FINAL
Remedial Investigation Report

Kerr-McGee Chemical Corp – Navassa Superfund Site
Navassa, North Carolina

EPA ID #NCD980557805

Prepared for:

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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
^{o}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
ERA	Ecological Risk Assessment
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
ISM	Incremental Sampling Methodology
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
USFWS	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 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 Corp – Navassa Superfund 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 Kerr-McGee Chemical Corporation (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, a National Priorities List (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 246 acres – 154 acres of upland areas and 92 acres of marsh – according to the Brunswick County tax maps. 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 Area) is undeveloped and wooded and bounded to the east by a marsh. Two 1-acre former residential parcels (the former residential parcels) are located within the east-central portion of the property and were accessed 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. The northwestern portion of the Site was 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 remedial investigation/feasibility study (RI/FS) 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 its 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, and product storage tanks were located in this area. The Process Area was approximately 5.8-acres. The wood treating process involved placing pre-cut timber in a treatment cylinder (KMCC, 1984). 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 southcentral 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 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 (KMCC, 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 by KMCC 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 the pond drained (KMCC, 1984).

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 important sources 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 stormwater 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 at the facility 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 and is approximately 80 feet wide and 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, 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 three 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 71 feet bgs 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

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 at concentrations above background values in four 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 arsenic is naturally occurring or the result of 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. 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 71 feet bgs near the Wastewater Ponds 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 two deep monitoring wells (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 below 71 feet bgs 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} centimeters per second (cm/sec), and SB-E where permeability is 8.1×10^{-7} cm/sec at 100 feet bgs and 5.2×10^{-6} cm/sec 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 highest concentrations of creosote-related SVOCs were observed in the Southern Marsh in the area of samples SD11 and SD12. 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 pervasive anthropogenic conditions.

Fate and Transport

Creosote was released during the wood treating process near several process units including 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 runoff 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 because wood treating activities have not been conducted since 1974 and no additional creosote is being added to the system. 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

Other migration mechanisms of importance are 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 of the Peedee Aquifer and the lack of an identified upward hydraulic gradient, groundwater in the Peedee Aquifer does not appear to directly discharge to the marsh. Additional data would be required to better define the discharge from the Peedee Aquifer.

As long as DNAPL is in contact with groundwater and/or residual soil sources can leach to groundwater, creosote constituents will continue to dissolve into groundwater. 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)

An HHRA was conducted as part of the RI process in accordance with CERCLA. The USEPA approved the HHRA in a letter dated June 28, 2019. The HHRA provides an evaluation of the nature and magnitude of health risks posed to future industrial (indoor and outdoor) workers, future construction workers, current/future teenage trespassers, and future residents at the Site due to exposures to site-related contaminants in the absence of any actions to control or mitigate these releases. The results of the HHRA aid in the determination of whether remedial action is warranted and are intended to help inform risk managers about potential risk to receptors potentially exposed to site-related contaminants in soil, sediment, surface water, and groundwater. For future construction workers, soil was divided into surface and subsurface soil and assessed separately. The other evaluated receptors do not have a complete exposure pathway to subsurface soil. The technical approach is consistent with current guidelines for human health risk assessment provided by USEPA and is presented in the HHRA (EarthCon, 2019).

For purposes of the HHRA, the property was divided into exposure 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 incremental cancer risk and non-cancer hazard posed for each receptor and media combination evaluated per exposure area. In addition, the risk drivers (i.e., those COPCs that individually contribute cancer risk greater than 1×10^{-6} or non-cancer hazard greater than 0.1) are identified for each receptor and media combination as well as identification of whether the risk driver contributes to cancer risk or non-cancer hazard or both. Based on this evaluation and/or lack of association of a COPC to historical Site activities, no COPCs were identified at Sturgeon Creek or West of Navassa Road.

A brief summary of the HHRA results is provided below for each remaining exposure area. Remedial action will be completed at exposure areas where unacceptable risks are present for the receptors associated with the anticipated future land use. Unacceptable risk for an exposure scenario is defined as contributing incremental cancer risk greater than 1×10^{-4} or a hazard index above 1.0.

Process Area

The cancer risks ranged from 5×10^{-4} for a future lifetime resident to 2×10^{-5} for a current/future teenage trespasser. The incremental cancer risk from combined surface and subsurface soil for the future construction worker was 3×10^{-5}. Benzo(b)fluoranthene, benzo(a)pyrene and other PAHs are cancer risk drivers for the Process Area. The future child resident and future construction worker were the only receptors with non-cancer hazard greater than 1.0. The non-cancer hazards ranged from 18 for a future construction worker (combined surface and subsurface soil) to 0.1 for the current/future teenage trespasser. The non-cancer hazard for the future child resident (HI=4) is primarily driven by ingestion of benzo(a)pyrene and dibenzofuran in surface soil. The non-cancer hazard for the construction worker is primarily driven by the inhalation of naphthalene (HI=14) in subsurface soil.

Pond Area

The cancer risks ranged from 1 x 10^{-3} for a future lifetime resident to 3 x 10^{-5} for the current/future teenage trespasser. Benzo(a)pyrene and other PAHs were identified as cancer risk drivers for the Pond Area. The non-cancer hazards ranged from 27 for the future construction worker to 0.7 (combined surface and subsurface soil) for the current/future teenage trespasser. Dibenzofuran, benzo(a)pyrene, and naphthalene were identified as non-cancer hazards to the future construction worker in the Pond Area.

Treated Wood Storage Area

The cancer risks ranged from 4 x 10^{-5} for the future lifetime resident to 2 x 10^{-7} for the construction worker (combined surface and subsurface soil) both below the cancer risk threshold of 1 x 10^{-4}. The non-cancer hazards ranged from 0.2 for the future child resident to 0.007 for the current/future teenage trespasser, both below the threshold of 1.0. Therefore, no unacceptable risks were identified for soil in the Treated Wood Storage Area.

Untreated Wood Storage Area

The cancer risks ranged from 3 x 10^{-5} for the future lifetime resident to 1 x 10^{-7} for the future construction worker, both below the cancer risk threshold of 1 x 10^{-4}. The non-cancer hazards ranged from 0.1 for the future child resident to 0.004 for the teenage trespasser, both below the non-cancer threshold of 1.0. Therefore, no unacceptable risks were identified for soil in the Untreated Wood Storage Area.

Eastern Upland Area

The cancer risks ranged from 2 x 10^{-5} for the future lifetime resident to 2 x 10^{-7} for the future construction worker, both below the cancer risk threshold of 1 x 10^{-4}. The non-cancer hazards ranged from 0.3 for the future child resident to 0.009 for the current/future teenage trespasser, both below the non-cancer threshold of 1.0. Therefore, no unacceptable risks were identified for soil in the Eastern Upland Area.

Southern Marsh

The future indoor worker, future construction worker, and future resident receptors do not have complete exposure pathways and were not evaluated in the HHRA for the Southern Marsh. The incremental cancer and non-cancer risks from exposures to sediment in the Southern Marsh for the teenage trespasser (2 x 10^{-5} and 0.4, respectively) and the future outdoor worker (4 x 10^{-5} and 0.7, respectively) are below the thresholds. Therefore, no unacceptable risks were identified for sediment in the Southern Marsh.

