COMMONWEALTH of VIRGINIA

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November 13, 2015

Mr. Michael Liberati
DuPont Corporate Remediation Group
Chestnut Run Plaza 715-236
Wilmington, DE 19805
VIA ELECTRONIC MAIL

Re: Revised Final RCRA Facility Investigation and Human Health Risk Assessment Reports for AOC-4
Former DuPont Waynesboro Plant, Waynesboro, Virginia
EPA ID# VAD003114832

Dear Mr. Liberati:

The Department of Environmental Quality, Office of Remediation Programs (DEQ) received the final revised AOC-4 RCRA Facility Investigation (RFI) Report, dated August 2015, and the revised Human Health Risk Assessment (HHRA), dated October 2015. These documents are associated with the Former DuPont Waynesboro Plant (Facility) located in Waynesboro, Virginia, and the Corrective Action requirements of the Hazardous Waste Management Permit for the facility.

The RFI and HHRA have been reviewed and are hereby approved as part of the facility's Site-Wide Corrective Action with no further comments. The final Ecological Risk Assessment (ERA) associated with the RFI was previously approved by DEQ on July 13, 2015. This concludes the RFI phase for AOC-4. However, additional focused investigation may be warranted as part of the remedy selection process.

At this time the facility should continue with the design and implementation of the approved Phase I Interim Measures Workplan. In addition, please contact me to schedule a meeting focused on the remedy selection process. This meeting is intended to bring all of the key decision makers together to discuss the corrective action objectives, stakeholder concerns, and establish a clear path forward for the project.

If you have any questions, you may contact me at 804-698-4064 or by email at Vincent.Maiden@deq.virginia.gov.

Sincerely,

Vincent A. Maiden
Office of Remediation Programs

cc: Brett Fisher, Sonal Iyer, File – DEQ CO
Andrea Barbieri, EPA Region III (3LC50)
Graham Simmerman, Don Kain – DEQ VRO
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Volume I of III

RCRA Facility Investigation (RFI) Report
Former DuPont Waynesboro Site
Area of Concern (AOC) 4

South River and a Segment of the South Fork Shenandoah River, Virginia

Date: August, 2014 (Revised)
August, 2015 (Final)

Project No.: 18986308

URS

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Acronym List

Acronym	Explanation
µg/g	Micrograms per gram
µm	Micrometer
AOC	Area of concern
BASS	Bioaccumulation and Aquatic System Simulator
BMA	Bank Management Area
BFC	Benthic Flux Chamber
ºC	Degrees Celsius
CD	Consent Decree
cfs	Cubic Feet per Second
cm	Centimeter
CBRs	Critical Body Residues
CMS	Corrective Measures Study
COPC	Constituents of Potential Concern
CRG	DuPont Corporate Remediation Group
CSMs	Conceptual System Models
$\delta^{15}N$	Ratio of stable nitrogen isotope (^{15}N:^{14}N)
DGT	Diffusion Gradient In Thin Films
DOC	Dissolved Organic Carbon
DuPont	E.I. du Pont de Nemours and Company
dw	Dry Weight
EAM	Enhanced Adaptive Management
ECSM	Ecological Conceptual Site Model
ERA	Ecological Risk Assessment
EXAFS	Extended X-Ray Absorption Fine Structure
f/ha	Fish per Hectare
Fe	Iron
FIHg	Inorganic Mercury in Filtered Water
FMeHg	Methylmercury Concentration in Filtered Water
FTHg	Total Mercury Concentration in Filtered Water
Hg	Mercury
HgCSM	Mercury Conceptual System Model
HgS	Mercury Sulfide (Cinnabar)
$Hg(II)_R$	Reducible Divalent Mercury
HHCSM	Human Health Conceptual Site Model
HHRA	Human Health Risk Assessment
HRADs	Mercury (Hg) release-age deposits
IHg	Inorganic Mercury
IHg_p	Particulate Inorganic Mercury
IM Work Plan	Interim Measures Design, Implementation and Monitoring Work Plan
IRM	Interim Remedial Measure
kg	Kilogram
km	Kilometer
LiDAR	Side-Scan Light Detection and Ranging
LOEs	Lines-of-evidence
LOI	Loss on Ignition
m	Meter
mg/kg	Milligram per Kilogram
mm	Millimeter

Acronym	Explanation
%MeHg	Percent of Total Mercury as Methylmercury
MeHg	Methylmercury
NFA	No Further Action
ng/g	Nanograms per Gram
ng/L	Nanograms per Liter
NRDC	Natural Resource Defense Council
OWPC	Office of Waste Permitting and Compliance
PIT	Passive Integrated Transponder
QA/QC	Quality Control/Quality Assurance
RAOs	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RDQA	Retrospective Data Quality Assessment
RFI	RCRA Facility Investigation
ROPs	Remedial Options Programs
RRM	Relative River Mile
SAV	Submerged Aquatic Vegetation
SERCC	Southeast Regional Climate Center
SFS	South Fork Shenandoah (River)
SLERA	Screening Level Ecological Risk Assessment
SQB	Sediment Quality Benchmark
SQT	Sediment Quality Triad
SRL	Stream Research Lab
SRST	South River Science Team
STP	Sewage Treatment Plant
SWCB	State Water Control Board
SWMU	Solid Waste Management Unit
TEC	Threshold Effects Concentration
THg	Total Mercury
THg_P	Particulate Total Mercury
UCL	Upper Confidence Limit
UMeHg	Methylmercury Concentration in Unfiltered Water
USGS	United States Geological Survey
URS	URS Corporation
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VADCR	Virginia Department of Conservation and Recreation
VDEQ	Virginia Department of Environmental Quality
VDH	Virginia Department of Health
VIMS	Virginia Institute of Marine Science
WOE	Weight-of-Evidence
YOY	Young-of-Year

Executive Summary

E.1 Introduction

This Resource Conservation and Recovery Act (RCRA) Facility Investigation Report (RFI Report) documents the results of a number of investigative activities conducted to characterize the nature and extent of mercury in environmental media in an off-site portion of the former E.I. du Pont de Nemours and Company (DuPont) Plant (the Site), in Waynesboro, Virginia. This off-site portion [Area of Concern (AOC 4)] includes the aquatic and riparian terrestrial systems (including the floodplain) along approximately 25 river miles of the South River downstream of the Site and parts of the South Fork Shenandoah (SFS) River in Virginia (see Figure 1-1 to Figure 1-7).

This RFI Report was prepared pursuant to a permit modification issued to DuPont by the Commonwealth of Virginia, Department of Environment Quality (VDEQ) in February 2014 under the corrective action provision of RCRA. The United States Environmental Protection Agency (USEPA) issued a Hazardous Waste Permit for Corrective Action (Permit) for on-site areas under RCRA in September 1998. A revised Permit (VAD003114832) was approved by VDEQ Office of Waste Permitting and Compliance (OWPC) on September 24, 2009 (VDEQ, 2009a). VDEQ signed a modification to the existing on-site RCRA permit, including the designation off-site areas as AOC 4.

Over more than three decades, DuPont has funded or undertaken numerous investigations of mercury in sediment, water, floodplain soil, and biological tissue of organisms that inhabit AOC 4. DuPont has also undertaken source control and other remediation activities on-site and off-site to prevent further mercury loading into AOC 4. As a part of the June 2005 Consent Decree (CD) among DuPont, the Natural Resource Defense Council (NRDC), and the Sierra Club (Virginia Chapter), an extensive, multi-year, multi-phase Ecological Study was conducted between 2006 and 2012 to systematically investigate the nature and extent of mercury concentrations in the South River system designated as AOC 4. The Ecological Study Report (URS, 2012) integrated the findings of the Ecological Study and various other studies. Also as a part of the 2005 CD, a Remediation Proposal was prepared in 2013 that proposed remedial actions for AOC 4 based on the findings of the Ecological Study Report.

In accordance with the modified RCRA Permit, this RFI Report relies on the Ecological Study Report and the Remediation Proposal to document the nature, extent, fate, and transport of mercury that has historically migrated from the Site into the surface water, sediments, floodplain soils, and biota within AOC 4.

E.2 Site Description

The Site is located on approximately 177 acres of flat lying land along the South River in the southeastern corner of Waynesboro, Virginia (see Figure 1-8).

AOC 4 includes the aquatic and riparian areas (including the floodplain) of parts of the South River downstream of the Site and parts of the SFS River, Virginia, and extends from approximately one mile upstream of the Site on the South River to five miles downstream of the confluence of the South River with the North River.

To describe the locations where data were collected in AOC 4, the terms relative river mile (RRM) or the distance from the Site in Waynesboro are used for various sampling efforts (see Figure 1-1 to 1-7).

E.3 Summary of Results and Investigations

DuPont and others have extensively investigated the physical, chemical, and biological components of off-site portions of the South River, SFS River, and associated floodplain areas (within AOC 4). On September 28, 2012, the Ecological Study Report was submitted to the NRDC and various state and federal regulatory agencies (URS, 2012). The Ecological Study Report integrated the findings of various studies and concluded that the largest mercury sources (river banks, outfalls from the former Waynesboro facility, and sediment) primarily occur in the first 12 river miles. Another important finding was that although the South River downstream of RRM 12 and the upper segment of the SFS River contain relatively few mercury sources [i.e., few river banks with high total mercury (THg) concentrations], these areas have elevated mercury concentrations in some media (e.g., fish and birds). The following sections summarize the findings of the extensive characterization of the physical, geological and geomorphological, chemical, and biological characteristics of the South River and discuss features of the upper segment of the SFS River.

E.3.1 Mercury Concentrations

The concentrations of mercury in various media within AOC 4 have been documented through various studies that have occurred over the past two decades. These studies are summarized below.

Floodplain Soils

In 2008, a comprehensive sampling of the South River floodplain soils was conducted to evaluate THg concentration distributions as a function of RRM, floodplain inundation frequency, and land use. Floodplain soil samples were collected from the top of the river banks to inland locations, set back from the river. The results indicated that THg concentrations:

- Decrease with increasing distance into the floodplain from the river and increasing distance downstream
- Were highest in the two- and five-year floodplains and within forested areas
- Were similar between floodplain wetlands and surrounding floodplain soils
- Were below the human health screening level of 17 mg/kg in 93% of the samples

Further, a study of tributary loading indicated that floodplain runoff was not a significant source of THg and methylmercury (MeHg) to the South River.

Bank Soils

A total of 207 river bank transects was sampled from RRMs 0.1 to 23.5. The bank soil samples were collected from the face of the river banks between the river's edge and the top of the banks. The vertically averaged THg concentration in the river bank soils range from 1 to 140 milligrams per kilogram (mg/kg), and the maximum concentrations in the discrete samples range from 3 to 515 mg/kg. These bank soils also include mercury release-age deposits (HRADs), which are near-channel deposits from 1929 and 1950 when mercury was in use at the Site. HRADs were identified through shoreline changes mapped on historical aerial photographs from 1937 and 2005. The majority of HRADs (39 of 47 or 83%) were located between RRMs 0 and 11.6, with a higher density of HRADs between RRMs 3 and 4 (six deposits), RRMs 5 and 6 (five deposits), and RRMs 8 and 9 (ten deposits). Concentrations of THg vary spatially within and between these HRADs.

Surface Water

Under baseline (or non-storm) conditions, the concentration of inorganic mercury (IHg) on particles in surface water generally increases immediately downstream of the outfall at RRM 0 and reaches a maximum at RRM 5.2. Particulate IHg concentrations remain relatively constant until approximately RRM 12, then decrease.

In general, surface water MeHg concentrations were highest between RRMs 10 and 12, but the areas with the highest surface water MeHg concentrations were more widely dispersed. Surface water MeHg concentrations exhibit strong seasonality, generally increasing when surface water temperatures reach approximately 12 degrees Celsius (^{o}C) and low flow conditions. Evaluation of mercury loading also indicated that surface water MeHg loading is generally higher at temperatures greater than 12 ^{o}C compared to temperatures below 12 ^{o}C, suggesting a role of methylation at higher temperatures.

In-Channel Sediment

Fine-grained sediment in the South River occurs primarily as channel margin deposits and as interstitial sediment within the coarser substrates of the stream bed. THg concentrations were highly variable in the channel margin deposits. Higher concentrations were found at depth, buried below fine sediment with lower concentrations relative to subsurface sediments. THg concentrations in interstitial sediment generally increase between RRMs 0 and 8.7 and decline farther downstream.

Biological Tissues

Extensive sampling and analysis of biological tissues across the range of trophic levels has been performed in the South River, including a variety of fish and shellfish, benthic invertebrates, and periphyton. Smallmouth bass (*Micropterus dolomieui*) are an important local sport fish. Because they are a high trophic level piscivore, bass generally have higher THg concentrations compared with other fish species. The geometric mean of length-normalized THg concentrations in smallmouth bass (1.1 mg/kg wet weight) is the highest in the reach between RRMs 6 and 13.

E.3.2 Sediment and Mercury Transport

At RRM 0, the South River carries an estimated 54 to 92 metric tons of suspended sediment per year. As suspended sediment is transported downstream, an average of approximately 6% of the annual load is deposited per mile on the floodplain. In addition, approximately 3% of the annual sediment load is deposited as fine-grained sediment deposits in eddies and other low energy areas near the banks, such as behind large woody debris and other obstructions. Newly deposited sediment originates mostly from the eroded banks but also from re-suspended surficial sediments of fine-grained sediment deposits. Bank soil erosion is a relatively small portion of the total sediment budget, but is important for mercury transport.

E.3.3 In-Channel Bed Stability

In-channel bed stability in the South River has been characterized through scour chain and other monitoring methods. In the scour chain method, a metal linked chain is buried vertically in the streambed with the top of the chain as close to flush with the streambed surface as possible. After a runoff period, the horizontal elbow of the chain at the new surface created after a flood event is located. The difference in the length of chain above the elbow before and after a flood yields the scour depth. Monitoring data collected over a period of about two years suggest that the South River bed is stable with no discernible scour. Scour data were not available for the river as a whole, but the conditions at RRM 4.3 were likely applicable to most of the reach between RRM 0 and 13, before river slope increases. Approximately 80% of the stored sediment in gravel beds and interstices is estimated to be less than 50 years old and the median age of stored sediment is estimated to be about 32 years, indicating that the bed is relatively stable and that sediment residence time in the coarse-grained beds is on the order of a few decades.

E.3.4 Bank Erosion

Bank erosion rates on the South River average approximately 4 centimeters per year (cm/yr) throughout the system. Removal of small mill dams on the South River is estimated to have increased bank erosion rates two- to three-fold after approximately 1957, compared to earlier periods. Elimination of these historical obstructions no longer impede the flow of the river and therefore, probably allow higher bank erosion rates at and downstream of the former dam locations. Present-day bank erosion rates tend to be higher near islands and at migrating bends.

E.3.5 Mercury Mass Balance

A present-day mass balance for mercury was developed for the first 10 river miles of the South River. Several different lines of evidence—including incremental loading rates and concentration gradients in surface water, sediment, and pore water—strongly suggest that non-channel (e.g., bank) sources of THg were primarily limited to the first 10 to 12 river miles of the South River.

Eroding banks were the largest current single source of THg loading to RRMs 0 to 10 of the South River, accounting for 40 to 60% of the THg loading. Other mechanisms by which THg stored in banks could potentially be transported to the water column include soil particle dispersion and colloidal transport, or soil-water and other biogeochemical interaction within the bank.

The Site outfalls continue to be a source of mercury to the South River. Unintended mercury releases through the Site outfalls have also recently occurred as a result of on-site remediation actions, including sewer cleaning. DuPont is evaluating alternatives jointly with USEPA for the remediation of upland mercury sources, including mercury discharges in the plant outfalls.

In-channel sediments in RRMs 0 to 12 are both a potential exposure medium and a source of MeHg to the South River. Although a relatively small source of THg to the South River, in-channel sediment currently accounts for approximately 74% of the MeHg loading between RRMs 0 and 2.7. THg concentrations in finer sediment deposits along the channel margin and THg attached to fine sediment that occurs within the interstices of the gravel-cobble matrix are sufficient to maintain ongoing methylation of THg throughout the system.

E.3.6 Biological Conditions

The South River is a generally functional ecological system supporting diverse land types and biological communities. A number of studies on biological conditions are summarized below.

Benthic Community

Benthic and epibenthic communities were found to be similar in the South River and reference areas when several metrics of biological integrity were evaluated. Taxa richness was not significantly different in the South River compared to reference sites, based on a range of metrics including dominant taxa, presence of pollution-intolerant species, and diversity and evenness measures. These comparisons indicate that that mercury is not adversely affecting benthic community structure in AOC 4 relative to the reference areas.

Bank Habitat

Riverbanks and the surrounding riparian zones also represent ecologically important habitats of the South River. These areas provide foraging, nesting/burrowing, and refugia opportunities for numerous species of songbirds, piscivorous birds, small mammals, and reptiles/amphibians. The extent and quality of bank and riparian habitats of the South River vary extensively with surrounding land use. For example, the first two miles of the river are mostly surrounded by a mixture of commercial, industrial, and residential land uses with minimal riparian habitats. From approximately RRMs 2.5 to 12, the dominant land use is agricultural, including pasture hay and row crop mixed with limited stands of hardwood forest. While the riparian corridor is fairly narrow (less than 60 feet) in most locations, with the exception of livestock grazing areas, it is relatively undisturbed and provides some level of ecological function.

E.3.7 Lower South River and South Fork Shenandoah River

One of the key findings of the Ecological Study Report is that areas with relatively high MeHg concentrations in environmental media (e.g., surface water) and biological tissue (e.g., fish) were observed in the downstream reach (e.g., at distances greater than approximately 12 miles distant from the Site). Three potential causes for this spatial offset between mercury sources and evidence of exposure are: 1) the more downstream points may reflect the accumulated mercury load from many diffuse non-point sources; 2) mercury methylation is a widely distributed process in South River sediment; and 3) IHg is highly persistent over time, which may be the case in the South River, where soil-water interactions and soil wetting and drying may lead to a prolonged ability for soil to release IHg.

E.3.8 Mercury Conceptual System Models (HgCSMs)

DuPont and others have investigated the physical, chemical and biological components of off-site portions of the South River, SFS River, and associated floodplain areas. The legacy mercury issue at the Site was discovered in 1976. A review of VDEQ monitoring data in 2000 showed that mercury remained elevated in the South River fish species, with potential implications for human and ecological exposure. After over three decades of investigation, biomagnification of mercury in the aquatic and terrestrial food webs, rather than direct toxicity to existing ecological receptors, has been identified as the primary cause for concern within AOC 4.

The following unique set of conditions is identified within the South River aquatic system that forms the basis for the aquatic HgCSM to help describe why fish tissue mercury concentrations continue to remain elevated:

- In addition to the IHg present in the surficial sediments, the ongoing mercury loading from the erosion of bank soils and other sources maintain a steady supply of bioavailable IHg within the South River.
- The continued supply of bioavailable IHg into the South River provides the necessary source for microbial methylation of IHg into MeHg, the form that readily bioaccumulates and biomagnifies within the aquatic food web.
- Natural recovery processes, including the supply of low-mercury sediment to attenuate the ongoing IHg source and de-methylation of MeHg, were not sufficient to overcome the ongoing mercury loading to the South River.

A preliminary terrestrial HgCSM has also been developed based on two lines of evidence – the MeHg concentration, and the stable nitrogen isotope ratio that quantifies the trophic position of the food web element. Terrestrial organisms were organized according to the trophic levels and MeHg concentrations. The MeHg mercury concentrations and nitrogen isotopes suggest that the main sources of MeHg to higher trophic levels in the floodplain were via detritivorous invertebrates and emergent aquatic insects. As a consequence, MeHg concentrations in the organisms that feed on this pathway (e.g., invertivorous mammals) were higher than in strictly herbivorous animals. The influence of MeHg from emergent aquatic insects can be seen in the high nitrogen isotope ratios and MeHg concentrations in terrestrial animals that feed on emergent aquatic insects (predatory spiders, aerial insectivorous birds and mammals).

E.3.9 Future Course of Actions in AOC 4

The findings summarized in the preceding sections formed the basis for the Remediation Proposal (Anchor QEA and URS, 2013), also prepared as a part of the 2005 Consent Decree between DuPont and NRDC. The Remediation Proposal develops site-specific remedial action objectives (RAOs) and evaluates a range of bank remediation alternatives, first to be applied to the upper reach of the South River in a logical upstream-to-downstream implementation sequence. In addition to ongoing efforts to control limited on-site mercury releases, the primary recommended remedy for AOC 4 includes enhanced vegetative and structural stabilization of target banks to substantively reduce mercury loading to the South River and accelerate natural recovery processes within channel areas.

Given the complexity, extent, and the uncertainty of the system(s) involved, an Enhanced Adaptive Management (EAM) approach is proposed to address ongoing mercury exposure in AOC 4. Ongoing and planned SRST studies will also continue to provide information relevant to the RFI. In addition, the results of the proposed EAM process may warrant investigative work. Additional information resulting from these activities will be evaluated as part of the RCRA process. Proposed human and ecological exposure monitoring (short-term and long-term) plans will also generate environmental data used for hypothesis testing within the EAM approach to track potential system responses to remedial actions and effectively integrate lessons learned. A final Phase I Interim Measures Design, Implementation, and Monitoring Work Plan (Phase I IM Work Plan) for AOC 4 was submitted and subsequently accepted, by the VDEQ in February, 2015.

DuPont will also continue to work closely with the various state and federal governmental agencies to conduct education and other outreach efforts for the communities along the South River and SFS River (e.g., via continued collaboration with *Promotores de Salud*, a public health program for the Hispanic community).

1.0 Introduction

This Resource Conservation and Recovery Act (RCRA) Facility Investigation Report (RFI Report) has been prepared by URS Corporation [(URS) currently AECOM] on behalf of E.I. du Pont de Nemours and Company (DuPont) for Area of Concern (AOC) 4 of the former DuPont Waynesboro Plant, Virginia. It has been prepared pursuant to a permit modification issued to DuPont by the Commonwealth of Virginia, Department of Environmental Quality (VDEQ) in February 2014 under the RCRA corrective action provision. The United States Environmental Protection Agency (USEPA) issued a Hazardous Waste Permit for Corrective Action (Permit) for on-site areas under RCRA in September 1998. A revised Permit (VAD003114832) was approved by VDEQ - Office of Waste Permitting and Compliance (OWPC) on September 24, 2009 (VDEQ, 2009a). VDEQ signed a modification to the existing on-site RCRA permit that now includes the off-site area. The off-site area was designated as AOC 4, and includes the aquatic and riparian terrestrial systems (including the floodplain) of parts of the South River downstream of the Site and parts of the South Fork Shenandoah (SFS) River, Virginia (see Figure 1-1 to 1-7).

1.1 Purpose and Scope

The main objective of this RFI Report is to describe the nature and extent of mercury contamination in AOC 4: identification of important source areas (e.g., bank and floodplain soils, near-channel historical deposits, and in-stream sediments), fate and transport of mercury within and from these source areas to other biotic and abiotic media within AOC 4. AOC 4 spans approximately 25 miles within the South River and SFSR systems (starting at Site and including parts of SFSR), and covers approximately 626 to 3,570 acres (based on the 0.3-year or the 62-year floodplain) along the 24-mile reach of the South River.

Mercury is the focal contaminant for AOC 4 because its biomagnification through the South River food web continues to be the central environmental issue in AOC 4. Mercury tissue residues in fish have remained elevated since the mid-1970s, and more recent studies have found elevated mercury tissue residues in various birds and bats within AOC 4, with implications for the health of both humans and wildlife. This RFI contains a summary of previous, ongoing, and proposed future investigative and remedial activities in AOC 4. It also summarizes a proposed Phase I Interim Measures program for relative river miles (RRM) 0 through 2 that is currently in progress. An extensive, multi-phase, multi-year study has been conducted for AOC 4, to specifically address the ecological impacts of the mercury used at the Site. The findings of this and other studies are provided in the Ecological Study Report (URS, 2012; Appendix A). A Remediation Proposal (Anchor QEA and URS, 2013; Appendix B) has also been prepared, based on the findings of the Ecological Study Report, that provides an Enhanced Adaptive Management (EAM) framework for the remediation in AOC 4. An EAM framework allows a flexible approach to integrate the lessons learned along the course of the remediation, which is critical for the scale and complexity represented by the remedial efforts at AOC 4.

This RFI Report relies largely on the Ecological Study Report and the Remediation Proposal to document the nature, extent, fate, and transport of mercury that has migrated from the Site to the surface water, sediments, floodplain soils, and biota inhabiting AOC 4. Both the Ecological Study Report and the Remediation Proposal relied on data collected through November, 2011. Investigations performed after November 2011 have generated additional data to specifically support various discrete elements of the RFI (including risk assessments, remedial pilot projects, and remedial designs). Although these data (collected through April 30, 2014) have not been evaluated in the RFI, the main findings of the Ecological Study Report are expected to remain unchanged regarding the nature and extent of mercury in AOC 4 because they are based on a solid foundation of extensive data collection and evaluation. Ongoing studies and further evaluation may help refine the major findings, but are unlikely to alter them.

The Ecological Study Report constitutes an extensive multi-year study conducted under the guidance of a multi-disciplinary team of experts and stakeholders [the South River Science Team (SRST)] to understand the nature and extent of mercury contamination in AOC 4, and to develop conceptual system models (CSMs) for the aquatic and terrestrial transfer of mercury. Comprehensive evaluations of the more recent datasets are not provided in this RFI Report, but the CSM continues to be revisited and revised as necessary based on recent data.

Recent data have been evaluated and presented as a part of the respective RFI elements, the Human Health (HHRA) and Ecological Risk Assessments (ERA), and the associated Retrospective Data Quality Assessments (RDQAs). Risk assessments are performed to identify and characterize potential mercury-associated risks in AOC 4. Findings from these risk assessments and additional ongoing studies are summarized in this RFI Report and will be considered under the EAM framework to inform remedial decision-making.

1.2 Background

Brief investigative backgrounds on both the on-site and off-site portions of AOC 4 are provided in this section.

1.2.1 Former DuPont Waynesboro Plant (On-Site Areas)

The Site is located on approximately 177 acres of flat lying land along the South River in the southeastern corner of Waynesboro, Virginia (see Figure 1-8). From 1929 to 1950, the Site used mercury compounds (e.g., mercuric sulfate) to produce acetate flake and yarn. The Site recovered the majority of the mercury from the process wastes at an on-site retort facility. Inadvertent mercury releases during that period were remediated in accordance with applicable waste management practices of the time. Areas and media impacted by these historical releases are currently the primary source of mercury loading from the Site to AOC 4.

A RCRA RFI was completed for the Site to investigate historical on-site sources in three separate phases from 2000 to 2009. A Comprehensive RFI Report was submitted to VDEQ and USEPA Region III on November 30, 2009 (URS, 2009). At the request of USEPA, additional activities were completed in 2011 to address data gaps in the Northeast Area of the Site. A revised Comprehensive RFI Report was submitted to

VDEQ and USEPA Region III in August 2012, which included the findings of the supplemental investigation. A revised version was submitted in November 2013 to address comments received from USEPA in May 2013 on the August 2012 submittal.

The revised Comprehensive RFI Report recommended that six Solid Waste Management Units (SWMUs 1, 2, 4, 6, 7, and 17) and one AOC (AOC 1) move forward into a Corrective Measures Study (CMS). Fourteen other SWMUs and one AOC were recommended for no further action (NFA). Other recommendations to complement the CMS were to continue groundwater and outfall monitoring and to implement recommendations from the sewer investigation.

DuPont received conditional approval of the report in July 2014 provided that USEPA comments were addressed in the final version. The final version was submitted to USEPA on May 19, 2015 and approved by the agency on May 27, 2015.

1.2.2 Area of Concern (AOC) 4 (Off-Site Areas)

AOC 4, the focus of this RFI Report, includes the aquatic, riparian, and terrestrial systems (including the floodplain) along approximately 25 miles of the South River downstream of the Site and parts of the SFS in Virginia. (see Figure 1-1 to 1-7). Accidental release of mercury to the South River occurred historically between 1929 and 1950 when mercury was in use at the Site. This legacy mercury that is currently within various compartments of AOC 4 continues to manifest in fish and other biota tissues at elevated levels compared reference areas. Consequently, AOC 4 is the focus of this RFI Report.

DuPont and others have extensively investigated the physical, chemical, and biological components of off-site portions of the South River, SFS River, and the associated floodplain areas. Mercury was discovered in Site soils and sewers in 1976. Between 1976 and 1999, studies were conducted by several different organizations, resulting in limited scientific oversight or interaction with the public. In 2000, fish tissue monitoring data were evaluated, and it was found that mercury concentrations were not declining in South River fish. The South River Science Team (SRST), a multi-stakeholder and collaborative program, was subsequently formed in 2001 to reassess legacy mercury in the South River and SFS River. The SRST applies a watershed-level, risk-based approach to evaluate the potential impact of legacy mercury in areas within AOC 4. To date, the SRST studies have resulted in more than 100 technical reports and publications, many of which were published in peer-reviewed journals.

A multi-year, multi-phase study was conducted in response to a June 2005 Consent Decree (CD) among DuPont, the Natural Resource Defense Council (NRDC), and the Sierra Club (Virginia Chapter). A final report, The Ecological Study Report, summarized the studies done under the CD, and was submitted to the NRDC and various state and federal regulatory agencies on September 28, 2012 (URS, 2012). The Ecological Study Report integrated the findings of these various studies and concluded that the mercury loading in AOC 4 begins at the Site and is primarily limited to approximately 10 to 12 RRMs downstream. Sources of mercury beyond RMMs 10 to 12 are limited, and the relatively high surface water mercury concentrations are due to upstream sources. Table 1-1 provides a list of the investigations and the associated data matrix that the

Ecological Study Report considered in its integrated evaluations. This RFI Report draws from the evaluations and findings of the Ecological Study Report.

A Remediation Proposal was also prepared as a part of the 2005 CD, to address mercury in AOC 4 (Anchor QEA and URS, 2013). This Remediation Proposal builds on the findings of the Ecological Study Report and various remediation pilot studies. The Remediation Proposal develops site-specific remedial action objectives (RAOs) and evaluates a range of bank remediation alternatives, first to be applied to the upper reach (RRMs 0 to 10) of the South River in a logical upstream-to-downstream implementation sequence. In addition to ongoing efforts to control limited on-site mercury releases, the primary recommended remedy for the South River includes enhanced vegetative and structural stabilization of target banks to substantively reduce mercury loading to the South River and accelerate natural recovery processes within channel areas.

Given the complexity, extent, and the uncertainty of the system(s) involved in AOC 4, an EAM approach is proposed that provides a framework to track system responses to remedial actions and effectively integrate lessons learned. Ongoing short-term and long-term monitoring will generate environmental data to support hypothesis testing within the EAM framework.

1.3 Retrospective Data Quality Assessment

DuPont and VDEQ developed a framework for Retrospective Data Quality Assessments (RDQAs) specifically for the datasets used in the HHRA and ERA. The objective of the RDQAs was to document that analytical data collected during the SRST investigations are of sufficient quality for use in risk assessments. The data review consisted of two components: data usability and data completeness. The data usability portion of the review addressed overall data quality components such as analytical methods, quantitation limits, and quality control/quality assurance (QA/QC) procedures. The data completeness portion of the review addressed data quantity components such as sampling design and purpose, spatial distribution, and exposure pathway characterization. The details of the RDQAs for the HHRA and ERA are provided in separate appendices to the respective reports (AECOM, 2015a; AECOM, 2015b).

1.4 Report Organization

The remainder of this report is organized as follows:

- Section 2 characterizes the physical and climatological environmental setting of AOC 4.
- Section 3 provides an understanding of the nature and extent of mercury in the physical media (surface water, pore water, and sediment) of the South River within AOC 4.
- Section 4 describes the physical and chemical characterization of systems and environmental media beyond the river channel, on the riverbank and floodplain soils.
- Section 5 provides a summary of the ecological and human health conceptual site models (ECSM and HHCSMs, respectively) that guide the data collection effort and form the basis of the risk assessments for AOC 4.

- Section 6 describes the nature and extent of mercury in aquatic and terrestrial biota within AOC 4.
- Section 7 provides Mercury Conceptual System Models (HgCSMs) that integrate the components of mercury transport and exposure pathways to focus on elements that contribute to the greatest potential exposures or to mercury loading within the aquatic and terrestrial compartments of the AOC 4.
- Section 8 is a brief summary of scope, findings, and remedial objectives.
- Section 9 summarizes the rationale for the next steps in the CMS by drawing upon data presented in previous sections, as well as pre-remedial design pilot studies, and provides a schedule of RFI-related events for AOC 4.
- Section 10 lists the references cited in this report.

Additionally, the Ecological Study Report and the Remediation Proposal (Anchor QEA and URS, 2013) are provided in Appendices A and B, respectively. Extensive datasets provided in these two reports will be incorporated by reference as part of this RFI Report.

2.0 Environmental Setting

The South River watershed surrounds the Site and acts as an important control on the geomorphological, chemical, and biological components of the South River, which in turn influence the fate, transport, and potential risks associated with the legacy mercury. A brief description of AOC 4 is provided below, along with the features important for the characterization of the nature and the extent of mercury in environmental media and remedial strategies to address mercury exposure.

2.1 Study Area

AOC 4 includes the aquatic and riparian areas (including the floodplain) of parts of the South River downstream of the Site and parts of the SFS River, Virginia (see Figure 1-1 to 1-7). AOC 4 spans approximately 25 miles within the South River and SFS River systems (starting at the Site and including parts of SFS River) and covers approximately 626 to 3,570 acres, based on the 0.3-year or the 62-year floodplain along the 24-mile reach of the South River. The 62-year floodplain corresponds to the largest storm on record since the inadvertent release of mercury from the former plant began in 1929 (Appendix C in CRG, 2008a). Therefore, the 62-year floodplain of the South River and SFS River corresponds to the maximum lateral extent of sediment and associated mercury deposition that may have occurred over this period.

As described in Section 1.2.1, the Site is located on approximately 177 acres of relatively flat land along the South River in the southeastern corner of Waynesboro, Virginia (see Figure 1-8) and abuts the South River within AOC 4. The South River flows approximately 25 miles north to its confluence with North River at Port Republic, Virginia where the combined flow forms the SFS River. The river channel within AOC 4 extends from RRM 0 at the outfall of the Site to approximately 5 miles downstream of the confluence (see Figure 1-1 to 1-7).

2.2 Land Use and Ecological Resources

AOC 4 land use features consist of the South River, adjacent floodplains, ponds, and agricultural, commercial/industrial and residential properties (see Figure 2-1). The Site is an active industrial facility. Open space areas and the South River are used for recreation. The area immediately adjacent to the South River predominantly consists of agricultural pastures and fields with a narrow border of trees along the banks, although riparian forests are present in some areas. Forested areas and the South River are used for hunting.

The South River watershed is composed of 33% agricultural, 56% forested, and 11% developed areas (Fry et al., 2009); Wetlands cover 0.01% of the watershed, which is less than the open water areas (0.6%) and barren lands (0.05%). Future land use with AOC 4 is expected to vary consistent with watershed development.

Specific consideration of land use within AOC 4 as it relates to mercury exposure is addressed in the HHRA and ERA Reports. Based on the current and future land use scenarios, the HHRA considers various potential receptors, including recreational users of the South River (swimming, fishing, boating, and wading), as well as residents, hunters, farmers, and industrial workers.

Ecological habitats within AOC 4 also support various ecological receptors, including, benthic, aquatic, and terrestrial organisms and wildlife. The Virginia Natural Heritage Resources Information database provided by the Virginia Department of Conservation and Recreation (VADCR) was queried to identify potential threatened or endangered species or species of concern using habitat within the boundaries of AOC 4. The query identified 24 species of special status in AOC 4, including a bivalve, Brook Floater (*Alasmidonta varicose*) as having a state status of "Listed Endangered," and two invertebrates [Madison Cave Isopod (*Antrolana lira*) and Madison Cave Amphipod (*Stygobromus stegerorum*)] were listed as having a state status of "Listed Threatened." Detailed results of the query are provided in the ERA Report, along with habitat or life history information. The ERA includes these special status species and their habitats for ecological evaluation.

2.3 Regional Geology

The South River within AOC 4 lies in the Central Valley section of the Valley and Ridge Province and the Blue Ridge physiographic province (Gaithright et al., 1977). The river valley is bounded to the east by the Blue Ridge Mountains, the core of which is composed of quartz-rich igneous and metamorphic rocks. These rocks are strongly resistant to erosion and have a higher topographic elevation than the Massanutten Mountains to the west. On the western side of the river valley, the bedrock is composed of carbonate to shaley carbonate rocks, which are more easily eroded and cause the mountains generally to have gentler slopes. A sequence of unconsolidated quaternary deposits (e.g., talus deposits, alluvial fans, terrace deposits, upland alluvial deposits, and floodplain deposits) overlies the bedrock.

2.4 Hydrogeology

The South River is a fourth order, high gradient, cool water river system, and is classified as a single-thread, sinuous (but non-meandering) gravel-bed bedrock river (Turowski et al., 2008). It joins the North River at Port Republic, Virginia to form the SFS River. The South River drainage basin is approximately 329 square kilometers (km^2) at Waynesboro, Virginia, and 549 km^2 at Harriston, Virginia [United States Geological Survey (USGS), 2007]. Tributaries that discharge to the South River throughout its length are generally first-order streams, and most are intermittent during periods of low precipitation.

2.5 Groundwater

Groundwater provides a potential mercury transport pathway from floodplain soils to the South River. The groundwater contribution (encompassing both alluvial groundwater flow and bedrock flow) to the flow in the South River is estimated to range from 40% to 70% (Grosso, 2006). However, groundwater contribution to mercury transport is not as important as the potential mercury transport due to the groundwater flow in the hyporheic zone, in which groundwater and surface water interact within an open channel system. A 2006 Study by SRST at RRM 3.5 detected MeHg and THg in five of the nine sampling wells. Concentrations ranged from < 1.5 to 25.8 nanograms per liter (ng/L) for THg, and <0.04 to 0.23 ng/L for MeHg in filtered groundwater samples.

The hyporheic zone includes river channel deposits that are primarily coarse-grained gravel and sand, but store fine-grained sediment with high mercury concentrations. Hyporheic zones are important for IHg storage and perhaps mercury methylation. Methylated mercury in these areas can flux from pore water to overlying water via advection and diffusion, or adsorb to particles in surface water, which can then serve as food items for detritus-feeding and filter-feeding aquatic invertebrates at the base of the aquatic food web. Due to the coarse materials present in the hyporheic zone, the direction and magnitude of water flow within these deposits may be affected by small-scale sediment features such as riffles or short-term weather pattern changes (e.g., precipitation events). These small-scale sediment features create a potential loading mechanism from the hyporheic zone to overlying water.

2.6 Climate

Changes in precipitation and temperature have a major influence on surface water temperature and flow and, hence, on the fate and transport of contaminants, including mercury (Schiedek, et al., 2007; Noyes, et al.,, 2009; Gouin, et al., 2013). Surface water hydrology is a function of past area precipitation and directly influence the mercury concentrations in surface water and other media in rivers. An understanding of the relationship between stream discharge and mercury loading and concentration is also critical for predicting the long-term consequences of weather patterns on the dynamics of mercury transport in AOC 4.

Waynesboro features a humid temperate climate, with average January temperatures of 6.1 ^{o}C, average July temperatures of 29.4 ^{o}C, and annual precipitation of 0.94 meters (m) as measured at the Staunton sewage plant, Virginia [Southeast Regional Climate Center (SERCC), 2007]. Precipitation is highest from March to September and slightly lower from October to February (URS, 2012). The average annual snowfall in Staunton, Virginia, is 0.51 m.

Surface water flow monitored as a part of the Ecological Study was representative of the hydrologic record as a whole and characterized typical baseline conditions for the South River. Discharge, as observed at the USGS Station 01627500 located in Harriston, Virginia was below the 68-year median discharge during 64% of water sampling events (see Table 2-1).

Average daily discharge patterns during the 6-year study period for the Ecological Study were compared against a long-term trend based on a 40-year record of daily average discharge measured at the Harriston, Virginia USGS gage (see Figure 2-2) to determine if the conditions were anomalous during the study period. Strong trends were observed in the monthly minimum discharge (see Figure 2-3), the values fluctuated seasonally, and a drought occurred between 1999 and 2003, prior to the period covered by the Ecological Study. In addition, monthly minimum discharges were low throughout the wet seasons from 2007 to 2009. This suggests that the conditions and results observed during the Ecological Study should broadly applicable to most conditions encountered, with the exception of extreme conditions such as drought.

Similar to average daily discharge, the surface water temperature trends during the 6-year study period were also compared against a long-term trend based on an estimated 40-year dataset. Surface water temperature data are available for the South River beginning in June 2005. To understand longer-term climactic conditions, a 40-year temperature dataset was created based on regression models using data collected at USGS stream gages on other nearby rivers. The estimated long-term data (see Figure 2-4) indicate that although the study period covered by the Ecological Study was a relatively warm period, the variation in surface water temperatures during the study period is broadly applicable to the historical record. Average and maximum temperatures were similarly elevated in the mid-1970s, but temperatures declined until the early 2000s when temperatures generally increase. Annual minimum temperatures appeared to decline, suggesting that the range of surface water temperatures was slightly higher during the study period.

Based on summer degree-days (the difference between the mean daily temperature and 12^{o}C) for each year from 1971 to 2010, the study period was particularly warm; three of the five warmest years in the long-term record (2006, 2008, and 2010) occurred during the study period. This finding is important because mercury methylation is favored at warmer temperatures.

2.7 Sediment Transport

Mercury is strongly adsorbed to suspended organic matter in aquatic systems (Meili, 1997; Gill and Bruland, 1990). Hence, the transport and storage of substances, such as organic matter, may significantly control mercury cycling in aquatic systems. The following sections describe several physical characteristics of the South River system that influence the fate and transport of mercury.

The channel bed of the South River is controlled physically by the presence of bedrock, and as a result has shown little or no main channel migration over time. Additionally, the channel substrate (primarily boulder, cobble and gravel) has a limited number of areas where fine-grained sediment has accumulated. The gravel matrix of the river bed also stores some fine-grained sediment (defined as the interstitial sediment).

On average, the South River carries 73 metric tons of suspended sediment per year at Waynesboro. In the process, an average of 5.9% of the annual sediment load is deposited per mile on the floodplain, 2.6% in quiescent areas near the banks referred to as fine-grained sediment deposits, and 0.01% in the hyporheic zone (Pizzuto, 2012). The new sediment originates mostly from the eroded floodplain but also from re-suspension of fine-grained sediment within the channel.

Bank erosion rates on the South River average approximately 4 cm/yr throughout the system although annual erosion rates vary widely from year to year and among banks (Rhoades et al., 2009). Breaching of small mill dams on the South River is estimated to have increased bank erosion rates two- to three-fold after approximately 1957, compared to earlier periods (Pizzuto and O’Neal, 2009). Present-day bank erosion rates tend to be higher near islands and at migrating bends, accounting for approximately 60% of all erosion reaches (Rhoades et al., 2009d.). Animals do not significantly contribute to the total volume of bank erosion in the South River; however, their effects may be important in certain localized areas, especially from livestock grazing. More detailed analysis of erosional reaches and refined erosion rates were provided in the Interim Measures Design Work Plan (Anchor QEA and URS, 2014).

Sediment deposition rates in the system were low relative to the sediment budget for the South River. Interstitial sediment is deposited and released from the river bed during periods of fill and scour.

2.7.1 Geomorphology

Geomorphology influences mercury methylation. In a river, areas of mercury methylation may include wetlands and remnant channels on the floodplain, fine-grained sediment deposits located in the channel, or the hyporheic zone.

Floodplain wetlands are generally considered to provide the most favorable geochemical conditions for methylation (i.e., organic carbon, anoxic or suboxic sediment, and electron acceptors). However, wetlands are not spatially prominent features along the South River.

The submerged aquatic habitats of the South River include the hyporheic zone and fine-grained sediment deposits. As indicated earlier in Section 2.5, these areas are important for IHg storage and potentially for mercury methylation; they also form the source of MeHg for the aquatic food web (see the Ecological Study Report).

2.7.2 Channel Bed

The river channel substrate is dominated primarily by cobbles and boulders, with bedrock exposed frequently along the channel perimeter and channel bottom, indicating a stable river bed. Studies of in-channel river bed scour and estimates of sediment residence times and bank erosion rates indicate that the South River is geomorphically stable.

A scour chain method was used in monitoring stability of the channel bed, in which a metal linked chain is buried vertically in the streambed with the top of the chain as close to flush with the streambed surface as possible. After a runoff period, the horizontal elbow of the chain is located relative to the new streambed surface. The difference in the length of chain above the elbow before and after a flood yields the scour depth. Monitoring data over a period of approximately two years suggest that the in-channel river bed is stable with no discernible scour. Pizzuto et al. (2011) measured no detectable scour using scour chains at RRM 4.3 following four 1-year recurrence interval discharges [approximately 2,000 cubic feet per second (cfs) at Waynesboro, Virginia]. Scour data were not available for the river as a whole, but the conditions at RRM 4.3 were likely applicable to most of the reaches between RRM 0 and 13, because this entire reach has similar geomorphology, based on sinuosity, slope, substrate, and floodplain features [Pizzuto et al. (2011); see Appendix B in the Ecological Study.

Estimates of residence time of interstitial sediments in the gravel bed using radionuclide age-dating methods were consistent with the finding of Pizzuto et al. (2011). Pomraning (2011) estimated that approximately 80% of the stored sediment is less than 50 years old, and the median age of stored sediment is about 32 years old in the South River channels.

3.0 Mercury in the Aquatic System of AOC 4

The Ecological Study Report provides a comprehensive account of the studies and their findings regarding the extent and nature of mercury in environmental media within the South River, including surface water, pore water, and sediment components of the aquatic system within AOC 4. This section provides an overview of the sampling and analysis, the extent of the investigations, and the mercury concentrations in the physical media (surface water, pore water, and sediment) of the aquatic system within AOC 4.

3.1 Surface Water

Historical surface water mercury datasets for the South River (from the early 1970s) were of limited use due to relatively high detection limits (e.g., 500 (ng/L)). VDEQ (as part of the 100-year monitoring plan) and the SRST have collected more recent data since 2002 on a monthly or seasonal basis under widely ranging environmental conditions. By integrating SRST studies with the Ecological Study, surface water collection methods have remained consistent over time and allowed data comparability. At the time the Ecological Study Report was developed, the South River surface water database included over 5,100 samples (analyzed for THg) and over 3,300 samples (analyzed for MeHg) collected primarily from the South River system within AOC 4 and to a lesser extent from other rivers in the watershed. Inorganic mercury (IHg) concentrations, which are based on the differences between corresponding THg and MeHg, are also presented in the following sections where discussions on mercury speciation are of importance.

Surface water samples were collected under baseline flow conditions and storm conditions. Samples for baseline flow conditions were collected when flows were increasing linearly along the extent of AOC 4. Discharge, as observed at USGS Station 01627500 located in Harriston, Virginia was below the 68-year median discharge during 64% of Phase I and Phase II baseline flow surface water sampling events (URS, 2012). Samples were also collected from several storms along the South River in 2006 and 2007.

