source areas are primarily impacted by creosote-related SVOCs and to a lesser extent VOCs. These constituents can volatilize, undergo abiotic degradation, biodegrade or accumulate in plants. Evidence of leaching to groundwater is demonstrated by the presence of chemicals of potential concern (COPCs) in groundwater.

The SVOCs and DNAPL in soil in the source areas will be transformed over time but will persist for many years. SVOCs in unsaturated zone soils and in deeper subsurface soils close to or in the water table will continue to be a contamination source to infiltrating water and eventually groundwater.

Groundwater

Another migration mechanism of importance is dissolution of creosote DNAPL compounds into groundwater and groundwater transport of dissolved-phase constituents. The groundwater transport is controlled by sorption and biodegradation as well as advection, diffusion, and dispersion. The dissolved constituents migrate outward from the source area in the general direction of groundwater flow. Infiltration of rainfall will also contribute to groundwater impacts as it migrates through shallow impacted soils to groundwater. These migration mechanisms will continue as long as these sources are present and in direct contact with groundwater.

Groundwater flow information for the Surficial Aquifer indicates that groundwater is flowing and likely discharging to surface water in the southern marsh; however, the tidal cycle impacts the groundwater flow. During high tides, water level elevations rise in monitoring wells near the marsh edge impeding the flow of groundwater into the marsh. Based on the depth to the Peedee Aquifer and the lack of an upward hydraulic gradient, groundwater in the Peedee Aquifer does not appear to discharge to the marsh. The groundwater gradient and general dip of the Peedee Formation to the southwest suggest that the Peedee Aquifer would discharge to the Cape Fear River.

As long as DNAPL is in contact with groundwater and/or residual soil sources can leach to groundwater, they will continue to dissolve contaminants. Based on aqueous solubility, the profile of dissolved constituents in groundwater may change over time from more soluble to less soluble. Natural attenuation mechanisms may stabilize the plume, but the plume itself is expected to persist as long as there are contributing sources.

Marsh Sediment

PAHs in sediments can adsorb, biodegrade, or accumulate in aquatic organisms. Sediment suspended in surface water, due to extreme weather or man-made disturbances, could result in

transport and redistribution of COPCs to other areas of the marsh or to downstream locations. The SVOCs in sediment will be transformed over time but will persist for many years.

Human Health Risk Assessment (HHRA)

A Human Health Risk Assessment (HHRA) was conducted as part of the RI process. The purpose of the HHRA is to characterize the carcinogenic and non-carcinogenic risk to human health from contamination at the Site in support of the Site's risk managers' decision-making process. Risk assessments provide an evaluation of the potential threat to human health and the environment in the absence of any remedial action and provide the basis for determining whether or not remedial action is necessary.

For purposes of the HHRA, the property was divided into areas based on historical activities and the risk levels for each area were determined separately. The areas evaluated included:

- Process Area
- Pond Area
- Treated Wood Storage Area
- Untreated Wood Storage Area
- Eastern Upland Area
- West of Navassa Road
- Southern Marsh
- Sturgeon Creek

Groundwater was evaluated across the property, though impacts to groundwater were limited to the southern portion of the property.

Constituents detected in each area for each medium were evaluated to determine the COPCs which primarily included metals, VOCs, and SVOCs. Each COPC was then evaluated to determine the risk posed for each receptor for each medium in each area. Each COPC exhibiting an incremental cancer risk greater than 1×10^{-6} (1.0E-06) or a Hazard Quotient (HQ) greater than 0.1 was retained as a chemical of concern (COC). Based on this evaluation, there were no COPCs associated with Sturgeon Creek or the area West of Navassa Road.

A summary of total cancer risk greater than 1×10^{-6} (1.0E-06) and a Hazard Index (HI) greater than 1 for each remaining area is provided below:

Process Area

- The cancer risk from surface soil for the future child resident is 4.2E-04 and the HI is 2.9 primarily due to ingestion of benzo(a)pyrene. For subsurface soil, the HI is 400 due primarily to vapor intrusion (VI) risks from naphthalene.
- The cancer risk from surface soil for the future adult resident is 2.3E-05 primarily due to ingestion of benzo(a)pyrene and phenanthrene, and inhalation of naphthalene. For subsurface soil, the HI is 400, primarily due to VI risks from naphthalene.
- The cancer risk from surface soil for the future construction worker is 2.7E-06 primarily due to ingestion of benzo(a)pyrene and phenanthrene. The cancer risk from subsurface soil is 6.1E-06 and the HI is 15, due primarily to ingestion of PAHs and SVOCs, and VI risks from 1,1-biphenyl and naphthalene.

- The cancer risk from surface soil for the future industrial worker is 2.2E-05 primarily from ingestion of PAHs and arsenic, and inhalation of hexavalent chromium. For subsurface soil the HI is 290, due primarily to VI risks from 2-methylnapthalene and naphthalene.
- The cancer risk from surface soil for the current and future teenage trespasser in the Process Area is 1.4E-05 primarily due to ingestion of benzo(a)pyrene.

Pond Area

- The cancer risk from surface soil for the future child resident is 8.2E-04 and the HI is 25 primarily due to ingestion of benzo(a)pyrene. For subsurface soil, the HI is 400 primarily due to VI risks from naphthalene.
- The cancer risk from surface soil for the future adult resident is 5.4E-05 and the HI is 8.9 primarily due to ingestion of benzo(a)pyrene, and inhalation of naphthalene and 1,1-biphenyl. For subsurface soil, the HI is 400 due primarily to VI risks from naphthalene.
- The cancer risk from surface soil for the future construction worker is 6.3E-06 with a HI of 6.3, primarily due to ingestion of arsenic, benzo(a)pyrene, and dibenzofuran. The cancer risk from subsurface soil is 7.7E-06 and the HI is 10, due primarily to ingestion of PAHs, and VI risks from 1,1-biphenyl and naphthalene.
- The cancer risk from surface soil for the future industrial worker is 4.8E-05 with a HI of 3.4, due primarily to ingestion of arsenic and PAHs, and inhalation of hexavalent chromium. The HI is 290 due primarily to VI risks from 2-methylnapthalene and naphthalene.
- The cancer risk from surface soil for the current and future teenage trespasser is 2.9E-05 primarily due to ingestion of arsenic, benzo(a)anthracene, and benzo(a)pyrene.

Treated Wood Storage Area

- The cancer risk from surface soil for the future child resident is 3.8E-05 primarily from ingestion of benzo(a)pyrene.
- The cancer risk from surface soil for the future adult resident is 2.8E-06 primarily from ingestion of benzo(a)pyrene.
- The cancer risk from surface soil for the future industrial worker is 2.5E-06 primarily from ingestion of arsenic and benzo(a)pyrene, and inhalation of aluminum.
- The cancer risk from surface soil for the current and future teenage trespasser is 1.4E-06 due primarily to ingestion of arsenic and benzo(a)pyrene.

Untreated Wood Storage Area

- The cancer risk from surface soil for the future child resident is 2.8E-05 primarily due to ingestion of arsenic and benzo(a)pyrene.
- The cancer risk from surface soil for the future adult resident is 3.3E-06 primarily due to ingestion of benzo(a)pyrene and arsenic.
- The cancer risk from surface soil for the future industrial worker is 6.1E-06 primarily due to ingestion of arsenic and benzo(a)pyrene and inhalation of hexavalent chromium.
- The cancer risk from surface soil for the current and future teenage trespasser is 1.0E-06 due primarily to ingestion of arsenic and benzo(a)pyrene.

Eastern Upland Area

- The cancer risk from surface soil for the future child resident is 1.3E-05 due to ingestion of arsenic and benzo(a)pyrene.
- The cancer risk from surface soil for the future adult resident is 3.0E-06 due to ingestion of arsenic.
- The cancer risk from surface soil for the future industrial worker is 4.4E-06 due to ingestion of arsenic and inhalation of hexavalent chromium.

Southern Marsh

- The cancer risk from sediment for the future child resident is 6.8E-04 with a HI is 8.5 primarily due to ingestion of arsenic, benzo(a)pyrene and benzo(a)anthracene.
- The cancer risk from sediment for the future adult resident is 3.4E-05 primarily due to ingestion of arsenic, cobalt, benzo(a)pyrene and benzo(a)anthracene.
- The cancer risk from Southern Marsh sediment for the current and future teenage trespasser is 2.3E-05 due primarily to ingestion of benzo(a)pyrene.

Groundwater

- The cancer risk from groundwater for a future child resident is 1.1E-03 and the HI is 47 primarily due to inhalation via VI and ingestion of arsenic, dibenzo(a,h)anthracene, 1-methylnaphthalene and pentachlorophenol.
- The cancer risk from groundwater for a future adult resident is 9.6E-04, and the HI is 35 primarily due to inhalation via VI and ingestion of arsenic, dibenzo(a,h)anthracene, 1-methylnaphthalene and pentachlorophenol.
- The cancer risk from groundwater for a future construction worker is 1.0E-05, and the HI is 5.4 primarily due to ingestion of arsenic and chloroform, and dermal contact with bis(2-ethylhexyl)phthalate.
- The cancer risk from groundwater for a future industrial worker is 6.0E-04, and the HI is 16 primarily due to ingestion of chloroform and naphthalene, and inhalation of naphthalene via VI.

Based on the results of the HHRA, the overall risk is unacceptable for the reasonably anticipated future land uses. All areas examined require additional evaluation in the following step of the CERCLA process, the feasibility study (FS), except for Sturgeon Creek and the area West of Navassa Road. Risks associated with these areas were below the lower end of the acceptable risk range.

Baseline Ecological Risk Assessment (BERA)

A Baseline Ecological Risk Assessment (BERA) was conducted as part of the RI process. The BERA presented data collected from the Southern Marsh (also referred to as the Marsh Study Area) in December 2016. The 2016 data, combined with historical data for the Marsh Study Area, were used to evaluate current and potential future ecological exposure and ecological risk for the Marsh Study Area (approximately 35 acres) using the following assessment endpoints:

- Benthic community structure and integrity
- Survival, reproduction, and growth of fish populations
- Survival, reproduction, and growth of bird and mammal populations

- Survival, reproduction, and growth of mammal populations

The BERA presents a screening of chemicals for the Marsh Study Area and demonstrates that the focus on PAHs is appropriate for protective risk-management decision-making in the marsh. Multiple lines of evidence were used to evaluate potential risks to these receptors. Lines of evidence included site-specific sediment toxicity testing in laboratory bioassays using sediment dwelling amphipods, benthic community assessments, and consideration of PAH concentrations in pore water using Solid Phase Microextraction (SPME) for estimates of bioavailable PAHs. Data were used for comparison to Early Life Stages (ELS) fish Ecological Screening Benchmarks. Data were also used to implement USEPA's equilibrium partitioning of PAHs to evaluate potential bioavailability and toxicity for sediment dwelling organisms. Finally, data were used for food web modeling to evaluate potential exposures and risks for mammal and bird populations that forage and inhabit the marsh.

There is adequate data in the BERA to conclude that more than 90% of the Marsh Study Area does not pose unacceptable risks to ecological receptors that inhabit the marsh; however, there is an isolated area of the marsh (less than approximately 10%) where potential impacts to individual organisms cannot be definitively ruled out.

A profile of temperature and conductivity trends in marsh surface water using conductivity and temperature probes was performed as part of the BERA investigation. The goal was to determine the magnitude of changes in marsh surface water temperature and conductivity to inform future investigations. Of the three probes deployed, one was not submerged at low tide, one maintained consistent readings, and one (CTD1) showed possible fluctuations with the tidal cycle. Probe CTD1 recorded a 5-degree Celsius variation in temperature as well as conductivity variation. This result will be used to inform any future sampling of surface or pore water in the marsh. This result can also inform future investigations of groundwater discharge into the marsh or groundwater seeps, as needed.

Conclusions

Based on the RI site characterization and the human health and ecological risk assessments for the Site, the following conclusions were developed:

- DNAPL is present in stringers throughout the Process Area and the Pond Area.
- Substantial future migration of the free phase DNAPL is not likely to occur as wood treating activities have not been conducted since 1974 and there is no longer a continuing source of creosote. However, DNAPL is a continuing source of dissolved phase groundwater contamination.
- Groundwater is impacted by VOCs and creosote-related SVOCs in the Process Area, Pond Area, and west of Navassa Road. Natural attenuation mechanisms may stabilize the plume, but the plume itself is expected to persist as long as there are contributing sources.
- Surface and subsurface soils are impacted in the Process and Pond Areas. Surface soils in drainage features are above residential RSLs in the Eastern Upland Area. The SVOCs in soil will be transformed over time by the mechanisms described in Section 5.3 but will persist for many years.
- Creosote-related SVOCs are present in sediment in the southern marsh. Sediment suspended in surface water could be transported and redistributed to other areas of the marsh or downstream locations by extreme weather or man-made disturbances. The SVOCs in sediment will be transformed over time but will persist for many years.

- Based on the results of the HHRA, each of the areas examined requires additional evaluation in the FS, except for Sturgeon Creek and the area West of Navassa Road.
- In general, the constituents detected over most of the marsh do not pose unacceptable risks to ecological receptors that inhabit the marsh; however, there is an area of the marsh where potential impacts to individual organisms cannot be definitely ruled out. The size of this area may be one to three acres, depending on which receptor groups and which TRVs are considered.

Recommendations

The following activities are recommended in the future:

- Conduct a plume stability evaluation to determine if the groundwater plume is increasing, decreasing, or stable. This information will be used in the FS to evaluate potential remedial alternatives.
- Evaluate potential remedial alternatives for mitigating contaminants that pose an unacceptable risk to human health or the environment in the FS. The remedial alternative evaluation is dependent on land use determination.
- Evaluate the area of the marsh that was identified in the BERA in the FS. The FS will include consideration of risk reduction balanced against the damage to the marsh due to remedial action (if any).

1.0 INTRODUCTION

The Kerr-McGee Chemical Corporation - Navassa (KMCC) Superfund Site (the Site) [United States Environmental Protection Agency (USEPA) ID# NCD980557805] is a former creosote-based wood treating facility located in Navassa, North Carolina. Wood treating operations occurred at the facility from 1936 until 1974. The former KMCC property has not been redeveloped or used for industrial activity since KMCC decommissioned the plant in 1980.

The State of North Carolina referred the Site to the USEPA because of widespread contamination on the KMCC property. The Site is being addressed by USEPA Region 4 under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) and the National Contingency Plan (NCP). The USEPA placed the Site on the National Priorities List (NPL) in 2010.

According to USEPA Guidance, an NPL "site" is best defined as that portion of a facility that includes the location of a release (or releases) of hazardous substances and wherever hazardous substances have come to be located. As such, the extent of a site is not limited by property boundaries and does not include clean areas within a facility's property boundaries. In this document, the former KMCC property will be referred to as "the property", the former wood treating areas will be referred to as "the former facility" and the areas of known impact will be referred to as "the Site".

Between 1984 and 2017, environmental investigations including a Remedial Investigation (RI) were performed at the Site and surrounding areas. This RI Report presents the RI activities conducted at the Site and surrounding areas and includes a summary of pre-RI investigations. This report was prepared by EarthCon Consultants of North Carolina, P.C. (EarthCon) for the Greenfield Environmental Multistate Trust, LLC, not individually but solely in its representative capacity as Trustee of the Multistate Environmental Response Trust (the Multistate Trust).

1.1 PURPOSE AND SCOPE OF THE RI REPORT

This RI Report summarizes investigative activities performed by KMCC and the Multistate Trust, documents Site characteristics, identifies the chemicals of potential concern (COPC), and describes the extent of impacts and fate and transport of COPCs in impacted media. The RI Report also provides a summary of the Human Health Risk Assessment (HHRA) and the Baseline Ecological Risk Assessment (BERA).

1.2 REPORT ORGANIZATION

The remainder of the RI Report has been prepared according to the outline presented below.

Section 2 (Site Investigation Activities): This section describes the investigative efforts performed during each phase of the RI. The field activities from each phase of the RI are combined to present a comprehensive summary of the field efforts for each matrix.

Section 3 (Physical Characteristics): This section describes the physical characteristics of the Site study area, including surface features, geology, hydrogeology, surface water hydrology, and ecology using information gathered from literature searches and field investigations.

Section 4 (Nature and Extent of Contamination): This section presents the results of sampling in the source areas and in each media. It summarizes the analytical data collected during each phase of the RI and presents the data in tables and figures.

Section 5 (Fate and Transport of Contaminants): This section describes the distribution and migration of COPCs in the various environmental media and presents the conceptual site model (CSM).

Section 6 (Human Health Risk Assessment): This section summarizes the results of the HHRA.

Section 7 (Baseline Ecological Risk Assessment): This section summarizes the results of the BERA.

Section 8 (Conclusions and Recommendations): This section presents the RI findings and conclusions regarding the nature and extent, the fate and transport of COPCs, the HHRA and the BERA. This section also provides recommendations for additional assessments and the feasibility study (FS).

Section 9 (References): This section lists the references cited in this report.

Tables, Figures, and **Appendices** for each section are presented at the end of the report text.

1.3 SITE BACKGROUND

This section provides the Site description and summarizes the Site history and administrative history. A summary of the previous investigations and a description of each phase of the remedial investigations are also provided.

1.3.1 Site Description

The Site is a former wood treating facility located within the limits of the Town of Navassa, in Brunswick County, North Carolina. The property is bounded to the north by Quality Drive and the former Rampage Boat Company, to the east by the Brunswick River, to the south by Sturgeon Creek, and to the west by Navassa Road (Figure 1-1). The Site coordinates are 34°14'50.0" North latitude and 77°59'56.5" West longitude (USEPA, 2009).

The property consists of approximately 244 acres, 152 acres of upland areas and 92 acres of marsh. The upland areas are owned by the Multistate Trust. The marsh is owned by the State of North Carolina. Figure 1-2 shows the property boundary on the 1969 historical aerial photograph. As indicated on Figure 1-2, the eastern two-thirds of the property (Eastern Upland) is undeveloped and wooded and bounded to the east by a marsh. Two 1-acre residential parcels (the Residential Parcels) are located within the east central portion of the property. Access to the Residential Parcels is via Canal Drive from Quality Drive. Canal Drive is an unpaved road approximately one half-mile long.

Historically, the western third of the property, consisting of approximately 58 acres, was used for the wood treating operations and is generally referred to as the Site. The northern and eastern portions of the Site were used primarily for storage of treated and untreated wood (Treated and Untreated Wood Storage Areas). The southern portion of the Site (Process Area and Pond Area) was used in the wood treating process. Areas of the tidal marsh south of the former wood treating facility that have been impacted by wood treating process releases are also included in the Site.

Currently, most of the Site is overgrown with trees and underbrush with little evidence of the former structures as shown on Figure 1-3. Vehicles can access the interior of the KMCC property at four locations: (1) the staging area on the west central side of the property, (2) an unpaved power line access road entering the north end of the property, (3) Canal Drive from the northern area of the property and (4) an unpaved access road on the southern boundary of the

property. There are locking gates at each of these access locations. A fence is located on the north and west boundaries of the Process Area. A fenced area is located within the western area of the property and is currently used as a staging area for the RI field activities. A field office is located on the northern property boundary near Quality Drive and Canal Drive.

1.3.2 Site History

From 1936 to 1974, KMCC operated a wood treating plant on the southwestern and western area of the property. KMCC treated wood used for railroad ties, utility poles, and pilings. The plant was originally constructed by Gulf States Creosoting Company in 1936. American Creosoting purchased the facility in 1958 and sold it to KMCC in 1965. KMCC reportedly used only creosote as a preservative in their wood treating process. Historic operations prior to KMCC are unknown; however, there are no indications that pentachlorophenol or chromated copper arsenate (CCA) were used at the facility. KMCC discontinued site operations in 1974. The plant was decommissioned and dismantled in late 1979 to early 1980. Plant equipment, treatment cylinders, buildings, and tanks were reportedly demolished and/or sold as scrap during the dismantling/closure process.

During plant operations, untreated wood was cut, dried, and stored in the Untreated Wood Storage Area shown on Figure 1-2. Creosote storage and application occurred in the Process Area. Wood treatment cylinders, a boiler house, product storage tanks, and drip tracks were located in this area. The Process Area, including the drip tracks, was approximately 5.8 acres in size (Figure 1-2).

The wood treating process involved placing pre-cut timber in a treatment cylinder. The cylinder was then filled with the creosote solution and pressurized, forcing the creosote into pore spaces within the cut timber. Treatment occurred in either of two 140-foot long by 8-foot diameter cylinders. The creosote was stored in steel, aboveground tanks situated within a diked containment area, located in the south-central end of the Process Area, just north of the Fire Protection Pond. The pressure cylinders and boiler house were in the central portion of the Process Area. The boiler house and treatment cylinder foundations remain on the Site.

Treated wood was removed from the cylinders and transported via railcar. The railcar was temporarily staged in the drip tracks area north of the cylinders. Excess creosote would drip from the treated wood onto the land surface. Treated wood was then transferred via rail car from the Process Area to the north where it was unloaded and staged in the Treated Wood Storage Area (Figure 1-2).

The wood treating process generated wastewater which was collected and discharged into two unlined earthen surface impoundments referred to as "process water treatment ponds" in 1984 and now referred to as the Wastewater Ponds. The Wastewater Ponds, which were originally constructed by Gulf States Creosoting, each measured approximately 125 feet by 60 feet by approximately 6 feet deep. Creosote was separated and reclaimed for reuse in the Wastewater Ponds. The effluent from the Wastewater Ponds was reportedly recycled to a condenser as make-up cooling water. After 1966, excess wastewater was discharged to an evaporation pond installed by KMCC. The former location of the Wastewater Ponds is shown on Figure 1-2.

Five other earthen, unlined surface impoundments were used at various times during facility operations, including: a Fire Protection Pond, two Boiler Ponds, and two Evaporation Ponds. Dikes used to contain liquids are still visible. The ponds are described below:

- The Fire Protection Pond was located at the southwest corner of the wood treating facility, adjacent to Navassa Road. The 140 by 170-foot pond was used to store water for firefighting. The berms for this pond are still in place. Based on the aerial

photographs provided in Appendix A, the Fire Protection Pond was constructed between 1961 and 1966.

- The Operations Evaporation Pond, reportedly constructed by KMCC, was located approximately 250 feet northeast of the Wastewater Pond. The Operations Evaporation Pond was 200 feet by 300 feet with a variable depth. It was used to hold excess wastewater from the Wastewater Ponds. Based on the aerial photographs provided in Appendix A, this pond was constructed between 1966 and 1969.

- The Decommissioning Evaporation Pond (visible on the 1975 aerial photograph) is located to the east of the Operations Evaporation Pond as shown on the 1975 aerial photograph (Appendix A). This pond is thought to have received water from the Wastewater Ponds during decommissioning. It was approximately 350 feet long and 150 feet wide.

- The Boiler Ponds were located approximately 100 feet to the north of the northeast corner of the Wastewater Ponds. Historical photographs from the 1960s indicate that Boiler Ponds 1 and 2 measured approximately 45 feet wide by 75 feet long. The boiler ponds were constructed between 1956 and 1961.

In 1980, the wood treating plant was decommissioned. As part of the decommissioning process, wastewater in the Wastewater Ponds was pumped to the Evaporation Pond(s). Creosote in the Wastewater Ponds was believed to be reclaimed, but creosote sludge from the Wastewater Ponds and the bottom of the creosote storage tanks was reportedly mixed with clean soil, consolidated and compacted in the bottom of the Wastewater Ponds. The upper portion of the ponds were then backfilled with clean soil and covered with a vegetative clay cap. The Boiler Ponds were reportedly drained and backfilled. The Fire Protection Pond dike was breached and drained.

The aerial photographs provided in Appendix A were reviewed to provide information about the timeline of operations, which is summarized below:

- **1938 Aerial Photograph:** The Process Area, including the aboveground storage tanks and cylinders is visible in the 1938 aerial photograph. The Treated and Untreated Wood Storage Areas are also evident in the photograph. The Wastewater Ponds are the only ponds visible in the photograph and the eastern pond is only partially constructed in this aerial, compared to later photographs. Ditches in the Treated Wood Storage Area appear to intersect with a ditch along Navassa Road. The property is bordered by Navassa Road. Residential and vacant property can be seen west of Navassa Road. Undeveloped areas and an industrial facility are located north of the railroad tracks. According to the *RI Report and Final Remedial Action Plan for the Holding Pond/USS Site* (Hart & Hickman 2016), the adjacent northeast property was owned by Amour Fertilizer Works in the 1930s. The Estech General Chemicals Site is located across Quality Drive from the Amour Fertilizer Works.

- **1951 Aerial Photograph:** The Process Area, Treated and Untreated Wood Storage Areas, and Wastewater Ponds are visible in the 1951 aerial photograph. The configuration of the Wastewater Ponds is consistent with subsequent aerial photographs. The area lacking vegetation in the marsh southeast of the Wastewater Ponds may be the result of overland flow from the Wastewater Ponds (since the Operations Evaporation Pond is not evident in the photograph). Smoke is visible in an area east of the Untreated Wood Storage Area. Similar to the 1938 photograph, residential, agricultural and vacant property can be seen west of Navassa Road and undeveloped land and railroad tracks are located north of the property with the Amour Fertilizer Works on the adjoining property to the northeast.

- **1956 Aerial Photograph:** The configuration of the Process Area, Treated and Untreated Wood Storage Areas, and Wastewater Ponds is unchanged. The surrounding properties are similar to those shown in the 1951 aerial photograph. The area lacking vegetation is still present in the marsh.

- **1961 Aerial Photograph:** The configuration of the Process Area, Treated and Untreated Wood Storage Areas, and the Wastewater Ponds is unchanged. The Boiler Ponds are visible in this photograph. Similar to the 1956 photograph, one can still see the area in the marsh lacking vegetation and properties north and northeast of the property are unchanged. However, properties to the west of Navassa Road appear to have been developed between 1956 and 1961.

- **1966 Aerial Photograph:** The Process Area, Treated Wood Storage Area, and Wastewater Ponds appear unchanged. The Boiler Ponds and Fire Protection Pond are clearly visible on the 1966 photograph. The Untreated Wood Storage Area is expanded to the east; the new area was reportedly used for cutting and sizing wood. The area lacking vegetation in the marsh is still apparent. Surrounding properties are similar to the 1961 aerial photograph.

- **1969 Aerial Photograph:** The Process Area, Treated and Untreated Wood Storage Areas, Wastewater Ponds, Fire Protection Pond and Boiler Ponds appear unchanged. The Operations Evaporation Pond is visible in this photograph. Smoke is visible east of the Untreated Wood Storage Area rather than south of the Untreated Wood Storage Area as can be seen in the 1951 aerial photograph. Similar to the 1966 aerial photograph, there is an area lacking vegetation in the marsh and surrounding property uses have not changed

- **1975 Aerial Photograph:** The Wastewater Ponds, Boiler Ponds, and Fire Protection Pond are similar to the 1969 aerial photograph. A second pond (the Decommissioning Evaporation Pond) is visible east of the Operations Evaporation Pond and the Operations Evaporation Pond appears to be filled in. Although tanks and buildings appear in the Process Area, wood is no longer stored in the Treated or Untreated Wood Storage Areas and the buildings in the Untreated Wood Storage Area have been removed. The area in the marsh that lacks vegetation is smaller in size. The surrounding property uses are similar to the 1969 aerial photograph.

- **1987 Aerial Photograph:** In the 1987 aerial photograph, the tanks and buildings are no longer present. Although the former pond locations are still visible, tree cover is denser on the property. The area in the marsh lacking vegetation appears smaller despite evidence of flooding in the marsh.

- **1993 Aerial Photograph:** In the 1993 photograph, the former wood treating and marsh areas are revegetated and the ponds are no longer visible.

1.3.3 Site Administrative History

Pertinent letters and reports documenting the site administrative history are described below.

- KMCC submitted a Notification of Hazardous Waste Site form to USEPA Region 4 on June 8, 1981.

- On July 11, 1984, the North Carolina Division of Health Services (NCDHS) sent a letter to KMCC requesting additional information.

- On August 14, 1984, KMCC sent a letter to the Solid and Hazardous Waste Management Branch, Environmental Health Section of the North Carolina Department of Human Resources providing background information on the closed KMCC facility in Navassa.

- On October 8, 1984, the NCDHS submitted a Preliminary Assessment (PA) to the USEPA recommending a screening site investigation (SSI) with a medium priority.

- On May 3, 1988, the NCDHS submitted the PA Update to the USEPA recommending a medium priority for an SSI.

- In 1988, the Superfund Section of the North Carolina Department of Environment, Health, and Natural Resources (NCDEHNR) performed a Site Inspection (SI) at the Site (NCDEHNR, 1989), which indicated the presence of creosote-related constituents in soil beneath the former Wastewater Ponds.

- Based on the results of the SI, NCDEHNR performed a Site Inspection Prioritization (SIP) investigation in May 1995, which also indicated creosote impacts to the Site. Based on the results of the SIP, the Site was recommended for a low priority Expanded Site Inspection (ESI).

- In April 1998, the NCDEHNR received notification of creosote discovered in a roadside excavation on the east side of Navassa Road. A contractor for Brunswick County was excavating to install wastewater lines and observed "dark material" and the odor of creosote at the water table.

- A NCDEHNR Memorandum of Off-site Visit dated April 17, 1998 indicated that a test pit containing visible creosote contamination was located on the east side of Navassa Road approximately 625 feet north of the edge of the wetlands on the north side of Sturgeon Creek and 990 feet north of the bridge span. An oily sheen was visible on the groundwater surface and a moderate tar/creosote odor was reported.

- In December 2001, the North Carolina Department of Transportation (NCDOT) retained Catlin Engineers and Scientists (Catlin) to perform a Preliminary Site Assessment (PSA) for a proposed right of way on a portion of the former wood treating facility and a parcel of property located on the west side of Navassa Road. This assessment indicated the presence of creosote-related constituents in soil along Navassa Road.

- In February 2003, the NCDOT retained Catlin to perform a targeted soil assessment associated with bridge replacement along the west side of Navassa Road to determine if soils in this area contained compounds associated with the former wood treating facility.

- Based on the results of the SI, SIP, and PSA, the North Carolina Department of Environment and Natural Resources (NCDENR) submitted a Site Re-Assessment letter to the USEPA in March 2003 (NCDENR, 2003). The Site Re-Assessment letter briefly highlighted the results of the previous investigations described above and recommended that the Site be considered for further evaluation by the USEPA.

- On June 14, 2004, USEPA and KMCC entered into an Administrative Order on Consent for the performance of the ESI. The purpose of the ESI was to obtain data for USEPA to evaluate the Site using the CERCLA Hazard Ranking System (HRS). The ESI results were to be used to determine the future course of action for the facility as part of its HRS evaluation under CERCLA.

- The ESI, which was implemented in November 2004, indicated the presence of creosote-related constituents in each of the sampled media (soil, sediment, surface water, and groundwater), with the highest concentrations detected in the areas where wood treating operations were conducted.

- In March 2006, KMCC created Tronox, LLC (Tronox) as a spin-off corporation and Tronox assumed responsibility for assessment and remediation activities at the former creosote wood treating facility in Navassa. Anadarko Petroleum acquired KMCC in August 2006.

- Based on the results presented in the ESI, in July 2006, USEPA and Tronox entered into an Administrative Order on Consent to perform a Remedial Investigation/Feasibility Study (RI/FS) pursuant to CERCLA. At that time, the Site had not been added to the NPL. Instead CERCLA activities were being conducted under the Superfund Alternative Approach (SAA).

- In January 2009, Tronox filed for Chapter 11 Bankruptcy Protection in Federal Court. As a result, the RI/FS process was temporarily halted.

- In September 2009, the NCDENR, in conjunction with the USEPA, completed a HRS Documentation Record for the Site using the ESI sampling results. The HRS scored 50 based on the surface water pathway.

- In March 2010, the USEPA issued a partial work takeover notice. This allowed the USEPA to conduct portions of the RI/FS including a marsh sediment sampling program, residential sampling program, and collection of tissue samples.

- In April 2010, the KMCC Site in Navassa was added to the NPL.

- On February 14, 2011, the Multistate Trust was established as part of the Tronox bankruptcy settlement to own and assume responsibility for hundreds of Tronox sites, including the Site in Navassa. In accordance with the bankruptcy Settlement Agreement, the Multistate Trust assumed ownership and responsibility for Site remediation under CERCLA. The Greenfield Environmental Multistate Trust, LLC, as Trustee of the Multistate Environmental Response Trust, is performing Environmental Actions at KMCC Site in Navassa as fiduciary whose sole beneficiaries are the USEPA and the State of North Carolina.

1.3.4 Previous Investigations

Beginning in the 1980s, multiple parties have performed pre-CERCLA environmental investigations at the Site and surrounding areas, including: KMCC, NCDEHNR [subsequently the NCDENR and now known as the North Carolina Department of Environmental Quality (NC DEQ)], the NCDOT, and the USEPA. The results of these historical investigations are summarized in the following sections. Investigations undertaken before the 2006 RI include the following:

- NCDEHNR Site Inspection
- NCDEHNR Site Inspection Prioritization
- NCDEHNR Memorandum of Off-Site Visit
- NCDOT Preliminary Site Assessment
- NCDOT Soil Assessment
- NCDENR Site Re-Assessment

- ENSR Expanded Site Inspection
- Pre-Remedial Investigation Soil Sampling

1.3.4.1 NCDEHNR Site Inspection (SI)

In October 1988, the Superfund Section of the NCDEHNR performed a SI to assess the potential for impacts to groundwater (NCDEHNR, 1989). The SI included a visual inspection of the Site and collection of six samples for laboratory analysis. Soil, sediment, and surface water samples were collected, and two private water supply wells located west of the Site were also sampled. Each sample was analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and select metals.

Polycyclic aromatic hydrocarbons (PAHs) were detected in a soil sample from the Wastewater Ponds at concentrations ranging from 1,183 to 7,600 milligrams per kilogram (mg/kg). No creosote-related constituents were found in the samples from the Boiler Ponds or in the two private water supply well samples. VOCs commonly associated with gasoline (benzene, toluene, ethylbenzene, and xylene) were reported in the water supply well sample collected from a well located 1,000 feet northwest and hydraulically upgradient of the former KMCC property. Based on the results for this sample, a second water sample was collected from this well by NCDEHNR. Analysis of this follow-up sample did not detect any VOCs.

1.3.4.2 NCDEHNR Site Inspection Prioritization (SIP)

Based on the SI results, NCDEHNR performed a SIP in May 1995 to assess potential threats posed to human health and the environment and to determine whether additional actions were required under CERCLA (NCDEHNR, 1995). The SIP included additional site reconnaissance visits, sampling of suspected on-site source areas, off-site water supplies, and other environmental media. Samples of surface water, surface soils, private well water and soil samples from deeper soil borings were collected during the SIP.

Creosote-related constituents were found in the samples collected from the former Operations Evaporation Pond, Wood Storage Areas, and a wetland channel. Based on the results of the SIP, the Site was recommended for an ESI with a low priority.

1.3.4.3 NCDEHNR Memorandum of Off-Site Visit

In April 1998, the NCDEHNR was notified of visible creosote contamination in a test pit excavated for a new wastewater pipeline. The pipeline was located on the east side of Navassa Road approximately 625 feet north of the edge of the wetlands on the north side of Sturgeon Creek and 990 feet north of the bridge span (NCDEHNR, 1998) over the Creek. The excavation, measuring 24 feet long, 6 feet wide and 7 to 8 feet deep, was reinforced with a steel trench box. A NCDEHNR memorandum dated April 17, 1998 indicated that an oily sheen was visible on the groundwater surface and a moderate tar/creosote odor was reported. Isolated, creosote-stained patches of soil were visible along the 95-foot interval of backfilled trench surface. Three test pits were excavated approximately 180 feet, 309 feet and 440 feet south of the trench. Visible soil contamination was not observed in these test pits.

1.3.4.4 NCDOT Preliminary Site Assessment (PSA)

In December 2001, the NCDOT retained Catlin to perform a PSA for a proposed right-of-way on a portion of the former wood treating facility and a parcel of property located on the west side of Navassa Road across from the former facility. The PSA results indicated the presence of several creosote constituents in subsurface soils within the proposed right-of-way (Catlin, 2002). Catlin collected ten subsurface soil samples and six groundwater samples from temporary wells installed along Navassa Road near Sturgeon Creek. Each sample was analyzed for VOCs,

SVOCs, and the eight Resource Conservation and Recovery Act (RCRA) metals. Arsenic was reported in several samples above the North Carolina Hazardous Waste Section (NCHWS) "contained out" levels for unrestricted use. No other RCRA metal was reported at a concentration above this regulatory threshold. Several SVOCs, primarily PAHs, were also detected in the majority of soil samples collected from locations nearest the southeast corner of the former wood treating facility.

1.3.4.5 NCDOT Soil Assessment

In February 2003, the NCDOT retained Catlin to perform a targeted soil assessment associated with bridge replacement along the west side of Navassa Road to determine if soils in this area contained compounds associated with the former wood treating facility (Catlin, 2003). Catlin collected eight subsurface soil/sediment samples, four from each side of Navassa Road along the approach to the bridge for Sturgeon Creek. Each sample was analyzed for VOCs, SVOCs, and the eight RCRA metals. Sample results indicated that only arsenic was reported above the NCHWS "contained out" levels for unrestricted use. No other constituents were reported at concentrations above this regulatory threshold (ENSR, 2005).

1.3.4.6 NCDENR Site Re-Assessment

Based on the results of the SI, SIP, and NCDOT PSA; NCDENR submitted a Site Re-Assessment letter to the USEPA in March 2003 (NCDENR, 2003). The Site Re-Assessment letter briefly highlighted the above-described results of the previous investigations and concluded that creosote contamination of subsurface soil and groundwater was evident along Navassa Road in proximity to the former wood treating facility. Based on these findings, the NCDENR recommended that the Site be considered for further evaluation by the USEPA.

1.3.4.7 ENSR Expanded Site Inspection (ESI)

CERCLA-related investigations were initiated in November 2004. The ESI was performed by ENSR Corporation of North Carolina (ENSR) under contract to Tronox. The purpose of the ESI was to evaluate and score the Site under USEPA's HRS process. The ESI was performed in two phases between November 2004 and March 2005, and included the following:

- Collection and analysis of 62 soil samples from 35 locations
- Collection and analysis of 84 sediment samples from 56 locations
- Collection and analysis of surface water samples from six locations
- Installation of 12 temporary wells and 8 permanent monitoring wells
- Collection and analysis of groundwater samples from seven temporary wells and seven permanent monitoring wells
- 34 cone penetration testing rapid optical screening tool (CPT/ROST™) borings

Based on historical knowledge and previous investigation data, samples were analyzed for the Target Compound List (TCL) SVOCs to detect creosote-related compounds. A complete Target Compound List/Target Analyte List (TCL/TAL) scan was not completed on any sample collected as part of the ESI. Data from the sampled media indicated the presence of creosote-related constituents. The highest concentrations in the sampled media were in areas associated with creosote storage and wood treatment as well as in the marsh south of the Pond Area. Based on the results of the ESI, additional site assessments were recommended.

1.3.4.8 Pre-Remedial Investigation (RI) Soil Sampling

The RI/FS Work Plan was prepared by Tronox under the oversight of USEPA, NC DEQ, United States Fish and Wildlife Service (USF&WS), United States Army Corps of Engineers (USACE),

and the National Oceanic and Atmospheric Administration (NOAA) (collectively, the Regulators). Because the ESI analyte list was limited to TCL SVOCs, the Regulators recommended collecting and analyzing additional samples using an expanded analyte list to establish a list of COPCs for use in the RI/FS. On March 2, 2006, USEPA approved the pre-RI sampling program proposed by Tronox.

ENSR implemented the pre-RI sampling program in March 2006, which included collection of 12 surface soil samples (SS1 through SS12) from locations across the former wood treating facility. As agreed by the Regulators, the samples were analyzed for TCL VOCs, TCL SVOCs, TCL organochlorine pesticides (pesticides), TCL polychlorinated biphenyls (PCBs), cyanide, and TAL metals. Creosote-related SVOCs were detected in most of the surface soil samples collected. The SVOC results were comparable to those from the ESI. Metals, pesticides, and VOCs were also detected in the 12 surface soil samples.

Based on a review of Pre-RI soil analytical data, the Regulators requested background soil samples be collected and analyzed for TCL pesticides, arsenic, aluminum, chromium, iron and vanadium so that results could be compared to the Pre-RI soil sample results. On April 18, 2006, ENSR collected four sets of background soil samples, two from locations sampled during the ESI (BRSB1 and BKSB3) and two from new locations north of the property (BKSB5 and BKSB6).

Results from the ESI and the pre-RI soil sampling program were used to develop the initial list of COPCs for the RI. The COPCs were identified by comparing ESI and pre-RI analytical results to human health screening values, ecological risk screening values, background values, and by determining frequency of compound detection. The COPC development process is detailed in Technical Memorandum 1 (ENSR, 2006a).

1.3.5 Remedial Investigation

Beginning in 2006, RI activities have been performed by ENSR and AECOM Technical Services of North Carolina, Inc. (AECOM) (under contract to Tronox), by USEPA, and by CH2M Hill and EarthCon (under contract to the Multistate Trust). The RI investigations include the ENSR/AECOM Phase 1 RI in 2006, the ENSR/AECOM Phase 2 RI in 2008, the USEPA Residential Sampling in 2010, the USEPA Marsh Edge Sampling in 2010, the USEPA Tissue Sampling in 2011, the AECOM Supplemental RI (SRI) in 2012, the CH2M Hill SRI conducted in 2015 and 2016, and the EarthCon SRI conducted in 2016 and 2017. The following sections provide a summary of the RI activities performed at the Site and surrounding areas. Sampling locations for all CERCLA-related investigations (including the ESI and RI sampling events) are highlighted on the Comprehensive Sample Locations Map provided as Figure 1-4.

1.3.5.1 ENSR/AECOM Phase 1 Remedial Investigation (RI)

The Phase 1 RI was conducted in November 2006 and focused on characterizing source areas (the Process and Wood Storage Areas) and delineating the extent of COPCs outside the source areas by expanding the ESI study area. Data from soil borings also provided geologic and lithologic information to help evaluate potential contaminant transport.

The areas investigated included the Treated Wood Storage Area, the Untreated Wood Storage Area, the Process Area, and the Wastewater Ponds. Temporary monitoring wells were used to assess groundwater quality and provide information for selecting permanent well locations in subsequent RI phases. The groundwater assessment focused on the surficial aquifer [depths ranging from 15 to 20 feet below ground surface (bgs)]. Marsh sediment and terrestrial surface water were assessed for impacts from former facility operations.

The RI Phase 1 tasks included the following:

- Using CPT in conjunction with ROST™ with Laser-Induced Fluorescence (LIF) to screen the subsurface in and near suspected source areas for separate-phase creosote product [also referred to as dense non-aqueous phase liquid (DNAPL)] at 43 locations
- Collecting 33 soil samples from 18 locations in and around source areas
- Collecting four sediment samples from two locations in the Process Area and two locations in the Boiler Ponds
- Collecting one surface water sample from a drainage swale that bounds the east side of the former Process Area and one surface water sample from a Boiler Pond
- Installing and sampling groundwater from 18 temporary monitoring wells
- Collecting groundwater samples from eight permanent monitoring wells

Results of the CPT borings identified areas of fluorescence beneath the Process Area, the Operations Evaporation Pond and along Navassa Road. Soil sample results indicated limited impact from creosote-related constituents in the northern portion of the property. The Phase 1 soil results also verified the presence of creosote-related constituents beneath the southern portion of the property. Groundwater results indicated that creosote related impacts are present in shallow groundwater in the southern portion of the property. Based on the RI Phase 1 results, additional investigations were recommended.

1.3.5.2 ENSR/AECOM Phase 2 Remedial Investigation (RI)

The Phase 2 RI activities, conducted in January 2008, focused on the southern area of the property. Soil borings were advanced to verify elevated LIF data and to better delineate previously sampled areas. The Phase 1 RI temporary well and CPT/ROST™ data identified groundwater data gaps to verify vertical and horizontal impact. Marsh sediment pore water and marsh sediment were assessed to delineate the extent of COPCs in the marsh areas.

The RI Phase 2 tasks included the following:

- Installing 13 additional permanent monitoring wells at locations identified during the Phase 1 RI
- Installing and sampling groundwater from one additional temporary monitoring well
- Collecting groundwater from the eight existing permanent monitoring wells and 10 of the newly installed permanent monitoring wells (deep wells MW-13D, MW-14D, and MW-16D were not sampled)
- Collecting six pore water/groundwater samples within the tidal marsh (south of the Pond Area)
- Collecting 13 sediment samples from 10 locations within the tidal marsh
- Collecting 40 soil samples from 22 locations within the Process Area

The Phase 2 RI results indicated that groundwater is impacted with creosote-related constituents in the southern area of the property. The extent of contamination in the deeper groundwater in the Process Area, south of the Wastewater Ponds, and southeast of the Operations Evaporation Pond was not delineated. Results of the sediment samples indicated the presence of creosote-related constituents in the marsh immediately south of the Pond Area, although contaminated sediments in the marsh were not fully delineated. Results of soil sampling indicated impacts in the Process Area and Pond Area. Soils data was limited in the northeastern and eastern portions of the property.

1.3.5.3 USEPA Residential Sampling

In June 2010, USEPA collected samples to determine if COPCs had migrated off the Site via surface water flow to the residential areas on the west side of Navassa Road and if COPCs were present in private wells south of Sturgeon Creek (USEPA, 2010a). Terrestrial sediment samples were collected at 12 locations in drainage ditches adjoining the residences along Navassa Road and surface soil samples were collected from three low-lying residential yards. One terrestrial sediment sample was also collected in a drainage ditch east of Navassa Road north of the Sturgeon Creek Bridge. Six private wells were sampled in the neighborhood south of Sturgeon Creek. Analytical results indicated the presence of PAHs in the drainage ditches. Risks associated with these detections are summarized in Section 6.5. Target SVOCs were not detected in the private wells south of Sturgeon Creek. SVOCs were detected at depths of 12 to 20 feet in saturated soils at 1 location in the Pond Area adjacent to the marsh. Further investigation of the marsh was recommended.

1.3.5.4 USEPA Marsh Edge Sampling

In November 2010, USEPA collected samples in the marsh area to determine if COPCs had migrated or had the potential to migrate via groundwater into the marsh (USEPA, 2010b) and to determine whether sediments in Sturgeon Creek south of the property had been impacted. Groundwater samples were collected from seven temporary wells installed at the marsh edge and four existing monitoring wells located along the southern border of the Pond Area at the edge of the marsh. Seven saturated soil samples were collected from the temporary well borings. Twelve sediment samples were also collected, 11 from Sturgeon Creek and one from the marsh. Results indicated that stream bottom sediments contain relatively low levels of PAHs. PAHs were detected in each of the groundwater samples collected. Naphthalene results in subsurface soil samples collected at the marsh edge ranged from less than 1,000 micrograms per kilogram (µg/kg) to greater than 500,000 µg/kg. The USEPA concluded that based on higher PAH levels in groundwater than in the overlying marsh, groundwater may contribute to contamination of marsh materials.

1.3.5.5 USEPA Tissue Sampling

In December 2011, the USEPA, the North Carolina Department of Health and Human Services (NCDHHS), NCDENR, and AECOM collected tissue samples from Sturgeon Creek and the marsh south of the property (USEPA, 2016a). Samples of channel catfish, blue catfish, mullet, striped bass, largemouth bass, blue crab, fiddler crab, striped killifish, and marsh clams were collected. Analytical data indicated that metals, low levels of PAHs, and PCBs are present in the tissue samples. The detected metals and PCBs in the tissue samples are not related to the creosote wood treating operations conducted at the Site. The tissue data are discussed in the HHRA and BERA Reports.

1.3.5.6 AECOM Supplemental Remedial Investigation (SRI)

Data from the Phase 1 and 2 RI sampling events was used to design the SRI, which was intended to complete delineation in soil, groundwater, and marsh sediments, and provide the final data set for risk characterization and remedy evaluation. Groundwater and pore water data from the Phase 1 and 2 RI indicated that naphthalene was the most prevalent COPC. The areas of highest dissolved-phase naphthalene were beneath the Process Area, the Operations Evaporation Pond, and the Wastewater Ponds. The data also suggested that dissolved-phase creosote constituents had migrated to the south/southwest beneath Navassa Road and the tidal marsh. In addition, the SRI provided data on areas believed to be unaffected by former facility operations.

The SRI activities conducted by AECOM in June and July 2012 included the following:

- Installing two shallow permanent monitoring wells on private property located southwest of the former facility to delineate elevated naphthalene concentrations
- Installing three deep monitoring wells in the source areas to delineate the vertical extent of dissolved PAHs
- Sampling groundwater from 13 existing monitoring wells and from the five newly installed groundwater monitoring wells
- Collecting one background sediment sample from the tidal marsh along the northeast section of the property that was not affected by creosote-related constituents
- Collecting sediment samples from 21 locations within the tidal marsh south of the Pond Area
- Collecting surface soil samples from four Decisions Units (DUs) using the Incremental Sampling Methodology (ISM) to evaluate surface soil quality across the eastern-northeastern portion of the property (Eastern Upland), including near the Residential Parcels, to evaluate that portion of the property not used for wood treating or storage

Results of the AECOM SRI indicated that the lateral extent of total PAH concentrations in surface soils had been delineated. The ISM program performed in the Eastern Upland indicated that surface soils had not been impacted by historical wood treating operations. The lateral extent of shallow groundwater contamination was delineated except off Site to the southwest and south beneath the marsh. The additional sediment data collected from the tidal marsh did not fully define the lateral and vertical extent of contamination.

1.3.5.7 AECOM Human Health Risk Assessment (HHRA)

A HHRA was conducted by AECOM in 2014 in accordance with the four-step process developed by the USEPA (USEPA, 1989) including:

- Data evaluation and hazard identification
- Exposure assessment
- Toxicity assessment
- Risk characterization

Samples collected during each phase of the AECOM RI were analyzed for the COPCs originally identified from the ESI in 2006. Following completion of the SRI in 2012, the COPC list for the HHRA was expanded to include additional constituents based on updated screening of the ESI and RI data collected through 2012. COPCs were selected by excluding essential nutrients and comparing the remaining detected constituents to risk-based screening levels and background concentrations. The revised COPC list was included in the AECOM Draft HHRA Report (AECOM, 2012).

The Draft HHRA Report was submitted in July 2014. AECOM divided the property into three areas for risk evaluation including the DU Area (Eastern Uplands), Northern Area (Treated and Untreated Wood Storage Areas), and the Southern Area (Process and Pond Areas). The following conclusions and recommendations were provided in the Draft HHRA Report:

- Eliminate the DU Areas from further evaluation for soil based on ISM results.
- The potential risks associated with non-residential use of the Northern Area were within acceptable limits, but further characterization of soil is needed if the Northern Area is considered for residential land use.
- Potential risks and hazards in the Southern Area exceeded a cancer risk level of 10^{-4} and/or Hazard Index (HI) of 1 for residential and non-residential uses in the future. The

risk for future residential use was driven by VOCs, SVOCs, arsenic and chromium in both the soil and groundwater. Benzene, chloroform, ethylbenzene and naphthalene were identified as chemicals of concern (COCs) for the vapor intrusion pathway. Uncertainties included the assumption that chromium in soil is in the hexavalent state, the inclusion of thallium and 2,6-dinitrotoluene as COCs for soil, and the inclusion of the drinking water pathway for the Southern Area. The non-residential risks include risks to current and future trespassers from surface soil, sediment and surface water, risks to future construction workers from soil and groundwater, and risks to future on-site workers from surface soil.

In December 2014, CH2M Hill reviewed the HHRA and determined that there were data gaps that required further investigation prior to finalizing the HHRA (CH2M Hill, 2014). The recommended additional field activities included collecting chromium speciation data, collecting arsenic and thallium background data, collecting additional inorganic data for groundwater, collecting additional surface water and sediment samples in the Boiler Ponds, collecting additional marsh and drainage swale surface water samples for site characterization, and collecting soil gas data to further evaluate the vapor intrusion pathway. Except for the soil gas sampling, the additional field investigations were accomplished in 2015 and 2016. Soil gas sampling was not completed due to shallow groundwater conditions.