Groundwater

Groundwater impacts are limited to areas in the southernmost portion of the Untreated Wood Storage Area, the Pond Area, and the Process Area. Consequently, groundwater risk was not included in the overall exposure area risk for the Eastern Upland Area, Treated Wood Storage Area, and Untreated Wood Storage Area. Exposure to groundwater is not considered to be a complete pathway for the teenage trespasser because teenage trespassers are not expected to encounter groundwater.

The incremental cancer risks and non-cancer hazards to current and future industrial (indoor and outdoor) workers, future construction workers, and future residents were calculated for potential exposure to groundwater from both direct pathways, if the water were used as a domestic supply, and for exposure from the migration of vapors to indoor air pathway (applies to the adult resident and indoor worker only). Additionally, because groundwater is less than 10 feet deep, the future construction worker was also evaluated for exposure during trenching activities.

The cancer risks from direct exposure and vapor intrusion ranged from 3 x 10^{-3} for the future lifetime resident to 7 x 10^{-7} for the future construction worker via direct contact during trenching. The non-cancer hazard was less than 1.0 for the future construction worker, but greater than the threshold of 1.0 for the future indoor workers (HI=17), future outdoor workers (HI=9), future adult residents (HI=79), and future child residents (HI=49). Naphthalene, chloroform, arsenic, benzo(a)pyrene, and 1-methylnaphthalene are identified as cancer risk drivers for all receptors from groundwater.

HHRA Summary

No COPCs were identified for Sturgeon Creek or for the soils West of Navassa Road. No unacceptable risks were identified for soil in the Eastern Upland Area, the Treated Wood Storage Area, or the Untreated Wood Storage Area. No unacceptable risks were identified for sediment in the Southern Marsh.

The overall risk from soil is unacceptable for the reasonably anticipated future land use in the Pond and Process Areas. These areas require further evaluation in a Feasibility Study (FS). The overall risk from groundwater is also unacceptable and will require evaluation in a FS.

Baseline Ecological Risk Assessment (BERA)

A BERA was conducted as part of the RI process. The USEPA approved the BERA in a letter dated March 6, 2019. 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 10-day 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.

The BERA results indicated that adverse impacts to the growth of sediment-dwelling organisms is expected at ∑34 PAH toxic units (TUs) greater than or equal to 40. It is expected that the threshold for no effects for survival and growth of sediment-dwelling organisms is between 1 and 40, but the actual threshold TU is uncertain. The areas that contribute the highest sediment exposures for birds and mammals are the same areas already identified with elevated TUs greater than 40. Similarly, these areas with elevated TUs correspond with the elevated TUs estimated using ELS fish screening values reported in the BERA.

The BERA included food web modeling to evaluate potential exposures and risks for mammal and bird populations that forage and inhabit the Marsh Study Area. The food web modeling was based on exposure assumptions for the incidental ingestion of sediment during foraging and feeding and the exposure to food items from the Marsh Study Area. Sediment invertebrate and fish tissue data from samples collected from the Marsh Study Area were used in the food web model. The food web results were compared to both no observable adverse effects level (NOAEL) and lowest observable adverse effects level (LOAEL) toxicity reference values (TRVs). The ratio of estimated ingestion exposure to the TRVs are reflected as hazard quotients (HQs), where HQs less than 1 indicate that adverse impacts to birds and mammals are not expected. The food web model HQ results were less than 1 for fish-eating birds and mammals, such as the osprey and river otter. Potential risks for birds and mammals that forage in the Marsh Study Area, such as the spotted sandpiper, green heron, mallard duck, and raccoon are less certain because some of the food web modeling resulted in HQs exceeding the threshold of 1. Additional food web modeling done as part of the uncertainty assessment showed HQs below the low effect threshold of 1. The HQs for the food web model appear to be most influenced by the sediment ingestion component of the question, meaning that species that ingest a high amount of sediment while foraging are potentially at greater risk than species that ingest less sediment while foraging. Based on the HQs calculated that exceed 1 and the uncertainties associated with TRVs and sediment ingestion, adverse effects to l birds and mammals could be occurring and it is not clear if the effect to birds and mammals would have an adverse effect on the local population of small home-range birds and mammals. The species most at potential risk are those that ingest sediment while foraging for food, such as the spotted sandpiper. The areas that contribute the highest sediment exposures for birds and mammals are the same areas already identified with elevated TUs from 40 to 260.

The BERA concludes 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 in the marsh with elevated TUs from 40 to 260 where potential impacts to organisms may occur. Additional data is needed to further identify this area of impact. The efforts to conduct additional characterization and 28-day toxicity testing to delineate the area where there is no benthic community risk (i.e., to identify a TU below which no unacceptable adverse impacts are expected) would also address uncertainty in potential risks to bird and mammal populations.

Temperature and conductivity in marsh surface water were measured 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 because wood treating activities have not been conducted since 1974 and no additional creosote is being

added to the system. 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 Area and the Pond Area. 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, only surface and subsurface soil in the Pond Area and the Process Area and groundwater require additional evaluation in the FS.
- The BERA results indicate that adverse impacts to sediment-dwelling organisms are expected at TUs greater than 40. The threshold for no effects for survival and growth of sediment-dwelling organisms is between 1 and 40. Additional data is required to identify a Site-specific threshold TU below which no unacceptable adverse impacts are expected.

Recommendations

The following activities are recommended in the future:

- Conduct a plume stability evaluation to determine the current condition of the dissolved phase groundwater plume (increasing, decreasing, or stable) and provide a baseline for future comparison. 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 in the FS the area of the marsh that was identified in the BERA. It is expected that the threshold for no effects for survival and growth of sediment-dwelling organisms is between 1 and 40, but the actual TU is uncertain. Additional sediment characterization for the Marsh Study Area will be conducted with an approved USEPA and NC DEQ work plan(s) and results will be provided to USEPA and NC DEQ in a “BERA Addendum” for use in the Marsh FS, as appropriate. Additional study may include sediment characterization using passive diffusion sampling approaches consistent with USEPA’s 2017 Guidance “*Developing Sediment Remediation Goals at Superfund Sites Based on Pore Water for the Protection of Benthic Organisms from Direct Toxicity to Nonionic Organic Contaminants.*” Additional toxicity testing using 28-day testing for survival and growth will also be considered for the marsh. The additional characterization and 28-day toxicity testing data will be used to identify a Site-specific threshold TU below which no unacceptable adverse impacts are expected for sediment-dwelling organisms, which can be used in the Marsh FS. The FS will also 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 Corp – Navassa 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 Kerr-McGee Chemical Corporation (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 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 (COPCs), and describes the extent of impacts and the 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 as follows.

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 media.

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, extent, 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 246 acres – 154 acres of upland areas and 92 acres of marsh – according to the Brunswick County tax maps. 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 Area) is undeveloped and wooded and bounded to the east by a marsh. Two 1-acre residential parcels (the former residential parcels) are located within the east central portion of the property and were accessed 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. The north western portion of the Site was 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, 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 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, and product storage tanks were located in this area. The Process Area was approximately 5.8 acres in size (Figure 1-2).