In general, under baseline flow conditions, IHg and MeHg concentrations in surface water increased immediately downstream of the historical outfall at RRM 0, and reached maximum levels at or before RRM 10 (see Section 3.1.1). Incremental loading studies indicated that IHg and MeHg loads were positive in the first 10 river miles downstream of the Site. Baseline flow MeHg concentrations exhibited strong seasonality, increasing when surface water temperatures reached approximately 12 °C but did not necessarily increase throughout the late summer. Although storm events affected mercury concentrations, the effect is temporary (lasting on the order of hours to days) (see Section 3.1.2). Increased IHg concentrations during storms resulted from re-mobilization of mercury existing within the river channel, not from more distant sources. For example, IHg and MeHg loads from tributaries and floodplain to the South River were generally several orders of magnitude lower than South River channel loads. These results are discussed in detail in the following sections.

3.1.1 Baseline Flow Concentrations and Loading

The dynamics and distribution of mercury under baseline flow have been extensively described in the Ecological Study Report. Samples were collected over a wide range of discharges (see Table 2-1 and Figure 2-2) and climatic conditions (see Figure 2-4). The results have indicated spatial and seasonal variation in mercury concentrations, as discussed below.

Spatial Variation

Initial sampling events in 2004-2005 identified gradually increasing surface water THg and MeHg concentrations between RRM 0 and RRM 10 and declining or similar concentrations from RRM 10 to the confluence with the North River. Additional close interval sampling was conducted within the area of increasing mercury concentrations (RRM 0 to 5) and over the length of the study area. Samples were collected at 500- to 4,000-feet intervals and included transverse sampling adjacent to eroding river banks. The results strongly suggested that mercury sources were distributed throughout the reach between RRM 0 and RRM 5 and potentially farther downstream to RRM 10. These data indicated a strong association between higher surface water mercury concentrations and the proximity to eroding river banks. These studies were also the first to document the seasonality of surface water MeHg concentrations in the South River.

Additional close interval sampling confirmed earlier observations that the primary sources to the river were widely distributed downstream of the Site but were largely limited within RRM 0 and RRM 10 (see Figure 3-1, Panel A). The average particulate IHg concentrations (IHg_P) under baseline flow conditions generally increased downstream of the historical point source, peaking at approximately 25 mg/kg at RRM 9.9 and declining thereafter. Filtered IHg concentrations (FIHg) increased monotonically, reaching an average of approximately 13 ng/L at RRM 11.8. In contrast to the IHg_p, FIHg was relatively constant throughout the downstream reach. Both particulate and filtered surface water MeHg indicated concentration trends that are generally similar to IHg (Figure 3-1, Panels B and C). Panels B and C also show that both $MeHg_P$ and FMeHg were higher at temperatures above 12^{o}C than below 12^{o}C. Also, as shown in Figure 3-1 (Panel D), both IHg and MeHg were strongly adsorbed to particles, but MeHg was less so, as is commonly observed in freshwater systems (Meili, 1997).

Seasonality

Surface water MeHg concentrations exhibited a strong relationship with water temperature in the South River, increasing as surface water temperatures reached approximately 12^{o}C during periods of low discharge. Figure 3-2 shows spatial plots of surface water FMeHg during 2006 to 2010 baseline conditions as a function of daily temperature at Harriston, Virginia (at RRM 16.5). FMeHg increases in the downstream direction, as temperature increases to approximately 12^{o}C; FMeHg generally peaks just before the temperature further increases to 16^{o}C. These results indicate a potentially optimal temperature range for mercury methylation. However, occasional occurrence of peak MeHg concentrations at higher temperatures show that additional factors also influence MeHg production and ultimately, concentration in surface water.

The tendency for concentrations of FMeHg to increase in the downstream direction and at warmer temperatures is in part explained by the seasonal variation in stream flow, which begins to decrease in late March and reaches a minimum base flow during the summer (see Figure 2-2). For a constant mercury load to the system, this decrease in flow will, at least in part, lead to an increase in FMeHg as observed. In addition, the steady increase in temperature that occurs from late April into the summer months (see Figure 2-4), likely leads to an increase in microbial activity and potentially an increase in methylation rate in the system, thereby leading to an increase in the absolute load of MeHg to the water column. The following evaluation of MeHg loading based on observed stream flow and FMeHg concentrations provide below support for this tendency.

Baseline Flow Loading

Quantification of mercury loading during baseline flow conditions was a critical component of mercury source identification. Investigations indicated that positive loads were generally constrained to the first 10 river miles, and that loads increased with increasing discharge. Details of baseline flow loading analysis can be found in the Ecological Study Report (see page 23)

Figure 3-3 (Upper Panel) shows the incremental UTHg loads as a function of discharge and river reach. The incremental increase or decrease in loading for a reach is the difference between loading at the beginning and end of the reach. The incremental UTHg mass loads (normalized to the reach) were the highest between RRM 5.1 and 9.9. UTHg loads were the highest at approximately RRM 10.0 (DuPont CRG, 2008a). HydroQual (2009) provided an independent analysis of incremental loading that supports these findings.

Figure 3-3 (Lower Panel) shows incremental UMeHg loads as a function of river reach at two temperature regimes. UMeHg loads were generally positive and greater from RRM 0 to 10 at temperatures above 12^{o}C, compared to temperatures from 3 to 12 ^{o}C. Coupled with this finding, the seasonal patterns of the highest MeHg concentrations between April and June 2006, during a period of low discharge (see Figure 2-2) and high temperatures (see Figure 2-4), indicated that *in situ* mercury methylation provides a primary source of MeHg to the river.

3.1.2 Episodic Storm Events

Storms may remobilize mercury stored on the floodplain, in the bank soils, as well as in the in-stream sediments. The Ecological Study Report provides an evaluation of the effect of storms on IHg and MeHg transport during four storms in 2006 and 2007. Table 2-1 lists the dates of the storms when samples were collected and the storm return interval. Figure 3-4 shows a summary of the storm discharge and sample collection. Summary findings are provided below, including concentration changes and storm loading.

Concentration Changes

Storms were observed to have short-term effects on the IHg and MeHg concentrations in the South River. Figure 3-5 shows the dynamics of IHg and MeHg transport during four storms in 2006 and 2007. Panel A shows discharges identifying the storm events; the other panels show IHg and MeHg concentrations in sediments, TSS, and filtered surface water.

Panel B shows that at high discharges, IHg in TSS were lower because of the re-equilibration of mercury between particulate and solution phases as cleaner solids (i.e., solids with low IHg concentrations) are transported from upstream of RRM 0 but return to pre-storm levels as discharge declines along with the cleaner solids. Panel E shows that despite periodic increases in discharge, the FIHg was relatively stable from month to month. Increases in FIHg on the falling limb of storms at several locations, was likely introduced by desorption and/or dissolution of mercury from soil particles (Flanders, et al., 2010; Turner and Bloom, 2005).

MeHg concentrations in TSS were also diluted by higher discharges (see Figure 3-5, Panel C). In contrast to FIHg, FMeHg following the storm appeared to be slightly lower than the pre-storm levels (compare Panels E and F). This suggests that the MeHg concentrations were slightly diluted by the higher TSS solid load and that net methylation rates may have been declining throughout the summer; this observation is consistent with observations from sediment and surface water, which generally had the highest concentrations in the spring.

Although storms strongly influence surface water mercury concentrations over short-time scales, additional data suggest that erosion during baseline flows was more important than storm flows at controlling the sediment THg concentration. Figure 3-6 shows surface water THg_P at various discharge regimes and their comparisons to THg concentrations in various related substrates (sediment, soil, FGCM). Panel A shows that THg_P generally decreases with increasing discharges, indicating dilution due to upstream TSS with lower THg_P. Panel B shows that the THg_P at the highest discharges sampled was lower than the THg concentrations in soil and fine-grained sediment deposits as well as average THg concentrations in sediment cores. In contrast, THg_P under discharges less than 321 cfs was generally similar to THg concentrations in other media. This similarity suggests that the majority of sediment accumulating in the wetted perimeter of the South River may have been transported during baseline flow rather than during storms.

Storm Loading

The highest loads of UTHg occurred during the peak flow periods and increased from the Site at RRM 0, to approximately RRM 10. Figure 3-7 shows the daily sum of UTHg loads during the four storm events in June, September, and November in 2006 and March, 2007. In general, the UTHg loads increased between RRM 0 and RRM 5.1, reaching a maximum of nearly 10,000 g/day (or 10 kg/day) at RRM 9.9, and remaining at similar levels downstream.

During the four storm events, incremental UTHg loadings were generally the highest from the reach between RRM 2.3 and RRM 5.1, compared to the UTHg loading at the location upstream of the Site (See Figure 3-7). In three of the four storm events, the loads were the highest in this reach. In November 2006, the highest incremental UTHg load occurred between RRM 20 and 23.9, and the second highest incremental UTHg load occurred between RRM 2.3 and 5.1.

3.1.3 Tributary Loading

Turner and Jensen (2005) evaluated tributaries as potential sources of mercury in a series of close-interval surface water sampling events. Concentrations at 1,000-foot intervals in the river channel had consistent, nearly linear increases, suggesting consistent inputs of THg and MeHg. Surface water MeHg concentrations in some tributaries and other point sources that were actively flowing were relatively high, but these tributaries and other point sources had insufficient discharges to account for the increases in loading measured in the river channel. Given that the close-interval sampling was conducted at different times of the year and under different discharge regimes, the conclusions are likely to be broadly applicable to the study area. Because of the discharges that were insufficient to account for the observed increases in loading in the river channel, the role of the tributaries in loading mercury during storms was not systematically evaluated in this early study.

As a part of the Ecological Study, a larger, focused loading study of tributaries was conducted that included near synoptic sampling of eight tributaries and from five bridges located between RRM -2.7 to RRM 9 [i.e., the discharge transect stations (on tributaries and floodplain drainages), the water level data loggers, and mercury sampling stations were co-located as closely as practicable (SRST, 2009a)]. Collectively, the eight selected tributaries account for 87% of the total tributary drainage area and 93% of the 100-year floodplain drainage area for the South River. Two sampling events were conducted (October 2007 and May 2008 storm events), and their complete results and methodology were described in SRST (2009). In summary, the results of both sampling events indicated that loading from the tributaries and floodplain drainage features were minor compared to the instantaneous loads measured at bridges or incremental loads between bridges [< 6.5% FMeHg < 3% UMeHg, < 8% total mercury concentrations in filtered water (FTHg) and < 2% total mercury concentrations in unfiltered water (UTHg)]. While the majority of the increase in discharge between RRM 0 and RRM 9.9 originated from tributaries and other outfalls during this storm the relative THg and MeHg load contribution is minor for tributaries (and floodplain drainage features).

The tributary loading study also included three mill race locations: two locations at approximately RRM 5.2 and 9.9 and the mill race for former Harriston Mill at RRMs 15.2-16.2. The findings indicated that mill races account for very small proportion of MeHg to the South River system. Additional discussions on mill races are provided in Section 4.3.1.

3.1.4 Mercury Speciation in Surface Water

Mercury speciation in surface water was performed to identify what portion of the total mercury concentration in surface water is bioavailable. Mercury bioavailability was assessed in river water at two locations using neutral (i.e., pH = 7) stannous citrate to determine the reducible divalent mercury [Mercury(II)$_R$]: one sample came from the main stem of the South River and the other from an outfall suspected to be one of the historical point sources (Flanders, et al., 2010). The Mercury(II)$_R$ is often referred to as ‘‘reactive Mercury” and likely includes mainly inorganic chloro- and hydroxyl complexed mercury that have higher aqueous solubility—and hence, bioavailability—than other mercury species. Therefore, this fraction is also operationally defined as “bioavailable IHg” (e.g., Bloom, 1994). The concentrations of Mercury(II)$_R$ in main stem river water accounted for up to 43% of FIHg, with the highest fractions occurring in the April 2007 survey immediately below the historical point source at RRM 0. As FTHg increased downstream, Mercury(II)$_R$ concentrations also increased, however, the fraction of FTHg that consisted of Mercury(II)$_R$ decreased.

3.1.5 Nature and Extent of Mercury in Surface Water

Various surface water investigations under baseline flow conditions that were summarized in Section 3.1.1 of this report (details are provided in Section 4.1.1 in the Ecological Study Report) indicate the following:

- Baseline flow IHg and MeHg concentrations in surface water increased immediately downstream of the historical outfall at RRM 0 and reach maximum levels at or before RRM 10.
- The areas with higher surface water MeHg concentrations tended to be more widely dispersed than IHg, likely due to the widespread methylating capacity of the South River sediment.
- Baseline flow MeHg concentrations exhibited strong seasonality (increasing when surface water temperatures reach approximately 12 °C, but did not necessarily increase with increasing temperature throughout the late summer).
- Baseline flow loadings suggested that positive incremental THg and MeHg loadings were constrained to approximately the first 10 river miles downstream of the Site.
- Surface water MeHg loading is also generally higher at temperatures greater than 12 ^{o}C compared to temperatures below 12 ^{o}C, suggesting a role of temperature in methylation.

The episodic storm event investigations summarized in Section 3.1.2 (details and provided in Section 4.1.2 in the Ecological Study Report) indicated the following:

- Mercury concentrations in surface water were affected by storms, but for relatively short durations (hours to days).
- Although the total concentrations of mercury increase during storms, the concentration on particles is diluted by low-mercury concentration particles from the watershed upstream of RRM 0.
- The major sources of increased IHg concentrations during storms resulted from the re-mobilization of mercury existing within the river channel and river bank soils, and not from more distant sources (e.g., tributaries and floodplain features).
- Incremental storm loads from the reach between RRM 2.3 and RRM 5.1 were the highest in three of the four storm events measured and the second highest in the fourth storm.
- THg and MeHg loads from tributaries and floodplain to the South River were generally several orders of magnitude lower than South River channel loads.

3.2 Pore Water

Pore water refers to the aqueous phase within sediment interstitial spaces and is an important medium for mercury transfer between the solid (sediment) and aqueous phases, as well as mercury methylation. Pore water in South River sediments has been characterized using several methods over much of AOC 4, including centrifugation, Henry Probes, and diffusion gradient in thin films (DGT). Specific details regarding methods and results are provided in the Ecological Study Report (see Section 4.6).

In general, the results of the pore water sampling have found that FIHg and FMeHg concentrations were generally higher in pore water samples than in co-located surface water samples and that FMeHg concentrations vary seasonally, spatially, and based on substrate type.

Habitats dominated by fine-grained sediment have higher FMeHg concentrations in pore water, but habitats with coarse-grained sediments (especially gravel beds) can also have high FMeHg concentrations in pore water, particularly in surficial sediment. Mineral phases of sediment, particularly iron and manganese were important for controlling the flux of mercury to overlying water. These and other findings are discussed in detail in the following sections.

3.2.1 Fine Grained Sediment Deposits

Pore water samples were collected over closely spaced intervals (10 to 20 m) at RRM 2.2 and over the entire AOC 4 by centrifuging fine-grained sediment deposits (Flanders et al., 2010). THg concentrations varied substantially in both bulk sediment and pore water over the 10- to 20-m distances along the river bank at RRM 2.2. However, sediment and pore water THg concentrations were highly correlated at collocated sampling locations. Pore water THg concentrations in the entire AOC 4 were the highest between RRM 0 and RRM 12. Similar to other studies on mercury in aquatic systems (Mason and Lawrence, 1999; Hammerschmidt et al., 2004), pore water IHg concentrations significantly correlated with the percentage of silts and clays, loss on ignition (LOI) in the overlying bed materials (a surrogate measurement for sediment organic matter), and with the dissolved organic carbon (DOC) concentration in pore water. This relationship was not evaluated for gravel bed pore water discussed below.

3.2.2 Gravel Beds

Gravel bed pore water samples were collected *in situ* by suction using Henry probes (URS, 2009). Gravel bed pore waters generally had higher FIHg and FMeHg concentrations than surface water samples at the same locations, but there was indication that upstream MeHg transport may have been a stronger influence on downstream surface water MeHg concentrations in AOC 4 than local MeHg production. Figure 3-8 shows the potential relationships among FIHg and FMeHg concentrations in pore water and surface water, and THg in bank soil. The 5-year average surface water mercury concentrations are included in the figure as a reference to compare the trends in pore water concentrations relative to the distance downstream. As shown in Figure 3-8, the number of pore water samples with higher mercury concentrations than the average mercury concentrations in surface water decreased as a function of distance downstream. At RRM

0.1, a majority of the pore water samples had FMeHg that were above the average surface water FMeHg concentration. At RRM 23.5, the majority of the pore water samples had FMeHg concentrations below the average surface water FMeHg concentrations.

Gravel bed pore water appears to have the highest mercury concentrations near areas of the river bank with high soil THg concentrations, indicating the local influence of soil on pore water. In Figure 3-8, the orange vertical lines indicate the general location of river banks (left or right) with elevated THg concentrations in bank soils. As shown in the figure, the pore water mercury concentrations generally decrease with distance away from the side of the bank with elevated soil THg concentrations to the side with lower soil THg concentrations.

Pore water FIHg concentrations were not statistically different between months or among substrate types in samples collected in 2009 (URS, 2009). In contrast, pore water FMeHg concentrations were statistically different between months, study sites, and among different substrate types. FMeHg was higher in pore water samples collected from surficial sediment (0 to 5 cm) relative to deeper sediment (12.5 to 36 cm), suggesting higher methylation activity in surface sediments. In contrast, FIHg was not different between the two sample depths, suggesting no vertical gradient in FIHg concentrations.

DGT is an alternative technique for pore water sampling of metals (e.g., Zhang and Davidson, 1995) and mercury (Docekalová and Diviš, 2005). DGT-based mercury measurements have also shown to be good predictors of net methylation rates in sediment (Clarisse, et al., 2011). Therefore, DGT measurements were also made in AOC 4 study areas, generally near the same location and substrate type (i.e. gravel beds) previously sampled with Henry probes, to allow for comparison of the two methodologies. Slight spatial variability was observed in pore water mercury concentrations, but overall the results agreed reasonably well between the two methodologies, thus broadly confirming the pore water THg and MeHg results in gravel bed substrates as measured by other studies in the South River (URS, 2012).

3.2.3 Benthic Flux

Previously conducted loading studies of the South River had indicated mercury entering the water column from diverse and potentially unknown sources. One hypothesized source was mercury flux from bed sediment, an important source in many systems (e.g., Gill, et al., 1999). A benthic flux chamber (BFC) study was conducted to evaluate the flux of FIHg, FMeHg, iron (Fe), and manganese (Mn) from a variety of habitats and substrate types in 31 locations within AOC 4 (CRG, 2008a).

Flux rates did not show consistent trends based on season or substrate type. However, a complex control mechanism(s) was identified for MeHg flux between pore water and overlying water. Figure 3-9 shows FIHg and FMeHg flux from various substrates measured in the months of May, June, August, and September between 2006 and 2009. As shown in the figure, seasonal effects evident in surface water, sediment, and pore water data were not observed in FMeHg or FIHg flux rates from any of the substrates measured. The results of the BFC study indicated that FMeHg flux was related, in part, to dissolution of mineral phases, including Fe and Mn. The FMeHg flux rates were statistically and positively correlated with dissolved Fe and Mn flux rates; there was no relationship for FIHg. Mineral oxides possibly adsorb MeHg as it diffuses from anoxic or suboxic microenvironments within the sediment. As oxides were reduced in the lower dissolved oxygen environment of the flux chambers, MeHg is released to overlying water.

Mercury flux estimates based on BFC studies and mass transfer model calculations indicated that the IHg flux from the sediment was the second highest loading source of IHg following bank erosion. However, this flux from the sediment was not sufficient to account for the IHg loading increases observed it the downstream direction. Mercury flux was estimated to evaluate the relative source contributions to surface water mercury and fish tissue mercury (see Appendix K of the Ecological Study Report). From RRM 0 to 10, average total Hg flux rate due to advection and diffusion from the river bed were on the order of 0.5 g per day per mile (g/d/mile), compared to Hg loading from banks which ranged from 1 to 4 g/d/mile.

In contrast, the estimated MeHg fluxes from the sediment were on the order of 0.05 g/d/mile, about ten times lower than that for IHg fluxes, but was estimated to account for 15-35% of MeHg that bioaccumulates in smallmouth bass in RRM 0 to 10 (see Appendix K of the Ecological Study Report).

3.2.4 Nature and Extent of Mercury in Pore Water

The findings of investigations of mercury in pore water indicated the following:

- FIHg and FMeHg concentrations were generally higher in pore water samples than in co-located surface water samples.
- FIHg concentrations were higher at RRM 3.5, 8.6, and 11.8 than at RRMs 0.1 and 23.5.
- FIHg concentrations did not indicate substrate-based or seasonal variability but indicated spatial variability, increasing with proximity to Hg release-age deposits (HRADs), which are near-channel deposits which formed from 1929 to 1950 when mercury was in use at the Site, as identified through shoreline changes mapped on historical aerial photographs from 1937 and 2005 (see section 4.4.1).
- FMeHg concentrations varied seasonally, spatially, and based on substrate type.
- Habitats dominated by fine-grained sediment have higher FMeHg concentrations in pore water, but habitats with coarse-grained sediments (especially gravel beds) can also have high FMeHg concentrations in pore water.
- Pore waters from surficial sediments have higher FMeHg concentrations relative to pore water from deeper sediments, suggesting that methylation was more active in the surficial sediments.
- Pore water concentrations measured by DGT sampling devices confirmed the results of other studies and provide evidence of *in situ* mercury methylation.
- Mercury flux rates for the movement of mercury between the sediment pore water and overlying water do not vary with season or substrate types.

- Correlations between FMeHg flux rates and the dissolved Mn and Fe flux rates suggest that mineral dissolution may contribute to the THg flux.
- Estimated IHg flux from the sediment bed to the water column within RRM 0 to 10 was not sufficient to explain the increases in the surface water IHg concentrations, but the MeHg flux was estimated to account for 15-35% of MeHg bioaccumulated by smallmouth bass.

3.3 Sediment

Based on analytical data obtained from various studies, the Ecological Study Report characterized the spatial and temporal distribution of mercury in bulk sediment and interstitial sediments in AOC 4. Bulk sediment samples were collected via traditional sediment sampling techniques (e.g., cores) from relatively thick deposits of sediment on channel margins. Pre-SRST sediment investigations collected samples from near-bank sediment, some of which were determined to be river bank soil samples. Because the sediment deposits in AOC 4 that could be sampled with traditional sampling techniques were spatially-limited, the SRST developed a suction technique to collect size-fractioned sediment from the interstices of the gravel and cobble beds that predominate in the South River (Jensen et al., 2006). Sediment samples collected by the SRST Method are defined as the “interstitial sediments” and treated separately from bulk sediments. Collection of interstitial sediments allowed the evaluation of sediment mercury concentrations throughout AOC 4, which is described in the following sections.

Fine-grained sediment in the South River occurs primarily in deposits on the channel margins, and as interstitial sediment in gravel and cobbles. Fine-grained sediment deposits have highly variable THg concentrations with concentrations increasing with depth. Fine-grained sediment deposits and interstitial sediment in embedded substrates generally contain higher MeHg concentrations than other sediment types, including environments generally considered favorable location for methylation, including floodplain wetlands; however, methylation is not limited to a particular sediment environment in the South River (Yu et al. 2011). In interstitial sediments, IHg concentrations generally increased between RRMs 0 and 8.7 (the areas with lower gradient) reaching a maximum of around 30 mg/kg before declining farther downstream where the river slope is greater. Over the study period reflected in the Ecological Study Report, IHg concentrations in interstitial sediment were relatively consistent (URS, 2012). In contrast to IHg, areas with higher MeHg concentrations were less spatially restricted, reflecting the widespread capacity for methylation in sediment. Temperature-dependence of MeHg concentrations was apparent in the occurrence of the highest measured MeHg concentrations in sediment when surface water temperatures exceed approximately 12°C. These findings are discussed in detail in the following sections.

3.3.1 Physical Characteristics

The majority of the South River substrate generally consists of gravel and cobble-sized materials with very few muddy, soft-bottomed areas containing fine-grained sediment. However, fine-grained sediment consisting of fine sand, silt, and clay is located within the gravel matrix of the river bed (interstitial sediment) and in deposits of varying thickness on the channel margins. Sediment is also found behind obstructions (e.g., downed trees) in the river and in other low flow velocity areas.

3.3.2 Fine-Grained Sediment Deposits

The sediment and mercury budgets of the South River were in part controlled by the fine sediment fraction within the wetted perimeter of the river channel. Fine sediments occur within the gravel matrix, in embedded gravels and as fine-grained sediment deposits. Between 2005 and 2007, fine-grained sediment deposits of a minimum size (30 cubic feet) were characterized along the 24 miles of the South River within AOC 4 (Skalak and Pizzuto, 2010). On average, these deposits were 25 m long, 5 m wide, and 0.3 m thick and accounted for 17% to 43% of the annual suspended sediment load. Their average grain size distribution was 54% sand and 23% each of clay and silt. Sediments in these deposits were on average 12 years old and were estimated to range in age from 1 to more than 60 years. Mercury concentrations in these deposits ranged from 0.1 to 884 μg THg/g.

In addition to storing mercury, fine-grained sediment deposits were likely more conducive to mercury methylation than the coarse-grained areas. Compared with gravel or cobble beds, fine-grained deposits contain much higher organic material on an area- or volume-basis. MeHg concentrations were generally higher in fine-grained sediment deposits than in other areas, including floodplain wetlands and mill races. However, high MeHg concentrations were not limited to fine-grained sediment deposits; MeHg concentrations were also high in gravel beds embedded with fine-grained sediment (see Table 3-1).

3.3.3 Interstitial Sediment

As a gravel-bed and bedrock river, the majority of the South River channel is covered with coarse-grained materials. Interstitial sediments were collected using the SRST suction method that separates fine-grained sediment by size from the interstices of gravel and cobble beds. The particle size distribution of interstitial sediment was similar to that of bulk sediment, with slightly lower sand content due to the collection method. Brief discussions of the results are provided in the following paragraphs. Details are provided in Section 4.2.2 in the Ecological Study Report.

Mercury concentrations in the interstitial sediments indicated spatial and but not seasonal trends. Figure 3-10 shows IHg, MeHg, and THg concentrations in sediment as function of river reach and temperature (for MeHg). As shown, the highest IHg concentrations were observed between RRM 3 and 8.7. The average IHg concentrations in sediment increased immediately downstream of the Site to a maximum of 22.1 µg THg/g at RRM 3; this concentration was similar to concentrations at stations as far as RRM 8.7, downstream of which IHg concentrations began to decline. IHg concentrations were largely consistent through time; however, infrequent but large changes in concentration were also observed. These anomalous changes potentially reflect spatial, rather than temporal variability, as these changes were observed following storm events. Thus, river bank soils or sediments were possibly mobilized during or after storm events.

Areas with MeHg concentrations in interstitial sediment were relatively widespread throughout AOC 4 (see Figure 3-10). During the warm season (i.e., when surface water temperatures exceed 12°C), the highest average MeHg concentration [206 nanograms per gram (ng/g)] was detected at RRM 8.7, which was similar to concentrations at RRM 3, 7, 11.8, 14.6, and 19. Although gravel beds would not appear to favor methylation, MeHg concentrations in some areas embedded with fine-grained sediment were routinely as high as those in the fine-grained sediment deposits (see Table 3-1).

Mercury is transported in the river primarily in the particulate form, as fine particles. Therefore, age (or residence time) of fine-grained sediment in the streambed is of fundamental importance in understanding mercury cycling. The age of particles in the streambed was estimated using isotopes and the roles of bed scouring and accretion were investigated (see Appendix B of the Ecological Study Report). Approximately 25% of the stored sediment is less than 10 years old while slightly less than 80% of the stored sediment is less than 50 years old. The median age of stored sediment is about 36 years old. If the mass of stored sediment and the distribution of ages have remained constant through time, then the reservoir theory predicts a residence time of 36 years for fine-grained sediment stored in the hyporheic zone. Scour data support the age results (see Section 2.7.2).

3.3.4 Mercury Speciation in Sediment

Speciation analyses indicate that IHg in AOC 4 sediments was bound to organic phases in sediment and this may, in part, control mercury methylation (Flanders et al., 2010). Sediment samples had a majority of THg extractable by strong acids, but up to 30% of THg was extractable by strong bases, suggesting THg complexation by sediment organic carbon. Bloom et al. (2003) found that samples with high base-extractable THg had an increased capacity to convert IHg to MeHg in anaerobically incubated sediment compared to samples with high THg in other fractions, including water- and acid-extractable fractions. THg concentration in base-extractable fraction increased with distance downstream, from an average of 3.1 microgram per gram (µg/g) at RRM 0.6 to a maximum of 10 µg/g at RRM 11.8. This increasing trend correlated with the MeHg concentration in sediment, suggesting that the sediment MeHg concentrations may be partly controlled by the bioavailable IHg concentration in this pool, consistent with other studies of sediment mercury (Castelle et al., 2007). There was evidence of seasonal change in base-extractable THg in sediments, indicating that mercury methylation in the South River is seasonally limited due to a drawdown of bioavailable mercury (CRG, 2008a).

3.3.5 Nature and Extent of Mercury in Sediment

Fine-grained sediment in the South River occurs primarily in fine-grained sediment deposits and as interstitial sediments. The areal extent of fine-grained sediment deposits is spatially-limited relative to the coarse-grained stream bed and is generally restricted to low-velocity areas near the channel margins and downstream of obstructions in some discrete river segments. A summary of further findings on the nature and extent of mercury in AOC 4 sediments follows. Details of these findings are provided in Section 4.2 of the Ecological Study Report.

Fine-grained sediment deposits have highly variable THg concentrations, ranging from 0.1 to 884 mg/kg (see Section 4.2 in the Ecological Study Report). Deeper fine-grained sediment deposits have higher THg concentrations than fine surficial sediment. Fine-grained sediment deposits and fine-grained sediment embedded in the coarse-grained stream bed generally had higher MeHg concentrations than other sediment types, including floodplain wetlands. Although concentrations were higher in fine-grained sediment deposits and embedded gravels, methylation is not limited to a particular sediment environment (Yu et al., 2011).

In interstitial sediments, IHg concentrations generally increased between RRMs 0 and 8.7 (the areas with gentler river gradient) reaching a maximum of around 30 mg/kg before declining farther downstream where the river gradient is steeper. Over the study period reflected in the Ecological Study Report, IHg concentrations in interstitial sediment were relatively consistent at sampling locations (see The Ecological Study Report). In contrast, sampling locations with higher MeHg concentrations were less spatially restricted, reflecting the widespread capacity for mercury methylation in sediment. Similarly to what was observed in surface water, MeHg concentrations in sediment increased when surface water temperatures exceeded approximately 12°C.

3.4 Summary

Investigations in AOC 4 used consistent sampling and analytical methods and sampling locations to characterize mercury concentrations in the various abiotic media described in the preceding sections. These analytical data were used to better understand the fate and transport of mercury within environmental media in AOC 4. These findings of these investigations provide the following insight into the system-specific components of the mercury cycle within AOC 4:

- Consistent IHg concentration gradients exist in surface water, sediment, and pore water in which mercury concentrations increase between RRM 0 and RRM 10 and then remain at similar levels or decline until the confluence with the North River.
- Mercury loading in surface water under baseline flow and storm conditions indicates that the majority of mercury is loaded in the upstream reach (RRM 0 to RRM 10).
- The areas with higher surface water MeHg concentrations tended to be more widely dispersed than IHg, likely due to the widespread methylating capacity of the South River sediment.
- Baseline flow MeHg concentrations exhibited strong seasonality (increasing when surface water temperatures reach approximately 12 °C, but did not necessarily increase with increasing temperature throughout the late summer).

4.0 Mercury in the Terrestrial System of AOC 4

This section provides an overview of the distribution and behavior of mercury in the terrestrial environment of AOC 4, including sampling and analysis, the extent of the investigations, and the mercury concentrations in the physical and biological media.

4.1 Overview

The South River is subject to flooding; between 1936 and 1996, the South River experienced nine major floods. In addition, the South River was used extensively as a source of power for mills. Up to 14 mill dams operated since the mid-1740s on the South River between Waynesboro and Port Republic, 25 river miles downstream, and were in place until the 1930s. These dams were breached by the 1970s, but many were functional for a portion of the time that mercury was used at the Site (Pizzuto and O'Neal, 2009). The presence and subsequent demise of mill dams, the frequency of major flooding events, and historical mercury releases at the Site created the potential for particle-bound mercury to be deposited on riverbank and floodplain soils, which are now the primary mercury repositories in the South River watershed within AOC 4.

Given the central role that the floodplain and the riverbanks play in the South River mercury cycle, several studies were conducted (by the SRST and as part of the Ecological Study) to evaluate the distribution of mercury in river bank and floodplain soils and were reported in the Ecological Study Report. The major investigations of soil mercury concentrations have focused on two primary areas: factors potentially controlling THg concentrations in the South River floodplain and variables associated with mercury storage and loading from river banks. Central aspects of these investigations and their findings are discussed in the following sections.

4.2 Sampling and Analysis

Information on soil sampling and analysis are provided in the following sections, as appropriate. Complete details can be found in the associated reports or work plans of the soil investigations listed below:

- Augusta Forestry Center sampling for garden plot study area (Berti et al., 2012)
- Greenway sampling near former DuPont plant (2003)
- South River floodplain soil sampling (2004 and 2005)
- Eroded bank sampling in 2003, 2004, and 2005 (Pizzuto, 2012)
- Sampling of RRM 1.8 soils (South River oxbow feature sampled in 2005)
- USEPA soil sampling at RRM 3.1 to 4.3 (2006)
- Floodplain soil sampling for 100-year monitoring plan (CRG, 2008b)
- Soil characterization for the pilot river bank stabilization at RRM 0.1 (URS, 2008)
- Soil sampling for the Phase II Ecological Study (URS, 2009)

- Floodplain pond and soil sampling (URS, 2011)
- Additional floodplain soil sampling to support HHRA (URS, 2014b)
- Bank soil sampling between RRM 0 and 5 in 2012, 2013, and 2014 (Anchor QEA and URS, 2013 and 2014)

4.3 Floodplain Soils

Tributary loading studies conducted during storm events show that the floodplain is not a significant source of THg and MeHg to the South River (see Section 3.1.3). However, the floodplain may have areas of elevated THg exposure to terrestrial ecological receptors, which is currently being evaluated as a part of the ERA. Two major investigations (Bolgiano, 1981; Green et al., 2012) that adequately characterize the extent of the mercury in the floodplain soils within AOC 4 are described below.

Bolgiano (1981) describes the initial floodplain study in the early 1980s by the Virginia State Water Control Board (SWCB), as part of the original investigation of the historical mercury release from the Site. The study indicated widespread distribution of greater than background THg concentrations in the 100-year floodplain soils. No soil samples from upstream of the Site, from the North River, or from the SFS River outside of the 100-year floodplain contained THg concentrations greater than 0.2 mg/kg. Within the 100-year floodplain downstream of the Site, soil THg concentrations ranged from 0.2 to 34.5 mg/kg. The highest THg concentration (34.5 mg/kg) was observed at RRM 5, at a distance of 12 m into the floodplain from the river bank. Below Port Republic in the SFS River, THg concentrations ranged from 0.2 mg/kg to 0.9 mg/kg. Long term trends in soil THg concentrations cannot be evaluated because the 2008 dataset is not directly comparable with historical datasets. Specifics of the samples collected in the early 1980s are not available, and sampling and analytical methods have changed over time. However, the range of mercury concentrations documented in the early 1980s (0.2 to 34.5 mg/kg) is consistent with the range documented in the 2008 study described below.

A comprehensive study of the floodplain soils in the South River was conducted in 2008 to evaluate the distribution of soil THg concentrations as a function of river mile, floodplain inundation frequency, and land use (CRG, 2008b; SRST, 2009a). The study was conducted based on a work plan (CRG, 2008b) and sampling design prepared by the members of the SRST to meet the requirements of the 100-year mercury monitoring plan (VDEQ, 2011a). Samples collected for the study included the following:

- Samples collected within each of the six bridge reaches (see Table 4-1)
- Samples collected within 2-year, 5-year, and 62-year storm inundation areas
- Samples collected within the three predominant land-use types for each reach [agriculture (cultivated crops), pasture (pasture/hay), forest, or open space]

Additional samples were collected to assess mercury concentrations at specific locations (e.g., 10 samples from a recreational area in Reach 1 at RRM 2.3 to -2.6 and 62 samples from floodplain wetlands). Between 6 and 23 locations were sampled in each land use (excluding wetlands) in each reach for a total of 618 samples. Ten wetland-land use locations were sampled in each reach for a total of 176 samples. Soil samples were analyzed from two depth intervals: surface to 6 inches and a composite of 6 inches to 30 inches.

Green et al. (2012) provided in Appendix D of the Ecological Study Report provides the study details and the findings. In summary, THg concentrations in the floodplain soil samples:

- Ranged from below detection limit to a maximum of 307 mg/kg;
- Decreased with increasing distance into the floodplain from the river, and increasing distance downstream from the Site;
- Were highest in the 2- and 5-year floodplains and tended to be in forested areas;
- Were similar in floodplain wetlands and the surrounding floodplain; and
- Were less than the human health screening level of 17 mg/kg, protective of multi-pathway ingestion, dermal contact and inhalation exposure, in 89% of the samples.

The rest of this section discusses specific historical features associated within the floodplain and migration/exposure pathways, including:

- Mill races and the Oxbow, which are historical features in the floodplains that may have specific characteristics with respect to soil mercury concentrations;
- The soil-to-groundwater migration pathway as it relates to the mercury in the floodplain soils; and,
- Well searches within the 62-year floodplain conducted to assess the potential for human exposure to groundwater within AOC 4.

4.3.1 Mill Races

A variety of sources indicate that 14 mill dams existed along the South River from Waynesboro to Port Republic in the early 20th Century (Appendix B of the Ecological Study Report). Many of these mill dams were built in the late 1700s and early 1800s, and all of them were breached by the mid-1970s. Eleven historical features (including the Oxbow discussed separately in the next section) were identified as historical mill race locations based on available aerial imagery from 1937 to 1974 (see Figures 4-1 and 4-2). Aquatic and/or benthic habitats are generally absent within these features; where present, the habitats are limited due to the nature of the mill race. In addition, these features in the floodplain have limited, if any, direct connectivity to the main South River channel with respect to mercury cycling. Hence, only soils were included in the historical floodplain soil investigations.

To evaluate the soil THg data in the historical mill race features, their approximate boundaries were delineated based on a 50-foot buffer on either side of the center of the features. This buffer is intended to account for the uncertainty in aerial extent of the features due to potential historical channel migrations. Accordingly, the feature areas range in size from approximately 2.6 acres to 13.1 acres (See Figure 4-2 and Table 4-2).

As described above, soil data were collected from the mill races as part of the 2008 floodplain soil sampling effort, and in various sampling events between 2008 and 2014. Available soil THg concentrations at the 0.0-0.5 and 0.5-2.0 ft depth intervals are compared in Table 4-2 for the mill races and the rest of the AOC 4 floodplain. Although some of the mill races lack soil THg data, available soil THg concentrations are similar in the mill races and the rest of the AOC 4 floodplain. A portion of the floodplain soils collected at the above locations are contained in the floodplain soil dataset with THg concentrations above the human health screening level of 17 mg/kg (or ~20% of the floodplain soil locations sampled). Floodplain soils in the specific historical mill race locations may be addressed as future IRM(s), including those locations within the RRM 0 to 2 reach—the bank soils within which are being addressed in the current IRM.

4.3.2 Oxbow

The South River was straightened opposite the Waynesboro sewage treatment plant in the late 1960s, cutting off a large meander in the river that is referred to as the Oxbow. A nearby tributary, Steele Run, thereafter became the primary source of water to this part of the old river channel. During high flow stages, the South River can still flow through the Oxbow, but Steele Run feeds the area under all but the highest flows (Jensen and Turner, 2005).

Similar to the mill race features, the approximate area within the Oxbow feature and a 50-ft buffer was delineated to be 35.3 acres in size, based on available aerial imagery (see Figure 4-2 and Table 4-2). Soil sampling locations within this area are shown in Figure 4-2 and the available data are summarized in Table 4-4.

The 0.3-year floodplain within the Oxbow area involves steep bank areas. For the rest of the floodplain, sufficient soil THg data are available to characterize soil THg within the Oxbow Area. Soil THg concentrations, particularly in the surficial soil, are generally greater in the Oxbow area than in the rest of AOC 4 floodplain. A total of 114 floodplain soil samples were collected at the 0-0.5 ft and 0.5-2.0 ft depth intervals in this area between 2008 and 2014. THg concentrations ranged between 0.34 mg/kg and 714 mg/kg, with ~57% of the sample locations containing samples detected above the human health screening level of 17 mg/kg. As noted above in the bulleted summary in Section 4.3, higher THg concentrations were generally observed in the 2- and 5-year floodplains in forested areas.

As indicated in the HHRA, there is limited potential for human exposure to mercury in the Oxbow feature under the current conditions. Current and future use of the area was evaluated in the HHRA. Routine activities do not currently occur in the Oxbow. The findings of the HHRA will be used to provide recommendations for the areas, including the Oxbow, which may require additional evaluation as part of the CMS.

As discussed in Section 4.3.3, limited mercury leaching observed in on-site soil indicates that limited soil-to-groundwater leaching would also be expected within AOC 4, including the Oxbow area. Additionally, a well search was conducted to identify potential receptors of groundwater within AOC 4 (see Section 4.3.4).

4.3.3 Soil-to-Groundwater Migration Pathway

Leaching of mercury in floodplain soil to underlying shallow alluvial groundwater is a potential transport pathway in AOC 4. To evaluate the AOC 4 soil migration-to-groundwater pathway, the following lines of evidence were considered:

- A comparison of THg concentrations in floodplain soil to generic soil screening levels (SSLs) protective of soil migration to groundwater,
- Direct observations of THg in paired off-site floodplain soil and groundwater samples; and,
- Observations observed in on-site plant soil and groundwater.

THg concentrations in floodplain soils were compared to generic SSLs derived using equations provided in USEPA's *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (USEPA, 2002). The equations and SSLs are detailed in Table 4-3. Consistent with USEPA guidance, SSLs were derived for a dilution attenuation factor (DAF) of 1 (no attenuation/dilution) and a DAF of 20 (0.5-acre source area).

A comparison of the SSLs to THg concentrations in floodplain soil is provided in Table 4-4. Floodplain soil data collected from 18 locations during the 2006 USEPA investigation at RRM 3.1 to 4.3 (Shifflett Property) were used for the evaluation. Locations are within the 2-year and 5-year inundation areas. Subsurface soil data have been collected at nine other properties (at depths between 2 and 10.5 ft bgs) within AOC 4. However, subsurface soil data collected at the Shifflett Farm Property were used for this evaluation, since direct observations of concentrations of THg in the soil column and in groundwater could be conducted. Empirical groundwater data are more appropriate to evaluate the migration pathway than a comparison to the generic criteria, particularly taking into account how shallow alluvial groundwater is used.

As shown in Table 4-4, soil data collected from the investigation demonstrate decreasing THg concentrations to below the SSL with depth. THg was not detected above the SSL in subsurface soil samples collected at depths greater than 2.5 feet bgs. In addition, as detailed in Table 4-5, THg was not detected in shallow alluvial groundwater above EPA's Regional Screening Level for tap water SL (5.7 μg/L for mercuric chloride) in the 18 monitoring wells sampled during the investigation.

Soil types described in boring logs at the Shifflet Property (see Attachment 2 in ICOR, 2007) are similar to those observed in on-site plant soils, where limited leaching to underlying groundwater has also been observed. The uppermost geologic unit at the plant is recent alluvium, which is comprised of floodplain and terrace deposits of the South River. This unit consists predominantly of fine to medium grained, silty sand and gravel as well as sandy silt and sandy clay (URS, 2013). Therefore, observations regarding leaching in on-site plant soils can be extrapolated to reflect off-site properties within AOC 4 with similar soil lithology.

THg concentrations on site in subsurface soil were several magnitudes higher in concentration than those observed in floodplain soil (i.e., maximum detected concentration of 35,600 mg/kg in source area SWMU 4 and 4,000 mg/kg in source area SWMU 1). Based on Synthetic Precipitation Leaching Procedure (SPLP) data collected during the on-site RFI at potential source areas (including SWMU 1), SPLP concentrations were less than the tap water SL (2 μg/L for elemental mercury) in 10 of 13 samples; and, SPLP mercury was non-detect in the deepest subsurface soil sample interval collected at four of six boring locations (see Table 4-1 in DuPont CRG, 2003). In addition, no widespread area of dissolved-phase mercury impact-to-groundwater (or "plume") has been identified on site. Dissolved-phase groundwater data are considered to be more representative of potential leaching from soil to groundwater.

Based on these observations and also that speciation of off-site floodplain soil indicates the presence of the less mobile metacinnabar, the potential for leaching of THg in AOC 4 floodplain soil, including the Oxbow and mill race areas, to underlying groundwater is limited.

4.3.4 Groundwater Use

A well search was conducted to identify groundwater use within AOC 4. The well search was completed by querying available VDEQ GIS datasets, and the Virginia Department of Health (VDH) Well Database. As indicated in Figure 4-3, no municipal drinking water wells were identified within the 62-year floodplain. The well search identified 123 parcels with private wells where at least a portion of the parcel was within the 62-year floodplain of the South River (Figure 4-3, Table 4-6). The main data sources for the private well search (the Augusta County parcel data and the VDH Well Database) did not provide coordinates or other information as to a well's location within a parcel, or information regarding its use (such as whether for irrigation or for domestic use). A weight-of-evidence approach, including field verification and aerial photo interpretation, was used to determine the locations of wells within these parcels. Field verification was conducted using a roadside survey to visually document the presence of a well and to determine, if possible, whether or not the well was located within the 62-year floodplain of the South River. For parcels where the well location was not visible from the road, and/or if a determination could not be readily confirmed on whether the well was within or outside of the 62-year floodplain, a desktop review of aerial photography was conducted to determine the relative location of the well.

The well search identified 39 properties within AOC 4 where groundwater wells of unknown use may be present. (Table 4-6). These 39 parcels include properties where the well was either visually verified to be located within the floodplain, or could not be ruled out to be outside of the floodplain based on aerial photography. Further investigation of groundwater use at these locations will be conducted, as part of the CMS.

4.4 Alluvial River Banks

Twenty-seven eroding river banks have been sampled over the vertical extent of the banks. The locations of the bank samples extend from RRM 0.1 to 23.5. The vertically averaged THg concentrations in the river banks ranged from 1 to 140 mg/kg, and maximum concentrations ranged from 2.6 to 584 mg/kg. Average and maximum THg concentrations exceed the human health screening level of 17 mg/kg in 7 of the 27 locations and 15 of the 27 locations, respectively. Bank soil was not evaluated in the HHRA; rather bulk sediment data collected at the toe of bank and within the river channel were used in the HHRA to evaluate potential South River sediment human exposure pathways.

Some of the eroding areas were surface expressions of HRADs; however, not all banks that have elevated soil THg concentrations can be ascribed to a particular type of HRAD. This suggests that the ability to predict the locations of elevated mercury concentrations in bank soils may be a challenge. A summary of THg concentrations in eroding banks is presented in Table 4-7. HRADs are discussed in the following section.

4.4.1 Mercury (Hg) Release-age Deposits (HRADs)

HRADs are areas where sediment (primarily silt and clay) has been deposited in large amounts on the channel margins due to historical flow patterns in the river. HRADs are hypothesized to store deposits with high THg concentrations because: i) mercury strongly adsorbs to silt and clay fractions of soil and sediment, and ii) the formation of these HRADs occurred during the period of mercury use at the former DuPont Waynesboro Plant (1929 to 1950). A summary of HRAD characterization is provided in this section. Further details can be found in Section 4.4.2 of the Ecological Study Report.