Based on additional data collection, updated screening levels, and modifications to the technical approach discussed in an October 6, 2016 meeting between the Multistate Trust, the USEPA, the NC DEQ, and EarthCon, the HHRA was updated (EarthCon, 2018) and the results are summarized in Section 6.0 of this RI Report.

1.3.5.8 AECOM Ecological Risk Assessment (ERA)

AECOM completed Steps 1 and 2 of the eight-step Ecological Risk Assessment (ERA) process and produced the Screening Level Ecological Risk Assessment (SLERA) identifying preliminary remediation goals and ecological COPCs. The SLERA was issued in draft form in July 2006 (ENSR, 2006b). The USEPA requested the draft SLERA be revised to more closely conform to ERA guidance documents. The revised SLERA was submitted for review in April 2013 (AECOM, 2013). In May 2013, NCDENR provided a limited set of comments for the revised SLERA. The SLERA was updated as "Revision 3" (AECOM, 2014a) to include any revised screening levels, additional or deleted listings for special species status, and a review of data collected from the marsh and Process Area for possible addition of new compounds to the list of Screening Level Compounds of Potential Concern. The Revision 3 SLERA concluded that a finding of "no significant ecological risk" could not be determined for several constituents in the different exposure areas and that additional evaluation was warranted.

The Problem Formation Statement (PFS) is Step 3 in the ecological risk process. Tronox originally submitted a Draft PFS and Draft PFS Addendum (ENSR, 2006c) to the Regulators on August 10, 2006 after the draft SLERA was completed. At the time, rather than require another version of the SLERA, the Regulators decided to respond to the SLERA comments in the Revised PFS. The general approach to the COPC refinement was discussed during a meeting held on August 14, 2006 and a Revised PFS was submitted in April 2007 (ENSR, 2007a). The PFS [referred to as Revision 2 (AECOM, 2014b)] was developed based on the results of the Revision 3 SLERA.

Based on additional data collection, updated screening levels, and modifications to the technical approach discussed an October 6, 2016 meeting between the Multistate Trust, the USEPA, the NC DEQ, and EarthCon, a BERA was prepared (Ramboll, 2018) and the results are summarized in Section 7.0 of this RI Report.

1.3.5.9 CH2M Hill Supplemental Remedial Investigation (SRI)

CH2M Hill conducted SRI activities from September 2015 to June 2016. The objective of the SRI was to further delineate the nature and extent of contamination at the Site, to develop sufficient information to assess potential risks to human health and the environment, and to support FS evaluations. The SRI centered on resolving data gaps in the AECOM RI including:

- Performing aquifer tests in select monitoring wells, installing monitoring wells in deeper portions of the Peedee Aquifer, gauging site-wide groundwater levels and assessing hydraulic gradients to obtain additional geologic and hydrogeologic information for site characterization.
- Conducting a tidal study to assess groundwater to surface water interaction by installing four paired piezometers to monitor water levels and water quality parameters.
- Further characterizing source material (DNAPL) by advancing 83 Tar-specific Green Optical Screening Tool (TarGOST®) borings and 28 deep soil borings in the Process Area, the Pond Area, and the southern marsh.
- Assessing potential source areas outside of known source areas using passive soil gas samplers to collect data from 45 sampling points.
- Collecting 53 soil samples from 32 locations in the northeastern area of the Site (Eastern Uplands) to provide information sufficient to support risk assessments and future land use decisions.
- Further delineating the nature and extent of COPCs in groundwater by installing nine shallow monitoring wells, eight monitoring wells screened in the upper portion of the Peedee Aquifer, and one monitoring well screened within the deeper portion of the Peedee Aquifer.
- Characterizing representative background groundwater concentrations by installing five additional background monitoring wells.
- Characterizing background and Site metals concentrations in soil, groundwater, surface water, and sediment by collecting and analyzing samples for arsenic, thallium (soil only) and total and hexavalent chromium.
- Further characterizing COPC distribution in the marsh by collecting 14 sediment samples and nine surface water samples from nine locations in the southern and eastern marsh areas and Sturgeon Creek.
- Evaluating COPC distribution in drainage swales by collecting 26 terrestrial sediment and/or surface soil samples.
- Evaluating the potential for vapor intrusion by installing soil gas probes.

Results of the TarGOST® evaluation indicated that discontinuous layers of DNAPL occur in the Process Area and the Pond Area; however, the marsh could not be assessed using this technology due to interference from organics in the marsh. Overall, the objectives for the SRI were achieved except for installation of the soil gas probes to address vapor intrusion, which could not be collected due to the presence of shallow groundwater.

1.3.5.10 EarthCon Supplemental Remedial Investigation (SRI)

EarthCon conducted SRI activities in 2016 and 2017 to address data gaps from the previous investigations including:

- Further characterizing the source material within and downgradient of potential source areas identified from site history and previous investigations by advancing 10 deep (100-

foot bgs) and three shallow (20-foot bgs) soil borings and measuring potential DNAPL in the existing monitoring wells.

- Collecting 46 soil samples from 27 soil borings from the Treated and Untreated Wood Storage Areas to provide information to support risk assessment and land use decisions.
- Installing 10 additional monitoring wells to refine/further delineate the extent of COPCs in groundwater.
- Collecting groundwater samples from wells MW-06 and MW-25S to confirm the presence of pentachlorophenol in groundwater.
- Collecting background soil samples from 15 locations within the Town of Navassa and groundwater samples from six background wells to compare to onsite concentrations.
- Collecting and analyzing three surface water samples from the southern marsh and groundwater samples from existing wells for total dissolved solids (TDS) and chloride to evaluate the groundwater/surface water interface.
- Conducting slug tests in five monitoring well pairs to refine characterization of the Site hydrogeology.
- Collecting undisturbed soil samples for geotechnical analysis for use in modeling the vapor intrusion pathway.
- Collecting pore water and sediment samples, conducting sediment bioassay tests, conducting benthic community assessment tests and assessing potential groundwater upwelling for the BERA.

RI activities conducted to date by ENSR/AECOM, the USEPA, CH2M Hill, and EarthCon are summarized in Section 2.0 by matrix. Results of the investigation are provided in Sections 3.0 and 4.0 of this RI Report.

2.0 CERCLA SITE INVESTIGATION ACTIVITIES

The following sections provide a summary of the CERCLA-related field activities conducted to date. Field activities were conducted in accordance with the work plans submitted for the KMCC Site including the Draft RI/FS Work Plan (ENSR, 2006d), the Phase 2 RI Work Plan (ENSR, 2007b), the Draft SRI Work Plan (AECOM, 2012), the SRI Work Plan (CH2M Hill, 2015a), the Supplemental SRI Work Plan Addendum (CH2M Hill, 2015b), the Draft SRI Update and Work Plan Addendum No. 2 (CH2M Hill, 2015c), and the SRI Work Plan Addendum No. 3 (EarthCon, 2016). Field activities were also conducted in accordance with the then-applicable USEPA Region 4 guidelines.

2.1 DNAPL INVESTIGATIONS

To characterize the presence of DNAPL in subsurface soils, CPT/ROST™, TarGOST®, and DNAPL investigations were performed as described below.

2.1.1 CPT/ROST™

During the ESI and Phase I RI, the CPT/ROST™ system was used to classify soils and identify subsurface areas where DNAPL may be present. The standard geotechnical sensor within the CPT cone tip measures resistance and sleeve friction to form the basis of the soil classification (e.g., sand, silt, clay, etc.). The CPT/ROST™ system uses a tunable laser mounted in the support truck that is connected to a down-hole sensor. The down-hole sensor consists of a small diameter sapphire window mounted flush with the side of the cone penetrometer probe. The laser light passes through the sapphire window and is absorbed by aromatic hydrocarbon molecules in contact with the window, as the probe is advanced causing them to fluoresce. A portion of the fluorescence emitted from any encountered aromatic constituents is returned through the sapphire window and conveyed by a second fiber optic cable to a detection system within the CPT rig, where it is continuously recorded.

Seventy-five CPT/ROST™ borings were advanced in the Process Area, Pond Area, along Navassa Road, and in the Treated and Untreated Wood Storage Areas at the locations shown on Figure 2-1. Two CPT/ROST™ borings were also advanced in the Eastern Upland area. The depths ranged from 2 feet bgs at RICPT20 (where a former building foundation was encountered) to as deep as 50.06 feet bgs at CPT-12. It was anticipated that the CPT/ROST™ tool could be advanced to a substantial depth (greater than 50 feet); however, due to the density of the subsurface sands, limitations of the support vehicle, and narrow drive rods, the borings were terminated at shallower depths than originally anticipated. Table 2-1 summarizes the CPT/ROST™ boring locations.

2.1.2 TarGOST® and Soil Borings

A DNAPL investigation was conducted in 2015 to profile the occurrence of DNAPL and to classify subsurface soil. TarGOST® profiling was conducted in 83 TarGOST® borings advanced at locations shown on Figure 2-1. Twenty-eight deep soil borings were advanced in conjunction with the TarGOST® borings to provide soil classification information. These borings (designated SB-A through SB-P) are shown on Figure 2-2.

TarGOST® is a laser-induced fluorescence screening tool that is designed to detect DNAPL in the subsurface by measuring the fluorescence of PAHs. The tool consists of a front-face fluorometer that is coupled via fiber optics to a sapphire-windowed probe that is advanced into the subsurface. As the probe is pushed into the subsurface, pulses of laser light strike the materials outside the surface of the window. If PAHs are present in this material, the PAHs absorb a portion of the light and emit a fluorescence that is measured by a spectrophotometer.

The initial investigation phase conducted in September 2015 consisted of installation of nine deep soil borings, drilled using rotosonic equipment and installed along a west-east transect bordering the marsh area (Figure 2-2). The borings were used to characterize site stratigraphy and assess the presence/distribution of DNAPL. TarGOST® was then deployed by a Geoprobe direct push technology (DPT) rig to conduct high-resolution vertical profiling of DNAPL at 28 locations. The TarGOST® borings were originally to be advanced to depths of 100 feet bgs. However, dense sands prevented advancement of the TarGOST® probe, and required auger drilling to penetrate to deeper zones. Although one boring was advanced to a depth of 100 feet bgs, most of the TarGOST® borings encountered refusal between 45 and 78 feet bgs, prior to complete vertical characterization. Consequently, it was agreed with USEPA that the TarGOST® profiles should be terminated at the depth of DPT refusal. Sonic drilling equipment was used to assess the vertical extent of DNAPL below the maximum depth achieved by the TarGOST® equipment.

In November and December of 2015, a second phase of investigations was performed, consisting of 18 deep soil borings and 55 TarGOST® borings. One additional deep boring was installed in February 2016. Table 2-2 provides a summary of the TarGOST® locations and Table 2-3 provides a summary of the deep soil borings. The soil boring logs are provided in Appendix B.

In addition to drilling difficulties, the TarGOST® interpretation of DNAPL in the marsh was hindered by matrix interferences from naturally occurring organics which also fluoresce. Further description of interferences is provided in Section 4.0.

2.1.3 2017 DNAPL Borings

In 2017, the lateral and vertical extent of DNAPL was further assessed through the installation of 10 deep (100 foot) and three shallow (20 foot) soil borings. The locations of these borings were based on the CPT/ROST™ and TarGOST® data. The boring locations (SB-100 through SB-112) are shown on Figure 2-2 and described below.

- Five deep borings were advanced west and southwest of the Process Area along Navassa Road to assess the area where DNAPL was previously identified by NCDOT and the CPT investigation.
- Two deep borings were advanced in the Wastewater Ponds to assess the depth of DNAPL at the source.
- Two deep borings were advanced downgradient of the Decommissioning Evaporation Pond and at the edge of the marsh to further delineate the extent of DNAPL along the southeastern perimeter of the Pond Area.
- One deep soil boring was advanced north of the Process Area in an area of former product storage and positive CPT/ROST™ screening detection to confirm the presence/depth of DNAPL.
- Three shallow borings were advanced, one in each of the two Boiler Ponds and one in the Fire Protection Pond to assess the presence of DNAPL.

The soil borings were advanced using rotosonic or DPT drilling techniques. Soil samples were collected continuously for visual evaluation and classification. Soil samples were visually examined for the presence of DNAPL and classified using the unified soil classification system (USCS) and American Society of Testing and Materials (ASTM) method D 2488. A summary of the soil boring locations is provided in Table 2-3 and the soil boring logs are provided in Appendix B.

The soil borings were abandoned by backfilling with cement/bentonite grout. The grout material was injected through a tremie pipe from the bottom of the borehole to ground surface. Once the grout had settled, the remaining borehole was filled to the ground surface with additional grout.

2.2 SOIL

Investigations of background soil, surface soil, terrestrial sediment, and subsurface soil are discussed in the following sections. Tables 2-3 through 2-5 summarize information regarding the soil sampling locations.

2.2.1 Background Soil

Results of previous investigations indicated the presence of PAHs and metals across the Site. PAHs are byproducts of combustion and are naturally occurring from forest fires and burning of other naturally occurring organic substances. PAHs are also ubiquitous in urban environments from sources such as asphalt roads, coal combustion and automobile exhaust (International Journal of Soil, Sediment and Water, 2008). Metals are also naturally occurring in the environment. To assist in differentiating Site-related concentrations from natural or anthropogenic concentrations of these constituents, background sampling was conducted at 15 locations across the Town of Navassa. The background samples were collected on property owned by the Town of Navassa (shown on Figure 2-3) by advancing a stainless-steel hand auger to 0.5 feet bgs, compositing the soil in a stainless-steel bowl, and placing the samples in laboratory-supplied containers. The samples were analyzed for PAHs and TAL metals. The background soil borings (BG-SO-01 through BG-SO-15) are described in Table 2-3 and the background surface soil samples are summarized in Table 2-4.

2.2.2 Surface Soil and Terrestrial Sediment

Surface soil and/or terrestrial sediment samples were collected in the ESI and in each phase of the RI. The soil boring locations are described in Table 2-3. A summary of the surface soil and terrestrial sediment samples is provided in Table 2-4. The sampling locations are shown on Figure 2-4. A total of 192 surface soil and terrestrial sediment samples have been collected from the Process Area, Pond Area, Eastern Upland Area, Treated and Untreated Wood Storage Areas, and from locations north and west of the property. Each of these samples was a grab sample except for the samples collected from the DUs and a composite sample from the private property located in the Eastern Upland Area. The grab samples were collected by advancing a stainless-steel hand auger from 0 to 0.5 feet bgs or from 0 to 1.0 feet bgs, compositing the soil in a stainless-steel bowl, and placing the samples in laboratory-supplied containers. The composite samples were analyzed for TCL SVOCs. The grab surface soil and terrestrial sediment samples were analyzed for either TCL SVOCs or PAHs. TCL VOCs, pesticides, PCBs, metals, hexavalent chromium, and total organic carbon (TOC) were also analyzed at select locations as summarized in Table 2-4.

The DU surface soil samples were collected in June 2012 from the Eastern Upland Area using the ISM in accordance with the draft SRI Work Plan (AECOM, 2012). Surface soil samples were collected from a grid system established in the eastern area of the property in four DUs as shown on Figure 2-4. Samples were collected from each incremental sample point in a DU using a small diameter stainless steel soil coring device, approximately ¾ inch in diameter. Each incremental sample was collected from a depth of 0 to 0.5 feet bgs. Once collected, each increment was transferred from the sampling device to a 1-liter amber glass container. Four 1-liter amber bottles were required to containerize the increment material volume from the locations in each DU. Once in the laboratory, the soil was removed from the container and sieved using a standard #10 (less than 2-millimeter size) to remove pebbles, organic debris (vegetative matter), etc. After the sample was sieved, it was spread evenly on a sample tray (or pan) and air dried. A grid pattern with at least 30 grid squares was then established within the sample tray. One increment was collected from each of the 30 grid squares established on the

soil slab and combined into one sample. This combined sample was then used for sample extraction and analysis for SVOCs.

One composite sample (designated PP-1) was also collected in November 2004 from one of the Residential Parcels located in the Eastern Upland Area. Surface soil samples were collected from five locations on the Residential Parcel and composited. The composite sample was analyzed for SVOCs.

Terrestrial sediment samples consist of sediment samples collected from drainage ditches or swales that only contain water intermittently. The samples are identified with an "SD" in either the sample location or sample identification columns in Table 2-4. Thirty terrestrial sediment samples were collected from drainage pathways that flow through the property and 13 terrestrial sediment samples were collected from drainage ditches along Navassa Road.

2.2.3 Subsurface Soil

A total of 129 subsurface soil samples have been collected for chemical analysis. The soil boring locations are described in Table 2-3 and shown on Figure 2-2. Subsurface soil samples (summarized in Table 2-5) were collected from the Process Area, Pond Area, Eastern Upland Area, Treated and Untreated Wood Storage Areas, and locations north and west of the property using DPT or rotosonic drilling equipment. Soil boring logs are provided in Appendix B.

The DPT rig has a 4 to 5-foot long, 2-inch diameter core barrel. The core barrel is fitted with a 1½ inch diameter disposable acetate liner that collects a soil core from a drilled interval. Once the core barrel was retrieved from the subsurface, the liner was removed and cut open to allow access to the soil core for screening, sampling, and visual examination.

The rotosonic rig uses a 10-foot long, 4-inch diameter core barrel. Once the core barrel reached the desired depth, a 6-inch diameter temporary outer casing was advanced over the core barrel to the same depth. The core barrel was then removed from the subsurface and the 6-inch diameter temporary outer casing remained in place temporarily to prevent borehole collapse. The soil core was then extruded into a clear, disposable polyethylene core bag. The material in the core bag was used for sample collection, screening, and examination by field personnel.

After sample collection, soil borings were abandoned by backfilling with cement/bentonite grout. The grout material was injected through a tremie pipe from the bottom of the borehole to ground surface. Once the grout had settled, the remaining borehole was filled to the ground surface with additional grout.

The depth to groundwater ranges from approximately 10 feet bgs in the northern portion of the property to approximately 4 feet bgs in the Pond Area. Groundwater is present within 1-foot of the ground surface at the marsh edge. Approximately 24 soil samples were collected at depths below the water table in saturated conditions. These saturated-zone samples were used for characterizing the nature, extent, fate and transport of contamination but not for risk assessment because the conceptual site exposure model (CSEM) considers only soil from the unsaturated zone. Soil contamination in the saturated zone is assumed to be in equilibrium with groundwater and; therefore, potential risks are characterized through the groundwater COPC concentration data.

2.3 GROUNDWATER

Forty-three temporary wells and 59 permanent monitoring wells have been installed and sampled to evaluate groundwater quality. Water quality results from 12 temporary wells that were installed in 2004 were used to select the locations of the first eight permanent monitoring wells installed in 2005. Since 2005, additional temporary and permanent monitoring wells have

been installed to further delineate vertical and lateral distribution of COPCs in groundwater. The temporary and permanent locations of monitoring wells are depicted on Figure 2-5. Well construction details and groundwater analytical data are provided in Table 2-6 and Table 2-7, respectively.

2.3.1 Temporary Well Installation

Temporary wells that were installed as part of the ESI, Phase 1 RI, and Phase 2 RI (TMW and RIGW locations) were drilled by advancing the boring to the desired depth and installing the well casing into the open boring. Each temporary well was constructed using 1-inch diameter, flush-threaded, schedule 40 polyvinyl chloride (PVC) casing and 10-foot long PVC 0.010 slotted screens. After the well materials were added to the borehole, filter pack material, consisting of 20/30 grade or equivalent sized silica sand, was poured into the well annulus from ground surface to a depth of approximately 1 foot above the well screen. If a temporary well could not be sampled within 24 hours of its installation, a bentonite seal was placed on top of the filter pack material and hydrated to prevent surface runoff from entering the well annulus which could possibly compromise the well. Temporary well construction details are provided in Table 2-6.

Groundwater samples were collected from temporary wells within 24 to 48 hours of installation. After sampling, each temporary well was abandoned in accordance with the North Carolina Administrative Code (NCAC) Title 15A Subchapter 2C Well Construction Standards (2C Standards). The drilling contractor removed the well material and backfilled the borehole with cement/bentonite grout. The grout material was injected through a tremie pipe from the bottom to ground surface. Once the grout had settled, the remaining borehole was filled to the ground surface with additional grout.

Temporary monitoring wells were developed by pumping groundwater with a peristaltic pump to remove fine-grained material. Groundwater quality parameters including pH, temperature, specific conductance (SC), turbidity, dissolved oxygen (DO), and oxidation reduction potential (ORP) were measured periodically until turbidity was reduced and other parameters stabilized.

Temporary wells were installed in the marsh sediments by the USEPA in 2010. The temporary wells were installed by isolating the borings from surface contamination by installing a 4-inch diameter PVC pipe as an outer casing. The material inside the PVC pipe was removed with a hand auger. The sampler was pushed into marsh material until a significant increase in resistance was observed. The increased resistance was the assumed transition to native geologic materials from marsh sediment. Screen-point samplers with disposable PVC screens were used to establish temporary wells with the screened interval from two to six feet below the assumed beginning of native geologic material. The wells were purged using a peristaltic pump and Teflon tubing until parameters stabilized. After sampling, the wells were grouted with 30 percent solids bentonite grout while removing the tool string, leaving the disposable screen in place.

2.3.2 Permanent Monitoring Well Installation

Permanent monitoring wells were installed using rotosonic or auger drilling methods. They were constructed using 2-inch diameter, flush-threaded, schedule 40 PVC or stainless-steel casing with 5-foot or 10-foot long PVC or stainless-steel wire-wrapped screens. Stainless steel material was used in areas where creosote was expected to be encountered, because it is resistant to chemical breakdown that can be caused by creosote. Schedule 40 PVC is susceptible to degradation by creosote-related constituents at high concentrations and was used in areas where those constituents were at low concentrations or absent. However, monitoring wells MW-06D, MW-10S, and MW-25S, which contain DNAPL, were constructed with PVC and may undergo degradation over time.

The well material was centered within the drill rig casing annulus while filter pack material (clean silica sand) was placed in the annular space surrounding the well screen. The filter pack covered the entire length of the well screen and extended approximately 2 feet above the top of the screen. The filter pack depth was measured periodically during placement, and while the drill rig casing was removed from the borehole. A 2-foot thick bentonite seal was then added on top of the filter pack. The filter pack and bentonite materials were installed in the casing annulus through a tremie pipe. Bentonite seals were hydrated for at least one hour prior to completing the well installation. Each well was finished by installing a cement/bentonite grout mixture from the top of the bentonite to within 2 feet of ground surface. Grout seals were installed in shallow well borings (less than 10 feet) by pouring/pumping into the borehole annulus from land surface. At deeper depths, a tremie pipe was used to install grout. Monitoring well construction details are provided in Table 2-6 and well boring and well construction diagrams are provided in Appendix B.

Permanent monitoring wells were developed within seven days of installation. Development was performed in general accordance with the USEPA Region 4 protocols at the time of installation. Wells were over-pumped with a submersible pump, promoting the evacuation of solids and conditioning of a well's filter pack. A minimum of three well volumes were removed before a well was considered developed. Groundwater quality parameters including pH, temperature, SC, turbidity, DO, and ORP were measured periodically during well development and recorded on well development forms. Stabilization of these parameters is an indicator that a well has been properly developed. Copies of the well development forms completed for each permanent well installed during the RI are included in Appendix C.

2.3.3 Groundwater Sampling

Temporary and permanent wells were purged and sampled using a peristaltic pump with dedicated disposable Teflon-lined tubing in general accordance with the USEPA Region 4 procedures in place at the time of sampling. A summary of the groundwater samples collected during the RI investigation is provided in Table 2-7.

During the AECOM RI, a section of disposable ¼-inch diameter polyethylene or Teflon tubing was inserted into the upper portion of the water column in a well. The tubing was connected to a disposable section of $^{3}/_{8}$-inch diameter silicon tubing that runs through the peristaltic pump. This tubing was connected to another section of ¼-inch diameter tubing which was used for discharge tubing. Discharge tubing was connected to a flow through cell which allowed periodic monitoring of water quality parameters. During the CH2M Hill and EarthCon SRI activities, purging was similar, but the tubing intake was placed in the middle of the screened interval of the well for low-flow sampling.

Water quality parameters (temperature, pH, and SC) were monitored to determine when the well was adequately purged. An adequate well purge was achieved when the pH, SC, and temperature of the groundwater stabilized. Stabilization is generally defined as pH constant within 0.1 Standard Unit, temperature and specific conductance constant within 10 percent, and turbidity below 10 nephelometric turbidity units (NTUs) or constant within 10 percent. Readings were generally recorded every 5 to 10 minutes or after each well casing volume had been purged. Temperature, pH, SC, DO, and ORP measurements were taken using a YSI 556 or equivalent water quality meter. Turbidity was measured with a HF Scientific, LaMotte, or equivalent turbidity meter. These meters were calibrated twice daily, prior to starting field work and again at the end of the field day.

Wells were purged and sampled using low-flow sampling procedures. If low-flow purging was not possible (i.e., when water quality parameters failed to stabilize), a minimum of three well volumes were removed from the well. If the water quality parameters had not stabilized after three volumes had been purged, additional volumes were removed until stability was achieved.

Well purging information (including water quality parameter data) was recorded on groundwater sampling forms. These forms, where available, are included in Appendix D.

2.3.4 Piezometer Installation

To allow evaluation of the vertical hydraulic gradients and potential groundwater migration pathways for contaminants to enter the tidal marsh, four piezometer pairs (PZ locations) were installed along the southern and southeastern margins of the tidal marsh at the locations shown on Figure 2-5. The shallowest piezometer was installed to monitor water quality and hydraulic head 1 to 3 feet below the sediment surface. The deeper piezometer in each pair was installed to a depth of approximately 20 feet below the sediment surface. The piezometers were constructed to accept a submersible multi-parameter water quality sonde. Materials and methods of construction were consistent with the terrestrial monitoring wells described previously.

Piezometer construction details are provided in Table 2-6 and construction diagrams are provided in Appendix B. The data recorded from the piezometers included changes in water quality and liquid levels in response to tidal and barometric pressure changes over five days.

2.3.5 Hydraulic Conductivity Testing

Slug tests were performed to estimate the hydraulic conductivity (K) of the Surficial Aquifer and upper Peedee Aquifer. Hydraulic conductivity data along with hydraulic gradient values are used to calculate groundwater flow velocities. This information is used to evaluate contaminant transport and support future remedial action evaluation in the FS. Slug test data collected by AECOM and EarthCon were used for the hydraulic conductivity evaluation.

To perform a slug test, a solid piece of pipe of known volume was lowered into a well below the water surface. The insertion of this slug caused a rise in the water level. The change in water level over time as it returned (or fell) to the original or static level was measured. This is known as a falling head test. A second test of each monitoring well was also performed following the falling head test by removing the solid pipe from the well, lowering the water level, and monitoring the recovery (or rise) of water level to static. This is known as a rising head test. The water level changes over time are evaluated to provide the data needed to calculate hydraulic conductivity.

2.3.6 Interstitial Pore Water Sampling

Six interstitial (IS) pore water samples were collected from five locations in the marsh as shown on Figure 2-5 and summarized in Table 2-7. Pore water is defined as water that fills the pores between the grains of sediment. The samples were collected using a 6-foot long, stainless steel Henry (or push point) sampler or an AMS™ sampling probe. Each device can be advanced by hand through the surface water column and the upper unconsolidated marsh material into underlying competent sediment. The IS pore water samples were collected from between 2 and 6 feet below the marsh surface, depending upon the device used and the thickness of the overlying marsh material or surface water.

After advancing the device to the desired depth, groundwater was purged from the sample interval with a peristaltic pump. Samples were collected from the push point device after purging, and the device was removed from the subsurface. Because of the small diameter of each device (between ¼ and $^{3}/_{8}$ inches), the unconsolidated material immediately collapsed into the boring after the device was removed.

2.4 MARSH SEDIMENT

A total of 148 sediment samples were collected from 114 locations for chemical analysis as described in Table 2-8. The sediment sample locations are shown on Figure 2-6. Sediment samples were collected from upstream locations, the southern marsh, the eastern marsh and Sturgeon Creek. Samples BKSD1, KM24, KM30, SD22, SD71, SD72, SD73, SD74, SD101, SD107, SD108, SD109, BG-SD-01, BG-SD-02, and BG-SD-03 were collected upstream of the property or in the eastern marsh and are considered background samples. Thirty-five of the marsh sediment samples were collected at depths greater than 0.5 feet. These samples were used to help delineate the vertical profile of COPCs in sediment (versus for risk assessment purposes).

Discrete surficial sediment samples were collected in general accordance with USEPA Region 4 procedures in place at the time of sampling. The samples were collected using a stainless-steel hand auger or stainless-steel spoon/scoop depending upon specific sampling location conditions. At locations where surface water was less than one-half foot in depth, surficial sediment samples were collected using a stainless-steel spoon or scoop. Subsurface samples and locations beneath more than one-half foot of water were collected with a stainless-steel hand auger or other sampling equipment. The sediment sample was placed in a decontaminated stainless steel or Pyrex bowl. The sample matrix was visually examined for composition, layering, odor, and discoloration, then homogenized (if appropriate) in the bowl and placed in appropriate sample containers.

2.5 SURFACE WATER

Twenty surface water samples were collected for chemical analysis as described in Table 2-9. As shown on Figure 2-6, 18 of these samples were collected from the southern and eastern marsh and from Sturgeon Creek. Two surface water samples were collected from standing water in the Pond and Process Areas. Upstream samples SW22 and SW101 and eastern marsh samples SW107, SW108, and SW109 are considered background samples.

Surface water samples were typically co-located with sediment sample locations. At each location surface water samples were obtained prior to collection of sediment samples. Surface water samples were collected from mid-channel depth in both water bodies, in general accordance with USEPA Region 4 procedures in use at the time of sample collection. Sample bottles were directly submerged into the water column with the cap in-place. At the desired sampling depth, the cap was removed under water and replaced once the container was filled. For containers with preservative, the bottle was submerged enough to allow surface water to slowly fill the bottle preventing the preservative from washing out of the sample container. The water quality parameters (temperature, pH, SC, DO and ORP) were measured at the time of sample collection by inserting the probe of a YSI 556 water quality meter directly into the water.

2.6 AIR

The vapor intrusion pathway is being evaluated using the results of a passive soil survey and a vapor intrusion model. Soil gas sampling was attempted in 2015 during the SRI to provide data for vapor intrusion assessment of the vadose zone soils in the Process Area, Untreated Wood Storage Area and Treated Wood Storage Area. However, due to the shallow groundwater conditions at the property which resulted in a vadose zone of less than 5 feet, the soil gas samples could not be collected in accordance with North Carolina vapor intrusion guidance (NCDENR, 2014). Soil gas samples proposed for collection west of Navassa Road could not be collected due to property access issues.

A passive soil gas sampling program was conducted in 2015 to assess potential contamination outside of the known sources in the Pond Area using naphthalene as an indicator of creosote.

Forty-five passive soil gas samples were collected and analyzed for VOCs as described in Table 2-10 and shown on Figure 2-7.

To provide data for the vapor intrusion modeling, six undisturbed (Shelby tube) soil samples were collected from four soil borings (SB-115 through SB-118) and analyzed for geotechnical parameters as described in Table 2-3. The boring locations are shown on Figure 2-2 and the boring logs are provided in Appendix B. The soil samples were collected from the 0 to 3 feet bgs and 3 to 6 feet bgs intervals to characterize the vadose zone material. Soil samples were collected using a direct push drill rig equipped with a 30-inch Shelby tube. The SRI Work Plan Addendum No. 3 (EarthCon, 2016) proposed collection of up to 12 samples from six borings; however, dense materials and visible contamination prevented sample collection at several locations and shallow groundwater conditions prevented collection of samples from the deeper interval in two borings.

Results of the geotechnical analysis were used to model the vapor intrusion pathway. Vapor intrusion modeling was performed for the vadose zone soil and groundwater and is presented in the HHRA.

2.7 SURVEYING

Temporary well, CPT/ROST™, TarGOST®, soil boring, surface soil, surface water, sediment, and passive soil gas locations were surveyed by a North Carolina Registered Land Surveyor (RLS) or by the field team using a hand-held GPS unit. Permanent monitoring well locations were surveyed by a North Carolina RLS to determine horizontal coordinates and vertical elevation. Vertical elevation data for monitoring wells was surveyed to an accuracy of 0.01 feet and horizontal position data to an accuracy of 0.1 feet. Top of well casing elevation data was used, in conjunction with depth to water in each well, to determine the elevation of the water table. Location coordinates for soil borings, monitoring wells, and soil, groundwater, sediment and surface water sampling locations are provided in Appendix F.

3.0 PHYSICAL CHARACTERISTICS

Section 3.0 describes the surface features, topography, local climate, the surrounding land uses, soils, geology, hydrogeology, surface water hydrology and ecology using information derived from published reports, previous investigations of the study area, and the RI field work. This section of the RI Report provides the framework for the subsequent sections, which discuss the nature and extent of COPCs (Section 4.0), contaminant fate and transport (Section 5.0) and human health and ecological risk assessments (Sections 6.0 and 7.0, respectively).

3.1 SURFACE FEATURES AND TOPOGRAPHY

Except for foundations for the boiler house and treatment vessels, and surface depressions of former process ponds, there is little visual evidence of structures associated with the creosote wood treating operation remaining at the Site, which is mostly overgrown with trees and underbrush which restricts visual identification of ground surface conditions (Figure 1-3). A number of structures were present on the Residential Parcels, which were acquired by the Multistate Trust in 2016. These structures were removed in 2017. The unpaved Canal Drive is approximately ½-mile long. Duke Energy (formerly Progress Energy) maintains a power line right-of-way that runs approximately 650 feet into the north central portion of the property and supplied electricity to the Residential Parcels.

There have been numerous vehicle access points at the property including the Duke Energy power line right-of-way and various uncontrolled openings along the edges of the property that border Navassa Road. All other points of access, including Canal Drive, are gated and secured

The topography generally slopes from flat terrain on the western half of the property to the south and east where the topography is slightly lower and undulating to within approximately 200 feet of the tidal marsh, where it flattens and slopes gently towards the marsh. Property elevations drop from a high of approximately 25 feet at the western limit of the property to just above mean sea level (MSL) in the southern and eastern marsh.

There are remnants of drainage swales across portions of the property including two east-west swales located in the Eastern Upland and a north-south swale along the east side of the Process Area as shown on Figure 1-2. Standing water was observed in the drainage swales (particularly after rainfall) and in the footprints of the Boiler Ponds and the Fire Protection Pond. The berms for the Fire Protection Pond and Wastewater Ponds are also visible.

3.2 CLIMATE AND METEOROLOGY

Climatic and meteorological information for the portion of North Carolina near the property was obtained from State Climate Office of North Carolina and is summarized below (NCSU, 2017).

Seasonal Temperatures (°F)	January	July
Mean maximum	56.3	89.9
Mean minimum	35.8	72.3
Mean	46.1	81.1

- The mean annual precipitation ranges from 56 to 60 inches.
- The mean days per year with thunderstorms range from 40 to 50 days per year.
- The prevailing wind direction and wind speed is South at 8.2 miles per hour.

3.3 SURROUNDING LAND USE

Land use in the Navassa area of Brunswick County is both rural residential and industrial. The residential areas are west of the Site and Navassa Road. Most of the land area to the north of the Town and the property remains undeveloped and consists of industrial sites and undeveloped coastal forest or low-lying marsh. The Mayor of Navassa has advised that prior to construction of Navassa Road in the 1940s a railroad bed was located along the present-day portion of Navassa Road that borders the western perimeter of the property

The Rampage Boat Company operated a boat manufacturing facility until 2009 on the property abutting the northeast area of the KMCC property. This property was previously owned by Amour Fertilizer Works in the 1930s (Hart & Hickman 2016). The Brunswick River runs along the eastern boundary of the KMCC property. Sturgeon Creek runs along the south boundary of the KMCC property with residential areas south of Sturgeon Creek. A railroad track, wooded land and a warehouse lies north-northwest of the property. The Estech General Chemicals Site, where fertilizer was manufactured from 1884 until the early 1980s is located to the north-northeast of the property and is currently being remediated under USEPA oversight due to the presence of arsenic and lead in soil, groundwater and sediment.

The Town of Navassa's 2011 zoning map has classified the Site and surrounding properties for a mix of heavy and light industrial, or residential uses (including the Residential Parcels).

3.4 SOILS

According to the Natural Resources Conservation Service (NRCS) several soil types are present within the property as depicted on Figure 3-1 and described below.

The majority of the Process Area and Treated and Untreated Wood Storage Areas are comprised of the Leon Fine Sands (Lo), Mandarin Fine Sands (Ma), and Foreston Loamy Fine Sands (Fo) soil series. These sandy soils range from very poorly to well drained with a variable soil permeability and thick beds of very strongly acidic, loamy marine sediments.

The Eastern Upland consists primarily of Bragg Fine Sandy Loam (BrB) and Baymeade Fine Sand (BaB) soils. The BrB and BaB soils are well drained, slowly to moderately rapid permeable, strongly acidic sands with a slightly higher percentage of silt and very small percentage of clay. The BaB soils form in stratified interbedded loamy and sandy marine sediments and the BrB soils are formed from cutting and filling operations (NRCS, 2017).

The southern and eastern marshes contain the Chowan Silt Loam (CH) soil type. The CH soils are silty loams, poorly drained, moderately slow to moderately rapid permeability that form as loamy marine sediments over highly decomposed organic material in floodplains (water covers the surface for six months during most years).

The Johns Fine Sandy Loam (Jo) soils are located in the eastern portion of the Pond Area and immediately north and west of the southern and eastern marshes. The Jo soils are somewhat poorly drained to moderately well drained with moderate permeability.

The published NRCS range of permeabilities and reported depths of soil types for the KMCC property are shown below:

Soil Type	Permeability (cm/sec)	Depth bgs (inches)
Baymeade Fine Sand (BaB)	0.0014 – 0.0141	80
Bragg Fine Sand (BrB)	0.0001 – 0.0042	80

Soil Type	Permeability (cm/sec)	Depth bgs (inches)
Chowan Silt Loam (CH)	0.0001 – 0.0042	80
Foreston Loamy Fine Sand (Fo)	0.0004 - 0.0141	90
Johns Fine Sandy Loam (Jo)	0.0004 - 0.0141	60
Leon Fine Sand (Lo)	0.0001 – 0.0141	110
Mandarin Fine Sand (Ma)	0.0004 – 0.0141	80

3.5 GEOLOGY

The property is in the Coastal Plain Physiographic Province. The sedimentary soils in this province consist of thickly bedded sand, silts and clays, shells, sandstone and limestone that are more than 1,000 feet thick and overlie igneous and metamorphic basement bedrock [United States Geological Survey (USGS), 2003]. The following sections provide a description of the regional and site-specific geology. The regional geology section is based largely on published information. The site-specific geology section is based on data derived from the numerous borings and monitoring wells installed during previous investigations and the RI.

3.5.1 Regional Geology

The property is in the northeast portion of Brunswick County. The sedimentary formations beneath the area are described below and shown on the Regional Geology and Hydrogeology Map provided as Figure 3-2.

The sedimentary deposits in Brunswick County thicken eastward and range in geologic age from Cretaceous to Holocene. The principal formations that make up the geologic sequence in the area of the property, from oldest to youngest, include the Cape Fear, Black Creek, Middendorf and Peedee Formations of the Upper Cretaceous age, the Undifferentiated Pleistocene and Pliocene deposits, and the Surficial sand deposits of the Holocene age. The River Bend (Oligocene age), Castle Hayne (Eocene age) and Beaufort Formations (Paleocene age) are not present in northeast Brunswick County and the Navassa area (USGS, 2003).

In the Navassa area, the Surficial sand deposits consist of light gray to light yellow, medium to fine grain sands with trace quantities of clay, coarse-grained sand and pebbles. Peat is abundant locally. The Pleistocene and Pliocene undifferentiated sediments underlie the Surficial sand deposits and consist of shelly quartz sands and carbonates (sandy shell hash and sandy marl to an indurated sandy moldic limestone). There is no obvious confining unit between the Surficial sand deposits/Undifferentiated Pleistocene and Pliocene deposits and the Peedee Formation in the Navassa area (USGS, 2003).

The Peedee Formation of Upper Cretaceous age is encountered at approximately 20 to 30 feet below sea level in the Navassa area. This formation consists of gray to greenish-gray fine to medium sands interbedded with gray to black silty clays and commonly contains glauconite. Shells are common throughout the formation. Thin beds of calcareous sandstone and impure limestone are interlayered in the sand beds.

The Peedee Formation lies conformably on the Black Creek Formation beneath the Navassa area. The Black Creek Formation is of Upper Cretaceous age and is encountered at approximately 350 feet below sea level in the Navassa area. Beneath northern Brunswick County this formation consists mainly of dark gray to black clay, but it also contains subordinate layers of gray to tan fine sands.

The Cape Fear Formation of late Cretaceous age is the deepest and oldest sedimentary formation beneath the Navassa area. The top of the Cape Fear Formation is reportedly encountered at approximately 550 feet below sea level in this area. Cape Fear sediments consist of an upper confining unit that contains clay, silty clay, and clayey sand beds. This confining unit, ranging from 40 to 60 feet thick, overlies a zone of poorly sorted sands with gravel. This sand and gravel unit is underlain by a lower confining unit consisting of silts and clays (USGS, 2003).

3.5.2 Site-Specific Geology

Numerous soil test borings and monitoring well installations have been logged and recorded by field geologists during multiple phases of the RI to describe the site-specific geology. These borings and monitoring wells have been installed across the property (Process Area, Treated and Untreated Wood Storage Areas, Pond Area, and Eastern Upland) and on adjoining properties. Figures 2-2 and 2-5 show the locations of the soil borings and monitoring wells, respectively. Table 2-3 presents the Soil Boring Summary and Table 2-6 presents a summary of monitoring well and piezometer construction details.

The deepest boring (MW-09D/SB-D) on the property was advanced to 150 feet bgs and the deepest monitoring well (MW-06D) on the property was installed to a depth of 95 feet bgs. Soil cores were collected from soil borings and temporary and permanent monitoring well borings to allow visual examination by field geologists. Results of the field inspection and examination were recorded by field personnel on soil boring or well construction logs. Copies of the soil boring logs and well construction logs are included in Appendix B.

Field personnel used the USCS to characterize and describe the soils encountered during soil coring/boring activities. Lithologic data obtained from these borings has provided information to allow classification of the subsurface soils beneath the property and correlation of site-specific data with the geologic formations described above.

In addition to visual observations and soil descriptions, geotechnical analyses were performed on selected samples collected from nine borings. Six shallow undisturbed soil samples representative of the surface soils at the property were collected from four soil borings (SB-115, SB-116, SB-117 and SB-118) drilled to depths of approximately five feet bgs. Thirteen deeper undisturbed soil samples, representative of the Peedee Formation, were collected from five soil borings (SB-B, SB-D-01, SB-E, SB-G and SB-I) drilled to depths ranging from 80 to 132 feet bgs. Soil penetration tests (SPT) were also performed on 10 soil samples collected from the five deep soil borings.

The geotechnical analyses that were performed on the undisturbed soil samples include sieve and hydrometer analysis (ASTM D 422-63) and flexible wall permeability test, permometer method (ASTM D 5084-10). Surface soil samples were also analyzed for specific gravity (ASTM D 854-14), porosity (ASTM D 2937-10), and TOC (Walkey Black). The geotechnical laboratory analytical reports are provided in Appendix G.

Results of the geotechnical laboratory analysis, as well as the United States Department of Agriculture (USDA) and USCS classifications, permeabilities, relative density and porosity are summarized on Table 3-1. The results of the geotechnical analysis of undisturbed samples collected from the surface soils at depths ranging from ground surface to five feet bgs, classify these soils as silty sands with a USCS classification symbol of SM. The permeability test results ranged from 2.0×10^{-6} to 7.3×10^{-4} centimeters per second (cm/sec) with an average of 2.5×10^{-4} cm/sec. Reported porosities ranged from 31 to 39 percent with an average of 36 percent.

The results of the geotechnical analysis of undisturbed samples collected in the Peedee Formation at depths ranging from 80 feet to 132 feet bgs classify the soils as dense to very

dense, silty sands with some (11 to 20 percent) to trace (less than 10 percent) clay. The USDA classification is Sandy Loam. The USCS classification symbol is SM. The permeability results of these soils ranged from 6.5×10^{-7} to 5.7×10^{-6} cm/sec with an average of 2.13×10^{-6} cm/sec. The porosities ranged from 37 to 50 percent with an average of 41 percent.

Lithologic information collected during the ESI and multiple phases of the RI has been used to develop five cross-sections of the subsurface soils beneath the property. The cross-sections show the relative surface features of the property, physical land features (i.e. Navassa Road, adjacent property, and marsh), locations of selected boring and monitoring wells and the correlated subsurface lithology recorded from the soil borings and monitoring well logs. Figure 3-3 shows the orientation of the five cross-sections and Figures 3-4 through 3-8 present cross sections A-A', B-B', C-C', D-D' and E-E', respectively.

Cross Section A-A' (Figure 3-4) traverses north to south along the western portion of the property, along Navassa Road, through the Treated Wood Storage Area and the Fire Protection Pond and terminates at the edge of the southern marsh. Cross Section B-B' (Figure 3-5) traverses north to south, through the center of the Process Area and the Pond Area (including the Wastewater Ponds) and terminates at the edge of the southern marsh. Cross Section C-C' (Figure 3-6) traverses north to south, along the eastern edge of the former wood treating facility through the Evaporation Ponds and terminates at the edge of the southern marsh.

Cross Section D-D' (Figure 3-7) traverses west to east, from west of Navassa Road, along the southern portion of the Process Area, through the Evaporation Ponds and terminates in the wooded area east of the Process Area. Cross Section E-E' (Figure 3-8) traverses west to east, from west of Navassa Road, along the bank of the southern marsh downgradient from the Wastewater and Evaporation Ponds and terminates in the eastern portion of the property.

As shown in the cross-sections and supported by data presented in the geotechnical reports, the property is underlain by surficial soils that consist of a pale yellow to gray, medium to fine sand with intermittent zones of silty to clayey sands with some natural organic material such as roots and abundant peat locally. These soils range in thickness from approximately 50 feet in the northern (MW-12, Figure 3-6) and eastern (SB-108, Figure 3-8) portions of the property to approximately 30 feet in the southern (MW-06D, Figures 3-5 and 3-8) and western (SB-105, Figure 3-8) portions of the property.

The uppermost surficial soils are underlain by a zone of pale yellow to light brown to gray predominantly finer grain material consisting of intermittent layers of silty sand with silty clay to clayey sands and clay. This soil horizon is referred to locally as a Gumbo clay. In general, this clay horizon ranges from approximately 15 feet thick north of the Process Area (MW30D, Figure 3-5), to less than 10-feet thick beneath the Process Area (RIGW-17, Figure 3-5), to less than 2-feet thick along the southern marsh edge (MW-32D, Figure 3-5). It is absent south and east of the Evaporation Ponds (Figure 3-8). This clay layer may cause temporary perching of groundwater in some areas. Shallow monitoring wells MW-10S, MW-11S, MW-12S and MW-25S, installed in the central portion of the Process Area and the Pond Area, encountered very shallow groundwater elevations perched above this clay interval.

The finer grained Gumbo clay is underlain by yellow to yellowish brown to pale gray medium sands with occasional thin layers of cemented sands. This interval averages approximately 20 feet in thickness. The cemented layers range from 2 to 4 inches in thickness and were encountered more commonly beneath the northern end of the property. The surficial soils, the Gumbo clay and the soils below the clay interval are considered to represent the Surficial Aquifer beneath the property.

Underlying the Surficial Aquifer is the uppermost portion of the Peedee Formation. During the RI, a confining unit was not encountered between the Surficial Aquifer and the Peedee Formation beneath the property. The contact with the Peedee Formation is characterized by a

distinct change in color from a yellowish brown to dark gray. The top of the Peedee Formation ranges in elevation from approximately -12 feet, North American Vertical Datum (NAVD), north of the Process Area (MW-09D, Figure 3-4) to approximately -45 feet, NAVD in the southeastern portion of the property (SB-109, Figure 3-8). The lithology of the Peedee Formation consists of silty medium sands with traces of mica and fine shell fragments. Thin layers (1 to 2 inches thick) of calcareous cemented sands are occasionally present between approximately 40 and 60 feet bgs.

Soils encountered in the deeper borings installed across the property, including wells MW-09D, MW-03D, MW-06D, and MW-08D, and borings SB-A through SB-P and SB-100 through SB-109, were similar to those encountered to depths of 60 feet with an increasing number of intermittent thin layers (2 to 4 inches thick) of dark gray silty clay encountered at greater depths. No borings penetrated the entire thickness of the Peedee Formation and no laterally extensive confining layer (i.e. thickness greater than five feet) was encountered at depth.

3.6 HYDROGEOLOGY

The following subsections provide a description of the hydrogeology. The Regional Hydrogeology section is based largely on published information. The Site Hydrogeology section is described based on site-specific data derived from the monitoring well network.

3.6.1 Regional Hydrogeology

The major aquifers in Brunswick County include the Surficial, Castle Hayne, Peedee, Black Creek, Upper Cape Fear and Lower Cape Fear Aquifers. Figure 3-2 shows the relative depths, elevations and thicknesses of these aquifers and confining units, if present, in the Navassa area. The Castle Hayne Aquifer is the most productive aquifer in Brunswick County and is the principal groundwater source for municipal supply. The Castle Hayne Aquifer is limited to southeastern Brunswick County and is absent in the Navassa area. The Surficial Aquifer and upper part of the Peedee Aquifer are an important source of groundwater supply for domestic and commercial use in Brunswick County.

Water from the shallow deposits is generally of good quality but locally may have high iron content. Wells in the shallow sediments have a low specific capacity (1 to 2 gallons per minute per foot of drawdown). However, the deposits are valuable as an aquifer in that they are widespread and furnish small supplies of potable water throughout the county.

The upper part of the Peedee Formation is an important source of water supply for domestic and commercial use. The average hydraulic conductivity of the Peedee Formation is 25.4 feet per day (USGS, 2003). It is used in conjunction with the Castle Hayne Formation as a source for the municipal supply in Brunswick County. The most important aquifer in Brunswick County is the Castle Hayne Limestone. The average hydraulic conductivity of the Castle Hayne Limestone is 90.5 feet per day (USGS, 2003). The Castle Hayne Aquifer extends across only the southeastern part of the county and is absent in the Navassa area.

The Black Creek and Cape Fear Formations are reportedly not used for potable water supplies in Brunswick County, as they contain brackish water. The deepest portion of these Cretaceous sediments is likely to be under pressure and can have artesian and flowing wells (USGS, 2003). In the area of the property, the uppermost portion of the Black Creek Formation, the Black Creek Confining Unit, is present at an approximate elevation of -350 feet MSL or approximately 400 feet bgs (Figure 3-2). The Cape Fear Confining Unit may be encountered at an approximate elevation of -550 feet MSL or approximately 600 feet bgs. In this area, the Cape Fear Aquifer reportedly yields salty water with up to 10,000 parts per million chlorides, which is not suitable for most uses (USGS, 2003).

3.6.2 Site Hydrogeology

Fifty-nine permanent monitoring wells were installed to monitor the groundwater quality beneath the property. The locations of these monitoring wells are shown on Figure 2-5 and in cross-sections on Figures 3-4 through 3-8. Six monitoring wells (MW-08S, MW-10S, MW-11S, MW-12S, MW-14S and MW-25S) were installed to depths ranging from 8.5 to 20 feet bgs. Thirty-one monitoring wells were installed in the Surficial Aquifer at depths ranging from approximately 20 to 45 feet bgs. Twenty-two monitoring wells were installed in the upper Peedee Aquifer at depths ranging from approximately 57 to 95 feet bgs. As described in Sections 3.5.1 and 3.6.1 of this report, the Castle Hayne Aquifer and the Peedee Confining Unit are not present in the Navassa area. Data collected as part of the RI confirmed this information; therefore, the Surficial Aquifer is in direct contact with the underlying Peedee Aquifer beneath the property.