The wood treating process involved placing pre-cut timber in a treatment cylinder (KMCC, 1984). 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 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 (KMCC, 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. Based on historical aerial photographs, construction of the Wastewater Ponds began prior to 1938. 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 (KMCC, 1984). 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 (KMCC, 1984). 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 reported by KMCC 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 (KMCC, 1984). The Boiler Ponds were reportedly drained and backfilled. The Fire Protection Pond dike was breached, and the pond 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 appear similar to how they looked in 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 appear similar to how they looked in 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 areas and the Southern Marsh 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 site inspection (SI) with a medium priority.
- On May 3, 1988, the NCDHS submitted the PA Update to the USEPA recommending a medium priority for a screening site investigation (SSI).
- In 1988, the Superfund Section of the North Carolina Department of Environment, Health, and Natural Resources (NCDEHNR) performed an 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 USEPA in March 2003 (NCDENR, 2003). The Site Re-Assessment letter briefly highlighted the results of the previous investigations described earlier 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 Site 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 the HRS Documentation Record for the Site using the ESI sampling results. The HRS scored 50 based on the surface water pathway.
- In March 2010, 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. Greenfield Environmental Multistate Trust LLC, as Trustee of the Multistate Environmental Response Trust, is performing Environmental Actions at the KMCC Site in Navassa as a 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 NCDENR and now known as the North Carolina Department of Environmental Quality (NC DEQ)], NCDOT, and 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 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 southwest 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 east 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 USEPA in March 2003 (NCDENR, 2003). The Site Re-Assessment letter briefly highlighted the earlier 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, NCDENR recommended that the Site be considered for further evaluation by 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 eight 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 (USFWS), 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, and 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 and 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^{TM} 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. Soil 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. Based on review of the residential soil and terrestrial sediment data, USEPA indicated that the concentrations are within an acceptable risk range and exposure to the contaminants is likely to be minimal (USEPA, 2010b). 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 one 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, 2010c) 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. 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, 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 were 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 Area) 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 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: 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, USEPA, NC DEQ, and EarthCon, the HHRA was updated (EarthCon, 2019) 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). A 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 in an October 6, 2016 meeting between the Multistate Trust, USEPA, NC DEQ, and EarthCon, a BERA was prepared (Ramboll, 2019) 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 on-Site 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 RI 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^{TM} 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 the molecules 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^{TM} 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^{TM} 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^{TM} 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 as follows.

- 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. Terrestrial sediment is surface soil from low lying areas (i.e., drainage swales and surface depressions) that are intermittently wet from rainfall. 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 screen (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 former residential parcels located in the Eastern Upland Area. Surface soil samples were collected from five locations on the former residential parcel and composited. The composite sample was analyzed for SVOCs.

Terrestrial sediment samples are soil 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; 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 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 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 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. Wells with measurable DNAPL were not sampled.

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 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^{TM} 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 interstitial 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. These samples are not representative of a surface water body but were collected from surface depressions that occasionally collect rainwater. 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 that restricts visual identification of ground surface conditions (Figure 1-3). A number of structures were present on the former 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 former 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 (ºF)	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 lie 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 former 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 as follows.

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
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 as follows 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 have provided information to allow classification of the subsurface soils beneath the property and correlation of Site-specific data with the geologic formations described previously.

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 in 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 x 10^{-6} to 7.3 x 10^{-4} centimeters per second (cm/sec) with an average of 2.5 x 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 x 10^{-7} to 5.7 x10^{-6} cm/sec with an average of 2.13 x 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 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 important sources 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 in 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 toward 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 21 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 in 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. The Peedee confining unit appears to be missing over large areas of Brunswick County, especially in the eastern half of the county (including the Site). Where the confining unit is missing, the aquifer is considered to be unconfined and in direct hydraulic contact with the overlying Surficial Aquifer (USGS, 2003). Based on the depth to the Peedee Aquifer and the lack of an identified upward hydraulic gradient, groundwater in the Peedee Aquifer does not appear to directly discharge to the marsh. However, given the direct contact with the Surficial Aquifer, there is a possibility of some leakage from the Peedee Aquifer into the overlying Surficial Aquifer. Additional data would be required to better define the Peedee Aquifer discharge.

3.6.2.2 Hydraulic Conductivity

The hydraulic gradients, along with K values of the screened soils, were 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 were 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, were 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 were 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 x 10^{-4} cm/s or 1.6 feet per day in well MW-05 to 5.5 x 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 x 10^{-6} cm/sec or 0.02 feet per day in well MW-04D to 1.1 x 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 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 stormwater 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 saltwater/freshwater interface. The following paragraphs summarize the findings from these studies.

AECOM Study

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 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 were 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 is presented in 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 described 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, traverses 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 USFWS 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).

A list of threatened and endangered species and an evaluation of their presence in the Southern Marsh are provided in Attachment H of the BERA (Ramboll, 2019). Information provided by NC DEQ in a July 19, 2018 meeting indicate that Atlantic and shortnose sturgeon, both endangered species, may be present in Sturgeon Creek. The North Carolina Division of Marine Fisheries has designated Mill Creek, Sturgeon Creek, and the Brunswick River as Anadromous Fish Spawning

Areas. The potential effect on both species of sturgeon is discussed in the BERA (Ramboll, 2019).

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 November 2018 (USEPA, 2018a). 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 summary table are derived using conservative default exposure assumptions, a target risk of 10^{-6}, and a hazard quotient (HQ) of 0.1.

4.1 CONTAMINANT SOURCE AREAS

Creosote was released during the wood treating process in areas formerly associated with process units, storage tanks and 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 continuing 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 and 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 (KMCC, 1984). 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 (KMCC, 1984). 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 (KMCC, 1984). 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^{TM} and TarGOST® investigations, visual inspection of soil cores, and measurement of DNAPL in groundwater monitoring wells. The CPT/ROST^{TM} 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. Surficial soils at the southeast corner of the Process Area (RISB35) extending to the former treatment vessel foundation (RICPT19 and RICPT20) and to the northeast (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. Results of laser-induced fluorescence analysis in the CPT/ROST™ borings indicated the presence of creosote-related constituents and possible DNAPL at various depths. The presence of DNAPL at shallow depths (less than 2 feet) was also indicated in borings RICPT19, RICPT20, RICPT21, RICPT22, RICPT26, RICPT27, and RICPT30. Results of the laser-induced fluorescence 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^{TM} 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^{TM} 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 north of the treatment cylinders 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^{TM} 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.

The presence of DNAPL was suggested or indicated in 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 71 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. However, further evaluation indicated that well MW-06D was compromised and the DNAPL in this well is likely from an upper zone (59 to 65 ft bgs) rather than the deeper screened interval. 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 71 feet bgs in boring SB-E located at the marsh edge. The vertical extent of DNAPL has been delineated except for the area immediately downgradient of the Wastewater Ponds around monitoring well MW-32D.