Approximately 47 HRADs were identified from RRM 2.7 to RRM 23.9 through shoreline changes mapped on historical aerial photographs from 1937 and 2005. The majority (39) of the HRADs were located between RRM 1.5 and RRM 11.6, with a high density of HRADs between RRM 3 and RRM 4 (six deposits), RRM 5 and RRM 6 (five deposits), and RRM 8 and RRM 9 (10 deposits).

Based on 34 cores collected to characterize mercury in HRADs along the South River, THg concentrations varied widely, even within the same HRAD. For example, an HRAD at RRM 8.1 had THg concentrations ranging from 0.3 µg/g to 270 µg/g. The maximum THg concentration detected in an HRAD was 839 µg/g at RRM 3.7.

4.4.2 Bank Erosion

As discussed in Sections 2.7.2, bank erosion rates in the South River have been measured by the University of Delaware using various methods including aerial photograph interpretation, side-scan light detection and ranging (LiDAR), analysis of exposed tree roots, and bank pins. Bank erosion rates throughout the South River average approximately 4 centimeters (cm)/yr but vary widely (1 cm/yr to 35 cm/yr) from year to year and among banks (Rhoades et al., 2009).

While direct observations of bank erosion were limited in RRMs 0 to 2, bank erosion rate measurements have been performed in downstream reaches of the South River (RRMs 2 to 10). The most accurate bank erosion rate measurements in RRMs 2 to 10 were obtained from analyses of exposed tree roots analyzed using both macroscopic and microscopic dendrochronology analysis techniques, which yielded similar results. More details of these erosion rate techniques and estimates can be found in Anchor QEA and URS (2014).

4.4.3 Mercury Loading from River Banks

A mathematical model has been created by University of Delaware to predict mercury loading rates from river bank erosion where mercury concentration and erosion data were not available (see Appendix C of the Ecological Study Report). River bank soil samples collected from approximately RRM 3.0 to approximately RRM 8.5 for mercury analyses in 2007 were used for model calibration. The resulting calibrated model explained 62% of the observed variation in mercury inventories.

Additionally, the SRST has been tasked with investigating mercury loading to the South River from river banks via bank erosion. As part of this effort, URS collected bank soil samples for THg analysis from RRM 0 through RRM 5 in 2012, with additional bank soil samples collected in 2013 to fill identified data gaps between RRM 0 through RRM 2. Evaluation of these datasets along with measures of bank stability has facilitated the establishment of preliminary Bank Management Areas (BMAs) and banks for further consideration in the IRMs. Additional soil samples were collected in the fall of 2013 and in 2014 to provide greater spatial resolution of bank soil mercury concentrations (URS, 2014a). These data, plus the additional bank stability data provided necessary information regarding mercury concentration, distribution, and potential loading to support the remedial design process for final selection of the BMAs.

4.5 Mercury Speciation in Floodplain Soil

Chemical speciation and spectroscopic analysis of South River floodplain soils identified that the majority of IHg in soil is present as metacinnabar, a mercury sulfide species. A full chemical speciation analysis following the method of Bloom et al. (2003) on soil samples collected at RRMs 0.1, 2.0, and 3.5 indicated that 60% to 90% of the THg were extracted by strong acids, consistent with IHg associations with metacinnabar (Flanders et al., 2010; Ptacek, 2011). Ptacek (2011) confirmed that IHg in soil samples collected from RRMs 0.1 and 3.5 was present as metacinnabar using an Extended X-ray Absorption Fine Structure (EXAFS) for speciation analysis. These findings were consistent with other studies of mercury in floodplains that indicated that metacinnabar is the primary mercury species in soil (e.g., Barnett et al., 1995). Metacinnabar is considerably less water soluble and hence less bioavailable than mercury salts typically used in toxicity studies (e.g., mercuric chloride).

Leachate and re-suspension experiments of South River floodplain soils and sediments using South River surface water indicated greater mobility of THg from floodplain soils when compared to sediments. The findings of leachate and re-suspension studies indicate that the re-suspension of soils and sediments releases THg to the water column; however, water column MeHg concentrations did not increase following re-suspension. Water column FTHg concentrations were greater in tests with re-suspended floodplain soils when compared to similar tests using re-suspended sediments (Mack and Mason, 2006). Successive extraction of a representative floodplain soil from RRM 2.7 generated very high extract concentrations (Flanders et al., 2010), with no evidence that the FTHg concentration would decrease with further extractions. In contrast, successively extracting two representative South River bulk sediment samples with river water generated much lower extract concentrations than for the soils and the THg concentrations in the extract decreased with each successive extraction (Flanders, et al., 2010). These results indicated greater mobility of THg from floodplain soils relative to sediment and suggested that soil is a potentially large source of THg to the water column.

Generally, the MeHg concentrations in the floodplain soils are very low compared to THg concentrations. SRST (2009) reported a maximum THg value of 66.9 mg/kg dry weight (dw) in a wetland soil within the floodplain, and a maximum MeHg concentration of 0.032 mg/kg dw. By comparison, in-river sediment MeHg ranged one to two times higher than the maximum MeHg concentration in wetlands soils. A survey was also conducted to evaluate THg and MeHg concentrations in paired earthworm and soil samples (SRST, 2009b; Cianchetti, 2009). Samples were collected from 12 relatively undisturbed locations along the South River floodplain within AOC 4. Soil THg concentrations ranged from 1.34 to 27.7 mg/kg dw, and MeHg concentrations ranged from 0.001 0.013 mg/kg dw (Cianchetti, 2009).

4.6 Nature and Extent of Mercury in Soils

A summary of findings from the soil investigations within AOC 4 is as follows:

- THg concentrations:
  - Decreased in floodplain soil samples with increasing distance into the floodplain from the river and increasing distance downstream of the Site.
  - Were the highest in the two- and five-year floodplains and tended to be in forested areas.
  - Were similar in floodplain wetlands and surrounding floodplain soils.
  - Were below the human health screening level of 17 mg/kg in 89% of the samples.
  - Do not indicate a release to underlying alluvial groundwater above drinking water screening levels.
- Eroding river banks have widely varying THg concentrations and occur over the extent of the South River.
- IHg is present in bank soils as metacinnabar, a relatively insoluble mercury-sulfide species. However, other mercury species in soil, such as those associated with the organic phase, were easily solubilized in river water.

5.0 Risk Assessments

The HHRA and ERA integrate physical, chemical, and biological data from the investigations conducted on the physical and biological media of AOC 4. Consistent with USEPA guidance, the HHRA and ERA draw on accepted risk assessment concepts including planning, problem formulation, the use of Human Health Conceptual Site Models (HHCSMs), and Ecological Conceptual Site Model (ECSM), exposure assessment, toxicity assessment, and risk characterization. As part of the risk assessments, the HHCSMs and ECSM identify the range of potential human and ecological exposure pathways in AOC 4, along the South River and SFS River and their adjacent floodplains, and guide the development of both the HHRA and ERA.

The HHRA and ERA for AOC 4 were performed based on the data and findings described in the preceding sections, as well additional more recent data. As indicated in Section 1.3, RDQAs were performed to evaluate the quality of the historical and more recent data specifically for use in the HHRA and ERA. The HHRA and ERA reports were submitted separately. The following sections provide brief descriptions of the risk assessment conceptual site models, technical approach, and summary of findings.

5.1 Risk Assessment Conceptual Site Models

A conceptual site model for risk assessment is a representational understanding of contaminant fate and transport from primary sources to media to which various receptors (human and wildlife) are potentially exposed. The models for AOC 4 synthesize extensive site-specific information discussed in the preceding sections with respect to the following:

- Understanding the fate and transport of mercury, focusing on the key linkages between mercury sources and potential receptors;
- Incorporating the fate and transport of mercury in AOC 4 through identification of potentially complete exposure pathways; and
- Identifying receptors (human and ecological) that may be exposed to mercury, as well as the routes of exposure.

Brief summaries of the HHCSMs and the ECSM are provided below. Details are provided in the respective risk assessment reports (AECOM, 2015a; AECOM, 2015b).

5.1.1 Human Health Conceptual Site Models (HHCSMs)

The HHRA was conducted consistent with RCRA requirements to evaluate potential exposure of human receptors to mercury detected in environmental media in the South River watershed. The primary goals of this assessment are (1) to evaluate potential risk for off-site current and future human receptors and (2) to provide risk information sufficient for remedial decisions consistent with USEPA and VDEQ requirements.

The HHCSMs (see Figures 5-1a and 5-1b) detail both potentially complete and incomplete pathways for each of the potential off-site receptors under current and future land use and hypothetical future land use. A description of each of the potentially complete and incomplete exposure pathways are provided in the HHRA. Potentially complete exposure pathways are evaluated quantitatively in the HHRA. These pathways include the following routes of exposure:

- Ingestion of and dermal contact with floodplain soil, and inhalation of floodplain-soil derived particulates
- Ingestion of and direct contact with South River surface water and sediment
- Ingestion of domesticated animals (i.e., beef, milk, poultry and eggs), small game (e.g., deer), waterfowl (ducks, geese), fish, other animals (e.g., snapping turtles), and garden crops grown on the floodplain

A draft HHRA was submitted to VDEQ in September 2014. The final HHRA was submitted to VDEQ in July 2015.

5.1.2 Ecological Conceptual Site Model

The ERA characterizes potential ecological risks to a range of ecological receptor groups exposed to mercury in surface water, sediment, pore water, soil, and biological tissue in AOC 4. A screening-level evaluation of the data was performed in the Ecological Study, which identified mercury as the primary constituent of potential ecological concern (URS, 2012). A formalized ERA was performed consistent with USEPA guidance on ecological risk assessment (USEPA, 1997) under the oversight of VDEQ under the RCRA regulatory program. The ERA assessed the risk to a wide range of ecological receptors via complete exposure pathways.

Consistent with EPA guidance on Screening Level Ecological Risk Assessment (SLERA), an initial screening level evaluation was performed for AOC 4 for all site-related contaminants (including mercury). Based on this evaluation, only mercury was carried forward for further evaluation. A graphical presentation of the ECSM is shown in Figure 5-2. Within AOC 4, mercury is present in soils, sediments, pore water, surface water, and biological tissues. Ecological receptors may encounter these media through their use of certain habitats, through their feeding habits or indirectly via their feeding behavior. Three potential ecological exposure pathways are identified: direct contact to abiotic media (surface water, sediment, pore water, and soil), ingestion of aquatic and terrestrial biota (i.e., dietary pathway), and incidental ingestion of sediment or soil particles (e.g., during feeding).

The ECSM also identifies the ecological receptor groups that are potentially exposed to mercury associated with AOC 4 through the three potential exposure pathways. These primary receptor groups include aquatic and terrestrial vegetation, benthic (including emergent insects) and terrestrial invertebrates, fish, birds, mammals, and amphibians. Understanding the aquatic food web structure is the key to determining potential risk to ecological receptors in the aquatic habitats within AOC 4. In addition, some terrestrial ecological receptors feed on portions of the aquatic food web, so there is a connection between the aquatic cycling of mercury and terrestrial exposure. Section 6 describes the biological communities of the South River.

The final ERA was reviewed and accepted by VDEQ on July 13, 2015.

5.2 Risk Assessment Approach

The risk assessments identify areas of potentially unacceptable risks to human or ecological receptors that may require corrective actions. These areas include media containing mercury concentrations that exceed risk-based criteria in floodplain soils, sediment, and/or dietary items (for either humans or ecological receptors). Such areas will be addressed under the RCRA regulatory program and as part of the EAM process.

The technical approach for the HHRA consists of the following basic steps: data review and identification of constituents of potential concern (COPCs), human exposure assessment, toxicity assessment, risk characterization, and uncertainty analysis. For the HHRA, toxicity factors (such as reference doses and reference concentrations) are applied in conjunction with exposure point concentrations (EPCs) and intake assumptions to estimate noncarcinogenic health risk. The EPCs are the lower of the 95% Upper Confidence Limit on the mean (95% UCL) or the maximum detected concentration. The 95% UCL on the mean or the maximum detected concentration are used, as recommended by EPA's ProUCL Software. EPA (1992) allows the maximum observed concentration to be used as the EPC rather than the calculated UCL in cases where the UCL exceeds the maximum concentration. Such an approach is reasonable in cases where the sample size is sufficiently large and samples are spatially representative, so that the observed maximum is unlikely to be smaller than the population mean, as is generally the case in the datasets associated with the current risk assessments. Each property with an exceedance of screening levels in floodplain soil is addressed quantitatively in the HHRA. The EPC selected for each property (or exposure unit) is based on the size of the dataset and the statistical distribution of the data results. Surface soil (0 to 2 feet below ground surface) and subsurface soil (>2 feet below ground surface) is evaluated separately. EPCs for surface water and sediment are segregated by river reach. EPCs for food sources are based on the individual dataset. Further details on EPCs are provided in the HHRA Report (AECOM, 2015a).

For the ERA, AOC 4 is divided into 16 exposure areas (or Assessment Reaches) based on river reaches. Similar to HHRA, EPCs for ERA are the lower of the 95% UCL or the maximum detected concentrations. Population-level survival, growth and reproduction assessment endpoints are evaluated for relevant receptor groups within each reach. Potential risks are evaluated using a weight-of-evidence approach, by primarily comparing IHg and MeHg EPCs for abiotic media and tissue residues and estimated doses to respective effects benchmarks, critical body residues, and toxicity reference values, biomagnification evaluation, and overall reach-specific food web considerations (with respect to EPCs). Further details are provided in the ERA Report (AECOM, 2015b).

5.3 Findings of the Risk Assessments

In summary, the HHRA shows limited potential for human health risks at the exposure areas evaluated under current land uses. As part of remedy evaluation, areas that are identified in the risk assessment as being of potential concern under current or reasonably anticipated future land use conditions will be further evaluated to determine appropriate remedial strategies to mitigate potential unacceptable risks.

The results of the ERA indicate that potential adverse effects to the ecological receptors are due to trophic transfer of MeHg originating in the South River system—a finding that is consistent with the current understanding of the system on which the proposed remedial strategy is based.

Specific findings of the HHRA and the ERA are summarized below. Further details can be found in the associated reports (AECOM, 2015a; AECOM, 2015b).

5.3.1 Human Health Risk Assessment

The HHRA provides non-cancer hazards for both THg and MeHg. Potential hazard associated with mercury exposure was evaluated at all properties. Hazard Indices (HI) were compared to EPA's and VADEQ's target hazard quotient (HQ) of 1.0 (EPA, 1989 and VDEQ, 2011b). The findings are summarized below.

- No unacceptable health risks were indicated for current residents (adult/child), current adult recreational users of floodplain area parks and current recreational users of the South River (adult/child).
- For current/future industrial/commercial workers and current/future construction/excavation workers, cumulative noncancer hazards ranged between 1.2 and 2.9. Ingestion of floodplain area surface soil was the exposure pathway of concern. Elevated THg concentrations were observed primarily in an area north of the Oxbow located on the Americast property. There are no current worker exposures in the area.
- Limited unacceptable health risks were indicated for current recreational users of floodplain area parks and current farmers.
    - Cumulative noncancer hazards for current child recreational users of floodplain area parks ranged from 1.5 to 2.4. Total HIs above 1.0 were observed in Constitution Park and North Park. Removal of outliers from both locations resulted in total HIs less than 1.0.
    - Cumulative noncancer hazards for current adult farmers were 1.1 and 1.4, and ranged from 1.1 to 4.0 for child farmers. Ingestion of floodplain soil was the exposure pathway of concern.
- Total HIs above acceptable levels were observed for current/future hunters. Ingestion of waterfowl (primarily mallards) was the exposure pathway of concern. Total HIs ranged from 7 to 8. Since snapping turtles would be obtained via trapping, indirect exposure to mercury in South River surface water, sediment and pore water via ingestion was evaluated separately. The HQ for this pathway was 71 (based on a 90th percentile ingestion rate) and 38 (based on a mean ingestion rate).
- Likewise, total HIs above acceptable levels were observed for future recreational users of the South River, future recreational users of floodplain area parks, future farmers and future hunters. Indirect exposure to mercury in South River or floodplain pond surface water, sediment and pore water via ingestion of fish was the exposure route of concern.

- A fish consumption advisory for the South River is currently in place. In the absence of the advisory, cumulative noncancer hazards ranged from 41 to 182 for an adult or child recreational user consuming fish from the South River. The highest noncancer hazards were observed in Reach 3. Noncancer hazards were also observed in the upstream reference location. Similar hazards were observed for fish ingestion in private floodplain area ponds.
- Cumulative noncancer hazards for future hypothetical residents and future hypothetical subsistence farmers were also above acceptable levels. Noncancer cumulative hazards for hypothetical future adult and child residents exceeded the HI of 1.0 in each of the properties evaluated. The cumulative noncancer hazards for adult residents ranged from 54 to 283, and for child residents from 50 to 262. The exposure pathway of concern was primarily ingestion of fish from South River and floodplain area ponds, with ingestion of waterfowl a lesser concern.

In summary, the risk assessment shows limited potential for human health risks at the exposure areas evaluated under current land uses. Although some site-specific assumptions were made for the risk assessment, the evaluation is considered conservative based on the choice of receptors and exposure assumptions (e.g., exposure frequency and duration) that were based primarily on the EPA and VADEQ guidance cited herein. As a result, the risk estimates presented in the HHRA provide a conservative yet meaningful basis upon which to evaluate remedial actions for AOC 4.

Exposure pathways that were identified in the risk assessment as being of potential concern under current or future potential land use conditions will be carried forward into the CMS for further consideration. The CMS will evaluate remedial options and will recommend remedial measures to ensure the protectiveness of the AOC to human health. The CMS will also define the numeric criteria for judging the effectiveness of the remedy.

5.3.2 Ecological Risk Assessment

The ERA assessed potential ecological risks to representative receptors of concern associated with the aquatic, semi-aquatic, and terrestrial habitats within AOC 4 due to their exposures to IHg and MeHg. Exposure pathways included direct contact to potential contaminated media, bioaccumulation, and diet. A weight-of-evidence evaluation is performed based on the results of various assessment endpoints for specific receptors. Overall findings are summarized below for the three groups of receptors:

- Aquatic Receptors: Mercury bioaccumulation poses potential ecological risks to invertebrates and fish species within AOC 4. No ecological risks were associated with the direct contact exposure pathway.
- Semi-Aquatic Receptors: Potential risks to amphibians and piscivorous birds due to bioaccumulation and/or dietary exposures to mercury within AOC 4 Assessment Reaches beyond RRM 2.7 cannot be ruled out. Uncertainties in assumptions bias conclusions toward overestimation of risks for these receptors.
- Terrestrial Receptors: Potential risks to carnivorous birds, invertivorous songbirds, and bats due to dietary exposures to mercury within AOC 4 cannot be

ruled out. Uncertainties in assumptions bias conclusions toward overestimation of risks for these receptors.

In summary, the results of the ERA indicate that potential risk to ecological receptors are due to trophic transfer of MeHg originating in the South River system—a finding that is consistent with the current understanding of the system on which the proposed remedial strategy is based. Owing to the size, linear nature, complexity, and spatial variability of the South River system, reduced exposure of ecological receptors, and subsequent overall risk reduction, will be best achieved in AOC 4 by implementing remedial measures within an EAM framework involving integration of various interim measures and monitoring. The results of the ERA provide further justification for such an approach, which is already being planned for the AOC 4, for ecological risk management and remedial decision-making.

6.0 Biological Investigations

The aquatic, benthic, riparian, and terrestrial habitats within AOC 4 support a variety of organisms that contribute to ecosystem functions. The protection of these receptors and ecosystem functions from adverse effects associated with mercury exposure was the focus of investigations in AOC 4. Comprehensive surveys of the aquatic and terrestrial food web have been conducted to understand the diversity and trophic status of organisms within AOC 4. Benthic invertebrate and fish studies focused primarily on community investigations and mercury tissue residue assessments. Additional investigations included mercury uptake, fish mark/recapture, and stomach content analyses. Submerged aquatic vegetation (SAV) was also investigated to aid in the understanding of its role in MeHg cycling. Other ecological receptors (including birds, reptiles, amphibians, and mammals) were also investigated by various members of the SRST. This chapter provides a description of the aquatic and terrestrial biota within AOC 4 to elucidate, to the extent possible, the nature and extent of mercury in the biota inhabiting AOC 4, and equally important, to understand the food web pathways that potentially expose human and ecological receptors to mercury that was historically released from the Site.

6.1 Study Locations

All studies were generally conducted at Phase II study locations at RRM 0.1, 3.5, 8.6, 11.8, 23.1 and reference areas. Details on the selection of these locations are provided in Section 3.2 of the Ecological Study Report. Briefly, the four study sites located at RRM 3.5, 8.6, 11.8, and 23.1 were selected due to the high concentrations of mercury in environmental and biological media; the study site at RRM 0.1 and the reference areas have relatively low mercury concentrations. This allows an evaluation across gradients of mercury and other key environmental parameters (e.g., microhabitat distribution). Additional or different locations specific to each study are selected to supplement or replace above study sites based on study-specific requirements.

6.2 Food Web Analysis

Newman and Tom (2008) and Newman et al. (2011) assessed THg and MeHg movement through the aquatic and terrestrial food webs using stable nitrogen isotope [^{15}N:^{14}N ($\delta^{15}N$)] measured in tissues. The nitrogen pools of organisms are enriched in ^{15}N relative to their food, with the top predators having the highest stable isotope concentrations. Hence, stable nitrogen isotopes quantify trophic position of individuals in a community trophic web, and regression models can be developed to predict mercury bioaccumulation based on correlations between $\delta^{15}N$ and THg and/or MeHg in tissues. Brief summaries are provided in the following sections; the complete details can be found in Appendix F of the Ecological Study Report.

6.2.1 Aquatic Trophic Transfer Model

The aquatic trophic transfer model for the aquatic habitats within AOC 4 provides a general structure of the food web through which mercury is transferred. Samples from 24 representative taxa of fish, benthic invertebrates, macrophytes and periphyton were collected from six study sites between Constitution Park (approximately RRM 0.1) and Grottoes Town Park (RRM 22.0). Seven fish species were sampled, including smallmouth bass (*Micropterus dolomieu*) and largemouth bass (*Micropterus salmoides*). Invertebrate samples included taxa from various families and orders representative of the benthic community in the South River and SFS River.

Aquatic trophic transfer models identified the basis of the food web and several organisms that biomagnified MeHg to a greater extent than other organisms. The models developed for the South River confirmed that the base of the food web is periphyton (an operationally defined sampling of the algae and suspended solids that were attached to cobbles and boulders). Surfaces of cobbles and boulders trap particles transported in surface water to which IHg and MeHg were adsorbed. Certain organisms were identified that accumulated more than the expected MeHg based on $\delta^{15}N$ measured in tissues. For example, mercury concentrations in black fly larvae (Diptera: Simuliidae) contained higher than predicted MeHg concentrations based on the $\delta^{15}N$ ratio. This finding was consistent with the food habits of black fly larvae, which filter colloidal organic material directly from the water (Pennak, 1953) and have been observed to accumulate more mercury in other systems (Harding et al., 2006).

6.2.2 Terrestrial Trophic Transfer Model

Terrestrial trophic transfer models were also developed based on $\delta^{15}N$ and MeHg and/or THg regressions, to evaluate the transfer of mercury within and to the terrestrial compartments within AOC 4. Terrestrial food webs at two locations within AOC 4 (adjacent to RRM 11.8 and 22.4) were assessed, including detritivores (based on both the aquatic and terrestrial origins) and, predominantly, herbivores. Detritivores of aquatic origin were comprised of emergent aquatic insects including mayfly (Ephemeroptera: Baetidae), midge (Diptera: Chironomidae) and caddisfly (Trichoptera: Hydropsychidae). Detritivores of terrestrial origin included the slug (*Propysaon dubium*), isopod (Isopoda: Microcerberidae), and red marsh worm (*Lumbricus rubellus*). The predominantly herbivorous terrestrial trophic compartment was comprised of the green tissues of vascular plants (*Festuca elatior*, *Viola striata*, and *Lonicera japonica*), whole insects, liver and muscle tissue of small mammals, and blood and feathers from several species of song birds. Complete results and discussion of the terrestrial transfer model are provided in Newman et al. (2011).

6.3 Benthic Invertebrates

Benthic invertebrate studies within targeted AOC 4 environments focused on potential relationships between benthic invertebrate consumers and mercury concentrations in abiotic and biotic exposure media. A combination of approaches was used, including invertebrate community, tissue burden, *in situ* uptake, and toxicity studies, as described in the following sections.

6.3.1 Community Investigations

The adequacy of the sampling approach used in the assessments of benthic invertebrates has been tested and established over time by multiple authors (e.g., Rabeni et al., 1999; Metzeling and Miller, 2001). Benthic community evaluations were performed on two occasions within AOC 4: 1) The preliminary 2006-2007 investigations, which are the subject of this section, and 2) The 2010 investigation as a part of Sediment Quality Triad (discussed in Section 6.2.4). Two studies, that follow, were conducted in 2006-2007 to evaluate the potential impacts on benthic invertebrate communities within AOC 4.

Invertebrate Community Evaluation

Benthic invertebrates were sampled quarterly from March 2006 to February 2007 in riffle and pool habitats in AOC 4 and regional reference areas. Study sites included RRM 0.6, RRM 5.2, RRM 11.8, RRM 14.6, RRM 19.0, RRM 22.4, and SFS-01. Reference areas included SR-01, NR-01, and NR-02. Study results indicated that benthic community structure and composition varies spatially and temporally within AOC 4. Among the study sites, the greatest difference in overall benthic community composition relative to reference areas was observed at study site RRM 5.2. This study site had benthic habitat impairments due to sedimentation of benthic habitat. Detailed results are discussed in Section 5.2.1 (page 50) of the Ecological Study Report.

Benthic Colonization Study

A benthic colonization study was implemented, based on procedures outlined by Klemm, et al. (1990) and Clements et al. (1989). Locations for the colonization study included three sites (RRM 0.1, RRM 3.5, and RRM 11.8) and two reference areas (SR-01 and MR-01).

Detailed study and results are discussed in Section 5.2.1 (page 52) of the Ecological Study Report. The data for the two reference areas were pooled for statistical comparisons to the study sites to represent reference “conditions” so as to account for variability among study sites. The results of the study indicated the following:

- The relative composition of functional feeding groups and major invertebrate class/orders was dynamic over the colonization period; however, at the end of colonization, it was not substantially different between study sites and pooled reference areas.
- The similarities increased over the six-week colonization period between benthic communities in colonization trays at study sites and pooled reference areas, and indicated general consistency in invertebrate community composition and structure.
- The benthic colonization study methodology adequately described resident benthic community structure in AOC 4 and reference areas.

6.3.2 Tissue Burden Studies

Benthic invertebrates were important food items for aquatic ecological receptors during their larval, aquatic stages of development, and for terrestrial receptors following emergence. Mercury concentrations in benthic invertebrate larval tissue (i.e., Diptera, Trichoptera, and Ephemeroptera) were evaluated in Phase I of the Ecological Study seasonally in AOC 4 as well as reference areas in the North River and South River. The results of the evaluation indicated that mercury concentrations in larvae were higher in AOC 4 than in the reference areas, generally increasing with increasing downstream distance from the Site. Seasonally, higher MeHg concentrations were observed in larval tissue samples collected in the spring relative to other seasons, with little variation among taxa (CRG, 2008a).

Cristol et al. (2008) indicated that emergent aquatic invertebrates form a link between the aquatic sources of mercury and the terrestrial receptors in the South River floodplain by measuring the concentrations of mercury in food items of passerine birds. An insect metamorphosis study (URS, 2012) sought to understand the potential effect of metamorphosis on mercury concentrations in emergent benthic invertebrates, which were potentially important prey items for avian receptors. Differences between whole body IHg and MeHg concentrations in larval and emerging adult benthic invertebrates were evaluated at RRM 3.5 and RRM 8.5 in the spring and summer of 2009. The study included two feeding types and representative organisms:

- Collector-filterers: net-spinning caddisflies (i.e., Trichoptera: Hydropyschidae)
- Collector-gatherers: mayflies (i.e., Ephmeroptera: Baetidae) and midges (i.e., Diptera: Chironomidae)

The study found that benthic invertebrate mercury body burden is not consistently correlated with IHg and MeHg concentrations in physical media. In addition, emergence may increase the concentrations of IHg and MeHg in some insect species particularly midges and mayflies, by as much as an order of magnitude. The finding of increased mercury concentrations in emergent insects is consistent with the findings reported in the literature. For example, Chetelat, et al. (2008) reported increased mercury concentrations in the midge during metamorphosis and concluded that this was due to body mass reduction during emergence to the non-feeding adult stage, combined with a minimal mercury mass reduction during emergence.

6.3.3 Uptake Studies

Two studies were designed and conducted to help understand mercury transport from physical media (surface water, sediment, pore water) into invertebrates in the South River, as summarized below.

Asiatic Clam Transplant Study

The Asiatic clam (*Corbicula fluminea)* plays an important role in the aquatic and terrestrial food webs of the South River. *Corbicula* is widely abundant, consumed by a variety of fish and wildlife species (e.g., crayfish, muskrat, raccoon, waterfowl, and white sucker) and is the subject of several previous studies in the South River. The characteristics of *Corbicula* also make it a good candidate for evaluating localized mercury bioavailability and uptake.

The Asiatic clam transplant study was conducted to investigate if mercury accumulation in *Corbicula* differs spatially among small-scale river channel habitats of the South River and/or based on feeding behavior. For the spring event, seeded *Corbicula* deployed in near bank locations showed significantly greater uptake of MeHg than caged *Corbicula* deployed in either mid-channel or near bank, or seeded *Corbicula* in mid-channel. A caged vs. seeded comparison could not be made for the summer sampling event because of high *Corbicula* mortality in caged organisms. During the summer sampling event, estimated *Corbicula* mortality after the first week of deployment was approximately 85%

in caged organisms and 30% in seeded organisms. After 14-week deployment, live *Corbicula* deployed during the spring were retrieved from each study site. Due to high mortality in caged organisms, mercury concentrations could be compared only between the seeded resident clams.

Uptake studies with transplanted *Corbicula* were conducted at RRM 0.1, RRM 3.5, RRM 8.5, and RRM 23.5 in the spring and summer of 2009. *Corbicula* were collected from reference areas on the Middle River and transplanted to each study site (URS, 2009; URS, 2012). Two types of deployments were conducted. Seeded *Corbicula* were labeled and allowed to burrow into embedded gravels and sand, where they ingested sediment from filtering surface water and directly from sediment. Caged *Corbicula* were enclosed in mesh bags and suspended in the water column, where they fed by filtering surface water. Comparing the results of mercury analysis of *Corbicula* from the two deployments allowed for a comparison of mercury uptake via sediment versus surface water.

For the spring sampling event, statistical analyses of IHg and MeHg tissue data were performed to assess the effects of deployment method (seeded or caged), habitat type (mercury transport or storage), and collection week. IHg concentrations in *Corbicula* tissue increased from RRM 0.1 to RRM 3.5, and then decreased with distance downstream. IHg and MeHg tissue data were transformed based on rank-order; a three-way ANOVA was then used to assess the effects of deployment method, habitat type, and collection week based on ranked IHg and MeHg concentrations with Tukey's Honestly Significant Difference (HSD) test for pairwise comparisons. Significant interactions were further analyzed with three-way, two-way, and one-way ANOVA to interpret significance ($\alpha = 0.05$). Tissue concentrations of IHg and MeHg were significantly higher at all three downstream study sites when compared to concentrations from study site RRM 0.1 (Tukey; $p < 0.001$). IHg concentrations were similar between RRM 3.5 and RRM 8.5 and were significantly higher than those measured at RRM 23.5 (Tukey; $p < 0.001$). Also, IHg concentrations were significantly higher in seeded *Corbicula* relative to caged *Corbicula* (Tukey; $p = 0.002$).

For the summer sampling event, seeded *Corbicula* that were deployed during the spring were collected from each study site after a 14 week deployment owing to the significant mortality in *Corbicula* deployed during the summer. IHg and MeHg tissue concentrations in 14-week deployment seeded clams were compared to tissue concentrations of resident clams using Mann-Whitney tests ($\alpha = 0.05$). Resident *Corbicula* had significantly greater IHg concentrations (median = 113 ng/g) than seeded *Corbicula* (median = 72 ng/g) [Mann-Whitney test (M-W); $p < 0.001$]. MeHg concentrations between seeded and resident *Corbicula* were similar (M-W; $p > 0.05$).

No specific study was conducted to evaluate the relationship of *Corbicula* size and tissue mercury; that is, whether larger clams collected from areas of higher mercury exposure concentrations and smaller clams collected from areas of lower mercury exposure concentrations would have similar tissue mercury concentrations. However, similar-sized (15-25 mm shell width) *Corbicula* were collected from the reference area for deployment in this study. Following the 5-week deployment period, in addition to having the higher mercury uptake, seeded *Corbicula* had higher growth rates than caged *Corbicula*. Seeded *Corbicula* showed significantly higher increases in mass and shell width compared to caged *Corbicula* (Tukey; $p < 0.001$). Spearman rank correlation analysis indicated that there was no significant relationship between tissue mass and shell width with tissue MeHg concentrations (r_s = -0.034 and r_s = -0.083, respectively) or tissue IHg concentrations (r_s = -0.365 and r_s = -0.184, respectively).

The overall findings based on above results are summarized below. Additional details are provided in the Ecological Study Report.

- Seeded *Corbicula* had greater IHg and MeHg uptake relative to caged *Corbicula.*
- *Corbicula* tissue MeHg concentrations increased with increasing distance downstream, whereas IHg concentrations increased from RRM 0.1 to RRM 3.5 and then decreased with increasing distance downstream.
- Seeded *Corbicula* reached near-resident tissue MeHg concentrations after 14 weeks of exposure.
- Habitat differences did not affect mercury uptake by *Corbicula*, indicating that mercury uptake is not habitat specific, but widespread in the South River.
- *Corbicula* size and tissue IHg and MeHg concentrations were not related.

In Situ Uptake Study

An *in situ* uptake study was also conducted to evaluate IHg and MeHg uptake by primary consumers at RRM 3.5, RRM 11.8 and RRM 23.5 in the spring and summer of 2010 (see Section 5.2.3 in the Ecological Study Report). The study was designed in general accordance with Burton, et al. (2005) and Clark and Clements (2006). Flathead mayfly nymphs (i.e., Trichoptera: Heptageniidae), a detritivore, and crayfish (i.e., *Orconectes* sp.), an omnivore, were transplanted from a reference area on the Middle River (MR-01) and placed in experimental chambers at South River study sites for a seven-day exposure period. Experimental chambers were completely sealed, with the exception of eight holes covered by 20 µm and 75 µm nylon mesh, to simulate the potential difference between aqueous and aqueous plus dietary pathways, respectively. The aqueous treatment chambers (20 µm mesh) contained uncolonized/clean substrates. The dietary treatment chambers (75 µm mesh) contained substrates colonized by resident periphyton and non-predatory macroinvertebrates, providing a food source for the study organisms. Uptake of THg and MeHg over the seven-day experimental period was estimated by subtracting the reference area baseline tissue concentrations from the observed tissue concentrations of the respective study samples. The results of the *in situ* uptake study indicated the following:

- The uptake of IHg and MeHg from aqueous (20 µm mesh) and dietary (75 µm mesh) treatments were generally similar for both mayflies and crayfish.
- It is not possible to definitively allocate relative uptake proportions between the aqueous and dietary pathways because the dietary (75 µm mesh) treatment included aqueous uptake.
- A greater uptake of IHg and MeHg was observed in mayflies than in crayfish.
- In mayflies:

  - The uptake of MeHg was generally greater in the spring and generally increased with increasing distance downstream.
  - The uptake of IHg was relatively rapid as the transplanted mayflies achieved near-resident tissue IHg concentrations after seven days of exposure in the South River.
- The uptake of MeHg by crayfish was generally greater in the spring than summer.
- The uptake of MeHg by crayfish and mayfly was correlated with interstitial sediment MeHg concentration, the uptake of MeHg by mayflies was correlated with surface water MeHg concentration, and the uptake of IHg by crayfish was correlated with seston IHg concentration.

6.3.4 Sediment Quality Triad (SQT) Investigation

As a weight-of-evidence (WOE) approach, a sediment quality triad (SQT) investigation evaluates sediment quality by integrating spatially- and temporally- matched bulk sediment chemistry, biological community, and sediment toxicity, as various lines-of-evidence (LOEs). An SQT investigation was conducted in May 2010 to evaluate potential sediment-associated impacts to benthic macroinvertebrate communities of the South River in AOC 4 (see Section 6.2.1 of the Ecological Study Report). SQT stations were established at RRM 0.1, RRM 3.5, RRM 11.8, and RRM 23.5 and two reference areas, one on the South River and another on the Middle River. The following LOEs were included, in descending relative weight (importance) based on their relevance to the site-specific evaluations:

- Benthic macroinvertebrate community analyses
- Sediment toxicity testing: 10-day *Hyalella azteca* and 10-day *Chironomus dilutus* tests
- Comparison of bulk sediment chemistry to Sediment Quality Benchmarks (SQBs)

The integrated LOEs (see Table 6-1) indicated that mercury exposure in interstitial sediments did not result in any measureable impacts to benthic macroinvertebrate communities of the South River as compared to pooled reference areas. Sediment THg concentrations in AOC 4 exceed Threshold Effects Concentration (TEC) and reference area THg concentrations. However, THg and MeHg concentrations were not indicative of adverse effects in sediment toxicity testing or benthic macroinvertebrate community analyses, as indicated below:

- Survival and growth endpoints for *H. azteca* and *C. dilutus* in 10-day sediment toxicity tests were not significantly lower at study sites when compared to pooled reference areas.
- Benthic macroinvertebrate community metrics did not differ significantly between study sites and pooled reference areas.

Site-specific community analyses and sediment toxicity testing were more relevant indicators of potential impacts than the bulk sediment mercury concentrations (that exceed generic TECs). Therefore, adverse effects to benthic macroinvertebrate communities were not anticipated at interstitial sediment mercury concentrations represented by SQT samples. The SQT evaluation provides a rigorous analysis of potential mercury-related effects on benthic invertebrate communities. Because no statistical differences were found in various community matrices and the observations were consistent with sediment toxicity tests, the results of the SQT evaluations form the basis of overall conclusions on the benthic community evaluations, rather than the results of the earlier, preliminary 2006-2007 investigations (see Section 6.2.1).

Although mercury bioaccumulation data indicate a potential for ecological risk to benthic macroinvertebrates due to MeHg, an overall WOE evaluation of the various lines of evidence, including mercury tissue residues, suggested that the exposure to mercury is not likely to impact AOC 4 benthic communities [see the ERA (AECOM, 2015)]. Mercury bioaccumulation by both larval and emergent benthic invertebrates pose potential ecological risks to higher trophic level wildlife due to aquatic and the terrestrial dietary exposure to MeHg [see Section 5.3 and the ERA (AECOM, 2015)].

THg and MeHg tissue residues in benthic macroinvertebrates were compared to critical body residues (CBRs) associated with no adverse effects (no-effects CBRs) and low adverse effects (low-effects CBRs) in a WOE evaluation. While THg tissue residues in larval and emergent macroinvertebrates were generally lower than the no-effects CBRs, MeHg tissue residues were higher than the no-effects CBRs; low-effects CBRs for MeHg were not available [see 6.1.3 in the ERA (AECOM, 2015)]. Overall, there was no potential for adverse effects to benthic macroinvertebrates exposed to mercury within AOC 4 based on the results of the WOE evaluation which included the SQT results.

6.3.5 In Situ Microcosm Study

An *in situ* microcosm study was conducted in the summer of 2010 to assess potential impacts of environmental stressors on benthic invertebrate communities in the South River within AOC 4 (see Section 6.2.2 in the Ecological Study Report). Substrate-filled colonization trays were deployed at a reference area on the North River (NR-01) in June 2010. After a 60-day colonization period, trays were selected at random and placed into *in situ* exposure chambers at RRM 0.1, RRM 3.5, RRM 11.8, and RRM 23.5 and reference areas (SR-01 and MR-01) for a seven-day exposure. The fine mesh in the exposure chambers essentially eliminates recruitment to the chambers and densities likely decline in all chambers over time because of natural mortality (Clark and Clements, 2006). Therefore, the experiments were restricted to seven days in order to maximize exposure while limiting natural mortality among study and control chambers, to allow for direct comparisons.

Differences between benthic macroinvertebrate communities exposed for seven days at the study sites and reference areas were statistically analyzed based on various community metrics, including abundance, taxa richness, and diversity index. The statistical results indicated that population or community-level differences did not exist between the study site and reference area benthic macroinvertebrate communities in the *in situ* microcosms.

6.4 Fish

Fish were an important component of the South River food web, representing a critical element of the mercury transport within the aquatic food web and to the terrestrial food web. Numerous studies assessing various aspects of South River fish communities have been conducted. Key studies that were described in the Ecological Study Report include the following:

- Community Composition Studies—Jordan (1890), Ross (1959), Cairns and Dickson (1972), URS (2008, 2010)
- Tissue Burden Studies—VDEQ Long-term tissue monitoring program (1977-2012), Murphy (2004), URS (2008, 2009-2011)
- Dietary Studies—Murphy (2004), URS (2010)

The VDEQ dataset provides consistent long-term datasets for the key fish species in the South River; analyses of these datasets indicated that mercury concentrations in these species remain at levels similar to the 1977-1983 baseline concentrations (Green, 2006). This finding is a key focus of the Ecological Study and the RFI for AOC 4. Brief summaries and findings of the above listed studies are provided in the following sections.

6.4.1 Community Composition

The resident fish community of the South River has been evaluated during several field investigations dating back to 1890 (Jordan, 1890; Cairns and Dickson, 1972; Ross, 1959; URS, 2007). The most recent study, Phase II of the Ecological Study (URS, 2012) assessed fish populations in the South River in the spring and late summer of 2010, using three-pass depletion electro-fishing methodology at four study sites (RRM 0.1, RRM 3.5, RRM 11.8, and RRM 23.5) and two regional reference areas (South River, SR-01 and Middle River, MR-01). The results of this study indicated the following:

- Taxonomic richness within AOC 4 documented in Phase II of the Ecological Study (40 species) was greater than that documented in Phase I (34 species) or earlier studies by Ross (1959; 26 and 24 species),
- Taxonomic composition of the fish community for the South River is generally comparable among study sites and between reference areas (spatially) as well as between seasons (temporally).
- Community composition varies between the upper (RRM 0 to 10) and lower reaches (beyond RRM 10) of the South River, likely reflecting longitudinal geomorphic variation.
- Invertivorous fish represent the largest percentage of fish collected within AOC 4.

6.4.2 Population Metrics

Fish population studies were used to evaluate the health of the South River aquatic system and to understand mercury transport. In the Phase II of the Ecological Study, seasonal variation between study sites was minimal, with the reference area (SR-01) having the highest, and RRM 23.5 having the lowest population density. Overall abundance metrics indicated a decreasing trend with increasing distance downstream from the reference area. During the spring sampling event, all study sites, with the exception of RRM 23.5, had greater population densities than reference area MR-01. Between seasons, population density increased at all study sites, with the exception of study site RRM 11.8.

Unlike overall population trends for the South River, which declined with increasing distance down river, population densities of smallmouth bass generally increased with the distance down river. The greatest population density documented for South River stations sampled during the spring sampling event was 122 fish per hectare (f/ha) at RRM 11.8; density was 132 f/ha at MR-01. The increase in smallmouth bass density measured at RRM 11.8 and RRM 23.5 is likely due to habitat availability and preference for more lotic (flowing) conditions at these locations (Edwards et al., 1983). The lowest population density of smallmouth bass for the spring event was zero at SR-01, followed by 24 f/ha at study site RRM 3.5.

6.4.3 Tissue Burden Studies

One of the important mercury fate and transport evaluations in the South River has been the fish tissue evaluation because of the human health implications of tissue mercury residues that have remained consistently elevated over the period of record. Extensive fish tissue data have been collected through the following efforts:

- VDEQ long-term tissue monitoring program, including evaluation of stocked trout(1977–2012)
- Study on mercury uptake and food habits of select fish species in the Shenandoah River Basin, Virginia (Murphy, 2004)
- Assessment of mercury in forage fish tissue, as a part of the 2006 Phase I for the Ecological Study (URS, 2012)
- Assessment of mercury in tissue of select fish species as a part of the 2009 – 2011 Phase II of the Ecological Study (URS, 2012)

The Ecological Study Report provides the details of the above studies and findings. Only THg concentrations were measured in the studies with the assumption that almost all of the mercury in fish is MeHg. The major findings indicate that fish tissue THg concentrations:

- Generally increase with trophic level and increasing distance down river for all species.
- Are significantly different between seasons (in smallmouth bass and redbreast sunfish) but not between the years of the Ecological Study for all species.
- Are higher in forage fish inhabiting riffles [*Rhinichthys cataractae* (longnose dace)] than those inhabiting pools [*Luxilus cornutus* (common shiner)].
- THg concentrations in stocked trout collected from two locations on the South River as part to the VDEQ long-term tissue monitoring program were consistently below 0.5 mg/kg.

6.4.4 Mark Recapture Study

Concurrent with fish tissue sampling during the 2009-2011 period (Phase II of the Ecological Study), smallmouth and largemouth bass were fitted with Passive Integrated Transponder (PIT) tags to assess temporal variation of THg in bass tissue, site fidelity, and seasonal movement of bass between stations. At the time of the drafting of the Ecological Study Report, 535 smallmouth bass had been tagged and sampled using non-lethal dermal (mid-dorsal) tissue biopsies for THg content for the South River. Excluding bass originally sampled in 2011, 33 bass were recaptured (7.3%). The majority of recaptures (91%) demonstrated a high degree of site fidelity, being recaptured at the site of original capture. Analysis of THg in recaptured bass revealed an increase in THg with length and days at large.

6.4.5 Fish Stomach Content Analyses

An understanding of temporal and spatial trends of fish diets can provide insight into the transport of mercury in the aquatic food web. Fish stomach contents were analyzed in conjunction with fish community and biopsy studies in the spring, summer, and fall of 2010. Over the three seasons, more than 500 fish stomach/intestinal contents were sampled. Organisms and material in the stomach content were identified to the lowest practical taxonomic level, with percent contribution to diet for each class of diet item being calculated by wet weight. Results are summarized below.

Dietary Compositions

Smallmouth Bass: Age-related shifts were observed in smallmouth bass dietary composition with aquatic insects constituting the majority of the diet (62%) in small fish (fish < 116 mm) and fish dominating the diet (approximately 40%) in intermediate bass (fish between 116 and 185 mm) and large bass (> 185 mm). Crayfish were noticeably absent in the diet in the smallest size class but constituted 43% of the diet in the largest size class. Seasonal shifts were also observed in smallmouth bass dietary composition. The abundance of aquatic insects in diets was the highest in the spring. Terrestrial insects constituted 15% stomach contents in the fall versus 1% in spring and summer. Crayfish consumption peaked in the summer, but no noticeable shifts occurred in piscivory between seasons.

Largemouth Bass: Aquatic insects constituted 69% of the diet in small fish (fish < 85 mm). Piscivory increased with size, representing 43% and > 50% of the diet in intermediate (fish 85–135 mm) and large fish (fish >135 mm), respectively. Similarly, crayfish consumption increased with growth in spring and summer samples, but such a trend was not apparent in the fall samples.