3.6.2.1 Groundwater Gradients

The depth to groundwater was measured in the monitoring well network at various times during the RI. The most comprehensive site-wide measurements were made in December 2016 and March 2017. Additional measurements were made in June and September 2017.

The groundwater level measurements were used to prepare potentiometric surface maps to determine groundwater flow directions, as well as horizontal and vertical gradients at the property. To determine the groundwater elevation at each monitoring well, the depth to groundwater was measured and recorded to the nearest 0.01 foot from the top of well casing. The depth to groundwater was then subtracted from the top of casing elevations that were determined by a North Carolina RLS. The top of casing and groundwater elevations are based on the NAVD of 1988. The depth to groundwater measurements and calculated groundwater elevations for December 2016, and March, June and September 2017 are summarized on Table 3-2.

Potentiometric surface maps were generated using data collected in March 2017 from monitoring wells screened in the Surficial Aquifer (Figure 3-9) and Peedee Aquifer (Figure 3-10). As shown on Figure 3-9, groundwater elevations in the Surficial Aquifer range from 6.53 feet, NAVD in upgradient monitoring well MW-23 to 2.12 feet, NAVD in downgradient monitoring well MW-29 located southwest of the property along the southern marsh. The direction of groundwater flow in the Surficial Aquifer is to the south-southeast towards the southern marsh and Sturgeon Creek with a southwesterly component in the southwest portion of the property

As shown on Figure 3-10, the groundwater elevations in the upper Peedee Aquifer range from 6.51 feet, NAVD in upgradient monitoring well MW-23D to 2.11 feet, NAVD in downgradient monitoring well MW-29D located southwest of the property along the southern marsh. The direction of groundwater flow in the Peedee Aquifer is to the south-southeast towards the southern marsh and Sturgeon Creek.

During the March 2017 event, groundwater elevations measured in shallow monitoring wells MW-10S, MW-11S, MW-12S and MW-25S ranged from 10.08 feet, NAVD to 20.38 feet, NAVD. These elevations are considerably higher than the surrounding groundwater elevations of approximately 4 to 5 feet. This localized perched groundwater condition is created from the infiltration of surface water through shallow soils, ponding on top of the finer grained less permeable Gumbo clay layer. Where the Gumbo clay is absent, the perched groundwater condition does not exist. Groundwater elevation data for these wells were not used to develop the potentiometric surface of the Surficial Aquifer shown on Figure 3-9.

Horizontal hydraulic gradients were calculated using the March 2017 Potentiometric Surface Maps prepared for the Surficial and Peedee Aquifers. The hydraulic gradient, i, is defined by the difference in hydraulic head, $(h_1 - h_2)$, divided by the distance, L, along the groundwater flow path identified on a potentiometric surface map. The hydraulic gradient calculation is as follows:

$$i = h_1 - h_2/L_1 - L_2$$

Using the potentiometric surface map shown on Figure 3-9, the hydraulic gradient for the Surficial Aquifer was determined to be 0.017 feet per foot. Using the potentiometric surface map shown on Figure 3-10, the hydraulic gradient for the upper Peedee Aquifer was determined to be 0.015 feet per foot.

Groundwater elevation data was also used to determine the vertical gradient between the monitoring wells screened in the Surficial Aquifer and the deeper monitoring wells, screened in the underlying Peedee Formation. An average vertical gradient across the property was calculated using data from twenty-one monitoring well clusters with wells that are screened in the Surficial and Peedee Aquifers. Table 3-3a presents the vertical hydraulic gradient calculations using groundwater data collected from seven monitoring events (June and September 2012, February and December 2016, and March, June and September 2017). As shown in Table 3-3a, there appears to be a slightly downward gradient during the June 2012, February and December 2016, and March, June and September 2017 monitoring events and a slightly upward gradient from the underlying Peedee formation during September 2012.

Evaluation of the vertical gradients from well pairs over the seven monitoring periods does not indicate an obvious, consistent upward or downward hydraulic gradient at any specific location on the property. The data also suggests a negligible vertical gradient between the Surficial and Peedee Aquifers. Because a vertical hydraulic gradient between the Surficial Aquifer and the Peedee Aquifer was not identified, dissolved creosote constituents are not expected to migrate downward through advection.

In September 2017, depth to groundwater measurements were collected from six well pairs located various distances from Sturgeon Creek. Two measurements were collected from each well during low tide and two measurements were collected from each well during high tide. As shown on Table 3-3b, the tide does not appear to affect the vertical gradient.

Discharge from the Peedee Aquifer occurs to local streams, the Cape Fear River, and the Atlantic Ocean (USGS, 2003). Based on the depth to the Peedee Aquifer and the lack of an upward hydraulic gradient, groundwater in the Peedee Aquifer does not appear to discharge to the marsh. The groundwater gradient and general dip of the Peedee Formation to the southwest, suggest that the Peedee Aquifer would discharge to the Cape Fear River.

3.6.2.2 Hydraulic Conductivity

The hydraulic gradients, along with K values of the screened soils, was used to calculate the groundwater flow velocities in the Surficial and Peedee Aquifers beneath the property. In-situ hydraulic conductivity (slug) tests were conducted in April 2007 for eight monitoring wells (MW-01, MW-02, MW-03, MW-04, MW-05, MW-06, MW-07 and MW-08) screened in the Surficial Aquifer. Slug tests were also conducted in December 2016 for an additional six monitoring wells screened in the Surficial Aquifer (MW-04, MW-11, MW-12, MW-15, MW-19 and MW-22) and four monitoring wells (MW-04D, MW-15D, MW-22D and MW-28D) screened in the upper Peedee Aquifer.

The slug test data was evaluated using commercially available AQTESOLV© and Super Slug™, computer software packages. These computer software packages allow a choice of published methods to evaluate slug test data to estimate K values of the screened soils. The Bouwer and Rice method for fully saturated screen was used to evaluate the data. The slug test data summary reports and computer printouts summarizing the hydraulic conductivity results are included in Appendix H.

Data generated during the falling and rising head tests from each well, except MW-02, was evaluated. The water column in well MW-02 (aquifer thickness of 9.95 feet) was less than the

slug length of 10 feet; therefore, when the slug was inserted it displaced water up into the filter pack above the water table. This allowed a more rapid "fall" in the water level which is not representative of aquifer conditions. Therefore, data from the falling head test in MW-2 was not used to calculate K.

Table 3-4 provides a summary of the hydraulic conductivity (slug) test results. As shown in Table 3-4, calculated K values for the Surficial Aquifer monitoring wells are within an order of magnitude, ranging from 5.7×10^{-4} cm/s or 1.6 feet per day in well MW-05 to 5.5×10^{-3} cm/sec or 15.6 feet per day in well MW-22. Calculated K values for the Peedee Aquifer monitoring wells are within two orders of magnitude, ranging from 5.3×10^{-6} cm/sec or 0.02 feet per day in well MW-04D to 1.1×10^{-4} cm/sec or 0.3 feet per day in well MW-22D.

Using the K values for the numerous tests, an average K value for the property was calculated by determining both the geometric mean and mathematical average for the Surficial Aquifer and Peedee Aquifer monitoring wells. The mathematical average and geometric mean values were 6.75 feet per day and 5.81 feet per day, respectively for the Surficial Aquifer wells and 0.19 feet per day and 0.14 feet per day, respectively for the Peedee Aquifer wells. Table 3-5 summarizes the geometric mean and mathematical average K value calculations.

3.6.2.3 Groundwater Flow Velocity

The calculated hydraulic gradients (0.017 feet per foot for the Surficial Aquifer and 0.015 feet per foot for the Peedee Aquifer) and the geometric mean K values (5.81 feet per day for the Surficial Aquifer and 0.14 feet per day for the Peedee Aquifer) were used to estimate groundwater flow velocity in the Surficial and Peedee Aquifers using Darcy's Law. The Darcy's Law equation used to calculate groundwater flow velocity is as follows:

$$V = Ki/n_e$$

Where:

V = Average Groundwater Flow Velocity (feet per day)

K = Hydraulic Conductivity (feet per day, geometric mean)

i = Groundwater Gradient (feet per foot)

n_e = Effective Porosity (percentage)

The effective porosity value is an assumed percentage – 30 percent (0.30), based on the soil type within the screen intervals (silty sand to poorly graded sand with silt and trace of clay) (Driscoll, 1986). Using the geometric mean K value, the hydraulic gradient, and the porosity values described above, the estimated horizontal groundwater flow velocity in the Surficial Aquifer beneath the property is calculated at 0.33 feet per day or 120 feet per year while the estimated horizontal groundwater flow velocity in the Peedee Aquifer beneath the property is calculated at 0.007 feet per day or 2.6 feet per year.

3.7 SURFACE WATER HYDROLOGY

The following section briefly describes the surface water hydrology for the Site and surrounding region.

3.7.1 Regional Surface Water Hydrology

Generally, the rivers in Brunswick County are under tidal influence and approximately one-fifth of Brunswick County consists of swampy or poorly drained land subject to seasonal flooding. The property is bounded to the east by a tidal marsh and the Brunswick River and to the south

by a tidal marsh and Sturgeon Creek. Sturgeon Creek drains wetland areas and a tidal marsh on the north side of the Town of Leland and to the west and south of the Town of Navassa. The eastern marsh is hydraulically connected to the Brunswick River. Sturgeon Creek flows into the Brunswick River at the southeastern point of the property (Figure 1-3).

The hydrologic budget summary for Brunswick County presented in "Hydrogeology and Ground-water Quality of Brunswick County, North Carolina", (USGS, 2003) is summarized below:

> "The average annual precipitation is 55 in/yr. Approximately 35 in/yr. of the annual precipitation is returned to the atmosphere through evapotranspiration and 9 in/yr. flows to streams or other surface-water bodies as overland runoff. The remaining 11 in/yr. infiltrates and recharges the shallow aquifer system. Of this amount, about 1 in/yr. is assumed to represent the downward percolation of recharge to the deeper aquifer system in Brunswick County."
>
> Note: in/yr. = inches per year

3.7.2 KMCC Property Surface Water Hydrology

The property has limited areas of standing water. Surface water found on the property is primarily localized and intermittent storm water typically associated with heavy or prolonged rainfall events. One of the former Boiler Ponds has been found to contain fluctuating amounts of standing water, primarily dependent upon rainfall accumulation. There are remnants of several drainage swales that cut across portions of the property, but these do not consistently contain standing water. None of the available data suggest that surface water on the property affects groundwater flow dynamics beneath the property.

3.7.3 Tidal Influence

During the RI, several tidal studies were performed to determine the tidal influence on groundwater elevations and quality beneath the property. In 2007, AECOM implemented a tidal study to determine if tidal fluctuations in Sturgeon Creek and the Brunswick River had an effect on groundwater elevations in monitoring wells installed in the Surficial Aquifer. In 2016, CH2M Hill performed a study on shallow and deep piezometers installed in pairs along the southern marsh to evaluate the response of water quality indicator parameters to the tidal change. In 2016, EarthCon also sampled groundwater monitoring wells and surface water locations in the marsh at low tide and analyzed the samples for chloride and TDS to evaluate the salt water/fresh water interface. The following paragraphs summarize the findings from these studies.

<u>AECOM Study</u>

AECOM conducted a tidal influence study over a period of 29 days, between April 19, 2007 and May 18, 2007. Transducers were installed in monitoring wells MW-03, MW-04, and MW-08 to monitor groundwater elevations and a temporary stilling well was constructed on a private dock located on the south side of Sturgeon Creek to monitor surface water levels. Trend graphs depicting groundwater elevations, surface water elevations in Sturgeon Creek, conductivity values and precipitation data and are provided in Appendix I.

A summary of the information provided on the graphs is as follows:

- Tidal fluctuations during the monitoring period range from four to six feet.
- Groundwater elevations recorded in wells MW-03, MW-04 and MW-08 responded directly to the tidal fluctuations in Sturgeon Creek with minimal lag time between tidal and groundwater elevation changes.

- The response to the tidal influence in monitoring well MW-04 was the most predominant of the three wells with approximately 0.4 feet of change in groundwater elevation. Monitoring well MW-04 is located within 100 feet of the tidal marsh and approximately 700 feet from Sturgeon Creek.
- The response to the tidal influence in monitoring well MW-08 resulted in approximately 0.3 feet of change in groundwater elevation. Monitoring well MW-08 is located within 100 feet of the tidal marsh and approximately 1,100 feet from Sturgeon Creek.
- The response to the tidal influence in monitoring well MW-03 was limited to approximately 0.1 feet of change in groundwater elevation. Monitoring well MW-03 is located 600 feet north of the tidal marsh and approximately 1,300 feet from Sturgeon Creek.
- Precipitation data obtained from the NOAA monitoring station at the New Hanover County Airport northwest of Wilmington, North Carolina was plotted on trend graphs for monitoring well MW-03 and MW-04. Groundwater elevation changes in response to three main precipitation events (less than one inch) were inconclusive.

In summary, AECOM's tidal study indicated tidal fluctuations influence groundwater elevations in monitoring wells installed in the Surficial Aquifer as far as 1,300 feet from Sturgeon Creek or more than 600 feet from the tidal marsh. Tidal fluctuations influence groundwater elevations as much as 0.4 feet in monitoring wells installed near the tidal marsh.

CH2M Hill Study

From March 2 through March 9, 2016, CH2M Hill monitored water level elevations and the water quality indicator parameters of conductivity, ORP, pH and temperature in eight piezometers to evaluate the response to the tidal fluctuations. The piezometers were installed as pairs in the southern marsh and consisted of a shallow piezometer installed to an approximate depth of five feet bgs and a deeper piezometer installed to an approximate depth of 20 feet bgs. The piezometers were constructed of one-inch, I.D. PVC pipe with one foot well screens. The locations of the piezometer pairs (PZ-B-01/PZ-B-02, PZ-D-01/PZ-D-02, PZ-I-01/PZ-I-02 and PZ-K-01/PZ-K-02) are shown on Figure 2-5. The time trend graphs for one day and one week for barometric pressure, conductivity, ORP, pH and temperature for the eight piezometers are presented in Appendix I. In general, the indicator parameters measured in the shallow piezometers demonstrated the most predominant response to tidal fluctuations. Additionally, the readings collected over the one-week test period provided better results than the daily test results.

EarthCon Study

In December 2016, EarthCon collected groundwater samples from 44 monitoring wells and surface water samples from three locations along the southern marsh. These samples were analyzed for chloride and TDS. A summary of chloride and TDS results are presented on Table 3-6. In general, chloride concentrations in groundwater in the Surficial and Peedee Aquifers are less than the chloride concentrations in surface water in the southern marsh. The TDS concentrations reported in groundwater samples are similar to those reported in surface water samples.

Data obtained during the tidal studies conducted by AECOM and CH2M Hill, along with the chloride data collected by EarthCon were further evaluated in the BERA to develop an understanding of the relationship between groundwater and surface water in the marsh.

3.8 ECOLOGICAL SETTING

The three major ecological habitats found at the property include forested terrestrial, tidal marsh, and riverine habitats, which are briefly describe in the following sections. A more detailed description of the ecological setting of the tidal marsh is provided in the BERA Report. Per the October 6, 2016 meeting between the Beneficiaries and the Multistate Trust, upland terrestrial areas were not included in the BERA due to uncertainty regarding future land use. The need to address upland terrestrial receptors may be reevaluated, as necessary, once remedial actions are complete.

3.8.1 Terrestrial Habitats

Habitat on the property is generally homogeneous throughout the terrestrial areas. The terrestrial area of the property is approximately 90 to 100 percent wooded with vegetation that has grown in the Process and Wood Storage Areas consisting mainly of Loblolly pine (*Pinus taeda*), from 6 to 12 inches in diameter. Understory plants include sweet gum (*Liquidambar styriciflua*), black gum (*Nyssa sylvatica*), water oak (*Quercus nigra*), hickory (*Carya* spp.), honeysuckle (*Lonicera japonica*), wax myrtle (*Myrica cerifera*), giant cane (*Arundinaria gigantea*), sweetbay magnolia (*Magnolia virginiana*), southern arrowwood (*Vibernum dentatum*), red maple (*Acer rubrum*), willow oak (*Quercus phellos*), dogwood (*Cornus florida*), black cherry (*Prunus serotina*), and chinquapin (*Castanea pumila*).

A patchy band of scrub/shrub vegetation is present at the edge of the marsh. Water oak, wax myrtle, sweetbay magnolia, red maple, southern arrowwood, willow oak, dogwood, and black cherry make up the scrub/shrub vegetation.

3.8.2 Tidal Marsh and Riverine Habitats

The southern marsh and Sturgeon Creek were selected for baseline ecological evaluation of potential risks to aquatic and benthic receptors. These areas are located adjacent to the suspected area of release and may contain creosote-related contaminants.

- The tidal marsh is controlled by semidiurnal tides and fluctuates from fresh to brackish, depending on the season (i.e. average rainfall). The wetland is dominated by short leaf cattail and bullrush with bald cypress on the outer fringe. The soils are highly organic, with some interlayered sand and silt. Most of the runoff and groundwater from the property flows directly toward the wetland. A series of manmade ditches, formerly used for rice cultivation, traverse the tidal marshes. These ditches significantly impact the hydrology of the wetlands, allowing a channelized flush of water during each tidal cycle. Tidal water level fluctuations of approximately 4 feet were noted during AECOM's field effort (AECOM 2013).
- Sturgeon Creek is a tidal creek that borders the southern end of the property. It flows approximately east-southeast in the study area before it flows into the Brunswick River. It is approximately 80 feet wide and ranges in depth from 2 to 15 feet. The portion of Sturgeon Creek that abuts the property, is approximately 13 feet deep. The tidal range is approximately 4 to 4.5 feet.

Sturgeon Creek is listed by the state of North Carolina as a Class C, Sw water. The designated uses of Sturgeon Creek include aquatic life propagation and survival, fishing, wildlife, secondary recreation, and agriculture, with a caveat indicating that the creek is a Swamp Water (Sw). As such, Sturgeon Creek is acknowledged to have lower velocity and other natural characteristics which are different from adjacent streams. The Brunswick River flows along the eastern edge of the property and receives Sturgeon Creek water at the southeast corner of the property. Brunswick River and the Cape Fear River at the confluence with the Brunswick River are Class

SC waters, designated as tidal salt waters appropriate for aquatic life propagation and survival, fishing, wildlife, and secondary recreation.

These water bodies are Surface Water Target Sensitive Environments because they (1) include protection and maintenance of aquatic life in their designated uses; (2) are spawning habitat for anadromous fish species including sturgeon, striped bass, shad, and river herring; (3) provide habitat known to be used by federal and state-listed endangered species; (4) include islands owned by the state used for game management; and (5) are contiguous to the in-water segment of the migration path. The tidal marshes located adjacent to the property along the south and east sides are also Surface Water Target Sensitive Environments. In addition to being wetlands, these areas are managed and protected under the North Carolina Coastal Zone Management Act.

Many wildlife receptors are expected to be present in the marsh and Sturgeon Creek. Species sighted during a limited site visit conducted by ENSR in 2004 included osprey, yellow rumped warbler, red tailed hawk, broad headed skink, and cottonmouth. ENSR sent letters to the USF&WS and North Carolina Natural Heritage Program requesting that the agencies provide information regarding the presence of rare, threatened, or endangered species that are known or suspected to occur in the area, for which the Site provides appropriate habitat. Copies of those letters were provided in Attachment C of the Revised SLERA (ENSR 2006b).

4.0 NATURE AND EXTENT OF CONTAMINATION

This section of the RI Report presents the RI analytical data and describes the nature and extent of DNAPL and related COPCs in environmental media at the Site and surrounding areas. Analytical laboratory reports and data validation reports for the RI are provided in Appendices J and K, respectively. Photographs from the RI field activities are provided in Appendix L.

The detected soil, groundwater, surface water and sediment results were compared to the residential screening values provided in the USEPA Regional Screening Levels (RSLs) for Chemical Contaminants at Superfund Sites summary tables dated June 2017 (USEPA, 2017a). The RSLs are conservative risk-based screening values developed by USEPA to help identify COPCs. They are not clean-up levels. The RSLs provided in the select summary table are derived using conservative default exposure assumptions, a target risk of 10^{-6}, and a hazard quotient (HQ) of 0.1. The screening values for PAHs provided in the June 2017 summary tables incorporate the updated toxicity values for benzo(a)pyrene. Incorporation of the new toxicity values resulted in an increase in the RSLs for several of the PAHs, including benzo(a)pyrene.

4.1 CONTAMINANT SOURCE AREAS

Creosote was released during the wood treating process in areas associated with process units, storage tanks and former surface water impoundments. The areas where residual creosote and soil impacts remain as a source of ongoing contamination to groundwater are referred to as source areas. Free-phase liquid creosote migrated from the source areas and remains within the subsurface soil as a continued source of dissolved constituents in groundwater. The density of the free-phase creosote is slightly heavier than water, classifying it as a DNAPL. Its migration through the subsurface is primarily controlled by gravity and capillary pressures and to a lesser extent by hydrodynamic pressure (i.e., viscous force) (Mercer and Cohen, 1993).

The SVOCs considered to be the primary indicators of creosote include PAHs, phenols, and 3 compounds closely associated with the PAHs (1,1-biphenyl, carbazole and dibenzofuran). For purposes of this RI Report, the SVOCs most commonly detected at concentrations greater than residential RSLs will be referred to as "creosote-related SVOCs" and will include the following constituents:

- 1,1-Biphenyl
- Carbazole
- Dibenzofuran
- 1-Methylnaphthalene
- 2-Methylnaphthalene
- Acenaphthene
- Acenaphthylene
- Anthracene
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(g,h,i)perylene
- Benzo(k)fluoranthene
- Chrysene
- Dibenz(a,h)anthracene
- Fluoranthene
- Fluorene
- Indeno(1,2,3-cd)pyrene
- Naphthalene
- Phenanthrene
- Pyrene

VOCs are often present at creosote wood treating sites due to their presence in carrier oil, fuel for machinery and vehicles, and their associated use in equipment maintenance. Petroleum products are sometimes added to dilute or "cut" the creosote. The VOCs most commonly associated with the Site include:

- Benzene
- Ethylbenzene
- Total xylenes
- 1,2,4-Trimethylbenzene
- 1,3,5-Trimethylbenzene

The potential source areas identified during the RI are the Process Area, the Wastewater Ponds, the Boiler Ponds, the Operations Evaporation Pond and the Decommissioning Evaporation Pond. The limited information on the historical operation of these areas is summarized below.

- Process Area – The Process Area was used for wood treating operations. The tanks, treatment cylinders, and transfer processes were potential sources of the creosote identified.
- Wastewater Ponds – The Wastewater Ponds were used to separate and reclaim creosote for reuse in the production process. The effluent from the Wastewater Ponds was reportedly recycled to a condenser as make-up cooling water. Prior to 1966, excess wastewater was likely transferred overland through drainage ditches to the southern marsh. After 1966, excess wastewater was discharged to the Operations Evaporation Pond. The Wastewater Ponds were unlined, and creosote may have migrated from the base of the ponds during the settling process. Wastewater may also have been released during heavy rain events.
- Boiler Ponds – Available information on historical operations indicates that the Boiler Ponds were used to store water for the boilers. The source of creosote in these ponds is unclear.
- Operations Evaporation Pond – The Operations Evaporation Pond was used to hold excess wastewater from the Wastewater Ponds after 1966. Creosote may have been transferred from the Wastewater Ponds with the wastewater.
- Decommissioning Evaporation Pond – The Decommissioning Evaporation Pond is thought to have received wastewater from the Wastewater Ponds during decommissioning. Creosote may have also been transferred from the Wastewater Ponds with the wastewater.

The following section describes the current understanding of the distribution of source material in these areas. The source material is creosote, primarily in the form of DNAPL.

4.2 RESIDUAL CREOSOTE AND DNAPL

Investigations to date have delineated the horizontal extent of DNAPL. The current understanding was developed from the results of CPT/ROST™ and TarGOST® investigations, visual inspection of soil cores, and measurement of DNAPL in groundwater monitoring wells. The CPT/ROST™ and TarGOST® data are considered screening data to identify potential areas of DNAPL. Table 4-1 provides a summary of DNAPL observations. Figure 4-1 shows the lateral distribution of DNAPL based on data from the CPT/ROST™ (as interpreted by AECOM), TarGOST® (as interpreted by CH2M Hill), and soil borings. Cross Sections A-A' through E-E', shown on Figures 3-4 through 3-8, respectively, illustrate the discontinuous nature of the creosote observed in the soil borings.

Interpretations of the CPT/ROST™ logs were derived from the ENSR ESI and AECOM draft RI reports. The CPT/ROST™ field logs from the 2006 Phase I RI were reviewed and are included in Appendix M.

The TarGOST® report is provided in Appendix N. The TarGOST® investigation was hindered by the drilling difficulties previously described and matrix interferences from native materials in the marsh. TarGOST® will respond to naturally fluorescent minerals, biogenic minerals (shells) and organic matter like peat or wood. In addition, decomposing wood can fluoresce as intensely as DNAPL. An attempt to differentiate between the naturally fluorescent materials and the DNAPL was conducted as described in Appendix N; however, the interpretation of TarGOST® data from the southern marsh is uncertain. Because of the limitations of the TarGOST® data, visual

observations from soil borings were primarily used to determine the distribution of DNAPL in the source areas and marsh sediment.

4.2.1 Process Area

Creosote releases were observed at land surface throughout the Process Area and along the former drip tracks. Surficial soils at the southwest corner of the Process Area (RISB35) extending to the former treatment vessel foundation (RICPT19 and RICPT20) and the former drip tracks (MW-10S), are stained black and emit a faint creosote odor when disturbed. Creosote saturated soil was observed at ground surface near monitoring well MW-10S in March 2017.

DNAPL was encountered at depth in CPT/ROST™ borings, TarGOST® borings, soil borings, and monitoring well borings advanced in the Process Area and in monitoring wells MW-02 and MW-10S. LIF signatures in CPT/ROST™ borings indicated the presence of creosote-related constituents and possible DNAPL at various depths. LIF signatures suggesting the presence of DNAPL at shallow depths (less than 2 feet) were noted in borings RICPT19, RICPT20, RICPT21, RICPT22, RICPT26, RICPT27, and RICPT30. LIF signatures suggesting the presence of DNAPL were noted in subsurface soils at borings RICPT17 (19 to 21 feet), RICPT18 (11 to 17 feet), RICPT21 (12 to 20 feet), RICPT24 (12 to 18 feet), RICPT26 (5 to 7 feet) and RICPT27 (5 to 9 feet). Results from TarGOST® borings TG-A-02, TG-A-03, TG-A-04, TG-B-03, TG-B-04, and TG-B-05 also indicated the presence of DNAPL at depth from 2 to 25 feet bgs.

DNAPL stringers were observed at multiple intervals between 10 and 18 feet in well boring MW-02 located at the western edge of the Process Area, between 8 and 18 feet bgs in boring MW-03 located in the central portion of the Process Area and between 10 and 15 feet bgs in well boring MW-10S located northeast of the former treatment vessel. DNAPL stringers were also observed in soil boring SB-B-03 from 1 to 15.5 feet bgs, SB-102 from 10.1 to 14 feet bgs, and SB-103 from 12.5 to 19.9 feet bgs. Additionally, DNAPL was measured in monitoring wells MW-02 (screened from 20 to 30 feet bgs) and MW-10S (screened from 5 to 10 feet bgs). DNAPL was not observed in monitoring well MW-10 (paired with MW-10S and screened from 27 to 37 feet bgs) indicating that the DNAPL in this portion of the Process Area is primarily limited to shallow soils above the Gumbo clay.

As shown on Figure 4-1, the CPT/ROST™ borings along Navassa Road indicate that the DNAPL has migrated to the west of Navassa Road near boring locations RICPT34, RICPT35, RICPT36, RICPT40, and RICPT41. LIF signatures from CPT/ROST™ borings located north (RICPT32, RICPT33, RICPT42, RICPT43) and south (RICPT37 and RICPT39) of the Process Area along Navassa Road did not indicate the presence of creosote indicating a localized impact along Navassa Road. Furthermore, DNAPL was not observed in soil borings SB-101 or SB-105 supporting the limited impact along Navassa Road. Because Navassa Road was reportedly the location of a railroad track before the mid-1940s, preferential migration may have occurred along the railroad bed in the more permeable fill materials resulting in the DNAPL identified by the NCDOT during the utility excavations.

In summary, DNAPL was detected in the former Process Area from the former drip tracks extending south to the Fire Protection Pond, west to Navassa Road and east to the Untreated Wood Storage Area (Figure 4-1). Evidence of DNAPL was observed from the land surface to depths of 25 feet bgs. Downward migration of DNAPL in the Process Area may have been limited by the presence of the Gumbo clay in this area. DNAPL observations indicated narrow discontinuous intervals or "stringers" of DNAPL in subsurface soils in the Process Area. DNAPL in the Process Area is delineated both horizontally and vertically.

4.2.2 Wastewater Ponds

Evidence of creosote was encountered in soil borings, CPT/ROST™ and TarGOST® borings, and monitoring wells advanced in and near the Wastewater Ponds. Borings advanced within the footprint of the Wastewater Ponds included RICPT11, RICPT12, TG-C-02, TG-D-02, WWSB04, WWSB05, WWSB06, WWSB08, RISB20, RISB41, SB106, and SB-107. Except for RISB20 (boring log unavailable), indications of creosote were observed in each of these borings from depths of 4 to 76 feet bgs. DNAPL was observed from 15.75 to 25 feet bgs in the deepest boring (SB-106) advanced to a depth of 99 feet bgs in the western Wastewater Pond. DNAPL was observed from 4.5 to 15.5 feet bgs and from 71.4 to 76 feet bgs in the deepest boring (SB-107) advanced to a depth of 99 feet bgs in the eastern Wastewater Pond.

LIF signatures suggesting the presence of DNAPL were noted from borings CPT4, CPT5, and CPT7 located south and downgradient of the Wastewater Ponds (near MW-05 and MW-06). Creosote signatures were also observed in TarGOST® borings downgradient of the Wastewater Ponds including TG-C-01, TG-D-01, TG-D-01R, TG-E-01, and TG-E-M01. DNAPL stringers were encountered at multiple depth intervals in well borings MW-05, MW-06, and MW-06D and soil borings SB-B, SB-C, SB-E and SB-E-M01 ranging from ground surface at SB-C to 102 feet bgs in boring SB-E. In March 2017, DNAPL was measured in wells MW-05, MW-06, MW-06D and MW-32D at thicknesses ranging from 0.08 feet in monitoring wells MW-05 and MW-06 to 6.38 feet in well MW-06D. As shown on Figure 4-1, the lateral extent of DNAPL at depths greater than 30 feet bgs extends from the Wastewater Ponds to the southern marsh. DNAPL was encountered from 4 feet bgs to 102 feet bgs in boring SB-E located at the marsh edge. The vertical extent of DNAPL near the Wastewater Ponds is not fully defined.

4.2.3 Boiler Ponds

TarGOST® borings TG-F-05 and TG-F-06 were advanced near the Boiler Ponds. A creosote signature was identified in TG-F-05 located at the western edge of the southern Boiler Pond at a depth of 18.5 to 23 feet bgs. A creosote signature was not identified in boring TG-F-06 located near the northern Boiler Pond. Soil borings BPSB9, BPSB11, SB-111, and SB-112 were advanced in and near the Boiler Ponds. DNAPL was observed in SB-111 located in the southern Boiler Pond at a depth of 16.5 to 17 feet. DNAPL was not observed in borings BPSB9 or BPSB11. DNAPL was observed in borings from the southern Boiler Pond at depths from 16 to 23 feet bgs. DNAPL was not observed in the northern Boiler Pond. The horizontal and vertical extent of DNAPL is delineated in the Boiler Pond area. The horizontal extent of DNAPL is shown on Figure 4-1.

4.2.4 Operations Evaporation Pond

Two CPT borings (RICPT6 and CPT15) and fourteen TarGOST® borings were advanced near the Operations Evaporation Pond. Creosote signatures were not identified in RICPT6 or CPT15; however, a petroleum signature was identified in CPT15. The TarGOST® borings advanced west of the pond (TG-K-05 and TG-J-04) and south of the pond (TG-I-03 and TG-J-02) did not indicate the presence of DNAPL. TarGOST® results from the remaining borings advanced within and east of the Operations Evaporation Pond indicate the presence of DNAPL from 3.5 to 25 feet bgs. Two borings (SB-M-01 and SB-K-01) were advanced to depths of 100 feet. DNAPL was observed in SB-M-01 at a depth of 8 to 9 feet bgs and in SB-K-01 at depths of 6 to 8 feet bgs and 15 feet bgs. DNAPL was also observed at 0.3 feet bgs and 13 to 14 feet bgs in well boring MW-25D, at 33 feet bgs in well boring MW-27D, and from 9 to 15 feet bgs in well boring MW-28D. In March 2017, DNAPL was measured in monitoring wells MW-25S, MW-27S, and MW-28D at thicknesses ranging from 0.06 feet in well MW-27D to 0.75 feet in well MW-27S.

Based on observations from soil borings, DNAPL appears to be present as discontinuous stringers at depths from 3.5 to 33 feet bgs. Measurable DNAPL was also observed in monitoring well MW-27D, which is screened from 50 to 60 feet bgs. The horizontal and vertical extent of DNAPL is delineated in the Operations Evaporation Pond area. The horizontal extent of DNAPL is shown on Figure 4-1.

4.2.5 Decommissioning Evaporation Pond

LIF signatures, possibly indicating petroleum presence, were noted in CPT11 and CPT12 located near the former Decommissioning Evaporation Pond. In CPT/ROST™ borings RICPT1 through RICPT5, LIF signatures suggesting the presence of DNAPL were noted in RICPT3 and RICPT4 between depths of 8 and 12 feet. TarGOST® boring TG-N-02 also indicated the presence of DNAPL at depths from 6 to 10 feet bgs. DNAPL stringers were encountered at multiple intervals in well borings MW-08 and MW-08D from 13.5 to 20.5 feet bgs. Based on these observations, DNAPL is present in the southern portion of the pond and is delineated to the south and west by borings SB-L, SB-M, SB-108, and SB-109. The vertical extent of DNAPL in the Decommissioning Evaporation Pond ranges from 6 to 20.5 feet bgs. The horizontal and vertical extent of DNAPL is delineated in the Decommissioning Evaporation Pond area. The horizontal extent of DNAPL is shown on Figure 4-1.

4.2.6 Marsh Sediments

Twenty-two TarGOST® borings and six soil borings (SB-B-M01, SB-C-M01, SB-D-M01, SB-E-M01, SB-F-MO1, SB-H-M01) were advanced in the southern marsh. The TarGOST® results did not correlate well with the adjacent soil boring visual observations. For instance, DNAPL was inferred in TG-C-M01 at 8 feet bgs; however, DNAPL was not observed in the collocated soil boring SB-C-M01. As described in the TarGOST® report in Appendix N, the TarGOST® results were affected by interferences from naturally fluorescent materials. Therefore, visual observations from soil borings in the southern marsh were used to evaluate the presence of DNAPL.

Based on visual observations, DNAPL at depth in the marsh is limited to the vicinity of SB-E-M01 located at the marsh edge where DNAPL was observed at depths of 60.6 feet and from 66 to 70 feet bgs. DNAPL was not observed in soil boring SB-D-M01 installed to a depth of 90 feet approximately 120 feet southwest of SB-E-M01 or in soil boring SB-F-M01 installed to a depth of 70 feet approximately 190 feet southeast of SB-E-M01. Therefore, the horizontal and vertical extent of DNAPL appears to be delineated in the southern marsh. The horizontal extent of DNAPL is shown on Figure 4-1.

4.2.7 Summary of Residual Creosote and DNAPL Extent

The RI investigations indicate DNAPL is present beneath several source areas including the Process Area, Wastewater Ponds, southern Boiler Pond, Operations Evaporation Pond and the Decommissioning Evaporation Pond. Visual examination of soil cores and the results of CPT/ROST™ and TarGOST® borings indicate the DNAPL is present in thin layers at multiple depths, from shallow subsurface soils beneath the Process Area to depths of up to 100 feet bgs in the area downgradient of the Wastewater Ponds. The results indicated narrow discontinuous intervals or "stringers" of DNAPL in subsurface soils in the Process Area, downgradient of the Wastewater Ponds, and beneath the Evaporation Ponds. The results also indicated the presence of DNAPL to a depth of 60.5 feet bgs at the marsh edge; however, DNAPL was not noted at depths greater than 60.5 feet in this area. None of the data indicate a large, continuous plume of DNAPL. As described above and shown on Figure 4-1, the horizontal extent of DNAPL has been delineated. The vertical extent of DNAPL has been delineated except for the area immediately downgradient of the Wastewater Ponds around monitoring wells MW-06D and MW-32D.

4.3 SOIL

The following subsections present the analytical results for background soil, surface soil and terrestrial sediment, and subsurface soil samples collected during the RI. Surface soil is defined as the interval from land surface to 1-foot bgs. This interval is significant because it is the soil most likely to be in direct contact with receptors (human and ecological). Terrestrial sediment samples are soil samples collected from low lying areas (i.e., drainage swales and surface depressions) that are intermittently wet from rainfall. Subsurface soil is defined as the interval below 1-foot bgs and above the water table (in the vadose zone). During the ESI and RI sampling events, saturated soil samples were collected below the water table and this data was used to evaluate the extent of contamination in the subsurface. However, as directed by the USEPA, data from saturated subsurface soils will not be included in the HHRA.

The soil sampling program, including analytical methods and target analytes, is described in Section 2.2. Detected sample results for background soil, surface soil and terrestrial sediment, and subsurface soil are presented in summary Tables 4-2, 4-3(a, b, c and d), and 4-4(a, b, c, and d), respectively. The summary tables include results for any analyte with at least one detection. The tabulated surface soil and terrestrial sediment, and subsurface soil analytical results are provided in Appendices O and P, respectively. Figures 4-2a, 4-2b, and 4-3 were generated to illustrate the interpreted extent of soil contamination at the site. The concentration contours were generated using best engineering judgment such that the distribution is aligned with historical use and anticipated transport directions. Locations with concentrations below residential RSLs were assigned a zero for contouring purposes.

As agreed with the USEPA and NC DEQ, the detected soil results were compared to the residential soil screening values provided in the USEPA summary tables dated June 2017 (USEPA, 2017a). The RSLs provided in the select summary table are derived using conservative default exposure assumptions, a TR of 10^{-6}, and a HQ of 0.1.

4.3.1 Background Soil

Background soil sampling was conducted in January 2017 by collecting 15 surface soil samples from locations within the Town of Navassa as shown on Figure 2-3. Each soil sample was analyzed for PAHs, TAL metals, and hexavalent chromium. Background concentrations were derived by calculating the arithmetic mean and multiplying by two for each constituent as described in the USEPA Region 4 *Human Health Risk Assessment Supplemental Guidance* (USEPA, 2014). A summary of the background soil results is provided in Table 4-2. The background soil concentrations were compared to soil sample results to determine if concentrations of these constituents are related to activities conducted at the Site or represent anthropogenic or naturally occurring concentrations.

4.3.2 Surface Soil and Terrestrial Sediment

Tables 4-3a, 4-3b, 4-3c, and 4-3d provide the results of the surface soil and terrestrial sediment samples. The sample locations are shown on Figure 2-4. Results of the surface soil and terrestrial sediment samples were compared to the higher of the background concentrations and residential RSLs.

4.3.2.1 Volatile Organic Compounds

A summary of the detected VOC results in surface soil and terrestrial sediment samples is provided in Table 4-3a. VOCs detected above residential RSLs include acrolein, benzene, ethylbenzene, and total xylenes.

Acrolein was detected in five terrestrial sediment samples (SD004, SD010, SD012, SD016 and SD019) located in the drainage swales in the Eastern Upland Area. Acrolein may be found in

some livestock feed and is used as a pesticide. Small amounts of acrolein can be formed and enter the air when organic matter, such as trees and other plants are burned and also when fuels, such as gasoline and oil, are burned (ATSDR, 2007). Acrolein may partition from air to rainwater and be transported by runoff. The presence of acrolein in the drainage swales may be due to its use as a pesticide or from the burning of organic matter.

Benzene was detected in terrestrial sediment sample RISD01 only, while ethylbenzene and total xylenes were detected in terrestrial sediment samples RISD01 and RISD02. These samples were collected from the Boiler Ponds. Benzene, ethylbenzene, and total xylenes are related to petroleum products such as gasoline and diesel fuel.

The only VOCs detected above RSLs in surface soil and terrestrial sediment are acrolein, benzene, ethylbenzene and total xylenes. These constituents were detected at concentrations above residential RSLs in less than 10 percent of the surface soil and terrestrial sediment samples.

4.3.2.2 Semi-Volatile Organic Compounds

A summary of the detected SVOC results in surface soil and terrestrial sediment samples is provided in Table 4-3b. Creosote-related SVOCs were the only SVOCs detected above the residential RSLs. The distribution of creosote-related SVOCs is shown on Figure 4-2a and described in the following section by area.

Eastern Upland Area

The DU composite surface soil samples were collected by AECOM in a grid pattern throughout the Eastern Upland Area. SVOCs were detected in the DU samples at concentrations below the residential RSLs.

As shown on Figure 4-2a, creosote-related SVOCs were detected at concentrations above the residential RSLs in 12 samples collected from locations in the Eastern Uplands Area. The samples, which were collected primarily in drainage swales, and their associated creosote-related SVOC concentration include the following:

- Surface soil sample SO031 (5.2 mg/kg) located at the northwest property boundary,
- Terrestrial sediment samples SD004 (1.68 mg/kg), SD006 (6.51 mg/kg), SD007 (4.27 mg/kg), and SD008 (2.56 mg/kg) located in the northern drainage swale,
- Terrestrial sediment samples SD012 (4.81 mg/kg), SD013 (32.95 mg/kg), SD015 (20.67 mg/kg), SD016 (5.52 mg/kg), SD017 (4.55 mg/kg), SD019 (7.26 mg/kg), and surface soil sample SS-10 (5.03 mg/kg) located in the central drainage swale.

Untreated Wood Storage Area

As shown on Figure 4-2a, creosote-related SVOCs were detected in surface soil in the Untreated Wood Storage Area at relatively low concentrations. The highest concentration of creosote-related SVOCs above residential RSLs was detected in surface soil samples SB-125 at a concentration of 113.44 mg/kg and terrestrial sediment sample SD021 at 170.6 mg/kg.

Creosote-related SVOCs were detected in surface soils throughout the Untreated Wood Storage Areas. Their presence, along with visual observations of area conditions confirms that a layer of clean fill material was not placed on the entire surface of the Untreated Wood Storage Area during facility decommissioning.

Treated Wood Storage Area

As shown on Figure 4-2a, creosote-related SVOCs were detected in surface soil samples in the Treated Wood Storage Area. The highest concentrations of creosote-related SVOCs were detected in sample RISB02 (150.35 mg/kg) which is located in the northern portion of the Treated Wood Storage Area and samples TWSB-27 (61.8 mg/kg), SB-133 (15.95 mg/kg), and RISB09 (98.03 mg/kg) which are located in the southern portion of the Treated Wood Storage Area.

Creosote-related SVOCs were detected in surface soils throughout the Treated Wood Storage Area. Their presence, along with visual observations of area conditions confirms that a layer of clean fill material was not placed on the entire surface of the Treated Wood Storage Area during facility decommissioning.

Process Area

As shown on Figure 4-2a, creosote-related SVOCs were detected in surface soil and terrestrial sediment samples throughout the Process Area. The highest concentrations of creosote-related SVOCs were detected in samples PASB19 (5,929 mg/kg) and SS02 (3,174.9 mg/kg) located near the tanks and treatment cylinders.

Pond Area

As shown on Figure 4-2a, creosote-related SVOCs were detected in surface soil and terrestrial sediment samples at concentrations above residential RSLs throughout the Pond Area with the highest concentrations detected in terrestrial sediment samples RISD01 (22,130 mg/kg) and RISD02 (22,300 mg/kg) located in the Boiler Ponds and sample TP-01 (13,531 mg/kg) located south of the Boiler Ponds. Creosote-related SVOCs were also detected at lower concentrations in the Decommissioning Evaporation Pond, the Wastewater Ponds, and the Fire Protection Pond.

4.3.2.3 Pesticides

Aldrin was the only constituent detected at a concentration above the residential RSL in the pesticide analysis of surface soil and terrestrial sediment samples. Aldrin was detected at a concentration of 0.15 mg/kg in terrestrial sediment sample RISD01 collected from the Boiler Ponds. Aldrin is an insecticide widely used from the 1950s to the 1970s (ATSDR, 2002). A summary of the detected pesticide results is provided in Table 4-3c.

4.3.2.4 Metals

Aluminum, arsenic, cobalt, iron, manganese, thallium, and vanadium were detected in the surface soil and terrestrial sediment samples at concentrations greater than both their respective residential RSL and background concentrations. These metals are not related to the creosote wood treating process. A summary of detected inorganics in surface soil and terrestrial sediment is provided in Table 4-3d. Aluminum and iron were detected sporadically at concentrations above their respective background and/or residential RSLs and were not addressed in this Section but were addressed in the HHRA Report. Each of the other detected metals are described below.

Cobalt was detected above the residential RSL of 2.34 mg/kg in terrestrial sediment sample SD013 (Eastern Upland Area) only at a concentration of 5.79 mg/kg. Manganese was only detected in terrestrial sediment sample SD010 at a concentration of 428 mg/kg. Thallium was detected at concentrations above the residential RSL at four locations: RISB03 (Treated Wood Storage Area), SD006 (Eastern Upland Area), SD111 (Process Area), SO061 (Pond Area). The thallium concentration detected at RISB03 (0.73 mg/kg) exceeds background; concentrations at

the other three locations range from 0.15 to 0.18 mg/kg, which are above the residential RSL but below the background value. Vanadium was detected at concentrations ranging from 40.5 to 78 mg/kg in four terrestrial sediment samples including RISD01 and RISD02 (Boiler Ponds), RISD03 (Process Area), and SD019 (Eastern Upland Area). Hexavalent chromium was detected at four locations: SD110 (drainage swale in the Process Area), SO024 (property boundary in Eastern Upland Area), SO040 (Untreated Wood Storage Area), and SO059 (Untreated Wood Storage Area). Concentrations range from 0.836 to 1.71 mg/kg, which are above the residential RSL but below the background value. These metals were detected sporadically and are not related to the creosote wood treating process.

As shown in Table 4-3d, the method detection limit (MDL) for both thallium and hexavalent chromium for the soil samples exceeds the residential RSL. Due to the uncertainty associated with the elevated MDL, as well as the small data set for hexavalent chromium, these constituents were further evaluated in the HHRA.

Arsenic was detected above the background concentration of 2.88 mg/kg in 26 of 83 samples at concentrations ranging from 2.98 mg/kg in SS12 to 30.3 mg/kg in sample SS03. The distribution of arsenic concentrations above background in surface soil and terrestrial sediment is shown on Figure 4-2b. Arsenic concentrations exceeded the background concentrations in the following areas:

- Surface soil sample SO031 collected at the northwest property boundary,
- Terrestrial sediment samples SD006, SD007, SD008, and SD010 collected from the northern drainage swale in the Eastern Upland Area,
- Terrestrial sediment samples SD012, SD013, SD015, SD019, SD020 and SS10 collected from the drainage swale south of the Residential Parcels in the Eastern Upland Area,
- Surface soil samples SD021, SO041, SO048, SO057, and SO059 collected from the Untreated Wood Storage Area,
- Surface soil sample SS12 located in the Treated Wood Storage Area,
- Surface soil and terrestrial sediment samples SD-111, SD-112, SS01, RISD03, and RISD04 located in the Process Area, and
- Terrestrial sediment samples RISD01 and RISD02 located in the Boiler Ponds and surface soil samples SS03 and SS07 located in the Pond Area.

As shown on Figure 4-2b, arsenic concentrations that exceed the background value were detected sporadically throughout the areas used for wood treating and in the drainage features located in the Eastern Upland Area. Arsenic is not typically used in the creosote wood treating process. Inorganic arsenic was the dominant pesticide used from the mid-1900s to 1940 and its presence may be related to historical agricultural uses on the property. Arsenic is also associated with the fertilizer manufacturing that occurred on the nearby Estech Chemical site.

4.3.3 Subsurface Soil

Tables 4-4a, 4-4b, 4-4c, and 4-4d provide the results for the subsurface soil samples. The sample locations are shown on Figure 2-2. Results of the subsurface soil samples were compared to the higher of the background concentrations and the residential RSLs.

4.3.3.1 Volatile Organic Compounds

A summary of the detected VOC results in subsurface soil samples is provided in Table 4-4a. Only ethylbenzene, which is a fuel-related constituent, was detected above a residential RSL.

Ethylbenzene was detected in subsurface soil samples RISB41 (30 mg/kg), located in the Wastewater Ponds and RISB43 (7.7 mg/kg) located in the Process Area.

4.3.3.2 Semi-Volatile Organic Compounds

A summary of the detected SVOC results in subsurface soil samples is provided in Table 4-4b. Creosote-related SVOCs were the only SVOCs detected above residential RSLs.

Creosote-related SVOCs were detected in subsurface soil in the Treated and Untreated Wood Storage Areas, the Process Area and the Pond Area. SVOCs were not detected above residential RSLs in the Eastern Upland Area. The distribution of creosote-related SVOCs detected above RSLs are shown on Figure 4-3 and described by area in the following sections.

Untreated Wood Storage Area

As shown on Figure 4-3, the occurrence of creosote-related SVOCs above residential RSLs in subsurface soil in the Untreated Wood Storage Area is limited to locations RISB05 and RISB42. Creosote-related SVOCs were detected at 22.61 mg/kg in sample RISB05 collected from 2 to 4 feet bgs and 1.6 mg/kg in sample RISB42 collected from 2 to 4 feet bgs. Except for location RISB05, concentrations in the subsurface soil samples were significantly lower than concentrations in the surface soil indicating surface releases of creosote.

Treated Wood Storage Area

As shown on Figure 4-3, the occurrence of creosote-related SVOCs above residential RSLs in subsurface soil in the Treated Wood Storage Area was limited to soil samples TWSB25 and RISB09. Creosote-related SVOCs were detected at 3.25 mg/kg in sample TWSB-25 collected from 1.5 to 2 feet bgs and at 3.21 mg/kg in sample RISB09 collected from 2 to 4 feet bgs. Concentrations in the subsurface soil samples were significantly lower than concentrations in the surface soil indicating surface releases of creosote consistent with the use of the area for storage of treated wood.

Process Area

As shown on Figure 4-3, creosote-related SVOCs were detected in subsurface soil samples in the Process Area from the former drip tracks located in the northern portion of the area (RISB23) throughout the southern portion of the Process Area. The highest concentrations of creosote-related SVOCs above residential RSLs were detected in sample PASB20 (56,713 mg/kg) located east of the creosote storage tanks and treatment cylinders. Soil contamination extends from the ground surface to the water table. Saturated soil data is limited as most of the soil samples were collected in the upper 5 feet with the exception samples SB-28, RISB26, RISB35, RISB40, and RISB43, which were collected at depths below the water table. The subsurface soil data combined with the DNAPL observations indicate that soil in the Process Area is impacted from the ground surface to a depth of 25 feet bgs.

Pond Area

As shown on Figure 4-3, creosote-related SVOCs were detected in the Pond Area near the Fire Protection Pond, the Boiler Ponds, the Wastewater Ponds, and the Decommissioning Evaporation Pond. The concentrations in samples from the Fire Protection Pond were relatively low (1.91 mg/kg in sample FWSB01 collected from 1.5 to 2.5 feet bgs and 2.68 mg/kg in sample FWSB02 collected from 0.5 to 1.5 feet bgs). Creosote odor and staining were not reported in soil boring SB-110 located in the footprint of the Fire Protection Pond until a depth of 11.8 to 16.5 feet bgs. At this depth, creosote odors indicative of a stringer of DNAPL were observed beneath the pond bottom. Because the subsurface soil concentrations were relatively low and

DNAPL was not observed at the pond bottom, the Fire Protection Pond does not appear to be the source of the observed DNAPL.