4.2.3 Boiler Ponds

TarGOST® borings TG-F-05 and TG-F-06 and soil borings BPSB9, BPSB11, SB-111, and SB-112 were advanced in and 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. DNAPL was also observed in SB-111 located in the southern Boiler Pond at a depth of 16.5 to 17 feet. DNAPL was not observed in boring BPSB11. In summary, DNAPL was observed in borings from the southern Boiler Pond at depths from 16 to 23 feet bgs. A creosote signature was not identified in boring TG-F-06 or BPSB9 located near 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 14 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-27D 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. 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

Results of laser-induced fluorescence, possibly indicating petroleum presence, were noted in CPT11 and CPT12 located near the former Decommissioning Evaporation Pond. In CPT/ROST™ borings RICPT1 through RICPT5, the presence of DNAPL was indicated 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 71 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 previously 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 well 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 is surface soil 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 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 4-2, 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.

The detected soil results were compared to the residential soil screening values provided in the USEPA summary tables (USEPA, 2018a). 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.

4.3.1 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, 2018b). 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.

As part of the HHRA, both a spatial analysis of the arsenic data and a literature search for background concentrations of arsenic were performed. The results of the arsenic evaluation, which are presented in Appendix H of the HHRA, indicated that a background concentration for arsenic in soil of 12.1 mg/kg, rather than the calculated background value of 2.88 mg/kg presented in Table 4-2, was appropriate for the Site.

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 or 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 samples collected from the Boiler Ponds and drainage swales only.

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 4-2 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 4-2, 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 4-2, 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 suggests that a layer of clean fill material was not placed on the entire surface of the Untreated Wood Storage Area during facility decommissioning. However, there is uncertainty regarding the disturbance of soil during decommissioning.

Treated Wood Storage Area

As shown on Figure 4-2, 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 (50.35 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 (51.08 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. However, there is uncertainty regarding the disturbance of soil during decommissioning.

Process Area

As shown on Figure 4-2, 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 4-2, 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

A summary of detected inorganics in surface soil and terrestrial sediment is provided in Table 4-3d. As shown in Table 4-3d, several metals were detected at concentrations greater than both their respective residential RSL and background concentrations. Since these metals were detected sporadically and are not related to the creosote wood treating process, further evaluation of their presence at the Site was conducted as part of the HHRA (EarthCon, 2019).

A Site-wide analysis of aluminum, iron, manganese, thallium and vanadium detections in surface soil and terrestrial sediment was performed for the Site and is presented in Appendix G of the HHRA. The results of the Site-wide analysis indicated that the presence of these metals at the Site is likely due to natural variation in background metals concentrations. A spatial analysis of the hexavalent chromium data was performed and is presented in Appendix F of the HHRA. Review of the hexavalent chromium data across the Site indicated that the detections may be related to interferences in the laboratory analyses and/or upstream sources in the marsh sediments. Based on the results of these evaluations, aluminum, iron, manganese, thallium, vanadium and hexavalent chromium detections were not addressed in this Section but were addressed in the HHRA.

Arsenic was detected above the background concentration of 12.1 mg/kg in 4 of 83 samples at concentrations ranging from 19 mg/kg in RISD01 to 30.3 mg/kg in sample SS03. Arsenic concentrations exceeded the background concentrations in terrestrial sediment sample SD013 collected from the drainage swale south of the former residential parcels in the Eastern Upland Area, terrestrial sediment samples RISD01 and RISD02 located in the Boiler Ponds, and surface soil sample SS03 located in the Pond Area.

Arsenic concentrations that exceed the background value were detected sporadically throughout the areas used for wood treating and in a drainage swale 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 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 because 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 metal detected above both the residential RSLs and background concentrations is aluminum. Aluminum was detected above background at only two locations. Aluminum is not associated with creosote wood treating operations and its 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 interstitial 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. Permanent monitoring wells with measurable DNAPL were not sampled during the December 2016 and March 2017 sampling events.

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 interstitial pore water data, surface water data, and residential well data south of Sturgeon Creek. The data were used qualitatively as the interstitial pore water 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.

The detected groundwater results were compared to the tapwater RSLs provided in the USEPA RSL summary tables (USEPA, 2018a). 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, bromodichloromethane, chloroform, ethylbenzene, xylenes, and naphthalene. Each of these constituents, except for bromodichloromethane and chloroform, is associated with petroleum products.

Chloroform and bromodichloromethane are drinking water disinfectants and common laboratory and field contaminants. Chloroform was not detected above the residential RSL consistently over time in any of the monitoring wells. Bromodichloromethane was detected once above the residential RSL in monitoring well MW-20. Because chloroform and bromodichloromethane are not related to wood treating operations, and were detected sporadically, these concentrations were not addressed in this Section but were addressed in the HHRA.

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 was 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 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. Wells with measurable DNAPL were not sampled. 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 are not addressed in this Section. 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 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 6.5×10^{-7} cm/sec and SB-E, where permeability is 8.1×10^{-7} cm/sec at 100 feet bgs and 5.2×10^{-6} cm/sec at 110 feet bgs (Table 3-1). 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.

Pentachlorophenol was not detected in surface or subsurface soils and there is no indication that it was ever used at the Site. Therefore, its presence is not anticipated to be due to wood treating activities. Further review of the groundwater data was conducted to evaluate the potential for the pentachlorophenol detections to be related to interference from DNAPL. While low concentrations of pentachlorophenol were reported in the samples, review of the mass spectra indicated that the ratios of the major ions associated with pentachlorophenol were not indicative of pentachlorophenol but could be associated with other phenolic compounds. Pentachlorophenol will be further evaluated during the FS for groundwater.

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 is 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.

The detected marsh sediment results were compared to the residential soil screening values provided in the USEPA RSL summary tables (USEPA, 2018a) to evaluate direct contact with marsh sediment. 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. The marsh sediment data were also incorporated into the BERA as described in Section 7.0.

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 benzo(a)pyrene above its residential RSL.

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. Samples RISWO1 and RISW04 are not representative of a surface water body but were collected from surface depressions that occasionally collect rainwater. Therefore, they are not discussed further in this Section. 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.

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 Site include surface and subsurface soil, sediment in the Southern Marsh, and groundwater. 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

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.

Substantial future migration of the DNAPL is not likely to occur as wood treating activities have not been conducted since 1974 and no additional creosote is being added to the system. 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 by-product 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).

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. 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.

The SVOCs 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 decrease 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).

5.3 SOIL

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. 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.

Groundwater flow information for the Surficial Aquifer indicates that groundwater is flowing and likely discharging to the Southern Marsh. Analytical results for the pore water samples collected from within the marsh indicate impact by COPCs. 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 identified upward hydraulic gradient, groundwater in the Peedee Aquifer does not appear to directly discharge to the Southern Marsh or to Sturgeon Creek. Additional data would be required to better define the Peedee Aquifer discharge.

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. Stormwater runoff from impacted surface soils in the Treated Wood Storage Area could migrate through the drainage swales, 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 was addressed in the HHRA and discussed in Section 6.0.