Redbreast Sunfish: Unlike in the bass species, age-related shifts in diet were not apparent in redbreast sunfish. However, a seasonal shift was apparent, most likely due to prey abundance. Three taxa of aquatic insects (midges, mayfly, and caddisfly) constituted approximately 50% of the stomach items. In the spring, midges formed the largest part of the diet (30%); in the summer, all three taxa contributed equally to the diet; in the fall, caddisfly dominated the prey species in the diet.

Forage Fish: Similar to redbreast sunfish, midges made up a larger portion of the diet in the spring than for other seasons for two species of forage fish (longnose dace and common shiner). For common shiners, mayflies and caddisflies were consumed in similar amounts as midges in spring. Consumption of algae and vegetation increased substantially throughout the seasons in both species likely reflecting the seasonal increase in abundance of these food items.

Trophic Organization of South River Species

Trophic organization of South River fish communities provides insight into the temporal and spatial trends into mercury transport in the South River aquatic food web. A cluster analysis was conducted using the five fish species sampled (above) to evaluate trophic organization in the aquatic food web. The trophic organization was divided into four major groups based on the cluster analysis: 1) forage fish that feed primarily on aquatic insects and vegetation, 2) all size classes of redbreast sunfish as well as summer feeding young-of-year for both bass species, 3) mid-sized bass species that consumed approximately equal proportions of fish and aquatic insects (approximately 35% each) and crayfish (15%) of the diet composition, and 4) the largest individuals of both bass species that consumed approximately 50% fish and 30% crayfish. In the fall, the final trophic level was occupied solely by largemouth bass > 101 mm, with a diet composition of greater than 60% fish.

6.4.6 Fish Bioaccumulation Model

To understand how MeHg is accumulated by higher level trophic level fish in AOC 4, the Bioaccumulation and Aquatic System Simulator (BASS) model was used to simulate food web responses to changes in MeHg concentration in South River media and the food web structure. The BASS model simulates the bioaccumulation dynamics of hydrophobic organic pollutants and borderline metals that complex with sulfhydryl groups (such as mercury) within an ecosystem context (Barber, 2008). The predictive performance of the BASS model for mercury has been verified by simulations of MeHg bioaccumulation dynamics in fish communities of the Florida Everglades (Barber, 2008) and the South River and SFS River (Murphy, 2004).

For the South River system, the BASS model (v2.4) simulated the dynamics of MeHg bioaccumulation by smallmouth bass, redbreast sunfish, and common shiners at RRM 0.1, RRM 3.5, RRM 11.8, and RRM 23.5. Information on aquatic communities, fish food habits, and MeHg concentrations in biotic and abiotic media collected during the Ecological Study and other SRST studies were integrated into the BASS model (CRG, 2008a). The integration of these additional data updated and expanded on the previous BASS model for the South River (Murphy, 2004).

Murphy (2004) provides the details on the model performance and sensitivity with respect to its application to the South River system. The model's predictive ability was graphically assessed through the evaluation of model predicted and observed MeHg concentrations in fish muscle tissue, as well as through the mean absolute percent error (deviance measure) between model-predicted and observed MeHg concentrations. Graphical analysis of MeHg concentration in fish muscle tissue indicated that model-predictions were comparable to observations in the South River. Mean absolute percent error between predicted and observed fish tissue MeHg concentrations was 52%, ranging from 17 to 127%.

BASS model sensitivity to food web structure was assessed by adjusting dietary composition, average length of prey, and specific growth rate (Murphy, 2004). Selection of these sensitivity parameters was based on discussion with the BASS developers. These parameters were important to the bioaccumulation dynamics of MeHg in fish communities and had not been evaluated previously. As the percentage of piscivory increased from 19.5 to 75.0%, MeHg uptake through dietary pathways increased from 88 to 95%. As the average length of prey increased from 9.5 to 42.6%, MeHg uptake through dietary pathways increased from 91 to 94%. MeHg accumulation through aqueous pathways was not affected by changes in the dietary composition or the average length of prey. MeHg uptake through aqueous and dietary pathways increased or decreased with changes in specific growth rate, but the MeHg uptake through each pathway remained relatively consistent.

CRG (2008a) provides the working BASS model for the South River that can be used to integrate the current data and predict MeHg bioaccumulation in resident fish species, to test the current understanding of factors controlling MeHg uptake by high trophic level aquatic organisms and the structure of the South River food web. As such, the BASS model can be used to understand the importance of dietary pathway for MeHg uptake and show that the MeHg concentration in food items varies spatially in the South River, and controls the concentrations in fish. More importantly, the BASS model can be used to: 1) support the remedy selection by simulating MeHg bioaccumulation under various scenarios represented by various remedial alternatives, and 2) to support the evaluation of effectiveness of the selected remedy by integrating the monitoring data to predict future conditions.

6.5 Submerged Aquatic Vegetation (SAV)

SAV is a dominant biological community in the South River, growing to high densities and seasonally altering the water flow path in many areas. The presence of SAV may affect the physical and chemical environment that is conducive for mercury methylation. Therefore, SAV may play an important role in MeHg cycling and food web dynamics in the South River.

A study was conducted to characterize the distribution and community composition of SAV in the South River and to understand its role in MeHg cycling [Appendix G of the Ecological Study Report (URS, 2012)]. The findings indicate that SAV beds were typically sparse in the upstream portion of the South River in AOC 4 and become denser and more frequent in downstream portions (e.g., RRM 3 to RRM 10). Between RRM 0 and RRM 10, SAV beds occupied 21% of the areas. Water stargrass (*Heteranthera dubia*), Elodea (*Elodea canadensis*), and curly leaf pond weed (*Potamogeton crispus*) were the most dominant taxa.

In general terms, the results suggest that the presence of SAV did not have a major influence on mercury methylation locally. Both MeHg concentrations and the percent of THg present as MeHg (%MeHg) were higher in interstitial sediment from SAV beds. In caddisfly larvae, MeHg concentrations and %MeHg were higher in riffle areas, but IHg concentrations were higher in SAV beds. Pore water MeHg concentrations were not significantly different between SAV beds and riffles, although IHg concentrations were lower in the SAV beds.

SAV is capable of sequestering higher IHg and MeHg in roots than in leaves. IHg and MeHg concentrations were 3 to 10 times higher in roots than in leaves at the sampled locations. SAV had considerably more MeHg in both leaves and roots (on a dry weight basis) than either sediment or particles in surface water. SAVs may, therefore, be a source of MeHg to organisms that consume SAV.

The findings of this study indicate that although SAV is capable of sequestering MeHg, it does not directly influence MeHg concentrations in the South River via a potential role in MeHg production. Generally higher MeHg concentrations SAV-associated interstitial sediment suggested that the methylation environment beneath SAV beds was affected. However, the lack of an effect on biota or surface water concentrations suggests that this potential effect on methylation environment is not reflected in biota. An alternative hypothesis is that demethylation rates in SAV beds were potentially higher due to their higher surface area, as comparison of pore water MeHg between SAV beds and adjacent SAV-free areas revealed no consistent increases in SAV bed pore water MeHg.

6.6 Other Receptors

Extensive SRTS studies have been conducted on birds, mammals, and herpetofauna that represent potentially important mercury exposure pathways in AOC 4. Generally these studies identify reference area(s) and compare the study parameters between the habitats in these reference area(s) and AOC 4. Exposure parameters generally include tissue mercury concentrations (blood, feather, eggs) and mercury concentrations in dietary items. Effect parameters encompass a wide range of effects including, survival, behavior, reproduction, growth, and immunity/endocrine function. The detailed findings of the studies can be found in the individual studies provided in the Ecological Study Report (URS, 2012). The ERA being performed for AOC 4 will evaluate the data collected as a part of these various studies and will quantify potential risks to the survival, growth, and reproduction of various representative wildlife receptor groups. This section provides an overview of these wildlife studies and other relevant studies.

6.6.1 Terrestrial Invertebrates

The roles of terrestrial invertebrates are twofold: they are receptors potentially exposed to mercury, and they can also serve as dietary items for other receptors. A survey was conducted to evaluate the relationship between THg and MeHg concentrations in paired earthworm and soil samples to understand the extent to which mercury bioaccumulates in earthworms (SRST, 2009b; Cianchetti, 2009). Samples were collected from 12 relatively undisturbed locations along the South River floodplain within AOC 4, including a reference site. THg concentrations in earthworm tissues ranged from <1.0 mg/kg dw in samples upstream of the Site and increased to about 13.0 to 15.0 mg/kg dw at RRM 1.8 and 12.4, declining to about 4.0 mg/kg dw at RRM 24.9 (SRST, 2009b). THg and MeHg concentrations were highly variable among quadrats within a location for both soils and earthworm samples. Additionally, tissue THg concentrations ranged from about 10% to < 60% of paired soil THg concentrations and were well correlated. In contrast, MeHg was 15 to 70 times greater in tissue compared to paired soil samples, and were not well correlated.

Additional data have been collected on various terrestrial invertebrates (including spiders) to supplement studies that investigated the dietary route of exposure to mercury in higher wildlife. These datasets will be discussed as part of the RDQAs and used in the risk assessments, where appropriate.

6.6.2 Songbirds

Songbirds form a vital component of the South River food web. Some species that feed on emergent aquatic species and predatory insects on the river banks form a recently identified link in mercury transport from the aquatic to the terrestrial systems (Cristol et al., 2008). Various studies have evaluated mercury exposures (based on tissue residues in blood, feather, eggs, and muscles) and various potential effects on several species of songbirds, which are resident or migrant in the South River habitats (Cristol and colleagues, 2008-2013). These species include tree swallows (*Tachycineta bicolor*), bluebirds (*Sialia sialis*), Carolina wren (*Thryothorus ludovicianus*), house wren (*Troglodytes aedon*), and song sparrow (*Melospiza melodia*) and one suboscine, the eastern phoebe (*Sayornis phoebe*), red-eyed vireo (*Vireo olivaceus*, and indigo bunting (*Passerina cyanea*). Songbirds are exposed through the consumption of both terrestrial and aquatic invertebrates, including spiders, which had higher mercury concentrations than blood of some piscivorous birds (Cristol et al 2008). As a result, some songbirds (e.g., Carolina wren), which feed on spiders, had higher mercury concentrations in feathers (representing cumulative exposure) than other birds, such as owls and woodpeckers (Cristol et al. 2008). Carolina wrens showed blood mercury concentrations higher than reference wrens; the average female blood THg level for AOC 4 was 2.24 μg/g in 2009 and 2.13 μg/g in 2010 (Jackson and Evers, 2010). For comparison, the average female blood THg level on reference sites was 0.38 μg/g in 2009 and 0.21 μg/g in 2010. In tree swallows, blood THg was significantly elevated in AOC 4 in 2005 to 2007 (2.84 ± 0.09 μg/g) compared to reference areas (0.17 ± 0.01 μg/g) (Hallinger et al., 2010).

6.6.3 Waterfowl

Waterfowl are abundant along the South River within AOC 4 and thus are potentially exposed to mercury via diet and incidental ingestion of sediments. They are also consumed by humans and hence, constitute potential exposure media for human exposure to mercury in AOC 4. As a part of the SRST studies, Savoy and Evers (2008) sampled waterfowl (mallard, wood duck and Canada geese) in 2007 and 2008 to evaluate mercury bioaccumulation in the South River. Mercury concentrations were measured in blood, eggs, and feathers and found to be higher in South River birds than in reference area birds. Stable nitrogen isotope ($\delta^{15}N$) ratio in blood correlated strongly with blood THg concentrations.

6.6.4 Piscivorous Birds

Piscivorous birds are abundant and particularly prone to mercury exposure *via* consumption of mercury contaminated fish species. Therefore, they form an important element of the South River food web. Studies have been conducted on the potential relationships between mercury exposure, physiological condition, and reproductive success in the belted kingfisher (*Megaceryle alcyon*), a representative piscivorous bird (Cristol, 2005; Cristol, 2006; White, 2007). In general terms, the study found no effects of mercury exposure on kingfisher survival, growth, or reproduction.

6.6.5 Amphibians

Amphibians consume plants and insects and in turn are consumed by other wildlife. As such, they are also integral part of the South River food web. Studies conducted on various amphibian species from the South River include maternal transfer and bioaccumulation MeHg in three amphibian species [southern two-lined salamander (*Plethodon cinereus*), red-backed salamander (*Eurycea bislineata cirrigera*), and American toad (*Bufo americanus*)] (Bergeron et al., 2010), potential effects of mercury exposure on *P. cinereus* and *B. americanus* (Burke, et al., 2010; Bergeron et al., 2011), maternal versus dietary mercury transfers and effects on *B. americanus* (Todd et al., 2011a, b, and c), and various effects of dietary mercury on wood frogs (*Rana sylvatica*), including endocrine effects (Wada et al., 2011).

Hopkins et al. (2011) synthesizes studies investigating the impact of mercury on amphibians in South River, VA. In summary, Hopkins et al. (2011) found that bioaccumulation of mercury occurs through dietary uptake, and that maternal transfer of mercury to eggs occurs in females. Elevated mercury in eggs had adverse effects on embryonic survival in some years and caused sublethal, latent effects in larvae and metamorphosed juveniles and adults. These include decreases in size, an increased frequency of spinal malformations, and an increased time required to complete metamorphosis. Of the two factors, maternal transfer was found to have a much greater negative impact than diet. No cumulative impacts of combined exposure through diet and maternal transfer in terms of either survival or individual quality (i.e., size, frequency of malformation, length of metamorphosis) were observed.

6.6.6 Reptiles

Mercury bioaccumulation has been investigated in several species of turtles (*Chelydra serpentina*, *Sternotherus odoratus*, *Chrysemys picta*, and *Pseudemys rubriventris*) (Bergeron et al., 2007; Hopkins et al., 2013) and snakes (*Nerodia sipedon*, *Regina septemvittata*, *Thamnophis sirtalis*, and *Pantherophis alleghaniensis*) (Drewett et al., 2013).

Bergeron et al. (2007) found elevated blood THg concentrations in three species of turtles (*C. serpentina*, *S. odoratus*, and *C. picta*) in AOC 4 compared to reference locations; Blood THg concentrations were 37 to 108-fold higher in AOC 4 depending on the species and the specific reference location.

Drewett et al. (2013) reported that the THg concentrations in northern water snake (*N. sipedon*) tail tissue at AOC 4 (ranging 2.25 to 13.84 mg/kg dry mass) were 11 to 19 times higher than reference locations. Blood THg concentrations (0.03 to 7.04 mg/kg wet mass) were strongly correlated with tail concentrations. Their findings also indicated the importance of diet but not of sexes in mercury bioaccumulation. Interspecies comparisons identified that aquatic species (water snakes and queen snakes) accumulated higher THg (mean of 5.6 ± 0.4 and 4.59 ± 0.38 mg/kg in tail tissue, respectively) than terrestrial species (garter snakes and rat snakes; 1.28 ± 0.32 and 0.26 ± 0.09 mg/kg, respectively).

Hopkins et al. (2013) synthesized the South River studies on reptiles, more specifically on common snapping turtle (*C. serpentine*). They found mercury concentrations in female *C. serpentine* tissues were strongly and positively correlated with mercury levels in their eggs, which in turn were negatively correlated with hatching success (driven by both increased egg infertility and embryonic mortality). However, in comparison to previous effects-based studies on other amniotes, their findings suggest that *C. serpentina* may be more resilient to mercury exposure and perhaps better suited for long-term monitoring of bioavailability of mercury than as indicators of adverse effects.

6.6.7 Mammals

As aerial invertivores, certain species of bats in the South River prey on emergent insects from the aquatic habitats; therefore, a complete exposure pathway exists for these bat species. Understanding of this exposure pathway is critical in evaluating the extent of mercury exposures and effects on wildlife. Studies on potential endocrine disruption and immunotoxicity related adverse effects have been examined for bats in AOC 4, as summarized below.

Adrenocortical, glucocorticoid, and stress hormone responses (using plasma cortisol concentrations) were used as a measure of the relative function of the hypothalamic-pituitary-adrenal axis (i.e. adrenocortical reactivity; Wada et al. 2009). Overall, the location (AOC 4 vs. reference) had no effect on cortisol levels, and neither blood nor fur mercury concentrations were correlated with either progesterone or any of the cortisol levels (Yates et al., 2007). Similarly, Wada et al. (2010) found that despite the large differences in mercury concentrations in female big brown bat tissue (blood and fur), adrenocortical responses were not different in bats from AOC 4 and nearby reference area.

Potential for mercury-related immunotoxicity in bats from AOC 4 were evaluated via cell-mediated and innate immune function assays (Hawley et al., 2009). Blood and fur mercury concentrations did not appear to affect cell-mediated adaptive immune responses in big brown or little brown bats collected in 2007 and 2008, respectively (Yates et al., 2007, 2008). However, bactericidal ability was weakest in blood from AOC 4 bats although no significant relationships were detected between the bactericidal ability of blood and blood or fur mercury concentration in 2007 or 2008 (Yates et al., 2007, 2008). Overall the variability of immune function in big and little brown bats in AOC 4 appears to be more related to sex, reproductive stage, colony-specific variation, and/or life history traits rather than mercury tissue burdens (Yates et al., 2007, 2008).

Additionally, Sleeman, et al. (2010) reported on the results of a visual and histopathological examination of a five-year-old female northern river otter (*Lontra canadensis*) found in the South River, as well as tissue mercury concentrations. Reported tissue THg levels were 121 to 353 mg/g dry weight in various tissues (kidney, liver, muscle, and brain) and 183 μg/g fresh weight in fur. Histopathological findings included severe, diffuse, chronic glomerulosclerosis, and moderate interstitial fibrosis.

6.7 Advisory Programs

Fish consumption is a potential human exposure pathway in AOC 4. Fish consumption bans and advisories issued by VDH and VDEQ have effectively managed this potential exposure pathway. A 1977 ban on fish consumption was replaced with a consumption advisory in 1980, which was modified again in 2001 to reflect new guidance from the U.S. National Academy of Sciences on an acceptable daily intake of mercury (VDH, 2001). The 2001 fish consumption advisory was subsequently modified in 2011 and remains in effect. The advisory is as follows:

- South River: No fish other than trout should be eaten from these waters. Stocked trout have been tested and are safe to eat.
- SFS River: No more than two meals (½ pound each or the size of your hand) of fish per month should be eaten from these waters. Women who are pregnant or may become pregnant, nursing mothers, and young children should not eat fish from these waters.

The SRST and Promotores de Salud began collaborating in early 2011 as part of the SRST's effort to effectively educate communities along the South River and SFS River about the fish consumption advisories due to mercury. The Hispanic population in the Central and Northern Shenandoah Valley has increased significantly in recent years, and the SRST has responded by taking a more interactive approach to communicate the fish consumption advisory to this community. Promotores de Salud is a community outreach program that the SRST, working through James Madison University, developed and implemented in 2010. The program has been in place for several years and has graduated more than a dozen "Promotores," members of the local community who educate numerous fellow residents in the watershed regarding fish consumption. The benefits go well beyond communication of fishing precautions, such as general health, nutrition, and well-being of the local Hispanic community. Recently, other non-English speaking groups, including Russian and Arabic speaking populations, have been identified and incorporated into the Promotores de Salud program.

6.8 Summary

Extensive studies have been conducted on mercury exposure to biota and its potential associated effects on community composition, body burden, and trophic structure of the biota inhabiting AOC 4. An ERA has also been conducted to assess the potential ecological risks in AOC 4 (see Section 5.0). The broad array of highly focused studies has provided the following insights:

- Observed benthic invertebrate and fish community composition throughout the South River are not statistically different from those observed at regional reference sites, and there appears to be little or no evidence to indicate that mercury exposure is adversely affecting these communities based on a weight of evidence evaluation provided in the ERA.
- Tissue THg and MeHg concentrations in biota vary spatially as well as seasonally.
- Tissue MeHg concentrations in biota generally increase with distance downstream.

- Mercury uptake rates by biota vary by trophic position and feeding behavior.
- Wildlife (amphibians, reptiles, birds, and mammals) are exposed to mercury in AOC 4; potential risk attributable to this exposure is assessed in the ERA (AECOM, 2015b).

Human exposure to mercury, primarily via fish consumption, is being effectively managed through various community outreach program (e.g., Promotores de Salud) to promote local adherence and awareness of fish consumption advisory; potential risks are evaluated separately in the HHRA (AECOM, 2015a).

7.0 Mercury Conceptual System Models (HgCSMs)

Conceptual system models are a simplified representation of mercury movement in the South River system from primary sources, to higher trophic-level organisms. These models integrate the findings of various studies to identify the most critical aspects of mercury fate and transport and transfer to direct the focus of the remedial efforts to achieve the appropriate interim and long-term remediation goals. Two HgCSMs have been developed for the aquatic and terrestrial systems within AOC 4. Additionally, a Relative Risk Model has been developed for AOC 4 to evaluate the contributions of mercury and other environmental stressors on various environmental assessment endpoints. The Relative Risk Model predictions can provide an understanding of the net risk reduced by implementing a potential remedial action and may thus be a valuable tool in remedial decision-making. This section provides discussions of the HgCSMs and the Relative Risk Model.

7.1 Aquatic Mercury Conceptual System Model

The current aquatic HgCSM integrates the geomorphological, chemical, and biological data collected by the SRST and others. Figure 7-1 shows a schematic of the current aquatic HgCSM. The aquatic HgCSM focuses on the three factors relevant to understanding the need for a remedial action: 1) mercury sources to the South River and the extent to which these sources are controlled; 2) mercury-impacted media—bank soils and in-channel sediments; and 3) the aquatic food web elements. The aquatic HgCSM depicts the transfer of mercury from sediments to the aquatic food web (to fish and from fish to piscivores).

The purpose of the aquatic HgCSM is to support remedial decision-making by identifying the most critical aspects of the mercury movement in AOC 4. Given the complexity of mercury cycling in the South River system, an EAM approach has been implemented (see Section 9.3.1), consistent with USEPA (2005) guidance, for necessary updates to the HgCSM and the basis for remediation.

Mercury movement from the sediments in AOC 4 to higher trophic level organisms is primarily driven by MeHg production. A key assumption in the aquatic HgCSM is that IHg from various sources are equally available for methylation. Ongoing examination of this assumption is necessary as analytical technology develops to measure the concentrations and the origins of bioavailable mercury. The following sections provide a summary of the findings of investigations conducted to date that support the current aquatic HgCSM.

7.1.1 Methylmercury Transfer through the Aquatic Food Web

To illustrate the movement of MeHg in the aquatic food web, the aquatic HgCSM considers MeHg bioaccumulation by top-level aquatic predators (e.g., the smallmouth bass) via the food web. Field studies and modeling were used to identify the trophic structure of the aquatic food web in the South River and associated MeHg fluxes. Field studies included fish tissue and stomach content analyses for several fish species, nitrogen isotope studies of the food web, invertebrate dietary studies (Merritt and Aotani, 2008), and MeHg uptake studies for mayfly nymph and crayfish. A brief discussion of these studies was provided in Section 6.3.3. More details can be found in the Ecological Study Report [Section 6.3 and Harris et al. (2012), which forms Appendix K Ecological Study Report].

A schematic of the MeHg flow through the food web to the smallmouth bass in the South River is shown in Figure 7-2. The BASS model was used to simulate the MeHg uptake by smallmouth bass. Consistent with several other studies, the diet supplied 90% or more of the estimated MeHg accumulated by the smallmouth bass. Uptake via the gill was not the primary bioaccumulation pathway; however, aqueous exposures are important for lower trophic level organisms (e.g., benthic invertebrates). Aquatic organisms accounted for approximately 90% of the predicted dietary MeHg uptake by smallmouth bass, while the terrestrial species accounted for the remaining approximately 10%.

Although direct MeHg uptake by smallmouth bass occurs via the diet, indirect uptake, which considers MeHg sources to its dietary items, indicates the importance of uptake from the water column. Approximately half of the MeHg ultimately accumulated by smallmouth bass originates indirectly from seston and surface water (as colloidal MeHg) while roughly one third originates from periphyton, surface coatings, and detritus associated with sediments or the sediment-water interface (where a component MeHg exposure in surface water is also likely involved).

As discussed in Section 3, mercury methylation is a widespread process in the South River, particularly in sediments. Production of MeHg in the sediment links the biotic and abiotic components of the South River. Methylation is assumed to occur *in situ* in surface sediments in areas with fine-grained material and well-oxygenated overlying water column. Section 3.3.5 discussed sediment environments in the South River that are conducive to methylation. The majority of MeHg in the South River is expected to be supplied by the interstitial areas of gravel beds because of the greater surface area of gravel beds compared to fine grained sediment areas (roughly 85% versus 15% on an area basis). Higher pore water IHg and MeHg concentrations in fine-grained sediment areas of the river resulted in slightly greater weighting of fine-grained sediment areas compared to using areal coverage alone.

Before ultimately bioaccumulating in smallmouth bass, MeHg produced in interstitial or bulk sediment must move into the base of the food web: periphyton, surface coatings on rocks, seston, pore water, SAV, and detritus/fine sediments. Based on the BASS model predictions, these base compartments contribute differently to the MeHg accumulation by dietary items for the smallmouth bass. For example, periphyton accounted for approximately 5 to 10%, less than detritus (approximately 25%) or the dissolved concentrations in surface water (>50%). Therefore, MeHg supplied to different base compartments of the aquatic food web is assumed to be immediately exchangeable among compartments.

Ultimately, smallmouth bass derive the majority of their MeHg from two sources: omnivorous invertebrates (e.g., crayfish) and insectivorous fish (e.g., longnose dace, common shiner). These organisms dominate the smallmouth bass diet, and they have high MeHg contents, relative to other food items.

7.1.2 Sources of Mercury to the South River

IHg that is converted to MeHg in sediment constitutes historically-released IHg and IHg from active ongoing sources. These sources are quantified in Figure 7-3. Independent estimates were made for each potential mercury source to zones of methylation in sediment, using data from the range of existing field and laboratory studies conducted in the South River. The loads from each of the sources were calculated or estimated based on the data collected for the Ecological Study Report, and the loads were summed to determine if the measured loads from the sources agreed with the net loading over the reach. Hyporheic zone source areas were not explicitly addressed in the quantitative modeling conducted to estimate source contributions because it is implicitly included in the contributions from the sediment flux. The sources of IHg to the South River are discussed in the following sections.

The identified sources and their relative contributions are generally consistent with the findings that supported the South River mercury total daily maximum load (TMDL) development and waste allocations (VDEQ, 2009b; Eggleston, 2009). Point sources (for Plant outfall and other permitted discharges) and other sources (precipitation, atmospheric deposition, surface runoff, channel margins and river banks, and groundwater) were identified as mercury sources to the South River, with channel margins contributing 84% of the total load (VDEQ, 2009b).

Plant Site

Mercury loading from the Site has been measured as part of the RCRA corrective action since 1998. Since the beginning of routine monitoring of mercury loads from the Plant, the average THg loads has been approximately 1 g/d. Several interim remedial measures have been conducted at the Plant to remove mercury from the stormwater system. In response, the loads were temporarily higher than 1 g/d but are declining to pre-remediation levels. Current MeHg loading from the Site is low (e.g., <0.01 g/d, or <1% of the total load) due to low MeHg concentrations in outfall water.

Baseline and Storm Flow Loading

Under baseline flow conditions, net THg loading to the water column is often negative downstream of RRM 10 (see Section 3.1). This indicates that the relatively high THg concentrations in surface water downstream of RRM 10 results from upstream sources, and that the THg sources are limited in this reach. This finding implies that addressing the mercury upstream of RRM 10 (i.e., source control) could result in significant reductions in fish MeHg exposures downstream.

During storms, however, net THg loading to the water column is positive in several reaches (see Section 3.1.2), owing to sediment re-suspension, increased contributions from bank erosion and floodplain runoff. The numeric model used by the USGS in the development of the mercury TMDL (Eggleston, 2009) suggests that floodplain runoff becomes a more important relative contributor to annual mercury loading to the water column downstream of RRM 10 because of decreased loading from eroding river banks.

Eroding Banks

The largest source (40% to 60% of IHg) is estimated to be erosion of river bank soils, which contain historically-released IHg that was deposited in near-bank areas. Supporting this estimate, statistical models developed for the South River found that THg loading from the banks was an important correlate for surface water, sediment, and biological tissue mercury concentrations. Bank erosion is not an important MeHg source because soil MeHg concentrations are low relative to in-stream sediments [1.04 to 12.87 ng/g dw in floodplain soils (Cianchetti, 2009) vs. 2.5 to 102 ng/g dw in sediments (see Table 3-2)].

Groundwater

Groundwater may account for 40-70% of river discharge in some reaches (Grosso, 2006), but it has relatively low mercury concentrations. A 2006 Study by SRST at RRM 3.5 detected MeHg and THg in 5 of 9 sampling wells. Concentrations ranged < 1.5 to 25.8 ng/L for THg and <0.04 to 0.23 ng/L for MeHg in filtered groundwater samples. However, the migration of groundwater through HRADs is currently being evaluated, which may result in locally higher loads following storm events (see Section 9.2.4). The HgCSMs will be updated if further work should alter these findings.

Flux from River Channel

The second largest IHg source (15% to 35% IHg) is estimated to be diffusive fluxes from sediments stored within the gravel matrix of the river bed. Flux of MeHg from sediments is the single most important MeHg source to the water column. Given the importance of aqueous MeHg uptake by clams and other invertebrates, sediment flux is an important component in MeHg fate and transport in the South River. The flux estimates are based on both measured rates from BFCs (see Section 3.3.3) and estimates of IHg and MeHg mass transfer. Consistency in BFC data between seasons and matrix types reflects the measurements mostly performed during the warm months (April to September) and the entire river bed, and not just fine-grained sediment deposits, acting as both IHg and MeHg sources.

Other Sources

Bank leaching is the process in which mercury is leached from the bank soils (via desorption and/or dissolution) and transported through soil pore spaces via advection. This process is estimated to be a minor IHg and MeHg source to the South River. Despite their role in draining areas of the floodplain with high mercury concentrations in soil, tributaries and floodplain drainage channels also represent small mercury sources to the river (see Section 3.1.3).

The WOE collected to date suggests that storms have transient and short-term effects on mercury concentrations in the South River. Studies indicate that runoff from the floodplain during storm events accounts for 15% of the total load to the downstream reaches.

7.1.3 Natural Attenuation

Mercury has remained higher in fish tissue than previously anticipated primarily because IHg inputs to the South River have not been mitigated through natural attenuation (recovery) as predicted in earlier reports [see Pizzuto (2012) in Appendix B of the Ecological Study Report. Several earlier reports suggested that sedimentation and other natural processes would ultimately reduce or eliminate entry of mercury into the South River (Wang et al., 2004). The South River is geologically constrained by bedrock, with only limited horizontal migration of the main channel over time. This lack of channel migration coupled with overall geological stability, reduces those processes that might otherwise transport sediment- and soil-associated mercury out of the river system. Additionally, the supply of sediment with low mercury concentration to the South River is not high enough to dilute the high IHg load from ongoing sources. In contrast, other aquatic systems where mercury has been found to naturally attenuate generally have few ongoing sources and higher rates of sedimentation than the South River. Legacy mercury continues to enter the South River and remains active in the river's overall hydrogeological processes, primarily through the mechanism of erosion of mercury-laden bank soils, and secondarily through re-suspension of the particulate-bound mercury that resides in bed sediments.

Demethylation is an additional natural process that may potentially attenuate MeHg concentrations in the South River. However, demethylation processes, i.e., the processes that convert MeHg back to IHg, are less efficient or active than methylation processes, which drive the conversion of the IHg to MeHg. Due to the ongoing inputs of bioavailable IHg through eroding bank soils and other sources, a steady source of IHg is available for the production of MeHg. The resulting net positive methylation may explain why natural recovery is not apparent in the South River.

Although the impacts of above conditions and processes on the South River system is uncertain, elimination or reduction of ongoing inputs of bioavailable IHg through eroding banks and other sources, likely results in a greater potential for natural recovery. The rate of natural recovery, however, is likely to be uncertain.

7.2 Terrestrial Mercury Conceptual System Model

A terrestrial HgCSM was created to synthesize existing information regarding trophic transfer of mercury in the terrestrial food web, the diversity and types of organisms present in the floodplain. The terrestrial HgCSM differs from the aquatic HgCSM (Section 7.1) in that loading rates or fluxes of mercury between compartments (soil, vegetation, tissue) were not measurable; however, the terrestrial HgCSM is based on actual field data and is integrated with the risk assessment approach for the South River, so the relationships can be used to plan potential remediation. The terrestrial HgCSM is shown in Figure 7-4.

The terrestrial HgCSM was designed based on two lines of evidence – the MeHg concentration and the $\delta^{15}N$ of the food web element. Terrestrial organisms were organized according to trophic levels and MeHg concentrations measured by Newman et al. (2011), described in Section 6.1.2. The height of the boxes is proportional to the range of MeHg concentrations and trophic position observed at several locations in the floodplain. Arrows depict potential paths and magnitudes of mercury trophic transfer, which is based in part on the ECSM (see Section 5.1.2) and the general life history characteristics of the terrestrial organisms.

MeHg concentrations and $\delta^{15}N$ suggest that the main sources of MeHg to higher trophic levels in the floodplain were via detritivorous invertebrates and emergent aquatic insects. Detritivorous invertebrates (e.g., earthworms) have much higher MeHg concentrations and a greater range in $\delta^{15}N$ than strictly herbivorous invertebrates (e.g., tent caterpillars). As a consequence, MeHg concentrations in the organisms that feed on this pathway (e.g., invertivorous mammals) were higher than in strictly herbivorous animals.

The influence of MeHg from emergent aquatic insects can be seen in the high $\delta^{15}N$ values and MeHg concentrations in terrestrial animals that feed on them (predatory spiders, aerial insectivorous birds, and mammals). MeHg concentrations and trophic positions were higher in predatory birds that feed on small mammals and birds.

7.3 Relative Risk Model

DuPont has voluntarily funded the development of a Relative Risk Model for AOC 4 to evaluate the contributions of mercury and other environmental stressors on various environmental and human health/societal (e.g., recreation) assessment endpoints. The Relative Risk Model predictions can provide an understanding of the net risk reduced by implementing a potential remedial action. Therefore, the model will be incorporated with the EAM process to provide a holistic view of the potential benefits from implementing specific remedial elements.

As a semi-quantitative approach to risk assessment, the Relative Risk Model serves as a tool to evaluate the contributions of multiple environmental stressors on various assessment endpoints. Relative evaluations were carried out among different habitat types, to provide a comparison of ecological risks across multiple regions (Landis and Weigers, 2005). Landis et al. (2015) used the Bayesian Network Relative Risk Model to assess the relative risk to various endpoints in the South River and SFS River watersheds. Six risk regions within the watershed were established to compare relative risks among the regions (see Figure 7-5). The study area extended from the upper South River, upstream of Waynesboro, to the confluence of the SFS River and Big Run. Each of the six risk regions was assessed relative to one another for four receptors (smallmouth bass, white sucker, belted kingfisher and Carolina wren), as well as four ecological service endpoints (water quality, fishing river use, swimming river use and boating river use.). Both anthropogenic and natural stressors were considered across habitats and locations suitable for each endpoint. A summary of findings from Landis et al. (2015) is shown in Figure 7-6. Key preliminary findings indicate the following:

- Potential risks to avian receptors are present in, and increase from Risk Region 2 to Risk Region 5, primarily driven by mercury tissue burden, as well as water temperature and available habitat.
- Exposure to mercury in dietary items contributed the most to potential risks to avian receptors.

- River temperature contributed the most to the potential risk to both fish species evaluated (smallmouth bass and white sucker), with exposures to mercury playing a significant role in potential risk to smallmouth bass, while stream cover in the form of submerged aquatic vegetation was important for white sucker.
- Achievement of water quality standards and recreational fishing (except fishing river use) were of secondary importance but at greater risk than biotic endpoints for AOC 4.

Additional work is being conducted by Western Washington University to integrate the Relative Risk Model with the HHRA and potential remedial action scenarios. Findings of the model and the Relative Risk Model itself will be incorporated with the EAM framework.

7.4 Summary

The HgCSM to support remedial decision-making in AOC 4 focuses on the critical pathways leading to the accumulation of mercury in top aquatic predators (smallmouth bass), which has implications for both piscivorous wildlife receptors and humans. The HgCSM builds on the findings of over 10 years of investigations, and those studies conducted specifically to support the development of the HgCSM. The findings indicate the following unique series of conditions within the South River that may explain why fish tissue mercury continues to remain elevated:

- In addition to mercury present in the surficial sediments, ongoing mercury loading from erosion of bank soils and other sources maintain a steady supply of potentially bioavailable IHg within the South River.
- The continued supply of bioavailable IHg in the South River provides the necessary source for microbial conversion into MeHg, the form that readily bioaccumulates and biomagnifies within the aquatic food web.
- Natural recovery processes, including the supply of sediment with relatively low mercury concentrations to attenuate the ongoing IHg source and MeHg de-methylation, were not sufficient to overcome the ongoing mercury loading to the South River.

8.0 Summary of Findings

The purpose of this RFI Report is to characterize the nature and extent of mercury in environmental media within AOC 4 due to historical releases at the former Site and to gather necessary data to support the environmental indicator determinations and a CMS. This RFI Report provides an overview description of the findings of extensive site-specific investigations and presents sufficient understanding of the nature and extent of mercury in environmental media within in AOC 4. This section provides brief summaries of the investigations and findings included in this RFI Report and the proposed remedial objectives and risk management goals based on these findings. Proposed remedial objectives and risk management goals are discussed in more detail in Section 9 and the Remediation Proposal (Anchor QEA and URS, 2013).

8.1 Scope

Investigations in AOC 4 included aquatic, benthic, and riparian habitats along approximately 24 RRMs and within the 100-year floodplains along the portions of the South River and SFS Rivers downstream of the former Site. This RFI Report provides an evaluation of the data collected up to and including April 2014. Although much of the investigations and data collection were not conducted under the purview of the federal RCRA program, standard methods and practices were followed. The RDQAs were conducted to support the use of appropriate data in separate ERA and HHRA investigations as part of the RFI process for AOC 4. The ERA and associated RDQA (AECOM, 2015b) were accepted by the VDEQ in April, 2015. The HHRA and the associated RDQA were revised following the VDEQ reviews. The final HHRA and the associated RDQA was submitted in July 2015.

8.2 Findings and Implications

This RFI Report provides a description of main aspects of the characterization of the physical, geologic and geomorphological, chemical, and biological studies of the South River and SFS River detailed in the Ecological Study Report. The Remediation Proposal also provides details on the findings that form the basis for further remedial actions within AOC 4. The major finding is that the largest mercury sources (riverbanks, outfalls from the former Site, and sediment) primarily occur in the first 12 river miles downstream of the Site. As a consequence, as described in the Remediation Proposal, remediation will begin in these areas and proceed downstream. Remediating isolated downstream areas prior to upstream source controls (former site outfalls) could result in mobilization of mercury from upstream sources, and declines in mercury concentrations or loads could be obscured by upstream loading. Bank stabilization upstream of the site will not be a target of remediation.

Additionally, although the South River downstream of RRM 12 and the upper segment of the SFS River contain relatively few sources (i.e., few riverbanks with high THg concentrations), these areas have elevated mercury concentrations in some media (e.g., fish and birds). The majority of mercury loaded to these reaches comes from the first 12 river miles not due to ‘migration’ of mercury but largely as a function of increased agricultural runoff and presence of mill dams during the time of mercury use at the Site. Demise of mill dams led to increased erosion of HRADs mostly in the upper 12 miles. THg is transported downstream but storage mechanisms such as HRADs are not active in downstream reaches beyond RRM 12.

Finally, an adequate understanding of mercury contamination in sediment deposits has been achieved at a reach scale. Management of deposits removed from individual locations may need additional evaluation or characterization on a case by case basis where adequate data does not exist.

8.3 Risk Management Goals

Based on the above findings, the remedial objectives in AOC 4 are the reduction of risks to humans and ecological receptors as a result of exposure to mercury. A key link between the risk assessment and remediation planning processes is the definition of risk management goals; these goals help guide the risk analysis process. The preliminary risk management goals are defined as follows:

- Quantifiably reduce THg and MeHg concentrations in surface water and fish tissue in AOC 4.
- Reduce exposure of ecological receptors to MeHg in AOC 4.
- To the extent practicable, relax or eliminate fish consumption advisories in AOC 4 through the reduction in fish mercury body burden.

8.4 Remedial Action Objectives (RAOs)

RAOs constitute a framework for developing protective, implementable, and effective remediation alternatives. Additionally, RAOs provide a basis for evaluating different remediation alternatives. Details of the proposed RAOs are provided in the Remediation Proposal (Anchor QEA and URS, 2013) and the Phase I IM Work Plan (Anchor QEA and URS, 2015). The RAOs associated with bioaccumulation and food web exposures are briefly discussed here.

The first segment of the South River within AOC 4 that is addressed by the Phase I IM Work Plan includes bank soils within the first two miles downstream of the former DuPont Waynesboro facility (i.e., RRMs 0 to 2). RRM 0 to 2 reach is currently targeted for initial bank remediation actions, subject to refinement during detailed design. The process will generally proceed in an upstream-to-downstream direction as additional data are collected as input to the remediation decision-making process using an EAM approach (see Section 9.3.1).

As described in the Phase I IM Work Plan, both short- and long-term RAOs are appropriate to address bioaccumulation and food web exposures. Short-term RAOs are expected to be met within a two year time frame, following remedial measure construction, while long-term RAOs may require additional remediation in other segments or throughout the South River before they are attained. Preliminary RAOs may be refined during remediation planning (e.g., corrective action design and development of detailed monitoring plans) as well as follow-on adaptive management. Some or all of these RAOs will likely also apply to other river segments during Phase 2 and beyond. Initial elements of the proposed short- and long-term RAOs include the following:

- Short-term RAOs
  - *General response objectives*: Reduce IHg transport and exposure and improve bank habitat functions within the upper two miles of the South River.
  - *Performance objectives*: Conduct and/or maintain bank remediation actions in the upper two miles of the South River to achieve sustainable reductions in mercury concentrations and improve water quality (based on various parameters, such as THg, MeHg, TSS, TOC, and DOC concentrations and nutrients) and bank habitat functions (based on benthic community surveys, bulk sediment mercury concentrations, and substrate conditions) within this reach.
  - *Measurable metrics*: Bank erosion rates, measured using detailed topographic surveys, establishment of bank vegetation; and mercury concentrations in physical media and biological tissues.
- Long-term RAOs
  - *General response objectives*: Reduce MeHg exposure and improve habitat conditions throughout the South River and SFS River.
  - *Performance objectives*: Conduct and/or maintain remediation actions that sustain reductions in tissue MeHg concentrations and improve water quality and habitat functions throughout the South River and SFS River.
  - *Measurable metrics*: Mercury concentrations in biological tissues (e.g., fish, invertebrates, birds, reptiles etc.) and physical media (surface water, sediment, pore water) and bank and in-channel habitat metrics (substrate condition).

9.0 Next Steps

The Remediation Proposal and the Phase I IM Work Plan (Anchor QEA and URS, 2013 and 2015) provide the details of the proposed remedial strategy for AOC 4. An EAM approach has been proposed for remediation because of the size, complexity, and the inherent uncertainty associated with mercury cycling within AOC 4. EAM is a structured and iterative implementation process that couples the IRM with active monitoring. New data from the monitoring are used to reduce uncertainty, determine effectiveness of the IRM, and adjust future actions accordingly. An EAM is a valuable framework for testing and monitoring actions, particularly where there is a need to assess effectiveness prior to undertaking additional actions, as is the situation in AOC 4. Where actions do not result in measureable changes in pre-selected criteria, changes in technologies and/or applications may be warranted.

This section provides a summary of the current understanding of the nature and extent of mercury in environmental media within AOC 4, which forms the basis for further actions in AOC 4. Additionally, this section provides information on ongoing investigations and studies that are aimed to support and develop the proposed remedial measures, remedial design concept and interim measures; to identify data needs; and to assess RFI objectives. A proposed schedule of RFI activities is also presented.

9.1 Current Understanding

The current understanding of the nature and extent of mercury in environmental media within AOC 4 indicates that the majority of mercury loading in the South River begins at the former Site and decreases approximately 10 to 12 RRM downstream. Additionally, a primary mechanism for the continued loading to this segment of the South River is through the slow but chronic erosion of legacy mercury that resides in river bank soils. Therefore, the next steps in the CMS are to evaluate and implement measures to reduce erosion and associated mercury loading to the South River from river banks in the first 12 miles downstream of the Site. Addressing mercury loading to the South River will not only reduce impacts in the aquatic environment but also reduce mercury transfer into the terrestrial food web apparent in AOC 4.

9.2 Pre-Remedial Design Studies

Several focused teams have been established under the SRST to identify remedial options [Remedial Options Program (ROPs) Work Group], design monitoring programs to measure remedial success and mercury exposure (Monitoring Sub Team), evaluate potential exposure of mercury to humans (Exposure Task Team), and conduct communications and outreach (Communications Task Team). Members of these teams, similar to the larger SRST, represent various stakeholders in AOC 4 and have been involved in the design and implementation of fieldwork and research efforts over the past several years. The final design, implementation, and monitoring proposed in the Remediation Proposal will have substantive input from these important groups, as well as other affected stakeholders, and ultimately will address the remediation requirements established by the regulatory agencies.

Over the past four years, the ROPs Work Group performed extensive scientific and engineering research aimed at advancing the most promising technologies to reduce mercury bioaccumulation. The ROPs Work Group continues to review, evaluate, and test other promising technologies to reduce mercury bioaccumulation in AOC 4. Several remedial options are being evaluated at pilot scales as summarized below.

9.2.1 Bank Stabilization Pilot Field Study

As eroding banks have been identified as the predominant ongoing source of IHg to the South River aquatic system, the ROPs Work Group selected a pilot site on the eastern (right) bank of the South River from approximately RRMs 0.11 to 0.16 (just downstream of the Site). The main objective of the pilot study is to evaluate the ability of bank stabilization approaches to reduce river bank erosion rates and particulate mercury loading to the river. Erosion rates were measured using detailed topographic surveys, erosion pins, and/or root analysis and establishment of bank vegetation. The pilot site, approximately 500 feet in length, was selected for a number of reasons, including evidence of bank erosion and above background bank soil mercury concentrations.

The bank stabilization pilot design incorporated three main components:

- A launchable rock toe, comprised of boulder sized rip rap, at the base of the bank for slope protection
- Soil lifts to engineer a more stable and gentler bank slope
- Native vegetation on both the slope and top of the bank to provide further stability and habitat

Additionally, woody debris was anchored to the rock toe to improve fish habitat. Weir rock was also incorporated into the toe design in the center of the pilot project area to allow for alterations of the stream bed, as recommended by the Virginia Department of Game and Inland Fisheries.

The first five years of monitoring following construction (in October 2009) demonstrated that mercury concentrations in bulk sediment and interstitial sediment pore water in the pilot project area decreased immediately following bank stabilization and have remained low. THg concentrations in sediment reflect those on particles suspended in the water column. Uptake of IHg and MeHg by Asiatic clams was significantly reduced during the first year following bank stabilization but subsequently increased in response to an unanticipated increase in mercury loading entering the pilot area from upstream sources (resulting from separate sewer clean-out actions at the former Site). Concentrations of IHg and MeHg in Asiatic clams decreased following sewer clean-outs at the former Site, demonstrating their responsiveness to changes in mercury loading within the water column.

Based on measurements of bank erosion rates, the pilot bank was stable under the shear stresses experienced during a 10-year storm that occurred in April 2011, and adequate vegetative cover has been established. A more detailed summary of this field pilot project is provided in the Remediation Proposal (Anchor QEA and URS, 2013) and the Bank Stabilization Pilot Technical Briefing Paper (URS, 2014c).