Creosote-related SVOCs were detected at 538.11 mg/kg in subsurface soil sample BPSB09 collected from a depth of 1 to 2 feet bgs in the footprint of the Boiler Ponds. Creosote odor and staining were not observed in soil boring SB-111 located in the southern Boiler Pond until a depth of 16.5 to 17 feet, where a DNAPL stringer was observed. Based upon the available data, it appears that there is creosote-related SVOC contamination that extends from the surface to at least 2 feet bgs in the footprint of the southern Boiler Pond and a DNAPL stringer under the pond.

Creosote-related SVOCs were detected at concentrations of 354.63 mg/kg in sample WWSB07 collected from 5 to 5.5 feet bgs and 598.1 mg/kg in sample WWSB06 collected from 5.5 to 6 feet bgs. These samples are in the footprint of the Wastewater Ponds. Observations from soil borings SB-106 and SB-107 indicate DNAPL stringers from 15.75 to 25 feet bgs in soil boring SB-106 located in the western Wastewater Pond and from 4.5 to 15.5 feet bgs and 71.4 to 76 feet bgs in soil boring SB-107 located in the eastern Wastewater Pond.

Creosote-related SVOCs were also detected above residential RSLs in the subsurface soils collected in the footprint of the Decommissioning Evaporation Pond. Creosote-related SVOCs were detected at concentrations as high as 23,895 mg/kg in sample RISB33 collected from 2 to 4 feet bgs. Based on observations from CPT11 and RICPT5 and observations from monitoring well borings MW-08 and MW-08D, DNAPL also exists in stringers from 5 to 20.5 feet bgs near the Decommissioning Evaporation Pond.

As shown on Figure 4-3, creosote-related SVOC concentrations in subsurface soils above the residential RSLs are primarily located in the Process Area and the Pond Area. The subsurface soil contamination extends to the south towards the southern marsh as evidenced by the samples collected by USEPA in 2010 (KM samples).

4.3.3.3 Pesticides

A summary of the detected pesticide results in subsurface soil samples is provided in Table 4-4c. Pesticides were not detected in subsurface soils at concentrations above the residential RSLs.

4.3.3.4 Metals

A summary of the detected metal results in subsurface soil samples is provided in Table 4-4d. The only metals detected above both the residential RSLs and background concentrations are aluminum and arsenic. Aluminum was detected above background at only two locations. Arsenic was detected in sample RISB19 collected at a depth of 9 to 12 feet bgs at a concentration of 3.6 mg/kg which exceeds the background concentration of 2.88 mg/kg. Arsenic and aluminum are not associated with creosote wood treating operations and their occurrence above background in the subsurface soil is isolated.

4.4 GROUNDWATER

Groundwater samples were collected from 19 temporary and 37 permanent monitoring wells installed in the Surficial Aquifer and 22 wells installed in the underlying Peedee Formation. Six IS pore water samples were also collected from five locations in the southern marsh. USEPA also collected groundwater samples from temporary and permanent wells located on the property and from residential wells located south of Sturgeon Creek.

The groundwater sampling program is presented in Section 2.3. Field parameter results for groundwater samples collected in December 2016 and March 2017 are provided in Table 4-5.

A summary of background groundwater results is provided in Table 4-6. The constituents detected in temporary well samples are summarized in Table 4-7. The temporary well data were used to locate the permanent monitoring wells and are provided for reference. Constituents detected in groundwater samples collected from permanent monitoring wells in 2016 and March 2017 are summarized in Tables 4-8a through 4-8d. Figures 4-4a, 4-4b, 4-5a, and 4-5b show the extent of VOCs and creosote-related SVOCs detected in groundwater in March 2017 while Figure 4-6 shows the extent of arsenic detected in Surficial groundwater in December 2016. The distribution of constituents in groundwater south of the Site was delineated using best engineering judgment based on historical data including IS porewater data, surface water data, and residential well data south of Sturgeon Creek. The data were used qualitatively as the IS data points were collected from intervals that may be influenced by surface water, the depths and screened intervals of the residential wells are not known, and the samples were collected from 7 to 13 years prior to the March 2017 sampling event. The tabulated groundwater analytical results, including historical results, are provided in Appendix Q.

As agreed with the USEPA and NC DEQ, the detected groundwater results were compared to the tapwater RSLs provided in the USEPA RSL summary tables dated June 2017 (USEPA, 2017a). The RSLs provided in the select summary table are derived using conservative default exposure assumptions, a target risk of 10^{-6}, and a HQ of 0.1.

4.4.1 Volatile Organic Compounds

A summary of the detected VOC results in groundwater samples collected in 2016 and March 2017 from permanent wells is provided in Table 4-8a. VOCs detected above tapwater RSLs include 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene, chloroform, ethylbenzene, xylenes, and naphthalene. Each of these constituents, except for chloroform, is associated with petroleum products.

Chloroform is a drinking water disinfectant and common laboratory and field contaminant. Chloroform was not detected above the residential RSL consistently over time in any of the monitoring wells. Because chloroform is not related to wood treating operations, and was detected sporadically, chloroform concentrations were not addressed in this Section but will be addressed in the HHRA Report.

Naphthalene was reported under both the VOC and SVOC analyte lists and thus is presented on both Table 4-8a and Table 4-8b. However, naphthalene was more consistently analyzed as a SVOC for all media and all sampling events. Therefore, naphthalene in groundwater will be evaluated in this RI Report as a SVOC and discussed in Section 4.4.2.

The extent of VOCs detected in the surficial groundwater in March 2017 is shown on Figure 4-4a. The contamination extends from MW-10S in the Process Area, southwest to well MW-18 located west of Navassa Road and southeast to well MW-11S located in the Untreated Wood Storage Area. Surficial groundwater in the Pond Area is impacted from well MW-25S southeast to well MW-08 and southwest to the Pond Area. These two areas of impacted groundwater combine in the Pond Area and extend south toward the southern marsh (wells MW-06 and MW-32). Groundwater data collected by the USEPA from residential irrigation wells located south of Sturgeon Creek did not find groundwater contamination on the south side of Sturgeon Creek.

As shown on Figure 4-4b, VOCs were detected at concentrations above tapwater RSLs in Peedee groundwater in four distinct locations including west of Navassa Road (MW-18D), the Operations Evaporation Pond (MW-27D), south of the Fire Protection Pond (MW-04D) and south of the Wastewater Ponds (MW-06D, and MW-32D). Although the lateral extent of VOCs

in Peedee groundwater is less than the lateral extent in Surficial groundwater; DNAPL was measured in wells MW-27D, MW-06D and MW-32D. Therefore, the vertical extent of impacts has not been fully characterized.

4.4.2 Semi-Volatile Organic Compounds

A summary of the detected SVOC results in groundwater samples collected in 2016 and March 2017 from permanent wells is provided in Table 4-8b. SVOCs detected above tapwater RSLs include PAHs, phenols, carbazole, and dibenzofuran. Additional SVOCs detected above tapwater RSLs include 4-nitroaniline, benzidine, bis(2-ethylhexyl)phthalate, and pyridine. Each of these constituents was detected only once above the RSL and was not detected consistently above the RSL in any monitoring well. These constituents are not related to creosote wood treating operations and were detected sporadically; therefore, these constituents will not be addressed further. As shown in Table 4-8b, the MDL for benzidine exceeds the tapwater RSL. The uncertainty associated with the elevated MDL is discussed in Section 6.4 and further addressed in the HHRA. Pentachlorophenol results are discussed in Section 4.4.3.

The extent of creosote-related SVOCs detected in surficial groundwater in March 2017 is shown on Figure 4-5a. The contamination extends from wells MW-30 located in the Process Area, southwest across Navassa Road to well MW-29, and south to well MW-11S located in the Untreated Wood Storage Area. Surficial groundwater in the Pond Area is impacted from well MW-12 east to well MW-24S and southwest toward MW-27S and the MW-14 well cluster. These two areas of impacted groundwater combine in the Pond Area and extend south toward the southern marsh (wells MW-06 and MW-32). Groundwater samples collect by USEPA from residential irrigation wells located south of Sturgeon Creek did not find groundwater contamination on the south side of Sturgeon Creek. Naphthalene was the only constituent detected in monitoring wells MW-20 and MW-29 which are located west of Navassa Road. While the extent of contamination to the west was not fully defined, the concentrations of naphthalene in these wells were relatively low. Continued monitoring will provide additional information regarding the extent of naphthalene to the west of Navassa Road.

Creosote-related SVOC concentrations ranged from 0.46 milligrams per liter (mg/L) in well MW-30 to 8,669.3 mg/L in well MW-06. Naphthalene was the only constituent detected above the tapwater RSLs in monitoring wells MW-19, MW-20, and MW-29 located west of Navassa Road, MW-07 and MW-28S located in the Pond Area, and MW-30 located in the Process Area. DNAPL was observed in monitoring wells MW-02, MW-05, MW-10S, MW-15 and MW-27S, located in the Process Area and the Pond Area.

As shown on Figure 4-5b, creosote-related SVOCs were detected in the Peedee groundwater in the Process Area (MW-09D and MW-30D), west of Navassa Road (MW-18D and MW-29D), and in the Pond Area from MW-04D extending north and east to monitoring wells MW-25D and MW-08D located near the Evaporation Ponds. Naphthalene was the only constituent detected above the tapwater RSL in monitoring wells MW-18D and MW-29D located west of Navassa Road, monitoring wells MW-09D and MW-30D located in the Process Area, and wells MW-04D, MW-08D, MW-16D, MW-26D and MW-28D located in the Pond Area. Although the lateral extent of creosote-related SVOCs in Peedee groundwater is less than the lateral extent in Surficial groundwater, DNAPL was measured in wells MW-27D, MW-06D and MW-32D. Therefore, the vertical extent of impacts has not been fully characterized. Deeper wells were not installed because boring log descriptions from nearby soil borings SB-E, SB-D, SB-D-01 and the boring log for monitoring well MW-06D do not indicate the presence of DNAPL or creosote odors below 88 feet bgs. In addition, based on geotechnical laboratory data, the soil becomes

progressively less permeable at depth as demonstrated in SB-D-01 where permeability at 130 feet is 6.5 x 10^{-7} and SB-E, where permeability is 8.1 x 10^{-7} at 100 feet bgs and 5.2 x 10^{-6} at 110 feet bgs. Based on field observations and soil permeability, the vertical extent of contamination in groundwater can be inferred.

4.4.3 Pentachlorophenol

Pentachlorophenol was detected in groundwater samples collected from three monitoring wells (MW-06, MW-11S, and MW-25S) in 2016 and/or March 2017. In February and June 2016, pentachlorophenol was analyzed as a pesticide using method SW8151A. In December 2016 and March 2017, pentachlorophenol was analyzed as an SVOC using method SW8270D due to the potential for interferences in the pesticide analysis from phenols. Table 4-8c provides the pentachlorophenol results by pesticide analysis and Table 4-8b provides the pentachlorophenol results by SVOC analysis. As shown in Table 4-8b, the MDL for pentachlorophenol exceeds the tapwater RSL. The uncertainty associated with the elevated MDL is discussed in Section 6.4 and further addressed in the HHRA.

Pentachlorophenol was detected in monitoring well MW-11S at a concentration of 0.24 micrograms per liter (µg/L) in December 2016 but was not confirmed in the sample collected in March 2017. Pentachlorophenol was detected in monitoring wells MW-06 and MW-25S by both the pesticide and SVOC methods. Concentrations in monitoring well MW-06 ranged from 1.15 µg/L to 2.1 µg/L and in monitoring well MW-25S from 0.191 µg/L to 3.3 µg/L. Both monitoring wells MW-06 and MW-25S contain measurable levels of DNAPL.

To evaluate the potential for pentachlorophenol detections related to interference from DNAPL, additional studies will be conducted. The results of these studies will be provided in a Technical Memorandum.

4.4.4 Metals

A summary of the detected metals results in groundwater samples collected in 2016 and 2017 from permanent wells is provided in Table 4-8d. A summary of background concentrations in groundwater is provided in Table 4-6. Metals detected above tapwater RSLs and background concentrations include aluminum, arsenic, chromium, cobalt, iron, manganese, selenium, and thallium. None of these metals are related to creosote wood treating operations. Detection of aluminum and iron may be related to naturally occurring concentrations. Each of the other detected metals are discussed below.

- Total chromium was detected above the background value in the sample from MW-07 collected in October 2006. Dissolved chromium was detected in the sample from MW-25S collected in February 2016 at a concentration above the background value. Both chromium detections are below the tapwater RSL for chromium (III); however, they are above the tapwater RSL for hexavalent chromium. Hexavalent chromium was not analyzed in the groundwater sample from MW-07. Hexavalent chromium was not detected in the groundwater samples analyzed (including MW-25S). However, the MDL was above the tapwater RSL.
- Cobalt was detected in monitoring wells MW-07 in October 2006 and MW-11S in February 2016 at concentrations exceeding both background and the tapwater RSL.
- Selenium was detected in monitoring well MW-25S in December 2016 at a concentration exceeding the tapwater RSL; however, the selenium concentration at this location in February 2016 was below the tapwater RSL.
- Thallium was detected in monitoring well MW-03 at a concentration exceeding the tapwater RSL and background value.

- Manganese was detected in each of the monitoring wells sampled at concentrations exceeding the tapwater RSL. Background values are not available for manganese. The detections may be related to naturally occurring concentrations of manganese.

Arsenic was detected in groundwater above the background value of 0.00225 mg/L at concentrations ranging from 0.0023 mg/L in monitoring wells MW-13D and MW-17 to 0.068 mg/L in monitoring well MW-06. As shown on Figure 4-6, arsenic concentrations above background are present in the surficial groundwater in the Process Area (MW-03) and the Untreated Wood Storage Area (MW-11S). Arsenic was detected in two distinct locations in the Pond Area, near the Evaporation Ponds and around the Wastewater Ponds. The arsenic detections generally correlate with monitoring wells installed in the Surficial groundwater in areas with high concentrations of PAHs and low oxidation-reduction potentials.

Because there is no record of CCA use at this Site, the presence of arsenic may be due to leaching of arsenic from naturally occurring arsenic in soil. Arsenic is a redox-sensitive element, which means that arsenic may gain or lose electrons in redox reactions. Arsenate and arsenite are the two forms of arsenic commonly found in groundwater. Arsenate generally predominates under oxidizing conditions and arsenite under reducing conditions. Reduction of arsenate to arsenite can promote arsenic mobility because arsenite is generally less strongly adsorbed to soil than arsenate (USGS, 1999).

4.4.5 Groundwater Summary

VOCs and creosote-related SVOCs are present in groundwater at concentrations greater than tapwater RSLs in the Process Area, the Pond Area and the area west of Navassa Road. The locations and concentrations of these constituents indicate that the primary sources of groundwater contamination were the creosote treating vessels, storage tanks and associated ponds that were in place during facility operations. The source of creosote-related SVOCs west of Navassa road is likely the creosote stringers detected in the subsurface along Navassa Road.

Arsenic concentrations above the tapwater RSL correlate with high concentrations of PAHs in the Surficial groundwater and low oxidation reduction potentials. Increased arsenic concentrations may be due to changes in groundwater chemistry due to the presence of DNAPL or high concentrations of dissolved phase creosote constituents.

4.5 MARSH SEDIMENT

The marsh sediment investigation included collection of 148 sediment samples as described in Section 2.4. A summary of background marsh sediment results is provided in Table 4-9. Detected sample results for marsh sediment samples are summarized in Tables 4-10a, 4-10b, and 4-10c. The tabulated marsh sediment analytical results are also provided in Appendix R.

As agreed with the USEPA and NC DEQ, the detected marsh sediment results were compared to the residential soil screening values provided in the USEPA RSL summary tables dated June 2017 (USEPA, 2017a) to evaluate direct contact with marsh sediment. The RSLs provided in the select summary table are derived using conservative default exposure assumptions, a TR of 10^{-6}, and a HQ of 0.1.

4.5.1 Volatile Organic Compounds

Several VOCs were detected in the marsh sediment samples including acetone, fuel-related compounds (toluene, ethylbenzene, xylenes, trimethylbenzene, butylbenzenes, propylbenzene, isopropylbenzene, and isopropyltoluene), carbon disulfide, chlorobenzene, methyl ethyl ketone and methyl acetate. The concentrations of the detected VOCs are below residential RSLs.

4.5.2 Semi-Volatile Organic Compounds

The SVOCs exceeding residential RSLs and background concentrations in the marsh sediments consist of creosote-related SVOCs; the most frequently detected were benzo(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene, fluoranthene, and pyrene. As shown on Figure 4-7, the highest concentration of creosote-related SVOCs is 34,170 mg/kg in sample SD12 collected from the disturbed area in the southern marsh. Results from sediment location VCHM01 indicate that concentrations in this area generally decrease with increasing depth. Dibenzofuran was the only constituent detected above residential RSLs in the deepest sample collected from VCHM01 at a depth of 4.5 to 5.5 feet bgs. The lateral extent of contamination ranges from west of Navassa Road (sample SD87) to southeast of the Pond Area (sample SD19) to approximately 500 feet south of the marsh edge (samples SD40 and SD48). USEPA sediment samples KM26 and KM35 located along the bank of Sturgeon Creek also contained concentrations of PAHs.

4.5.3 Inorganics

Background samples collected from the marsh were analyzed for arsenic, chromium, hexavalent chromium and thallium. Metals detected above the residential RSLs and/or background concentrations include aluminum, arsenic, hexavalent chromium, cobalt, iron, manganese, thallium, and vanadium.

Arsenic was detected in each of the sediment samples collected including the background samples. Arsenic concentrations in the samples from the marsh sediment were in the same range as the background samples and may be indicative of natural conditions in the marsh and/or anthropogenic conditions. Hexavalent chromium was detected once in marsh sediment sample SD106 at a concentration of 44.2 mg/kg, which is higher than concentrations of 7.06 mg/kg and 1.49 mg/kg detected in background marsh sediment samples. This concentration is also higher than the total chromium concentration of 29.7 mg/kg detected in sample SD-106 which makes the hexavalent chromium result suspect. Thallium was detected in four of the ten marsh sediment samples analyzed.

The metals detected in the marsh sediment are not associated with the creosote wood treating activities conducted at the Site. These metals may be naturally occurring, or their presence may be due to deposition from upstream sources.

4.6 SURFACE WATER

The RI surface water investigation included sampling at background locations SW-22 and SW101 collected upstream in Sturgeon Creek, three background locations (SW-107, SW-108, and SW-109) collected from the eastern marsh, 13 surface water samples from the southern marsh, sample RISW01 from standing water in the Boiler Pond and sample RISW04 from standing water in a drainage swale in the Process Area. The surface water sampling program is presented in Section 2.5. A summary of the detected constituents in surface water is provided in Table 4-11. The tabulated surface water analytical results are provided in Appendix S.

Surface water sample results were compared to the lower of the NC DEQ 15A NCAC 02B Water Supply or Human Health surface water quality standards (SWQS). Comparison to ecological criteria is provided in the BERA and discussed Section 7.0.

<u>Sturgeon Creek and Southern Marsh</u>

Five surface water samples (SW20, SW23, SW24, SW26 and SW28) were collected from the southern marsh or Sturgeon Creek and analyzed for SVOCs. SVOC results for these samples were non-detect. Five additional surface water samples (SW102, SW103, SW104, SW105, and SW106) were collected from the southern marsh or Sturgeon Creek and analyzed for total and

dissolved arsenic, chromium, trivalent chromium (chromium III) and thallium. Arsenic and chromium results were generally consistent with the results from background surface water locations. Concentrations of detected constituents are below the applicable SWQS. The surface water system in the tidal marsh is dynamic with substantial tidal fluctuations averaging 4 to 5 feet per tidal cycle. Based on these conditions and the surface water data collected to date from the tidal marsh and Sturgeon Creek, it appears that surface water quality in this area is not being influenced by discharge of groundwater or from the impacted sediments on the southern end of the property.

Boiler Pond

Sample RISW01 was collected from standing water in the southern Boiler Pond. Pesticides and PCBs were not detected in sample RISW01. Acetone, 2-methylnaphthalene, naphthalene, acenaphthene, and fluorene were the only VOC and SVOC detections in this sample. Several metals were also detected in the sample. The detected VOC, SVOC and metal results from RISW01 were below applicable SWQS. The surface water in the Boiler Pond footprint is not connected to other bodies of water and does not discharge to surface water off the Site. The amount of surface water in this area is solely dependent on rainfall.

Process Area

VOCs, pesticides and PCBs were not detected in surface water sample RISW04 collected from standing water in a drainage swale in the Process Area. Naphthalene was the only SVOC detected. The detected naphthalene and metal concentrations were below applicable SWQS. The surface water in the Process Area is not connected to other bodies of water and does not discharge to surface water off the Site. The amount of surface water in this area is solely dependent on rainfall.

4.7 AIR

A passive soil gas sampling program was conducted to assess potential contamination outside of the known sources in the Pond Area using naphthalene as an indicator of creosote. Forty-five passive soil gas samples were collected and analyzed for VOCs. The VOC results are provided in Table 2-10 and locations are shown on Figure 2-7. The passive soil gas report is provided in Appendix E.

Results of the passive soil gas survey indicate the presence of benzene, toluene, ethylbenzene, xylenes and/or naphthalene at five locations in the Pond Area including PSG-C4, PSG-D4, PSG-D5, PSG-D7, and PSG-E3. Passive soil gas samples PSG-C4, PSG-D4, PSG-D5 and PSG-E3 were collected near the Operations Evaporation Pond and sample PSG-D7 was collected southeast of the Operations Evaporation Pond. These areas correlate with detections of VOCs and SVOCs in the Surficial groundwater.

5.0 FATE AND TRANSPORT OF CONTAMINANTS

The media affected by creosote released from the wood treating processes at the KMCC Site include surface and subsurface soil, sediment in the southern marsh, and groundwater. The impacts are primarily in the southernmost portion of the property and include source areas associated with creosote storage, wood treating, and wastewater handling activities performed during the facility's operation. Impacts are also present in the Treated and Untreated Wood Storage Areas. This section presents the migration mechanisms and contaminant persistence for each affected media. Figure 5-1 is a simplified CSM showing the release and potential migration and exposure pathways.

Creosote is a combustible, yellowish, dark-green to brown or black liquid. It is made by fractional distillation of coal tar. The following table provides a summary of the physical properties of creosote.

Property	**Value**
Synonyms	Coal tar creosote, creosote oil, coal tar oil, creosote P1
CAS Nos.	8001-58-9; 90640-80-5 (anthracene oil); 61789-28-4
Molecular mass	Variable (complex mixture of hydrocarbons)
Boiling range	~200 to 400 degrees Celsius (°C)
Density	1.00 to 1.17 grams per cubic centimeter (g/cm^3) at 25 °C
Viscosity	4–14 millimeters squared per second (mm^2/s) at 40 °C
Flash point	Above 66 °C
Ignition temperature	500 °C
Octanol/water partition coefficient (log K_{ow})	1.0
Solubility in organic solvents	Miscible with many organic solvents
Solubility in water	Slightly soluble / immiscible

Source: ITC 1990.

There are six major classes of compounds in creosote: aromatic hydrocarbons, including PAHs and alkylated PAHs (which can constitute up to 90 percent of creosote); phenolics; nitrogen-containing heterocycles; aromatic amines; sulfur-containing heterocycles; and oxygen-containing heterocycles, including dibenzofurans. The physical and chemical properties of the individual components of creosote vary widely; some, for example, are highly soluble in water. Of the ten USEPA priority PAHs in creosote, the effective solubilities range from 0.00023 mg/L for benzo(a)pyrene to 16.4 mg/L for naphthalene.

5.1 CREOSOTE DNAPL FATE AND TRANSPORT

As described in Section 4.1, creosote was released during the wood treating process in the vicinity of several process units, and areas where creosote remains in soils are sources of ongoing contamination to groundwater. To some extent, process water and overland precipitation run-off containing dissolved-phase creosote constituents were also released from the Process Area.

Following a surface release, creosote migrates vertically through the unsaturated zone under forces of gravity and soil capillarity (USEPA, 1991a). Continued migration can then occur in one or all of four phases as described below:

1. Air phase – contaminants may be present as vapors;
2. Solid phase – contaminants may adsorb or partition onto the soil or aquifer material;
3. Water phase – contaminants may dissolve into the water according to their solubility; and,
4. Immiscible or Free phase – contaminants may be present as DNAPL.

Creosote in the free phase will continue to migrate downward vertically until migration is impeded by less permeable zones (e.g. a clay or silt layer), where it may spread horizontally. If the volume of DNAPL is sufficient, it will continue to migrate into the saturated zone until the volume is eventually exhausted by the residual saturation process or until it is intercepted by a low permeable formation where it begins to migrate laterally. The DNAPL will continue to migrate vertically and horizontally until it reaches a less permeable boundary. If the lower permeable boundary is "bowl shaped", the DNAPL will pond as a reservoir.

The biodegradability of creosote constituents is variable. Generally, the efficacy of aerobic degradation is greater than that of anaerobic degradation. Phenolic compounds are relatively easily degraded. Within PAHs, degradability appears to be inversely related to the number of aromatic rings. Some heteroaromatic compounds are quickly removed, whereas others are recalcitrant. Biotransformation of creosote components appears to dominate over mineralization. In some cases, the intermediates formed can be more persistent, mobile, or toxic than their parent compounds. Besides structural features of the chemicals, a number of other factors, such as bioavailability, microbial adaptation, oxygen supply, and nutrient availability, influence their degradation or transformation in situ.

DNAPL is present beneath several of the source areas on the Site, though it is not present as a large interconnected plume. Thin layers of DNAPL (stringers) have been encountered at numerous depths. As presented in Section 3.0, the property is underlain by intervals of fine sand, with intermittent zones of silty to clayey sands, and medium to fine sands. The finer grain intervals allow temporary water perching and slow vertical migration of DNAPL. Cemented sand layers were also encountered in areas. The thin layers of DNAPL observed correlate with the zones of higher permeability (medium to fine sands) also observed at the Site.

Substantial future migration of the DNAPL is not likely to occur as wood treating activities have not been conducted since 1974 and there is no longer a continuing source of creosote. The smaller zones of this material will continue to be a source of impact to groundwater and infiltrating rainwater as it migrates through DNAPL zones in the subsurface. Natural processes including tidal influence and the presence of naturally occurring organic carbon will help control the plume size and stability but are not expected to completely attenuate the DNAPL source zones or dissolved phase plume.

5.2 CREOSOTE CONSTITUENTS

Creosote is generated as part of the distillation process of coal tar. The byproduct of this process contains a variety of hydrocarbons with a complex structure and heavy molecular weight, including PAHs. The chemical constituents associated with creosote include SVOCs and, to a lesser extent, VOCs. Creosote contains approximately 85 percent PAHs by weight (ATSDR, 1995). Information available from the former facility processes suggests that inorganic wood preservatives (i.e., copper, chromium, or arsenic) and pentachlorophenol were not used.

VOCs are often present at creosote sites due to their presence in carrier oil, fuel for machinery and vehicles, and use for equipment maintenance. Petroleum products will sometimes be added to dilute or cut the creosote. VOCs were primarily detected in groundwater and were infrequently detected in soils and sediments. The aromatic VOCs most frequently detected above screening levels include benzene, ethylbenzene, trimethylbenzenes, and xylene. These VOCs are the most soluble of the creosote-related constituents and were most commonly detected in groundwater samples. Aromatic VOCs will naturally attenuate in the environment. Natural attenuation processes include biodegradation, dispersion, sorption, and volatilization. These processes cause a reduction in the total mass, toxicity, mobility, volume and/or concentration of a dissolved constituent.

SVOCs were frequently detected above applicable screening values in soil, sediment, and groundwater. The contaminants considered to be the primary indicators of creosote impact include 1,1 biphenyl, carbazole dibenzofuran, 2-methylnaphthalane, acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene. In general, PAHs are soluble in lipids and have low solubility in water. The physical and chemical properties of PAHs are governed by the size and shape of the individual molecule. The aqueous solubility and volatility decreases with increasing molecular weight. Except for naphthalene, PAHs have low water solubilities and low vapor pressures. Their octanol-water partition coefficients (K_{ow}) are relatively high, indicating a relatively high potential for adsorption to suspended particulates in the air, in water and in soil (NRCC, 1983; Slooff et al., 1989). PAHs that have higher molecular weights are relatively immobile due to their size, low volatility, and low solubility (Eisler, 2000).

Media were also sampled for pesticides, PCBs, and TAL inorganics. These constituents were infrequently detected. PCBs were not detected above MDLs in any samples collected from the Site. A limited number of the pesticides and metals were detected above screening values. Many of the metals were also present in background samples. Pesticides are not typically associated with creosote wood preserving processes and are not believed to be associated with the wood-preserving processes at the former facility.

5.3 SOIL

The RI data have verified that surface and subsurface soils and sediments in the source areas are primarily impacted by creosote-related SVOCs. The highest concentrations in surface soils were encountered in the Process Area and Pond Area. This is consistent with observations of stained surface soils observed in the eastern portion of the Process Area and the former drip track area. Elevated PAH values are also present near the Wastewater Ponds and extend northward to the Treated Wood Storage Area. The PAH extent in subsurface soils encompasses a smaller area than the surface soil impacts.

PAHs detected in soil can volatilize, undergo abiotic degradation (photolysis and oxidation), biodegrade or accumulate in plants. They can also enter groundwater and migrate within an aquifer (ATSDR, 1995). Evidence of leaching to groundwater is demonstrated by the presence

of PAHs in numerous monitoring wells screened beneath several source areas and the southern end of the Site.

The SVOCs and DNAPL in soil will be transformed over time by the mechanisms described in Section 5.1 but will persist for many years. SVOCs in unsaturated zone soils may continue to be a contamination source to infiltrating water. SVOCs in deeper subsurface soil close to or in the water table will continue to be a source of SVOCs to groundwater. VOC concentrations in subsurface soils are much lower than SVOC concentrations and are likely not a continuing source of contamination to groundwater.

5.4 GROUNDWATER

Another migration mechanism of importance is dissolution of creosote DNAPL compounds into groundwater and groundwater transport of dissolved-phase constituents. The groundwater transport is controlled by sorption and biodegradation as well as advection, diffusion, and dispersion.

A dissolved-phase plume is formed through the dissolution of contaminants from a DNAPL or residual soil source to groundwater. The effective aqueous solubility of compounds in a DNAPL mixture is equal to the pure compound's solubility limit times the mole fraction of that compound in the DNAPL mixture. As more soluble constituents are depleted, their mole fraction decreases, and equilibrium concentration decreases. Consequently, the relative mole fraction of less soluble constituents will increase over time, as will their effective aqueous solubility. If significant residual DNAPL remains in contact with groundwater along its flow path, the upgradient DNAPL will be depleted before the more downgradient locations. A higher groundwater flux or flow velocity will result in a higher rate of depletion.

The fate and transport of dissolved constituents are controlled by several mechanisms, which include the following:

- **Advection** – the transport of the constituent molecules with groundwater
- **Diffusion** – the migration of constituent molecules caused by differences in concentration gradients, i.e., chemicals diffuse from areas of high concentration to areas of low concentration
- **Dispersion** – the transport of constituent molecules resulting from the flow of groundwater through pathways between soil particles
- **Sorption** – the slowing or retardation of contaminant transport caused by the binding of organic molecules on soil particles and associated organic matter
- **Degradation** – the removal of constituent molecules through some combination of a biological transformation by naturally occurring organisms, hydrolysis, and/or chemical oxidation-reduction

A combination of advection, diffusion, and dispersion processes results in the formation of a dissolved-phase plume, with dissolved constituents migrating outward from the source area in the general direction of groundwater flow. The amount that the plume spreads laterally and vertically is primarily a function of advection combined with diffusion and dispersion.

Loss mechanisms, such as intrinsic biodegradation, affect the extent of the plume and the total plume mass. To date, there have been no data collected to specifically evaluate the potential biological transformation processes. Currently that mechanism is assumed to be minimal. For most creosote constituents, the rate at which the plume migrates is predominantly controlled by

sorption and retardation. Retardation results from the inherent chemical properties of various creosote constituents, which govern their tendency to bind to the soil particles and the naturally occurring organic material that is present within the subsurface soil matrix. Constituents such as benzene and naphthalene have lower retardation coefficients compared to other PAHs found in creosote, indicating that they tend to migrate more easily within the subsurface. However, these constituents are also more likely to biodegrade.

Groundwater flow velocities for the Surficial and Peedee Aquifers are 0.33 feet per day and 0.007 feet per day, respectively. Due to retardation, migration velocities of contaminants are less than the groundwater flow velocity and vary by constituent. The higher molecular weight constituents migrate at a slower rate than the constituents with a lower molecular weight which is demonstrated by the presence of naphthalene only at the plume boundaries.

The primary route of migration for the COPCs would be via groundwater, which generally flows to the south. Because a vertical hydraulic gradient between the Surficial Aquifer and the Peedee Aquifer was not identified, dissolved creosote constituents are not expected to migrate downward through advection. While groundwater flow is primarily to the south, naphthalene was observed west of Navassa Road. The presence of naphthalene west of Navassa Road may be from stringers of creosote and/or a potential southwesterly component to groundwater flow in the southwest portion of the property. Continued groundwater monitoring will provide additional information regarding the migration of naphthalene. As indicated in Section 4.0, surface and subsurface soils in the source areas are heavily impacted. Elevated concentrations of several dissolved COPCs have been encountered in the Process Area, Wastewater Ponds, and Evaporation Ponds. Evidence of DNAPL has been indicated by CPT/ROST™ and TarGOST® and visual observations have confirmed the presence of DNAPL beneath the Process Area and Pond Area. Migration of groundwater through these heavily impacted areas has caused dissolved constituents to move south along the direction of groundwater flow. Infiltration of rainfall will also likely contribute to groundwater impacts as it migrates through shallow impacted soils to groundwater. The tidal cycle also influences groundwater flux. These migration mechanisms will continue while these sources are present and in direct contact with groundwater.

Petroleum-related constituents (benzene, ethylbenzene and trimethylbenzenes) are the most frequently detected VOCs above residential RSLs in groundwater samples collected from the Site. The SVOCs most commonly detected in groundwater above residential RSLs include 2-methylnapthalene, naphthalene, fluorene and phenanthrene. The VOCs and lighter molecular weight PAHs are more soluble in water and are therefore more commonly detected in groundwater samples. Heavier molecular weight PAHs were also detected in samples from monitoring wells in the Process Area and Ponds Area which were installed through zones with thin layers (stringers) of DNAPL present. Elevated naphthalene concentrations in groundwater are beneath the source areas at the southern end and to the southwest of the property. Data from deeper monitoring wells installed in source areas also indicate naphthalene at elevated concentrations in the upper portion of the Peedee Formation.

Groundwater flow information for the Surficial Aquifer indicates that groundwater is flowing and likely discharging to the southern marsh. Based on the depth to the Peedee Aquifer and the lack of an upward hydraulic gradient, groundwater in the Peedee Aquifer does not appear to discharge to the marsh. The groundwater gradient and general dip of the Peedee Formation to the southwest, suggest that the Peedee Aquifer would discharge to the Cape Fear River. Analytical results for the pore water samples collected from within the marsh indicate impact by COPCs.

As described in this subsection, while DNAPL is in contact with groundwater and/or residual soil sources can leach to groundwater, they will continue to dissolve contaminants. A comparison of DNAPL and SVOC extent in the Surficial and Peedee groundwater is shown on Figures 5-2 and

5-3, respectively. Based on aqueous solubility, the profile of dissolved constituents in groundwater may change over time from more soluble to less soluble. Natural attenuation mechanisms may stabilize the plume, but the plume itself is expected to persist as long as there are contributing sources. A plume stability analysis will be conducted during the FS after four quarters of groundwater data have been collected to further evaluate the groundwater migration pathway.

5.5 SEDIMENT

Surficial sediments in the marsh south of the former facility have been affected by historical plant operations. Creosote-related constituents are present in shallow sediments in this area. Based on review of historical aerial photographs, the source of creosote in the marsh sediment is believed to be overland flow from the Wastewater Ponds to the marsh prior to installation of the Operations Evaporation Pond in the mid-1960s. The highest concentrations are at locations closest to the marsh edge southeast of the Wastewater Ponds.

Total PAH concentrations are lower in the subsurface samples across the marsh. Subsurface sediments have been impacted by the direct release of COPCs into the marsh by overland flow, and by the discharge of groundwater containing dissolved COPCs.

PAHs in sediments can adsorb, biodegrade, or accumulate in aquatic organisms. Sediment suspended in surface water, due to extreme weather or man-made disturbances, could result in transport and redistribution of COPCs to other areas of the marsh or downstream locations. The SVOCs in sediment will be transformed over time by the mechanisms described in the beginning of this subsection but will persist for many years.

5.6 SURFACE WATER

There are no interconnected surface water bodies on the property; therefore, surface water is not a continuous mechanism for transport of contaminants. Storm water run-off from impacted surface soils in the Treated Wood Storage Area could migrate to the west through the drainage swales, but this would only occur as a result of a substantial storm event (such as a hurricane or heavy rains that cause flooding) since the area is currently heavily vegetated.

As noted in Section 5.5, surficial and shallow subsurface sediments in the southern marsh are impacted with creosote COPCs. Surface water may be affected by dissolution from sediment and groundwater discharge but is diluted and washed out by the tide. The surface water data collected from the tidal marsh area to date has shown little evidence of the impacted sediments degrading surface water quality. Therefore, leaching from impacted sediments to surface water is not anticipated to be a significant migration pathway based on the data available at this time.

5.7 AIR

The Site has not been used for wood treating operations since the 1970s. As indicated in Section 1.3, production, treating, or product storage buildings and equipment have been removed and the Site is now heavily vegetated. Due to the age of the release and relatively low concentrations of VOCs in surface and shallow subsurface soil, volatilization of constituents located near land surface is not expected.

There is currently no completed vapor migration pathway for the Site. If vegetation is cleared or deep excavation occurs in the future, it is possible that dust may contribute to the spread of impacted material, or deeper more volatile COPCs could be exposed to ambient air. The potential for vapor intrusion in the future will be addressed in the HHRA and discussed in Section 6.0.

6.0 HUMAN HEALTH RISK ASSESSMENT (HHRA)

The purpose of the HHRA is to evaluate the potential chronic human health hazard and risks from contamination at the Site. The HHRA estimates incremental risk (i.e., the additional risk a receptor encounters due to exposure to Site contaminants) from exposure pathways. Due to the generic nature of the exposure assumptions, the estimates are not absolute, nor are they predictions of the actual occurrence of illness. They are conservative estimates that represent the high-end of potential exposure at the Site.

The HHRA was prepared in general accordance with USEPA guidance for conducting a risk assessment. For purposes of the HHRA, the property was divided into areas based on historical activities, and the risk levels for each area were determined separately. The areas evaluated included:

- Process Area
- Pond Area
- Treated Wood Storage Area
- Untreated Wood Storage Area
- Eastern Upland Area
- West of Navassa Road
- Southern Marsh
- Sturgeon Creek

Groundwater was evaluated across the property, though impacts to groundwater were observed in the southern portion of the property only.

The analytical data used in the HHRA include data collected during the ESI and RI activities; earlier data, which were not analyzed as per CERCLA protocol, were not incorporated. CERCLA-related investigative efforts were initiated in November 2004; therefore, data collected before this date were used to describe the Site history but were not included in the HHRA.

Based on discussions with the USEPA and NC DEQ, saturated soil samples were used in the characterization of the nature and extent of contamination but were not included in the risk calculations. Subsurface soil is considered the portion of the vadose zone deeper than 1-foot bgs and above the water table. Table 2-5 lists the soil samples that were collected from below the water table, and therefore, excluded from the HHRA. Historical data provided as "total PAHs" [including both low molecular weight (LMW) and high molecular weight (HMW)] were not used in the HHRA. These samples were collected for a proposed forensic analysis which was rejected by USEPA. Soil sample KM16 was initially included with samples from the area West of Navassa Road, but it was later removed from that data set when it was established that KM16 was actually collected from the east side of Navassa Road. Additionally, there were two sediment samples collected for Toxicity Characteristic Leaching Procedure analysis. These samples were collected to evaluate leaching potential, and therefore, were excluded from the HHRA.

6.1 IDENTIFICATION OF COPCs

The concentrations of VOCs, PAHs/SVOCs, and inorganics detected in soil, groundwater, surface water, and sediment at the property were screened to determine whether the levels

warrant further risk evaluation. For the purposes of the HHRA, references to "soil" include both surface and subsurface soil while references to "surface soil" include terrestrial sediment.

Detected constituents were screened based on toxicity. The screening criteria are as follows:

- Constituents in groundwater with maximum concentrations greater than the tapwater RSL, were included as COPCs.
- Constituents in soil or sediment with maximum concentrations greater than the residential RSL were included as COPCs.

The June 2017 USEPA residential RSLs (USEPA, 2017a) were used as appropriate screening values. It is important to note that the RSLs are conservative risk-based screening values developed by USEPA to assist in identifying COPCs. RSLs are not intended to be used as clean-up values. The risk-based RSLs for noncarcinogenic chemicals based on a target HQ of 0.1 were used to account for potential additivity of constituents with the same toxic endpoint. The risk-based RSLs for carcinogenic chemicals are based on a target risk level of 1×10^{-6} (1.0E-06), which is at the lower end of USEPA's target risk range of 1×10^{-6} (1.0E-06) to 1×10^{-4} (1.0E-04) (USEPA, 1991b).

Three additional screens were employed to determine Site COPCs. Chemicals (principally metals) that are essential nutrients were excluded from further evaluation. These constituents include calcium, chloride, magnesium, potassium and sodium. Analyses used to determine physical characteristics of soils, groundwater or surface water were also excluded from further evaluation. These include percent moisture, percent solids, pH, total solids, total dissolved solids, and hardness. Detected constituents were also compared to background values to evaluate whether their concentrations exceeded levels observed without influence from the Site. Where no RSL is available for a constituent, an appropriate surrogate chemical was identified based on structural or toxicological similarities. The HHRA Report provides a full description of the COPC screening procedures.

Exposure to surface water is not considered a complete exposure pathway; therefore, constituents in surface water from the Southern Marsh and Sturgeon Creek were not retained as COPCs. Because the surface water from the Boiler Ponds and drainage swales is ephemeral, no COPCs were selected from these samples. The constituents retained as COPCs for each area, which include inorganics, VOCs, and SVOCs (primarily PAHs), are summarized in Table 6-1.

6.2 EXPOSURE ASSESSMENT

The objective of the exposure assessment is to evaluate the nature and magnitude of potential chemical exposures that populations may receive from either direct or indirect contact with COPCs. The exposure assessment identifies potentially exposed populations, exposure media, and exposure pathways. The purpose of the exposure assessment is to develop upper-bound estimates of the theoretical intakes (or doses) of COPCs. Estimates of human intake are a function of exposure parameters, such as duration, frequency, and contact rates.

The exposure assessment is a critical element of the HHRA because it identifies which potential human exposure pathways and populations are potentially complete and included for further quantitative risk characterization, which pathways may be qualitatively evaluated, and which pathways are incomplete and not carried forward in the evaluation. The key elements of this effort included:

1. Developing the conceptual site exposure model (CSEM) that identifies receptor populations and possible future exposure pathways;
2. Calculating the magnitude of contaminant concentrations in the relevant impacted media at the Site; and
3. Identifying and developing relevant exposure factors for each significant subpopulation and pathway to quantitatively estimate risks for potentially complete exposure pathways.

The former KMCC property is currently zoned for commercial/industrial land use, with residential areas to the west and south of the Site. The property presently has no office buildings or similar structures that would house commercial workers for extended periods of time. The following receptors were evaluated in the HHRA: current/future adult and child resident; future industrial/commercial worker; future construction worker, and; current/future teenage trespasser. Current worker exposure is limited to field sampling teams conducting site investigation activities. Health and safety of these workers is provided through the OSHA HAZWOPER standard and exposures are controlled using appropriate personal protective equipment, hygiene, and other procedures specified in the Health and Safety Plan.

To be conservative, the HHRA assumes that a construction worker may conduct short-term digging or maintenance activities at the Site without following appropriate health and safety procedures. Construction worker exposures to Site-related chemicals during possible Site redevelopment activities are also considered in the HHRA. It is possible that new buildings will be constructed as part of redevelopment; therefore, a hypothetical "future industrial/commercial worker" was also evaluated in the HHRA.

Due to the multiple areas addressed in the HHRA, four CSEMs (Figures 6-1a through 6-1d) were created for the Site, each representing two of the areas (Process and Pond Area; Treated and Untreated Wood Storage Areas; Eastern Upland Area and West of Navassa Road; and the Southern Marsh and Sturgeon Creek, respectively). The CSEMs illustrate the sources/release mechanisms, modes of transport, primary and secondary impacted media, exposure routes, and potentially exposed receptors for the Site.

6.3 TOXICITY ASSESSMENT

The toxicity assessment identifies and qualifies the toxicity values that were used, in conjunction with the exposures described in the exposure assessment to evaluate potential human cancer risks and noncancer health effects in the risk characterization. The COPCs that have demonstrated evidence of carcinogenicity are referred to as carcinogens. Excessive exposure to COPCs can produce adverse noncancer health effects, while the potential for causing cancer is limited to carcinogens. Therefore, all COPCs were evaluated for potential noncarcinogenic

effects, while potential cancer effects were evaluated only for carcinogens. Carcinogens that are considered mutagenic were also evaluated for the child resident and teenage trespasser receptors.

PAHs are commonly associated with wood treating sites, and they have been observed at the Site at concentrations above residential RSLs. However, PAHs are also products of incomplete combustion of organic materials; sources are, thus, widespread, including cigarette smoke, municipal waste incineration, wood stove emissions, coal conversion, energy production form fossil fuels, and automobile and diesel exhaust. As PAHs are common environmental contaminants, USEPA has tried to produce a scientifically justified, consistent approach to the evaluation of human health risk from exposure to these compounds. However, for most PAHs classified as probable human carcinogens, data are insufficient for calculation of risk. Benzo(a)pyrene is the most thoroughly studied of the PAHs, and data are sufficient for calculation of quantitative estimates of its carcinogenic potency. Therefore, the toxicity factors for the other carcinogenic PAHs are expressed as ratios of benzo(a)pyrene's toxicity factors.

6.4 RISK CHARACTERIZATION

Risk characterization is the process in which the toxicity information is combined with quantitative estimates of human exposure derived in the exposure assessment. The result is a quantitative estimate of adverse health effects that humans may experience under the exposure assumptions made.

Carcinogenic risk and potential noncarcinogenic hazard are characterized for each potentially completed exposure pathway considered. Potential carcinogenic risk is evaluated by averaging exposure over a normal human lifetime, which, based on USEPA risk assessment guidance (USEPA, 1989), is assumed to be 70 years. Potential noncarcinogenic hazard is evaluated by averaging exposure over the total exposure period.

Potential carcinogenic risks are calculated for each receptor by summing across multiple chemicals and pathways. In addition to calculating carcinogenic risks for each age group, the child and adult age group carcinogenic risks are summed to estimate potential cumulative risks to one individual who is assumed to be exposed over the full residential exposure period (6 years as a young child and 20 years as an adult). Exposure duration for an industrial worker is assumed to be 25 years.

The potential for exposure to a chemical to result in adverse noncarcinogenic health effects is estimated for each receptor by comparing the chronic intake for each COPC with the toxicity value for that COPC. The HI is calculated for each exposure pathway by summing the HQs for each individual chemical. The total site HI is calculated for each potential receptor by summing the HIs for each pathway associated with that receptor.

Table 6-2 summarizes the carcinogenic and non-carcinogenic risks from each area for the child resident, adult resident, construction worker, industrial worker, and teenage trespasser, broken down by each exposure medium. For the future child resident, the cancer risk is the sum of non-mutagenic carcinogens and a weighted average of mutagenic risk for the 0-2 and 2-6 age

ranges. Mutagenic and non-mutagenic carcinogens are also summed to derive the carcinogenic risk for the teenage trespasser. Risks from soil gas and soil concentrations protective of groundwater are presented in the HHRA Report.

A summary of the HI for each receptor was compared to the USEPA's target HI of 1. Each COPC with an HQ in exceedance of 0.1 for a particular receptor was designated a COC. COPCs with an HQ below 0.1 were not identified as COCs. If the sum of HQs for a medium (i.e., the HI) for a receptor is less than 1.0, then the medium is not considered to be of concern for that receptor in that area. However, the medium may still be of concern if modeling of the transfer of contaminants across media (e.g., soil vapor impacts from groundwater or soil, leaching from soil to groundwater) indicate an HI exceedance of 1.0 as a result of the contaminant transfer. A discussion of total cancer risk greater than 1.0E-06 and a HI greater than 1 per applicable receptor per area is presented below.

Process Area

- The cancer risk from surface soil for the future child resident is 4.2E-04, which includes non-mutagenic carcinogens, and a weighted average incorporating mutagenic effects for the 0-2 and 2-6 age ranges; and the HI is 2.9. Ingestion of benzo(a)pyrene the biggest risk driver. For subsurface soil, the HI is 400 mainly due to VI risks from naphthalene.

- The cancer risk from surface soil for the future adult resident is 2.3E-05. Most of the risk is from ingestion of benzo(a)pyrene and phenanthrene, and inhalation of naphthalene. From subsurface soil, the HI is 400, due primarily to VI risks from naphthalene and to a lesser extent, 2-methylnapthalene.

- The cancer risk from surface soil for the future construction worker is 2.7E-06 principally from ingestion of benzo(a)pyrene and phenanthrene. The cancer risk from subsurface soil is 6.1E-06 and the HI is 15, due primarily to ingestion of dibenzo(a,h)anthracene, dibenzofuran, indeno(1,2,3-cd)pyrene, and 2-methylnapthalene, and inhalation risks from 1,1-biphenyl and naphthalene.

- The cancer risk from surface soil for the future industrial worker is 2.2E-05 principally from ingestion of benzo(a)pyrene, as well as arsenic, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and dibenzo(a,h)anthracene and, via inhalation, hexavalent chromium. From subsurface soil the HI is 290, due primarily to inhalation via VI of 2-methylnapthalene and naphthalene.

- The cancer risk from surface soil for the current and future teenage trespasser in the Process Area is 1.4E-05, which incorporates mutagenic effects of the carcinogenic COCs with ingestion of benzo(a)pyrene the biggest risk driver.

Pond Area

- The cancer risk from surface soil for the future child resident is 8.2E-04, which includes non-mutagenic carcinogens, and a weighted average incorporating mutagenic effects for

the 0-2 and 2-6 age ranges. The HI is 25. PAHs present the most risk with benzo(a)pyrene being the biggest risk driver. For subsurface soil, the HI is 400 mainly due to VI risks from naphthalene.

- The cancer risk from surface soil for the future adult resident is 5.4E-05 and the HI is 8.9. Most of the risk is from ingestion of benzo(a)pyrene and inhalation of naphthalene and 1,1-biphenyl. From subsurface soil the HI is 400 due primarily to VI risks from naphthalene and to a lesser extent, 2-methylnapthalene.

- The cancer risk from surface soil for the future construction worker is 6.3E-06 with a HI of 6.3, principally from ingestion of arsenic, benzo(a)pyrene and dibenzofuran. The cancer risk from subsurface soil is 7.7E-06 and the HI is 10, due primarily to ingestion of benzo(a)anthracene, benzo(a)pyrene, dibenzofuran, and phenanthrene, and inhalation risks from 1,1-biphenyl and naphthalene.

- The cancer risk from surface soil for the future industrial worker is 4.8E-05 with a HI of 3.4, principally from ingestion of benzo(a)pyrene, arsenic, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and dibenzo(a,h)anthracene; and via inhalation, hexavalent chromium. The HI from subsurface soil is 290, due primarily to inhalation via VI of 2-methylnapthalene and naphthalene.

- The cancer risk from surface soil for the current and future teenage trespasser in the Pond Area is 2.9E-05, which incorporates mutagenic effects of the carcinogenic COCs with ingestion of arsenic, benzo(a)anthracene, and benzo(a)pyrene the biggest risk drivers.