6.0 HUMAN HEALTH RISK ASSESSMENT (HHRA)

A HHRA was conducted as part of the RI process in accordance with CERCLA. The HHRA provides an evaluation of the nature and magnitude of health risks posed to future industrial (indoor and outdoor) workers, future construction workers, current/future teenage trespassers, and future residents at the Site due to exposures to Site-related contaminants in the absence of any actions to control or mitigate these releases. The results of the HHRA aid in the determination of whether remedial action is warranted and are intended to help inform risk managers about potential risk to receptors potentially exposed to Site-related contaminants in soil, sediment, surface water, and groundwater. The technical approach is consistent with current guidelines for human health provided by USEPA and is presented in the HHRA (EarthCon, 2019). USEPA approved the HHRA in a letter dated June 28, 2019.

6.1 EXPOSURE ASSESSMENT

The risk assessment evaluated the potential current and future adverse health effects caused by releases from the Site in the absence of any actions to control or mitigate these releases. The results of the HHRA aid in the development, evaluation, and selection of appropriate remedial alternatives.

The Site was sub-divided into eight areas based on historical activities and risk assessments were then conducted for each area. The areas evaluated consisted of the Process Area, Pond Area, Treated Wood Storage Area, Untreated Wood Storage Area, Eastern Upland Area, West of Navassa Road, Southern Marsh, and Sturgeon Creek. Groundwater was evaluated across the property, though impacts to groundwater were observed in the southern portion of the property only. The HHRA evaluated the potential risks to human receptors that may be exposed to Site-related contaminants present in soil, sediment, surface water, and groundwater based on the current and reasonably anticipated future uses of the Site.

Four conceptual site exposure models (CSEMs) (Figure 6-1a through 6-1d) were developed for the Site, each representing two of the exposure areas (Process and Pond Areas; Treated and Untreated Wood Storage Areas; Eastern Upland Area and West of Navassa Road; and the Southern Marsh and Sturgeon Creek, respectively). A fifth CSEM was created for the groundwater and is presented as Figure 6-1e. The CSEMs illustrate the sources/release mechanisms, modes of transport, primary and secondary impacted media, exposure routes, and potentially exposed receptors for the Site.

Each of the areas was assessed under both an industrial/commercial scenario and a residential use basis. Potentially exposed populations include future industrial (indoor and outdoor) 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, potentially complete exposure pathways include surface soil and soil gas (from soil and groundwater). Direct contact with subsurface soil is anticipated to be a potentially complete pathway only for the future construction worker. Direct exposure to groundwater is not currently a complete pathway for any receptors. However, the incremental cancer risks and non-cancer hazards to current and future industrial (indoor and outdoor) workers, future construction workers, and future residents were calculated for potential exposure to groundwater from both direct pathways, if the water were used as a potable supply, and for exposure from the migration of vapors to indoor air pathway (applies to the adult resident and indoor worker only). Additionally, because groundwater is less than 10 feet deep, the future construction worker was also evaluated for exposure during trenching activities.

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 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 that was rejected by USEPA. 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.

The technical approach for this risk assessment was conducted in accordance with USEPA guidance under CERCLA, and was a four-part process consisting of the following components: 1) data analysis and COPC selection, 2) exposure assessment, 3) toxicity assessment and 4) risk characterization. This approach documents that the range of risks over various population subgroups are characterized for potential activities and land/water uses. The exposed populations evaluated included: future industrial (indoor and outdoor) workers, future construction workers, current/future teenage trespassers, and future residents. The constituents retained as COPCs for each area, which include inorganics, VOCs, and SVOCs (primarily PAHs), are summarized in Table 6-1.

6.2 RISK CHARACTERIZATION

A brief summary of the HHRA results is provided below for each exposure area. Unacceptable risk for an exposure scenario is defined as contributing incremental cancer risk greater than 1 x 10^{-4} or a hazard index (HI) above 1.0. Table 6-2 summarizes the carcinogenic and non-carcinogenic risks from each exposure area for the industrial worker (indoor and outdoor), construction worker, teenage trespasser, and adult and child residents. Table 6-3 presents a summary of the COCs identified by area for each exposure medium and Table 6-4 presents a summary of COCs by area for each exposure medium and receptor.

Process Area

The incremental cancer risks and non-cancer hazards to future industrial workers, future construction workers, current/future teenage trespassers, and future residents in the Process Area were calculated for exposures to surface soil. The cancer risks ranged from 5 x 10^{-4} for a future lifetime resident (child and adult) to 2 x 10^{-5} for a current/future teenage trespasser. The future construction worker was also evaluated for exposure to subsurface soil above the water table. The incremental cancer risk from combined surface and subsurface soil for the future construction worker was 3 x 10^{-5}. Benzo(b)fluoranthene, benzo(a)pyrene and other PAHs are the cancer risk drivers for the Process Area. The future child resident and future construction worker were the only receptors with non-cancer hazard greater than 1.0. The non-cancer hazards ranged from HI=18 for a future construction worker (combined surface and subsurface soil) to 0.1 for the current/future teenage trespasser. The non-cancer hazard for the future child resident (HI=4) is primarily driven by ingestion of benzo(a)pyrene and dibenzofuran in surface soil. The non-cancer hazard for the construction worker is primarily driven by the inhalation of naphthalene (HI=14) in subsurface soil.

Pond Area

The incremental cancer risks and non-cancer hazards to current and future industrial workers, future construction workers, current/future teenage trespassers, and future residents at the Pond Area were calculated for exposures to surface soil. The future construction worker was also evaluated for exposure to subsurface soil above the water table. The cancer risks ranged from 1 x 10^{-3} for a future lifetime resident to 3 x 10^{-5} for the current/future teenage trespasser. Benzo(a)pyrene and other PAHs were identified as cancer risk drivers for the Pond Area. The non-cancer hazards ranged from HI=27 for the future construction worker to HI=0.7 for the current/future teenage trespasser. Dibenzofuran, benzo(a)pyrene, and naphthalene were identified as non-cancer hazards to the future construction worker in the Pond Area.

Treated Wood Storage Area

The incremental cancer risks and non-cancer hazards to current and future industrial workers, future construction workers, current/future teenage trespassers, and future residents at the Treated Wood Storage Area were calculated for exposures to surface soil. The future construction worker was also evaluated for exposure to subsurface soil above the water table. The cancer risks ranged from 4 x 10^{-5} for the future lifetime resident to 2 x 10^{-7} for the construction worker (combined surface and subsurface soil) which are below the cancer risk threshold of 1 x 10^{-4}. The non-cancer hazards ranged from 0.2 for the future child resident to 0.007 for the current/future teenage trespasser, both below the threshold of 1.0. Therefore, no unacceptable risks were identified for soil in the Treated Wood Storage Area.

Untreated Wood Storage Area

The incremental cancer risks and non-cancer hazards to current and future industrial workers, future construction workers, current/future teenage trespassers, and future residents at the Untreated Wood Storage Area were calculated for exposures to surface soil. The future construction worker was also evaluated for exposure to subsurface soil above the water table. The cancer risks ranged from 3 x 10^{-5} for the future lifetime resident to 1 x 10^{-7} for the future construction worker, both below the cancer risk threshold of 1 x 10^{-4}. The non-cancer hazards ranged from 0.1 for the future child resident to 0.004 for the current/future teenage trespasser, both below the non-cancer threshold of 1.0. Therefore, no unacceptable risks were identified for soil in the Untreated Wood Storage Area.