9.2.2 Pond Pilot Field Study

To assess the viability and efficacy of biochar, a sediment carbon amendment in limiting the bioavailability of sediment IHg, a field pilot study (the Pond Pilot Study) was implemented in 2011 in a South River floodplain pond (URS, 2011) and completed in 2014. A typical pond within the two-year floodplain of the South River was selected and partitioned using a physical barrier: one half of the pond to serve as the treatment and the other half of the pond as the control. The setup of the pilot study was intended to eliminate differences between the treatment and control cells. However, the barrier between the two sections was breached on several occasions during flooding. Thus, the results of the studies need to be evaluated in the light of these barrier breaches and the likely impact of surface water mixing between the two sections. Monitoring was conducted prior to barrier installation ("pre-barrier"), prior to adding the carbon amendment ("baseline"), and at various time intervals between 1 and 157 weeks post-amendment (since July 2011 to July 2014).

Detailed summary of this field pilot project is provided in the Pond Pilot Technical Briefing Paper (URS, 2014d). In summary, the biochar application appeared to remove mercury from the water column and reduce MeHg uptake by aquatic receptors that are more closely associated with surface water exposures, including snails, wood frog tadpoles, and young-of-year bluegill. These results are consistent with the current HgCSM finding that aqueous exposures account for 50% of the mercury accumulated by low trophic level and young organisms.

Additionally, DGT sampling results also showed a 50% decrease in pore water MeHg concentrations, strongly suggesting that methylation is suppressed, demethylation is enhanced in sediment, or that MeHg partitioning to sediments is increased due to presence of the biochar. Given that MeHg concentrations were lower in sediment following amendment, the reduction in pore water MeHg concentration is likely associated with suppressed methylation and/or enhanced demethylation by the biochar amendment.

9.2.3 Floodplain Pilot Study

To assess the viability and efficacy of biochar amendment in floodplain soils, a laboratory pilot study (the Floodplain Pilot Study) was conducted in 2013/2014 (URS, 2014b). The purpose of the study was to test whether biochar amendment of the soils in the floodplain reduces mercury bioavailability (and hence toxicity) toward terrestrial receptors (invertebrates and plants) without any unintended adverse effects. Two floodplain soils (from RRM 11.8 and a reference location) were collected and subjected to treatments with biochar at 0% (control), 5%, and 10% biochar amendment. The effects of biochar on survival, growth, and reproductive endpoints on earthworms (*Eisenia fetida)* and three plant species (wheat, soybean, and radish) were studied, as well as mercury bioaccumulation in this species.

The results of the Floodplain Pilot Study indicated that biochar amendments in the RRM 11.8 soil did not have any unintended adverse effects on *E. fetida* survival, growth, and reproduction, as well as on the emergence and growth of the three plant species tested. On the contrary, the biochar amendment appeared to have beneficial effects by reducing

E. fetida mortality and growth of wheat and radish. The results of mercury uptake measurements indicated that biochar amendments reduced MeHg bioavailability and bioaccumulation in juvenile *E. fetida*.

Based on the results of the above laboratory pilot study, a Phase II Floodplain Amendment Pilot Study (AECOM, 2015c) has been initiated in 2015 to meet the following objectives:

- Assess potential efficacy of carbon amendments in reducing the bioavailability of IHg and MeHg to invertebrates in AOC 4 soils,
- Identify and monitor potential unintended consequences in invertebrates and plants, and
- Demonstrate progress toward innovative remedial strategies.

The intent of Phase II is to initiate a preliminary field test of the safety and efficacy of carbon amendments in limiting the bioavailability of mercury to indigenous terrestrial ecological receptors (AECOM, 2015c).

9.2.4 Other Studies

The SRST has investigated the biological, chemical, and hydrogeological dynamics of mercury cycling and proposed remediation alternatives within AOC 4. Several of these investigations have been performed at RRM 3.5 to better understand the influence of the surface water-groundwater dynamic on mercury methylation and transport.

Various ongoing studies aim to enhance and/or augment the current understanding of the nature of mercury in AOC 4. Several studies also aim to understand the efficacies and implications of various treatment materials potentially applicable in the AOC 4 sediments and soils to reduce mercury bioavailability and methylation. These ongoing studies have the potential to improve the current HgCSM, with particular focus on identifying more effective remedial options. Coupled with the various short and long-term monitoring results, the results of these studies are expected to inform the remedial decisions in the proposed EAM framework for the AOC 4. Brief summaries of the ongoing studies are provided below. Further details of these studies can be found in the Biogeochemical Research and Investigation Work Plan (AECOM, 2015d).

Efficacy of Sediment Amendments and Biological Effects

Sediment amendments are being investigated as a remediation option to reduce mercury bioavailability without unintentionally diminishing important sediment qualities. The sediment amendment study is being conducted by Dr. Michael C. Newman at the Virginia Institute of Marine Science (VIMS) at the College of William and Mary.

The objectives of this study are as follows

- Assess the efficacy of the two sorbents, Cowboy Charcoal and Sedimite®, in reducing mercury bioavailability in the South River sediments and their potential unintended impact on benthic organisms (using freshwater amphipod *Hyalella azteca*) based on 10-day exposures.

- Quantify the long-term effects (up to 6 months of exposures) of the two sorbents on their efficacy and potential biological effects.

Ecological Effects of Biochar on Benthic Communities

Similar to the study being conducted by VIMS on the potential adverse effects of sediment amendments using Cowboy Charcoal and Sedimite®, Dr. William H. Clements of the Colorado State University is evaluating potential adverse ecological effects of biochar on benthic community health and structure using simulated stream environment mesocosms at the Colorado State University Stream Research Laboratory (SRL). The proposed mesocosm study will assess potential effects of biochar on each of the major macroinvertebrate functional groups (filter-feeders, collector-gatherers, grazers, and predators).

The objectives of the study are as follows:

- Examine the potential unintended adverse effects of biochar on the structure and function of aquatic ecosystems (based on the effects on various benthic community attributes).
- Investigate whether the potential adverse effects vary with the particle size of the biochar material.

Stable Mercury Isotope Characterization Study

Knowledge gaps exist in the understanding of the spatial and temporal variations in mercury methylation and demethylation by different mechanisms and the transport of THg and MeHg within the AOC 4. Dr. Joel D. Blum of the University of Michigan has proposed a research study using mercury stable isotope method to better understand MeHg production and degradation and the correlation between MeHg and THg in the South River sediments and biota.

The objective of this study is to utilize variations in natural mercury stable isotope composition in South River media to enhance the understanding of IHg sources, mobility, speciation, and bioavailability. Specific objectives include the characterization the mercury isotopic composition in spatially in various media (both biotic and abiotic) within AOC 4.

Mercury Speciation and Evaluation of Reactive Capping

To provide ongoing support on remedial planning for AOC 4, Dr. Daniel Reible's team at Texas Tech and Duke Universities are conducting studies to understand the controls on mercury speciation (and hence its bioavailability) and the application of a related remedial approach using reactive capping.

Mercury speciation (using DGT), geochemical and redox characterizations (using voltammetric and conventional methods), and geochemical modeling of groundwater will be used to investigate mercury bioavailability in sediment pore waters. The extent of the occurrence and bioavailability of nano-scale particulate mercury in South River sediments will be investigated using DGT samplers and laboratory microcosm and mesocosm studies to assess mercury uptake by benthic organisms. This investigation seeks to elucidate the role of dissolved, colloidal, and particulate phases of mercury species, more specifically the nano-scale particulate mercury sulfide (HgS), in the biological uptake and methylation of mercury in the South River.

Additionally, various reactive materials (iron sulfide, manganese oxide, activated carbon, and biochar) will be evaluated for their abilities to reduce sediment mercury bioavailability and methylation (as determined by DGT and voltammetric evaluations).

Geochemical Characterization Soil and Sediment Mercury and Treatment Studies

Dr. Carol J. Ptacek of the University of Waterloo is conducting studies to characterize mercury leachability in South River sediments and soils to groundwater and surface water. These studies are intended to improve the understanding of biogeochemical mechanisms influencing mercury release to surface water along the South River. Additional experiments will be conducted to evaluate approaches to minimize the release of mercury and its biological transformation to MeHg. The laboratory experiments will be designed to evaluate the influence of changing physical and biogeochemical conditions on mercury release and stabilization.

Hydrologic Flux Evaluations at RRM 3.5

River banks may load IHg to the South River via bank erosion and through advective flux of mercury in groundwater from river banks. Previous work has been conducted to evaluate the net discharge of groundwater to the river from the bank environment and ultimately estimate mass transfer of mercury from groundwater to surface water.

The principal objective of the hydrological RRM 3.5 study is to quantify the volumetric flux (discharge) of groundwater from the river bank to the South River. Specific objectives included the following:

- Evaluate return frequency of high water events at RRM 3.5.
- Understand the relation of high water events to hydraulic flow through embankment soils.

URS installed 5 sets of shallow and deep piezometers at RRM 3.5 to calculate the direction and magnitude of the hydraulic gradient. Such flux (discharge) estimates may be compiled based on average stream flow and also based on the expected frequencies of storm events. The hydrological evaluation was conducted and groundwater flux rate was calculated based on measurements of river stage elevations and measurements of groundwater head within the stream bank. Preliminary hydrological flux model suggests that cumulative groundwater discharge is fairly steady overtime. Further evaluation of the variability of dissolved mercury concentrations in groundwater as a function of stream stage (or seasonality) and bank length will be conducted to estimate the lower and upper bounds of mass flux from the stream bank.

9.3 Remedial Design Concept

The main findings of the investigations to date indicate that the majority of mercury loading in the South River begins at the former DuPont facility in Waynesboro and subsides approximately 10 to 12 miles downstream. Sources of mercury beyond RMMs

10 to 12 are limited, and the upstream sources result in the relatively high surface water mercury concentrations beyond RRMs 10 to 12. The primary source of mercury loading in this segment is associated with the slow but chronic erosion of the bank soils with legacy mercury. Therefore, the remedial design is conceptually directed at reducing erosion and associated mercury loading to the South River. Addressing this mercury loading to the South River is not only expected to reduce impacts in the aquatic environment but also to reduce mercury transfer into the terrestrial food web.

The Remediation Proposal develops site-specific remedial action objectives and evaluates a range of bank remediation alternatives, which will first be applied to the upper reach (RRM 0 to 10) of the South River and then in a logical upstream-to-downstream implementation sequence. Alternatives analyses indicate that compared to more invasive removal options and less invasive institutional control options, vegetative and/or structural stabilization of banks, which contribute disproportionately to mercury loading to the river, is expected to achieve greater protectiveness with less short-term impact on the environment (during remedy implementation), the community, and sustainability core elements (Anchor QEA and URS, 2013). Vegetative and structural stabilization of target banks is thus the primary Phase 1 recommended remedy to substantively reduce mercury loading to the South River and accelerate natural recovery processes within channel areas. However, all promising technologies and stakeholder inputs will be considered and integrated into comprehensive remedies for individual banks to maximize overall protectiveness and minimize disruption in an optimal balance.

FGCM deposits located immediately adjacent to BMAs (likely reflecting recent bank erosion from the adjacent BMA) are incorporated into the delineation of the BMA remedy during final design of the interim measures as practicable, to provide an efficient remediation approach. Embedded gravel sediment deposits not located immediately adjacent to the BMAs will be evaluated within an adaptive management framework and in the CMS, after interim measures have been completed and monitoring data become available. Specific methods/approaches for addressing these deposits will be established during the final BMA design process.

Monitoring results for in-channel sediments and biota will be evaluated after the bank remediation is complete to track and effectively integrate lessons learned under the EAM approach. In addition, DuPont will continue to work closely with the various state and federal governmental agencies to conduct education and other outreach efforts for the communities along the South River and SFS River. Examples of this education and outreach include continued collaboration with *Promotores de Salud*, angler surveys to monitor adherence to the existing fish consumption advisory, and communicating with local health clinics and physicians regarding prevention of potential human exposure to mercury in fish.

9.3.1 Enhanced Adaptive Management

As described in the Remediation Proposal, an adaptive management approach for remediation has been integrated into the remediation approach because of the size and complexity, the inherent uncertainty associated with mercury cycling in AOC 4, and challenges noted from remediation of other mercury sites. Adaptive management promotes flexible decision-making in the face of uncertainty. It allows the identification of the most robust course of action, given a range of scenarios under consideration. Careful monitoring of the outcome of implemented actions advances understanding of remedy effectiveness and helps adjust future remediation decisions as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in ecological systems and variability in measures of effectiveness of remedial actions.

Adaptive management is particularly well-suited to remedial actions in AOC 4, in part because remedial actions will be implemented sequentially over several years or more, providing an opportunity to effectively integrate lessons learned. It will facilitate testing and monitoring remedial actions, particularly where there is a need to assess effectiveness prior to undertaking additional actions, as is the situation in AOC 4. Where actions do not result in measureable improvements, changes in technologies or applications may be required. Implementation of remedial actions in AOC 4 will also require landowner acceptance and flexibility to consider other stakeholder needs.

The U.S. Army Corps of Engineers (USACE) Engineer Research and Development Center is assisting DuPont in developing an EAM plan that consists of the following three key components (see Figure 9-1):

1. Decision Model to predict the effects of remedial alternatives on monitoring endpoints and objectives (decision criteria)
2. Decision Analysis to prioritize alternatives relative to specific objectives, predicted performance, stakeholder preferences, and uncertainties
3. Monitoring and Analysis Plan to collect and analyze data about key conditions that test the predictions and assumptions of the decision model and inform future management decisions

Use of the EAM learning approach (see Figure 9-2), along with relative risk modeling being performed by the SRST (see Section 7.3), is expected to provide quantitative feedback on net environmental improvements resulting from remedial actions.

9.3.2 River

The primary goal involving the aquatic habitats in AOC 4 is to reduce the mercury loading from external sources, which are identified as the outfall of the Site, eroding river bank substrate and floodplain runoff containing legacy mercury. Sources at the Site are being addressed as a part of the on-site RCRA corrective actions (see Section 9.4.1). River bank stabilization (to reduce bank soil erosion rates) proposed as an interim measure for the areas between RRM 0 to RRM 2 (see Section 9.4.2), has remained stable for several years under relatively high discharges (i.e., ten-year recurrence interval storms) at a field pilot scale (see Section 9.2.1). Measures to control mercury loading via floodplain runoff are likely to have low potential impact on the overall mercury loading into the river attributed to floodplain runoff is limited compared to other sources (see Section 3.1.3).

The internal sources of mercury to the river include the mercury already present in the fine-grained sediment deposits, interstitial sediments, and the water column (as dissolved or particulate mercury). In addition to monitored natural attenuation (see Section 7.1.3), which may reduce mercury fluxes from sediment, the potential use of permeable, impermeable, and/or reactive capping may be used to control mercury loading via the existing internal mercury sources.

9.3.3 Floodplain

The nature and extent of mercury in the floodplain within AOC 4 indicates that mercury uptake (primarily by soil invertebrates) and methylation (by soil microbes) is the primary concern for ecological exposure. Therefore, the primary goal involving the riparian and terrestrial habitats in AOC 4 is to reduce mercury bioavailability for uptake and methylation. The Floodplain Pilot Study (see Section 9.2.3) and several ongoing SRST investigations are being conducted in an effort to understand the efficacy of biochar to reduce mercury bioavailability in soils without causing any unintended adverse effects.

9.4 Interim Measures

Interim measures include point source remediation at the Plant Site and bank stabilization between RRMs 0 and 2 because these are the primary sources of mercury loading to the South River. Brief descriptions of these interim measures follow.

9.4.1 Point Source Remediation: Plant Site

Recent on-site remedial measures unexpectedly resulted in increased mercury loading to the South River that temporarily increased mercury concentrations in surface water and biota compared to previous observations. In response, USEPA and VDEQ required additional interim measures to further control off-site mercury migration. The interim measures under consideration include sewer and below ground pipe abandonments, cleaning, slip lining, and installation of filtration sumps to intercept sewer water, remove sediment, and filter out mercury from these historical structures. The sumps will intercept contaminated sediment during and after remediation. Implementation of the interim measures began in the summer/fall of 2013, and chemical and biological monitoring, as noted below, is being implemented over the short term to evaluate the efficacy of these actions to reduce mercury loading to the South River.

Additionally, DuPont funded an SRST study (Brent, 2011) to determine potential effects of a recent upgrade to the Waynesboro sewage treatment plant (STP) on MeHg concentrations in periphyton. The study evaluated mercury concentrations in periphyton, which are the communities of attached algae and other microbial organisms and fine detrital material. The study documented that the STP upgrades have resulted in decreased nutrient loading, but sufficient non-point background sources are available so that the nutrient is not the limiting factor in periphyton growth. Decreased nutrient loading to the system may have contributed to locally depressed MeHg concentrations in the South River via its effect on methylation. However, factors other than nutrients have a greater effect on mercury methylation in the South River system. These include geochemical conditions (e.g., anoxia, presence of electron acceptors), the concentration and bioavailability of IHg, temperature, and composition of the microbial community. The preliminary monitoring plan outlined in Section 9.5 includes collection of data on nutrient concentrations and other ancillary parameters important for understanding mercury behavior.

9.4.2 Bank Stabilization: RRM 0 to RRM 2

The primary interim remedial options recommended for RRM 0 to RRM 2 were enhanced vegetative stabilization and structural stabilization, with integration of other technologies and stakeholder inputs into comprehensive remedies for individual banks. A pilot scale implementation of these remedial options has been implemented and has demonstrated that bank stabilization can be conducted to withstand moderate (e.g., 10-year recurrence interval storm events; see Section 9.2.1).

Additional detail and clarification regarding the remedial measures selection process and the selected interim measures are provided in the Phase I IM Work Plan (Anchor QEA and URS, 2015) that the VDEQ accepted in February, 2015. Following completion of the IRMs, their efficacy and other potential remedial options will be evaluated in the EAM framework and included in the CMS.

The primary goals of these interim measures are to reduce mercury transport and exposure associated with river banks and to improve bank habitat functions between RRM 0 and RRM 2. Bank erosion is considered the most likely transport pathway for THg from river banks, so several measurable metrics and success criteria are included in the short-term monitoring effort to confirm that bank erosion rates decline and banks maintain their stability in response to remedial actions.

Bank management areas (BMAs) within RRM 0 and RRM 2 are identified to maximize the mercury source control, while minimizing the potentially adverse impacts to sensitive habitats. These initial BMAs are estimated to contribute 90% of Hg loading to the river reach. They were identified using a WOE approach that included bank condition surveys, review of historical bank erosion measurements, side-scan light detection and ranging (LiDAR) surveys, hydrological modeling and analytical sampling for mercury. The details can be found in the Phase I IM Work Plan (Anchor QEA and URS, 2015). Additionally, the protection of sensitive habitats including mature trees is also being incorporated within the BMA selection and preliminary design process.

FGCM deposits located immediately adjacent to BMAs (likely reflecting recent bank erosion from adjacent BMA) will be incorporated into the delineation of the BMA remedy during final design of the interim measures as practicable, to provide an efficient remediation approach. Embedded gravel sediment deposits not located immediately adjacent to the BMAs will be evaluated within the EAM framework in the CMS, after interim measures have been completed, and monitoring data become available. Specific methods and approaches to address these deposits will be established during the final BMA design process.

9.5 Long-Term and Short-Term Monitoring

An important element of the EAM is its ability to evaluate, on an on-going basis, the efficacy of the remedial measures to achieve the remedial goals. Short-term and long-term monitoring plans have been developed to evaluate the effectiveness of the remedial actions relative to short- and long-term RAOs (URS, 2015a and b). The monitoring plans recognize the important information that has been collected by the various groups over the past several decades. The short-term (2-10 years) and the long-term (>10 years) monitoring plans [Appendices D and E, respectively, in the Phase I IM Work Plan

(Anchor QEA and URS, 2015)] have similar overall goals, but differ in spatial and temporal aspects. Short-term monitoring is spatially limited (e.g., to specific bank areas and Plant site) and focused on relative rapid reduction of mercury loading locally at individual locations, whereas the long-term monitoring applies to the improvements at the watershed level. A brief summary of the goals and rationale are provided in the following sections for the ongoing and proposed monitoring plans with respect to remedy implementations in AOC 4. Details can be found in URS (2015a and 2015b).

9.5.1 Short-Term Monitoring

The short-term monitoring plan is designed to work within the EAM framework, by defining success criteria, contingency actions, and decision analysis options. As discussed below, short-term monitoring supports the understanding of the influence of specific remedial alternatives, including point source remediation at the Plant Site and bank stabilization between RRM 0 and RRM 2.

Point Source Remediation: Plant Site

A monitoring regime was implemented in advance of the interim measures to evaluate the effectiveness of the planned on-site interim measures to reduce mercury transport and exposure in the South River. The monitoring regime includes sampling periphyton, transplanted Asiatic clam tissue, and benthic invertebrates at RRMs 0.2 and 2.3, along with quarterly sampling at the outfall and monthly surface water sampling in the South River. Two sampling events were conducted in Spring 2013, prior to implementing the interim measures, and two events were conducted in Fall 2013, following their completion. Resulting data on IHg and MeHg concentrations in the South River food web will be evaluated, and the findings will be integrated in further remedial design.

Bank Stabilization: RRM 0 to RRM 2

The short-term monitoring plan for the initial phase of the interim remedy provides an array of tools to evaluate the system responses to specific remedial alternatives implemented between RRMs 0 and 2. Routine annual inspections for the first three years, followed by event-based inspections (e.g., 5-year storm event) will be an important component to understand potential long-term bank stability. Information gained from these inspections can be used to improve designs for other reaches, if necessary.

The short-term monitoring plan also includes other measureable metrics to capture changes in transport or exposure pathways (primarily bank erosion), including the following:

- THg and MeHg concentrations in surface sediment, which may reflect particle migration from upstream areas of the river
- THg and MeHg concentrations in pore water
- THg and MeHg concentrations in biological tissue (periphyton and Asiatic clam tissue)

Elements of the short-term monitoring plan (e.g., sample size, sampling frequency and intervals, etc.) could change as other reaches are considered or other technologies are adopted. Table 2-2 in the short-term monitoring plan provides the details regarding the objectives, criteria, and incorporation in the EAM framework for the short-term monitoring elements [Appendix D to the Phase I IM Work Plan (Anchor QEA and URS, 2015)].

9.5.2 Long-Term Monitoring

The elements of the long-term monitoring included in the Remediation Proposal address currently planned remedies. This plan may be expanded once downstream and floodplain remediation areas are defined. The general long-term RAOs are as follows:

- Reduce MeHg exposure to human and ecological receptors.
- Improve habitat conditions throughout the South River and SFS River.

Potential human and ecological receptor exposure to MeHg occurs primarily via the dietary intake of food items that bioaccumulate MeHg. Due to the nature of mercury fate and transport in aquatic environments, exposure to MeHg in biological tissue is not expected to change significantly over the short term. The long-term monitoring plan aims to identify any long-term changes in the potential MeHg exposure due to the remedial actions.

Additionally, bank erosion control as part of the remedy may also have benefits for the benthic invertebrate community on a long-term basis. Therefore, the long-term monitoring plan also includes elements that address the changes in the habitat conditions throughout the South River and SFS River.

The following sections provide brief introduction to the biotic media that will be sampled for mercury analyses within the river and the floodplain as part of the long-term monitoring plan. Table 2-2 in the long-term monitoring plan provides the details regarding the objectives, criteria, and incorporation in the EAM framework for the long-term monitoring elements [Appendix E to the Phase I IM Work Plan (Anchor QEA and URS, 2015)].

River Biota

Adult Fish: Fish consumption is one of the main sources of human exposures to mercury in AOC 4. Therefore, MeHg in the tissues of fish from the South River forms the primary biological medium to be monitored for the evaluation of long-term trends in MeHg exposure to humans.

Snapping Turtles: Snapping turtles are semi-aquatic piscivorous ecological receptors that are common in the South River. They are apex predators and long-lived (up to 50 years), feeding on relatively large fish and capable of accumulating mercury to a greater degree than other animals in the South River (Hopkins et al., 2013). Snapping turtles may be consumed by some individuals in the South River and SFS river watersheds. Existing data indicate up to four eight-ounce portions of turtle meat can be safely consumed each year. THg and MeHg concentrations in snapping turtle tissue (based on non-lethal sampling of toe nail) will be monitored and evaluated against historical results.

Mallard duck: Although mallards sampled from contaminated portions of the South River had blood and feather mercury concentrations that were higher than those observed in reference areas, subsequent sampling of muscle and liver tissue by VDEQ reported lower THg concentrations in these tissues. Ducks may be consumed by individuals in the South River and SFS river watersheds. Existing data indicate up to 16 eight-ounce portions of duck meat can be safely consumed each year. Tissue THg and MeHg concentrations in mallard duck breast muscles (potentially consumed by humans) will be monitored and evaluated against historical results. Results from these human exposure monitoring efforts will be shared and discussed with VDH and other relevant regulatory agencies to determine the need for additional outreach to local communities, and potentially whether additional consumption advisories are warranted.

Young-of-Year (YOY) Fish: YOY fish are an ideal monitoring element to track changes in mercury exposure resulting from remediation or interannual variation due to the relatively short exposures they experience and their site fidelity or small home range (Harris et al., 2007; Slotton, 2008; Minns, 1995). YOY fish also serve as representative dietary item for several piscivorous wildlife receptors; however, YOY fish are not typically consumed by humans.

Sediment and Benthic Invertebrates

The long-term monitoring plan includes THg and MeHg measurement in sediments to assess whether the remedy is effective in reducing concentrations in channel margins and in the gravel matrix. It is expected that MeHg concentrations in the gravel matrix of the streambed will decline over time as the result of natural processes. As part of the long-term monitoring effort, fine-grained sediment will be collected from the stream bed in the South River and SFS River.

The long-term monitoring plan for the South River will also include the collection of benthic invertebrates for mercury tissue residue and community evaluations. Periphyton and particulate organic material transported by the water column form the base of the food web in the South River; benthic invertebrates feed on these items (Tom et al., 2010). Invertebrates, in turn, are preyed upon by forage fish and are a key element in the trophic transfer of mercury. Several long-term monitoring plans in the United States have measured and used metal levels in benthic invertebrates to quantify improvements in water quality and restoration effectiveness (Clements et al., 2000; Hornberger et al., 2009).

Floodplain

Terrestrial organisms are exposed to MeHg primarily via dietary items that have accumulated MeHg from the terrestrial and aquatic food web. Stable isotope studies suggest that mercury concentrations in top-level terrestrial predators can be explained by bioaccumulation from terrestrial sources (Newman et al., 2011), such as through ingestion of soil-dwelling invertebrates (e.g., earthworms). In addition, spiders accumulate mercury by feeding on a variety of invertebrates, including emergent aquatic insects (Howie, 2010); songbirds subsequently accumulate mercury through the consumption of spiders (Cristol et al., 2008). For this reason, long-term terrestrial exposure monitoring will provide data to evaluate these exposure pathways by collecting samples of spiders, earthworms, and songbirds from the floodplains.

Monitoring Data in the Adaptive Management Framework

The monitoring plan is designed to be front-loaded and iterative. The scope of the sampling is broad to confirm that an adequate pre-remediation baseline dataset exists. Datasets that indicate no changes in mercury exposures or provide ambiguous results, may be collected at a reduced frequency, replaced by the collection of data from an alternate medium, modified, or eliminated from the plan in the context of the EAM strategy. For example, if THg or MeHg concentrations in earthworm tissue do not change significantly over the first three years, sample frequency may be reduced to once every two years. However, in this case, the decision of whether to continue with specific sample locations, tests, or analytes will be focused on their usefulness in the context of the EAM framework and any ongoing or planned remedial actions.

9.6 Summary and Recommendations

An EAM approach has been proposed to address mercury in AOC 4. Of primary importance in the next steps is the evaluation of data, generated from the monitoring program, that are designed to operate within a statistical and hypothesis-testing framework. As a part of the Phase I IM Work Plan (Anchor QEA and URS, 2015), monitoring data will be collected to evaluate the effect of remediation on mercury transport pathways and/or routes of human or ecological exposures. As the monitoring program proceeds, results will be analyzed and reviewed with the appropriate regulatory agencies within the RCRA framework to determine the degree to which transport pathways and/or exposure routes are limiting mercury exposures. The results of the Interim Measures program and the risk assessments will be evaluated within the RCRA framework to develop the CMS for the aquatic and terrestrial floodplain portions of AOC 4. Specific details of the approach will be developed in a stepwise strategy as data become available and are evaluated.

9.7 Program Schedule

The modified RCRA Permit for the Site specifies the schedule for the overall program. The current schedule for key documents and activities is described in this section.

Risk Assessments: The AOC 4 ERA and the associated RDQA were accepted by VDEQ on July 13, 2015 (AECOM, 2015b). The AOC 4 HHRA and the associated RDQA were submitted to VDEQ in July 2015. The design and implementation of the Phase 1 interim measures incorporates the findings of the HHRA and ERA.

Phase 1 IM Work Plan: The final Phase 1 IM Work Plan was submitted in February 2015 and subsequently accepted by the VDEQ (Anchor QEA and URS, 2015). Design of the Phase 1 interim measures is anticipated to be completed in 2015. Landowner and permitting agency discussions to refine the designs of the prospective bank remediation actions described in Sections 9.4.2 are anticipated to be completed in fall 2015. Construction of the Phase 1 remedy is currently targeted to begin in late spring 2016, shortly after completion of corrective actions and source controls at the Site. Phase 1 construction is likely to continue through 2017.

CMS Report: The CMS Report will be developed parallel to the design and is currently targeted for completion in early 2016. Design and permitting of follow-on corrective actions in AOC 4 are anticipated to occur in 2016 and 2017, with Phase 2 construction targeted to begin in 2018. DuPont and VDEQ will update the project schedule at least quarterly during the Phase 1 IMs design period. Additionally, meetings will be scheduled periodically to discuss the status of ongoing efforts, upcoming events, and deliverables to resolve any issues that may arise.

The nature of the EAM framework strategy of the remedy can influence the current schedule, particularly in subsequent remedial phases as monitoring data are collected and evaluated. Any schedule modifications would be based on direction from the VDEQ.

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Tables

Table 1-1
Ecological Study Data Matrix
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	INVESTIGATOR(S)	CITATION
Habitat and Geophysical Characterizations																			
RRM 0 - 1	Discharge Characterization	2009						x	x	x			x		0.1	Q (cfs)	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
										x					0.1	Velocity (f/s)	Pilot Bank Stabilization: Pre-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
		2010						x							0.1	Velocity (f/s)	Pilot Bank Stabilization: Post-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
	Habitat Characterization	2005									x				0.6		Phase I Ecostudy: Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2006									x				0.6		Phase I Ecostudy: Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2009			x			x							0.1		Phase II Ecostudy: Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
										x					0.1		Pilot Bank Stabilization: Pre-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
		2010			x		x		x			x			0.1		Pilot Bank Stabilization: Post-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
		2011				x									0.1		Pilot Bank Stabilization: Post-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
	Morphology Assessment	2005													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
		2006													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
		2007											x		0.1		Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
									x						NS		Comprehensive Geomorphological Study: Reconnaissance Investigation of Floodplain Deposits Formed Through Channel Migration	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
		2009								x					0.1		Pilot Bank Stabilization: Pre-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
		2010			x		x		x			x			0.1		Pilot Bank Stabilization: Post-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
		2011					x								0.1		Pilot Bank Stabilization: Post-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
									x						NS		Substrate and Aquatic Macrophyte Mapping	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
Physical and Chemical Monitoring / Assessments																			
RRM 0 - 1	Soil	2003										x			0.1 - 0.4	THg	Greenway Sampling	UE	
		2006												x	0.5	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU	Cianchetti, J. 2009. Survey of the Mercury Content of Earthworms on the South River, Va., Floodplain. Thesis (M.S.). James Madison University.
		2007		x											0.0 - 0.4	THg, MeHg, LOI, Other Analytes	Turner Plant Reach Sediments	UE	
													x		0.1 - 0.2	THg, MeHg	University of Delaware Bank Survey Soils	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
		2008								x					0 - 0.2, 0.9 - 1.0	THg, MeHg, VOCs	Bank Stabilization Sediment	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
				x	x	x									0.0 - 1.0	THg	Phase II Ecostudy: Floodplain Soil Investigation	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2009			x										0.1	THg	Phase II Ecostudy: River Bank Soil for Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010			x										0.1	THg	Pilot Bank Stabilization: River Bank Soil for Post-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
	Sediment	2003									x				0.3 - 0.4	THg, Metals	VADEQ Historical Floodplain Monitoring	VADEQ	
		2004					x								0.2 - 0.3	THg, Other Analytes	Sediment Sampling	UE	
		2005									x				0.2 - 0.3	THg, MeHg, LOI, Other Analytes	Transect Program	UE	
					x										0.3 - 0.6	THg, MeHg, LOI, Other Analytes	Water Sampling	UE	
		2006			x	x	x	x	x	x	x	x	x	x	0.6	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
												x			0.0, 0.3	THg, MeHg	Mercury Source Tracing and Mechanistic Source Studies	RTG, UE	
		2007	x	x											0.6	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
										x					0.1 - 0.4	THg, Other Metals	VADEQ Sediment Sampling	VADEQ	
		2009			x										0.1	THg	Phase II Ecostudy: Near-Bank Sediment for Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010				x									0.1	THg, MeHg, PCBs, PAHs, Herbicides, Pesticides, Other Analytes	Phase II Ecostudy: Interstitial Sediment for Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
					x										0.1	THg	Pilot Bank Stabilization: Near-Bank Sediment for Post-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
		2011				x									0.1	THg	Pilot Bank Stabilization: Near-Bank Sediment for Post-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
	Ground Water	2006	x						x			x	x	x	0.1	THg and Water Elev.	Mercury Source Tracing and Mechanistic Source Studies: Basic Park GW	RTG, UE	
		2007		x		x	x	x	x	x	x	x			0.1	THg and Water Elev.	Mercury Source Tracing and Mechanistic Source Studies: Basic Park GW	RTG, UE	
		2009						x	x	x			x		0.1	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
								x							0.1	THg	Pilot Bank Stabilization: Physical Loading Pre-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
					x										0.0 - 1.0	Spatial Analysis	River Corridor Infrared Thermal Imaging	SITS	
		2010						x							0.1	THg, MeHg	Pilot Bank Stabilization: Physical Loading Post-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
	Pore Water	2006										x			0.0, 0.3	THg, MeHg	Mercury Source Tracing and Mechanistic Source Studies	RTG, UE	
		2007	x	x	x	x	x	x	x						0.1	THg	Mercury Source Tracing and Mechanistic Source Studies: Long-Profile Pore Water	RTG, UE	
				x											0.0 - 0.4	THg	Turner Plant Reach Pore Water and Surface Water	UE	
									x						0.2 - 0.3	MeHg	Turner Spin Pore Waters	UE	
		2009						x	x	x			x		0.1	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010						x							0.1	THg, MeHg	Pilot Bank Stabilization: Physical Loading Post-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
		2011						x							0.1	THg, MeHg	Pilot Bank Stabilization: Physical Loading Post-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
	Surface Water	2001											x		0.2 - 0.3	THg, Metals, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2002	x		x			x		x		x		x	0.2 - 0.3	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
									x						0.9 - 1	THg, TSS, Other Analytes	VADEQ Historical Intensive 1	VADEQ	
		2003								x					0.0 - 0.3	THg, TSS, Other Analytes	VADEQ Historical Intensive 2	VADEQ	
				x		x		x		x		x			0.2 - 0.3	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2004										x			0.1 - 0.2	THg	Cutback Survey Sampling	UE	
											x				0.1 - 0.3	THg, MeHg, TSS	Flood Sampling	UE	
										x					0.2 - 0.3	THg, MeHg, TSS	Hg Speciation Study	UE	
			x	x		x		x		x		x			0.2 - 0.3	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2005	x	x											0.1 - 0.4, 0.5 - 0.6, 0.7 - 0.8, 0.9 - 1.0	THg, MeHg, TSS	Surface Water/Sediments	UE	
											x				0.2 - 0.3	THg, MeHg, TSS	Transect Program	UE	
					x		x		x		x		x		0.2 - 0.3	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
			x												0.2 - 0.3	TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
							x								0.2 - 0.3, 0.4 - 0.5, 0.9 - 1	THg, MeHg, TSS	Water Sampling	UE	
					x										0.4 - 0.5	THg, MeHg, Metals, TSS, Other Analytes	Water Sampling	UE	
		2006										x			0.0	THg, MeHg	Mercury Source Tracing and Mechanistic Source Studies	RTG, UE	
								x		x			x		0.4	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
					x	x	x	x	x	x	x	x	x	x	0.6	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
											x	x			0.0 - 0.4	THg	Turner Plant Reach Pore Water and Surface Water	UE	
			x		x		x		x		x		x		0.2 - 0.3	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2007										x			0.1	THg, MeHg	Phase II Ecostudy: Targeted Tributary Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
					x										0.4	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
				x											0.1 - 0.2	THg	Turner Plant Reach Pore Water and Surface Water	UE	
			x		x		x		x		x		x		0.2 - 0.3	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
			x	x		x	x			x		x		x	0.4, 0.6	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2008					x								0.1	THg, MeHg	Phase II Ecostudy: Targeted Tributary Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
				x				x		x		x			0.4	THg, MeHg	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
			x		x		x		x		x		x		0.2 - 0.3	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2009								x					0.1	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
								x	x	x			x		0.1	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
				x			x			x					0.4	THg, MeHg	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
			x												0.2 - 0.3	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2010						x							0.1	THg, MeHg	Pilot Bank Stabilization: Physical Loading Post-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
			x	x	x		x	x	x	x	x	x	x	x	0.4	THg, MeHg, Nutrients, Other Analytes	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
					x		x		x		x		x		0.3 - 0.4	Nitrate, Nitrite, Nitrogen	VADEQ Surface Water	VADEQ	
		2011		x				x		x		x			0.1	THg, MeHg, Other Analytes	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
			x		x		x		x		x		x		0.1	THg, MeHg, Other Analytes	VADEQ Surface Water	VADEQ	

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Biological Monitoring / Assessments																			
Aquatic Vegetation / Algae																			
RRM 0 - 1	Tissue	2005							x						0.3, 1	THg, MeHg	Periphyton Assessment	VIMS	Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
RRM 0 - 1	Tissue	2006								x					0.6	THg, MeHg	Phase I Ecostudy: Macrophytes	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 0 - 1	Tissue	2006					x			x				x	0.6	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 0 - 1	Tissue	2007					x		x						0.6	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
RRM 0 - 1	Tissue	2007		x											0.6	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 0 - 1	Tissue	2008						x		x					0.3	THg, MeHg, δN15, δC13	VIMS Sed and Periphyton Study 2008	VIMS	Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
Aquatic Invertebrates																			
RRM 0 - 1	Population / Community	2006					x			x				x	0.6		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 0 - 1	Population / Community	2007		x											0.6		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 0 - 1	Population / Community	2010				x									0.1		Phase II Ecostudy: Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 0 - 1	Population / Community	2011					x	x							0.1		Phase II Ecostudy: Benthic Colonization Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 0 - 1	Feeding	2010						x		x		x			0.1	δN15, δC13	Phase II Ecostudy: Basal Resource Utilization Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 0 - 1	Tissue	2002											x		0.1, 0.4, 0.6, 0.8, 1.0	THg	Clam Tissue Study	JMU, EMU	Bowles, M.W. 2003, Biomonitoring of Mercury in the South River Using Asiatic Clam, Corbicula fluminea. Undergraduate Thesis. James Madison University, Harrisonburg, Virginia.
RRM 0 - 1	Tissue	2003											x		0.1	THg, MeHg	Clam Tissue Study	JMU, EMU	Bowles, M.W. 2003, Biomonitoring of Mercury in the South River Using Asiatic Clam, Corbicula fluminea. Undergraduate Thesis. James Madison University, Harrisonburg, Virginia.
RRM 0 - 1	Tissue	2006					x			x				x	0.6	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 0 - 1	Tissue	2006			x	x	x	x	x	x	x	x	x	x	0.6	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 0 - 1	Tissue	2007					x								0.6	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
RRM 0 - 1	Tissue	2007		x											0.6	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 0 - 1	Tissue	2007	x	x											0.6	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 0 - 1	Tissue	2009					x	x							0.1	THg, MeHg	Phase II Ecostudy: Asian Clam Uptake Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 0 - 1	Tissue	2010						x							0.1	THg, MeHg	Pilot Bank Stabilization: Asian Clam Uptake Study for Post-Construction Study	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
RRM 0 - 1	Tissue	2011					x	x							0.1	THg, MeHg	Pilot Bank Study: Clam Tissue	URS	URS, 2014a. Technical Briefing Paper: Bank Stabilization Pilot Study. South River Science Team Briefing Paper. September 2014.
RRM 0 - 1	Toxicity	2010								x					0.1		Phase II Ecostudy: Field Microcosm Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 0 - 1	Toxicity	2010					x								0.1		Phase II Ecostudy: Laboratory Sediment Bioassays for Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
Fish																			
RRM 0 - 1	Population / Community	2006					x			x					0.6		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 0 - 1	Population / Community	2010					x				x				0.1		Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 0 - 1	Stomach Contents	2010					x				x	x			0.1		Phase II Ecostudy: Bass, Sunfish, and Forage Fish	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 0 - 1	Tissue	2001				x									0.0	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
RRM 0 - 1	Tissue	2002				x									0.0	THg, MeHg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
RRM 0 - 1	Tissue	2005				x									0.0	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
RRM 0 - 1	Tissue	2006					x			x					0.6	THg, MeHg	Phase I Ecostudy: Forage Fish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 0 - 1	Tissue					x									0.0	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
RRM 0 - 1	Tissue	2007					x								0.6	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
RRM 0 - 1	Tissue	2009					x				x				0.1	THg, MeHg	Phase II Ecostudy: Bass	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 0 - 1	Tissue	2010					x				x				0.1	THg, MeHg	Phase II Ecostudy: Bass	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 0 - 1	Tissue	2010					x				x	x			0.1	THg, MeHg	Phase II Ecostudy: Forage Fish	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 0 - 1	Tissue	2010					x				x				0.1	THg, MeHg	Phase II Ecostudy: Sunfish	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 0 - 1	Tissue	2011					x								0.1	THg, MeHg	Phase II Ecostudy: Bass	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
Herpetofauna																			
RRM 0 - 1	Tissue	2007					x								1.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT	Hopkins, W.A., C.M. Bergeron, M.J. Hepner, B.D. Todd, J.D. Willson. 2011. From individual-level responses to population-level change: individual and interactive effects of maternal and dietary mercury on amphibians along the South River, VA Final Report. Prepared for E.I. DuPont de Nemours Company.
Terrestrial Invertebrates																			
RRM 0 - 1	Tissue	2006												x	0.5	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU	Cianchetti, J. 2009. Survey of the Mercury Content of Earthworms on the South River, Va., Floodplain. Thesis (M.S.). James Madison University.
Habitat and Geophysical Characterizations																			
RRM 1 - 6	Discharge Characterization	2000	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
RRM 1 - 6	Discharge Characterization	2001	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
RRM 1 - 6	Discharge Characterization	2002	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
RRM 1 - 6	Discharge Characterization	2003	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
RRM 1 - 6	Discharge Characterization	2004	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
RRM 1 - 6	Discharge Characterization	2005	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
RRM 1 - 6	Discharge Characterization	2006	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
RRM 1 - 6	Discharge Characterization	2007	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
RRM 1 - 6	Discharge Characterization	2008	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
RRM 1 - 6	Discharge Characterization	2009	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
RRM 1 - 6	Discharge Characterization	2009						x	x	x			x		3.5	Q (cfs)	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 1 - 6	Discharge Characterization	2010	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
RRM 1 - 6	Precipitation Monitoring	2000										x	x	x	1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA	
RRM 1 - 6	Precipitation Monitoring	2001	x		x	x	x	x	x	x	x	x	x	x	1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA	
RRM 1 - 6	Precipitation Monitoring	2002	x	x	x	x	x		x	x	x	x	x		1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA	
RRM 1 - 6	Precipitation Monitoring	2003	x			x		x	x	x	x	x	x	x	1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA	
RRM 1 - 6	Precipitation Monitoring	2004	x		x	x		x	x	x			x		1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA	
RRM 1 - 6	Precipitation Monitoring	2005	x		x			x	x	x	x	x	x		1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA	
RRM 1 - 6	Precipitation Monitoring	2006	x	x	x	x	x	x			x	x	x	x	1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA	
RRM 1 - 6	Precipitation Monitoring	2007	x	x	x	x	x	x	x	x					1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA	
RRM 1 - 6	Habitat Characterization	2005									x				2.0, 3.0, 4.2, 5.2		Phase I Ecostudy: Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 1 - 6	Habitat Characterization	2006									x				5.2		Phase I Ecostudy: Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 1 - 6	Habitat Characterization	2009			x			x							3.0, 3.5, 3.7		Phase II Ecostudy: Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 1 - 6	Morphology Assessment	2005													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
RRM 1 - 6	Morphology Assessment	2006	x				x								1.8, 3.0		Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
RRM 1 - 6	Morphology Assessment	2006													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
RRM 1 - 6	Morphology Assessment	2007							x						NS		Comprehensive Geomorphological Study: Reconnaissance Investigation of Floodplain Deposits Formed Through Channel Migration	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
RRM 1 - 6	Morphology Assessment	2007			x										3.0, 5.4		Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
RRM 1 - 6	Morphology Assessment	2011							x						NS		Substrate and Aquatic Macrophyte Mapping	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.