Treated Wood Storage Area

- The cancer risk from surface soil for the future child resident is 3.8E-05, which includes non-mutagenic carcinogens, and a weighted average incorporating mutagenic effects for the 0-2 and 2-6 age ranges. PAHs, principally benzo(a)pyrene, present the majority of the risk.

- The cancer risk from surface soil for the future adult resident is 2.8E-06. The risk is mainly from ingestion of benzo(a)pyrene.

- The cancer risk from surface soil for the future industrial worker is 2.5E-06, principally from ingestion of arsenic and benzo(a)pyrene and inhalation of aluminum.

- The cancer risk from surface soil for the current and future teenage trespasser is 1.4E-06, which incorporates mutagenic effects of the carcinogenic COCs. Ingestion of arsenic and benzo(a)pyrene present the biggest risk.

Untreated Wood Storage Area

- The cancer risk from surface soil for the future child resident is 2.8E-05, which includes non-mutagenic carcinogens, and a weighted average incorporating mutagenic effects for the 0-2 and 2-6 age ranges. Arsenic and benzo(a)pyrene are the biggest risk drivers.
- The cancer risk from surface soil for the future adult resident is 3.3E-06 primarily due to ingestion of benzo(a)pyrene and arsenic.
- The cancer risk from surface soil for the future industrial worker is 6.1E-06 principally from ingestion of arsenic and benzo(a)pyrene, and inhalation of hexavalent chromium.
- The cancer risk from surface soil for the current and future teenage trespasser is 1.0E-06, which incorporates mutagenic effects of the carcinogenic COCs. Ingestion of arsenic and benzo(a)pyrene present the biggest risk.

Eastern Upland Area

- The cancer risk from surface soil for the future child resident is 1.3E-05, which includes non-mutagenic carcinogens, and a weighted average incorporating mutagenic effects for the 0-2 and 2-6 age ranges. Arsenic and benzo(a)pyrene present the greatest risk.
- The cancer risk from surface soil for the future adult resident is 3.0E-06. The risk is mainly from ingestion of arsenic.
- The cancer risk from surface soil for the future industrial worker is 4.4E-06, mainly from ingestion of arsenic and inhalation of hexavalent chromium.

Southern Marsh

- The cancer risk from sediment for the future child resident is 6.8E-04, which includes non-mutagenic carcinogens, and a weighted average incorporating mutagenic effects for the 0-2 and 2-6 age ranges. The HI is 8.5. Metals and PAHs are the principal COCs with arsenic, benzo(a)pyrene and benzo(a)anthracene presenting the most risk.
- The cancer risk from sediment for the future adult resident is 3.4E-05. The risk is mainly from ingestion of arsenic, cobalt, benzo(a)pyrene and benzo(a)anthracene.
- The cancer risk from Southern Marsh sediment for the current and future teenage trespasser is 2.3E-05, which incorporates mutagenic effects of the carcinogenic COCs. Ingestion of benzo(a)pyrene presents the biggest risk.

Groundwater

- The cancer risk from groundwater as potable water for a future child resident is 1.1E-03, which includes non-mutagenic carcinogens, and a weighted average incorporating mutagenic effects for the 0-2 and 2-6 age ranges. The HI is 47. COCs include metals, VOCs, SVOCs, PAHs, and pentachlorophenol with the majority of risk presented by

ingestion of arsenic, dibenzo(a,h)anthracene, 1-methylnaphthalene, and pentachlorophenol. Inhalation via VI and ingestion are the principal exposure routes.

- The cancer risk from groundwater as potable water for a future adult resident is 9.6E-04 and the HI is 35. COCs include metals, VOCs, SVOCs, PAHs, and pentachlorophenol with the majority of risk presented by ingestion of arsenic, dibenzo(a,h)anthracene, 1-methylnaphthalene and pentachlorophenol. Inhalation via VI and ingestion are the principal exposure routes.

- The cancer risk from groundwater for a future construction worker is 1.0E-05 and the HI is 5.4. COCs include metals, VOCs, SVOCs, PAHs, and pentachlorophenol with the majority of risk presented by ingestion of arsenic and chloroform and by dermal contact with bis(2-ethylhexyl)phthalate.

- The cancer risk from groundwater for a future industrial worker is 6.0E-04 and the HI is 16. COCs include metals, VOCs, SVOCs, PAHs, and pentachlorophenol with the majority of risk presented by ingestion of chloroform and naphthalene and by inhalation of naphthalene via VI.

Table 6-3 summarizes the COCs for each area and medium while Table 6-4 presents a summary of risk by area for each medium, COC and receptor.

Uncertainty

The purpose of the uncertainty analysis is to put the calculated risks in proper context. The risks presented in HHRAs are conditional estimates, based on numerous assumptions about exposure and toxicity given a particular land use scenario.

Uncertainty in the HHRA process begins with the site characterization. It is assumed that the Site has been thoroughly and accurately characterized. However, the following gaps in Site characterization are known:

- No soil gas data could be effectively collected at the Site due to shallow depths to groundwater.

- The vertical extent of DNAPL and dissolved phase groundwater contamination has not been fully delineated in the Pond Area.

Uncertainties are inherent in the calculations and assumptions used to estimate risk. To compensate for these unavoidable uncertainties, the HHRA was developed using purposefully conservative (i.e., health protective) methods and assumptions. Consequently, it overestimates exposures, resulting in risk estimates likely to be much higher than actual risks. A discussion of the key uncertainties used in estimation of risk for the HHRA is presented below.

Elevated detection limits were a source of uncertainty for the HHRA. Many soil and groundwater samples from the Process and Pond Areas contained elevated levels of

contaminants, primarily PAHs. As a result, many of the SVOC sample results had elevated detection limits due to dilution, often above the screening criteria used for the constituent (typically residential RSLs) (i.e., pentachlorophenol in Process Area soils; 3.3'-dichlorobenzidine in Pond Area soils; and aniline, benzaldehyde, benzidine, methylene chloride and o-chlorotoluene in groundwater). In cases where the detection limit for a constituent exceeded its RSL and was otherwise not detected, the constituent was not retained for further evaluation in the risk assessment as per USEPA's recommendation.

Another source of uncertainty was the gap between screening criteria and achievable detection limits. For some constituents, the RSL is at such a low level that it can't be achieved by standard USEPA analytical methods. An example is naphthalene with a tapwater RSL of 0.17 µg/L, which is used to screen groundwater samples. The detection limits for naphthalene in groundwater were typically two to three times higher than the tapwater RSL. Many groundwater samples contained detectable levels of naphthalene, particularly those collected from the former Process Area and Pond Area, and naphthalene screened in for most media in many locations.

Other than the two issues described above, the analytical data were generally of good quality with acceptable accuracy and precision. Little blank contamination was encountered. Holding times were generally met. Matrix spike/matrix spike duplicate recoveries were generally within acceptable limits.

Surrogates were used for multiple constituents for which toxicological data were not available; four of these constituents screened in the HHRA. Each of the constituents was a PAH or SVOC:

- Acenaphthylene
- Benzo(g,h,i)perylene
- Carbazole
- Phenanthrene

Pyrene was the surrogate used for each of these constituents.

Other sources of uncertainty included minimal sample size for statistical analyses, frequency of detection and the limitations on the existing VI models associated with high heterogeneity of VOC concentrations in small-aliquot VOC soil samples, inhomogeneities in bulk soil samples, shallow groundwater and the presence of DNAPL. A complete description of the uncertainties associated with the risk assessment is provided in the HHRA Report.

6.5 HHRA RISK SUMMARY

Seven Site areas with complete pathways were evaluated in the HHRA, including the Process Area, Pond Area, Treated Wood Storage Area, Untreated Wood Storage Area, Eastern Upland Area, the residential area West of Navassa Road, and the Southern Marsh. Additionally, groundwater was evaluated across the Site. Each of the areas has been assessed under both an industrial/commercial scenario and a residential use basis. Potentially exposed populations include future industrial/commercial workers, future construction workers, future on-Site adult and child residents, adult and child residents off-Site and the on-Site teenage trespasser. As

illustrated in the CSEMs provided as Figures 6-1a through 6-1d, potentially complete exposure pathways include surface soil and soil gas (from soil and groundwater). Direct exposure to groundwater is not currently a potentially complete pathway for any receptors; however, future adult and child residents, and a future construction worker could potentially be exposed to groundwater, and therefore, risks were calculated for those future scenarios. Additionally, direct contact with subsurface soil is anticipated to be a potentially complete pathway only for the future construction worker.

Each of the areas evaluated are impacted primarily with PAHs, but elevated levels of VOCs, SVOCs, metals, and to a lesser extent, pesticides, were observed in some locations. As anticipated, impacts are concentrated in the Process Area and Pond Area. Impacts are lighter in the Treated and Untreated Wood Storage Areas and are limited to surface soil in the Eastern Upland Area.

Groundwater in the former operational areas (Pond Area and Process Area) has been impacted, as has groundwater downgradient from those areas. Elevated PAH levels were observed in marsh sediments; however, only low concentrations were found in sediment from Sturgeon Creek.

Carcinogenic risk levels calculated for the Process and Pond Areas and sediment in the marsh exceed the upper end of the acceptable risk range of 1.0E-04 for the future resident child and are between the lower and upper ends of the risk target range (1.0E-06 to 1.0E-04) for the other potential receptors. The Untreated Wood Storage Area, Treated Wood Storage Area, and Eastern Upland Area, risk levels exceed the lower end of the risk target range of 1.0E-06 but are less than 1.0E-04 for the potential receptors except the future construction worker for whom risks are less than 1.0E-06. Most of the risk is from surface soil impacts, but subsurface soil in the Process and Pond Areas is also significantly impacted. The distribution of non-carcinogenic risks is similar to that of carcinogenic risks. The risk from groundwater in the southern portion of the property exceeds the upper end of the risk range (1.0E-04) for the potential receptors except the future construction worker for whom risks are 1.0E-05.

Based on the results of the HHRA, the overall risk is unacceptable for the reasonably anticipated future land uses. All areas examined require additional evaluation in the FS, except for Sturgeon Creek and the area West of Navassa Road. No constituent exceeded its residential RSL for soil in the area West of Navassa Road. Risks associated with Sturgeon Creek were insignificant due to lack of a complete exposure pathway for surface water, and calculated risks from sediment impacts were one to two orders of magnitude below the 1.0E-06 level and the HQ was 0.0. Therefore, additional evaluation of Sturgeon Creek is not required.

7.0 BASELINE ECOLOGICAL RISK ASSESSMENT (BERA)

This section presents a summary of the BERA for the marsh at the Site conducted in accordance with the SRI Work Plan Addendum No. 3 (EarthCon, 2016). Per the October 6, 2016 meeting between the Beneficiaries and the Multistate Trust, evaluation of upland terrestrial areas was not included in the BERA due to uncertainty regarding future land use. The need to address upland terrestrial receptors may be reevaluated, as necessary, once remedial actions are complete. The BERA is provided as a separate report (Ramboll, 2018). This section provides a summary of the BERA results and discusses key findings. The BERA provides a systematic evaluation of ecological exposures to chemicals and the results inform risk management decisions protective of the environment. This BERA is consistent with national and regional USEPA guidance for conducting ecological risk assessments, as described in the BERA Report.

The efforts to date, including collaborative agreement with USEPA Region 4 on data gaps, data collection methods, and the BERA approach, correspond to multiple steps and scientific management decision points within the USEPA 8-Step Process for Conducting ERAs (USEPA, 1997). Specifically, this BERA section of the RI provides a summary of:

- The BERA goals and focus using elements of the problem formulation
- The data obtained as part of the implementation of the BERA investigation and expresses data analysis in terms of ecological exposure and effects assessments
- A risk characterization of the Southern Marsh (also referred to as the "marsh" or "Marsh Study Area", approximately 35 acres)

7.1 PROBLEM FORMULATION

The BERA Report presents a detailed problem formulation for the Marsh Study Area. The most relevant elements of the problem formulation are discussed in this section.

7.1.1 Ecological Receptors and Exposure Pathways

The problem formulation identifies the ecological receptors and exposure pathways as part of the development of an ecological risk CSM. An ecological risk CSM is discussed in the BERA Report and described in Figure 7-1 with a food web model shown on Figure 7-2. The following ecological receptors are relevant for the BERA:

- Benthic invertebrate community
- Fish populations
- Bird and mammal populations

The most important exposure pathways for the Marsh Study Area and those considered in the BERA are:

- Direct contact with sediment/pore water for sediment dwelling organisms
- Ingestion of chemicals via the food web

- Incidental ingestion of contaminated sediment and dietary prey that have accumulated chemicals

7.1.2 Selection of Assessment Endpoints

Assessment endpoints are the explicit expression of ecological entities (e.g., mammal populations) and attributes (e.g., reproductive ability) to be protected. The selection of assessment endpoints depends on knowledge about the receiving environment, chemicals released, and the values that will drive risk management decision making. Assessment endpoints selected for evaluation in the BERA are summarized on Table 7-1 and include:

- Benthic community structure and integrity
- Survival, reproduction, and growth of fish populations
- Survival, reproduction, and growth of bird and mammal populations

7.1.3 Selection of Measurement Endpoints

Measurement endpoints are measurable ecological characteristics that are related to the assessment endpoints. Measurement endpoints are identified on Table 7-1 and described below for each ecological receptor as identified in Section 7.1.1.

Sediment dwelling invertebrate community:

- A sediment quality triad approach is used to evaluate potential risks to sediment dwelling organisms. This is comprised of toxicity testing, the evaluation of sediment chemistry, and consideration of the actual organisms living in the marsh (i.e., the biology). A brief description of each is described here:
    - Toxicity: sediment toxicity testing (i.e., bioassays) was measured in laboratory toxicity tests using whole sediment tests (i.e., whole sediment from the marsh were tested to see if they were toxic to sediment dwelling organisms) and dilution series tests (i.e., sediments from the marsh were diluted with clean sediment to understand if there is some "PAH dose" that is toxic to marsh sediment dwelling organism verses as "PAH dose" that is not toxic to sediment dwelling organisms;
    - Chemistry: measured sediment PAH concentrations were compared to protective ecological benchmarks for sediment dwelling organisms; and
    - Biology: the actual organisms in the marsh were measured for abundance, richness (diversity), and composition of sediment dwelling organism community, relative to reference stations of comparable habitat ("community structure").

Fish populations:

Sediment pore water PAH concentrations were compared to PAH TRVs that are considered protective of larval fish stages. Larval fish stage is considered the most sensitive fish stage for exposure and toxicity.

Bird and mammal populations:

Comparison of modelled dietary intake of PAHs compared to TRVs. Herbivorous, invertivorous, piscivorous, and omnivorous avian species are represented by mallard duck, spotted sandpiper,

green heron, and osprey, respectively. Omnivorous and piscivorous mammals are represented by the raccoon and river otter, respectively.

7.2 EXPOSURE ASSESSMENT

The exposure assessment describes the exposures likely to occur in the endpoints evaluated, exposure routes specific to the marsh, and the selected measurement endpoints. A screening of COPCs provided in the BERA Report indicates that PAHs, carbazole and dibenzofuran should be retained for further assessment. Due to limited information on toxicity of carbazole and dibenzofuran, these two chemicals are discussed qualitatively in the uncertainty section of the BERA Report, and PAHs were the focus of the quantitative exposure assessment in the BERA. The BERA Report includes a detailed description of which data was used for each exposure endpoint. The methods of estimating exposure for each assessment endpoint differ, as detailed in the following sections.

7.2.1 Exposure Assessment for Sediment Dwelling Invertebrate Community

Exposure for sediment dwelling invertebrates is evaluated based on the sediment quality triad approach which incorporates toxicity testing, sediment chemistry, and benthic community assessments, also known as lines of evidence (LOEs). The BERA Report contains a detailed summary of the methods used to estimate exposure for each LOE (i.e., each measurement endpoint) used to evaluate potential risks to the benthic community structure and integrity.

7.2.1.1 Sediment Toxicity Testing

Sediment toxicity testing, conducted as part of the BERA investigation, is described in detail in the BERA Report and summarized below. Two types of testing were conducted using a sensitive laboratory organism (amphipod, *Hyalella azteca*) that conservatively reflects the types of organisms that may be present in the marsh (discussed further in Section 7.4):

- Whole sediment tests: Samples collected throughout the Marsh Study Area and background samples were used in the whole sediment toxicity study as is and were considered as undiluted sediments. This reflects the potential for toxicity associated with typical marsh conditions both in areas with residual PAHs and background areas.
- Dilution series tests: Additional sediment was collected from location SD-M1 and SD-M2 and used in the dilution series toxicity study in efforts to establish an understanding of the dose-response relationship for PAHs. Sediment from these locations were diluted to 6.25%, 12.5%, 25%, and 50% site sediment using background sediment. The M1 and M2 locations were targeted for the dilution series test in view of the PAH concentrations reported in previous investigations.

7.2.1.2 Sediment Chemistry Exposure Assessment

Exposure was also evaluated based on consideration of PAH concentrations in sediment and pore water using bulk chemical analysis and solid phase microextraction (SPME). The SPME method measures freely dissolved PAHs in small volumes of pore water and provides an indicator of the bioavailability of PAHs in sediment. The BERA Report provides the data from the sediment and pore water analyzed, and a detailed description of how these data were used to calculate site-specific organic carbon-water partition coefficient (Koc) values for use in

USEPA's equilibrium partitioning (EqP) approach for estimating potential exposures (USEPA, 2003). The sediment and pore water chemistry results are discussed in Section 7.4.

7.2.1.3 Benthic Community Assessment

A benthic invertebrate survey was conducted in the Marsh Study Area and in background areas, as detailed in the BERA Report. Data from the benthic community assessment is presented in the BERA Report and discussed in Section 7.4.

7.2.2 Exposure Assessment for Fish Populations and Community

Fish populations and community are evaluated based on two measurement endpoints:

- Sediment chemical data with toxic units (TUs) and HQs; and
- Sediment pore water and consideration of PAH TRVs compared to water quality criteria.

The BERA Report contains a detailed summary of the methods used to assess this exposure to the fish population at the Marsh Study Area for each measurement endpoint.

7.2.3 Exposure Assessment for Bird and Mammal Populations

Exposures for birds and mammals are estimated from PAH concentrations in sediment and modeled into food web exposures specific for each wildlife receptor. Estimated doses in the diet for birds and mammals are compared to USEPA Region 4 approved TRVs.

The exposure assessment portion of the food web model involves estimation of the total daily intake (TDI) calculations for the wildlife measurement endpoints via diet and incidental ingestion of sediment while foraging or preening/grooming. PAHs in sediment were considered on a high HMW and LMW basis. The estimated exposure dose concentrations for sediment were based on the 95% UCLs. Descriptions of the exposure estimates, dietary uptake factors, bioaccumulation factors and TDI estimates used in the food web model are provided in the BERA Report, including USEPA Region 4 identified preferred exposure parameters that were used in the food web model.

7.3 EFFECTS ASSESSMENT

The methods used to characterize potential toxic effects (if any) for each receptor group, as well as the outcomes of those analyses, are described below.

7.3.1 Benthic Invertebrate Effects Assessment

The lines of evidence for the benthic community are sediment toxicity testing, sediment/pore water chemistry, and benthic community assessment.

7.3.1.1 Sediment Toxicity Testing

The effects metric for the "toxicity testing" is a statistical comparison of toxicity tests from the marsh sediments versus the laboratory control sediments and background areas. The results of the statistical testing and the significance of these results are discussed in Section 7.4.

Dilution testing was one LOE used to evaluate potential site-specific effects levels for benthic organisms through the evaluation of dose-response relationships over a range of sediment concentrations. Dilution series testing provides insight into dose-response relationships for benthic organisms as described in the BERA Report. The implications of these site-specific effects levels are discussed in Section 7.4.

7.3.1.2 Sediment/Pore Water Chemistry and Physical Analysis

In December 2016, co-located sediment and pore water samples were collected from locations SD-M1 through SD-M7. The pore water samples were analyzed for PAHs using SPME and the sediment samples were analyzed for the full suite of 34 PAHs as described in the BERA Report. PAH TUs are calculated using dry weight concentrations of individual PAHs in sediment, site-specific organic carbon concentrations, and an adjustment factor to account for the toxicological contribution of unmeasured PAHs. A TU value of 1 may be considered indicative of threshold for toxicity, but very often, the TU may be higher than 1 before toxic responses are observed (Nakles and Reible, 2010). The BERA Report provides a more detailed discussion on TUs along with a compilation of data from Nakles and Reible that demonstrate TUs between 5 and 50 may also reflect conditions that do not pose toxic effects to sediment dwelling organisms. This is important with regard to the interpretation of site-specific TUs greater than 1 in the Marsh Study Area as the PAHs appear to have limited bioavailability and decreased toxicity.

The BERA data for the marsh collected in December 2016 were considered directly because the samples included the full suite of 34 PAHs as well as the biological measurements (i.e., toxicity studies, benthic community assessment studies). The larger marsh sediment dataset was also used to calculate TUs with extrapolation from 17 to 34 PAHs as described in the BERA Report. The calculated PAH TUs are provided in the BERA Report and discussed in Section 7.4.

7.3.1.3 Benthic Community Assessment

Assessments of the structure of benthic macroinvertebrate communities provides direct evidence of the effects of sediment contaminants on naturally occurring communities. The metrics used to characterize the benthic community were abundance, taxa richness, community density, a diversity index, dominant taxon, and a North Carolina biotic index.

Each metric provides a component of the overall understanding of benthic community condition. The implications of these results are discussed further in Section 7.4.

7.3.2 Effects Assessment for Fish Populations

PAH HQ and summed TUs are used to estimate potential risks to fish populations. Fish are evaluated considering sediment pore water data for the marsh collected by SPME. Sediment pore water is a very conservative dataset for use in understanding potential exposures for ELS fish because fish are not directly exposed to pore water and considerable dilution occurs as pore water mixes with overlying surface water. As part of the overall evaluation of fish, pore water concentrations for PAHs were compared to literature based TRVs. TRVs for ELS fish were obtained from both the literature and the USEPA's ECOTOX database (USEPA, 2017b).

7.3.3 Effects Assessment for Bird and Mammal Populations

The effects assessment for wildlife is based on TRVs that relate ingested daily dose to ecotoxicological endpoints. TRVs for wildlife are literature-derived doses, below which adverse effects are unlikely (e.g., Sample et al., 1996). No observed adverse effect level (NOAEL) TRVs are indicative of doses of constituents that have had no deleterious effects on a wildlife receptor. Lowest observed adverse effect level (LOAEL) TRVs are the minimum doses of constituents where adverse effects are apparent. Realistically, the dose level at which an individual ecological receptor may experience deleterious effects occurs between the NOAEL and LOAELs. USEPA Region 4 identified conservative protective avian and mammal TRVs for use in the food web model. For this BERA, those TRVs are used, and a detailed discussion of these TRVs is provided in the BERA Report.

The BERA also identifies additional TRVs that are considered conservative and protective for use in the food web model so as to provide a range of TRVs for informative purposes (referred to as Alternative #1 and Alternative #2). These additional TRVs are discussed in the uncertainty section of the BERA Report.

7.4 RISK CHARACTERIZATION

Risk characterization involves the integration of the exposure assessment and effects assessment to evaluate the likelihood, severity, and spatial distribution of predicted or observed effects, as described in the BERA Report. This section provides the following:

- Risk Characterization for the Benthic Invertebrate Communities
- Risk Characterization for the Fish Populations
- Risk Characterization for the Avian and Mammalian Wildlife
- Uncertainty Evaluation

7.4.1 Risk Characterization for Benthic Invertebrate Communities

7.4.1.1 Sediment Toxicity Testing

Sediment toxicity testing using the amphipod *H. azteca* was conducted as part of the BERA investigation. Toxicity testing results are summarized based on the two measured endpoints of survival and weight. Figures 7-3 and 7-4 provide a summary of some of the toxicity testing information provided in the BERA Report. The following observations apply for the whole sediment tests:

- Survival (Figure 7-3): No statistically significant adverse impacts to survival were observed for the amphipods. There are no statistically significant differences between the laboratory control, background locations, or Marsh Study Area locations.
- Weight (Figure 7-3): Six of the seven locations showed no statistically significant reductions in growth for the amphipods. Location SD-M2 showed significantly lower growth than other Marsh Study Area and background samples.

The dilution series results for SD-M2 (approximately 4,000 mg Σ17 PAH/kg) showing survival and growth endpoints are provided on Figure 7-4. A similar dilution series toxicity test was

conducted for location SD-M1, but results are not shown because there were no impacts to survival or growth at any concentration tested (maximum 242 mg Σ17 PAH/kg for SD-M1). The following observations and conclusions can be drawn for location SD-M2:

- Figure 7-4 shows a hypothetical dose-response relationship (upper left image). As can be seen by the SD-M2 results, there is no dose-response relationship for survival or growth even in the maximum concentration tested (approximately 4,000 mg ∑17 PAH/kg).
- Growth is a more sensitive endpoint and SD-M2 results indicate statistically significant suppressed growth compared to the marsh background and dilutions for SD-M2 sediments at ambient concentration and at the 50 percent dilution. The results indicate that the ambient concentration and the dilutions are comparable to laboratory controls.

The sediment toxicity testing results are considered further in the weight-of-evidence evaluation with other lines of evidence for the benthic community.

7.4.1.2 Sediment and Pore Water Chemistry

The risk characterization for PAHs employs USEPA's EqP approach, as defined in previous sections of this report. Results are discussed in terms of TUs where TUs less than the value of 1 reflect conditions below toxicity thresholds. The toxicity testing from the Marsh Study Area indicates that the threshold for toxicity in the marsh may be greater than one. A dose-response relationship was not observed for survival or growth in SD-M2 where the TU is 40

PAH TUs are provided on Figure 7-5a. The majority of TUs for the marsh are less than a TU of 1 which reflects protective threshold for no adverse effects from PAHs. The dilution series testing provides information to support a site-specific threshold of 40, above which, impacts are likely to occur. The following observations and conclusions are noted:

- A PAH TU of approximately 40 results in limited suppression of the growth of sediment dwelling organisms but no significant reduction in the survival of sediment dwelling organisms. This was seen at location SD-M2 where co-located sediment toxicity tests were conducted.
- All other elevated TUs shown on Figure 7-5a reflect historical sediment sample results, some as much as 10 years old.
- Figure 7-5b shows the area of the marsh with PAHs TUs exceeding 40. Outside of the area shown in Figure 7-5b, no adverse effects are predicted by the EqP approach considering the site-specific TU threshold of 40 demonstrated by toxicity tests.

7.4.1.3 Benthic Community Analysis

The benthic community assessment reflects a field study of the organisms living in the marsh. The results are discussed in detail in the BERA Report, with example metrics provided on Figure 7-6. The benthic community assessment results demonstrate that sediments even in areas with elevated PAH residues support a sediment dwelling organism community at comparable diversity and abundance as that seen in the background areas. Figure 7-6 provides examples of the benthic community assessment metrics discussed further in the BERA Report.

7.4.1.4 Risk Characterization Summary Benthic Invertebrate Communities

Sediment toxicity testing, sediment and pore water chemistry, and benthic invertebrate community assessment, are three LOEs considered in the assessment of risks for sediment dwelling invertebrates. The findings from each LOE are discussed independently in the preceding sections. A weight of evidence evaluation is provided in the BERA Report. In summary, the following conclusions can be drawn:

- The benthic community in the marsh is similar to the background conditions, and at some locations exceeds background conditions with regard to taxa richness, community density and abundance indicating that better conditions were exhibited in the marsh when compared to background. Even within the area identified on Figure 7-5b (Location SD-M2), benthic community assessment results are similar to background areas.
- The dilution series data indicated there may be an effect on organism growth as data collected from SD-M2 suggests reduced growth compared to lower concentrations and background areas. The benthic community assessment did not assess growth via biomass, but the abundance of organisms shown in the benthic community assessment indicated location SD-M2 had more organisms and greater taxa richness than the background areas.
- As a conservative measure, locations with sediment toxic units above 40 (which is equivalent to approximately 4,000 mg $\sum$17 PAHs/kg) are considered to have adverse effects on individual organisms.
- Based on the EqP results, adverse impacts to some benthic organisms cannot be ruled out in a focused area of the marsh. The remainder of the marsh does not have PAH concentrations that are expected to harm the sediment dwelling organisms. There are eight samples at seven locations with TUs greater than 40. Except for location SD29, the locations with TUs greater than 40 (values ranging from 42 to 260) are concentrated in one area of the marsh in an area that is approximately one acre in size (Figure 7-5b). SD29 is located approximately 200 feet west of SD10, the westernmost location of this cluster. Although SD29 has a TU of 92, two other samples taken at the same location (SD08 and its duplicate) have TUs of 7.7 and 13. In addition, adjacent locations have TUs ranging from less than 1 to 8.7, making SD29 uncertain in toxicity and potentially related to the heterogeneous nature of the sediments of the marsh where sampling occurred. Based on this TU result for SD29, the potential for risks to benthic organisms cannot be definitively ruled out based on the EqP approach alone. Therefore, as shown on Figure 7-5b, SD29 is identified as an additional area of uncertainty. If one contiguous area of the marsh is considered that includes the area identified on Figure 7-5b and SD29, that area of interest would be approximately 3 acres of the marsh.

7.4.2 Risk Characterization for the Fish Populations and Community

The comparison of pore water data to larval fish TRVs is very protective because PAH concentrations in surface water where fish are found are much lower than that in the sediment pore water. Based on the most conservative TRVs, which are predominantly reflecting "no effects," there were some HQs for individual PAHs that exceeded a threshold value of 1, with a maximum HQ of 20 for fluoranthene at location SD-M2. When HQs for the individual PAHs were summed to provide a TU for the locations, all TUs were below 1 except for locations SD-M2, SD-M1, SD-M5, and SD-M4, which had TUs ranging from 3 to 79. When more realistic TRVs are considered, HQs were less than 1 for all individual PAHs except for location SD-M2 which had a maximum HQ of 10 for C3-naphthalenes; however, the TU sum was still greater

than 1 for locations SD-M2 (TU of 55 and 58), SD-M1 (TU of 4), SD-M5 (TU of 2), and SD-M4 (TU of 2). The TUs do not account for dilution effect between pore water and surface water. Using only sediment pore water for understanding fish larvae exposure is a very conservative approach because fish are not directly exposed to pore water and considerable dilution occurs as pore water mixes with overlying surface water. In addition, this approach does not account for variable exposures for larval fish that disperse when the tide rises and falls. During low tide, larval fish are not present in the marsh. Based on the above information, PAHs do not pose unacceptable risks for fish populations, including the sensitive stage larval fish because the PAH HQs and TUs are low and fish are not directly exposed to sediment pore water.

7.4.3 Risk Characterization for Bird and Mammal Populations

The characterization of risks for wildlife involves food web modeling for PAHs using sediment chemistry and measured invertebrate and tissue chemistry, with a comparison to protective TRVs as described in Section 7.3. The ratio of ingested PAHs relative to the chemical-specific TRVs is provided as an HQ for the risk characterization. HQ values greater than a value of 1 warrant further consideration. HQs provide a basis for understanding potential effects to individual birds and mammals. Understanding potential effects to populations requires some consideration of the spatial scale of effects and an understanding of how birds and mammals use the environment. Table 7-2 provides a summary of HQs for each of the wildlife species for the marsh and background areas. A detailed summary of food web calculations is provided in the BERA Report.

A summary of the BERA results is provided below, with more detailed information provided in Table 7-2 based on LOAEL TRVs. NOAEL HQs are presented and are discussed in the BERA Report. The BERA Report (Table 6-3) indicates that there are some NOAEL HQs that exceed a value of 1. The LOAEL TRVs are summarized here and in Table 7-2 because the LOAEL reflects the concentration above which low impacts to individual birds and mammals are considered more likely to occur.

Based on the USEPA Region 4 LOAEL TRVs:

- PAHs in the marsh do not pose unacceptable risks for the osprey or river otter because LOAEL HQs are less than the threshold value of 1.
- LOAEL HQs exceed a value of 1 using USEPA Region 4 LOAEL TRVs for the mallard duck, spotted sandpiper, green heron and raccoon. The HQs are higher when it is assumed that these species live and feed only from the Marsh Study Area. LOAEL HQs are lower, but still exceed the threshold value of 1 using the USEPA Region 4 LOAEL TRVs when species-specific area use factors are considered. Based on these LOAEL HQs, potential risks cannot be definitively ruled out for individual mallard duck, spotted sandpiper, green heron, or raccoons based on the USEPA Region 4 TRVs. For this reason, additional protective TRVs were also considered in the uncertainty section and the BERA Report.

The potential for unacceptable risks to individual birds and mammals cannot be definitively ruled out based on food web model HQs alone considering the USEPA Region 4 TRVs and the conservative assumptions. Therefore, the basis of the HQs must be considered and discussed. The following observations can be made:

- The highest HQs are seen in Table 7-2 when it is assumed birds and mammals spend the entirety of their lives inhabiting, foraging, and living only in the Marsh Study Area. HQs are lower when home ranges typical of the bird or mammal are considered.
- The highest HQs are seen for the spotted sandpiper (80). Individual sandpipers have small home ranges, so consideration of home ranges does not change the HQ for the sandpipers.
- The mallard duck HQs range from less than 6 to 20, depending on the amount of sediment ingestion assumed and home range is excluded. When home range is considered, HQs range from less than 1 to 2.
- The green heron and raccoon HQs range from 2 to 5 in the conservative and more realistic scenarios.
- Direct sediment ingestion is the greatest contributor of exposure and risk from the food web model for each of these receptors: mallard (2 to 11%), green heron (2%), sandpiper (18%), and raccoon (9%). The direct ingestion of sediment comprises more than 90% of the HQs for each of these birds and the raccoon. The 95% UCL sediment concentrations are greatly influenced by the small number of highest concentration samples.
- Based on HQs derived using the USEPA identified TRVs, potential impacts to individual birds and mammals cannot be ruled out for those that feed in the area of the marsh influenced by the highest PAH concentrations. Because these HQs exceed a value of 1, additional TRVs are considered in the uncertainty assessment of this RI section and in the BERA Report, as agreed upon with USEPA. Figure 7-7 identifies the area of the marsh with the highest concentrations of PAHs that influence the 95% UCL.

Given the small area of elevated PAHs relative to the wide area of the marsh, population-level impacts to birds and mammals due to the direct ingestion of residual PAHs in the marsh is highly unlikely even when the USEPA TRVs are used. This concept of individual versus population level impacts is described in detail in the BERA Report. In addition, the basis of the TRVs are discussed in more detail in the BERA Report.

7.4.4 Uncertainties

The goal of the risk assessment process is to provide meaningful information to risk managers to inform risk-management decisions. The ERA process has inherent uncertainty and efforts to reduce and manage uncertainty were made for this BERA for the Marsh Study Area. This section describes some of the uncertainties and their potential influence on the overestimate or underestimate of risk, to the extent that the influence is known. Uncertainty can be introduced into a BERA at every step in the process, as information of varying quality is gathered from diverse sources to be integrated into a complex framework. The analytical data collection effort for this BERA was designed to reduce uncertainties related to chemical bioaccumulation and bioavailability. The BERA Report provides a detailed summary of the uncertainties associated with the BERA and their potential influence on the overestimate or underestimate of risk (if known). Key uncertainties discussed in the BERA Report include:

- Uncertainty associated with aquatic invertebrate assessment, such as:
  - Insufficient information about the applicability of sediment toxicity tests to the actual conditions at the Marsh Study Area which may include tolerance and adaption of the

local organisms as well as limited tolerance of the test organisms for Site sediments due to grain size and organic carbon.

- Uncertainty associated with the wildlife assessment, including:
  - The USEPA identified TRVs for this BERA that are discussed in the BERA Report. Additional protective TRVs also can be considered that provide additional information to inform risk managers. The alternative TRVs are also discussed in the BERA Report. Table 7-3 in this RI summarizes the LOAEL HQs calculated using the alternative TRVs. These show that LOAEL HQs are less than 1 for each of the mammals and birds.
  - Hazard quotients that indicate that risks are greater than "no effect" concentrations but less than "low effect" concentrations.
  - Use of standardized receptor parameters that may not be reflective of the actual body weights, intakes, or dietary preferences of organisms at the Site.
  - Area use and exposure duration factors that may not reflect actual organism use of the Site, particularly given human disturbances at the Site.
- Additional sources of uncertainty are:
  - Appropriateness of background locations.
  - Variability between sampling intervals with respect to instrumentation and analytical methods, including some detection limits that are greater than the benchmarks.
  - Uncertainty about the effects of multiple stressors on the receptors.
  - The links between effects on individual organisms and populations or communities of those organisms are unknown.
  - Overestimation of central tendency risks by treating non-detect concentrations as a detect at one-half the detection limit.

7.5 POTENTIAL GROUNDWATER UPWELLING

The 2016 marsh investigation included collection of conductivity and temperature data using 24-hour probes to evaluate potential groundwater upwelling in three areas of the marsh (CTD1, CTD2, CTD3). The goal was to determine the magnitude of changes in marsh surface water temperature and conductivity to inform future investigations. Of the three probes deployed, one was not submerged at low tide, one maintained consistent readings and one (CTD1) showed possible fluctuations with the tidal cycle. Probe CTD1 recorded a variation of temperature of 5-degrees Celsius and a variation in conductivity. This result will be used to inform any future sampling of surface or pore water in the marsh. This result can also inform future investigation of groundwater discharge into the marsh or groundwater seeps.

7.6 BERA RISK SUMMARY

A screening of COPCs was conducted in the BERA and based on this screening, it was determined that a focus on PAHs for the RI is warranted. The BERA Report provides a discussion of carbazole and dibenzofuran as it relates to the understanding of PAHs in the marsh.

The BERA focused on multiple lines of evidence to evaluate potential risks to ecological receptors that inhabit the marsh. The lines of evidence and the weight of evidence evaluation provided in the BERA Report support the following conclusions for the Marsh Study Area for each assessment endpoint:

- Benthic community structure and integrity
  - Laboratory sediment toxicity testing on sensitive laboratory organisms selected to reflect those likely to be present in the marsh showed that in areas with elevated PAH residues (approximately 4,000 $\sum$17 PAH/mg), amphipod survival is comparable to the background areas. This means site-specific conditions are limiting PAHs bioavailable and toxicity as it relates to the survival of sediment dwelling organisms.
  - Sediment toxicity testing showed that amphipod growth was impacted at the highest concentration tested (approximately 4,000 $\sum$17 PAH/mg), as this testing showed statistically significant differences in area SD-M2 compared to background marsh locations. Amphipod growth in the other locations tested was similar to the background marsh areas.
  - Data from the SPME and bulk sediment analyses were used to evaluate site-specific bioavailability using the USEPA EqP approach. The EqP approach shows that the majority of PAH TUs are less than 1. A site-specific PAH TU threshold of approximately 40 can be used to identify areas where suppression of the growth of sediment dwelling organisms may be seen.
  - Field study of the Marsh Study Area demonstrates that sediments across a range of PAH concentrations in the marsh support a sediment dwelling organism community at comparable diversity and abundance as that seen in the background areas.
  - The BERA Report included a weight of evidence evaluation considering each of the lines of evidence collectively. The conclusion for the BERA is that overall, the PAH residues in the majority of the Marsh Study Area do not pose unacceptable risks for sediment dwelling organisms; however, potentially unacceptable risks cannot be definitively ruled out for all sediment dwelling organisms in the areas of the marsh with the highest PAH concentrations (Figure 7-7). This area may be approximately one to 3 acres, depending on whether location SD-29 is considered in isolation or as a contiguous area with other elevated PAHs.
- Survival and reproduction of fish populations
  - The evaluation of SPME pore water data in comparison to protective TRVs for larval fish survival and growth showed that PAHs in the area of highest concentrations have TUs exceeding the threshold value of 1. Fish larvae are considered the most sensitive among the fish stages. The comparison of pore water data to larval fish TRVs is very protective because PAH concentrations in water would be much lower than that in the sediment pore water. Given the low PAHs and considering that fish are not directly exposed to sediment pore water, the BERA can conclude that the residual PAHs do not adversely affect fish populations.
- Survival and reproduction of bird and mammal populations
  - The BERA included a food web model for four bird species and two mammals that reflect the types of birds and mammals that can be expected in the marsh. HQs were less than the threshold value of 1 for osprey and the river otter, indicating that PAHs do not pose unacceptable risks for these receptors.
  - Both conservative and more realistic exposure assumptions were considered. TRVs identified by USEPA were used as part of the main BERA discussion and alternative

TRVs were used in the uncertainty assessment, as agreed upon with USEPA. The BERA food web model results show the greatest potential risk for individual spotted sandpipers. BERA food web model also showed much lower potential risks for mallard ducks, green heron, and raccoon. The risk estimates are elevated for those individual birds or mammals that feed exclusively from the marsh sediments and incidentally ingest a large amount of sediment from areas with the highest concentrations of residual PAHs (Figure 7-7). USEPA's 1999 Ecological Risk Assessment and Management Principles (Number 1) state that Superfund's goal is to reduce ecological risks to levels that will result in the recovery and maintenance of healthy populations and communities of biota. The BERA Report explains how distinctions between individual organisms and populations can be made when population studies are not directly available. The BERA for the Marsh Study Area concludes that it is likely that the Marsh Study Area as a whole supports conditions that do not adversely impact populations and communities of birds and mammals; however, impacts to individual organisms cannot be definitely ruled out.

8.0 SUMMARY AND CONCLUSIONS

This section summarizes the results of the site characterization. Recommendations for potential future activities are also provided.

8.1 SUMMARY

The following subsections summarize the nature and extent of contamination at the property, the fate and transport of site-related constituents, and the human health and ecological risk assessments.

8.1.1 Nature and Extent of Contamination

Limited available historical records indicate that creosote was the only wood treating chemical used at this Site. Releases of wood treating chemicals have resulted in the presence of DNAPL, creosote constituents and fuel-related constituents in surface and terrestrial sediment, subsurface soil, groundwater, and marsh sediment.

The SVOCs considered to be the primary indicators of creosote include PAHs, phenols, and 3 compounds closely associated with the PAHs (1,1-biphenyl, carbazole and dibenzofuran). For purposes of this RI Report, the SVOCs most commonly detected at concentrations greater than residential RSLs will be referred to as "creosote-related SVOCs" and will include the following constituents:

- 1,1-Biphenyl
- Carbazole
- Dibenzofuran
- 1-Methylnaphthalene
- 2-Methylnaphthalene
- Acenaphthene
- Acenaphthylene
- Anthracene
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(g,h,i)perylene
- Benzo(k)fluoranthene
- Chrysene
- Dibenz(a,h)anthracene
- Fluoranthene
- Fluorene
- Indeno(1,2,3-cd)pyrene
- Naphthalene
- Phenanthrene
- Pyrene

VOCs are often present at creosote wood treating sites due to their presence in carrier oil, fuel for machinery and vehicles, and their associated use in equipment maintenance. Petroleum products are sometimes added to dilute or "cut" the creosote. The VOCs most commonly associated with the Site include:

- Benzene
- Ethylbenzene
- Total xylenes
- 1,2,4-Trimethylbenzene
- 1,3,5-Trimethylbenzene

<u>DNAPL</u>

DNAPL is present in thin layers or "stringers" in subsurface soils in the Process Area, downgradient of the Wastewater Ponds and beneath the Evaporation Ponds. None of the data indicate a large, continuous plume of DNAPL. DNAPL stringers were identified in the Process

Area at depths from the ground surface to 25 feet bgs. DNAPL stringers were also observed near the Wastewater Ponds at depths ranging from the ground surface to 100 feet extending to the Southern Marsh. DNAPL was also present beneath the Boiler Ponds, the Operations Evaporation Pond, the Decommissioning Evaporation Pond and the marsh sediments.

Surface Soil and Terrestrial Sediment

Creosote-related constituents were detected above residential RSLs throughout the Process Area, Treated Wood Storage Area, Untreated Wood Storage Area, and Pond Area as shown on Figure 4-2a. SVOCs were detected in the Eastern Upland Area primarily in drainage swales. Arsenic was also detected in 26 of the 83 surface soil samples throughout the property. The arsenic concentrations that exceed background values were detected sporadically throughout the areas used for wood treating and the Eastern Upland Area as shown on Figure 4-2b. Because there is no record of CCA (an alternative wood preservative) use at this Site, the presence of arsenic may be related to historical agricultural uses on the property.

Subsurface Soil

Fuel-related VOCs were detected in subsurface soil samples in the Pond and Process Areas. Creosote-related SVOCs were detected in subsurface soils in the Treated and Untreated Wood Storage Areas, the Process Area, and the Pond Area. SVOCs were not detected above residential RSLs in subsurface soil from the Eastern Upland Area. Concentrations of SVOCs in subsurface soil from the Treated Wood Storage Area were less than the concentrations in the surface soil indicating surface releases of creosote consistent with the use of this area. The occurrence of SVOCs above residential RSLs in the subsurface soil in the Untreated Wood Storage Area was limited to two samples. Subsurface soil data combined with DNAPL observations indicate that soil in the Process Area is impacted from the ground surface to 25 feet bgs. Subsurface soil data and DNAPL observations in the Pond area indicate impacts from ground surface to 100 feet at the Wastewater Pond extending to the Southern Marsh.

Groundwater

VOCs are present in groundwater in the Surficial Aquifer extending from the Process Area southwest across Navassa Road, and from the Evaporation Ponds extending southwest to the marsh. Groundwater in the Peedee Aquifer is impacted west of Navassa Road, near the Operations Evaporation Pond, south of the Fire Protection Pond and south of the Wastewater Ponds. The sources of groundwater contamination include DNAPL and creosote impacted soil. Based on the similarity of the groundwater plume and DNAPL configuration (Figure 5-2), the primary source appears to be DNAPL.

SVOCs are present in groundwater in the Surficial Aquifer from the Process Area southwest across Navassa Road and from the Evaporation Ponds extending south to the marsh. SVOCs are present in the Peedee Aquifer in the Process Area, west of Navassa Road and in the Pond Area. Results of groundwater samples collected by USEPA from residential irrigation wells located south of Sturgeon Creek do not indicate the presence of groundwater contamination south of Sturgeon Creek. Naphthalene was the only constituent detected in monitoring wells

MW-20 and MW-29 which are located west of Navassa Road. While the extent of contamination to the west was not fully defined, the concentrations of naphthalene in these wells were relatively low. Continued monitoring will provide additional information regarding the extent of naphthalene west of Navassa Road.

The lateral extent of VOCs and SVOCs in Peedee groundwater is less than the lateral extent in Surficial groundwater. However, DNAPL was measured in three deep monitoring wells (MW-06D, MW-27D and MW-32D). Deeper wells were not installed because boring log descriptions from nearby soil borings SB-E, SB-D, SB-D01 and the boring log for monitoring well MW-06D do not indicate the presence of DNAPL or creosote odors below 88 feet bgs. In addition, based on geotechnical laboratory data, the soil becomes progressively less permeable at depth as demonstrated in SB-D-1 where permeability at 130 feet is 6.5×10^{-7} and SB-E, where permeability is 8.1×10^{-7} at 100 feet bgs and 5.2×10^{-6} at 110 feet bgs. Based on field observations and soil permeability, the vertical extent of contamination in groundwater can be inferred.

Arsenic concentrations above residential RSLs generally correlate with high concentrations of PAHs in Surficial groundwater and low oxidation reduction potentials. Because there is no record of CCA (an alternative wood preservative) use at this Site, the presence of arsenic may be due to changes in groundwater chemistry due to the presence of DNAPL or high concentrations of dissolved phase creosote constituents.

Marsh Sediment

SVOCs were detected in marsh sediments at concentrations exceeding residential RSLs, Ecological Screening Levels and/or background concentrations. The constituents detected consist primarily of creosote-related compounds including PAHs, carbazole and dibenzofuran. The most frequently detected PAHs were benzo(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene, fluoranthene, and pyrene. The highest concentrations of total SVOCs were observed in the disturbed area in the southern marsh. The SVOC concentrations in this area generally decrease with increasing depth. The lateral extent of contamination ranges from west of Navassa Road to southeast of the Pond Area to approximately 500 feet south of the marsh edge.

Arsenic was detected in each of the sediment samples collected including the background samples. Arsenic concentrations in the samples from the marsh sediment were in the same range as the background samples and may be indicative of natural conditions in the marsh and/or anthropogenic conditions.

8.1.2 Fate and Transport

Creosote was released during the wood treating process near several process units including the drip tracks, the treatment vessels, and the product tanks located in the Process Area as well as the Wastewater Ponds and Evaporation Ponds. To some extent, process water and overland precipitation run-off containing dissolved-phase creosote constituents were also released from the Process Area. Creosote in the free phase will continue to migrate downward

vertically until migration is impeded by less permeable zones (e.g. a clay or silt layer), where it may spread horizontally. If the volume of DNAPL is sufficient, it will continue to migrate into the saturated zone until the volume is eventually exhausted by the residual saturation process or until it is intercepted by a low permeable formation where it begins to migrate laterally. The DNAPL will continue to migrate vertically and horizontally until it reaches a less permeable boundary.

DNAPL is present beneath several of the source areas at the property, though it is not present as a large interconnected plume. Thin layers of DNAPL (stringers) have been encountered at numerous depths. As presented in Section 3.0, the property is underlain by intervals of fine sand, with intermittent zones of silty to clayey sands, and medium to fine sands. The finer grain intervals allow temporary water perching and slow vertical migration of DNAPL. Cemented sand layers were also encountered in areas. Lithology that has larger pore space material with interbedded layers of finer material correlates to the thin layers of DNAPL present at varying depths, which have been characterized to date.

Substantial future migration of the DNAPL is not likely to occur as wood treating activities have not been conducted since 1974 and there is no longer a continuing source of creosote. Natural processes including tidal influence and the presence of naturally occurring organic carbon will help control the plume size and stability but are not expected to completely attenuate the DNAPL source zones or dissolved phase plume.

Soil

The RI data have verified that surface and subsurface soils and sediments in the source areas are primarily impacted by creosote-related SVOCs and to a lesser extent VOCs. The highest concentrations in surface and subsurface soils were encountered in the Process Area and Pond Area. The SVOCs and DNAPL in soil in the Process Area and the Pond Area will be transformed over time by the mechanisms described in Section 5.3 but will persist for many years. SVOCs and VOCs in unsaturated zone soils and in deeper subsurface soil close to or in the water table will continue to be a contamination source to infiltrating water, and eventually groundwater.

Concentrations of several SVOCs in subsurface soil from the Treated and Untreated Wood Storage Areas exceed the conservative default risk-based SSLs Protective of Groundwater as described in the HHRA Report. However, because concentrations of SVOCs decrease from the surface to the subsurface soils in these areas and groundwater concentrations are below tapwater RSLs, the residual SVOCs in soil in these areas are not anticipated to be a continuing source to groundwater. Concentrations of SVOCs in surface soil in the Eastern Upland Area only slightly exceed default SSLs Protective of Groundwater and do not appear to be a continuing source to groundwater based on the groundwater results from the area.

Groundwater

Another migration mechanism of importance is dissolution of creosote DNAPL compounds into groundwater and groundwater transport of dissolved-phase constituents. The primary route of

migration for the COPCs would be via groundwater which generally flows to the south. As indicated in Section 4.0, surface and subsurface soils in the source areas are heavily impacted. Elevated concentrations of several dissolved COPCs have been encountered in the Process Area, Wastewater Ponds, and Evaporation Ponds. Evidence of DNAPL has been observed beneath the Process Area and Pond Area. Migration of groundwater through these heavily impacted areas has caused dissolved constituents to move south along the direction of groundwater flow. Infiltration of rainfall will also contribute to groundwater impacts as it migrates through shallow impacted soils to groundwater. These migration mechanisms will continue while these sources are present and in direct contact with groundwater.

The VOCs and lighter molecular weight PAHs are more soluble in water and are therefore more commonly detected in groundwater samples. Heavier molecular weight PAHs were also detected in samples from monitoring wells in the Process Area and Ponds Area which were installed through zones with thin layers (stringers) of DNAPL present. Elevated naphthalene concentrations in groundwater are beneath the source areas at the southern end and southwest of the property. Data from deeper monitoring wells installed in source areas also indicate naphthalene at concentrations above tapwater RSLs in the upper portion of the Peedee Formation.