Eastern Upland Area

The incremental cancer risks and non-cancer hazards to current and future industrial workers, future construction workers, current/future trespassers, and future residents in the Eastern Upland Area were calculated for exposures to surface soil. The future construction worker was also evaluated for exposure to subsurface soil. The cancer risks ranged from 2 x 10^{-5} for the future lifetime resident to 2 x 10^{-7} for the future construction worker, both below the cancer risk threshold of 1 x 10^{-4}. The non-cancer hazards ranged from 0.3 for the future child resident to 0.009 for the current/future teenage trespasser, both below the non-cancer threshold of 1.0. Therefore, no unacceptable risks were identified for soil in the Eastern Upland Area.

West of Navassa Road

No constituents in soil exceeded the applicable screening criteria in the area West of Navassa Road. This indicates the area is below USEPA's level of concern for all receptors identified in the HHRA. Therefore, risk was not quantified in the HHRA for this exposure area.

Southern Marsh

The Southern Marsh is a wetlands area; therefore, the future indoor worker, future construction worker, and future resident receptors do not have complete exposure pathways and were not evaluated in the HHRA for the Southern Marsh. The incremental cancer and non-cancer risks from exposures to sediment in the Southern Marsh for the teenage trespasser (2 x 10^{-5} and 0.4, respectively) and the future outdoor worker (4 x 10^{-5} and 0.7, respectively) are below the thresholds. Therefore, no unacceptable risks were identified for sediment in the Southern Marsh.

Sturgeon Creek

Benzo(a)pyrene was the only site-related COPC identified in sediments in Sturgeon Creek. However, in accordance with USEPA Region 4 HHRA Supplemental Guidance (USEPA, 2018b), risk from sediments that are submerged in water most of the year are not quantified in the HHRA as sediments tend to wash off skin upon exiting the surface water body resulting in insignificant risk via this exposure pathway. No COPCs were identified in surface water for Sturgeon Creek. Therefore, risks associated with Sturgeon Creek were insignificant due to lack of a complete exposure pathway for surface water and sediments.

Groundwater

Groundwater impacts are limited to areas in the southernmost portion of the Untreated Wood Storage Area, the Pond Area and the Process Area. Consequently, groundwater risk was not included in the overall exposure area risk for the Eastern Upland Area, Treated Wood Storage Area, and Untreated Wood Storage Area. Exposure to groundwater is not considered to be a complete pathway for the teenage trespasser because teenage trespassers are not expected to encounter groundwater.

For the Pond and Process Areas, the incremental cancer risks and non-cancer hazards to future industrial (indoor and outdoor) workers, future construction workers, and future residents were calculated for potential exposure to groundwater from both direct pathways, if the water were used as a domestic supply, and for exposure from the migration of vapors to indoor air pathway (applies to the adult resident and indoor worker only). Additionally, because groundwater is less than 10 feet deep, the future construction worker was also evaluated for exposure during trenching activities.

The cancer risks from direct exposure and vapor intrusion ranged from 3×10^{-3} for the future lifetime resident to 7×10^{-7} for the future construction worker via direct contact during trenching. The non-cancer hazard was less than 1.0 for the future construction worker, but greater than the threshold for the future indoor worker (HI=17), future outdoor worker (HI=9), future adult resident (HI=79), and future child resident (HI=49). Naphthalene, chloroform, arsenic, benzo(a)pyrene, and 1-methylnaphthalene are identified as cancer risk drivers for all receptors from groundwater in the Pond and Process Areas.

6.3 HHRA SUMMARY

Based on the results of the HHRA, no unacceptable risks were identified for soil in the Eastern Upland Area, the Treated Wood Storage Area, or the Untreated Wood Storage Area. No unacceptable risks were identified for sediment in the Southern Marsh. 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 sediments. Therefore, additional evaluation of Sturgeon Creek is not required.

The overall risk from soil is unacceptable for the reasonably anticipated future land uses in the Pond and Process Areas. These areas require additional evaluation in the FS. The overall risk from groundwater is also unacceptable and will require additional evaluation in the FS.

7.0 BASELINE ECOLOGICAL RISK ASSESSMENT (BERA)

The ecological risk to terrestrial receptors associated with the upland portions of the Site were addressed in the SLERA (ENSR, 2006b) and the Draft Problem Formulation Statement for Ecological Risk Assessment (ENSR, 2007a). This section presents a summary of the BERA for the marsh at the Site (also referred to as the “marsh” or “Marsh Study Area”, approximately 35 acres) conducted in accordance with the SRI Work Plan Addendum No. 3 (EarthCon, 2016). The BERA is provided as a separate report (Ramboll, 2019). USEPA approved the BERA in a letter dated March 6, 2019.

7.1 PROBLEM FORMULATION

The BERA Report presents a detailed problem formulation for the Marsh Study Area. 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 on 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, and bird and mammal populations.

Assessment and measurement endpoints for the BERA are provided in Table 7-1 for the sediment-dwelling community, fish populations, and bird and mammal populations. The ecological 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

7.2 EXPOSURE ASSESSMENT

The BERA Report describes in detail the complete exposure pathways and exposure parameters for the Marsh Study Area. Based on a screening of COPCs provided in the BERA Report, PAHs were the focus of the quantitative exposure assessment in the BERA. The methods of estimating exposure for each assessment endpoint differ, as summarized 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 10-day 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.

Sediment Toxicity Testing

Sediment toxicity testing, conducted as part of the BERA investigation, is described in detail in the BERA Report. Two types of testing [whole sediment tests and dilution series tests (6.25%, 12.5%, 25%, and 50%)] were conducted using a sensitive laboratory organism (amphipod, Hyalella azteca) that conservatively reflects the types of organisms that may be present in the marsh. Data from the 10-day toxicity testing is presented in the BERA Report and discussed in Section 7.4.

Sediment Chemistry Exposure Assessment

Exposure was also evaluated based on consideration of PAH concentrations in sediment and pore water using bulk chemical analysis, solid phase microextraction (SPME), and the USEPA equilibrium partitioning (EqP) approach (USEPA, 2003). Data from the sediment chemistry assessment is presented in the BERA Report and discussed in Section 7.4.

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, with exposures estimated using:

- Sediment chemical data with toxic units (TUs); and
- Sediment pore water and consideration of PAH toxicity reference values (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 [considered on a high molecular weight (HMW) and low molecular weight (LMW) basis] in sediment and modeled using exposure parameters specific for each wildlife receptor. Descriptions of the exposure estimates, dietary uptake factors, bioaccumulation factors and total daily intake (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. Estimated doses in the diet for birds and mammals are compared to USEPA Region 4 approved TRVs.

7.3 EFFECTS ASSESSMENT

The BERA Report describes the methods used to characterize potential toxic effects (if any) for each receptor group, as well as the outcomes of those analyses; however, a brief summary is provided below.