Table 1-1
Ecological Study Data Matrix
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	INVESTIGATOR(S)	CITATION
Physical and Chemical Monitoring / Assessments																			
RRM 1 - 6	Soil	2004						x							1.1 - 1.2, 1.6 - 1.9	THg	Floodplain Hg Sampling	UE	
												x			2.5 - 2.6	THg	Cutback Survey Sampling	UE	
		2005									x				2.1 - 2.2, 2.5 - 2.6	THg, MeHg	Core Sampling	UE	
			x												2.5 - 2.6	THg	Floodplain Soil Sampling	UE	
			x												2.5 - 2.6	THg	Surface Water/Sediments	UE	
		2006										x	x	x	1.0, 2.1, 2.4, 5.0	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU	Cianchetti, J. 2009. Survey of the Mercury Content of Earthworms on the South River, Va., Floodplain. Thesis (M.S.). James Madison University.
													x		1.7 - 1.8, 5.3 - 5.4	THg, MeHg, LOI, Other Analytes	Turner Crimora Sediments	UE	
								x			x				2.1 - 2.2, 3.1 - 3.2, 5.3 - 5.4	THg, MeHg, Mn, Fe, LOI	Flux Chamber Study (Loading)	DuPont	URS 2009. Technical Briefing Paper: Use of Benthic Flux Chambers to Measure Inorganic Mercury and Methylmercury Fluxes in the South River. South River Science Team Briefing Paper. March 2009.
							x								2.1 - 2.3	THg, MeHg, LOI, Other Analytes	Bank Flux Sediment / Soils	UE	
											x				2.1 - 2.3	THg, MeHg, LOI, Other Analytes	Turner Basic Park Sediment	UE	
												x			2.9 - 3, 3.4 - 4.9, 5.4 - 5.5	THg	USEPA Shifflet Farm Sampling	USEPA	
		2007													1.6, 2.2, 3.5, 4.8, 5.4	THg, MeHg	Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
			x	x											2.1 - 2.3	THg, MeHg, LOI, Other Analytes	Turner Basic Park Sediment	UE	
			x	x											2.1 - 2.3	THg, MeHg, LOI, Other Analytes	Turner Basic Park Sediment Pore Water	UE	
												x			2.9 - 3.0,	THg, MeHg, VOCs	Fine Grained Sediment Study	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
		2008		x	x	x									1.1 - 6.0	THg	Phase II Ecostudy: Floodplain Soil Investigation	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
				x	x	x		x							1.6 - 1.8, 2.1 - 2.2, 2.9 - 3.1, 3.3 - 3.4, 3.5 - 3.7, 3.9 – 4.0, 4.1 - 4.2, 4.7 - 4.9, 5.1 - 5.2, 5.3 - 5.4, 5.8 - 5.9	THg, MeHg	Comprehensive Geomorphological Study: Bank Erosion and Mercury Content	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
															1.6, 2.2, 3.5, 4.8, 5.4	THg, MeHg	Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
												x			2.8 - 2.9, 3.1 - 3.2, 4.3 - 4.4, 4.6 - 4.7, 4.8 - 4.9	THg, MeHg, LOI	Flux Chamber Study (Loading)	DuPont	URS 2009. Technical Briefing Paper: Use of Benthic Flux Chambers to Measure Inorganic Mercury and Methylmercury Fluxes in the South River. South River Science Team Briefing Paper. March 2009.
		2009						x							2.8 - 3.1	THg, MeHg	River Mile 3.0 Sediment Study	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
					x										3.0, 3.5, 3.7	THg	Phase II Ecostudy: River Bank Soil for Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2011					x								0.0 - 0.3, 0.5 - 0.6	THg	Floodplain Soils Investigation	URS	URS. 2014b. Floodplain Laboratory Pilot Report for AOC 4. Former DuPont Waynesboro Plant, Waynesboro, Virginia. Draft. May 2014.
	Sediment	2002										x			4.8 - 4.9, 5.6 - 5.7	THg, MeHg, LOI, Other Analytes	Sediment Core Study - LLI	URS	
		2004						x							1.7 - 1.8	THg, % Moisture	Floodplain Hg Sampling	UE	
		2005			x		x								1.5 - 1.6, 1.7 - 1.8, 2.5 - 2.6	THg, MeHg, LOI, Other Analytes	Water Sampling	UE	
			x												1.7 - 1.8	THg, % Moisture	Oxbow Core Sampling	UE	
									x	x					1.7 - 1.8, 2.1 - 2.2, 2.4 - 2.5, 3.8 - 3.9, 4.2 - 4.3, 4.6 - 4.7	THg, LOI, Other Analytes	University of Delaware Program	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
											x				1.7 - 1.8, 2.4 - 2.6	THg, MeHg, LOI, Other Analytes	Core Sampling	UE	
											x				1.7 - 1.9, 5.0 - 5.1	THg, MeHg, LOI, Other Analytes	Transect Program	UE	
		2006			x	x	x	x	x	x	x	x	x	x	2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007							x	x	x				1.0 - 1.2, 1.7 - 1.8, 2.3 - 2.4, 2.6 - 2.7, 3.5 - 3.6, 4.7 - 4.9, 5.0 - 5.1, 5.2 - 5.3, 5.5 - 5.6	THg, Other Metals	VADEQ Sediment Sampling	VADEQ	
			x	x						x		x		x	2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
												x			3.0, 3.8, 3.9, 4.2, 4.6, 4.8, 5.4	THg, MeHg	Phase I Ecostudy: Channel Margin Deposit Cores for Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2008		x		x		x		x		x			1.6, 3.0, 4.6, 5.2	THg, MeHg	Phase II Ecostudy: Interstitial Sediment	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2009			x										3.0, 3.5, 3.7	THg	Phase II Ecostudy: Near-Bank Sediment for Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010				x									3.5	THg, MeHg, PCBs, PAHs, Herbicides, Pesticides, Other Analytes	Phase II Ecostudy: Interstitial Sediment for Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Ground Water	2006										x			2.1 - 2.3	THg	Turner Pore / Well Water I & II	UE	
												x			2.1 - 2.3	THg, MeHg, Other Analytes	Turner Wells / Turner Wells and Extract	UE	
												x			3.7 - 4.3	THg, MeHg, TSS, TOC, VOCs, Other Analytes	Shifflet Farm GW and Pond Sampling: Direct Push Sampling	USEPA	
		2007				x									2.1 - 2.3	THg, MeHg, Other Analytes	Turner Wells / Turner Wells and Extract	UE	
				x											2.1 - 2.3	THg	Turner Wells and Ultra	UE	
		2009			x										1.1 - 6.0	Spatial Analysis	River Corridor Infrared Thermal Imaging	SITS	
	Pore Water	2006										x			2.1 - 2.2	THg, MeHg, Other Analytes	Turner Wells / Turner Wells and Extract	UE	
							x		x						2.1 - 2.3	THg	Bank Flux Pore Water and Surface Water	UE	
												x			2.1 - 2.3	THg	Turner Pore / Well Water I	UE	
		2007						x							2.1 - 2.2	THg, MeHg, Other Analytes	Basic Park Surface Water Flux	UE	
			x	x											2.1 - 2.2	THg, MeHg	Turner Basic Park Longitudinal Profile Pore Water and Surface Water	UE	
			x	x											2.1 - 2.2	THg, MeHg	Turner Basic Park Sediment Pore Water	UE	
						x									2.1 - 2.2	Fe	Turner Centrifuge Project	UE	
									x						2.1 - 2.2, 5.3 - 5.4	MeHg	Turner Spin Pore Waters	UE	
		2008						x							2.1 - 2.2	Fe, Mn	Turner Hyporheic Samples	UE	
		2009						x	x	x			x		3.5	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Surface Water	2001											x		1.3 - 1.4, 2.3 - 2.4, 5 - 5.1	THg, Metals, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2002							x						1.0 - 2.6	THg, TSS, Other Analytes	VADEQ Historical Intensive 1	VADEQ	
										x					1.2 - 1.3, 1.4 - 1.5, 2.4 - 2.5	THg, TSS	VADEQ Historical Intensive 2	VADEQ	
										x					1.3 - 1.4	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
			x		x			x		x		x		x	1.3 - 1.4, 2.3 - 2.4, 5 - 5.1	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2003		x		x		x		x		x			1.3 - 1.4, 2.3 - 2.4, 5 - 5.1	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
										x					2.3 - 2.6	THg, TSS, Other Analytes	VADEQ Historical Intensive 2	VADEQ	
									x		x			x	5 - 5.1	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
		2004									x				1.2 - 1.3, 1.7 - 1.8, 1.8 - 1.9, 5 - 5.1	THg, MeHg, TSS	Flood Sampling	UE	
										x					1.2 - 1.3, 1.7 - 1.8, 1.8 - 1.9, 5 - 5.1	THg, MeHg, TSS	Hg Speciation Study	UE	
			x	x		x		x		x		x			1.3 - 1.4, 2.3 - 2.4, 5 - 5.1	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
							x								1.7 - 1.8	THg, MeHg	Oxbow Water Sampling	UE	
				x		x		x	x		x		x		5 - 5.1	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
		2005	x	x											1.1 - 1.2, 1.3 - 2.0, 2.1 - 2.2, 2.4 - 2.5, 2.6 - 3.2, 3.4 - 3.5, 3.6 - 3.7, 3.8 - 3.9, 4.1 - 4.2, 4.4 - 4.6, 4.8 - 4.9, 5.0 - 5.1	THg, MeHg, TSS	Surface Water/Sediments	UE	
			x												1.3 - 1.4, 5.0 - 5.1	TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
											x				1.3 - 1.5, 1.7 - 1.9, 2.4 - 2.6, 3.2 - 3.3, 5.0 - 5.1	THg, MeHg, TSS	Transect Program	UE	
					x										1.3 - 1.6, 1.7 - 1.8, 5.0 - 5.1, 5.2 - 5.5, 5.6 - 5.7, 5.8 - 5.9	THg, MeHg, Metals, TSS, Other Analytes	Water Sampling	UE	
							x								1.5 - 1.6, 1.8 - 2.0, 2.2 - 2.7, 3.4 - 3.5, 4.4 - 4.5, 4.7 - 4.9, 5.0 - 5.1, 5.2 - 5.3	THg, MeHg, TSS	Water Sampling	UE	
		2005			x		x		x		x		x		2.3 - 2.4, 5.0 - 5.1	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
					x		x								5 - 5.1	Nutrients, E. Coli, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring	VADEQ	
			x												5 - 5.1	Nutrients	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
			x												5 - 5.1	TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
											x				5 - 5.1	THg, TSS	VADEQ Storm Sampling	VADEQ	
											x				5.2 - 5.3	THg, MeHg, TSS	Concurrent Sampling	RTG	
		2006										x			3.8	THg, MeHg, TSS, TOC, VOCs, Other Analytes	Shifflet Farm GW and Pond Sampling: Direct Push Sampling	USEPA	
					x	x	x	x	x	x	x	x	x	x	2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
												x			2.1 - 2.2	THg, MeHg, Other Analytes	Turner Wells / Turner Wells and Extract	UE	
								x			x				2.1 - 2.2, 3.1 - 3.2, 5.3 - 5.4	THg, MeHg, Mn, Fe, LOI	Flux Chamber Study (Loading)	DuPont	URS 2009. Technical Briefing Paper: Use of Benthic Flux Chambers to Measure Inorganic Mercury and Methylmercury Fluxes in the South River. South River Science Team Briefing Paper. March 2009.
							x		x						2.1 - 2.3	THg	Bank Flux Pore Water and Surface Water	UE	
											x				2.1 - 2.3	THg, MeHg, Other Analytes	Basic Park Surface Water Flux	UE	
												x			2.1 - 2.3	THg	Turner Pore / Well Water I & II	UE	
			x		x		x		x		x		x		2.3 - 2.4, 5.0 - 5.1	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
								x		x			x		2.3, 5.1	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007										x			1.5, 2.5, 4.7, 5.6	THg, MeHg	Phase II Ecostudy: Targeted Tributary Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
			x	x		x	x								2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x					x							2.1 - 2.2	THg, MeHg, Other Analytes	Basic Park Surface Water Flux	UE	
			x	x		x									2.1 - 2.2	THg, MeHg	Turner Basic Park Longitudinal Profile Pore Water and Surface Water	UE	
						x									2.1 - 2.2	THg	Turner Uptake Study	UE	
						x									2.1 - 2.2	THg, MeHg, Other Analytes	Turner Wells / Turner Wells and Extract	UE	
			x	x				x	x						2.1 - 2.3	THg, MeHg	Basic Park Surface Water	UE	
					x										2.3 - 2.4	Nutrients, Bacteria, Hg, Other Analytes	VADEQHIST Fishkill	VADEQ	
			x		x		x		x		x		x		2.3 - 2.4, 5.0 - 5.1	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
										x		x		x	2.3, 5.1	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
					x										2.3, 5.1	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x	x	x	x	x	x	x	x	x		x	x	5.0 - 5.1	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
		2008					x								1.2, 5.2	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
							x								1.5, 3.1, 4.7, 5.6	THg, MeHg	Phase II Ecostudy: Targeted Tributary Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
								x							2.3 - 2.4, 5.0 - 5.1	THg, MeHg, Mn, Fe	Flux Chamber Study (Loading)	DuPont	URS 2009. Technical Briefing Paper: Use of Benthic Flux Chambers to Measure Inorganic Mercury and Methylmercury Fluxes in the South River. South River Science Team Briefing Paper. March 2009.
			x		x		x		x		x		x		2.3 - 2.4, 5.0 - 5.1	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
				x				x		x		x			2.3, 5.1	THg, MeHg	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
											x				2.7, 3.0, 4.0, 4.6, 4.9	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
								x							2.8, 4.0, 4.5, 4.6	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
										x					3.0, 4.6	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
											x				4.5 - 4.6	Fe, Mn	Turner Surface Waters	UE	
		2009								x					3.5	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
								x	x	x			x		3.5	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
			x												1.3 - 1.4, 5.0 - 5.1	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
			x												2.3 - 2.4, 5.0 - 5.1	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
				x			x			x					2.3, 5.1	THg, MeHg	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010							x						1.3, 1.7, 2.0, 2.4	THg, MeHg, Nutrients	Sewage Treatment Plant Surface Water Studies	JMU	Brent, R. 2011. Impacts of Waynesboro Wastewater Treatment Plant Upgrades on South River. South River Science Team, Harrisonburg, VA. April 26.
					x		x		x		x		x		2.3 - 2.4, 5.2 -5.3	Nitrate, Nitrite, Nitrogen	VADEQ Surface Water	VADEQ	
			x	x	x		x	x	x	x	x	x	x	x	2.3, 5.1	THg, MeHg, Nutrients, Other Analytes	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2011		x				x		x		x			3.5	THg, MeHg, Other Analytes	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
			x		x		x		x		x		x		3.5	THg, MeHg, Other Analytes	VADEQ Surface Water	VADEQ	
							x								4.2, 5.4	THg, MeHg	Floodplain Ponds Investigation	URS	

Table 1-1
Ecological Study Data Matrix
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	INVESTIGATOR(S)	CITATION
Biological Monitoring / Assessments																			
Aquatic Vegetation / Algae																			
RRM 1 - 6	Tissue	2005							x						2.0, 5.0	THg, MeHg	Periphyton Assessment	VIMS	Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
		2006					x	x							5.2	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
										x					2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Macrophytes	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x			x				x	2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007		x											2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x		x						2.0, 5.2	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
		2008						x		x					1.1, 2.1, 5.4	THg, MeHg, δN15, δC13	VIMS Sed and Periphyton Study 2008	VIMS	Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
Aquatic Invertebrates																			
RRM 1 - 6	Population / Community	2006					x			x				x	5.2		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007		x											5.2		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2010				x									3.5		Phase II Ecostudy: Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2011					x	x							3.5		Phase II Ecostudy: Benthic Colonization Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Feeding	2010						x		x		x			3.5	δN15, δC13	Phase II Ecostudy: Basal Resource Utilization Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Tissue	2002											x		1.2, 1.4, 1.8, 2.0, 2.5, 2.8, 3.3, 3.7, 4.2, 4.7, 5.0	THg	Clam Tissue Study	JMU, EMU	Bowles, M.W. 2003, Biomonitoring of Mercury in the South River Using Asiatic Clam, Corbicula fluminea. Undergraduate Thesis. James Madison University, Harrisonburg, Virginia.
		2003											x		1.2, 1.8, 2.5, 5	THg, MeHg	Clam Tissue Study	JMU, EMU	Bowles, M.W. 2003, Biomonitoring of Mercury in the South River Using Asiatic Clam, Corbicula fluminea. Undergraduate Thesis. James Madison University, Harrisonburg, Virginia.
						x									1.2, 2.2	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
									x						1.2, 2.2	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
												x		x	1.2, 2.2	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
		2006					x	x							5.2	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
							x			x				x	2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
					x	x	x	x	x	x	x	x	x	x	2.0, 3.0, 4.2, 5.2	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007		x											2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x	x											2.0, 3.0, 4.2, 5.2	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x								2.0, 5.2	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
		2009					x			x					3.5	THg, δN15, δC13	Phase II Ecostudy: Aquatic Insect Metamorphosis Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
							x	x							3.5	THg, MeHg	Phase II Ecostudy: Asian Clam Uptake Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010						x		x					3.5	THg, MeHg	Phase II Ecostudy: Aquatic Invertebrates Uptake Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Toxicity	2010					x								3.5		Phase II Ecostudy: Laboratory Sediment Bioassays for Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
Fish																			
RRM 1 - 6	Population / Community	2006					x			x					5.2		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2010					x				x				3.5		Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Stomach Contents	2010					x				x	x			3.5	THg, MeHg	Phase II Ecostudy: Bass, Sunfish, and Forage Fish	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Tissue	2001				x									2.4	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
		2002				x									1.37, 2.4, 4.9	THg, MeHg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
		2003				x	x								1.2, 2.2	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
									x						1.2, 2.2	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
												x			1.2, 2.2	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
		2005				x	x								1.37, 2.4, 4.9	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
		2006					x			x					2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Forage Fish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007				x									1.37, 2.4, 4.9	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
							x								2.0, 5.2	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
		2010					x				x	x			3.5	THg, MeHg	Phase II Ecostudy: Bass	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
							x				x	x			3.5	THg, MeHg	Phase II Ecostudy: Forage Fish	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
							x				x				3.5	THg, MeHg	Phase II Ecostudy: Sunfish	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2011					x								3.5	THg, MeHg	Phase II Ecostudy: Bass	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
							x								4.2, 5.4	THg, MeHg	Floodplain Ponds Investigation	URS	
Herpetofauna																			
RRM 1 - 6	Tissue	2007			x	x	x								2.0, 5.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT	Hopkins, W.A., C.M. Bergeron, M.J. Hepner, B.D. Todd, J.D. Willson. 2011. From Individual-level responses to population-level change: individual and interactive effects of maternal and dietary mercury on amphibians along the South River, VA Final Report. Prepared for E.I. DuPont de Nemours Company.
Terrestrial Invertebrates																			
RRM 1 - 6	Tissue	2003				x									1.2	THg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
									x						1.2, 2.2	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
												x			1.2, 2.2	THg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
		2006										x	x	x	1.0, 2.1, 2.4, 5.0	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU	Cianchetti, J. 2009. Survey of the Mercury Content of Earthworms on the South River, Va., Floodplain. Thesis (M.S.). James Madison University.
		2008					x	x							3.0, 5.1	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Spiders	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
Birds																			
RRM 1 - 6	Blood	2005					x	x	x						NS	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
	Blood, Feather, Egg	2007				x	x								2.0, 5.0	THg	Pilot Assessment of Methyl-Mercury Availability to Mallards	BRI	Savoy, L. and D.C. Evers. 2008. Pilot assessment of methylmercury availability to Mallards on the South River, Virginia – 2008. Report BRI 2009-12 Rough Draft submitted to DuPont Corporate Remediation Group, Newark, Delaware and the U.S. Fish Wildl. Serv., Gloucester, Virginia. BioDiversity Research Institute, Gorham, ME. 43pp.
	Blood, Wing, Feather, Egg	2006				x	x	x	x	x					1.7, 2.0, 2.4, 2.7, 3.0, 4.1, 5.1	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
		2007					x	x	x						1.7, 2.0, 2.4, 2.7, 3.0, 4.1, 5.1	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
		2008					x	x	x						1.7, 2.0, 2.4, 2.7, 3.0, 4.1, 5.1	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
	Tissue, Liver	2008									x		x	x	2.6, 4.3	THg, MeHg, Total Solids	VADEQ Waterfowl Samples	VADEQ	
		2010										x			3.0, 5.1, 5.6	THg, MeHg, Total Solids	VADEQ Waterfowl Samples	VADEQ	
Mammals																			
RRM 1 - 6	Blood, Skin, Fur	2007						x							2.0	THg, MeHg	Pilot Assessment of Methyl-Mercury Availability to Bats	BRI	Yates, D., M. Moore, T. Kunz, and D.C. Evers. 2008. Pilot assessment of methylmercury availability to bats on the South River, Virginia - 2008. Report BRI 2009-16 submitted to DuPont Corporate Remediation Group, Newark, Delaware and the U.S. Fish Wildl. Serv., Gloucester, Virginia. BioDiversity Research Institute, Gorham, ME. 47pp.

Table 1-1
Ecological Study Data Matrix
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	INVESTIGATOR(S)	CITATION
Habitat and Geophysical Characterizations																			
RRM 6 - 16	Discharge Characterization	2009						x	x	x			x		8.5	Q (cfs)	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010						x							11.8	Q (cfs)	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Habitat Characterization	2005									x				7.1		Phase I Ecostudy: Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2006									x				11.8		Phase I Ecostudy: Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2009						x							8.5		Phase II Ecostudy: Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
					x										8.5, 8.8		Phase II Ecostudy: Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010				x									11.8		Phase II Ecostudy: Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Morphology Assessment	2005													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
		2006													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
		2007							x						NS		Comprehensive Geomorphological Study: Reconnaissance Investigation of Floodplain Deposits Formed Through Channel Migration	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
		2011							x						NS		Substrate and Aquatic Macrophyte Mapping	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
Physical and Chemical Monitoring / Assessments																			
RRM 6 - 16	Soil	2003				x	x					x			11.0 - 11.2, 11.4 - 11.7	THg	Forestry Center Soil	Berti	Berti, W.R.; A. Guiseppi-Elie; E. Quinn; R.H. Jensen; and D. Cocking. 2013. “Evaluation of Garden Crop Mercury Uptake and Potential Exposure from Consumption of Garden Crops Grown on Floodplain Soils.” Human and Ecological Risk Assessment 19:215-231
													x		11.5 - 11.6	THg	Forestry Center Garden	Berti	Berti, W.R.; A. Guiseppi-Elie; E. Quinn; R.H. Jensen; and D. Cocking. 2013. “Evaluation of Garden Crop Mercury Uptake and Potential Exposure from Consumption of Garden Crops Grown on Floodplain Soils.” Human and Ecological Risk Assessment 19:215-231
		2004						x							9.8 - 10.0, 11.6 - 11.7	THg	Floodplain Hg Sampling	UE	
								x							9.9 - 10	THg	Floodplain Hg Sampling	UE	
		2005			x										11.5 - 11.6	THg	Water Sampling	UE	
											x				9.9 - 10	THg, MeHg	Core Sampling	UE	
		2006						x			x				13.2 - 13.3	THg, MeHg, Mn, Fe, LOI	Flux Chamber Study (Loading)	DuPont	URS 2009. Technical Briefing Paper: Use of Benthic Flux Chambers to Measure Inorganic Mercury and Methylmercury Fluxes in the South River. South River Science Team Briefing Paper. March 2009.
											x		x		7.6, 9.8, 11.7, 13.9	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU	Cianchetti, J. 2009. Survey of the Mercury Content of Earthworms on the South River, Va., Floodplain. Thesis (M.S.). James Madison University.
							x								9.7 - 9.8	THg, MeHg, LOI, Other Analytes	Crimora Hot Spot	UE	
									x						9.7 - 9.9	THg, MeHg, LOI, Other Analytes	Turner Crimora Sediments	UE	
		2007										x			7.4 - 7.5, 8.1 - 8.2, 8.5 - 8.6, 8.8 - 8.9, 9.9 - 10, 12.8 - 12.9	THg, MeHg, VOCs	Fine Grained Sediment Study	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
															7.4, 7.7, 8.8, 9.8, 11.6, 13.1, 15.4	THg, MeHg	Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
		2008		x	x	x									6.1 - 16.0	THg	Phase II Ecostudy: Floodplain Soil Investigation	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
				x	x		x	x							7.4 - 7.5, 7.7 - 7.8, 8.0 - 8.1, 8.2 - 8.3, 8.4 - 8.9, 9.2 - 9.3, 9.4 - 9.6, 9.7 - 9.8, 13.1 - 13.2 , 13.7 -13.8, 15.3 - 15.4	THg, MeHg	Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
															7.4, 7.7, 8.8, 9.8, 11.6, 13.1, 15.4	THg, MeHg	Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
		2009			x										8.5	THg	Phase II Ecostudy: River Bank Soil for Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010						x	x						11.8	THg, MeHg	Mesocosm Study	JMU	Brent, R.N., 2010. Use of experimental stream mesocosms to assess mercury uptake in periphyton. South River Science Team, Harrisonburg, Virginia, October 5, 2010.
						x									11.8	THg	Phase II Ecostudy: River Bank Soil for Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2011					x								9.8 - 9.9	THg	Floodplain Soils Investigation	URS	URS. 2014b. Floodplain Laboratory Pilot Report for AOC 4. Former DuPont Waynesboro Plant, Waynesboro, Virginia. Draft. May 2014.
	Sediment	2003									x				11.9 - 12	THg, Metals	VADEQ Historical Floodplain Monitoring	VADEQ	
		2005								x					11.5 - 11.6	THg, LOI, Other Analytes	Comprehensive Geomorphological Study: Bank Erosion and Mercury Content	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
											x				9.9 - 10.0, 11.6 - 11.7	THg, MeHg, LOI, Other Analytes	Transect Program	UE	
		2006			x	x	x	x	x	x	x	x	x	x	7.1, 8.7, 11.8, 8.2, 8.4, 8.6, 9.9, 12.7, 12.8	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007								x		x		x	6.2, 7.4, 8.6, 8.7, 9.9, 14.6	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
										x	x				6.5 - 6.6, 7.4 - 7.5, 8.5 - 8.6, 9.4 - 9.6, 10.4 - 10.5, 11.3 - 11.4, 12.3 - 12.4, 13.2 -13.3, 14.2 -14.3, 15.2 -15.3	THg, Other Metals	VADEQ Sediment Sampling	VADEQ	
			x	x											7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
												x			7.4, 8.2, 8.4, 8.6, 9.9, 12.7, 12.8	THg, MeHg	Phase I Ecostudy: Channel Margin Deposit Cores for Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2008		x		x		x		x		x			6.2, 7.4, 8.6, 8.7, 9.9, 14.6	THg, MeHg	Phase II Ecostudy: Interstitial Sediment	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2009			x										8.5, 8.8	THg	Phase II Ecostudy: Near-Bank Sediment for Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010				x									11.8	THg, MeHg, PCBs, PAHs, Herbicides, Pesticides, Other Analytes	Phase II Ecostudy: Interstitial Sediment for Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
						x									11.8	THg	Phase II Ecostudy: Near-Bank Sediment for Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Ground Water	2006					x								11.5 - 11.6	THg	Forest Station Ground Water	Berti	
		2007	x	x											11.5 - 11.7	THg	Turner Wells and Ultra	UE	
		2009			x										6.1 - 16.0	Spatial Analysis	River Corridor Infrared Thermal Imaging	SITS	
	Pore Water	2006							x						11.5 - 11.6	THg	Bank Flux Pore Water and Surface Water	UE	
												x			11.5 - 11.6	THg	Turner Pore / Well Water I	UE	
		2007							x						9.7 - 9.8, 11.5 - 11.6	MeHg	Turner Spin Pore Waters	UE	
		2008						x							9.8 - 9.9	Fe, Mn	Turner Hyporheic Samples	UE	
		2009						x	x	x			x		8.5	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010						x							11.8	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Surface Water	2002								x					9.8 - 9.9	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
								x							9.8 - 9.9	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2003							x		x			x	9.8 - 9.9	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
		2004								x					6 - 6.1, 7.4 - 7.5, 9.9 - 10, 11.6 - 11.7	THg, MeHg, TSS	Hg Speciation Study	UE	
				x		x		x	x		x		x		9.8 - 9.9	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
												x			9.8 - 9.9	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
											x				9.9 - 10, 11.6 - 11.7	THg, MeHg, TSS	Flood Sampling	UE	
		2005			x										10.7 - 10.8	THg, Metals, Nutrients, Other Analytes	VADEQ Probability Monitoring	VADEQ	
												x			11.5 - 11.6	THg	Forest Station Groundwater	Berti	
					x		x		x		x		x		11.6 - 11.7	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
			x												11.6 - 11.7	TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
					x										6 - 6.1, 6.2 - 6.3, 6.4 - 6.5, 6.5 - 6.6, 6.8 - 6.9, 7 - 7.1, 7.2 - 7.3, 7.4 - 7.5, 7.7 - 7.8, 7.8 - 7.9, 8.1 - 8.2, 8.5 - 8.6, 8.7 - 8.8, 8.9 - 9, 9.2 - 9.3, 9.5 - 9.6, 9.6 - 9.7, 9.7 - 9.8, 9.8 - 9.9	THg, MeHg, Metals, TSS, Other Analytes	Water Sampling	UE	
							x								6 - 6.1, 6.8 - 6.9, 7.7 - 7.8, 8.7 - 8.8, 9.6 - 9.7, 10.1 - 10.2, 10.4 - 10.5, 10.8 - 10.9, 11.3 - 11.4, 11.6 - 11.7, 12 - 12.1, 12.4 - 12.5, 12.9 - 13, 13.2 - 13.3, 13.7 - 13.8, 14.1 - 14.2, 14.7 - 14.8, 15.3 - 15.4	THg, MeHg, TSS	Water Sampling	UE	
											x				6 - 6.1, 9.7 - 9.8, 9.9 - 10, 11.6 - 11.7	THg, MeHg, TSS	Transect Program	UE	
							x								9.8 - 9.9	Nutrients, E. Coli, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring	VADEQ	
			x												9.8 - 9.9	Nutrients	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
				x											9.9 - 10, 11.6 - 11.7	THg, MeHg, TSS	Surface Water/Sediments	UE	
		2006						x		x			x		9.9	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x		x		x		x		x		x		11.6 - 11.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
								x			x				13.2 - 13.3	THg, MeHg, Mn, Fe, LOI	Flux Chamber Study (Loading)	DuPont	URS 2009. Technical Briefing Paper: Use of Benthic Flux Chambers to Measure Inorganic Mercury and Methylmercury Fluxes in the South River. South River Science Team Briefing Paper. March 2009.
					x	x	x	x	x	x	x	x	x	x	7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x								9.7 - 9.9	THg, MeHg	Crimora Hot Spot	UE	
									x				x		9.7 - 9.9	THg, MeHg	Crimora Surface Waters	UE	
		2007			x										9.9	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
						x									11.5 - 11.6	THg	Turner Uptake Study	UE	
			x		x		x		x		x		x		11.6 - 11.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
										x		x		x	6.2, 7.4, 8.6, 8.7, 9.9, 14.6	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
												x			6.7, 7.2, 8.8, 9.6	THg, MeHg	Phase II Ecostudy: Targeted Tributary Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
			x	x		x	x								7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x	x											9.7 - 9.9	THg, MeHg	Crimora Surface Waters	UE	
		2008	x		x		x		x		x		x		11.6 - 11.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
							x								6.2, 12.8	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
				x				x		x		x			6.2, 7.4, 8.6, 8.7, 9.9, 14.6	THg, MeHg	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
										x					6.2, 7.4, 8.7, 12.8	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
							x								6.7, 7.2, 8.6, 8.8, 9.9	THg, MeHg	Phase II Ecostudy: Targeted Tributary Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
			x	x	x	x	x	x	x	x	x	x	x	x	9.8 - 9.9	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
		2009								x					8.5	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
								x	x	x			x		8.5	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
			x												11.6 - 11.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
				x			x			x					6.2, 7.4, 8.6, 8.7, 9.9, 14.6	THg, MeHg	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
			x												9.8 - 9.9	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	

Table 1-1
Ecological Study Data Matrix
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	INVESTIGATOR(S)	CITATION
RRM 6-16	Surface Water	2010						x	x						11.8	THg, MeHg	Mesocosm Study	JMU	Brent, R.N., 2010. Use of experimental stream mesocosms to assess mercury uptake in periphyton. South River Science Team, Harrisonburg, Virginia, October 5, 2010.
								x							11.8	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
									x	x					11.8	THg, MeHg, Nutrients	Sewage Treatment Plant Surface Water Studies	JMU	Brent, R. 2011. Impacts of Waynesboro Wastewater Treatment Plant Upgrades on South River. South River Science Team, Harrisonburg, VA. April 26.
			x	x	x		x	x	x	x	x	x	x	x	6.2, 7.4, 8.6, 8.7, 9.9, 14.6	THg, MeHg, Nutrients, Other Analytes	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
					x		x		x		x		x		9.8 - 9.9	Nitrate, Nitrite, Nitrogen	VADEQ Surface Water	VADEQ	
		2011		x				x		x		x			11.8	THg, MeHg	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
			x		x		x		x		x		x		11.8	THg, MeHg	VADEQ Surface Water	VADEQ	
							x								6.9, 7.7, 9.4, 9.6	THg, MeHg	Floodplain Ponds Investigation	URS	
Biological Monitoring / Assessments																			
Aquatic Vegetation / Algae																			
RRM 6 - 16	Tissue	2006								x					7.1	THg, MeHg	Phase I Ecostudy: Macrophytes	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x			x				x	7.1	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x	x							11.8	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
		2007		x											7.1	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x		x						8.7, 11.8	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
		2008						x		x					11.6	THg, MeHg, δN15, δC13	VIMS Sed and Periphyton Study 2008	VIMS	Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
		2010						x	x	x					11.8	THg, MeHg	Mesocosm Study	JMU	Brent, R.N., 2010. Use of experimental stream mesocosms to assess mercury uptake in periphyton. South River Science Team, Harrisonburg, Virginia, October 5, 2010.
Aquatic Invertebrates																			
RRM 6 - 16	Population / Community	2006					x			x				x	11.8, 14.6		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007		x											11.8, 14.6		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2010				x									11.8		Phase II Ecostudy: Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2011					x	x							11.8		Phase II Ecostudy: Benthic Colonization Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Feeding	2010						x		x		x			11.8	δN15, δC13	Phase II Ecostudy: Basal Resource Utilization Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Tissue	2003											x		11.6	THg, MeHg	Clam Transplant Study	JMU, EMU	Bowles, M.W. 2003, Biomonitoring of Mercury in the South River Using Asiatic Clam, Corbicula fluminea. Undergraduate Thesis. James Madison University, Harrisonburg, Virginia.
						x									11.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
									x						11.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
												x		x	11.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
		2004	x		x		x	x							11.6	THg, MeHg	Clam Transplant Study	JMU, EMU	Bowles, M.W. 2003, Biomonitoring of Mercury in the South River Using Asiatic Clam, Corbicula fluminea. Undergraduate Thesis. James Madison University, Harrisonburg, Virginia.
		2006					x	x							11.8	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
							x			x				x	7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
					x	x	x	x	x	x	x	x	x	x	7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007		x											7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x	x											7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x		x						8.7, 11.8	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
		2009					x			x					8.5, 11.8	THg, δN15, δC13	Phase II Ecostudy: Aquatic Insect Metamorphosis Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
							x	x							8.5	THg, MeHg	Phase II Ecostudy: Asian Clam Uptake Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010						x		x					11.8	THg, MeHg	Phase II Ecostudy: Aquatic Invertebrates Uptake Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Toxicity	2010								x					11.8		Phase II Ecostudy: Field Microcosm Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
							x								11.8		Phase II Ecostudy: Laboratory Sediment Bioassays for Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
Fish																			
RRM 6 - 16	Population / Community	2006					x			x					11.8, 14.6		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2010					x				x				11.8		Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Stomach Contents	2010					x				x	x			11.8		Phase II Ecostudy: Bass, Sunfish, and Forage Fish	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Tissue	2002				x									9.8	THg, MeHg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
		2003				x									11.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
									x						11.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
												x			11.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
		2005				x									9.9	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
		2006					x			x					7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg	Phase I Ecostudy: Forage Fish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007				x									11.6	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
							x								8.7, 11.8	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
		2009					x				x				11.8	THg, MeHg	Phase II Ecostudy: Bass	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010					x				x	x			11.8	THg, MeHg	Phase II Ecostudy: Bass	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
							x				x	x			11.8	THg, MeHg	Phase II Ecostudy: Forage Fish	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
							x				x				11.8	THg, MeHg	Phase II Ecostudy: Sunfish	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2011					x								6.9, 7.7, 9.4, 9.6	THg, MeHg	Floodplain Ponds Investigation	URS	
							x								11.8	THg, MeHg	Phase II Ecostudy: Bass	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
Herpetofauna																			
RRM 6 - 16	Tissue	2006					x	x	x						9.7, 12.8, 13.7	THg, MeHg, δN15, δC13	Turtle Study	VT	Hopkins, B.C., J.D. Wilson, and W.A. Hopkins. 2013. Mercury exposure is associated with negative effects on turtle reproduction. Environmental Science and Technology 47:2416-2422.; Bergeron, C. M., J. F. Husak, J. M. Unrine, C. S. Romanek, and W. A. Hopkins. 2007. Influence of feeding ecology on blood mercury concentrations in four species of turtles. Environmental Toxicology and Chemistry, Vol. 26, No. 8, pp. 1733–1741
		2007			x	x	x								9.0, 11.0, 13.0, 14.0, 16.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT	Hopkins, W.A., C.M. Bergeron, M.J. Hepner, B.D. Todd, J.D. Willson. 2011. From Individual-level responses to population-level change: individual and interactive effects of maternal and dietary mercury on amphibians along the South River, VA Final Report. Prepared for E.I. DuPont de Nemours Company.
		2008			x	x									9.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT	Hopkins, W.A., C.M. Bergeron, M.J. Hepner, B.D. Todd, J.D. Willson. 2011. From Individual-level responses to population-level change: individual and interactive effects of maternal and dietary mercury on amphibians along the South River, VA Final Report. Prepared for E.I. DuPont de Nemours Company.
		2009				x									9.0, 14.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT	Hopkins, W.A., C.M. Bergeron, M.J. Hepner, B.D. Todd, J.D. Willson. 2011. From Individual-level responses to population-level change: individual and interactive effects of maternal and dietary mercury on amphibians along the South River, VA Final Report. Prepared for E.I. DuPont de Nemours Company.
Terrestrial Invertebrates																			
RRM 6 - 16	Tissue	2003				x									11.6	THg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
									x						11.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
												x			11.6	THg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
		2006									x		x		7.6, 9.8, 11.7, 13.9	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU	Cianchetti, J. 2009. Survey of the Mercury Content of Earthworms on the South River, Va., Floodplain. Thesis (M.S.). James Madison University.
		2007					x	x	x						8.6, 9.6, 11, 11.4, 12, 14.3, 14.8	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Spiders	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
		2008					x	x							9.6, 11.4, 14.5	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Spiders	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.

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AOC 4 RFI Report
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South River and a Segment of the South Fork Shenandoah River, Va

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	INVESTIGATOR(S)	CITATION
Birds																			
RRM 6 - 16	Blood	2005					x	x	x						NS	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
	Blood, Feather	2007				x	x								11.0	THg	Pilot Assessment of Methyl-Mercury Availability to Mallards	BRI	Savoy, L. and D.C. Evers. 2008. Pilot assessment of methylmercury availability to Mallards on the South River, Virginia – 2008. Report BRI 2009-12 Rough Draft submitted to DuPont Corporate Remediation Group, Newark, Delaware and the U.S. Fish Wildl. Serv., Gloucester, Virginia. BioDiversity Research Institute, Gorham, ME. 43pp.
	Blood, Feather, Egg	2007				x	x								17.0	THg	Pilot Assessment of Methyl-Mercury Availability to Mallards	BRI	Savoy, L. and D.C. Evers. 2008. Pilot assessment of methylmercury availability to Mallards on the South River, Virginia – 2008. Report BRI 2009-12 Rough Draft submitted to DuPont Corporate Remediation Group, Newark, Delaware and the U.S. Fish Wildl. Serv., Gloucester, Virginia. BioDiversity Research Institute, Gorham, ME. 43pp.
	Blood, Wing, Feather, Egg	2006				x	x	x	x	x					8.6, 9.0, 9.5, 9.6, 11.0, 11.4, 11.5, 11.8, 12.0, 12.1, 13.8, 14.3, 14.4, 14.5, 14.8, 15.5	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
		2007		x		x	x	x	x	x	x			x	8.6, 9.0, 9.5, 9.6, 11.0, 11.4, 11.5, 11.8, 12.0, 12.1, 13.8, 14.3, 14.4, 14.5, 14.8, 15.5	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
		2008				x	x	x	x						8.6, 9.0, 9.5, 9.6, 11.0, 11.4, 11.5, 11.8, 12.0, 12.1, 13.8, 14.3, 14.4, 14.5, 14.8, 15.5	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
	Tissue, Liver	2008									x		x	x	7.0, 7.6, 8.5, 8.9, 11.0, 12.8 14.5, 15.4	THg, MeHg, Total Solids	VADEQ Waterfowl Samples	VADEQ	
		2010										x			7.8, 8.3, 10.8	THg, MeHg, Total Solids	VADEQ Waterfowl Samples	VADEQ	
Mammals																			
RRM 6 - 16	Blood, Muscle, Fur	2008													10.0, 12.0, 14.5, 16.0, 16.7	THg, MeHg	Pilot Assessment of Methyl-Mercury Availability to Muskrat and Shrews	BRI	
	Blood, Skin, Fur	2007						x							12.0, 16.0	THg, MeHg	Pilot Assessment of Methyl-Mercury Availability to Bats	BRI	Yates, D., M. Moore, T. Kunz, and D.C. Evers. 2008. Pilot assessment of methylmercury availability to bats on the South River, Virginia - 2008. Report BRI 2009-16 submitted to DuPont Corporate Remediation Group, Newark, Delaware and the U.S. Fish Wildl. Serv., Gloucester, Virginia. BioDiversity Research Institute, Gorham, ME. 47pp.
	Tissue, Liver	2010			x										11.8	THg, MeHg	VADEQ White Tailed Deer Samples	VADEQ	
Habitat and Geophysical Characterizations																			
RRM 16 - 24	Discharge Characterization	2000	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
		2001	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
		2002	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
		2003	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
		2004	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
		2005	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
		2006	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
		2007	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
		2008	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
		2009	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
								x	x	x			x		23.5	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
	Habitat Characterization	2005									x				19.0, 22.4		Phase I Ecostudy: Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2006									x				19.0, 22.4		Phase I Ecostudy: Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2009			x			x							23.5		Phase II Ecostudy: Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Morphology Assessment	2005													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
		2006													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
Physical and Chemical Monitoring / Assessments																			
RRM 16 - 24	Soil	2004						x							19.7 - 19.8, 22.0 - 22.1, 23.9 - 24.0	THg	Floodplain Hg Sampling	UE	
		2006										x			19.8, 24.0	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU	Cianchetti, J. 2009. Survey of the Mercury Content of Earthworms on the South River, Va., Floodplain. Thesis (M.S.). James Madison University.
		2007													19.8, 22.3, 22.6, 23.1	THg, MeHg	Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
		2008		x	x	x									16.1 - 24.0	THg	Phase II Ecostudy: Floodplain Soil Investigation	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
															19.8, 22.3, 22.6, 23.1	THg, MeHg	Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
				x		x	x								22.3 - 22.4, 22.6 - 22.7, 23.1 - 23.2, 23.4 - 23.5	THg, MeHg	Comprehensive Geomorphological Study: Bank Erosion and Mercury Content	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
		2009			x										23.5	THg	Phase II Ecostudy: River Bank Soil for Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2011					x								23.1 - 23.4, 23.4 - 23.5	THg	Floodplain Soils Investigation	URS	URS. 2014b. Floodplain Laboratory Pilot Report for AOC 4. Former DuPont Waynesboro Plant, Waynesboro, Virginia. Draft. May 2014.
	Sediment	2003									x				16.4 - 16.5	THg, Metals	VADEQ Historical Floodplain Monitoring	VADEQ	
		2005									x				16.5 - 16.6, 22.0 - 22.1	THg, MeHg, LOI, Other Analytes	Transect Program	UE	
		2006			x	x	x	x	x	x	x	x	x	x	19.0, 22.4	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007								x					17.1 - 17.2, 18.2 - 18.3, 19.2 - 19.3, 20.2 - 20.3, 21.2 - 21.3, 22.1 - 22.2, 23.0 - 23.1, 23.8 - 23.9	THg, Other Metals	VADEQ Sediment Sampling	VADEQ	
			x	x											19.0, 22.4	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2009			x										23.5	THg	Phase II Ecostudy: Near-Bank Sediment for Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010				x									23.5	THg, MeHg, PCBs, PAHs, Herbicides, Pesticides, Other Analytes	Phase II Ecostudy: Interstitial Sediment for Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Ground Water	2009			x										16.1 - 24.0	Spatial Analysis	River Corridor Infrared Thermal Imaging	SITS	
	Pore Water	2007							x						23.8 - 23.9	MeHg	Turner Spin Pore Waters	UE	
		2009						x	x	x			x		23.5	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Surface Water	2000		x	x	x	x	x	x	x	x	x	x	x	16.4 - 16.5	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
										x		x		x	16.4 - 16.5	THg, Metals, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2001		x		x		x		x		x			16.4 - 16.5	THg, Metals, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
			x	x	x	x	x	x	x		x			x	16.4 - 16.5, 22 - 22.1	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
		2002		x		x		x	x	x	x	x	x	x	16.4 - 16.5, 22 - 22.1	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
			x		x			x		x		x		x	16.4 - 16.5, 22 - 22.1	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2003		x		x		x		x		x			16.4 - 16.5	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
			x	x	x	x	x	x	x		x			x	16.4 - 16.5, 22 - 22.1	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
		2004	x		x		x		x		x		x		16.4 - 16.5	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
			x	x		x		x		x	x	x			16.4 - 16.5, 22 - 22.1	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
										x					16.5 - 16.6, 19.8 - 19.9	THg, MeHg, TSS	Hg Speciation Study	UE	
											x				16.5 - 16.6, 22 - 22.1	THg, MeHg, TSS	Flood Sampling	UE	
		2005					x								16.0 - 16.1, 16.5 - 16.6, 17.2 - 17.3, 17.8 - 17.9, 18.4 - 18.5, 19.0 - 19.1, 19.7 - 19.8, 20.2 - 20.3, 20.8 - 20.9, 21.4 - 21.5, 22.1 - 22.2, 22.7 - 22.8, 23.2 - 23.3, 23.9 - 24	THg, MeHg, TSS	Water Sampling	UE	
					x		x		x			x	x	x	16.4 - 16.5	Nutrients, E. Coli, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring	VADEQ	
			x												16.4 - 16.5	Nutrients	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
					x				x					x	16.4 - 16.5	THg, TSS	VADEQ Storm Sampling	VADEQ	
					x		x		x		x		x		16.4 - 16.5, 22 - 22.1	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
			x												16.4 - 16.5, 22 - 22.1	TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
				x											16.5 - 16.6, 19.8 - 19.9, 22 - 22.1	THg, MeHg, TSS	Surface Water/Sediments	UE	
											x				16.5 - 16.6, 19.8 - 19.9, 22 - 22.1, 23.9 - 24	THg, MeHg, TSS	Transect Program	UE	
		2006	x			x	x		x		x		x		16.4 - 16.5	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
				x		x									16.4 - 16.5	Nutrients, Bacteria, THg, Other Analytes	VADEQHIST Fishkill	VADEQ	
			x												16.4 - 16.5	THg, TSS	VADEQHIST Storm	VADEQ	
			x		x		x		x		x		x		16.4 - 16.5, 22.0 - 22.1	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
										x			x		16.5, 19.5, 23.9	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
								x							16.5, 23.9	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
					x	x	x	x	x	x	x	x	x	x	19.0, 22.4	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007								x		x		x	16.5	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x	x		x	x								19.0	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x	x	x	x	x	x							16.4 - 16.5	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
					x	x									16.4 - 16.5, 19.7 - 19.8	Nutrients, Bacteria, THg, Other Analytes	VADEQHIST Fishkill	VADEQ	
			x		x		x		x		x		x		16.4 - 16.5, 22.0 - 22.1	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
					x										16.5, 19.5, 23.9	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2008		x				x		x		x			16.5, 19.9, 23.9	THg, MeHg	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
			x		x		x		x		x		x		16.4 - 16.5, 22.0 - 22.1	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2009						x	x	x			x		23.5	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
				x			x			x					16.5, 19.9, 23.9	THg, MeHg	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
			x												16.4 - 16.5	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
			x												16.4 - 16.5, 22.0 - 22.1	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2010							x	x					23.4	THg, MeHg, Nutrients	Sewage Treatment Plant Surface Water Studies	JMU	Brent, R. 2011. Impacts of Waynesboro Wastewater Treatment Plant Upgrades on South River. South River Science Team, Harrisonburg, VA. April 26.
			x												16.5, 19.9, 23.9	THg, MeHg, Nutrients, Other Analytes	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
				x	x		x	x	x	x	x	x	x	x	16.5, 23.9	THg, MeHg, Nutrients, Other Analytes	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
					x		x		x		x		x		16.4 - 16.5, 23.8 - 23.9	Nitrate, Nitrite, Nitrogen	VADEQ Surface Water	VADEQ	
		2011		x				x		x		x			23.5	THg, MeHg	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
			x		x		x		x		x		x		23.5	THg, MeHg	VADEQ Surface Water	VADEQ	
							x								17.1, 17.3, 17.5, 22.1	THg, MeHg	Floodplain Ponds Investigation	URS	