Groundwater flow information for the Surficial Aquifer indicates that groundwater is flowing and discharging to surface water in the southern marsh; however, the tidal cycle impacts the groundwater flow. During high tides, water level elevations rise in monitoring wells near the marsh edge impeding the flow of groundwater into the marsh. Based on the depth to the Peedee Aquifer and the lack of an upward hydraulic gradient, groundwater in the Peedee Aquifer does not appear to discharge to the marsh. Analytical results for the pore water samples collected from within the marsh indicate impact by COPCs.

As long as DNAPL is in contact with groundwater and/or residual soil sources can leach to groundwater, they will continue to dissolve contaminants. Based on aqueous solubility, the profile of dissolved constituents in groundwater may change over time from more soluble to less soluble. Natural attenuation mechanisms may stabilize the plume, but the plume itself is expected to persist as long as there are contributing sources.

Marsh Sediment

Surficial sediments in the marsh south of the former facility have been affected by historical plant operations. Creosote-related constituents are present in shallow sediments in this area. Based on review of historical aerial photographs, the source of creosote in the marsh sediment is believed to be overland flow from the Wastewater Ponds to the marsh prior to installation of the Operations Evaporation Pond in the mid-1960s. The highest concentrations are at locations closest to the marsh edge southeast of the Wastewater Ponds. PAHs in sediments can adsorb, biodegrade, or accumulate in aquatic organisms. Sediment suspended in surface water, due to extreme weather or man-made disturbances, could result in transport and redistribution of COPCs to other areas of the marsh or downstream locations. The SVOCs in sediment will be transformed over time but will persist for many years.

8.1.3 Human Health Risk Assessment

The objective of the HHRA was to characterize the carcinogenic and non-carcinogenic risk to human health from contamination at the Site in support of the Site's risk managers' decision-making process. The Site was divided into areas based on its operational history, and the risk levels for each area were determined separately. The areas evaluated included the Process Area, Pond Area, Treated Wood Storage Area, Untreated Wood Storage Area, Eastern Upland Area, the area West of Navassa Road, the Southern Marsh and Sturgeon Creek. Groundwater was evaluated across the Site, though impacts to groundwater were limited to the southern portion of the Site. A summary of the risk evaluation for the Site is as follows:

- Carcinogenic risk levels calculated for the Process and Pond Areas and sediment in the Southern Marsh exceed the upper end of the acceptable risk range of 1.0E-04 for the future resident child and are between the lower and upper ends of the risk target range (1.0E-06 to 1.0E-04) for the other potential receptors.
- The Untreated Wood Storage Area, Treated Wood Storage Area and Eastern Upland Area risk levels exceed the lower end of the risk target range of 1.0E-06 but are less than 1.0E-04 for the potential receptors except the future construction worker for whom risks are less than 1.0E-06.
- Most of the risk is from surface soil impacts, but subsurface soil in the Process and Pond Areas is also significantly impacted.
- The distribution of non-carcinogenic risks is similar to that of carcinogenic risks.
- Risks from groundwater in the southern portion of the property exceed the upper end of the risk range (1.0E-04) for the potential receptors except the future construction worker for whom risks are 1.0E-05.
- No significant risks are presented by conditions in the area West of Navassa Road or Sturgeon Creek.

8.1.4 Ecological Risk Assessment

BERA investigation data was collected from the Marsh Study Area in December 2016. The 2016 data, combined with historical data for the Marsh Study Area were used to evaluate current and potential future ecological exposure and ecological risk for the Marsh Study Area.

The BERA presented a screening of COPCs for the Marsh Study Area and demonstrated that the focus on PAHs is appropriate for protective risk-management decision-making in the marsh. Lines of evidence included site-specific sediment toxicity testing in laboratory bioassays using sediment dwelling amphipods, benthic community assessments, consideration of PAH concentrations in pore water using SPME for estimates of bioavailable PAHs for comparison to ELS fish Ecological Screening Benchmarks, consideration of USEPA's EqP of PAHs as they may relate to toxicity to sediment dwelling organisms, and bulk sediment chemistry of PAHs and comparison to sediment quality benchmarks and food web modelling for mammals and birds.

- Benthic community structure and integrity
  - The BERA included a weight of evidence evaluation considering each of the lines of evidence collectively. The conclusion for the BERA is that overall, the PAH residues in the majority of the Marsh Study Area do not pose unacceptable risks for sediment dwelling organisms; however, there may be risk for sediment dwelling organisms in the areas of the marsh with the highest PAH concentrations as summarized in Figure 7-7. The sediment dwelling organisms are not considered threatened or endangered species and impacts are on a scale that would not be expected to adversely impact the overall food web ecological services provided by the sediment dwelling community.
- Survival and reproduction of fish populations
  - The evaluation of SPME pore water data in comparison to protective TRVs for larval fish survival and growth showed that the residual PAHs in the sediment pore water do not pose an unacceptable risk to fish populations via impacts to larval fish.
- Survival and reproduction of bird and mammal populations
  - The BERA included a food web model for four bird species and two mammals that reflect the types of birds and mammals that can be expected in the marsh. Both conservative and more realistic exposure assumptions and USEPA Region 4 TRVs were considered. The BERA food web model results show the greatest potential risk for individual mallards, spotted sandpipers, green heron, and raccoon that feed exclusively from the marsh sediments and incidentally ingest a large amount of sediment from areas with the highest concentrations of residual PAHs. However, there is uncertainty in the food web model evaluation, particularly when the USEPA Region 4 recommended TRVs are considered in conjunction with alternate TRVs and more realistic exposure scenarios, as discussed in the uncertainty section of the BERA Report. Also, it is noted that the true potential risk to individual birds and mammals is likely reflected by some value between the NOAEL and LOAEL toxicity reference values. USEPA's 1999 Ecological Risk Assessment and Management Principles (Number 1) state that Superfund's goal is to reduce ecological risks to levels that will result in the recovery and maintenance of healthy populations and communities of biota. This BERA suggests that there may be risk to mallards, sandpipers, green herons, and raccoons but that this risk is most likely confined to the area of the Marsh Study Area with elevated PAHs.

An evaluation of potential groundwater upwelling was also performed using conductivity and temperature probes. The goal was to determine the magnitude of changes in marsh surface water temperature and conductivity to inform future investigations.

8.2 CONCLUSIONS

The following conclusions are based on the RI site characterization and the human health and ecological risk assessments for the Site:

- DNAPL is present in stringers throughout the Process Area and the Pond Area extending to the southern marsh. Based on the results of the investigation to date, the DNAPL has been delineated.

- Substantial future migration of the creosote is not likely to occur as wood treating activities have not been conducted since 1974 and there is no longer a continuing source of creosote. DNAPL is a continuing source of dissolved phase groundwater contamination. Continued groundwater sampling will provide information regarding plume stability and an additional line of evidence regarding the migration of DNAPL and dissolved phase contamination.

- Groundwater is impacted by VOCs and creosote-related SVOCs in the Process Area, Pond Area, and west of Navassa Road. The lateral extent of contamination is not fully characterized west of Navassa Road; however, the detected concentrations of constituents west of Navassa Road are low. The vertical extent of contamination has not been fully characterized in the Peedee Aquifer; however, based on observations from nearby borings and the permeability of deeper soils, the vertical extent of contamination can be inferred.

- Surface and subsurface soils are impacted in the Process and Pond Areas and will continue to leach contaminants to groundwater. The SVOCs in soil will be transformed over time by the mechanisms described in Section 5.3 but will persist for many years.

- Concentrations of SVOCs in the ISM samples collected from the DUs in the Eastern Upland Area are below residential RSLs; however, surface soils in drainage features are above residential RSLs.

- Concentrations of several SVOCs in subsurface soil from the Treated and Untreated Wood Storage Areas exceed the conservative default risk-based SSL Protective of Groundwater. However, because concentrations of SVOCs decrease from the surface to the subsurface soils in these areas and groundwater concentrations are below residential RSLs, the residual SVOCs in soil in these areas are not anticipated to be a continuing source to groundwater.

- Creosote-related SVOCs are present in sediment in the southern marsh. There is an isolated area of the southern marsh with higher concentrations of SVOCs. Concentrations of SVOCs in this area generally decrease with increasing depth.

- Based on the results of the HHRA, the overall risk is unacceptable for the reasonably anticipated future land uses. All areas examined require additional evaluation in the FS, except for Sturgeon Creek and the area West of Navassa Road. No constituent exceeded its residential RSL for soil in the area West of Navassa Road; therefore, no COPCs were determined for that area. Risks associated with Sturgeon Creek were insignificant due to lack of a complete exposure pathway for surface water and calculated risks from sediment impacts were one to two orders of magnitude below the

1.0E-06 level and the HQ was below the target risk range. Therefore, additional assessment of Sturgeon Creek is not recommended.

- BERA results conclude that the majority of the Marsh Study Area does not pose unacceptable risks to ecological receptors that inhabit the marsh; however, there is an area of high PAH concentration in the marsh where potential impacts to individual organisms cannot be definitely ruled out. The BERA Report explains how distinctions between individual organisms and populations can be made when population studies are not directly available. The BERA for the Marsh Study Area concludes that it is likely that the Marsh Study Area as a whole supports conditions that do not adversely impact populations and communities of birds and mammals. The area of the Marsh Study Area with elevated PAHs will be evaluated in the FS, particularly given some of the uncertainty when the most conservative toxicity reference values are used in the BERA. The area of interest for the FS may be one to three acres, depending on whether or not a contiguous area is considered that includes SD-29 (Figure 7-7).

8.3 RECOMMENDATIONS FOR FUTURE WORK

The following activities are recommended in the future:

- Conduct a groundwater plume stability evaluation to determine if the groundwater plume is increasing, decreasing, or stable. Semi-annual groundwater sampling is currently being performed to provide input to the plume stability evaluation. This information will be used in the FS to evaluate potential remedial alternatives and to refine the plume boundary to the west of Navassa Road.

- Evaluate potential remedial alternatives for mitigating contaminants that pose an unacceptable risk to human health or the environment in the FS with consideration to reasonably anticipated future land use. Consistent with USEPA 1999 Ecological Risk Assessment Principles and Practices, the FS should also evaluate the net environmental benefit to potential remedial actions and consider the ecological impact of implementation and construction activities.

- Evaluate the area of the marsh that was identified in the BERA as an area where risk to individual organisms may exist. As such, the area of the Marsh Study Area with elevated PAHs may be addressed in the FS, with consideration of how impact to the marsh may be balanced against risk reduction for individual organisms.

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Former Kerr-McGee Chemical Corporation Superfund Site Navassa, NC

Public Meeting
March 14, 2017

U.S. Environmental Protection Agency
North Carolina Department of Environmental Quality
Greenfield Environmental Multistate Trust LLC,
Trustee of Multistate Environmental Response Trust

Public Meeting Agenda

- ✓ Introductions
- ✓ Update on EPA Information Repository
- ✓ NCEERC Update
- ✓ NC DEQ Update on Navassa Trustees Council and on Other Sites in the Area
- ✓ Overview and roles of EPA, NC DEQ, Multistate Trust and Stakeholders
- ✓ Status of the Site Investigations
    - Summary of Activities Completed in December 2016 and January 2017
    - Field Work Planned for 2017
    - Timeline for Remainder of Cleanup
- ✓ Kerr-McGee Navassa Redevelopment Planning Initiative
- ✓ Questions and Discussion

Introductions

Tonya Spencer, EPA

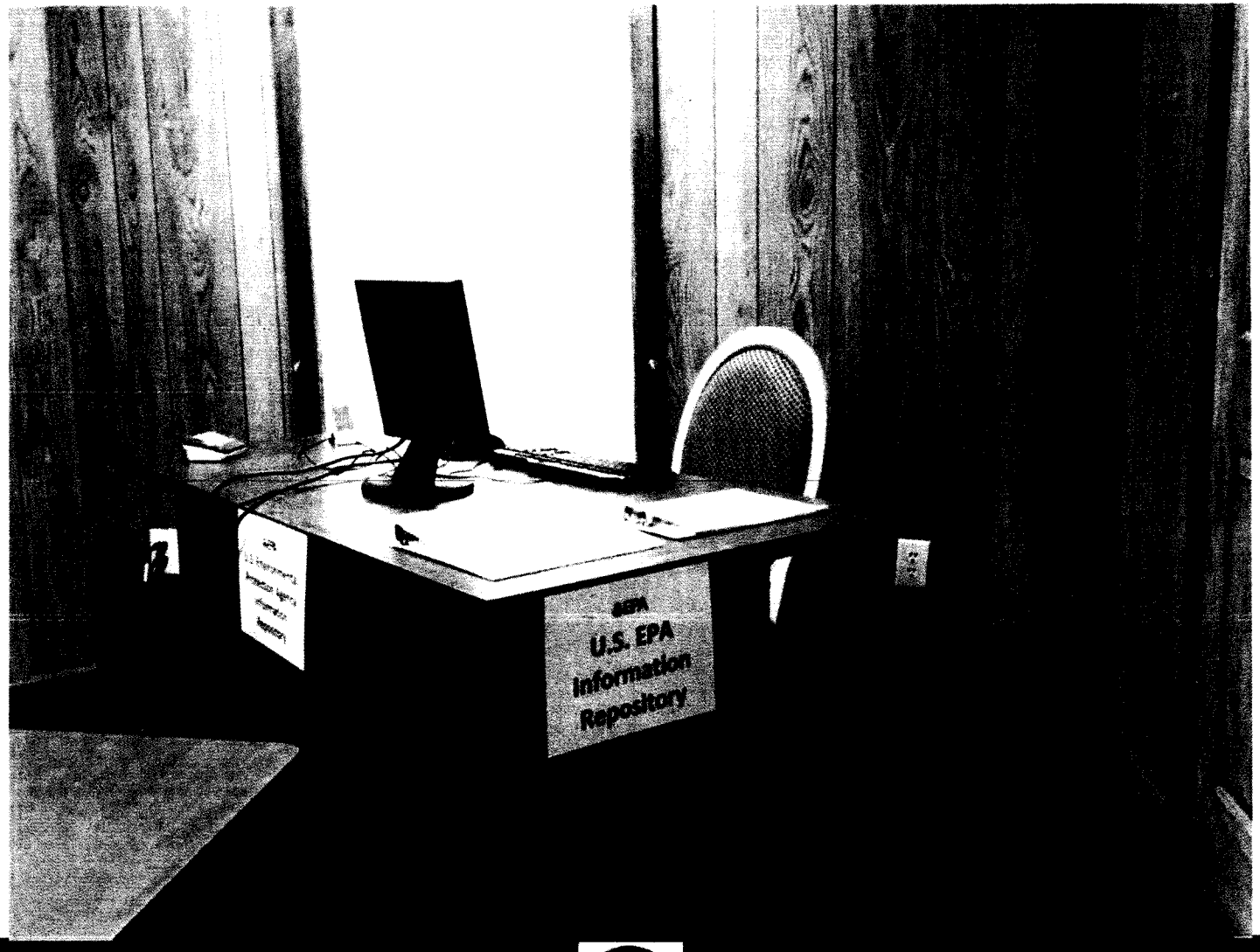
Introductions – Tonya Spencer, EPA

- ✓ Navassa Superfund Site Cleanup Team
  - U.S. Environmental Protection Agency (EPA)
  - North Carolina Department of Environmental Quality (NC DEQ)
  - Multistate Environmental Response Trust (Multistate Trust)
- ✓ Navassa Community Economic & Environmental Re-Development Corporation (NCEERC) – Community group
  - Technical Assistance Grant (TAG) update
- ✓ Navassa Trustees Council
- ✓ Partners in other efforts
  - National Oceanic and Atmospheric Administration (NOAA)
    - Natural resource restoration
  - North Carolina Division of Public Health (NCDPH)
    - Health education and outreach
  - University of North Carolina – Wilmington (UNCW)

Update on
EPA Information Repository

Public Meetings Every Quarter
Next Meeting in June 2017

Information Repository



NCEERC Update

Chris Graham, NCEERC

NC DEQ Activities
and
Update on Navassa Trustees Council

Jim Bateson, NC DEQ

Overview of Cleanup

Erik Spalvins, EPA

Cleanup Overview

- EPA, NCDEQ, Multistate Trust will:
  - Cleanup the site to enable reuse as supported by and beneficial to the community
  - Inform the public of the nature of the environmental issues and of the progress being made
  - Involve the public in the decision-making processes that will affect them and in the cleanup decisions under consideration
  - Conduct the cleanup so it can have a broad, positive community impact
- The role of the community - Provide Vision
  - Pick up where the Superfund cleanup stops

Roles and Responsibilities

NC DEQ

Joint activities

- Discuss and Plan Scope of Actions
- Coordinate with stakeholders and residents

"Multistate Environmental Response Trust"

GETG
Greenfield Environmental Trust Group

EPA and NC DEQ Activities

- Ultimate responsibility for cleanup
- Review and Approve Work Plans
- Provide Oversight of Cleanup Work
- NC DEQ is responsible for long term care, if needed

Multistate Trust Activities

- Conduct "Environmental Actions" per Bankruptcy Agreement
  - Investigation
  - Cleanup
  - Long term care, etc.
- **Coordination and integration of reuse and remedial efforts and initiatives**

EPA

TVA Kingston / EPA Reuse Collaboration

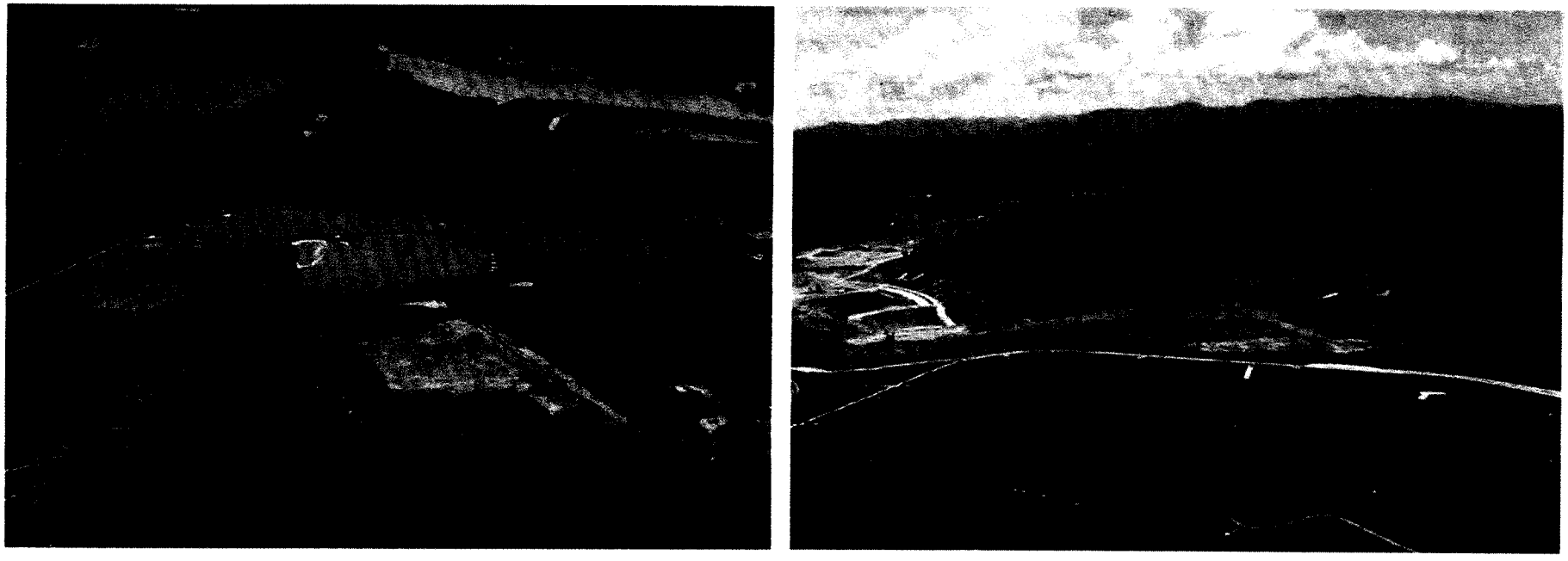
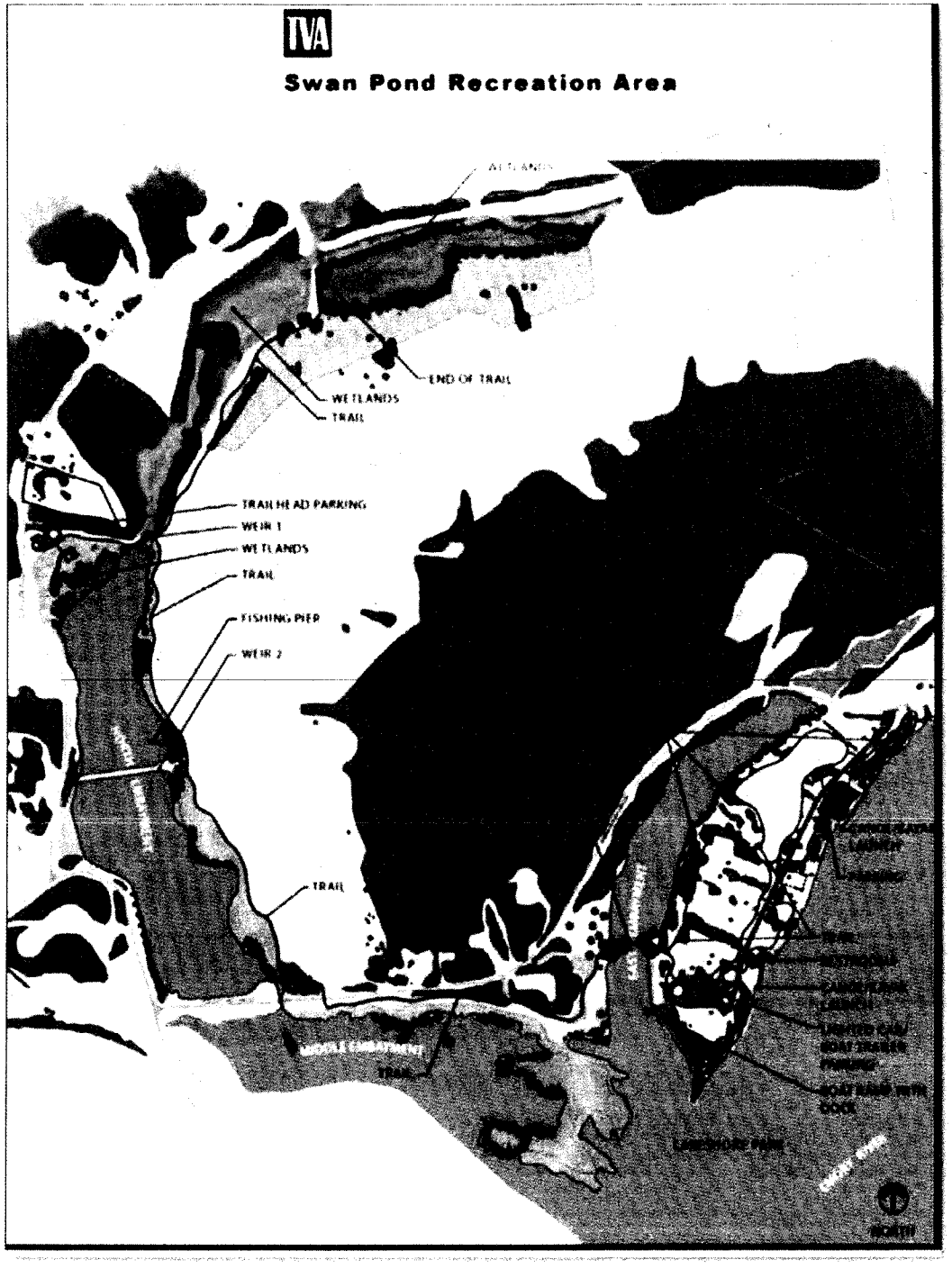


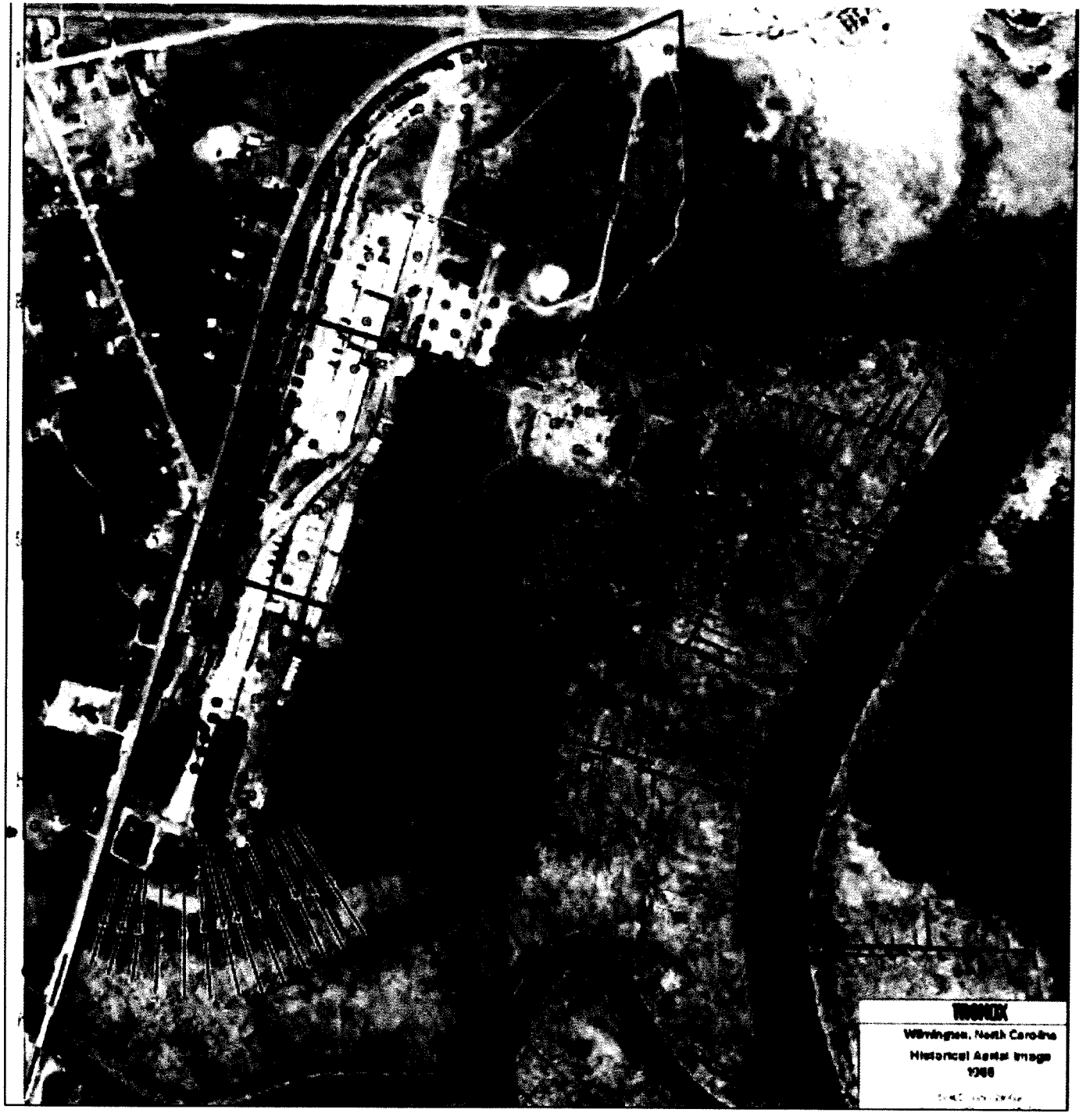
Figure 1. Aerial view of the coal ash spill in 2008 (left). Capped landfill and recreation area at the Site in 2015 (right).

TVA Swan Pond Recreation Area Plan

Lessons Learned:

1. Integrate cleanup and reuse.
2. Rely on diverse expertise for complex cleanups.
3. Make sure all community voices are heard.
4. Consider potential community impacts of cleanup activities and adjust plans accordingly.




Wilmington, North Carolina
Historical Aerial Image
1968

Site Work Update

Richard Elliott, Multistate Trust

Supplemental Remedial Investigations (SRI)
Richard Elliott, Multistate Trust

Purpose of Supplemental Remedial Investigations (SRI): Characterize Nature and Extent of Contaminants of Concern

- Determine lateral and vertical distribution of contaminants
- Investigate all media: soil, sediment, groundwater and surface water
- Use SRI results to determine risk posed by contamination to human health and the environment

J5 Safety Meeting Prior to Clearing Activities
November 2016

EPA

December 2016 NAPL Measurements
Wells MW-27S and MW-06D

December 2016 NAPL Measurements
Wells MW-27S and MW-06D

March 2017 Core From Site

Supplemental Remedial Investigation (SRI) Activities Completed December 2016 through January 2017

Groundwater Sampling Event December 2016

- ✓ Collected water level measurements from 49 existing monitoring wells
- ✓ Measured each well for the presence of DNAPL
  - Measurable amounts found in 7 wells at thicknesses ranging from 0.07 feet to 3.44 feet
- ✓ Collected groundwater samples from 44 monitoring wells
  - Analyzed for VOCs, SVOCs, and select inorganic constituents
- ✓ Groundwater analytical results are consistent with historical concentrations

EPA

Supplemental Remedial Investigation (SRI) Activities Completed December 2016 through January 2017

Surface Water and Sediment Sampling Event December 2016

- ✓ Collected sediment samples from 3 background locations in the Marsh
  - Analyzed for SVOCs and chromium
- ✓ Collected surface water from 3 locations in the Marsh
  - Analyzed for select inorganic constituents
- ✓ Analytical results are being evaluated

Supplemental Remedial Investigation (SRI) Activities Completed December 2016 through January 2017

Ecological Sampling Event
December 2016

- ✓ Collected bulk sediment samples from 10 locations in the Marsh
  - Analyzed for PAHs and TOC
- ✓ Pore water extracted from the 10 sediment samples
  - Analyzed for PAHs
- ✓ Toxicity testing conducted using an amphipod species (crustacean) as the test organism
- ✓ Benthic community assessment samples collected from 10 locations
- ✓ Ecological samples results are being evaluated

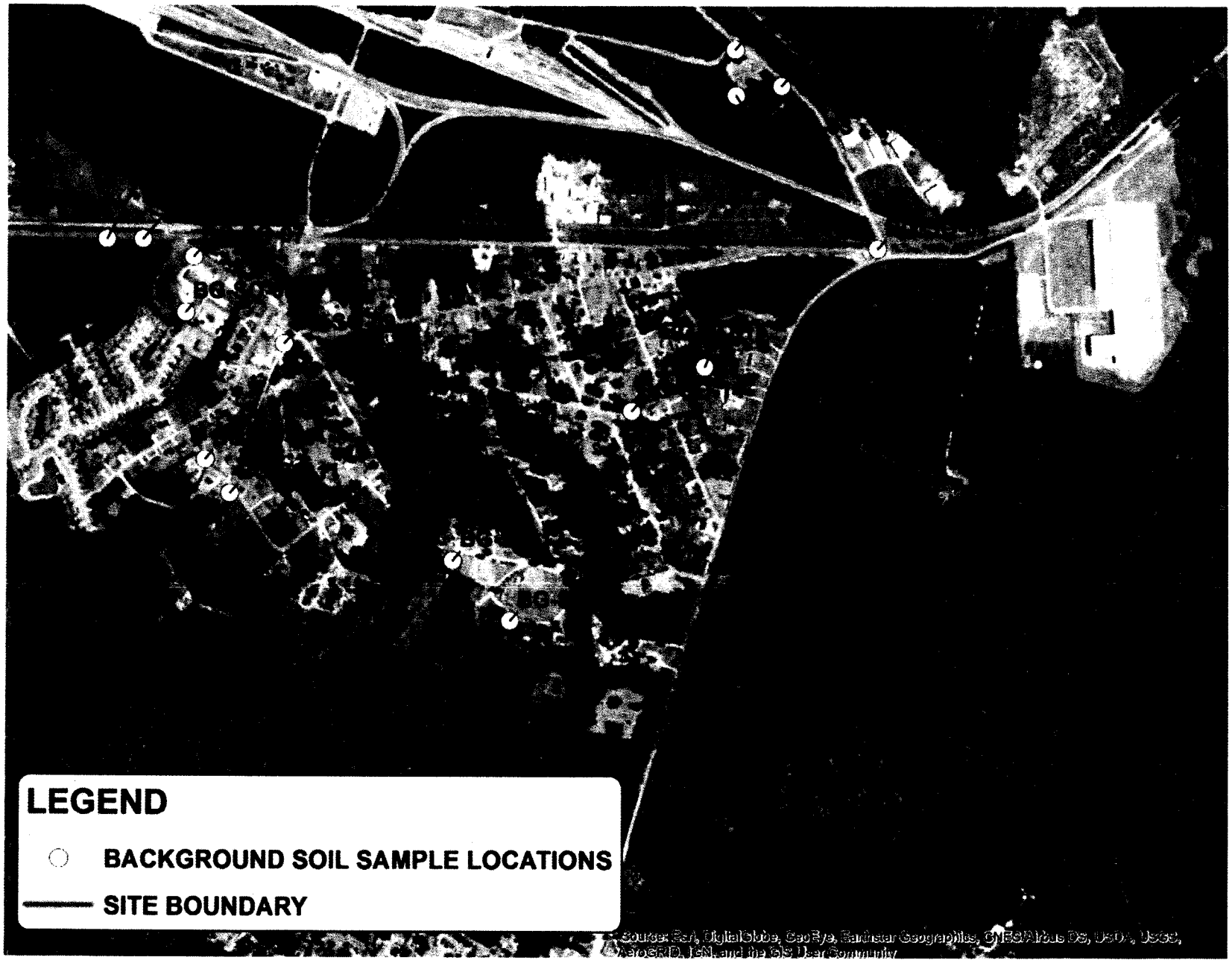
EPA

Supplemental Remedial Investigation (SRI) Activities Completed December 2016 through January 2017

Background Soil Sampling Event
January 2017

- ✓ Collected surface soil samples (0 to 0.5 feet deep) from 15 locations on Town of Navassa property
  - Analyzed for metals and PAHs
- ✓ Analytical results indicated detected concentrations are below EPA Residential Regional Removal Management Level (RML)

Background Soil Sample Locations



2017 SRI Data Collection Activities

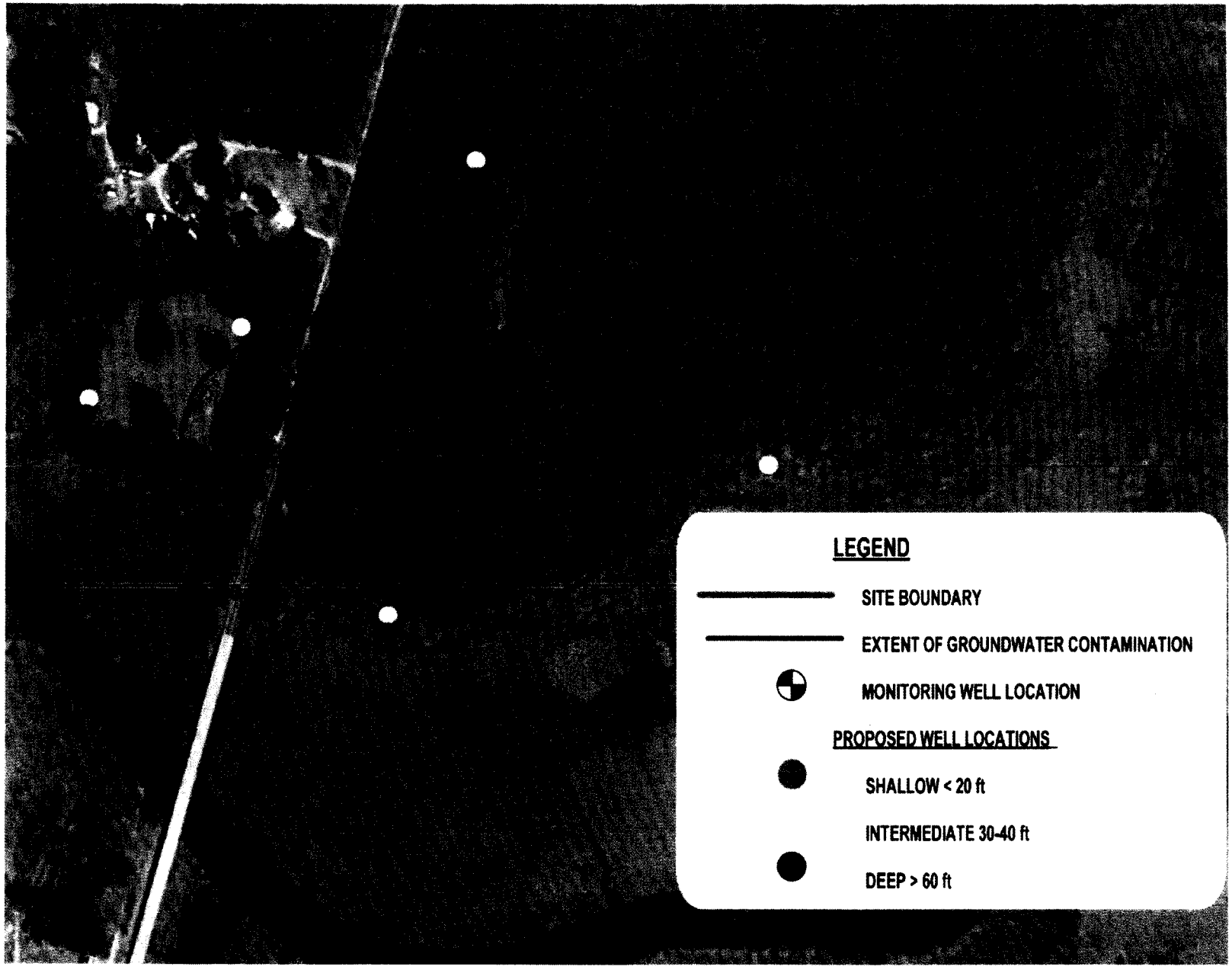
✓ **First Quarter 2017**

- Geotechnical samples for vapor intrusion analysis
- Additional on-site and off-site monitoring wells
- Additional soil samples from northern areas of Site
- Additional soil borings for DNAPL investigations

✓ **Quarterly groundwater sampling in March, June, September and December**

✓ **Work began March 6, 2017**

Proposed Monitoring Well Locations



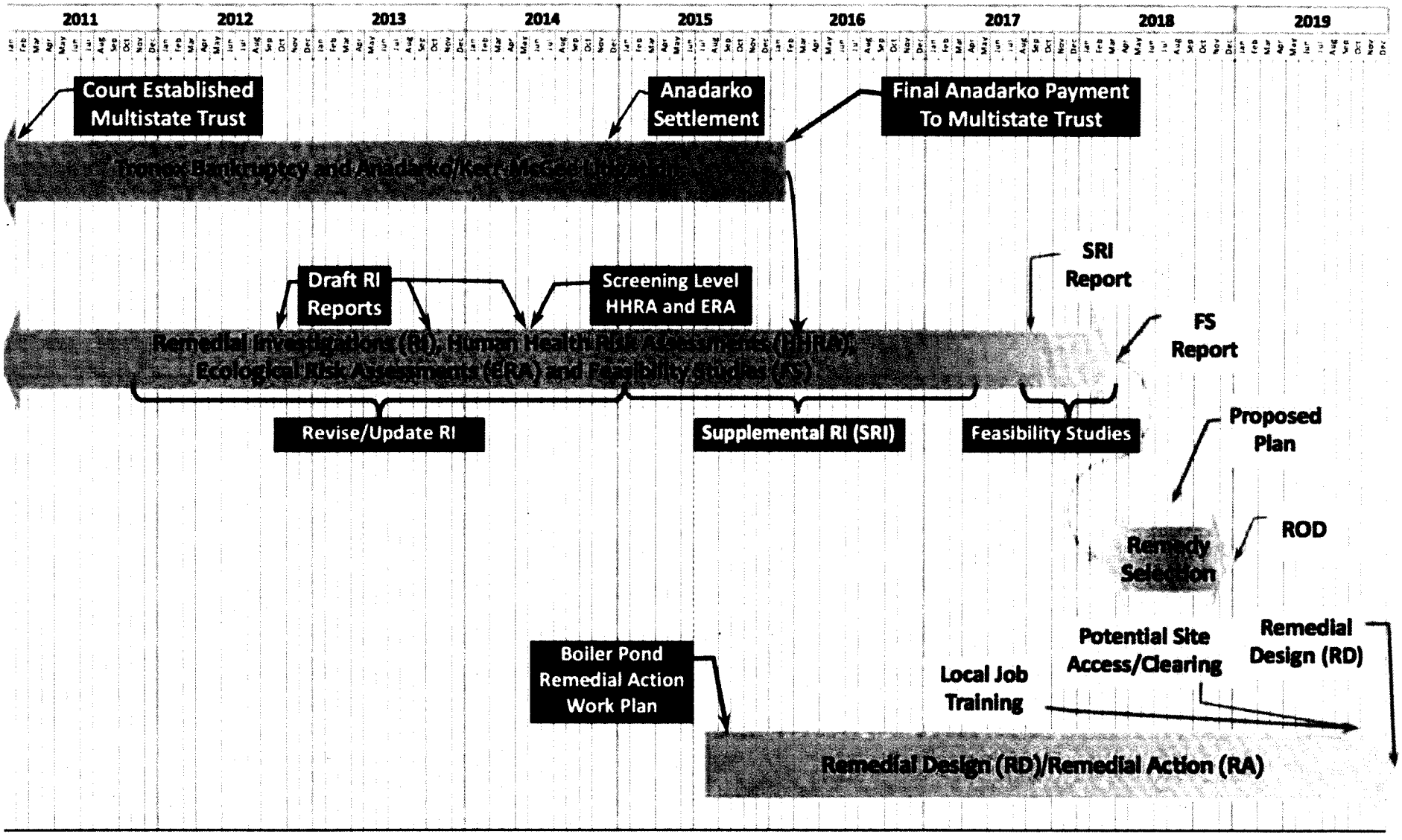
First Quarter 2017 Field Schedule

- ✓ Field activities will be conducted in three 10-day shifts
- ✓ **Shift 1 – March 6 to March 15**
  - Installation of 4 wells at off-site locations
  - Soil sampling from 31 locations in wood storage areas
  - Vapor intrusion soil sampling from 6 locations
- ✓ **Shift 2 – March 20 to March 29**
  - DNAPL assessment – 10 deep and 3 shallow soil borings
  - Installation of 6 wells at on-site locations
- ✓ **Shift 3 – April 3 to April 12**
  - Groundwater sampling

2017 Risk Assessments and Feasibility Studies

- ✓ Risk Assessments
  - Human Health and Ecological Risk Assessments
  - Scheduled to be complete June 2017
- ✓ Remedial Investigation (RI) Report scheduled to be issued September 2017
- ✓ Initiate Feasibility Study (FS) October 2017

Kerr-McGee Navassa Superfund Site Overview of Cleanup Plans



Kerr-McGee Navassa Redevelopment Planning Initiative (RPI)

Cindy Brooks, Multistate Trust

KMCC RPI Community Involvement

Redevelopment Working Group

- Residents of Navassa
- Town of Navassa
- NCEERC
- Business Interest

Coordinator

- Multistate Trust—Cindy Brooks and Richard Elliott
- Land Use Planner—Jason Epley (Benchmark Planners)

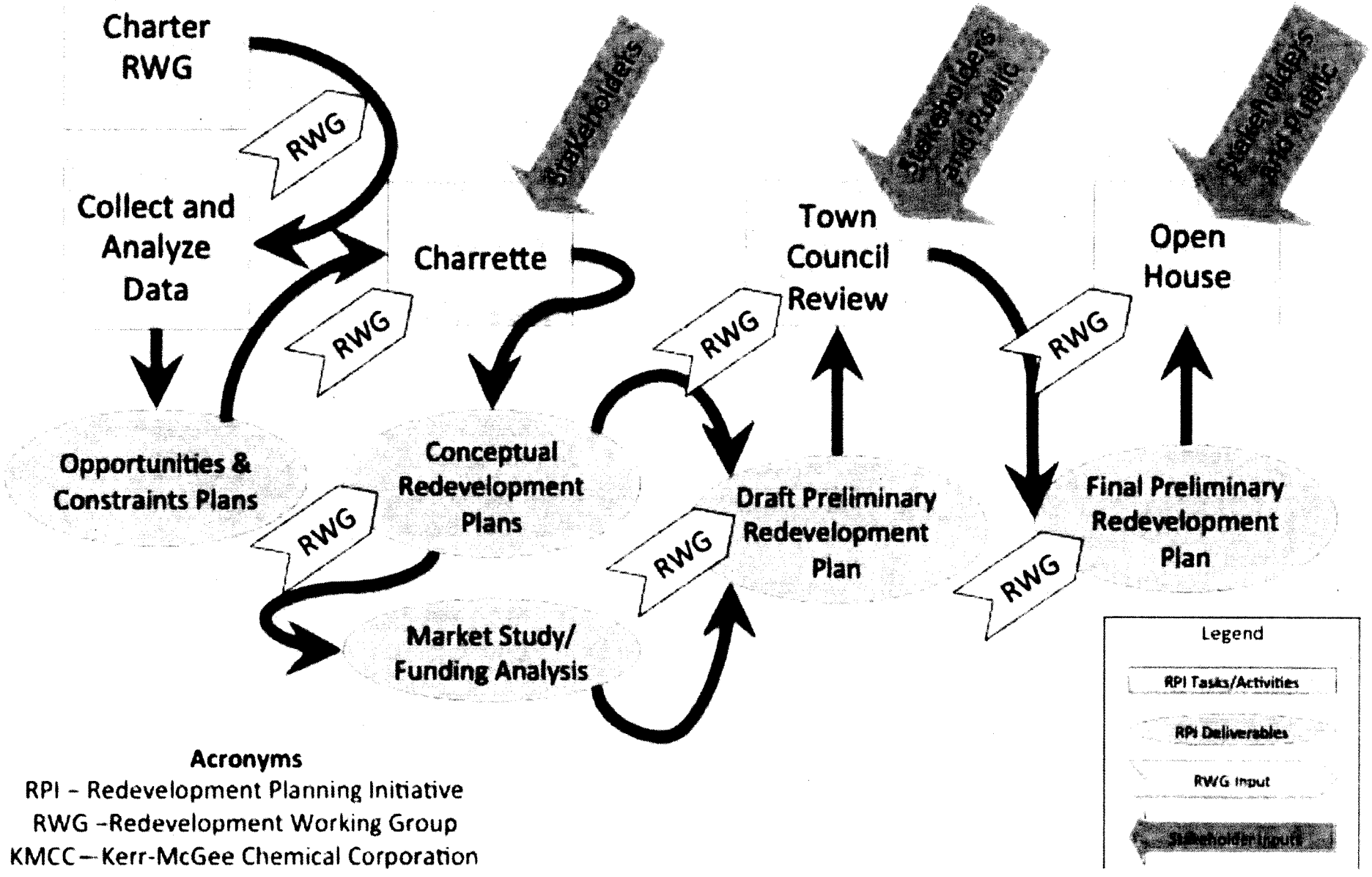
Advisors

- Navassa Trustees Council—Anjie Ackerman
- US EPA—Erik Spalvins and Tonya Spencer
- NCDEQ—Anjie Ackerman

What Should Redevelopment Plan Do?

- ✓ Protective of Human Health and the Environment
- ✓ Endorsed by Community Stakeholders
- ✓ Technically Feasible
- ✓ Economically Viable/Sustainable
- ✓ Consistent with Superfund Laws, Zoning, etc.