7.3.1 Benthic Invertebrate Effects Assessment

The lines of evidence for the benthic community are 10-day sediment toxicity testing, sediment/pore water chemistry, and benthic community assessment.

Sediment Toxicity Testing

10-day toxicity testing was conducted as part of the BERA. The effects metric for the "toxicity testing" is a statistical comparison of toxicity tests from the marsh sediments versus background areas. The results of the statistical testing and the significance of these results are discussed in Section 7.4.

Sediment/Pore Water Chemistry and Physical Analysis

Co-located sediment and pore water samples collected in December 2016 and analyzed for the full suite of 34 PAHs as well as the biological measurements (i.e., 10-day toxicity studies, benthic community assessment studies) were considered directly, as described in the BERA Report. The larger marsh sediment dataset was also used to calculate TUs with extrapolation from 17 to 34 PAHs, as described in the BERA Report. Details on the calculation and the PAH TUs are provided in the BERA Report and discussed in Section 7.4.

Benthic Community Assessment

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. The implications of these results are discussed further in Section 7.4.

7.3.2 Effects Assessment for Fish Populations

PAH HQs and summed TUs are used to conservatively estimate potential risks to fish populations, as described in the BERA Report. Fish TRVs are those that reflect larval fish toxicity.

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, as described in the BERA Report. USEPA Region 4 identified conservative protective avian and mammal TRVs for use in the food web model for the Marsh Study Area. 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. The USEPA TRVs are discussed in the main body of the BERA. The Alternative TRVs are discussed in the uncertainty assessment of the BERA Report.

7.4 RISK CHARACTERIZATION

The BERA Report details the risk characterization for the Marsh Study Area; however, a brief summary is provided below.

7.4.1 Risk Characterization for Benthic Invertebrate Communities

Sediment Toxicity Testing

10-day toxicity testing was conducted as part of the BERA. 10-day toxicity testing results for the amphipod *H. azteca* 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 10-day 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.

- Weight (Figure 7-3): Six of the seven locations showed no statistically significant reductions in growth for the amphipods. Location ECO-SD-M2 showed significantly lower growth than other Marsh Study Area and background samples.

The dilution series results for ECO-SD-M2 (approximately 4,000 mg Σ17 PAH/kg) showing survival and growth endpoints are provided on Figure 7-4. A similar dilution series 10-day toxicity test was conducted for location EDO-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 ECO-SD-M2:

- There is no statistically significant dose-response relationship for survival in the maximum concentration tested (ECO-SD-M2 at approximately 4,000 mg ∑17 PAH/kg) (Figure 7-4). However, there are some reductions in survival observed compared to conditions at the background locations.

- ECO-SD-M2 results indicate statistically significant suppressed growth compared to the marsh background and dilutions for ECO-SD-M2 sediments at ambient concentration and at the 50 percent dilution. This indicates a dose-response relationship for growth.

- The threshold TU for growth where impacts are expected is a TU of 40. The threshold for no effects on survival and growth is expected to be between 1 and 40.

The sediment 10-day toxicity testing results are considered further in the weight-of-evidence (WOE) evaluation with other lines of evidence for the benthic community.

Sediment and Pore Water Chemistry

PAH TUs are provided on Figure 7-5a and 7-5b. The majority of TUs for the marsh are less than a TU of 1 which reflects the protective threshold for no adverse effects from PAHs. The dilution series testing provides information to support a Site-specific effects threshold of 40, at and above which impacts are expected to occur; however, there is still some uncertainty regarding the establishment of a no adverse effects level.

Benthic Community Analysis

The results of the benthic community assessment are discussed in detail in the BERA Report, with example metrics provided on Figure 7-6. Overall, results demonstrate that sediments with elevated TUs support a sediment-dwelling organism community at comparable diversity and abundance as that seen in the background areas.

Risk Characterization Summary Benthic Invertebrate Communities

A detailed WOE evaluation is provided in the BERA Report; however, results from the three LOEs indicate that the overall conclusion is that adverse impacts to some benthic organisms may occur in a focused area of the marsh with TUs ranging from 5 to 260, which may be one to three acres (Figure 7-5b).

7.4.2 Risk Characterization for the Fish Populations and Community

The BERA Report provides a detailed description of the risk characterization for the fish populations. The results suggest that although there were some locations with HQs greater than 1 using central tendency average scenario TRVs (ECO-SD-M2, ECO-SD-1, ECO-SD-M5, and ECO-SD-M4), PAHs are not expected to pose unacceptable risks to the fish populations, including the sensitive larval fish, once Site-specific factors are accounted for (e.g., dilution effect, exposure variability, tidal cycles).

7.4.3 Risk Characterization for Bird and Mammal Populations

The BERA Report describes the risk characterization process for wildlife. Table 7-2 provides a summary of the food web modeling results based on LOAEL TRVs for each of the wildlife species for the marsh and background areas, with detailed calculations provided in the BERA Report. The LOAEL TRVs are summarized here because they reflect the concentration above which impacts to birds and mammals are considered more likely to occur. HQ values greater than 1 warrant further consideration.

Based on the USEPA Region 4 LOAEL TRVs, LOAEL HQs exceed a value of 1 for the mallard duck, spotted sandpiper, green heron and raccoon using species-specific area use factors (osprey and river otter were below the threshold value of 1). The greatest risk is for the spotted sandpiper. For this reason, alternate TRVs were also considered in the uncertainty section of the BERA Report.

7.4.4 Uncertainties

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).

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) (Figure 7-8). 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 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

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

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

- Benthic community structure and integrity – PAH residues in the majority of the Marsh Study Area do not pose unacceptable risks for sediment-dwelling organisms; however, the BERA results indicated that adverse impacts to the growth of sediment-dwelling organisms are expected at ∑34 PAH TUs greater than or equal to 40 (Figure 7-7). The threshold for no effects for survival and growth of sediment-dwelling organisms is uncertain and is expected to be between 1 and 40.
- 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 residual PAHs in the sediment pore water do not pose an unacceptable risk to fish populations via impacts to larval fish even though there were some locations with TUs exceeding the threshold value of 1.
- Survival and reproduction of bird and mammal populations – The BERA food web model results show the greatest potential risk for spotted sandpipers as well as lower potential

risks for mallard ducks, green heron, and raccoon. The HQs for these receptors appear to be most influenced by the sediment ingestion component of the question, meaning that species that ingest a high amount of sediment while foraging are potentially at greater risk than species that ingest less sediment while foraging. Based on the HQs calculated that exceed 1 and the uncertainties associated with TRVs and sediment ingestion, adverse effects to birds and mammals could be occurring and it is not clear if this would have an adverse effect on the local population of small home-range birds and mammals.

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 soil, 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 and 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

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. 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 71 feet bgs 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

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.