Table 1-1
Ecological Study Data Matrix
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	INVESTIGATOR(S)	CITATION
Biological Monitoring / Assessments																			
Aquatic Vegetation / Algae																			
RRM 16 - 24	Tissue	2006					x	x							19.0	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
RRM 16 - 24	Tissue	2006								x					19.0, 22.4	THg, MeHg	Phase I Ecostudy: Macrophytes	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 16 - 24	Tissue	2006					x			x				x	19.0, 22.4	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 16 - 24	Tissue	2007					x		x						22.4	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
RRM 16 - 24	Tissue	2007		x											19.0, 22.4	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 16 - 24	Tissue	2008						x		x					22.1	THg, MeHg, δN15, δC13	VIMS Sed and Periphyton Study 2008	VIMS	Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
Aquatic Invertebrates																			
RRM 16 - 24	Population / Community	2006					x			x				x	19.0, 22.4		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 16 - 24	Population / Community	2007		x											19.0, 22.4		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 16 - 24	Population / Community	2010				x									23.5		Phase II Ecostudy: Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 16 - 24	Population / Community	2011					x	x							23.5		Phase II Ecostudy: Benthic Colonization Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 16 - 24	Feeding	2010						x		x		x			23.5	δN15, δC13	Phase II Ecostudy: Basal Resource Utilization Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 16 - 24	Tissue	2003											x		24.0	THg, MeHg	Clam Tissue Study	JMU, EMU	Bowles, M.W. 2003, Biomonitoring of Mercury in the South River Using Asiatic Clam, Corbicula fluminea. Undergraduate Thesis. James Madison University, Harrisonburg, Virginia.
RRM 16 - 24	Tissue	2006					x	x							19.0	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
RRM 16 - 24	Tissue	2006					x			x				x	19.0, 22.4	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 16 - 24	Tissue	2006			x	x	x	x	x	x	x	x	x	x	19.0, 22.4	THg, MeHg	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 16 - 24	Tissue	2007					x								22.4	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
RRM 16 - 24	Tissue	2007		x											19.0, 22.4	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 16 - 24	Tissue	2007	x	x											19.0, 22.4	THg, MeHg	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 16 - 24	Tissue	2009					x			x					22.1	THg, δN15, δC13	Phase II Ecostudy: Aquatic Insect Metamorphosis Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 16 - 24	Tissue	2009					x	x							23.5	THg, MeHg	Phase II Ecostudy: Asian Clam Uptake Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 16 - 24	Tissue	2010						x		x					23.5	THg, MeHg	Phase II Ecostudy: Aquatic Invertebrates Uptake Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 16 - 24	Toxicity	2010					x								23.5		Phase II Ecostudy: Laboratory Sediment Bioassays for Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
Fish																			
RRM 16 - 24	Population / Community	2006					x			x					19.0, 22.4		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 16 - 24	Population / Community	2010					x				x				23.5		Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 16 - 24	Stomach Contents	2010					x				x	x			23.5		Phase II Ecostudy: Bass, Sunfish, and Forage Fish	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 16 - 24	Tissue	2002				x									19.8	THg, MeHg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
RRM 16 - 24	Tissue	2005				x									19.8	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
RRM 16 - 24	Tissue	2006					x			x					19.0, 22.4	THg, MeHg	Phase I Ecostudy: Forage Fish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
RRM 16 - 24	Tissue	2007					x								22.4	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS	Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. DuPont de Nemours and Company.;Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
RRM 16 - 24	Tissue	2007				x									16.5, 22.1	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
RRM 16 - 24	Tissue	2009					x				x				23.5	THg, MeHg	Phase II Ecostudy: Bass	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 16 - 24	Tissue	2010					x				x	x			23.5	THg, MeHg	Phase II Ecostudy: Forage Fish	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 16 - 24	Tissue	2010					x				x				23.5	THg, MeHg	Phase II Ecostudy: Sunfish	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 16 - 24	Tissue	2010					x				x				NS	THg, MeHg	Phase II Ecostudy: Bass	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
RRM 16 - 24	Tissue	2011					x								17.1, 17.3, 17.5, 22.1	THg, MeHg	Floodplain Ponds Investigation	URS	
RRM 16 - 24	Tissue	2011					x								23.5	THg, MeHg	Phase II Ecostudy: Bass	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
Herpetofauna																			
RRM 16 - 24	Tissue	2006					x	x							16.7, 20.1	THg, MeHg, δN15, δC13	Turtle Study	VT	Hopkins, B.C., J.D. Wilson, and W.A. Hopkins. 2013. Mercury exposure is associated with negative effects on turtle reproduction. Environmental Science and Technology 47:2416-2422.; Bergeron, C. M., J. F. Husak, J. M. Unrine, C. S. Romanek, and W. A. Hopkins. 2007. Influence of feeding ecology on blood mercury concentrations in four species of turtles. Environmental Toxicology and Chemistry, Vol. 26, No. 8, pp. 1733–1741
RRM 16 - 24	Tissue	2007				x	x								20.0, 22.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT	Hopkins, W.A., C.M. Bergeron, M.J. Hepner, B.D. Todd, J.D. Willson. 2011. From Individual-level responses to population-level change: individual and interactive effects of maternal and dietary mercury on amphibians along the South River, VA Final Report. Prepared for E.I. DuPont de Nemours Company.
RRM 16 - 24	Tissue	2008				x									20.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT	Hopkins, W.A., C.M. Bergeron, M.J. Hepner, B.D. Todd, J.D. Willson. 2011. From Individual-level responses to population-level change: individual and interactive effects of maternal and dietary mercury on amphibians along the South River, VA Final Report. Prepared for E.I. DuPont de Nemours Company.
Terrestrial Invertebrates																			
RRM 16 - 24	Tissue	2006										x			19.8, 24.0	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU	Cianchetti, J. 2009. Survey of the Mercury Content of Earthworms on the South River, Va., Floodplain. Thesis (M.S.). James Madison University.
RRM 16 - 24	Tissue	2007					x	x							17.4, 19.6, 19.8, 21.9, 23.8		Examining the Fate and Effects of Mercury Contamination on Spiders	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
RRM 16 - 24	Tissue	2008					x	x							19.8, 21.9, 23.8		Examining the Fate and Effects of Mercury Contamination on Spiders	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
Birds																			
RRM 16 - 24	Blood	2005					x	x	x						NS	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
RRM 16 - 24	Blood, Feather, Egg	2007				x	x								20.0, 24	THg	Pilot Assessment of Methyl-Mercury Availability to Mallards	BRI	Savoy, L. and D.C. Evers. 2008. Pilot assessment of methylmercury availability to Mallards on the South River, Virginia – 2008. Report BRI 2009-12 Rough Draft submitted to DuPont Corporate Remediation Group, Newark, Delaware and the U.S. Fish Wildl. Serv., Gloucester, Virginia. BioDiversity Research Institute, Gorham, ME. 43pp.
RRM 16 - 24	Blood, Wing, Feather, Egg	2006				x	x	x	x	x				x	17.4, 18.6, 19.6, 19.8, 21.9, 23.8	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
RRM 16 - 24	Blood, Wing, Feather, Egg	2007	x			x	x	x	x	x				x	17.4, 18.6, 19.6, 19.8, 21.9, 23.8	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
RRM 16 - 24	Blood, Wing, Feather, Egg	2008				x	x	x							17.4, 18.6, 19.6, 19.8, 21.9, 23.8	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
RRM 16 - 24	Tissue, Liver	2008									x		x	x	16.2, 19.1	THg, MeHg, Total Solids	VADEQ Waterfowl Samples	VADEQ	
Mammals																			
RRM 16 - 24	Blood, Skin, Fur	2006							x	x					17.0, 18	THg, MeHg	Pilot Assessment of Methyl-Mercury Availability to Bats	BRI	Yates, D., M. Moore, T. Kunz, and D.C. Evers. 2008. Pilot assessment of methylmercury availability to bats on the South River, Virginia - 2008. Report BRI 2009-16 submitted to DuPont Corporate Remediation Group, Newark, Delaware and the U.S. Fish Wildl. Serv., Gloucester, Virginia. BioDiversity Research Institute, Gorham, ME. 47pp.
Habitat and Geophysical Characterizations																			
Reference	Discharge Characterization	2000	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
Reference	Discharge Characterization	2001	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
Reference	Discharge Characterization	2002	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
Reference	Discharge Characterization	2003	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
Reference	Discharge Characterization	2004	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
Reference	Discharge Characterization	2005	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
Reference	Discharge Characterization	2006	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
Reference	Discharge Characterization	2007	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
Reference	Discharge Characterization	2008	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
Reference	Discharge Characterization	2009	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.
Reference	Discharge Characterization	2010	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS	USGS (U.S. Geological Survey), 2007. National Water Information System: Web Interface. Updated: January 31, 2013. Available from: http://waterdata.usgs.gov/nwis/nwis.

Table 1-1
Ecological Study Data Matrix
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	INVESTIGATOR(S)	CITATION
Reference	Precipitation Monitoring	2000	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA	
		2001	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA	
		2002	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA	
		2003	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA	
		2004	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA	
		2005	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA	
		2006	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA	
		2007	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA	
		2008	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA	
		2009	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA	
		2010	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA	
	Habitat Characterization	2005									x				NR - 01		Phase I Ecostudy: Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2006									x				NR - 01		Phase I Ecostudy: Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007											x		MR - 01		Phase I Ecostudy: Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2010			x	x									MR - 01		Phase II Ecostudy: Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
					x										MR - 01		Phase II Ecostudy: Phase II Site Characterization	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
Physical and Chemical Monitoring / Assessments																			
Reference Site	Soil	2003										x			-0.6 - -0.5, -0.5 - -0.4, -0.1 - -0.0	THg	Greenway Sampling	UE	
		2006										x			-1.5	THg, MeHg	Survey of the Mercury Content of Earthworms on the South River Virginia Floodplain	JMU	Cianchetti, J. 2009. Survey of the Mercury Content of Earthworms on the South River, Va., Floodplain. Thesis (M.S.). James Madison University.
											x				-2.6 - -2.5	THg, MeHg, LOI	Flux Chamber Study (Loading)	DuPont	URS 2009. Technical Briefing Paper: Use of Benthic Flux Chambers to Measure Inorganic Mercury and Methylmercury Fluxes in the South River. South River Science Team Briefing Paper. March 2009.
		2010						x	x						NR	THg, MeHg	Mesocosm Study	JMU	Brent, R.N., 2010. Use of experimental stream mesocosms to assess mercury uptake in periphyton. South River Science Team, Harrisonburg, Virginia, October 5, 2010.
	Sediment	2003			x								x		-4.1 - -4.2	THg, Metals, VOCs	VADEQ Historical Floodplain Sediments	VADEQ	
													x		-4.1 - -4.2	VOCs, Pesticides, PCBs	VADEQ Probability Monitoring	VADEQ	
		2004					x								-0.5 - -0.1	THg, Other Analytes	Sediment Sampling	UE	
		2005								x					-2.7 - -2.8	THg, LOI, Other Analytes	Comprehensive Geomorphological Study: Bank Erosion and Mercury Content	UD	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. September 2012. Appendix B Geomorphology Report
											x				-2.7 - -2.8	THg, MeHg, LOI, Other Analytes	Transect Program	UE	
		2006										x			-1.0 , -0.7	THg, MeHg	Mercury Source Tracing and Mechanistic Source Studies	RTG, UE	
					x	x	x	x	x	x	x	x	x	x	NR - 01	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
					x	x	x	x	x	x	x	x	x	x	NR - 02	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
					x	x	x	x	x	x	x	x	x	x	SR - 01	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007								x					0 - -0.1	THg, Other Metals	VADEQ Sediment Sampling	VADEQ	
			x	x											NR - 01	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x	x											NR - 02	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x	x											SR - 01	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2010				x									MR - 01	THg, MeHg, PCBs, PAHs, Herbicides, Pesticides, Other Analytes	Phase II Ecostudy: Interstitial Sediment for Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
						x									SR - 01	THg, MeHg, PCBs, PAHs, Herbicides, Pesticides, Other Analytes	Phase II Ecostudy: Interstitial Sediment for Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Pore Water	2006										x			-1.0 , -0.7	THg, MeHg	Mercury Source Tracing and Mechanistic Source Studies	RTG, UE	
		2007		x											-0.6 - -0.5, -0.4 - -0.3, -0.2 - -0.1, -0.1 - 0.0	THg	Turner Plant Reach Pore Water and Surface Water	UE	
	Surface Water	2000	x	x	x	x	x	x	x	x	x	x	x	x	-2.7 - -2.8	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
		2001											x		-1.6 - -1.7, -0.7 - -0.8	THg, Metals, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
			x	x	x	x	x	x		x		x		x	-2.7 - -2.8	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
		2002	x		x			x		x		x		x	-1.6 - -1.7, -0.7 - -0.8	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
				x		x		x	x		x		x		-2.7 - -2.8	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
		2003								x					-0.8 - -0.7, -0.6 - 0.0	THg, TSS, Other Analytes	VADEQ Historical Intensive 2	VADEQ	
				x		x		x		x		x			-1.6 - -1.7, -0.7 - -0.8	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
													x		-4.1 - -4.2	Pesticides	VADEQ Historical Sediments	VADEQ	
			x		x		x		x		x			x	-4.1 - -4.2, -2.7 - -2.8	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
		2004										x			-0.4 - -0.5	THg	Cutback Survey Sampling	UE	
			x												-0.4 - -0.5	THg, TSS	VADEQ Historical Intensive 2 (Follow Up)	VADEQ	
			x	x		x		x		x		x			-1.6 - -1.7, -0.7 - -0.8	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
										x					-2.7 - -2.8	THg, MeHg, TSS	Hg Speciation Study	UE	
				x		x		x	x	x	x	x	x	x	-2.7 - -2.8	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
											x				-2.7 - -2.8, -0.4 - -0.5	THg, MeHg, TSS	Flood Sampling	UE	
		2005					x								-0.4 - -0.5	THg, MeHg, TSS	Water Sampling	UE	
					x		x		x		x		x		-1.6 - -1.7, -0.7 - -0.8	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
			x												-1.6 - -1.7, -0.7 - -0.8	TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
											x				-2.7 - -2.8	THg, MeHg, TSS	Concurrent Sampling	RTG	
					x	x	x	x	x	x	x		x	x	-2.7 - -2.8	Nutrients, E. Coli, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring	VADEQ	
			x												-2.7 - -2.8	Nutrients	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
											x				-2.7 - -2.8	THg, TSS	VADEQ Storm Sampling	VADEQ	
			x	x											-2.7 - -2.8, -0.4 - -0.5	THg, MeHg, TSS	Surface Water/Sediments	UE	
											x				-2.7 - -2.8, -0.4 - -0.5	THg, MeHg, TSS	Transect Program	UE	
					x										-2.7 - -2.8, -0.4 - -0.5	THg, MeHg, Metals, TSS, Other Analytes	Water Sampling	UE	
		2006						x			x				-1.0	THg, MeHg	Flux Chamber Study (Loading)	DuPont	URS 2009. Technical Briefing Paper: Use of Benthic Flux Chambers to Measure Inorganic Mercury and Methylmercury Fluxes in the South River. South River Science Team Briefing Paper. March 2009.
												x			-1.0 , -0.7	THg, MeHg	Mercury Source Tracing and Mechanistic Source Studies	RTG, UE	
			x		x		x		x		x		x		-1.7 - -1.6, -0.8 - -0.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
												x			-2.8 - -2.7	THg, MeHg	Turner Wells / Turner Wells and Extract	UE	
			x	x	x	x	x	x		x	x	x	x	x	-2.8 - -2.7	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
											x	x			-2.8 - -2.7, -0.8 - -0.7, -0.6 - -0.5, -0.5 - -0.4, -0.1 - 0.0	THg	Turner Plant Reach Pore Water and Surface Water	UE	
					x	x	x	x	x	x	x	x	x	x	NR - 01	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
					x	x	x	x	x	x	x	x	x	x	NR - 02	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
					x	x	x	x	x	x	x	x	x	x	SR - 01	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
								x		x			x		SR - 01	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007	x		x		x		x		x		x		-1.7 - -1.6, -0.8 - -0.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
			x	x		x	x		x	x	x	x		x	-2.8 - -2.7	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
				x											-2.8 - -2.7, -0.8 - -0.7, -0.5 - -0.4, -0.4 - -0.3	THg	Turner Plant Reach Pore Water and Surface Water	UE	
			x	x											NR - 01	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x	x											NR - 02	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x	x		x	x								SR - 01	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
					x										SR - 01	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2008	x		x		x		x		x		x		-1.7 - -1.6, -0.8 - -0.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
			x	x	x	x	x	x	x	x	x	x	x	x	-2.8 - -2.7	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
														x	NS	Temperature	Analysis of South River Temperatures	JMU	
		2009	x												-1.7 - -1.6, -0.8 - -0.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
			x	x											-2.8 - -2.7	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
				x			x			x					SR - 01	THg, MeHg	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2010			x		x		x		x		x		-2.8 - -2.7	Nitrate, Nitrite, Nitrogen	VADEQ Surface Water	VADEQ	
			x	x	x		x	x	x	x	x	x	x	x	SR - 01	THg, MeHg, Nutrients, Other Analytes	Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
Biological Monitoring / Assessments																			
Aquatic Vegetation / Algae																			
Reference Site	Tissue	2005							x						-4.1	THg, MeHg	Periphyton Assessment	VIMS	Newman, M.C. and K. Tom. 2008. Mercury trophic transfer models: South River aquatic food web - 2007 annual report. Prepared for E.I. DuPont de Nemours and Company. 32 pp.
		2006								x					NR - 01	THg, MeHg	Phase I Ecostudy: Macrophytes	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x			x				x	NR - 01	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
										x					NR - 02	THg, MeHg	Phase I Ecostudy: Macrophytes	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x			x				x	NR - 02	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
										x					SR - 01	THg, MeHg	Phase I Ecostudy: Macrophytes	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x			x				x	SR - 01	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007		x											NR - 01	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
				x											NR - 02	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
				x											SR - 01	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
Aquatic Invertebrates																			
Reference Site	Population / Community	2006					x			x				x	NR - 01		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x			x				x	NR - 02		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x			x				x	SR - 01		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007		x											NR - 01		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
				x											NR - 02		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
				x											SR - 01		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2010				x									MR - 01		Phase II Ecostudy: Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
						x									SR - 01		Phase II Ecostudy: Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
		2011					x	x							MR - 01		Phase II Ecostudy: Benthic Colonization Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
							x	x							SR - 01		Phase II Ecostudy: Benthic Colonization Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.

Table 1-1
Ecological Study Data Matrix
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	INVESTIGATOR(S)	CITATION
Reference Site	Tissue	2002											x		-1.8, -0.7	THg	Clam Tissue Study	JMU, EMU	Bowles, M.W. 2003, Biomonitoring of Mercury in the South River Using Asiatic Clam, Corbicula fluminea. Undergraduate Thesis. James Madison University, Harrisonburg, Virginia.
		2003											x		-1.8	THg, MeHg	Clam Tissue Study	JMU, EMU	Bowles, M.W. 2003, Biomonitoring of Mercury in the South River Using Asiatic Clam, Corbicula fluminea. Undergraduate Thesis. James Madison University, Harrisonburg, Virginia.
						x									NR	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
		2004					x		x						NR	THg, MeHg	Clam Transplant Study	JMU, EMU	Bowles, M.W. 2003, Biomonitoring of Mercury in the South River Using Asiatic Clam, Corbicula fluminea. Undergraduate Thesis. James Madison University, Harrisonburg, Virginia.
		2006					x			x				x	NR - 01	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
					x	x	x	x	x	x	x	x	x	x	NR - 01	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x			x				x	NR - 02	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
					x	x	x	x	x	x	x	x	x	x	NR - 02	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x			x				x	SR - 01	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
					x	x	x	x	x	x	x	x	x	x	SR - 01	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007		x											NR - 01	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x	x											NR - 01	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
				x											NR - 02	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x	x											NR - 02	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
				x											SR - 01	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x	x											SR - 01	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
	Toxicity	2010					x								MR - 01		Phase II Ecostudy: Laboratory Sediment Bioassays for Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
										x					NR - 01		Phase II Ecostudy: Field Microcosm Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
										x					NR - 02		Phase II Ecostudy: Field Microcosm Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
										x					SR - 01		Phase II Ecostudy: Field Microcosm Study	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
							x								SR - 01		Phase II Ecostudy: Laboratory Sediment Bioassays for Sediment Quality Triad	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
Fish																			
Reference Site	Population / Community	2006					x			x					NR - 01		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x			x					NR - 02		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x			x					SR - 01		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2010					x				x				MR-01		Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
							x				x				SR - 01		Phase II Ecostudy	URS	URS. 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.
	Tissue	2001				x									-0.7	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
		2002				x									-0.7	THg, MeHg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
						x									NR	THg, MeHg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
		2003				x									NR	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
		2005				x	x								-0.7	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
						x									NR	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
		2006					x			x					NR - 01	THg, MeHg	Phase I Ecostudy: Forage Fish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x			x					NR - 02	THg, MeHg	Phase I Ecostudy: Forage Fish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x			x					SR - 01	THg, MeHg	Phase I Ecostudy: Forage Fish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007				x									-0.7	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
						x									NR	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
Herpetofauna																			
Reference Site	Tissue	2007			x	x	x								-1.0, -2.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT	Hopkins, W.A., C.M. Bergeron, M.J. Hepner, B.D. Todd, J.D. Willson. 2011. From Individual-level responses to population-level change: individual and interactive effects of maternal and dietary mercury on amphibians along the South River, VA Final Report. Prepared for E.I. DuPont de Nemours Company.
		2008			x	x									-1.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT	Hopkins, W.A., C.M. Bergeron, M.J. Hepner, B.D. Todd, J.D. Willson. 2011. From Individual-level responses to population-level change: individual and interactive effects of maternal and dietary mercury on amphibians along the South River, VA Final Report. Prepared for E.I. DuPont de Nemours Company.
Terrestrial Invertebrates																			
Reference Site	Tissue	2006										x			-1.5	THg, MeHg	Survey of the Mercury Content of Earthworms on the South River Virginia Floodplain	JMU	Cianchetti, J. 2009. Survey of the Mercury Content of Earthworms on the South River, Va., Floodplain. Thesis (M.S.). James Madison University.
		2007					x								NR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Spiders	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
		2008					x								NR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Spiders	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
Birds																			
Reference Site	Blood	2005					x	x	x						NS	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
	Blood, Feather	2007				x	x								MR	THg	Pilot Assessment of Methyl-Mercury Availability to Mallards	BRI	Savoy, L. and D.C. Evers. 2008. Pilot assessment of methylmercury availability to Mallards on the South River, Virginia – 2008. Report BRI 2009-12 Rough Draft submitted to DuPont Corporate Remediation Group, Newark, Delaware and the U.S. Fish Wildl. Serv., Gloucester, Virginia. BioDiversity Research Institute, Gorham, ME. 43pp.
	Blood, Feather, Egg	2007				x	x								NR	THg	Pilot Assessment of Methyl-Mercury Availability to Mallards	BRI	Savoy, L. and D.C. Evers. 2008. Pilot assessment of methylmercury availability to Mallards on the South River, Virginia – 2008. Report BRI 2009-12 Rough Draft submitted to DuPont Corporate Remediation Group, Newark, Delaware and the U.S. Fish Wildl. Serv., Gloucester, Virginia. BioDiversity Research Institute, Gorham, ME. 43pp.
	Blood, Wing, Feather, Egg	2006				x	x	x	x						MR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
						x	x	x	x						NR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
		2007				x	x	x	x						MR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
							x	x	x						NR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
		2008					x	x							MR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
							x	x							NR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.
Mammals																			
Reference Site	Blood, Skin, Fur	2007							x	x					MR	THg, MeHg	Pilot Assessment of Methyl-Mercury Availability to Bats	BRI	Yates, D., M. Moore, T. Kunz, and D.C. Evers. 2008. Pilot assessment of methylmercury availability to bats on the South River, Virginia - 2008. Report BRI 2009-16 submitted to DuPont Corporate Remediation Group, Newark, Delaware and the U.S. Fish Wildl. Serv., Gloucester, Virginia. BioDiversity Research Institute, Gorham, ME. 47pp.
		2008						x	x	x					MR	THg, MeHg	Pilot Assessment of Methyl-Mercury Availability to Bats	BRI	Yates, D., M. Moore, T. Kunz, and D.C. Evers. 2008. Pilot assessment of methylmercury availability to bats on the South River, Virginia - 2008. Report BRI 2009-16 submitted to DuPont Corporate Remediation Group, Newark, Delaware and the U.S. Fish Wildl. Serv., Gloucester, Virginia. BioDiversity Research Institute, Gorham, ME. 47pp.
	Tissue, Liver	2010				x									MR	THg, MeHg	VADEQ White Tailed Deer Samples	VADEQ	
Habitat and Geophysical Characterizations																			
SFS	Habitat Characterization	2005									x				SFS - 1		Phase I Ecostudy: Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2006									x				SFS - 1		Phase I Ecostudy: Phase I Site Characterization	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
Physical and Chemical Monitoring / Assessments																			
SFS	Soil	2004										x			31 - 32	THg	Cutback Survey Sampling	UE	
		2006					x								40 - 41	THg	VADEQ Probability Monitoring	VADEQ	
								x							26 - 27, 72 - 73, 121 - 122	THg	VADEQ Fish Kill Sediment Sampling	VADEQ	
	Sediment	2003											x		40 - 41	VOCs, Pesticides, PCBs	VADEQ Probability Monitoring	VADEQ	
		2005									x				24 - 25, 34 - 35	THg, MeHg, LOI, Other Analytes	Transect Program	UE	
											x				30 - 31, 32 - 33	THg, MeHg, LOI, Other Analytes	McGaheysville Dam Samples	UE	
		2006			x	x	x	x	x	x	x	x	x	x	SFS - 1	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007	x	x											SFS - 1	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
										x	x				26 - 27, 33 - 34, 40 - 41, 43 - 44, 50 - 51, 55 - 56, 57 - 58, 65 - 66, 72 - 73, 75 - 76, 79 - 80, 86 - 87, 91 - 92, 95 - 96, 103 - 104, 106 - 107, 110 - 111, 115 - 116, 121 - 122, 125 - 126	THg, Other Metals	VADEQ Sediment Sampling	VADEQ	
	Ground Water	2009			x										NS	Spatial Analysis	River Corridor Infrared Thermal Imaging	SITS	
	Surface Water	2003									x	x	x	x	26 - 27, 48 - 49, 65 - 66, 72 - 73, 121 - 122, 125 - 126	Nutrients, E. Coli, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring	VADEQ	
												x			48 - 49, 72 - 73, 94 - 95	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2004									x				24 - 25	THg, MeHg, TSS	Flood Sampling	UE	
										x					24 - 25, 30 - 31, 32 - 33	THg, MeHg, TSS	Hg Speciation Study	UE	
			x		x		x	x	x	x	x	x	x	x	26 - 27, 48 - 49, 65 - 66, 72 - 73, 79 - 80, 121 - 122, 125 - 126	Nutrients, E. Coli, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring	VADEQ	
			x	x		x		x		x		x			26 - 27, 48 - 49, 72 - 73, 94 - 95	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2005			x										24 - 25	THg, MeHg, Metals, TSS, Other Analytes	Water Sampling	UE	
				x											24 - 25	THg, MeHg, TSS	Surface Water/Sediments	UE	
											x				24 - 25, 30 - 31, 32 - 33, 34 - 35	THg, MeHg, TSS	Transect Program	UE	
			x	x	x	x	x	x	x	x	x	x	x	x	26 - 27, 48 - 49, 65 - 66, 72 - 73, 79 - 80, 121 - 122, 125 - 126	Nutrients, E. Coli, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring	VADEQ	
			x		x		x		x		x		x		26 - 27, 48 - 49, 94 - 95	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
		2006		x	x	x	x	x	x	x	x	x	x	x	26 - 27, 33 - 34, 72 - 73, 121 - 122	Nutrients, Bacteria, THg, Other Analytes	VADEQHIST Fishkill	VADEQ	
			x		x		x		x		x		x		26 - 27, 48 - 49, 94 - 95	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
				x		x		x		x		x		x	26 - 27, 72 - 73, 121 - 122	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
						x	x						x		40 - 41, 72 -73	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Probability Monitoring	VADEQ	
					x	x	x	x	x	x	x	x	x	x	SFS - 1	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007	x	x	x	x	x	x	x	x					26 - 27, 33 - 34, 72 - 73, , 121 - 122	Nutrients, Bacteria, THg, Other Analytes	VADEQHIST Fishkill	VADEQ	
			x	x	x	x	x	x	x	x	x	x	x	x	26 - 27, 48 - 49, 72 - 73, 79 - 80, 115 - 116, 121 - 122	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
			x		x		x		x		x		x		26 - 27, 48 - 49, 94 - 95	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
			x	x											SFS-1	THg, MeHg	Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2008	x		x		x		x		x		x		26 - 27, 48 - 49, 94 - 95	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
			x	x	x	x	x	x	x	x	x	x	x	x	26 - 27, 72 - 73, 79 - 80, 115 - 116, 121- 122	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	
					x	x	x								33 - 34	Nutrients, Bacteria, THg, Other Analytes	VADEQHIST Fishkill	VADEQ	
		2009	x												26 - 27, 48 - 49, 94 - 95	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ	
				x											26 - 27, 72 - 73	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ	

Table 1-1
Ecological Study Data Matrix
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	INVESTIGATOR(S)	CITATION
Biological Monitoring / Assessments																			
Aquatic Vegetation / Algae																			
SFS	Tissue	2003							x						92.6	THg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
		2006								x					SFS - 1	THg, MeHg	Phase I Ecostudy: Macrophytes	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
							x			x				x	SFS - 1	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007		x											SFS - 1	THg, MeHg	Phase I Ecostudy: Periphyton	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
Aquatic Invertebrates																			
SFS	Population / Community	2006					x			x				x	SFS - 1		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007		x											SFS - 1		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
	Tissue	2003				x									92.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
									x						92.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
												x		x	92.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
		2006					x			x				x	SFS - 1	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
					x	x	x	x	x	x	x	x	x	x	SFS - 1	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007		x											SFS - 1	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
			x	x											SFS - 1	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
Fish																			
SFS	Population / Community	2006					x			x					SFS - 1		Phase I Ecostudy	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
	Tissue	2001					x								135, 144.5, 160	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
		2002				x	x		x			x			27.9, 49.7, 65.0, 77.5, 93.0, 108.7, 124.3, 144.5, 160.0	THg, MeHg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
		2003	x												27.9	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
						x									92.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
									x						92.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
												x			92.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT	Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Master's Thesis. Virginia Tech, Blacksburg, Virginia.
		2005				x	x								27.9, 49.7, 65.0, 77.5, 93.0, 108.7, 124.3, 144.5	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
		2006					x			x					SFS - 1	THg, MeHg	Phase I Ecostudy: Forage Fish	URS	CRG. 2008. Phase 1, Year 1 Progress Report: Ecological Study of the South River and a segment of the South Fork Shenandoah River, Virginia. Wilmington, Delaware.
		2007			x	x									27.9, 49.7, 65.0, 77.5, 93.0, 108.7, 124.3, 144.5, 160.0	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ	
Herpetofauna																			
SFS	Tissue	2007					x								34.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT	Hopkins, W.A., C.M. Bergeron, M.J. Hepner, B.D. Todd, J.D. Willson. 2011. From individual-level responses to population-level change: individual and interactive effects of maternal and dietary mercury on amphibians along the South River, VA Final Report. Prepared for E.I. DuPont de Nemours Company.
Birds																			
SFS	Blood	2005					x	x	x						NS	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU	Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Master's Thesis. College of William & Mary, Williamsburg, VA.

Notes:
The records presented in this table were obtained from the URS Master Database from 2000 to 2011 and from the South River Science Team Web Server (2006-2010). Research conducted by outside organizations was compiled to the fullest extent possible, however, some studies may not be represented. Relative River Miles (RRM) are determined by the streamline distance downstream (+), or distance upstream (-) of the footbridge located in downtown Waynesboro, VA. The locations reported are based on the coordinates or site descriptions provided in the source dataset and may not be fully comprehensive. For sites in the Middle River (MR) and North River (NR), no specific RRM is provided.
NS = Not Specified; SFS = South Fork Shenandoah River; *Analytes* : LOI = Loss on Ignition; MeHg = Methyl Mercury; δN15/ δC13 = Stable Isotopes; PAHs = Polyaromatic Hydrocarbons; PCBs = Polychlorinated Biphenyls; THg = Total Mercury; TOC = Total Organic Carbon; TSS = Total Suspended Solids; VOCs = Volatile Organic Compounds
DuPont = E. I. du Pont de Nemours and Company; EMU = Eastern Mennonite Univ.; JMU = James Madison Univ.; NOAA = National Oceanic and Atmospheric Admin.; RTG = Ralph Turner Geosciences; SITS = Stockton Infrared Thermographic Services; UD = Univ. of Delaware; UE = Unique Environmental
URS = URS Corporation; USEPA = US Environmental Protection Agency; USGS = US Geologic Survey; VADEQ = VA Dept. of Environmental Quality; VIMS = Virginia Institute of Marine Science; VT = Virginia Tech
Source: Table 1-3 in the Ecological Study Report (URS, 2012).

Table 2-1
Summary of Surface Water Flows
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Event Type	Date	Discharge at Harriston (CFS)	Daily Median Discharge (CFS)[a]
Baseline	3/14/2006	133	262
	4/13/2006	122	256
	5/14/2006	151	207
	6/13/2006	71	129
	6/30/2006	97	107
	8/13/2006	66	87
	9/13/2006	110	81
	10/13/2006	209	94
	11/12/2006	541	114
	12/13/2006	209	159
	1/12/2007	299	190
	2/12/2007	253	229
	4/13/2007	296	256
	5/14/2007	151	207
	8/13/2007	103	87
	10/13/2007	58	94
	12/13/2007	63	159
	2/12/2008	152	229
	5/13/2008	206	213
	6/12/2008	94	130
	8/12/2008	50	84
	10/12/2008	71	91
	12/12/2008	257	161
	2/11/2009	97	232
	5/31/2009	289	155
	8/30/2009	61	82
	1/12/2010	227	190
	2/18/2010	266	254
	6/6/2010	120	158
	9/2/2010	65	80
	1/4/2011	105	201
	6/5/2011	154	165
Event Type	**Date**	**Peak Discharge (CFS)**	**Return Interval[b]**
Storm	9/2/2006	3010	0.28
	6/27/2006	2620	0.2
	10/6/2002	6840	1.9
	11/8/2006	1780	0.08
	3/2/2007	1270	0.03

Notes:

[a]Median daily discharge calculated for the entire 68-year period of record at Harriston, VA.

[b]The return period is a value indicating the frequency of peak flow events. Low values (e.g., 2 year events) indicate relatively frequent events.

See Ecological Study Data Matrix (Table 1-1) for more information regarding study details.

Source: Table 2-1 in the Ecological Study Report (URS, 2012).

Table 3-1
Comparison of Sediment Chemistry Among Different Environments
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Habitat Type	Distance from Source (RRM)	August, 2007		October, 2007	December, 2007		February, 2008	May, 2008		
		IHg (µg/g dry wt.)	MeHg (ng/g dry wt.)	MeHg (ng/g dry wt.)	MeHg (ng/g dry wt.)	AVS (µmol/g dry wt.)	MeHg (ng/g dry wt.)	MeHg (ng/g dry wt.)	AVS (µmol/g dry wt.)	Fe(II):Fe(III)
Floodplain wetland	1.6	4 (0.2)	7.7 (2.3)	3.1 (1)	4.5 (0.5)	5 (2.4)	3.1 (1)	5.3 (0.4)	<1.75	1.3 (0.01)
Embedded pool	4.6	21 (2.6)	53.6 (2.9)	48.9 (1.7)	41.5 (3.5)	<3.35	48.9 (1.7)	76.7 (11)	<2	2.4 (0.08)
Mill race	5.2	45.2 (11.5)	20.1 (0.3)	27 (29.7)	43 (21)	3.8 (2.8)	27 (29.7)	57.6 (5)	<1.2	2 (0.03)
FGCM deposit	6.4	18.9 (2.2)	70.7 (10.6)	20 (0.4)	19.5 (3.5)	12.6 (3.2)	20 (0.4)	114 (9)	<2.6	3 (0.36)
Embedded pool	7.4	22 (2.2)	81.1 (2.3)	65.4 (2.4)	57 (5)	< 2.4	65.4 (2.4)	97 (0.9)	<2.3	1.3 (0.04)
Floodplain wetland	8.6	17.8 (1.9)	18.2 (7.7)	2.5 (0)	11.5 (0.5)	< 1.55	2.5 (0)	99.9 (3.2)	<2.5	1.7 (0.1)
Toe of pool	8.7	21.1 (0.1)	68.4 (4.5)	21.8 (15.4)	37	< 3.75	21.8 (15.4)	47.4 (0)	<2.5	0.4 (0)
Mill race	9.9	6.3 (2)	13.2 (1.8)	17.4 (7)	5	5 (0.5)	17.4 (7)	39.2 (9.9)	6.1 (1.5)	7.7 (0.07)
Toe of pool	12.7	20.4 (0.05)	60 (19)	41.1 (1.7)	45	< 4	41.1 (1.7)	55.5 (2.8)	<1.9	1 (0.02)
FGCM deposit	12.8	22.6 (6)	18.1 (1.2)	25.5 (2.5)	21 (3)	9.1 (0.8)	25.5 (2.5)	102.4 (21.7)	3.7	4.3 (0.26)

Notes:

Concentrations of inorganic mercury (IHg), methylmercury (MeHg), acid-volatile sulfide (AVS) and reduced Fe, expressed as the ratio of Fe(II):Fe(III) in fine-grained sediment from five habitat types present in the South River. Data represented as average (standard deviation). FGCM=fine-grained channel margin. Reprinted with permission from Flanders et al. (2010). See Ecological Study Data Matrix (Table 1-1) for more information regarding study details.

Source: Table 4-2 in the Ecological Study Report (URS, 2012).

Table 4-1
River Reaches for 2008 Floodplain Soil Investigation
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Reach	Description	Relative River Mile[a]
1	Main Street (Waynesboro) Bridge to Hopeman Parkway Bridge	0.5 - 2
2	Hopeman Parkway Bridge to Holsinger Farm Footbridge	2 - 8
3	Holsinger Farm Footbridge (Dooms) to New Hope and Crimora Rd Bridge	8 - 10
4	New Hope and Crimora Rd Bridge to Patterson Mill Bridge	10 - 16.2
5	Patterson Mill Bridge to Grand Caverns Bridge	16.2 - 19.8
6	Grand Cavern Bridge to Port Republic Rd Bridge	19.8 - 24.8

Notes:
[a]Relative river mile origin is defined by the footbridge at the former DuPont facility in Waynesboro, Virginia.
Six river reaches as defined by South River bridge crossings from the Main Street Bridge to the Port Republic Bridge near the confluence of the South and North Rivers.
Source: Table 2 in Appendix D of the Ecological Study Report (URS, 2012).

Table 4-2
Summary of Mill Race and Oxbow Area Soil THg Concentrations
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Sample Area Description	Approximate Feature Location	Approximate Feature Acreage	Floodplain	Total Mercury (THg)									
				Sample Depth (0.0'- 0.5')					Sample Depth (0.5'- 2.0')				
				Sample Size (n)	Detected Sample Size (n)	Minimum (mg/kg)[a]	Maximum (mg/kg)[a]	Mean (mg/kg)[a]	Sample Size (n)	Detected Sample Size (n)	Minimum (mg/kg)[a]	Maximum (mg/kg)[a]	Mean (mg/kg)[a]
Mill Race and Oxbow Area Features													
Plant Mill Race	RRM -0.05 to RRM 0.5	10.8	0.3 Year	0	--	--	--	--	0	--	--	--	--
			2 Year	6	6	1.3	3.5	2.2	1	1	25	25	25
			5 Year	3	3	0.49	9.6	3.6	0	--	--	--	--
			62 year	4	4	0.73	28	13	4	4	0.09	249	71
North Park Mill Race	RRM 1.1 to RRM 1.9	7.9	0.3 Year	0	--	--	--	--	0	--	--	--	--
			2 Year	1	1	2.6	2.6	2.6	2	2	1.8	3.7	2.8
			5 Year	7	7	3.8	20	12	0	--	--	--	--
			62 year	0	--	--	--	--	0	--	--	--	--
Oxbow Area	RRM 1.55 to RRM 1.85	35.3	0.3 Year	17	17	4.2	89	25	9	9	8.9	47	20
			2 Year	12	12	1.1	27	8.6	7	7	0.34	72	35
			5 Year	39	39	0.90	307	25	16	16	2.7	714	164
			62 Year	12	12	0.62	6.2	3.0	2	2	0.35	0.96	0.66
Dooms Dam Mill Race	RRM 4.9 to RRM 5.4	6.5	0.3 Year	2	2	1.9	5.0	3.4	2	2	3.6	7.2	5.4
			2 Year	0	--	--	--	--	0	--	--	--	--
			5 Year	2	2	0.42	8.7	4.5	2	2	0.07	1.4	0.74
			62 year	1	1	0.72	0.72	0.72	1	1	0.17	0.17	0.17
Above Crimora Mill Race	RRM 9.6 to RRM 10.8	13.1	0.3 Year	1	1	3.1	3.1	3.1	1	1	12	12	12
			2 Year	0	--	--	--	--	0	--	--	--	--
			5 Year	0	--	--	--	--	0	--	--	--	--
			62 year	0	--	--	--	--	0	--	--	--	--
Red Mill Lane Mill Race	RRM 11.6 to RRM 12.1	5.2	0.3 Year	0	--	--	--	--	0	--	--	--	--
			2 Year	1	1	11	11	11	1	1	3.0	3.0	3.0
			5 Year	2	2	4.6	17	11	2	2	0.06	1.3	0.70
			62 year	0	--	--	--	--	0	--	--	--	--
Harriston Mill Race	RRM 16.1 to RRM 16.35	3.8	0.3 Year	0	--	--	--	--	0	--	--	--	--
			2 Year	0	--	--	--	--	0	--	--	--	--
			5 Year	0	--	--	--	--	0	--	--	--	--
			62 year	0	--	--	--	--	0	--	--	--	--
Above Grand Caverns Mill Race	RRM 19.35 to RRM 19.55	2.6	0.3 Year	4	4	2.6	5.4	3.8	4	4	0.52	4.6	2.5
			2 Year	0	--	--	--	--	0	--	--	--	--
			5 Year	0	--	--	--	--	0	--	--	--	--
			62 year	0	--	--	--	--	0	--	--	--	--
Below Grand Caverns Mill Race	RRM 20.2 to RRM 20.6	4.2	0.3 Year	0	--	--	--	--	0	--	--	--	--
			2 Year	0	--	--	--	--	0	--	--	--	--
			5 Year	0	--	--	--	--	0	--	--	--	--
			62 year	0	--	--	--	--	0	--	--	--	--
Below Grottoes Mill Race	RRM 22.9 to RRM 23.45	8.0	0.3 Year	2	2	33	33	33	2	2	11	31	21
			2 Year	2	2	0.09	18	8.9	2	2	5.1	7.8	6.5
			5 Year	6	6	0.48	26	5.6	6	6	0.23	16	3.4
			62 year	0	--	--	--	--	0	--	--	--	--
Above Port Republic Mill Race	RRM 23.6 to RRM 24.0	5.2	0.3 Year	0	--	--	--	--	0	--	--	--	--
			2 Year	1	1	2.3	2.3	2.3	1	1	0.27	0.27	0.27
			5 Year	0	--	--	--	--	0	--	--	--	--
			62 year	0	--	--	--	--	0	--	--	--	--
South River Study Area[b]													
South River Study Area[b]	RRM 0.0 to RRM 24.0	--	0.3 Year	2155	2148	0.02	941	17	249	248	0.05	608	26
			2 Year	614	612	0.01	180	17	211	207	0.02	270	12
			5 Year	341	341	0.01	185	7.1	284	281	0.01	248	7
			62 year	257	254	0.01	86	2.5	213	209	0.01	341	7.2

Notes:
a, Based on detected samples only.
b, Entire South River Study Area, excluding mill races and Oxbow Area.

Table 4-3
Mercury Soil Screening Level for Protection of Migration to Groundwater
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Soil Screening Level Partitioning Equation for Migration to Groundwater

$$SSL\ (mg/kg) = C_w * \left[K_d + \frac{Q_w + Q_a H']}{P_b} \right.$$

USEPA, 1996 Equation 22

Parameter	Definition	Value	Source
SSL	Soil screening level (mg/kg)		USEPA, 1996
C_w	Target soil leachate concentration (mg/L)	Calculated	
where	C_w = SL x DAF		
SL	Target soil leachate concentration (mg/L)	Chemical-Specific	EPA Tap Water SL for Mercuric Chloride
DAF	Dilution Attenuation Factor, unitless	1 or 20	DAF = 1 (no dilution/attenuation), DAF=20 (0.5-acre source area)
K_d	Soil-water distribution coefficient (L/kg), inorganics	Chemical-Specific	USEPA, 2002 for elemental mercury, value for mercuric chloride not available
Q_w	Water-filled soil porosity (Lwater/Lsoil)	0.2	Default
Q_a	Air-filled soil porosity (Lpore/Lsoil)	0.13	Default
H'	Henry's Law Constant (dimensionless)	Chemical-Specific	USEPA, 2002 for elemental mercury, value for mercuric chloride not available
P_b	Dry Soil Bulk Density (kg/L)	1.5	Default

Chemical	H'	Kd	Source	SL (mg/L)	Cw (mg/L)	SSL (mg/kg) (DAF=1)	Cw (mg/L)	SSL (mg/kg) (DAF=20)
Mercury	4.67E-01	5.20E+01	USEPA, 2002	5.70E-03	5.70E-03	2.97E-01	1.14E-01	5.95E+00

References:

USEPA, 1996. Soil Screening Guidance: User's Guide. Interim Final. Office of Solid Waste and Emergency Response. Washington, D.C. July.

USEPA, 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Office of Solid Waste and Emergency Response. OSWER 9355.4-24. March.