KMCC Redevelopment Planning Initiative (RPI) Process



Acronyms

RPI – Redevelopment Planning Initiative
RWG –Redevelopment Working Group
KMCC – Kerr-McGee Chemical Corporation

Public Meeting Agenda

Redevelopment Working Group (RWG) Meetings/Events and Target Schedule	
Meetings or RPI Events	**Target Schedule**
RWG Chartering Meeting	April 2017
RWG Charrette Planning Meeting	July 2017
Charrette	September 2017
RWG Comments on Draft Conceptual Redevelopment Plans	October 2017
RWG Review of Draft Preliminary Redevelopment Plans	November 2017
Presentation of Draft Preliminary Redevelopment Plans to Town Council	November 2017
Open House—Final Preliminary Redevelopment Plans Presented to General Public	December 2017

Contact Information

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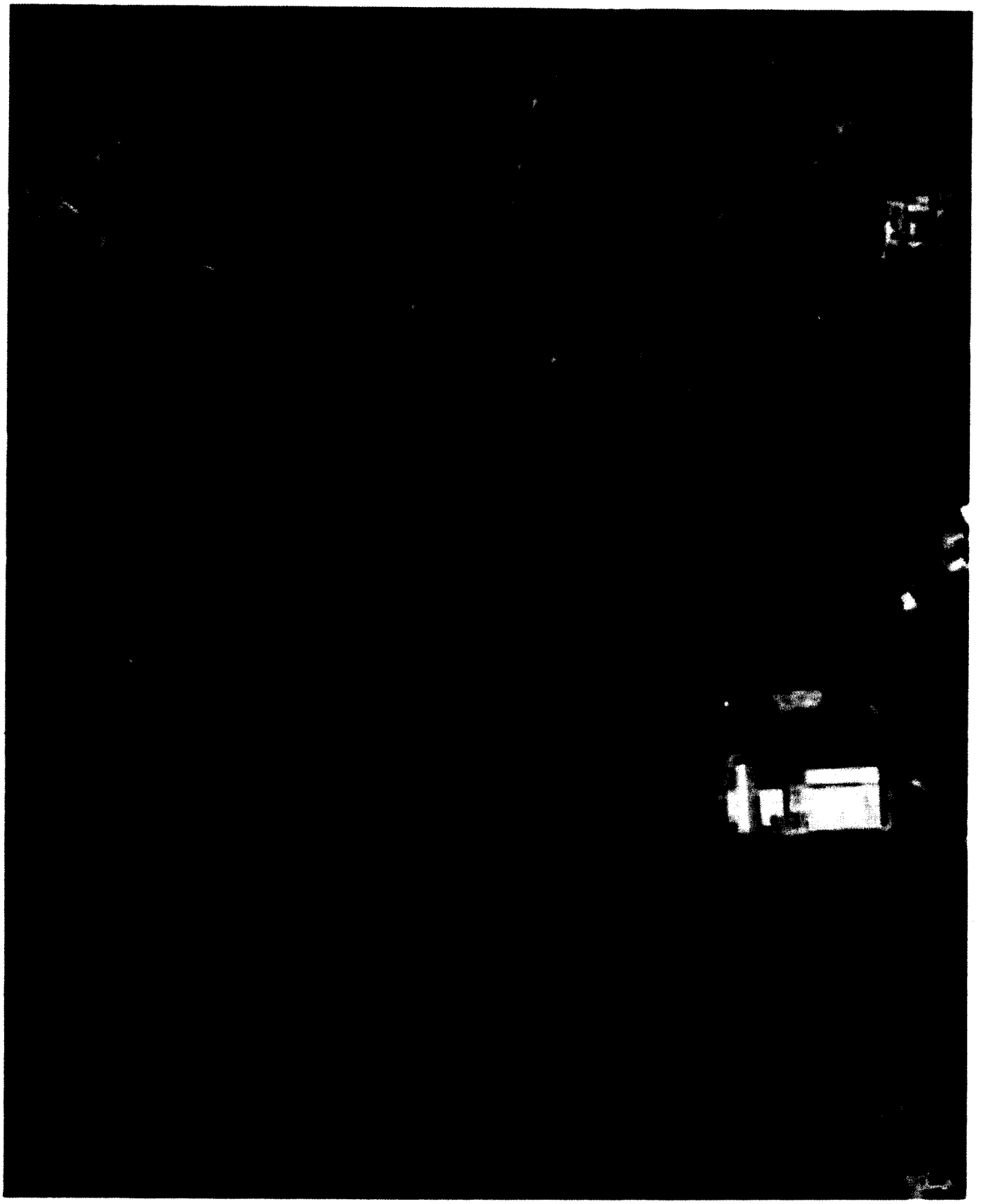
  - (404) 562-8938, spalvins.erik@epa.gov
- Tonya Spencer, EPA Community Involvement Coordinator
  - (404) 562-8463, spencer.latonya@epa.gov
- David Mattison, NCDEQ Superfund Section Project Manager
  - (919) 707-8336, david.mattison@ncdenr.gov
- Cindy Brooks, Multistate Trust Managing Principal
  - (617) 448-9762, cb@g-etg.com
- Richard Elliott, Multistate Trust Project Manager
  - (617) 953-1154, re@g-etg.com

Questions and Discussion



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Former Kerr-McGee Chemical Corporation Superfund Site Navassa, NC

Public Meeting
September 19, 2017

U.S. Environmental Protection Agency
N. C. Department of Environmental Quality
Greenfield Environmental Multistate Trust LLC,
Trustee of the Multistate Environmental Response Trust

Public Meeting Agenda

- ✓ Introductions
- ✓ Update on EPA Information Repository
- ✓ Overview and roles of EPA, N.C. DEQ, Multistate Trust and Stakeholders
- ✓ NCEERC Update
- ✓ N.C. DEQ Update on Navassa Trustees Council
- ✓ N.C. DHHS DPH Update on Fish Study
- ✓ Status of the Site Investigations
    - Summary of Activities Completed in 2017
    - Work Planned for 2017 and 2018
    - Timeline for Remainder of Remedial Actions
- ✓ Kerr-McGee Navassa Redevelopment Planning Initiative
- ✓ Questions and Discussion

Introductions

Tonya Spencer, EPA

Introductions – Tonya Spencer, EPA

- ✓ Navassa Superfund Site Cleanup Team
  - U.S. Environmental Protection Agency (EPA)
  - N.C. Department of Environmental Quality (N.C. DEQ)
  - Multistate Environmental Response Trust (Multistate Trust)
- ✓ Navassa Community Economic & Environmental Re-Development Corporation (NCEERC) – Community group
  - Technical Assistance Grant (TAG) update
- ✓ Redevelopment Working Group (RWG) update
- ✓ Navassa Trustees Council – Natural Resource Damage (NRD) Restoration Represented by USFWS, N.C. DEQ and NOAA
- ✓ Partners in other efforts
  - N.C. Department of Health and Human Services/N.C. Division of Public Heath (N.C. DPH) – Heath education and outreach
  - University of North Carolina – Wilmington (UNCW) – College / Underserved Community Partnership Program (CUPP)

EPA NC

Update on
EPA Information Repository

Public Meetings Every Quarter
Next Meeting January 16, 2018

Navassa Community Economic & Environmental Re-Development Corporation

NCEERC Update

Chris Graham, NCEERC

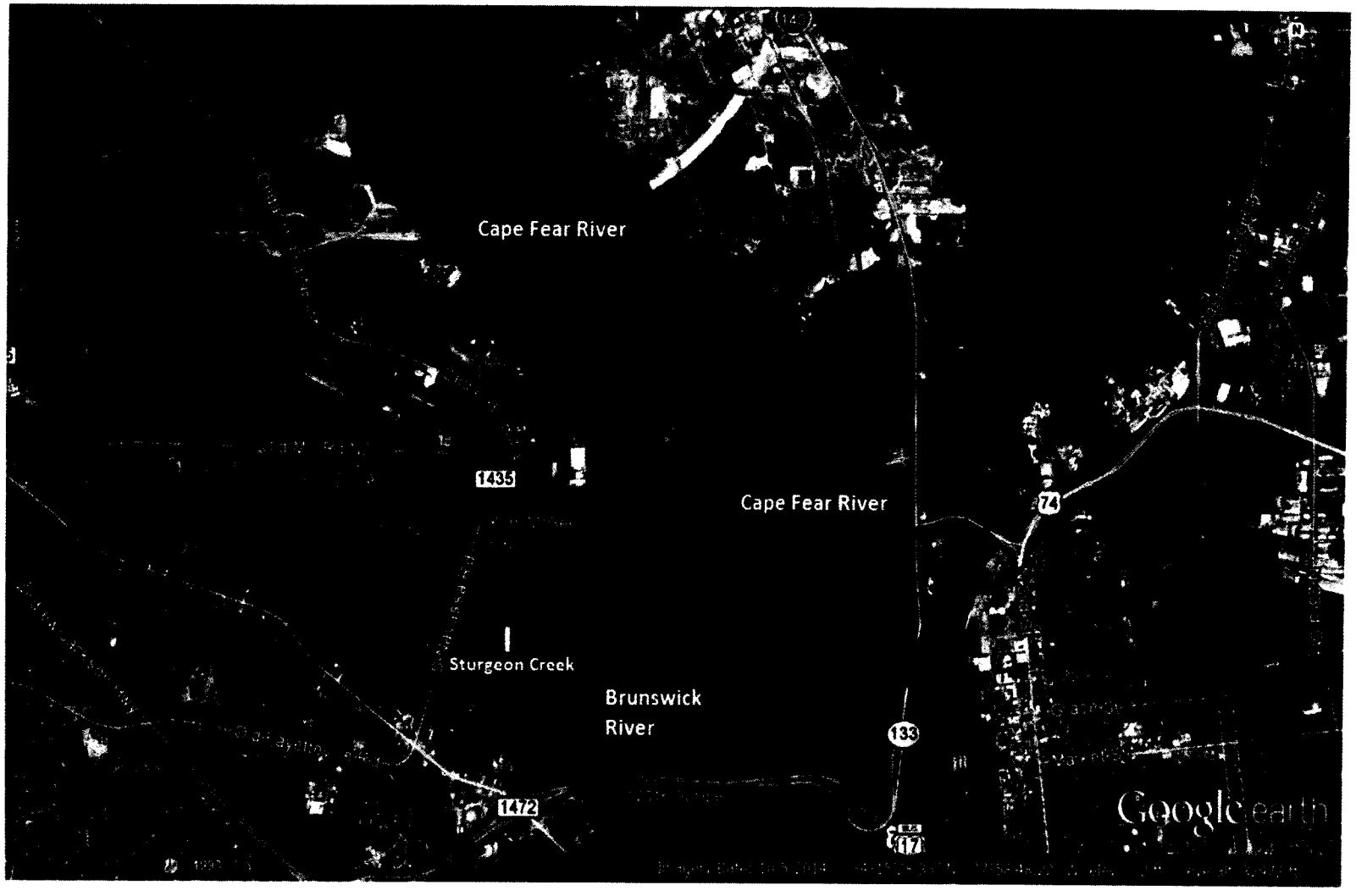
N.C. DEQ Activities
and
Update on Navassa Trustees Council

David Mattison and Anjie Ackerman, N.C. DEQ

N.C. Department of Heath and Human Services Division of Public Health Update on Fish Study

Jamie Pritchett, N.C. DHHS DPH

Fish Sampling Area



Recommendations

- Follow the existing statewide fish consumption advisory for mercury

Women of Childbearing Age (15-44 years), Pregnant Women, Nursing Women and Children under 15:	
HIGH in mercury	Do not eat, includes catfish and largemouth bass
LOW in mercury	Up to 2 meals per week
All Other Individuals:	
HIGH in mercury	No more than 1 meal per week, includes catfish and largemouth bass
LOW in mercury	Up to 4 meals per week

Recommendations Cont.

- Follow these additional meal consumption limits for fish and shellfish in this area:

Fish Consumption Recommendations for Sturgeon Creek, Brunswick River, and Cape Fear River near Navassa		
Species	**Meals per week**	**Contaminant(s) ***
Striped Bass	Up to 2	Mercury
Striped Mullet	Up to 3	Hexavalent Chromium
Blue Crab	Up to 3	Arsenic, Hexavalent Chromium, Mercury

* Not associated with the Kerr-McGee site. Could be from other man-made sources or naturally occurring

Next Steps

- N.C. DPH will issue a fish advisory for this area based on the above recommendations
- N.C. DPH will continue to monitor and assess the site as additional environmental data is collected
- Public Comment Period Ends **September 25**

Agency for Toxic Substances and Disease Registry (ATSDR) Community Activities Survey

Overview of Cleanup

David Mattison, N.C. DEQ
For Erik Spalvins, EPA

How we got here

- 2005, Kerr McGee created "Tronox", which went bankrupt in 2009
- EPA took over investigation in 2010
- Tronox Bankruptcy Environmental Settlement Agreement was finalized in February 2011
  - Funds for cleanup and Natural Resource Restoration
  - Cleanup by "Multistate Environmental Response Trust"
  - Natural Resource Restoration by NOAA, N.C. DEQ, FWS
- Multistate Environmental Response Trust started work in 2011

"Cleanup"

Total Funds about $92 Million

'Multistate Environmental Response Trust' conducts cleanup.

Cleanup Beneficiaries: Government agencies that would have been responsible for the cleanup if funds had not been made available from the bankruptcy settlement.

"Restoration"

Total Funds about $23 Million

Natural Resource Trustees: government agencies responsible for natural resource damage

Cleanup Mission Statement

- EPA, N.C. DEQ, Multistate Trust commitment:
  - Clean up the Site to enable reuse(s) supported by and beneficial to the community
  - Inform the public of environmental conditions at the Site and cleanup progress
  - Encourage public involvement in the cleanup process
  - Conduct the cleanup so it can have a broad, positive community impact
- The role of the community – Vision and Voice
  - Pick up where the Superfund cleanup stops

Frequently asked questions

- What if there is not enough money?
  - The EPA and N.C. DEQ will take over the Site and fund the cleanup.
  - Marathon not sprint.
- What if there is money left over after the Trust completes the cleanup?
  - The funds will be distributed to other sites left by Kerr-McGee sites with a funding shortfall.
- Where did the funding come from?
  - Tronox provided initial funds during bankruptcy settlement
  - Anadarko provided funds after settlement of Anadarko lawsuit
  - All cleanup funds came from the parties responsible for contamination of the Kerr-McGee sites (and not from the U.S. or N.C. taxpayers)

Site Work Update

Richard Elliott, Multistate Trust

Remedial Investigations (RI)
Richard Elliott, Multistate Trust

Purpose of Remedial Investigations (RI): Identify areas of contamination and evaluate potential risk

- ✓ Determine the extent (lateral and vertical) and concentration of contaminants
- ✓ Investigate all media: soil, sediment, groundwater and surface water
- ✓ Use RI results to evaluate potential risk to human health and the environment from contact with contamination and evaluate technologies and options for addressing such risks

2017 RI Data Collection Activities

- ✓ **First Quarter 2017**
  - Geotechnical samples for vapor intrusion analysis
  - Additional on-site and off-site monitoring wells
  - Additional soil samples from northern areas of Site
  - Additional soil borings for Dense Non- Aqueous Phase Liquid (DNAPL) investigations (in groundwater)

- ✓ **Quarterly groundwater sampling in March, June, September and December**

- ✓ **Third quarterly groundwater sampling event scheduled for the week of September 25, 2017**

Water Sampling Training

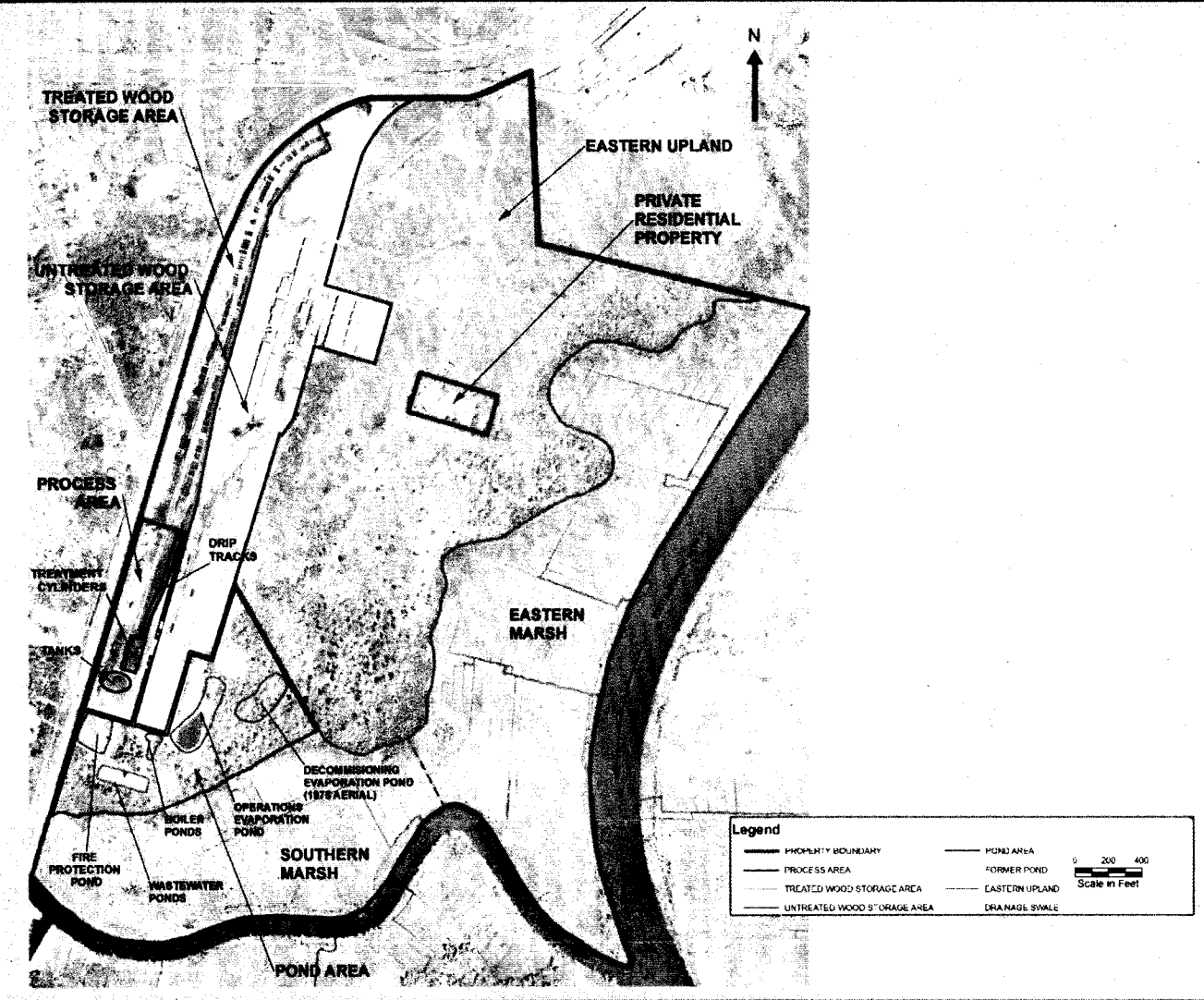
2017 Risk Assessments and Feasibility Study

- ✓ Risk Assessments
  - Human Health and Ecological Risk Assessments
  - Scheduled to be completed September 2017
- ✓ Remedial Investigation (RI) Report scheduled to be issued December 2017
- ✓ RI Report will be presented at the January 2018 quarterly meeting
- ✓ Feasibility Study strategy discussions began in September 2017

2017 Feasibility Studies

- ✓ Purpose of Feasibility Study (FS)
  - Identify and evaluate potential remedies that eliminate risks
  - Consider alternate approaches to the different parts of the Site
- ✓ Process
  - Identify and 'Screen' Potential Technologies
  - Develop Remedial Action Alternatives
  - Perform detailed Analysis of Alternatives Using Nine Criteria
  - Issue Feasibility Study Report
- ✓ FS Report to be completed 2018

Feasibility Strategy



2017 Feasibility Study Nine Criteria

✓ Threshold Criteria

1. Overall Protection of Human Health and the Environment
2. Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

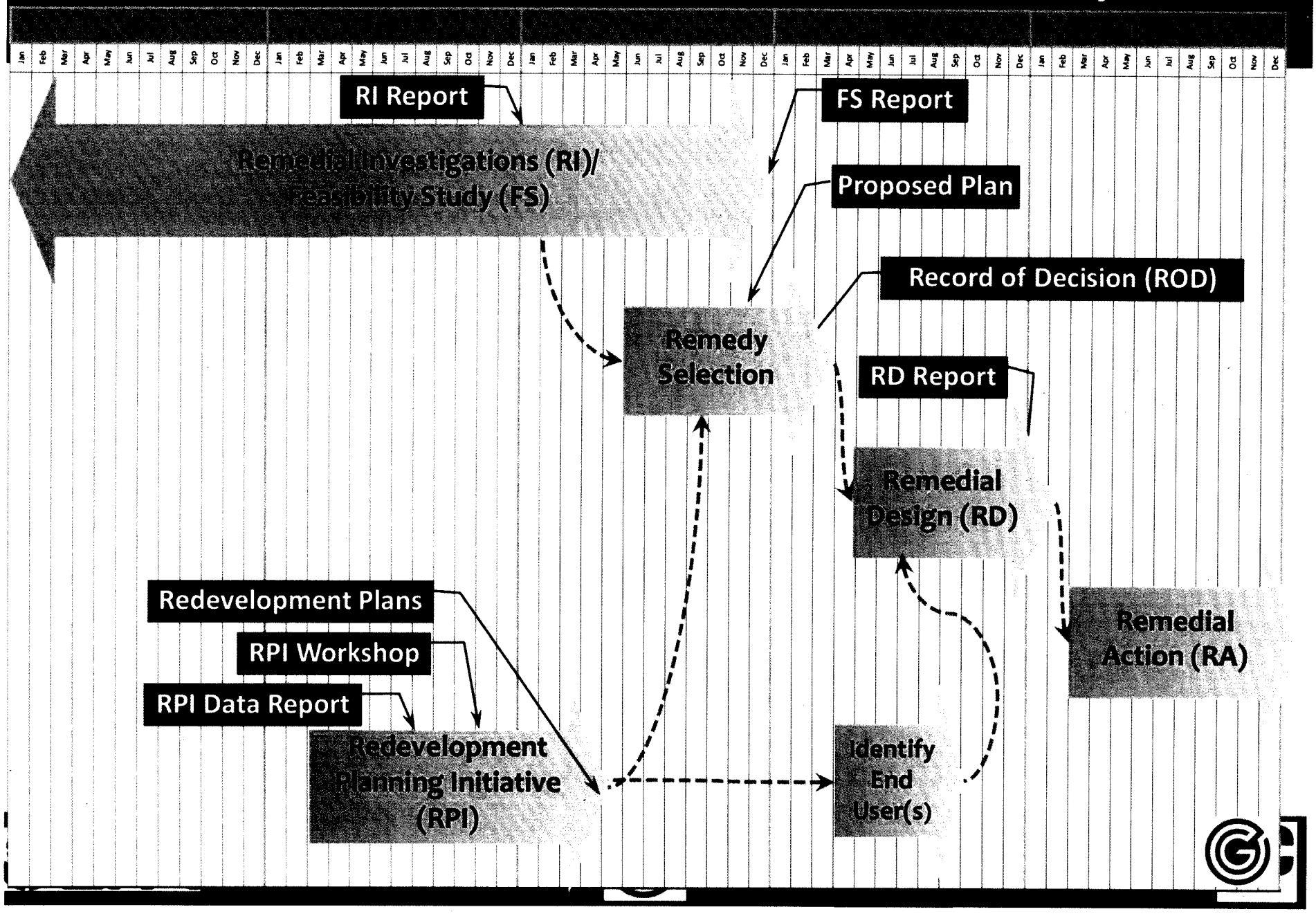
✓ Balancing Criteria

1. Long-term Effectiveness and Performance
2. Reduction of Toxicity, Mobility, or Volume Through Treatment
3. Short-term Effectiveness
4. Implementability
5. Cost

✓ Modifying Criteria

1. State/Support Agency Acceptance
2. Community Acceptance

Navassa Superfund Site Overview of Cleanup Plans



Kerr-McGee Navassa Redevelopment Planning Initiative (RPI)

Richard Elliott, Multistate Trust

Kerr-McGee Navassa Superfund Site
Redevelopment Planning Initiative (RPI)
Richard Elliott—Multistate Trust

- Opportunities for Community Input/Engagement
  - Redevelopment Working Group (RWG)
  - Community Survey
  - Focus Groups
  - Community Visioning Workshop
  - Open House
- RPI Process and Deliverables
- RPI Schedule

Kerr-McGee Navassa
Redevelopment Planning Initiative (RPI)
Opportunities for Community Input/Engagement

- ✓ Redevelopment Working Group (RWG)
- ✓ Community Survey and Interviews
- ✓ Community Visioning Workshop
- ✓ Open House

Redevelopment Planning Initiative (RPI)
Redevelopment Working Group

Role of the Redevelopment Working Group (RWG)

- ✓ Act as steering committee for RPI
- ✓ Help engage broad cross-section of residents and community stakeholders in RPI process
- ✓ Provide insight into community goals and concerns about future reuse
- ✓ Review and comment on key RPI deliverables

Bridging the Gateway to a Millennial Community

EPA

Kerr-McGee Redevelopment Planning Initiative (RPI) Redevelopment Working Group

Redevelopment Working Group (RWG) Participants

- **Town of Navassa**
  - Town Council (Councilors Bethel, Brown, Burns, Merrick, and Mooring)
  - Mayor Willis
- **Residents of Navassa**
  - Kalitah Crawford, Malcolm Dorman and Melvin Walker
- **Navassa Community Economic & Environmental Redevelopment Corporation (NCEERC)**
  - ✓ LaTanya Beatty-Nixon
  - ✓ Chris Graham
  - ✓ Conswalia Green
  - ✓ Marcell Hatten
  - ✓ Clarence Toland
- **Other Stakeholders**
  - ✓ Resea Willis/President/Brunswick Housing Opportunities (BHO)
  - ✓ Veronica Carter/Board Member/North Carolina Coastal Federation (NCCF)

EPA NC

Redevelopment Planning Initiative (RPI)
Community Survey

✓ **Purpose of Community Survey**

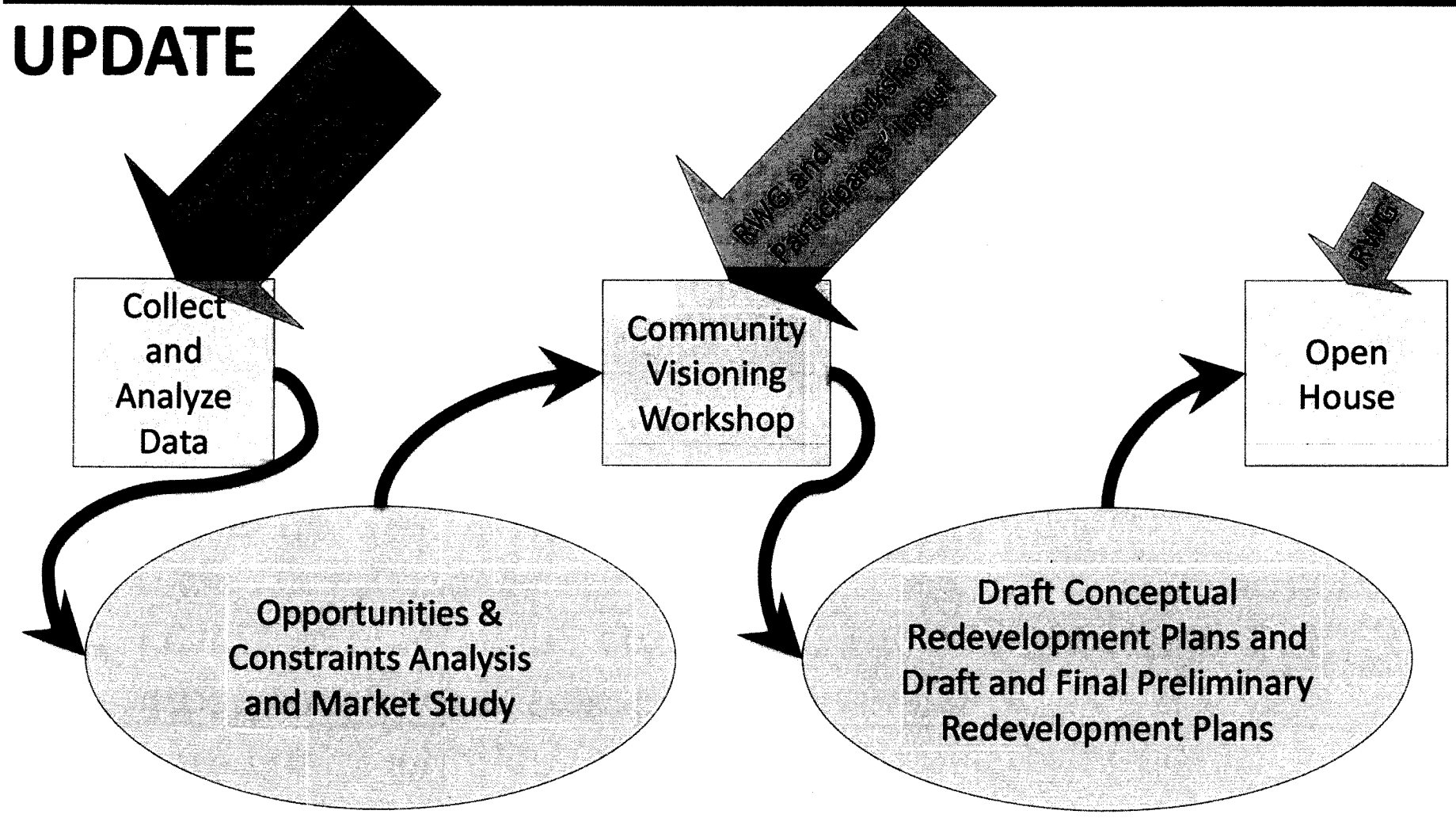
- Community input on redevelopment goals/priorities
- Broad spectrum of stakeholder interests
- Results to be used in Community Visioning Workshop

✓ **Options for submitting completed surveys**

- U.S. Mail
- Online (Survey Monkey)
- Drop box at Public Meetings, Availability Sessions and Town Hall
- Return to Multistate Trust (Chris, Richard or Cindy)

✓ **Survey Closes September 30, 2017**

Redevelopment Planning Initiative (RPI) Process and Deliverables



Redevelopment Planning Initiative (RPI)
Community Visioning Workshop

Purpose

- ✓ Define community vision for future of Kerr-McGee Superfund Site
- ✓ Develop clear, realistic ideas for redevelopment that address community goals and priorities
- ✓ Provide real-time input to planning process

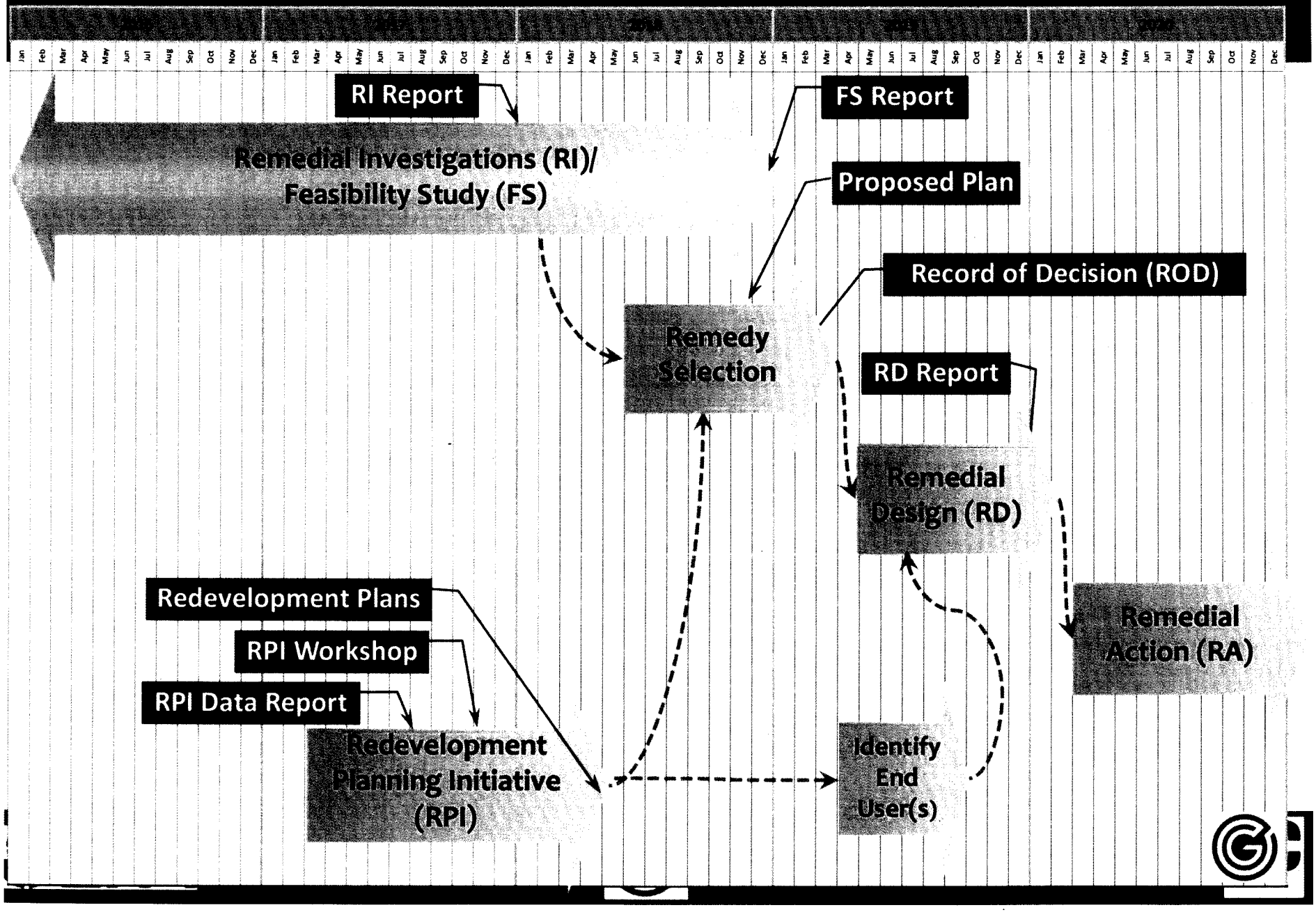
Format and Process

- ✓ Building on data collection results, three-day intensive planning sessions facilitated by land use planners
- ✓ Organized into subgroups to focus on key reuse options
- ✓ Forum for brainstorming ideas and providing immediate feedback to land use planners
- ✓ Public participation on Friday, Dec. 1 (evening), and Saturday, Dec. 2 (full day)
- ✓ Community Fish Fry on Saturday

Schedule: **Thursday Nov. 30, Friday, Dec. 1 (evenings) and Saturday, December 2, 2017 (all day)**

EPA

Navassa Superfund Site Overview of Cleanup Plans



Contact Information

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- Tonya Spencer, EPA Community Involvement Coordinator
  - (404) 562-8463, spencer.latonya@epa.gov
- David Mattison, NCDEQ Superfund Section Project Manager
  - (919) 707-8336, david.mattison@ncdenr.gov
- Cindy Brooks, Multistate Trust Managing Principal
  - (617) 448-9762, cb@g-etg.com
- Richard Elliott, Multistate Trust Project Manager
  - (617) 953-1154, re@g-etg.com

Questions and Discussion

- **BACKUP**

Redevelopment Planning Initiative (RPI) Definitions

Remediation: The activities intended to reduce human and ecological exposure to contaminants. For Kerr McGee, this is work is managed by the Multistate Trust.

Redevelopment: Returning the property to productive use. For Kerr McGee, the Multistate Trust is facilitating a process to identify potential future uses of the Site. The actual redevelopment will be implemented by one or more third parties.

Restoration: Covers activities designed to address damage or harm to ecosystems caused by contamination. For Kerr McGee, the Navassa Trustees Council is managing restoration activities.

EPA

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A Citizen's Guide to Excavation of Contaminated Soil

EPA

What Is the Excavation of Contaminated Soil?

Excavation of contaminated soil from a site involves digging it up for "ex situ" (above-ground) treatment or for disposal in a landfill. Excavation also may involve removing old drums of chemicals and other buried debris that might be contaminated. Removing these potential sources of contamination keeps people from coming into contact with contamination and helps speed the cleanup of contaminated groundwater that may be present.

How Does It Work?

Before excavation can begin, the contaminated areas must be identified. This requires researching past activities at the site to identify what contaminants may have been released and where. The soil is then tested to better define where contaminants are present.

Contaminated soil is excavated using standard construction equipment, like backhoes and excavator trackhoes. The equipment chosen depends on how large and deep the contaminated area is, and whether access is limited by the presence of buildings or other structures that cannot be moved. Long-arm excavators can reach as deep as 100 feet below ground, but excavations are generally limited to much shallower depths due to safety concerns and difficulty keeping the hole open. Sometimes soil is excavated below the water table, which requires walling off the contaminated area and pumping out the water to keep dry during excavation.

Soil piles are covered with plastic tarps during excavation.

Worker collects soil samples to confirm that soil left onsite is clean.

If excavated soil will be disposed of in a landfill, it may be placed directly on a dump truck for transport. If it is to be disposed of elsewhere on the site or treated, it first may be stock piled on plastic tarps or in containers. The soil is then covered with tarps to prevent wind and rain from blowing or washing it away and to keep workers from coming into contact with contaminated soil. Excavation is complete when test results show that the remaining soil around the hole meets established cleanup levels.

The excavated soil may be cleaned using a mobile treatment facility brought to the site or disposed offsite. If the soil is treated onsite, treated soil may be used to fill in the excavated area. Clean soil obtained from other locations may be needed to fill in holes as well. After an excavation is filled in, the area may be landscaped to prevent soil erosion and make the site more attractive.

How Long Will It Take?

Excavating contaminated soil may take as little as one day or as long as several years. The actual time it takes to excavate will depend on several factors. For example, it may take longer where:

- The contaminated area is large, very deep, or below the water table.

- Contaminant concentrations are high, requiring extra safety precautions.
- The contaminated soil contains a lot of rocks or debris.
- Buildings or site activities limit the movement of equipment.
- The site is remote, or the treatment and disposal facilities are far away.

These factors vary from site to site.

Is Excavation Safe?

Handling contaminated soil requires precautions to ensure safety. Site workers are trained to follow safety procedures while excavating soil to avoid contact with contaminants and prevent the spread of contamination offsite. Site workers typically wear protective clothing such as rubber gloves, boots, hard hats, and coveralls. These items are either washed or disposed of before leaving the site to keep workers from carrying contaminated soil offsite on their shoes and clothing. The tires and exteriors of trucks and other earth-moving equipment are also washed before leaving the site so that the soil is not tracked through neighboring streets.

Workers monitor the air to make sure dust and contaminant vapors are not present at levels that may pose a breathing risk, and monitors may be placed around the site to ensure that dust or vapors are not leaving it. Site workers close to the excavation may need to wear "respirators," which are face masks equipped with filters that remove dust and contaminants from the air. Contaminated soil is usually covered until it can be treated or disposed of to prevent airborne dust or being washed away with rainwater. Contaminant vapors may be suppressed with foams or other materials.

How Might It Affect Me?

Nearby residents and businesses may notice increased truck traffic during soil excavation and the noise of earth-moving equipment. Excavations are fenced off to prevent entry to the area until it is backfilled and covered with clean soil.

Why Excavate Contaminated Soil?

Excavation is commonly used where in situ cleanup methods will not work quickly enough or will be too expensive. Offsite disposal and ex situ treatment are often the fastest ways to deal with high levels of contamination that pose an immediate risk to people or the environment. Excavation is also a cost-effective approach for small amounts of contaminated soil.

Example

Soil excavation for offsite treatment and disposal was used to clean up the Federal Creosote Superfund site in New Jersey. Residential housing and a shopping mall had been built on the 50-acre property after a wood-treating facility closed in the 1950s. Creosote and waste chemicals that had been stored in lagoons were buried during construction.

Contamination was discovered in the 1990s. Between 2002 and 2008, soil was excavated from as deep as 35 feet near 93 homes. Some residents were relocated, and 18 homes were demolished to reach the contaminated soil beneath. A total of 275,000 tons of soil from this area was transported offsite for treatment and disposal. Another 177,000 tons were excavated from the mall property. Clean soil was used to fill in the excavations.

Throughout the work, workers monitored the air. Soil was covered with foam and plastic sheets to reduce odors from the creosote. Trucks were cleaned prior to leaving the property.

For More Information

For more information about this and other technologies in the Citizen's Guide Series, visit:

www.cluin.org/remediation
www.cluin.org/products/citguide

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United States Environmental Protection Agency

Office of Solid Waste and Emergency Response (5102G)

EPA 542-F-12-007
September 2012
www.epa.gov/superfund/sites
www.cluin.org

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A Citizen's Guide to In Situ Chemical Oxidation

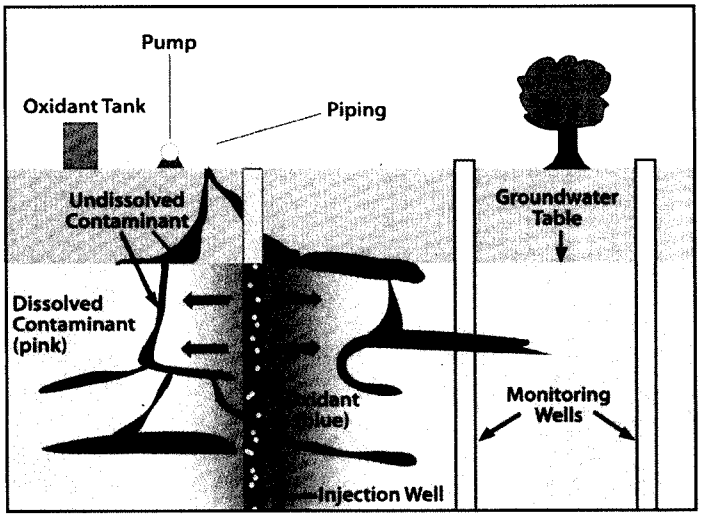
EPA

What Is In Situ Chemical Oxidation?

Chemical oxidation uses chemicals called "oxidants" to help change harmful contaminants into less toxic ones. It is commonly described as "in situ" because it is conducted in place, without having to excavate soil or pump out groundwater for aboveground cleanup. In situ chemical oxidation, or "ISCO," can be used to treat many types of contaminants like fuels, solvents, and pesticides. ISCO is usually used to treat soil and groundwater contamination in the source area where contaminants were originally released. The source area may contain contaminants that have not yet dissolved into groundwater. Following ISCO, other cleanup methods, such as pump and treat or monitored natural attenuation, are often used to clean up the smaller amounts of contaminants left behind. (See *A Citizen's Guide to Pump and Treat* [EPA 542-F-12-017] and *A Citizen's Guide to Monitored Natural Attenuation* [EPA 542-F-12-014].)

How Does It Work?

When oxidants are added to contaminated soil and groundwater, a chemical reaction occurs that destroys contaminants and produces harmless byproducts. To treat soil and groundwater in situ, the oxidants are typically injected underground by pumping them into wells. The wells are installed at different depths in the source area to reach as much dissolved and undissolved contamination as possible. Once the oxidant is pumped down the wells, it spreads into the surrounding soil and groundwater where it mixes and reacts with contaminants.



To improve mixing, the groundwater and oxidants may be recirculated between wells. This involves pumping oxidants down one well and then pumping the groundwater mixed with oxidants out another well. After the mixture is pumped out, more oxidant is added, and it is pumped back (recirculated) down the first well. Recirculation helps treat a larger area faster. Another option is to inject and mix oxidants using mechanical augers or excavation equipment. This may be particularly helpful for clay soil.

The four major oxidants used for ISCO are permanganate, persulfate, hydrogen peroxide and ozone. The first three oxidants are typically injected as liquids. Although ozone is a strong oxidant, it is a gas, which can be more difficult to use. As a result, it is used less often.

Catalysts are sometimes used with certain oxidants. A catalyst is a substance that increases the speed of a chemical reaction. For instance, if hydrogen peroxide is added with an iron catalyst, the mixture becomes more reactive and destroys more contaminants than hydrogen peroxide alone.

Following treatment, if contaminant concentrations begin to climb back up or "rebound," a second or third injection may be needed. Concentrations will rebound if the injected oxidants did not reach all of the contamination, or if the oxidant is used up before all the contamination is treated. It may take several weeks to months for the contamination to reach monitoring wells and to determine if rebound is occurring.

ISCO may produce enough heat underground to cause the contaminants in soil and groundwater to evaporate and rise to the ground surface. Controlling the amount of oxidant helps avoid excessive heat, and if significant gases are produced, they can be captured and treated.

How Long Will It Take?

ISCO works relatively quickly to clean up a source area. Cleanup may take a few months or years, rather than several years or decades. The actual cleanup time depends on several factors that vary site to site. For example, ISCO will take longer where:

- The source area is large.
- Contaminants are trapped in hard-to-reach areas like fractures or clay.
- The soil or rock does not allow the oxidant to spread quickly and evenly.
- Groundwater flow is slow.
- The oxidant does not last long underground.

Is ISCO Safe?

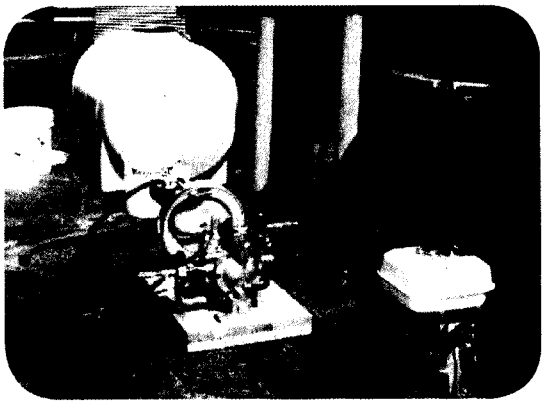
The use of ISCO poses little risk to the surrounding community. Workers wear protective clothing when handling oxidants, and when handled properly, these chemicals are not harmful to the environment or people. Because contaminated soil and groundwater are cleaned up underground, ISCO does not expose workers or others at the site to contamination. Workers test soil and groundwater regularly to make sure ISCO is working.

How Might It Affect Me?

Nearby residents and businesses may see drilling rigs and tanker trucks with oxidants and supplies as they are driven to the site. Residents may also hear the operation of drilling rigs, pumps, and other equipment leading up to and during the injection period. Following an injection, however, the cleanup process occurs underground with little aboveground disruption. Workers may visit the site to collect soil and groundwater samples to monitor cleanup progress.

Why Use ISCO?

ISCO is usually selected to clean up a source area, where it destroys the bulk of contaminants in situ without having to dig up soil or pump out groundwater for aboveground treatment. This can save time and money. ISCO has successfully cleaned up many contaminated sites and has been selected or is being used at around 40 Superfund sites and many other sites across the country.



ISCO system installed behind a small drycleaning facility.

Example

Groundwater near a former wastewater treatment plant at the Naval Air Station Pensacola in Florida was contaminated with solvents and acids from painting and electroplating. A groundwater pump and treat system had operated for more than 10 years to control migration of contaminated groundwater. However, it did not do much to lower the concentrations of contaminants. ISCO using hydrogen peroxide with an iron catalyst was chosen to reduce contaminant concentrations in the source area enough to allow monitored natural attenuation to complete the cleanup.

The natural chemistry of the site's groundwater was found to limit the effectiveness of the first phase of injections. In the second phase, a chemical was added to the reagent mix to stabilize the oxidant mixture. Contaminant levels fell substantially. The successful use of ISCO at this site was estimated to save several million dollars compared with continued pump and treat.

For More Information

For more information about this and other technologies in the Citizen's Guide Series, visit:

www.cluin.org/remediation
www.cluin.org/products/citguide
www.cluin.org/chemox

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United States Environmental Protection Agency

Office of Solid Waste and Emergency Response (5102G)

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September 2012
www.epa.gov/superfund/sites
www.cluin.org

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A Citizen's Guide to In Situ Thermal Treatment

EPA

What is In Situ Thermal Treatment?

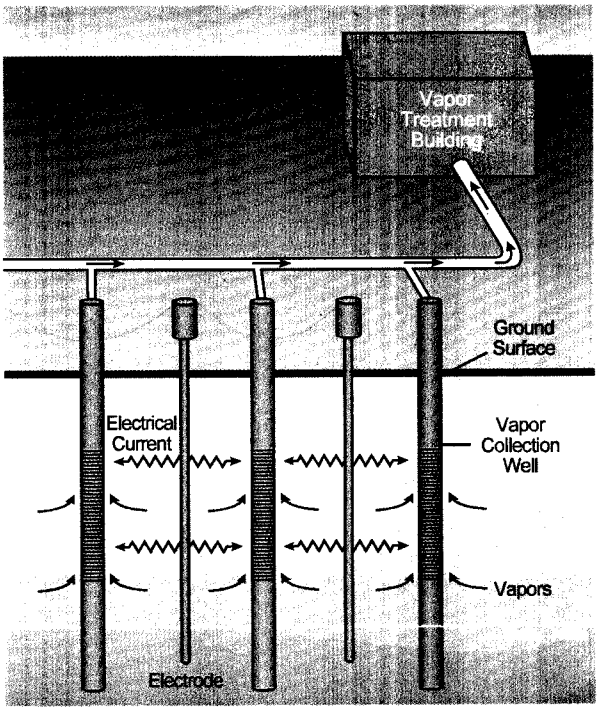
In situ thermal treatment methods move or "mobilize" harmful chemicals in soil and groundwater using heat. The chemicals move through soil and groundwater toward wells where they are collected and piped to the ground surface to be treated using other cleanup methods. Some chemicals are destroyed underground during the heating process. Thermal treatment is described as "in situ" because the heat is applied underground directly to the contaminated area. It can be particularly useful for chemicals called "non-aqueous phase liquids" or "NAPLs," which do not dissolve readily in groundwater and can be a source of groundwater contamination for a long time if not treated. Examples of NAPLs include solvents, petroleum, and creosote (a wood preservative).

How Does It Work?

In situ thermal treatment methods heat contaminated soil, and sometimes nearby groundwater, to very high temperatures. The heat vaporizes (evaporates) the chemicals and water changing them into gases. These gases, also referred to as "vapors," can move more easily through soil. The heating process can make it easier to remove NAPLs from both soil and groundwater. High temperatures also can destroy some chemicals in the area being heated.

In situ thermal methods generate heat in different ways:

- **Electrical resistance heating (ERH)** delivers an electrical current between metal rods called "electrodes" installed underground. The heat generated as movement of the current meets resistance from soil converts groundwater and water in soil into steam, vaporizing contaminants.
- **Steam enhanced extraction (SEE)** injects steam underground by pumping it through wells drilled in the contaminated area. The steam heats the area and mobilizes and evaporates contaminants.
- **Thermal conduction heating (TCH)** uses heaters placed in underground steel pipes. TCH can heat the contaminated area hot enough to destroy some chemicals.



The chemical and water vapors are pulled to collection wells and brought to the ground surface by applying a vacuum. (See *A Citizen's Guide to Soil Vapor Extraction and Air Sparging* [EPA 542-12-018] for information on how this is done.) The vapors are then treated above ground using one of several cleanup methods available. Or, if concentrations are high, the vapors can be condensed back to liquid chemicals and reused.

How Long Will It Take?

In situ thermal treatment might take a few months to a few years to clean up a site. The actual cleanup time will depend on several factors. For example, it might take longer where:

- Contaminant concentrations are high.
- The contaminated area is large or deep.
- A variety of soil types are present, causing the ground to heat unevenly.
- The soil has a lot of organic matter, which causes chemicals to stick to the soil and not evaporate easily.

These factors vary from site to site.

Are In Situ Thermal Treatment Methods Safe?

In situ thermal treatment methods do not pose a threat to site workers or the community when properly operated. For instance, when using ERH, the electrical current is prevented from traveling outside of the treatment area or to aboveground structures by using common electrical grounding techniques. A thermal treatment area is usually covered with an impermeable surface cover (such as concrete, asphalt, or a heavy-duty tarp) to keep the heat and steam underground. Such seals also help prevent the release of chemical vapors to the air. In addition, workers test air samples to make sure that vapors are being captured.

How Might It Affect Me?

In situ thermal treatment requires the use of drilling equipment and other heavy machinery to install wells or electrodes and to collect and treat vapors. Neighborhoods near the site may experience some increased truck traffic as the equipment is delivered and later removed. Nearby residents and businesses also may hear operating equipment.

Why Use In Situ Thermal Treatment?

In situ thermal treatment methods speed the cleanup of many types of chemicals, and are among the few in situ methods that can clean up NAPLs. Thermal treatment can be used in silty or clayey soil where other cleanup methods do not perform well. They also can reach contamination deep underground or beneath buildings, which would otherwise be difficult or costly to dig up to treat above ground. In situ thermal treatment has been selected or is being used in cleanups of at least 12 Superfund sites as well as dozens of other sites across the country.

ERH system cleans up contaminated soil and groundwater.

Example

SEE was used to speed clean up of the Southern California Edison Co., Visalia Pole Yard Superfund site in California. Use of chemicals to treat wooden utility poles contaminated soil and groundwater at the facility. Conventional "pump and treat," begun in 1984, did not show much progress in meeting cleanup objectives. In 1997, 14 steam injection wells were installed around the contaminated area. Steam was injected into the ground at depths of 80-100 feet, vaporizing the chemicals and forcing them toward the collection wells.

Initially, about 13,000 pounds of contaminants were pumped from the collection wells every day. SEE was stopped after three years when the wells began collecting less than 4 pounds per day, indicating that most of the chemicals had been removed. The pump and treat system was turned off in 2004. Overall, about 1.3 million pounds of contaminants were removed, and groundwater contaminant concentrations were reduced to below drinking water standards. By using SEE as part of the cleanup effort, the overall site cleanup was reduced from an estimated 120 years to 20 years.

For More Information

For more information about this and other technologies in the Citizen's Guide Series, visit:

www.cluin.org/remediation
www.cluin.org/products/citguide
www.cluin.org/products/Thermal In

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United States Environmental Protection Agency

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A Citizen's Guide to Monitored Natural Attenuation

EPA

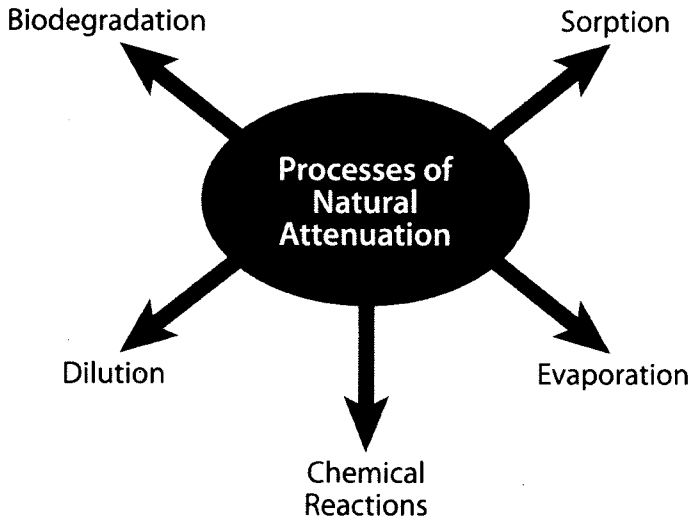
What Is Monitored Natural Attenuation?

Natural attenuation relies on natural processes to decrease or "attenuate" concentrations of contaminants in soil and groundwater. Scientists monitor these conditions to make sure natural attenuation is working. Monitoring typically involves collecting soil and groundwater samples to analyze them for the presence of contaminants and other site characteristics. The entire process is called "monitored natural attenuation" or "MNA." Natural attenuation occurs at most contaminated sites. However, the right conditions must exist underground to clean sites properly and quickly enough. Regular monitoring must be conducted to ensure that MNA continues to work.

How Does It Work?

When the environment is contaminated with harmful chemicals, nature may work in five ways to clean it up:

- *Biodegradation* occurs when very small organisms, known as "microbes," eat contaminants and change them into small amounts of water and gases during digestion. Microbes live in soil and groundwater and some microbes use contaminants for food and energy. (*A Citizen's Guide to Bioremediation* [EPA 542-F-12-003] describes how microbes work.)