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 71 feet bgs 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. The sources of groundwater contamination include DNAPL and creosote-impacted soil. Based on the similarity of the groundwater plume and DNAPL configuration, the primary source appears to be DNAPL. 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 (ranging from 4.9 to 11.5 ug/L). 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 two deep monitoring wells (MW-27D and MW-32D). DNAPL was also measured in well MW-06D. However subsequent evaluation indicated well MW-06D was compromised and the DNAPL was likely from an upper zone. Deeper wells were not installed because boring log descriptions from nearby soil borings SB-E, SB-D, and 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 x 10^{-7} cm/sec and SB-E, where permeability is 8.1 x 10^{-7} cm/sec at 100 feet bgs and 5.2 x 10^{-6} cm/sec 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 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 runoff 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.

Substantial future migration of the DNAPL is not likely to occur as wood treating activities have not been conducted since 1974 and no additional creosote is being added to the system. 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. Analytical results for the pore water samples collected from within the marsh indicate impact by COPCs. Based on the depth to the Peedee Aquifer and the lack of an identified upward hydraulic gradient, groundwater in the Peedee Aquifer does not appear to directly discharge to the marsh.

As long as DNAPL is in contact with groundwater and/or residual soil sources that can leach to groundwater, creosote constituents will continue to dissolve into groundwater. 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 (Southern Marsh) 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:

- Risks from soil in the Process Area and the Pond Area exceed the upper end of the acceptable cancer risk range of 1 x 10^{-4} for future residents only. The non-cancer threshold of 1.0 was exceeded for future residents, future outdoor workers, and future construction workers in either the Process or Pond Areas or both. Other exposure areas present soil risks that are either below or within USEPA's acceptable risk range (1 x 10^{-6} to 1 x 10^{-4}).
- Cancer risks from soil in the Treated Wood Storage Area, Untreated Wood Storage Area, and Eastern Upland Area exceeded the lower end of the risk range of 1 x 10^{-6} but are less than the threshold of 1 x 10^{-4} for the receptors evaluated except the future construction worker in the Treated Wood Storage Area and the current/future teenage trespasser and future construction worker in the Untreated Wood Storage Area and Eastern Upland Area for whom risks are below 1 x 10^{-6}.
- For the future construction worker, the distribution of incremental cancer risk and non-cancer hazard are attributed to surface soil impacts for the Treated Wood Storage Area, Untreated Wood Storage Area, and Eastern Upland Area. However, risks from subsurface soil are greater than the surface soil in the Pond Area and the Process Area.
- Risks from groundwater in the southern portion of the property exceed the upper end of the cancer risk range (1 x 10^{-4}) for the potential receptors evaluated in the HHRA except the future construction worker for whom risks are 7 x 10^{-7}, below the threshold. The non-cancer hazard of 0.8 for the future construction worker is also below the threshold of 1.0. However, the non-cancer hazard for the other potential receptors were above the threshold.
- 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 10-day 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, bulk sediment chemistry of PAHs and comparison to sediment quality benchmarks and food web modeling for mammals and birds.

- Benthic community structure and integrity – The BERA included a WOE 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, the BERA results indicated that adverse impacts to the growth of sediment-dwelling organisms are expected at ∑34 PAH TUs greater than or equal to 40. It is expected that the threshold for no effects for survival and growth of sediment-dwelling organisms is between 1 and 40, but the actual TU is uncertain. The areas of the marsh with the highest PAH concentrations are shown on Figure 7-7. .
- 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 reflects the types of birds and mammals that can be expected in the marsh. A range of exposure assumptions and USEPA Region 4 TRVs were considered. The food web modeling results were below the threshold value of 1 for fish eating birds and mammals, such as osprey and river otter. The potential for risks from PAH exposure was identified for birds and mammals that forage in the Marsh Study Area, such as the spotted sandpiper, green heron, mallard duck, and raccoon, as some of the food chain modeling resulted in LOAEL-based HQs greater than 1. Additional food web modeling done as part of the uncertainty assessment using less conservative TRVs showed HQs below the low effect threshold of 1. As described in the BERA, the less conservative TRVs are alternative values protective of growth and survival. The HQs for the food web model appear to be most influenced by the sediment ingestion component of the question, meaning that species that ingest a high amount of sediment while foraging are potentially at greater risk than species that ingest less

sediment while foraging. Based on the HQs calculated that exceed the threshold value of 1 and the uncertainties associated with TRVs and sediment ingestion, it is possible that adverse effects to birds and mammals could be occurring and it is not clear if this would have an adverse effect on the local population of small home range birds and mammals. The species most at potential risk are those that ingest sediment while foraging for food, such as the spotted sandpiper. The areas that contribute the highest sediment exposures for birds and mammals are the same areas already identified with elevated TUs from 40 to 260.

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 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 well MW-32D.
- Substantial future migration of the creosote is not likely to occur as wood treating activities have not been conducted since 1974 and no additional creosote is being added to the system. 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 Area and the Pond Area 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 Wood Storage Area and the Untreated Wood Storage Area 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 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 in the Process Area and Pond Area. Overall risk is also unacceptable for groundwater. No constituent exceeded its residential RSL for soil in the area West of Navassa Road; therefore, no COPCs were determined for that area. No COCs were identified for the Treated Wood Storage Area, Untreated Wood Storage Area, Eastern Upland Area or the Southern Marsh. Risks associated with Sturgeon Creek were insignificant due to lack of a complete exposure pathway.
- The BERA results indicate that adverse impacts to sediment-dwelling organisms are expected at TUs greater than 40. The threshold for no effects for survival and growth of sediment-dwelling organisms is between 1 and 40. Additional data is required to identify a Site-specific threshold TU below which no unacceptable adverse impacts are expected. Recommendations for future work are described in Section 8.3, including elements of work related to sediment chemistry and toxicity evaluations.

8.3 RECOMMENDATIONS FOR FUTURE WORK

The following activities are recommended in the future:

- Conduct a groundwater plume stability evaluation to determine the current condition of the dissolved phase groundwater plume (increasing, decreasing, or stable) and provide a baseline for future comparison. 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 in the FS the area of the marsh that was identified in the BERA. The BERA results indicated that adverse impacts to the growth of sediment-dwelling organisms are expected at ∑34 PAH TUs greater than or equal to 40. It is expected that the threshold for no effects for survival and growth of sediment-dwelling organisms is between 1 and 40, but the actual TU is uncertain. Therefore, additional sediment characterization for the Marsh Study Area will be conducted in accordance with approved USEPA and NC DEQ work plan(s) and results will be provided to USEPA and NC DEQ in a “BERA Addendum” for use in the Marsh FS, as appropriate. Additional study may include sediment characterization using passive diffusion sampling approaches consistent with USEPA’s Guidance “Developing Sediment Remediation Goals at Superfund Sites Based on Pore Water for the Protection of Benthic Organisms from Direct Toxicity to Nonionic Organic Contaminants” (USEPA, 2017c). Additional toxicity testing using 28-day testing for survival and growth will also be considered for the marsh. The additional characterization and 28-day toxicity testing data will be used to identify a Site-specific threshold TU below which no unacceptable adverse impacts are expected for sediment-dwelling organisms, which can be used in the Marsh FS. In accordance with USEPA Risk Management Principles (1999), the Marsh FS should include consideration of how the potential impact to the Marsh Study Area may be balanced against risk reduction.

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