- *Sorption* causes contaminants to stick to soil particles. Sorption does not destroy the contaminants, but it keeps them from moving deeper underground or from leaving the site with groundwater flow.
- *Dilution* decreases the concentrations of contaminants as they move through and mix with clean groundwater.
- *Evaporation* causes some contaminants, like gasoline and industrial solvents, to change from liquids to gases within the soil. If these gases escape to the air at the ground surface, air will dilute them and sunlight may destroy them.
- *Chemical reactions* with natural substances underground may convert contaminants into less harmful forms. For example, in low-oxygen environments underground, the highly toxic "chromium 6" can be converted to a much less toxic and mobile form called "chromium 3" when it reacts with naturally occurring iron and water.

MNA works best where the source of contamination has been removed. For instance, any waste buried underground must be dug up and disposed of properly, or removed using other available cleanup methods. When the source is no longer present, natural processes may be able to remove the remaining, smaller amount of contaminants in the soil or groundwater. The site is monitored regularly to make sure that contaminants attenuate fast enough to meet site cleanup objectives and that contaminants are not spreading.

How Long Will It Take?

MNA may take several years to decades to clean up a site. The actual cleanup time will depend on several factors. For example, cleanup will take longer when:

- Contaminant concentrations are higher.
- The contaminated area is large.
- Site conditions (such as temperature, groundwater flow, soil type) provide a less favorable environment for biodegradation, sorption or dilution.

These factors vary from site to site.

Is It Safe?

MNA does not pose a threat to the community or to site workers. MNA does not involve excavating soil or pumping groundwater to the surface for above ground treatment, so the potential to contact contaminants is limited. Long-term, regular monitoring is conducted to make sure contamination does not leave the site and that it is being attenuated at a rate that's consistent with cleanup goals for the site. This ensures that people and the environment are protected during the cleanup process.

How Might It Affect Me?

Generally, MNA does not cause much disruption to the surrounding community since no heavy machinery or other equipment is required during the MNA process. Residents and businesses near the site may initially see and hear drilling rigs when wells to monitor groundwater quality are installed. Once installed, workers will need to visit the site to collect samples of groundwater, soil or sediment to ensure MNA is working properly and is protective of human health and the environment. At those times, residents may hear the pumps and generators often used to collect groundwater samples from the wells.

Why Use Monitored Natural Attenuation?

MNA is selected when any contaminant source has been removed and only low concentrations of contaminants remain in soil or groundwater. The anticipated cleanup time for MNA must be reasonable compared to that of other more active cleanup methods. MNA requires less equipment and labor than most methods, which decreases cleanup costs. However, the cost of many years of monitoring can be high. MNA has been selected or is being used at over 100 Superfund sites across the country.

Monitoring natural attenuation at the site by collecting a groundwater sample.

Example

MNA is being used to complete groundwater cleanup at a former landfill on the Kings Bay Naval Submarine Base, Georgia. From 1993 to 2001, other cleanup methods were used to contain and treat the source of solvents in the groundwater. The goal was to reduce solvent concentrations to a level at which MNA would ensure safe concentrations at the property boundary, and unsafe levels of solvents would no longer flow beneath nearby housing. MNA was considered an efficient final treatment because of the right conditions for bioremediation to occur.

Monitoring for natural attenuation has been occurring monthly since 1998. Groundwater is being sampled for solvents and other conditions that indicate MNA is working. The long-term objective is to reduce contaminant concentrations across the site to below Maximum Contaminant Levels (MCLs). Concentrations have decreased at most wells, but the groundwater in the former source area is still expected to take decades to reach MCLs.

For More Information

For more information about this and other technologies in the Citizen's Guide Series, visit:

www.cluin.org/remediation
www.cluin.org/products/citguide
www.cluin.org/products/MNA

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A Citizen's Guide to Phytoremediation

EPA

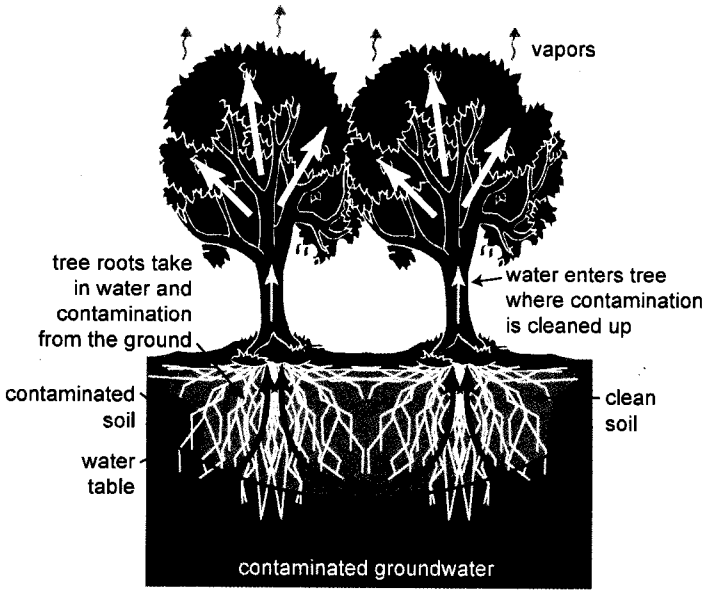
What Is Phytoremediation?

Phytoremediation uses plants to clean up contaminated environments. Plants can help clean up many types of contaminants including metals, pesticides, explosives, and oil. However, they work best where contaminant levels are low because high concentrations may limit plant growth and take too long to clean up. Plants also help prevent wind, rain, and groundwater flow from carrying contaminants away from the site to surrounding areas or deeper underground.

How Does It Work?

Certain plants are able to remove or break down harmful chemicals from the ground when their roots take in water and nutrients from the contaminated soil, sediment, or groundwater. Plants can help clean up contaminants as deep as their roots can reach using natural processes to:

- Store the contaminants in the roots, stems, or leaves.
- Convert them to less harmful chemicals within the plant or, more commonly, the root zone.
- Convert them to vapors, which are released into the air.
- Sorb (stick) contaminants onto their roots where very small organisms called "microbes" (such as bacteria) that live in the soil break down the sorbed contaminants to less harmful chemicals. (See *A Citizen's Guide to Bioremediation* [EPA 542-F-12-003].)



Phytoremediation often is used to slow the movement of contaminated groundwater. Trees act like a pump, drawing the groundwater up through their roots to keep it from moving. This method of phytoremediation is called "hydraulic control." It reduces the movement of contaminated groundwater toward clean areas offsite.

Constructed wetlands are another form of phytoremediation. A wetland may be created at a site to treat acid mine drainage that flows through it or as a final treatment step for water discharged from other treatment systems. Water treated with constructed wetlands generally has very low concentrations of contaminants that need to be removed before it may be discharged into a lake or stream. The construction of wetlands may involve some excavation or regrading of soil at the site in order for water to flow through it without pumping. The area is planted with grasses and other vegetation typical of naturally occurring wetlands in the area.

Certain plants are better at removing contaminants than others. Plants used for phytoremediation must be able to tolerate the types and concentrations of contaminants present. They also must be able to grow and survive in the local climate. Depth of contamination is another factor. Small plants like ferns and grasses have been used where contamination is shallow. Because tree roots grow deeper, trees such as poplars and willows are used for hydraulic control or to clean up deeper soil contamination and contaminated groundwater.

How Long Will It Take?

Phytoremediation may take several years to clean up a site. The cleanup time will depend on several factors. For example, phytoremediation will take longer where:

- Contaminant concentrations are high.
- The contaminated area is large or deep.
- Plants that have a long growing time are used.
- The growing season is short.

These factors vary from site to site. Plants may have to be replaced if they are damaged by extreme weather, pests, or animals. This also will add time to the cleanup.

Is Phytoremediation Safe?

Phytoremediation is a low-risk and attractive cleanup method. Fences and other barriers are constructed to keep wildlife from feeding on contaminated plants. In certain instances, plants may release chemical vapors into the air in a process called "phytovolatilization." When this occurs, workers sample the air to make sure the plants are not releasing harmful amounts of vapors.

How Might It Affect Me?

Phytoremediation cleanups cause little disruption to the site or surrounding community. Initial work may involve grading or tilling of the soil with earth-moving equipment, and backhoes may be needed to plant trees and large shrubs. Residents and businesses near the site may hear equipment noise or detect an odor if fertilizer is added to the soil. Any airborne dust can be minimized by watering down the soil.

Plants used for phytoremediation can make a site more attractive. The use of native plants is encouraged since they are better adapted to the area's conditions and less likely to attract nuisance animals or pests.

Why Use Phytoremediation?

EPA uses phytoremediation for many reasons. It takes advantage of natural plant processes and requires less equipment and labor than other methods since plants do most of the work. Also, the site can be cleaned up without digging up and hauling soil or pumping groundwater, which saves energy. Trees and smaller plants used in phytoremediation help control soil erosion, make a site more attractive, reduce noise, and improve surrounding air quality.

Phytoremediation has been successfully used at many sites, including at least 10 Superfund sites across the country.

Poplar trees at a phytoremediation site.

Example

Phytoremediation is being used to clean up contaminated groundwater near a former disposal area at the Aberdeen Proving Ground in Maryland. This area was used for disposal and burning of industrial and warfare chemicals from 1940 through the 1970s. Chemicals used as industrial degreasers and solvents were found to be a particular problem in the groundwater.

In the spring of 1996, 183 poplar trees were planted in a one-acre area. The trees draw in contaminated groundwater and break down contaminants in the root zone. The groundwater levels near the trees show that they are keeping the plume of contaminants from moving to clean areas. EPA estimates that within 30 years of the start of cleanup, the contaminants in groundwater at the site may be reduced by up to 85 percent.

For More Information

For more information about this and other technologies in the Citizen's Guide Series, visit:

www.cluin.org/remediation
www.cluin.org/products/citguide
www.cluin.org/phyto

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A Citizen's Guide to Pump and Treat

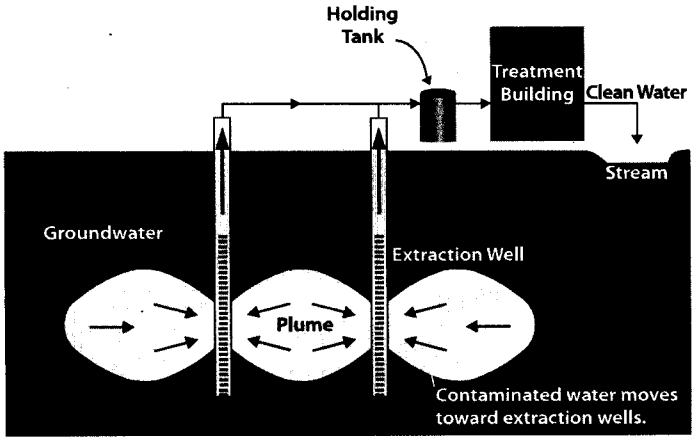
EPA

What Is Pump And Treat?

Pump and treat is a common method for cleaning up groundwater contaminated with dissolved chemicals, including industrial solvents, metals, and fuel oil. Groundwater is pumped from wells to an above-ground treatment system that removes the contaminants. Pump and treat systems also are used to "contain" the contaminant plume. Containment of the plume keeps it from spreading by pumping contaminated water toward the wells. This pumping helps keep contaminants from reaching drinking water wells, wetlands, streams, and other natural resources.

How Does It Work?

Pump and treat methods may involve installing one or more wells to extract the contaminated groundwater. Groundwater is pumped from these "extraction wells" to the ground surface, either directly into a treatment system or into a holding tank until treatment can begin. The treatment system may consist of a single cleanup method, such as activated carbon or air stripping, to clean the water. (See *A Citizen's Guide to Activated Carbon* [EPA 542-F-12-001] and *A Citizen's Guide to Air Stripping* [EPA 542-F-12-002].) However, treatment often requires several cleanup methods if the groundwater contains different types of contaminants or high concentrations of a single contaminant. The approach to treatment may be modified as contaminant concentrations decrease.



Example of a Pump and Treat System with Two Extraction Wells.

Once treated water meets regulatory standards, it may be discharged for disposal or further use. For example, treated water may be pumped back underground or into a nearby stream, or a sprinkler system may distribute the water over the ground surface to irrigate soil and plants. Treated water also may be discharged to the area's public sewer system for further treatment at the local wastewater treatment plant. Other wastes produced as a result of treatment, such as sludge or used filters, are disposed of properly.

Is Pump And Treat Safe?

Pump and treat is a safe way to both clean up contaminated groundwater and keep it from moving to other areas where it may affect drinking water supplies, wildlife habitats, or recreational rivers and lakes. Although pumping brings contamination to the ground surface, it does not expose people to that contamination. A pump and treat system is monitored to ensure the extraction wells and treatment units operate as designed. Also, the groundwater is sampled to ensure the plume is decreasing in concentration and is not spreading.

How Long Will It Take?

Pump and treat may last from a few years to several decades. The actual cleanup time will depend on several factors, which vary from site to site. For example, it may take longer where:

- Contaminant concentrations are high, or the contamination source has not been completely removed.
- The contaminant plume is large.
- Groundwater flow is slow, or the flow path is complex.

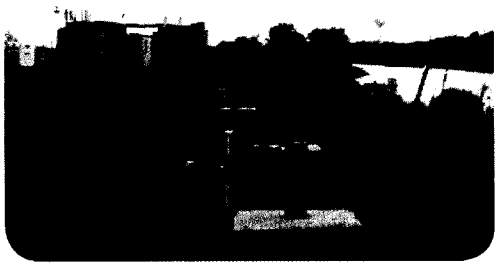
How Might It Affect Me?

People living or working near the site may see increased truck traffic while the system is being built as drill rigs and construction supplies arrive at the site. They also may hear the machinery used to drill wells

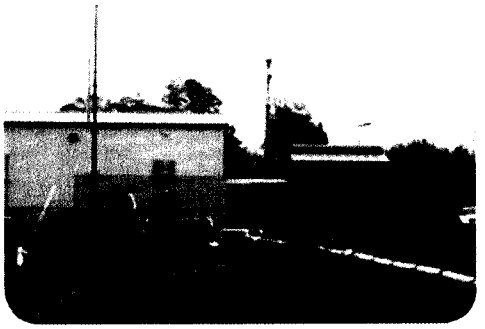
or construct the treatment system. Treatment systems usually are designed to minimize noise while operating. Because pump and treat cleanups can take a long time, systems can be designed so that other site activities may continue during cleanup. For example, the treatment system may be constructed in a location as far as possible from an office building or parking lot. It also may be enclosed by a fence or a shed so that it is less obvious.

Why Use Pump And Treat?

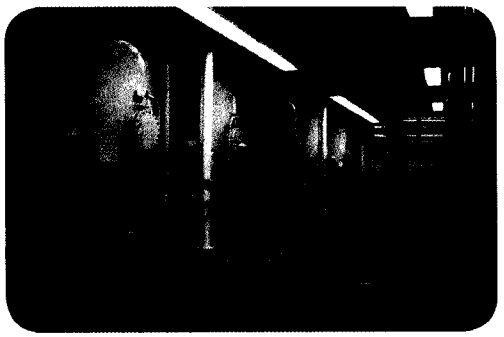
Pump and treat is used to remove a wide range of contaminants that are dissolved in groundwater. Pump and treat typically is used once the source of groundwater contamination, such as leaking drums and contaminated soil, has been treated or removed from the site. It also is used to contain plumes so that they do not move offsite or toward lakes, streams, and water supplies. Pump and treat is the most common cleanup method for groundwater. It has been selected or is being used at over 800 Superfund sites across the country.



Groundwater Pumping Wells



Groundwater Treatment Building



Indoor Treatment Facility

Outdoor Treatment Facility

Example

The Baird and McGuire Superfund site in Massachusetts was contaminated when chemicals stored in tanks leaked into the soil and groundwater. The contaminated groundwater plume flowed offsite, contaminating and closing the town's main water supply. Since 1993, a pump and treat system has been containing the plume and cleaning up groundwater.

Pump and treat began after much of the contaminated soil at the site was excavated for treatment. Eight pumping wells were installed at the site (seven still operate) typically pumping a total of about 127 gallons of groundwater per minute. The treatment plant includes a metals removal system, air strippers, and activated carbon units to remove a wide range of contaminants. It also has filters and a sludge disposal system. Treated water is pumped back underground at the site. Groundwater sampling has shown that treatment continues to protect human health and the environment by containing the plume and removing contaminants. The system is expected to operate well into the future.

For More Information

For more information about this and other technologies in the Citizen's Guide Series, visit:

www.cluin.org/remediation
www.cluin.org/products/citguide

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A Citizen's Guide to Solidification and Stabilization

EPA

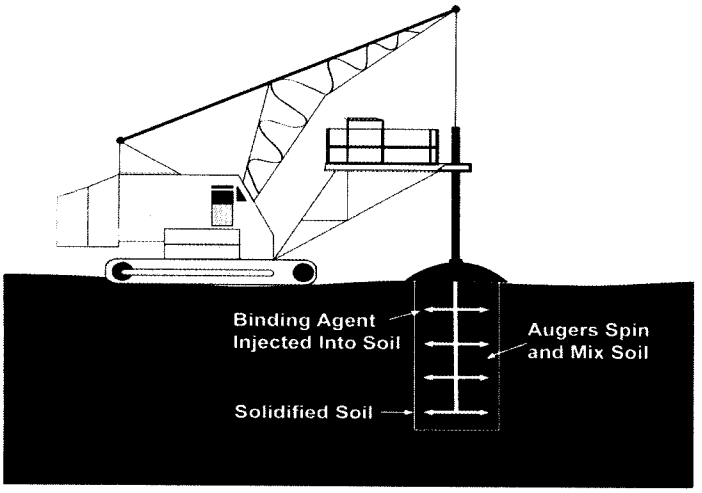
What Are Solidification And Stabilization?

Solidification and stabilization refer to a group of cleanup methods that prevent or slow the release of harmful chemicals from wastes, such as contaminated soil, sediment, and sludge. These methods usually do not destroy the contaminants. Instead, they keep them from "leaching" above safe levels into the surrounding environment. Leaching occurs when water from rain or other sources dissolves contaminants and carries them downward into groundwater or over land into lakes and streams.

Solidification binds the waste in a solid block of material and traps it in place. This block is also less permeable to water than the waste. Stabilization causes a chemical reaction that makes contaminants less likely to be leached into the environment. They are often used together to prevent people and wildlife from being exposed to contaminants, particularly metals and radioactive contaminants. However, certain types of organic contaminants, such as PCBs and pesticides, can also be solidified.

How Does It Work?

Solidification involves mixing a waste with a binding agent, which is a substance that makes loose materials stick together. Common binding agents include cement, asphalt, fly ash, and clay. Water must be added to most mixtures for binding to occur; then the mixture is allowed to dry and harden to form a solid block.



Binding agents can be injected into soil and mixed using augers.

Similar to solidification, stabilization also involves mixing wastes with binding agents. However, the binding agents also cause a chemical reaction with contaminants to make them less likely to be released into the environment. For example, when soil contaminated with metals is mixed with water and lime — a white powder produced from limestone — a reaction changes the metals into a form that will not dissolve in water.

Additives can be mixed into the waste while still in the ground (often referred to as "in situ"). This usually involves drilling holes using cranes with large mixers or augers, which both inject the additives underground and mix them with the waste. The number of holes needed depends on the size of the augers and the contaminated area. Dozens of holes may need to be drilled. When the waste is shallow enough, the contaminated soil or waste is excavated and additives are mixed with it above ground (often referred to as "ex situ"). The waste is either mixed using backhoes and front end loaders or placed in machines called "pug mills." Pug mills can grind and mix materials at the same time.

Solidified or stabilized waste mixed above ground is either used to fill in the excavation or transported to a landfill for disposal. Waste mixed in situ is usually covered with a "cap" to prevent water from contacting treated waste (See *A Citizen's Guide to Capping* [EPA 542-12-004].)

How Long Will It Take?

Solidification and stabilization may take weeks or months to complete. The actual time it takes will depend on several factors. For example, they may take longer where:

- The contaminated area is large or deep.
- The soil is dense or rocky, making it harder to mix with the binding agent.
- Mixing occurs above ground, which requires excavation.
- Extreme cold or rainfall delays treatment.

Are Solidification And Stabilization Safe?

The additives used in solidification and stabilization often are materials used in construction and other activities. When properly handled, these materials do not pose a threat to workers or the community. Water or foam can be sprayed on the ground to make sure that dust and contaminants are not released to the air during mixing. If necessary, the waste can be mixed inside tanks, or the mixing area can be covered to minimize dust and vapors. The final solidified or stabilized product is tested to ensure that contaminants do not leach. The strength and durability of the solidified materials are also tested.

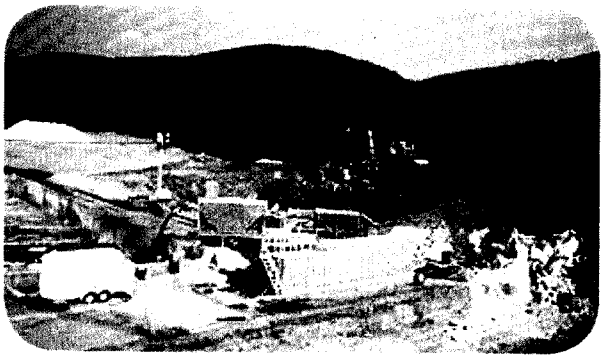
Large augers inject and mix binding agent with contaminated soil.

How Might It Affect Me?

Nearby residents or businesses may notice increased truck traffic as equipment and additives are brought to the site or as treated waste is transported to a landfill. They also may hear earth-moving equipment as waste is excavated or mixed. When cleanup is complete, the land often can be redeveloped.

Why Use Solidification Or Stabilization?

Solidification and stabilization provide a relatively quick and lower-cost way to prevent exposure to contaminants, particularly metals and radioactive contaminants. Solidification and stabilization have been selected or are being used in cleanups at over 250 Superfund sites across the country.



Contaminated soil mixed with cement in a pug mill is spread on the ground as pavement.

Example

Solidification and stabilization were used to clean up contaminated sludge and soil at the South 8th Street Landfill Superfund site in Arkansas. From the 1960s to 1970s, municipal and industrial wastes were disposed at the site, including a 2.5-acre pit of waste-oil sludge. In the 1980s, that area was found to be contaminated with oily wastes, PCBs, pesticides, and lead.

In 1999, cranes with augers were used to inject and mix limestone, fly ash, and Portland cement with 40,000 cubic yards of sludge and soil in the pit. These additives helped solidify the mixture as well as stabilize the lead and other metals. The hardened material was left in place and covered with a soil cap. Evaluations in 2004 and 2009 indicated that the cleanup approach is still protecting human health and the environment. The site has been deleted from the National Priorities List, the list of the nations most serious hazardous waste sites.

For More Information

For more information about this and other technologies in the Citizen's Guide Series, visit:

www.cluin.org/remediation
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A Citizen's Guide to Vertical Engineered Barriers

What Are Vertical Engineered Barriers?

A vertical engineered barrier, or "VEB," is a wall built below ground to control the flow of groundwater. VEBs may be used to divert the direction of contaminated groundwater flow to keep it from reaching drinking water wells, wetlands, or streams. They also may be used to contain and isolate contaminated soil and groundwater to keep them from mixing with clean groundwater. VEBs differ from permeable reactive barriers in that they do not clean up contaminated groundwater. (See *A Citizens Guide to Permeable Reactive Barriers* [EPA 542-F-12-015].) However, cleanup methods often are used together with VEBs to treat the isolated soil or groundwater.

How Do They Work?

VEBs are made of impermeable or slightly permeable materials, which means they prevent or minimize the flow of water and contaminants through the wall. A slurry wall is the most common type of VEB. It is constructed by digging a narrow trench, usually 2 to 4 feet wide with a backhoe or long-reach excavator. The trench is filled with slurry, which consists of soil mixed with water and clay. A type of clay called "bentonite" is used most often because it expands when wet to fill gaps or holes in the VEB. Cement may be added to make the slurry wall stronger.

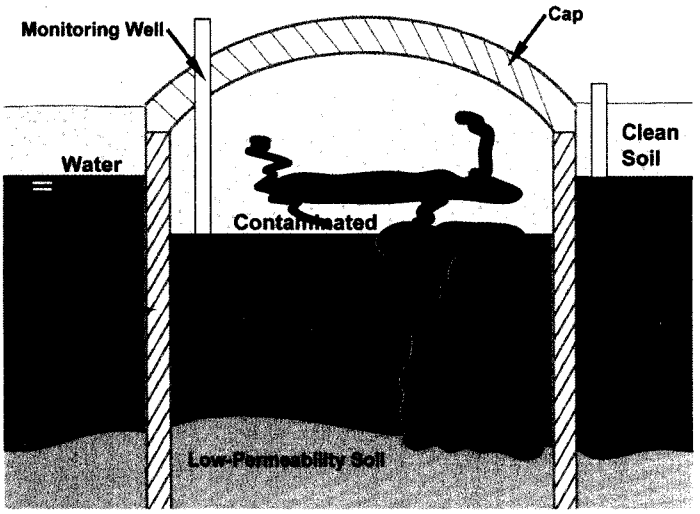


Illustration of a VEB containment system around a contaminated area

A VEB also can be constructed using sheet pilings made of steel, vinyl, or other materials. Sheet pilings are large sheets linked together at their edges to form a wall. Equipment is used to hammer or vibrate the sheets into the ground.

Where possible, the bottom of the VEB is "keyed into" a low-permeability layer of soil or bedrock. This means the bottom of the wall extends several inches into the soil or to the top of the bedrock, which helps to keep groundwater from seeping beneath the wall. A protective cap may be installed atop the VEB to prevent damage from vehicle traffic or other activities. A larger impermeable cap often is placed over the entire contaminated area enclosed by the VEB to prevent rain water and snow melt from entering it. (See *A Citizen's Guide to Capping* [EPA 542-F-12-004].)

Even when surrounded by a VEB and cap, contaminated groundwater may build up in the isolated area or move outward through small openings in the VEB toward clean areas. To prevent this, wells may be drilled within the isolated area to pump out groundwater. Contaminated groundwater that has been pumped to the ground surface usually will require treatment.

The VEB, cap, and pumping wells are maintained and monitored to ensure the contaminated area remains isolated and that contaminated groundwater does not spread to clean areas.

How Long Will It Take?

Building a VEB may take anywhere from several days to several months. Construction of a VEB may take longer where:

- The contaminated area is large or deep.
- Soil is hard or rocky.
- The VEB is wide.

These factors vary from site to site. Some VEBs may stay in place permanently.

Are Vertical Engineered Barriers Safe?

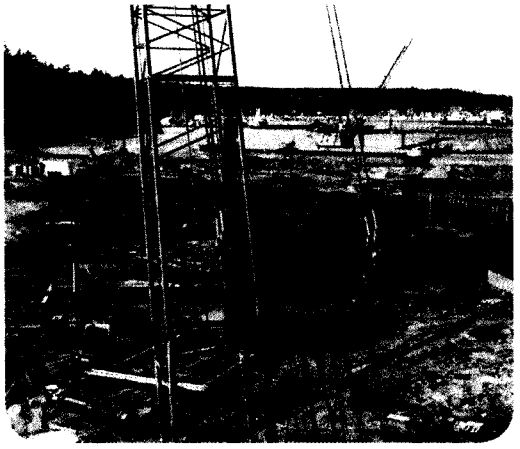
The materials used to construct a VEB generally pose little risk to people or the environment. VEBs are effective at keeping contaminated groundwater from flowing toward clean areas. A VEB will continue to be protective as long as it is properly inspected and maintained. VEBs and the groundwater are monitored to make sure that there is no damage to the wall and contaminants are not moving to other areas.

How Might It Affect Me?

Residents near the site may see increased truck traffic as materials are brought to the site. Construction of the VEB may involve backhoes, pile drivers, or other noisy machines. If sheet pilings are hammered or vibrated into place, nearby residents also may feel the vibrations. If buildings or people are nearby, monitoring can be conducted to make sure noise and vibration levels do not exceed limits. Workers often use equipment that cause as little noise and vibration as possible. Workers will need to access the area for VEB maintenance and repairs or to collect groundwater samples to ensure the VEB is working. At sites where groundwater is being removed and treated, workers may be present for longer periods of time.

Why Use Vertical Engineered Barriers?

VEBs may be selected at sites where cleanup of contaminated groundwater is difficult and expensive, or cannot be completed before contamination spreads to areas where people and wildlife can come in contact with it. VEBs are also helpful in cases where cleanup methods could push contaminants to uncontaminated areas. VEBs typically are less expensive to build and maintain than other types of technologies, especially in large contaminated areas. VEBs have been selected or are being used at dozens Superfund sites across the United States.



Installation of sheet piling

Excavation of a slurry wall trench

Example

Spills of wood-treating chemicals contaminated the soil and groundwater at the Taylor Lumber and Treating Superfund site in Oregon. A 2,040-foot long, 2½-foot wide, VEB was constructed of bentonite and soil to isolate a plume of contaminated groundwater. The VEB encloses a 6-acre area and extends 14 to 16 feet below ground where it is keyed into bedrock. A protective asphalt cap installed over the VEB and contaminated area protect the VEB from heavy equipment traffic and prevent rainwater from soaking into the area it encloses.

As part of the long-term operation and maintenance of the VEB, groundwater is pumped from four wells in the contaminated area to keep contaminants and groundwater from seeping outside the wall. Groundwater outside the VEB is regularly sampled to make sure contaminants remain in the enclosed area and do not pose a threat to human health or the environment.

For More Information

For more information about this and other technologies in the Citizen's Guide Series, visit:

www.cluin.org/remediation
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Office of Solid Waste and Emergency Response (5102G)

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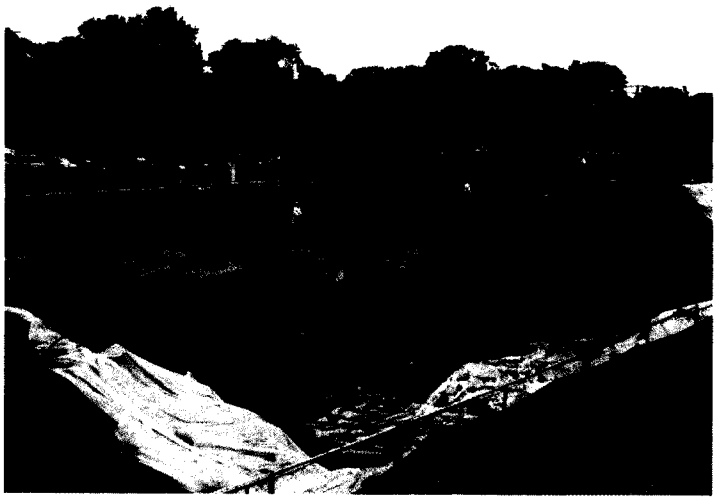
Cleanup Technolog

From the U.S. Environmental Protection Agency's "A Citizen's Guide to Cleanup Technologies" https://c

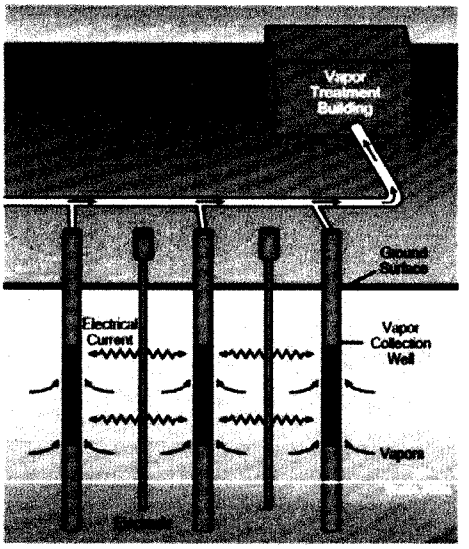
Physical removal

Remove contaminated soil, sediments or groundwater by excavating or e

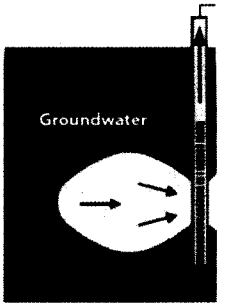
Excavating contaminated soil from a site involves digging it up for above-ground treatment or for disposal in a landfill.



In situ, thermal enhanced extraction "mobilizes" harmful chemicals in soil and groundwater using heat.



Pump and tre
groundwater
above-groun
Pump and tre
used to "cont
plume.

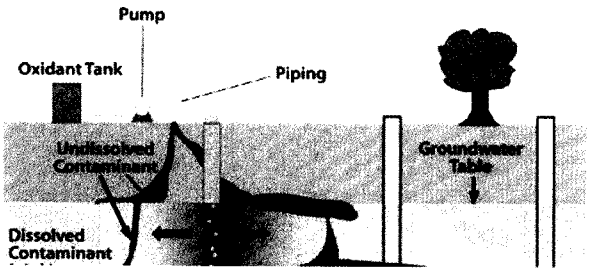


Example of a Pump ar

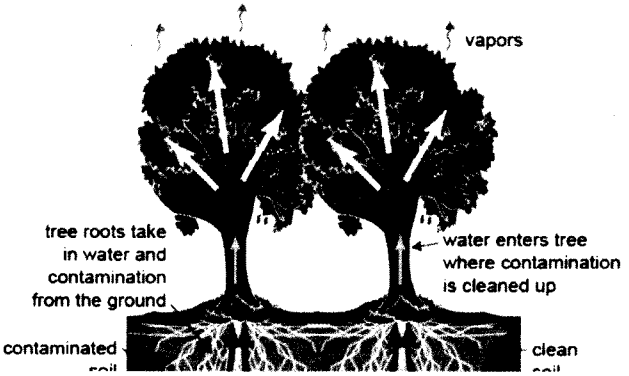
Chemical/biological treatment

Treat contamination to destroy or convert it to less harmful for

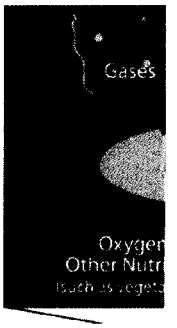
Chemical oxidation uses chemicals called "oxidants" to help change harmful contaminants into less toxic ones.



Phytoremediation uses plants to clean up contamination.



Enhanced
compound
to clean up



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A Citizen's Guide to Bioremediation

EPA

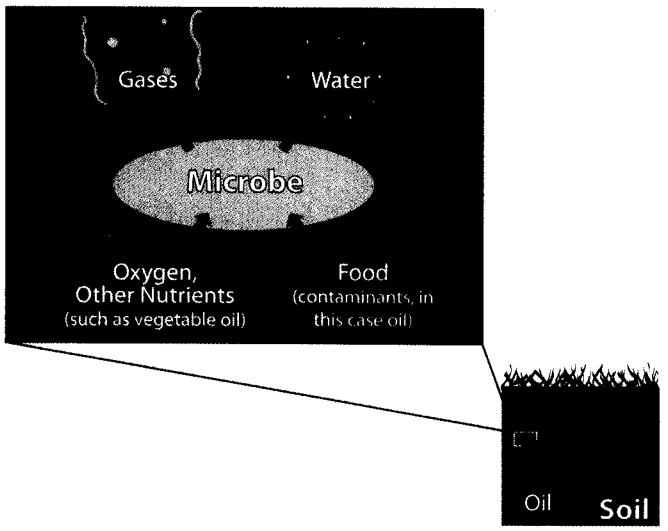
What Is Bioremediation?

Bioremediation is the use of microbes to clean up contaminated soil and groundwater. Microbes are very small organisms, such as bacteria, that live naturally in the environment. Bioremediation stimulates the growth of certain microbes that use contaminants as a source of food and energy. Contaminants treated using bioremediation include oil and other petroleum products, solvents, and pesticides.

How Does It Work?

Some types of microbes eat and digest contaminants, usually changing them into small amounts of water and harmless gases like carbon dioxide and ethene. If soil and groundwater do not have enough of the right microbes, they can be added in a process called "bioaugmentation."

For bioremediation to be effective, the right temperature, nutrients, and food also must be present. Proper conditions allow the right microbes to grow and multiply—and eat more contaminants. If conditions are not right, microbes grow too slowly or die, and contaminants are not cleaned up. Conditions may be improved by adding "amendments." Amendments range from household items like molasses and vegetable oil, to air and chemicals that produce oxygen. Amendments are often pumped underground through wells to treat soil and groundwater in situ (in place).



Microbe takes in oil, oxygen, and nutrients and releases gases and water.

The conditions necessary for bioremediation in soil cannot always be achieved in situ, however. At some sites, the climate may be too cold for microbes to be active, or the soil might be too dense to allow amendments to spread evenly underground. At such sites, EPA might dig up the soil to clean it "ex situ" (above ground) on a pad or in tanks. The soil may then be heated, stirred, or mixed with amendments to improve conditions.

Sometimes mixing soil can cause contaminants to evaporate before the microbes can eat them. To prevent the vapors from contaminating the air, the soil can be mixed inside a special tank or building where vapors from chemicals that evaporate may be collected and treated.

Is Oxygen Always Needed?

Some contaminants can only be bioremediated in an aerobic environment—one that contains oxygen. Others can only be bioremediated in an anaerobic environment without oxygen. Anaerobic microbes do not need oxygen to grow.

To clean up contaminated groundwater in situ, wells are drilled to pump some of the groundwater into above ground tanks. Here, the water is mixed with amendments before it is pumped back into the ground. The groundwater enriched with amendments allows microbes to bioremediate the rest of the contaminated groundwater underground. Groundwater also can be pumped into a "bioreactor" for ex situ treatment. Bioreactors are tanks in which groundwater is mixed with microbes and amendments for treatment. Depending on the site, the treated water may be pumped back to the ground or discharged to surface water or to a municipal wastewater system.

How Long Will It Take?

It may take a few months or even several years for microbes to clean up a site, depending on several factors. For example, bioremediation will take longer where:

- Contaminant concentrations are high, or contaminants are trapped in hard-to-reach areas, like rock fractures and dense soil.
- The contaminated area is large or deep.

- Conditions such as temperature, nutrients, and microbe population must be modified.
- Cleanup occurs ex situ.

Is Bioremediation Safe?

Bioremediation relies on microbes that live naturally in soil and groundwater. These microbes pose no threat to people at the site or in the community. Microbes added to the site for bioaugmentation typically die off once contamination and the conditions needed for bioremediation are gone. The chemicals added to stimulate bioremediation are safe. For example, the nutrients added to make microbes grow are commonly used on lawns and gardens, and only enough nutrients to promote bioremediation are added. To ensure that the treatment is working and to measure progress, samples of soil and groundwater are tested regularly.

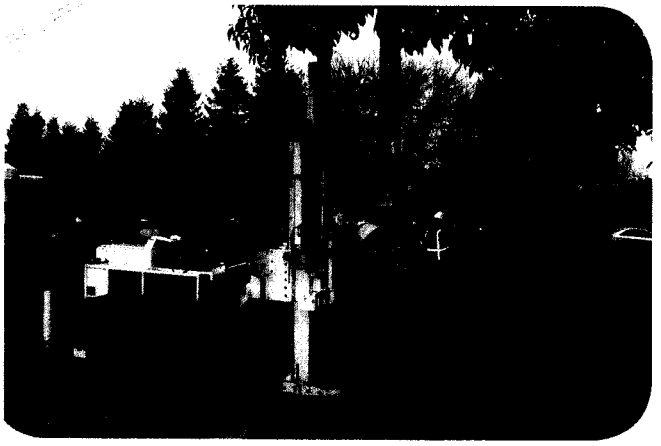
How Might It Affect Me?

Bioremediation often occurs underground and does not cause much disruption to the site or surrounding community. Contaminated soil and groundwater stay onsite, reducing truck traffic, compared with some other cleanup methods. However, area residents and businesses may hear the operation of pumps, mixers, and other construction equipment used to add amendments or improve site conditions to begin the bioremediation process. Excavation and pumping also will occur for ex situ bioremediation. (See a *Citizen's Guide to Excavation of Contaminated Soil* [EPA 542-F-12-007].)

Why Use Bioremediation?

Bioremediation has the advantage of using natural processes to clean up sites. Because it may not require as much equipment, labor, or energy as some cleanup methods, it can be cheaper. Another advantage is that contaminated soil and groundwater are treated onsite without having to dig, pump, and transport them elsewhere for treatment. Because microbes change the harmful chemicals into small amounts of water and gases, few if any waste byproducts are created.

Bioremediation has successfully cleaned up many polluted sites and has been selected or is being used at over 100 Superfund sites across the country.



Injection of vegetable oil underground to improve conditions for bioremediation.

Example

Bioremediation is cleaning up groundwater contaminated with dry cleaning solvent at the Iceland Coin Laundry Superfund site in New Jersey. To improve the conditions at the site for bioremediation, amendments were added. A solution of vegetable oil and baking soda was injected into the groundwater in an area of particularly high contaminant concentrations. Bacteria also were added to increase the existing population of microbes. The treatment area is about 1800 feet long, 500 feet wide and extends 40 feet below ground.

Preliminary testing of the groundwater has shown that bioremediation is working and contaminant concentrations are decreasing. The objective is to continue to reduce the concentration of contaminants from 10 or more parts per billion to less than 1 part per billion.

For More Information

For more information about this and other technologies in the Citizen's Guide Series, visit:

www.cluin.org/remediation
www.cluin.org/products/citguide
www.cluin.org/bioreactor
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A Citizen's Guide to Capping

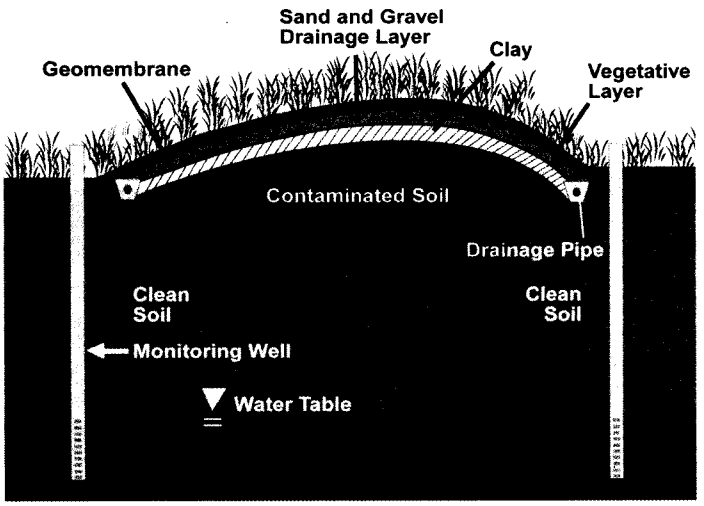
What Is Capping?

Capping involves placing a cover over contaminated material such as landfill waste or contaminated soil. Such covers are called "caps." Caps do not destroy or remove contaminants. Instead, they isolate them and keep them in place to avoid the spread of contamination. Caps prevent people and wildlife from coming in contact with contaminants.

How Does It Work?

A cap isolates and prevents the spread of contamination in several ways. For example, it can:

- Stop rain and snowmelt from seeping through the material and carrying contaminants to the groundwater.
- Keep storm water runoff from carrying contaminated material offsite or into lakes and streams.
- Prevent wind from blowing contaminated material offsite.
- Control releases of gas from wastes containing or producing "volatile" chemicals (those that evaporate).
- Keep people and wildlife from coming into contact with the hazardous material and tracking contaminants offsite.



Example of a cover with several layers.

The cap design selected for a site will depend on several factors, including the types and concentrations of contaminants present, the size of the site, the amount of rainfall the area receives, and the future use of the property. Construction of a cap can be as simple as placing a single layer of a material over lightly contaminated soil to placing several layers of different materials to isolate more highly contaminated wastes. For example, an asphalt cap might be selected to cover low levels of soil contamination on a property whose future reuse requires a parking lot. A cap for a hazardous waste landfill, however, might require several layers, including a vegetative layer, drainage layer, geomembrane, and clay layer. The following are some of the options for caps:

- **Asphalt or concrete:** A layer of these materials can serve as a parking lot or building slab foundation.
- **Vegetative layer:** A top layer of soil planted with grass or other vegetation can help prevent soil erosion and make the area look more natural and attractive. An evapotranspiration or "ET" cover is a vegetative cap in which the plants and underlying soil keep rain and snowmelt from soaking down into the contaminated area. (For more information, please see *A Citizen's Guide to Evapotranspiration Covers* [EPA 542-F-12-006.)
- **Drainage layer:** A layer of sand and gravel, often containing rows of slotted pipes, is built to collect and drain any water that makes it through the top layers of a cap.
- **Geomembrane:** A sheet of strong plastic-like material is used to prevent downward drainage of water and upward escape of gases.
- **Clay:** A layer of compacted clay also can help prevent the downward drainage of water.

Some landfill covers, such as those for municipal landfills, may also include collection and venting systems for methane and other gases that could build up underground.

How Long Will It Take?

Building a cap can take a few days up to several months. Construction may take longer when:

- The contaminated area is large.
- The design of the cap is thick or complex.
- Supplies of clean topsoil, clay, or other cap materials are not available locally.

Caps can be effective for many years when they are properly maintained. They are maintained for as long as the contaminated materials remain in place.

Is Capping Safe?

When properly built and maintained, a cap can safely keep contaminated material in place. A cap will continue to isolate contamination as long as it does not erode or develop cracks or holes that allow water to reach the contaminated material. Regular inspections are made to make sure that the weather, plant roots, and human activity have not damaged the cap and that plants on vegetative caps are still growing. Also, groundwater monitoring wells are placed around the capped area and sampled to help determine if leaks occur.

How Might It Affect Me?

Residents and businesses close to a site may see increased truck traffic as cap materials are brought to the site. Construction of the cap may involve bulldozers, backhoes, and other noisy equipment, and some soil may need to be excavated for use in the cap. Dust from excavation and construction can be controlled by spraying water or covering stockpiled materials with tarps.

Why Use Capping?

Capping is the traditional method for isolating landfill wastes and contaminants. It sometimes is used to address large volumes of soil or waste with low-levels of contamination. Caps made of asphalt or concrete, or even a layer of soil planted with grass, can allow some sites to be reused. Caps have been selected for use at many Superfund sites across the country.

Spring grasses grow on the cap of a hazardous waste landfill.

Example

Capping is one of several methods being used to protect people and the environment from contamination at the Roebling Steel Superfund site in New Jersey. Drums and other wastes were removed from one 5-acre area of the site. Two areas of soil that remained contained metals and other contaminants from steel manufacturing. In 2005, this soil was covered with two types of caps: asphalt and clean soil planted with grass. The purpose of these caps was to avoid the spread of contaminants and to prevent people from coming into contact with contaminated soil.

The caps also were designed with the future use of the site in mind. A station for New Jersey's light rail system was constructed on the property, and the asphalt cap serves as its parking lot. The grassy landscaping surrounds the remainder of the property. A plan is in place for the long-term maintenance and monitoring of the caps to ensure that they remain protective. Future excavation through the soil cap is not permitted.

For More Information

For more information about this and other technologies in the Citizen's Guide Series, visit:

www.cluin.org/remediation
www.cluin.org/products/citguide

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A Citizen's Guide to Ecological Revitalization

EPA

What Is Ecological Revitalization?

Ecological revitalization is the process of returning a contaminated site to a natural environment, similar to the one that existed before the property was developed. The development of a property for industrial, commercial, and other uses can displace the plants and animals living there and disrupt the ecology (the ways these organisms interact with each other and their environment). Returning a meadow, forest, or wetlands to the property can restore the habitats and other natural characteristics of the area. This process can "revitalize" or give new life to a community with the creation of a new park, natural recreational area, or nature preserve.

How Does It Work?

Returning a site to a natural environment will involve different approaches, depending on the property and how it was altered during development and use. Ecological revitalization first requires an understanding of the plant and animal species, soil types, weather, and other characteristics of the site, both past and present. This may involve looking at old photographs and maps of the site, visiting nearby natural areas, and talking to local residents to get a better idea of what needs to be done. Ecological revitalization is most successful when considered during site cleanup. Common steps include:

- Demolition of buildings and other infrastructure.
- Regrading the ground surface to remove or create slopes.

- Bringing in fertile soil or adding nutrients and other natural materials, also known as "amendments," to existing soil to help plants grow.
- Creating or restoring wetlands and natural stream channels.
- Planting native trees, grasses, and other vegetation.
- Reestablishing wildlife.

The links between soil, plants, and wildlife, including birds, insects, and even microscopic organisms are an important part of ecological revitalization. For example, many native flowering plants in the United States rely on bees, bats, hummingbirds or other "pollinators" that feed on nectar to help them reproduce and spread.

The purpose of ecological revitalization is to provide an environment where both plants and animals can thrive.

Is Ecological Revitalization Safe?

When properly planned and managed, ecological revitalization is very safe. If there is any chance that contaminated soil or groundwater will remain at the site, EPA will combine revitalization with cleanup methods that isolate contaminants from people, plants, and wildlife. For instance a protective cap may be placed over contaminated soil or a vertical engineered barrier may be placed around the contaminated soil or groundwater. (See *A Citizen's Guide to Capping* [EPA 542-F-12-004] and *A Citizen's Guide to Vertical Engineered Barriers* [EPA 542-F-12-022].) Revitalization also can be conducted with methods that continue to actively clean up contamination.

How Long Will It Take?

An ecological revitalization project may take anywhere from a few months to several years. The time it takes to reestablish natural habitat will depend on several factors. For example, it may take longer where:

- Plants have a long life cycle and take longer to reach maturity.
- Unfavorable weather for seed germination or plant growth (such as drought) occurs.

- Plants that are eaten by animals or insects must be replaced.
- Stream channels must be restored or must be stabilized to prevent severe erosion, or if habitats, such as wetlands, need to be built from scratch.
- Soil conditions such as temperature, nutrient levels, and microorganism populations must be modified.

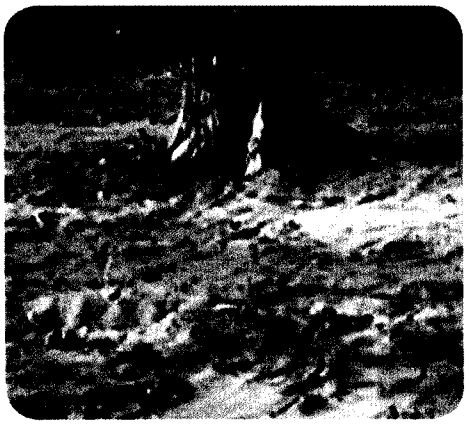
These factors vary from site to site.

How Might It Affect Me?

Generally, ecological revitalization does not cause much disruption to the surrounding community. Initial work may involve grading or tilling the soil with earth-moving equipment. Residents and businesses near the site may hear equipment noise or detect odor if the soil is mixed with natural amendments, such as compost, manure, and yard/wood waste. Airborne dust can be controlled by watering down the soil.

Why Use Ecological Revitalization?

Ecological revitalization is usually used with soil and groundwater cleanup methods to improve the condition of a contaminated site. It is most successful when the process starts during site cleanup. Ecological revitalization is often conducted to reclaim lost land and transform an eyesore into an attractive environmental resource for the community. It can help isolate or remove contamination from people and wildlife and can also reduce soil erosion. Revitalized sites help create wildlife habitats, improve air and water quality, and provide added green space for parks, recreation, and nature preserves. Returning contaminated sites to beneficial use can lead to increased property values, recreational centers, and protected open space in what are often densely developed areas.



Superfund site before and after ecological revitalization.

Example

Not long ago, the Army Creek Landfill in Delaware, was filled to capacity with tons of trash that contaminated nearby Army Creek and local water supply wells. After the site was cleaned up and a protective cap built over the remaining lightly contaminated soil, EPA planted grasses, wild flowers, and other native plants to provide resting and feeding habitats for migrating birds. Bird boxes were installed along the creek to encourage nesting, and gooseberry was planted as a food source.

The site is mowed once a year during the fall so that bird habitats are not disturbed during nesting season. The tall grass throughout the spring and summer provides shelter for birds and other small animals as well as seeds and an attractive habitat for insects, another source of food for birds. EPA also built wetlands to provide habitat for many species of plants, animals, and birds. Ecological revitalization transformed the site into a vibrant wildlife enhancement area for the commmunity.

For More Information

For more information about this and other technologies in the Citizen's Guide Series, visit:

www.cluin.org/remediation
www.cluin.org/products/citguide
www.cluin.org/ecotools

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