Table 4-4
Summary of Soil Analytical Results, 2006 Investigation (RRM 3.1- 4.3)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Analyte	Units	SSL DAF=1 (DAF=20)	Sample ID	SB1 (0-0.5)	SB1 (0.5-1)	SB1 (1-1.5)	SB1 (1.5-2)	SB1 (2-2.5)	SB2 (0-0.5)	SB2 (0.5-1)	SB2 (0.5-1)	SB2 (1-1.5)	SB2 (1.5-2)
			Sample Date	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006
			Start Depth (feet)	0	0.5	1	1.5	2	0	0.5	0.5	1	1.5
			End Depth (feet)	0.5	1	1.5	2	2.5	0.5	1	1	1.5	2
			Sample Purpose	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample
Mercury	MG/KG	0.30 (5.95)		*11*	*14.7*	5	1	0.1	5.7	*6.3*	*6.3*	5.6	3.9

Notes:

Soil screening level (SSL) for protection of migration to groundwater

Value for mercury is based on mercuric chloride

Concentrations in italics indicate an exceedance of screening criteria (DAF=20)

Table 4-4
Summary of Soil Analytical Results, 2006 Investigation (RRM 3.1- 4.3)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Analyte	Units	SSL DAF=1 (DAF=20)	Sample ID	SB2 (2-2.5)	SB2 (10-10.5)	SB-3 (0-0.5)	SB-3 (0.5-1)	SB-3 (1-1.5)	SB-3 (1.5-2)	SB-3 (2-2.5)	SB-4 (0-0.5)	SB-4 (0.5-1)	SB-4 (1-1.5)
			Sample Date	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006
			Start Depth (feet)	2	10	0	0.5	1	1.5	2	0	0.5	1
			End Depth (feet)	2.5	10.5	0.5	1	1.5	2	2.5	0.5	1	1.5
			Sample Purpose	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample
Mercury	MG/KG	0.30 (5.95)		0.2	< 0.041	1.9	0.2	0.1	0.5	0.2	*16.9*	*29.3*	*35.8*

Notes:
Soil screening level (SSL) for protection of migration to groundwater
Value for mercury is based on mercuric chloride
Concentrations in italics indicate an exceedance of screening criteria (DAF=20)

Table 4-4
Summary of Soil Analytical Results, 2006 Investigation (RRM 3.1- 4.3)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Analyte	Units	SSL DAF=1 (DAF=20)	Sample ID	SB-4 (1.5-2)	SB-4 (2-2.5)	SB-5 (0-0.5)	SB-5 (0.5-1)	SB-5 (1-1.5)	SB-5 (1.5-2)	SB-5 (2-2.5)	SB-6 (0-0.5)	SB-6 (0.5-1)	SB-6 (1-1.5)
			Sample Date	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006
			Start Depth (feet)	1.5	2	0	0.5	1	1.5	2	0	0.5	1
			End Depth (feet)	2	2.5	0.5	1	1.5	2	2.5	0.5	1	1.5
			Sample Purpose	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample
Mercury	MG/KG	0.30 (5.95)		*47.6*	*35*	*10.7*	*11.4*	*20.8*	*27.1*	*15.1*	*8.9*	*8.8*	5.6

Notes:
Soil screening level (SSL) for protection of migration to groundwater
Value for mercury is based on mercuric chloride
Concentrations in italics indicate an exceedance of screening criteria (DAF=20)

Table 4-4
Summary of Soil Analytical Results, 2006 Investigation (RRM 3.1- 4.3)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Analyte	Units	SSL DAF=1 (DAF=20)	Sample ID	SB-6 (1.5-2)	SB-6 (2-2.5)	SB-7 (0-0.5)	SB-7 (0.5-1)	SB-7 (1-1.5)	SB-7 (1.5-2)	SB-7 (5.5-6)	SB-8 (0-0.5)	SB-8 (0.5-1)	SB-8 (1-1.5)
			Sample Date	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006
			Start Depth (feet)	1.5	2	0	0.5	1	1.5	5.5	0	0.5	1
			End Depth (feet)	2	2.5	0.5	1	1.5	2	6	0.5	1	1.5
			Sample Purpose	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample
Mercury	MG/KG	0.30 (5.95)		0.8	< 0.037	*23.9*	*31.5*	*24.3*	0.5	< 0.038	*14.6*	*56.1*	*136*

Notes:
Soil screening level (SSL) for protection of migration to groundwater
Value for mercury is based on mercuric chloride
Concentrations in italics indicate an exceedance of screening criteria (DAF=20)

Table 4-4
Summary of Soil Analytical Results, 2006 Investigation (RRM 3.1- 4.3)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Analyte	Units	SSL DAF=1 (DAF=20)	Sample ID	SB-8 (1.5-2)	SB-8 (2.5-3)	SB-8 (3-3.5)	SB-9 (0-0.5)	SB-9 (0.5-1)	SB-9 (1-1.5)	SB-9 (1.5-2)	SB-9 (2.5-3)	SB-9 (3.5-4)	SB-10 (0-0.5)
			Sample Date	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006
			Start Depth (feet)	1.5	2.5	3	0	0.5	1	1.5	2.5	3.5	0
			End Depth (feet)	2	3	3.5	0.5	1	1.5	2	3	4	0.5
			Sample Purpose	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample
Mercury	MG/KG	0.30 (5.95)		6.1	< 0.034	0.047	33.2	*31.3*	4.9	2.6	0.1	0.1	*43.6*

Notes:
Soil screening level (SSL) for protection of migration to groundwater
Value for mercury is based on mercuric chloride
Concentrations in italics indicate an exceedance of screening criteria (DAF=20)

Table 4-4
Summary of Soil Analytical Results, 2006 Investigation (RRM 3.1- 4.3)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Analyte	Units	SSL DAF=1 (DAF=20)	Sample ID	SB-10 (0.5-1)	SB-10 (1-1.5)	SB-10 (1.5-2)	SB-10 (2.5-3)	SB-10 (3.5-4)	SB-11 (0-0.5)	SB-11 (0.5-1)	SB-11 (1-1.5)	SB-11 (1.5-2)	SB-11 (2-2.5)
			Sample Date	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/16/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006
			Start Depth (feet)	0.5	1	1.5	2.5	3.5	0	0.5	1	1.5	2
			End Depth (feet)	1	1.5	2	3	4	0.5	1	1.5	2	2.5
			Sample Purpose	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample
Mercury	MG/KG	0.30 (5.95)		2.5	0.3	0.2	0.04	0.044	*7.1*	4.2	0.9	0.7	0.3

Notes:
Soil screening level (SSL) for protection of migration to groundwater
Value for mercury is based on mercuric chloride
Concentrations in italics indicate an exceedance of screening criteria (DAF=20)

Table 4-4
Summary of Soil Analytical Results, 2006 Investigation (RRM 3.1- 4.3)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Analyte	Units	SSL DAF=1 (DAF=20)	Sample ID	SB-12 (0-0.5)	SB-12 (0.5-1)	SB-12 (1-1.5)	SB-12 (1.5-2)	SB-12 (2-2.5)	SB-13 (0-0.5)	SB-13 (0.5-1)	SB-13 (1-1.5)	SB-13 (1.5-2)	SB-13 (2-2.5)
			Sample Date	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006
			Start Depth (feet)	0	0.5	1	1.5	2	0	0.5	1	1.5	2
			End Depth (feet)	0.5	1	1.5	2	2.5	0.5	1	1.5	2	2.5
			Sample Purpose	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample
Mercury	MG/KG	0.30 (5.95)		*48.8*	*69.1*	*40.1*	*27.1*	1	*62.1*	*56.8*	*21.7*	1.7	< 0.041

Notes:
Soil screening level (SSL) for protection of migration to groundwater
Value for mercury is based on mercuric chloride
Concentrations in italics indicate an exceedance of screening criteria (DAF=20)

Table 4-4
Summary of Soil Analytical Results, 2006 Investigation (RRM 3.1- 4.3)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Analyte	Units	SSL DAF=1 (DAF=20)	Sample ID	SB-14 (0-0.5)	SB-14 (0.5-1)	SB-14 (1-1.5)	SB-14 (1.5-2)	SB-14 (2-2.5)	SB-15 (0-0.5)	SB-15 (0.5-1)	SB-15 (1-1.5)	SB-15 (1.5-2)	SB-15 (2-2.5)
			Sample Date	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006
			Start Depth (feet)	0	0.5	1	1.5	2	0	0.5	1	1.5	2
			End Depth (feet)	0.5	1	1.5	2	2.5	0.5	1	1.5	2	2.5
			Sample Purpose	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample
Mercury	MG/KG	0.30 (5.95)		*12*	*14.7*	*17.4*	*29.5*	*74.6*	*12.9*	*19.1*	*29.8*	*6.7*	0.6

Notes:
Soil screening level (SSL) for protection of migration to groundwater
Value for mercury is based on mercuric chloride
Concentrations in italics indicate an exceedance of screening criteria (DAF=20)

Table 4-4
Summary of Soil Analytical Results, 2006 Investigation (RRM 3.1- 4.3)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Analyte	Units	SSL DAF=1 (DAF=20)	Sample ID	SB-16 (0-0.5)	SB-16 (0.5-1)	SB-16 (1-1.5)	SB-16 (1.5-2)	SB-16 (2-2.5)	SB-17 (0-0.5)	SB-17 (0.5-1)	SB-17 (1-1.5)	SB-17 (1.5-2)	SB-17 (2-2.5)
			Sample Date	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006
			Start Depth (feet)	0	0.5	1	1.5	2	0	0.5	1	1.5	2
			End Depth (feet)	0.5	1	1.5	2	2.5	0.5	1	1.5	2	2.5
			Sample Purpose	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample
Mercury	MG/KG	0.30 (5.95)		*15.1*	*3.7*	0.089	< 0.038	0.055	5.2	1.6	0.4	0.1	0.045

Notes:
Soil screening level (SSL) for protection of migration to groundwater
Value for mercury is based on mercuric chloride
Concentrations in italics indicate an exceedance of screening criteria (DAF=20)

Table 4-4
Summary of Soil Analytical Results, 2006 Investigation (RRM 3.1- 4.3)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Analyte	Units	SSL DAF=1 (DAF=20)	Sample ID	SB-18 (0-0.5)	SB-18 (0.5-1)	SB-18 (1-1.5)	SB-18 (1.5-2)	SB-18 (2-2.5)
			Sample Date	10/17/2006	10/17/2006	10/17/2006	10/17/2006	10/17/2006
			Start Depth (feet)	0	0.5	1	1.5	2
			End Depth (feet)	0.5	1	1.5	2	2.5
			Sample Purpose	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample
Mercury	MG/KG	0.30 (5.95)		*7.2*	0.6	0.3	< 0.035	< 0.041

Notes:
Soil screening level (SSL) for protection of migration to groundwater
Value for mercury is based on mercuric chloride
Concentrations in italics indicate an exceedance of screening criteria (DAF=20)

Table 4-5
Summary of Groundwater Analytical Results, 2006 Investigation (RRM 3.1- 4.3)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Analyte	Units	Total/ Dissolved	EPA Tap Water SL	Project	EPA Shifflet Investigation					
				Location	SB-3	SB-4	SB-5	SB-6	SB-7	SB-8
				Sample Date	10/18/2006	10/18/2006	10/18/2006	10/18/2006	10/18/2006	10/18/2006
				Sample Purpose	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample
Mercury	NG/L	T	5700		< 1.5	219	12.8	96	7.8	273

Notes:
EPA Regional Screening Level (EPA SL) for tap water (May 2014 version)
(based on a HQ=1). Value for mercury is mercuric chloride.
Concentrations in italics indicates an exceedance of screening criteria

Table 4-5
Summary of Groundwater Analytical Results, 2006 Investigation (RRM 3.1- 4.3)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Analyte	Units	Total/ Dissolved	EPA Tap Water SL	Project	EPA Shifflet Investigation					
				Location	SB-9	SB-10	SB-11	SB-12	SB-13	SB-14
				Sample Date	10/18/2006	10/18/2006	10/19/2006	10/19/2006	10/19/2006	10/18/2006
				Sample Purpose	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample
Mercury	NG/L	T	5700		63.9	21.6	7	301	103	778

Notes:
EPA Regional Screening Level (EPA SL) for tap water (May 2014 version)
(based on a HQ=1). Value for mercury is mercuric chloride.
Concentrations in italics indicates an exceedance of screening criteria

Table 4-5
Summary of Groundwater Analytical Results, 2006 Investigation (RRM 3.1- 4.3)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Analyte	Units	Total/ Dissolved	EPA Tap Water SL	Project	EPA Shifflet Investigation					
				Location	SB-15	SB-16	SB-17	SB-18	EPA MW-1	EPA MW-2
				Sample Date	10/18/2006	10/18/2006	10/18/2006	10/18/2006	10/18/2006	10/18/2006
				Sample Purpose	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample	Regular Sample
Mercury	NG/L	T	5700		734	5.6	8.7	25.5	3.1	< 1.5

Notes:
EPA Regional Screening Level (EPA SL) for tap water (May 2014 version)
(based on a HQ=1). Value for mercury is mercuric chloride.
Concentrations in italics indicates an exceedance of screening criteria

Table 4-6
Summary of Well Search Results
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Extent	Tax Parcel ID	Physical Address	City	Well In Floodplain (Yes / No / Unk)	Notes
1	27-1-A2	503 W MAIN ST, SUITE 203	WAYNESBORO	Yes	VDEQ monitoring well located. Unknown well was not located.
1	55-2- A	PO BOX 610	WAYNESBORO	Yes	
1	65-3-A	400 DUPONT BLVD	WAYNESBORO	Yes	DuPont mercury monitoring wells and plant production wells.
2	68-52	123 DOOMS CROSSING RD	WAYNESBORO	Yes	House is in flood plain.
2 and 3	68-63	656 EAST SIDE HWY	WAYNESBORO	Yes	House is in flood plain.
3 and 4	48-133	1564 NEW HOPE AND CRIM RD	CRIMORA	Yes	House is in flood plain.
4	39-10E	91 TRIXIE LN	GROTTOES	Yes	House is in flood plain.
4	39-20	3624 EAST SIDE HWY	GROTTOES	Yes	House is in flood plain.
4	39-20A	3622 EAST SIDE HWY	GROTTOES	Yes	House is in flood plain.
4	48-159	287 RED MILL LN	CRIMORA	Yes	House and well are in the flood plain.
4	48-162	182 MCGUSLIN LN	CRIMORA	Yes	House sits near flood plain boundary.
4	48-168	249 BELVIDERE RD	CRIMORA	Yes	House is in flood plain.
5	29-11	70 COSBY MILL LN	GROTTOES	Yes	House and well are in the flood plain.
5	29-11A	72 COSBY MILL LN	GROTTOES	Yes	House and well are in the flood plain.
5	29-8	304 CAVE HILL LN.	GROTTOES	Yes	House sits outside flood plain.
5	39-22	1564 PATTERSON MILL RD	GROTTOES	Yes	House and well are in the flood plain.
5	39A-1-1	1599 PATTERSON MILL RD	GROTTOES	Yes	House and well are in the flood plain.
5	39A-1-2	1587 PATTERSON MILL RD	GROTTOES	Yes	House and well are in the flood plain.
5	39A-2-1A	1580 PATTERSON MILL RD	GROTTOES	Yes	House and well are in the flood plain.
6	152(A)117B1	8204 WATER STREET	PORT REPUBLIC	Yes	House and well are in the flood plain.
2	68-52A	120 DOOMS CROSSING RD	WAYNESBORO	Unk	Flood plain boundary lies on top of the house on aerial photograph.
3	58-105B	1619 NEW HOPE AND CRIM RD	CRIMORA	Unk	Well appears to be located on flood plain boundary line.
3	58-111	273 HOLLOWAY FARM LN	WAYNESBORO	Unk	House is located near flood plain boundary.
3	58-95	ROCKFISH RD	CRIMORA	Unk	Home location could not be verified.
4	39-9	39-9 HARRISTON NICHOLS MILL PROP 10143 AC	GROTTOES	Unk	Parcel recorded as undeveloped/agricultural land.
4	48-161	48-161 RED MILLS SOUTH RIVER E RT 865 122903 AC	CRIMORA	Unk	Well associated with barn on agricultural land.
4	48-163A	ADDRESS UNKNOWN	CRIMORA	Unk	Listed as vacant land.
4	48-164	ROCKFISH RD	CRIMORA	Unk	Well associated with non-residential farm buildings. Listed as having spring water.
4	49-49A	MCGUSLIN LN	GROTTOES	Unk	Building appears to be outside of flood plain & is listed as not having water service.
5	39-22A4	9 MARY ANNA LN	GROTTOES	Unk	House sits near flood plain boundary
5	39-22H	117 SOUTH RIVER RD	GROTTOES	Unk	House sits near flood plain boundary
5	39-22N	97 SOUTH RIVER RD	GROTTOES	Unk	House sits near flood plain boundary.
5	39-22R	29 SOUTH RIVER RD	GROTTOES	Unk	House sits near flood plain boundary.
5	39-22S	39 SOUTH RIVER RD	GROTTOES	Unk	House sits near flood plain boundary.
5	39-22U	53 SOUTH RIVER RD	GROTTOES	Unk	House sits near flood plain boundary.
5	39-22Y1	SOUTH RIVER RD	GROTTOES	Unk	Need better address to better locate house on property.
5	39-55	213 SOUTH RIVER RD	GROTTOES	Unk	House is located near flood plain boundary.
5	39-55L	239 SOUTH RIVER RD	GROTTOES	Unk	House is located near flood plain boundary.
5	39-6	411 TRIXIE LN	GROTTOES	Unk	House is located near flood plain boundary.
6	29-5D	94 CIRCLE LN	GROTTOES	Unk	House is located near flood plain boundary.
6	29-5G	29-5G S SIDE OF RT 256 ON SOUTH RIVER 2601 AC WYERS CAVE RD	GROTTOES	Unk	Well associated with non-residential farm buildings.
1	26-1-A	1150 SHERWOOD AVE	WAYNESBORO	No	Well adjacent to house which sits on high bluff above the river.
1	45-2-29	503 W MAIN ST, SUITE 203	WAYNESBORO	No	City parking lot - no wells were observed. Possible abandoned monitoring well.
1	55-2-C	PO BOX 2936	WAYNESBORO	No	Invista parking lot - search did not discover any wells.
1	68-42	1595 DUKE RD	WAYNESBORO	No	Home sits on bluff above river, outside of the flood plain.
1	72-4-16A3	61 S OAK LANE	WAYNESBORO	No	House & well are along South River well upstream of former DuPont plant.
2	68-49	51 ANEN TOWN LN	WAYNESBORO	No	House sits outside flood plain.
2	68-49C	391 ROCKFISH RD	WAYNESBORO	No	Well adjacent to house which sits on bluff above the river.
2	68-49D	112 ANEN TOWN LN	WAYNESBORO	No	House sits outside flood plain.
2	68-51	593 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
2	68-51B	511 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
2	68-51D	561 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
2	68-52K	126 DOOMS CROSSING RD	WAYNESBORO	No	House sits outside flood plain.
2	68-54B	597 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
2 and 3	68-54	ROCKFISH RD	WAYNESBORO	No	Undeveloped land.
2 and 3	68-55	717 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	58-104	65 KENNEDY LN	CRIMORA	No	House sits outside flood plain.
3	58-105	41 KENNEDY LN	CRIMORA	No	House sits outside flood plain.
3	58-112	146 PATRICK MILL LN	WAYNESBORO	No	House sits outside flood plain.
3	58-113A	1219 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	58-113G	1145 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	58-113H	1157 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	58-113L	1111 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	58-113N	1177 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	58-113R	1217 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	58-115E	1057 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	58-92D	87 SUNNYFIELD LN	WAYNESBORO	No	House sits outside flood plain.
3	58-92N	1373 ROCKFISH ROAD	WAYNESBORO	No	House sits outside flood plain.
3	58-97	1831 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	58-99A5	206 ROBERT TURK LN	WAYNESBORO	No	House & well sit outside flood plain.
3	58-99C1	1504 EAST SIDE HWY	WAYNESBORO	No	House sits outside flood plain.
3	68-56	773 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	68-58	797 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	68-59B	923 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	68-59F	831 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	68-59G	849 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	68-59H	861 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3	68-60	901 ROCKFISH RD	WAYNESBORO	No	House sits outside flood plain.
3 and 4	48-132	1386 NEW HOPE AND CRIM RD	CRIMORA	No	House sits outside flood plain.
3 and 4	49-62	2062 EAST SIDE HWY	CRIMORA	No	Buildings located outside of flood plain.
4	39-10	39-10 NEAR HARRISTON W SIDE SOUTH RIVER 194842 PATTERSON MILL RD AND STRICKLEY RD	GROTTOES	No	Well associated with poultry house, which sits outside flood plain.
4	39-11	75 CUSTARD LN	GROTTOES	No	House sits outside flood plain.
4	39-14R	3454 EAST SIDE HWY	GROTTOES	No	House sits outside flood plain.
4	39-17	3488 EAST SIDE HWY	GROTTOES	No	House sits outside flood plain.
4	39-18A	3546 EAST SIDE HWY	GROTTOES	No	House sits outside flood plain.
4	48-119B	149 RED MILL LN	CRIMORA	No	House sits outside flood plain.
4	48-134	96 WALKING STICK LANE	CRIMORA	No	House sits outside flood plain.
4	48-135	82 WALKING STICK LN	CRIMORA	No	House sits outside flood plain.
4	48-155	2236 EAST SIDE HWY	CRIMORA	No	House sits outside flood plain.
4	48-157	2563 ROCKFISH RD	CRIMORA	No	House sits outside flood plain.
4	48-158	63 FORESTRY CTR LN	CRIMORA	No	Well located outside of flood plain.
4	48-160A	260 RED MILL LN	CRIMORA	No	House sits outside flood plain.
4	48-160B	64 RED MILL LN	CRIMORA	No	All buildings located outside flood plain.
4	48-160C	212 RED MILL LN	CRIMORA	No	House sits outside flood plain.
4	48-165	230 BELVIDERE RD	CRIMORA	No	House sits outside flood plain.
4	48-166	3131 ROCKFISH RD	CRIMORA	No	House sits outside flood plain.
4	49-22	193 SERENDIPITY LN	CRIMORA	No	House sits outside flood plain.
4	49-22B	106 SERENDIPITY LN	CRIMORA	No	House sits outside flood plain.
4	49-47	2718 EAST SIDE HWY	CRIMORA	No	House sits outside flood plain.
4	49-47A	2758 EAST SIDE HWY	CRIMORA	No	House sits outside flood plain.
4	49-47D	2820 EAST SIDE HWY	CRIMORA	No	House sits outside flood plain.
4	49B-22	3292 EAST SIDE HWY	GROTTOES	No	House sits outside flood plain.

Table 4-6
Summary of Well Search Results
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Extent	Tax Parcel ID	Physical Address	City	Well In Floodplain (Yes / No / Unk)	Notes
4	49B-22C	3294 EAST SIDE HWY	GROTTOES	No	House sits outside flood plain.
5	29-14	149 GRAND CAVERNS DRIVE	GROTTOES	No	Only portion of large site is front corner of parking lot.
5	29-6	5 CAVERNS BOULEVARD	GROTTOES	No	Buildings located outside of flood plain.
5	29-6A	5 CAVERNS BOULEVARD	GROTTOES	No	Buildings located outside of flood plain.
5	29-9	748 SOUTH RIVER RD	GROTTOES	No	Buildings sit outside of flood plain.
5	39-1A	301 FOUNTAIN CAVE RD.	GROTTOES	No	House sits outside flood plain.
5	39-22A3	23 MARY ANNA LN	GROTTOES	No	House sits outside flood plain.
5	39-22E	103 SOUTH RIVER RD	GROTTOES	No	House sits outside flood plain.
5	39-22L	11 RIVERS EDGE LN	GROTTOES	No	House sits outside flood plain.
5	39-22P	44 RIVERS EDGE LN	GROTTOES	No	House sits outside flood plain.
5	39-22Q	49 SOUTH RIVER RD	GROTTOES	No	House sits outside flood plain.
5	39-22T	91 SOUTH RIVER RD	GROTTOES	No	House sits outside flood plain.
5	39-22W	45 SOUTH RIVER RD	GROTTOES	No	House sits outside flood plain.
5	39-22Y	26 MARY ANNA LN	GROTTOES	No	House sits outside flood plain.
5	39-22Y2	14 MARY ANNA LN	GROTTOES	No	House sits outside flood plain.
5	39-23	187 SOUTH RIVER RD	GROTTOES	No	House sits outside flood plain.
5	39-50	465 SOUTH RIVER RD	GROTTOES	No	House sits outside flood plain.
5	39-54	295 SOUTH RIVER RD	GROTTOES	No	House sits outside flood plain.
5	39-5A	197 TRIXIE LN	GROTTOES	No	House is located outside flood plain.
5	39-6A	173 TRIXIE LN	GROTTOES	No	House sits outside flood plain.
5	39-6B	175 TRIXIE LN	GROTTOES	No	House sits outside flood plain.

Table 4-7
Eroding Bank THg Concentration Summary
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

RRM	Average THg (µg/g dry wt.)	Maximum THg (µg/g dry wt.)
0.1*	NA	584
1.55	2	3
1.75	2	5
1.75	1	10
2.18	8	61
2.2*	140	515
2.6*	23	88
2.96*	43	110
3.54	9	29
4.75	6	18
5.36*	31	120
5.4	2	18
7.4*	23	83
7.7*	43	117
8.25	3	8
8.5	7	26
8.78	4	9
8.8	3	16
9.75*	24	80
11.58	10	37
13.13	2	3
15.4	2	8
19.84	5	30
22.3	3	5
22.58	2	3
22.61	1	6
23.1	4	13

Notes:

RRM - Relative River Mile

The data shown are the vertically averaged and maximum total mercury (THg) concentrations in eroding banks. The location of the eroding banks, in relative river miles (RRM), was determined based on visual evaluation of the bank.

* Indicate banks that are eroding Historic Release Age Deposits (HRADs), which are summarized in Table 4-6 of the Ecological Study Report (URS, 2012).

Samples were collected between February 19 and June 18 2008. See Ecological Study Data Matrix (Table 1-1) for more information regarding study details.

NA: not applicable; several vertically averaged cores were collected on this bank.

Source: Table 4-7 in the Ecological Study Report (URS, 2012).

Table 6-1
Sediment Quality Triad Investigation - Summary of SQT Lines-of-Evidence
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

SQT Station	Sediment Chemistry			Sediment Toxicity Testing: *Chironomus dilutus*		Sediment Toxicity Testing: *Hyalella azteca*		Benthic Community Structure Metric Analyses								
	Mercury (µg/g dry weight)	Other Metals	Heptachlor	10-day Survival	10-day Growth	10-day Survival	10-day Growth	Taxa Richness	EPT Richness*	% EPT	% Ephemeroptera	% Trichoptera	% Diptera	% Dominant Taxon	Shannon's Diversity (H')	Pielou's Evenness (J')
RRM 0.1	+ (0.943)	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–
RRM 3.5	+ (18.9)	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
RRM 11.8	+ (16.7)	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
RRM 23.5	+ (12.5)	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Key:	+	–
Sediment Chemistry	Site concentration > reference concentrations and ecological benchmark	Site concentration < reference concentrations and ecological benchmark
Sediment Toxicity Testing	Endpoint significantly lower than pooled reference replicates	Endpoint not significantly lower than pooled reference replicates
Benthic Community Structure	Metric significantly different than pooled reference replicates	Metric not significantly different than pooled reference replicates

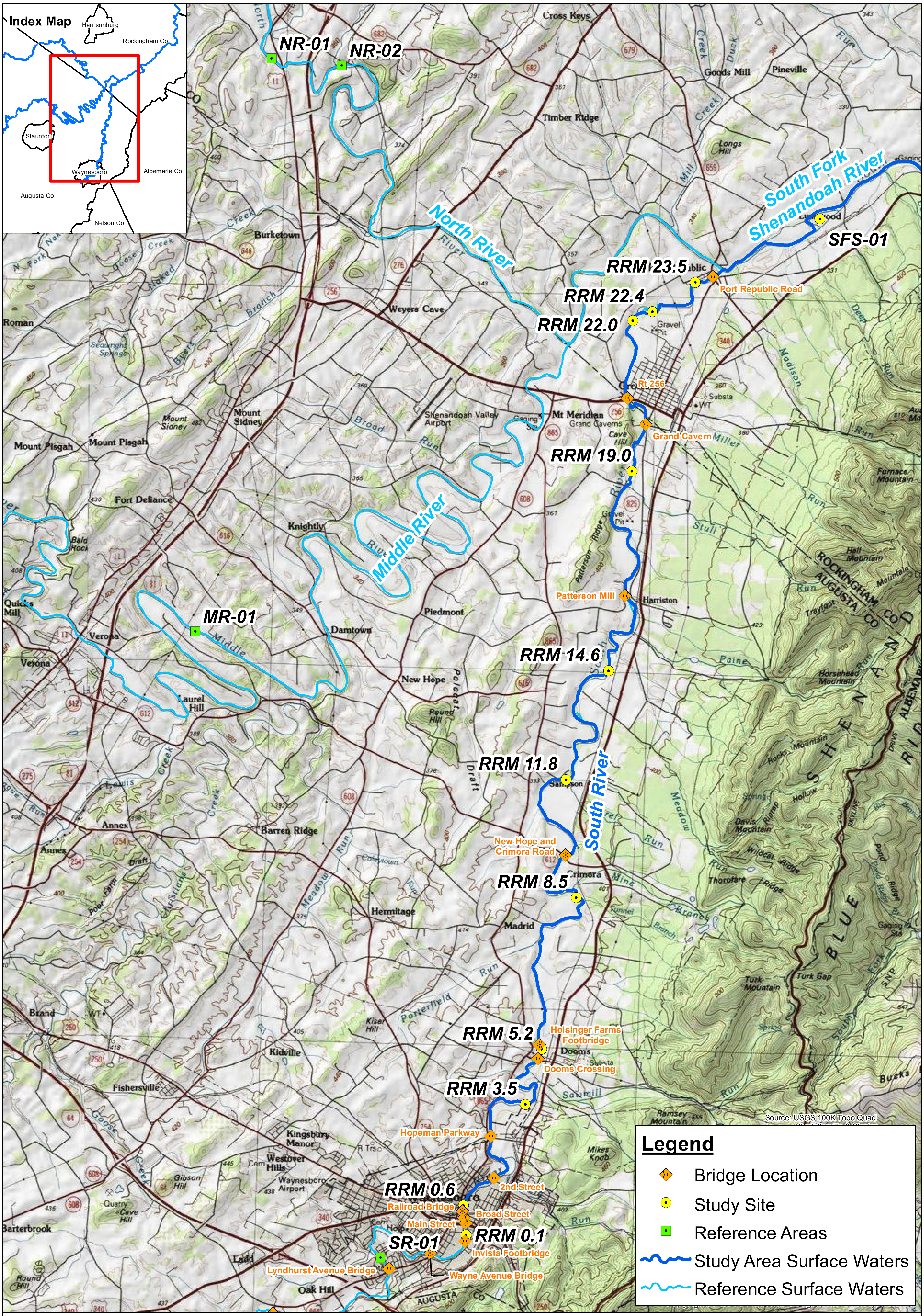
Notes:
* One-way analysis of variance (ANOVA) indicated significant differences (p=0.034) between reference and site stations; however, Tukey HSD multi-comparison testing did not detect statistically significant pairwise comparisons.

RRM = relative river mile

Data were collected in May 2010. See Ecological Study Data Matrix (Table 1-1) for more information regarding study details.

Source: Table 6-6 in the Ecological Study Report (URS, 2012)

Figures



URS

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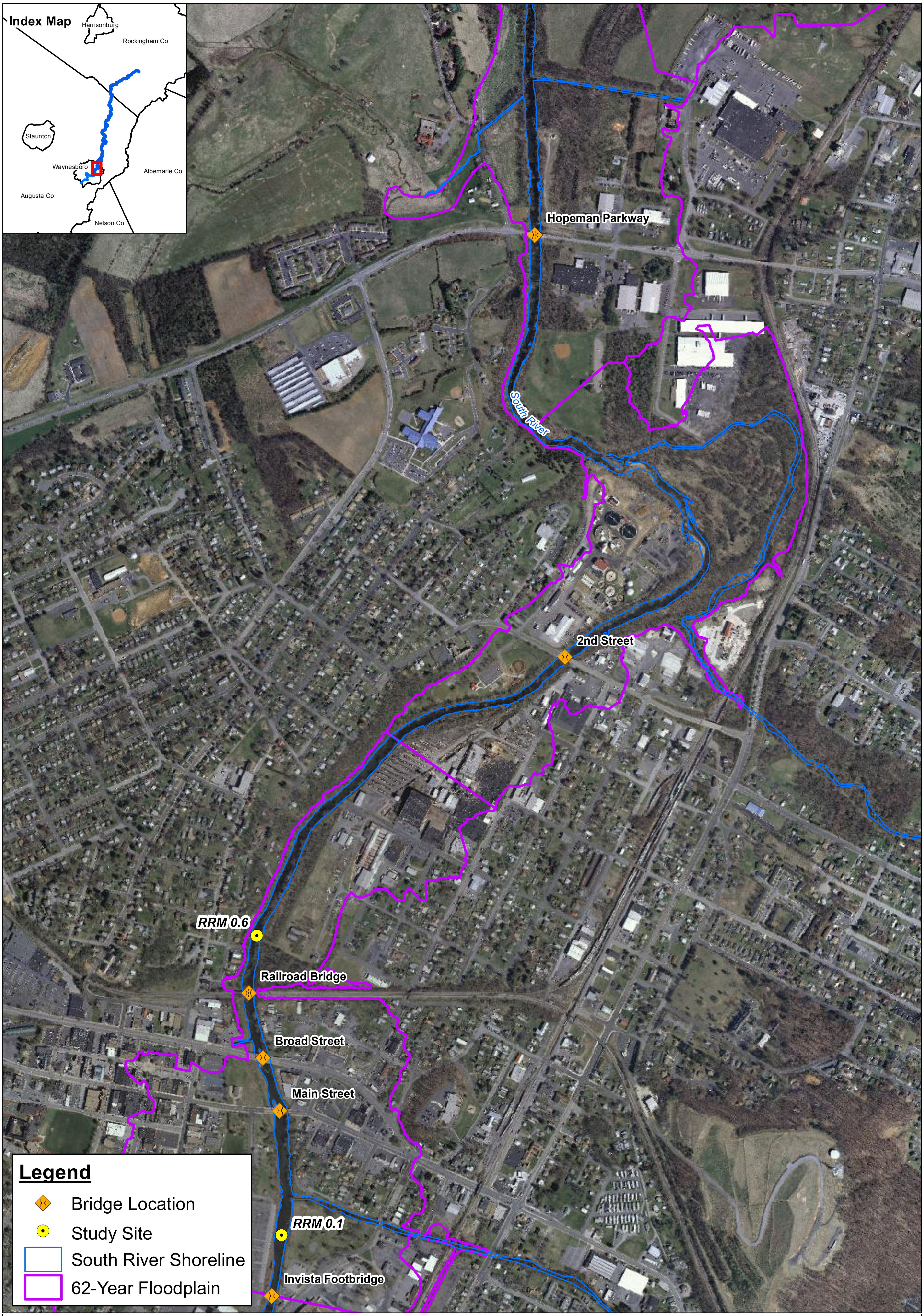
SOUTH RIVER PROJECT

PROJECT NO. 18986307

0 0.5 1 2 3
Miles

Figure 1-1
Investigation Area Overview Map
AOC 4 RFI Report
Former DuPont Waynesboro Site
Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Path: S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\07302015\Figure 1-1 Investigation Area Overview Map - 073015.mxd



Source:
VBMP Most Recent Imagery
URS Custom Data

N

E. I. du PONT de NEMOURS & COMPANY

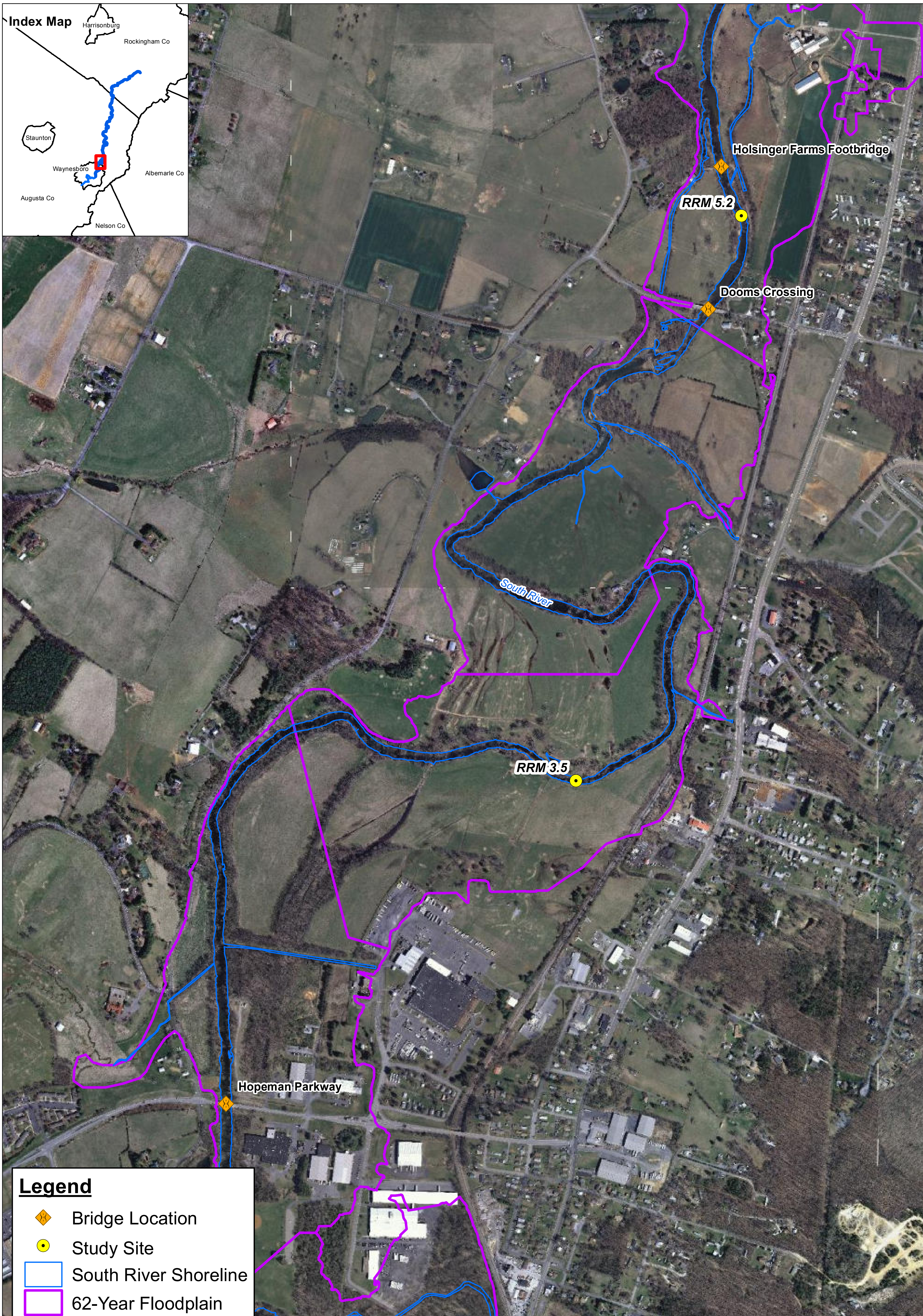
SOUTH RIVER PROJECT

PROJECT NO. 18986307

0 0.05 0.1 0.2 0.3
Miles

Figure 1-2
Investigation Area Overview Map – Panel 1
AOC 4 RFI Report
Former DuPont Waynesboro Site
Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Path: S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\07302015\Figure 1-2 Investigation Area Overview Map - Panel 1 - 073015.mxd



Source:
VBMP Most Recent Imagery
URS Custom Data

N

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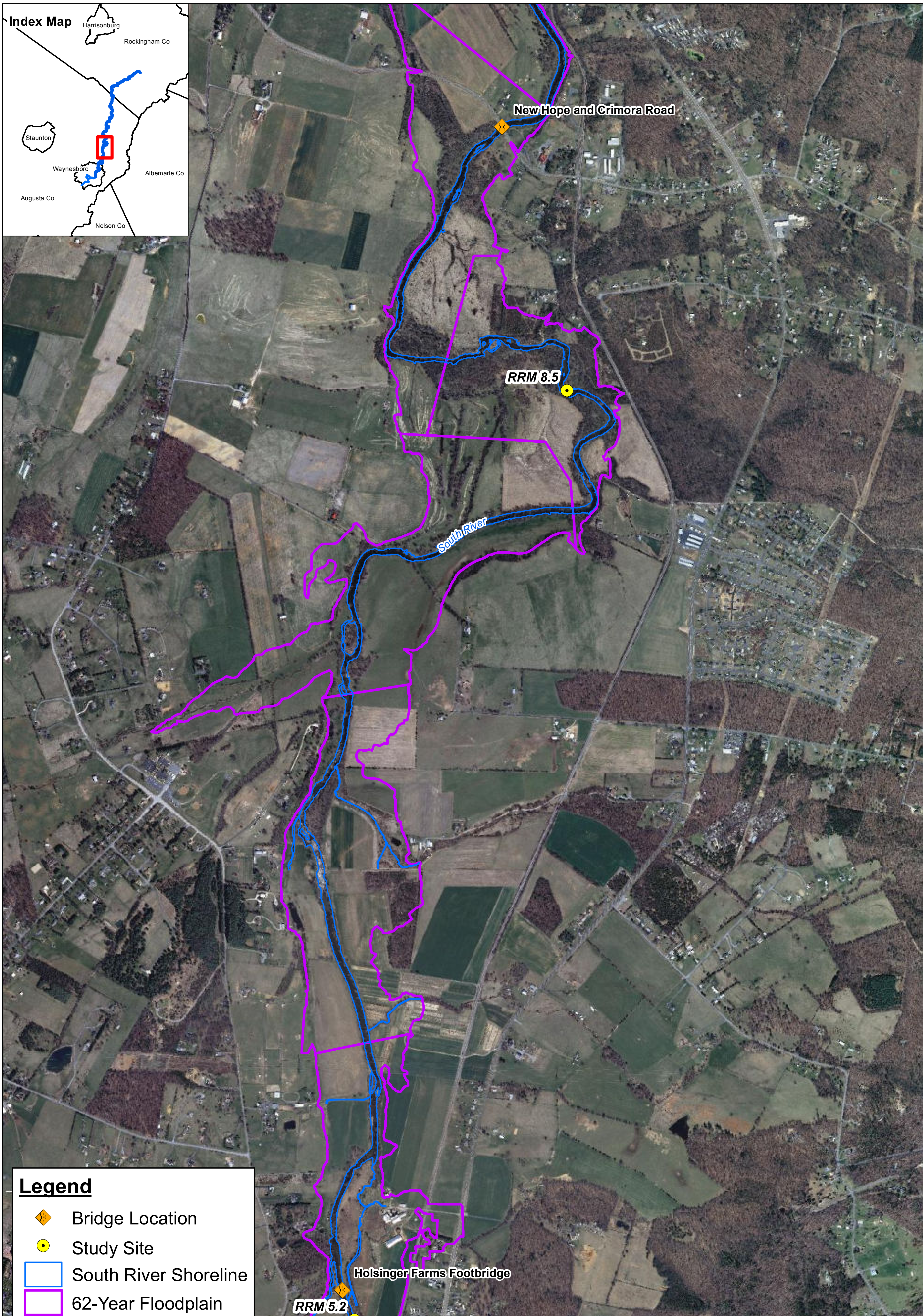
SOUTH RIVER PROJECT

PROJECT NO. 18986307

0 0.05 0.1 0.2 0.3
Miles

Figure 1-3
Investigation Area Overview Map – Panel 2
AOC 4 RFI Report
Former DuPont Waynesboro Site
Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Path: S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\07302015\Figure 1-3 Investigation Area Overview Map - Panel 2 - 073015.mxd



URS

Source:
VBMP Most Recent Imagery
URS Custom Data

N

E. I. du PONT de NEMOURS & COMPANY

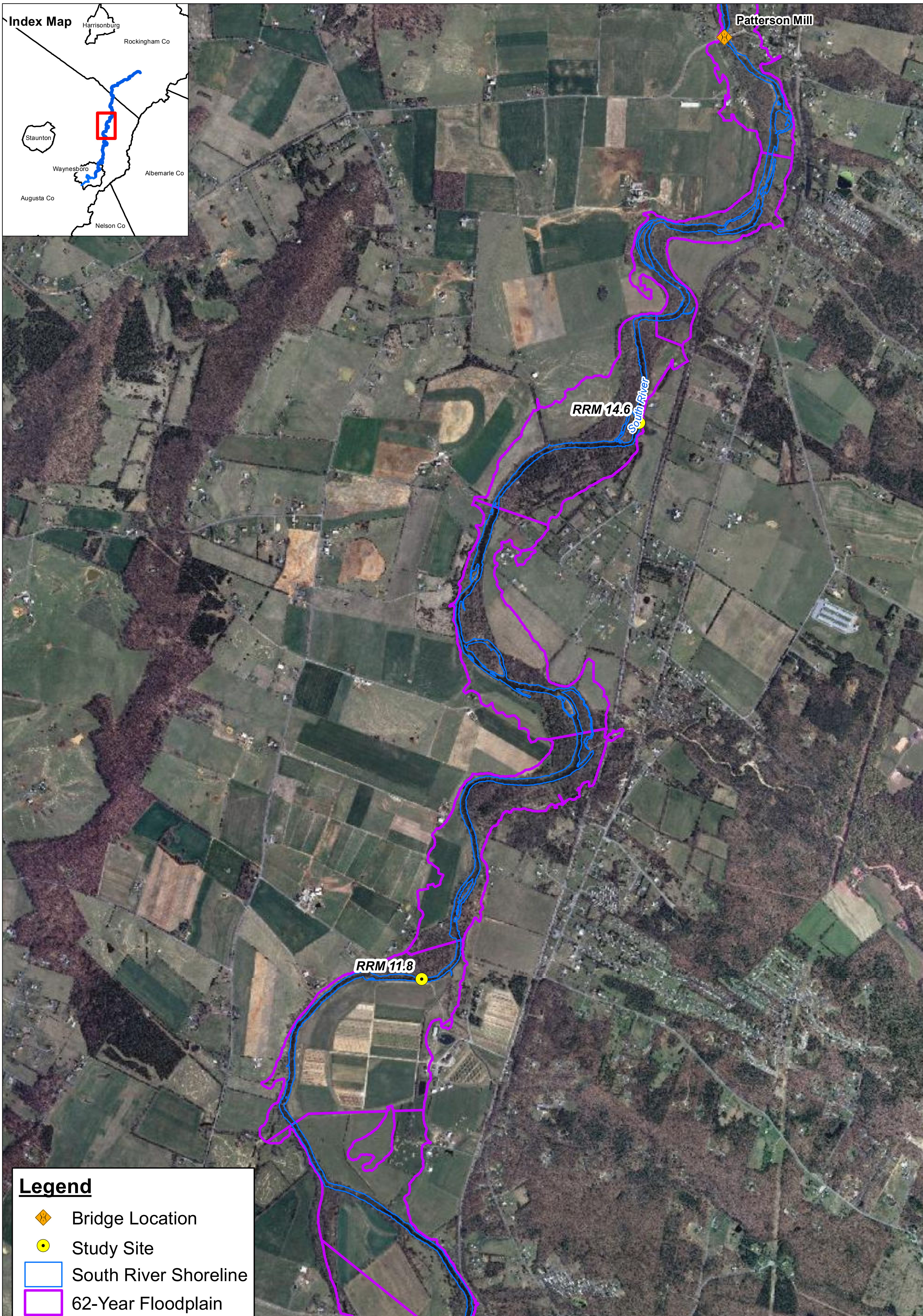
SOUTH RIVER PROJECT

PROJECT NO. 18986307

0 0.1 0.2 0.4 0.6
Miles

Figure 1-4
Investigation Area Overview Map – Panel 3
AOC 4 RFI Report
Former DuPont Waynesboro Site
Area of Concern 4
South River and a Segment of the
South Fork Shenandoah River, Va

Path: S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\07302015\Figure 1-4 Investigation Area Overview Map - Panel 3 - 073015.mxd



URS

Source:
VBMP Most Recent Imagery
URS Custom Data

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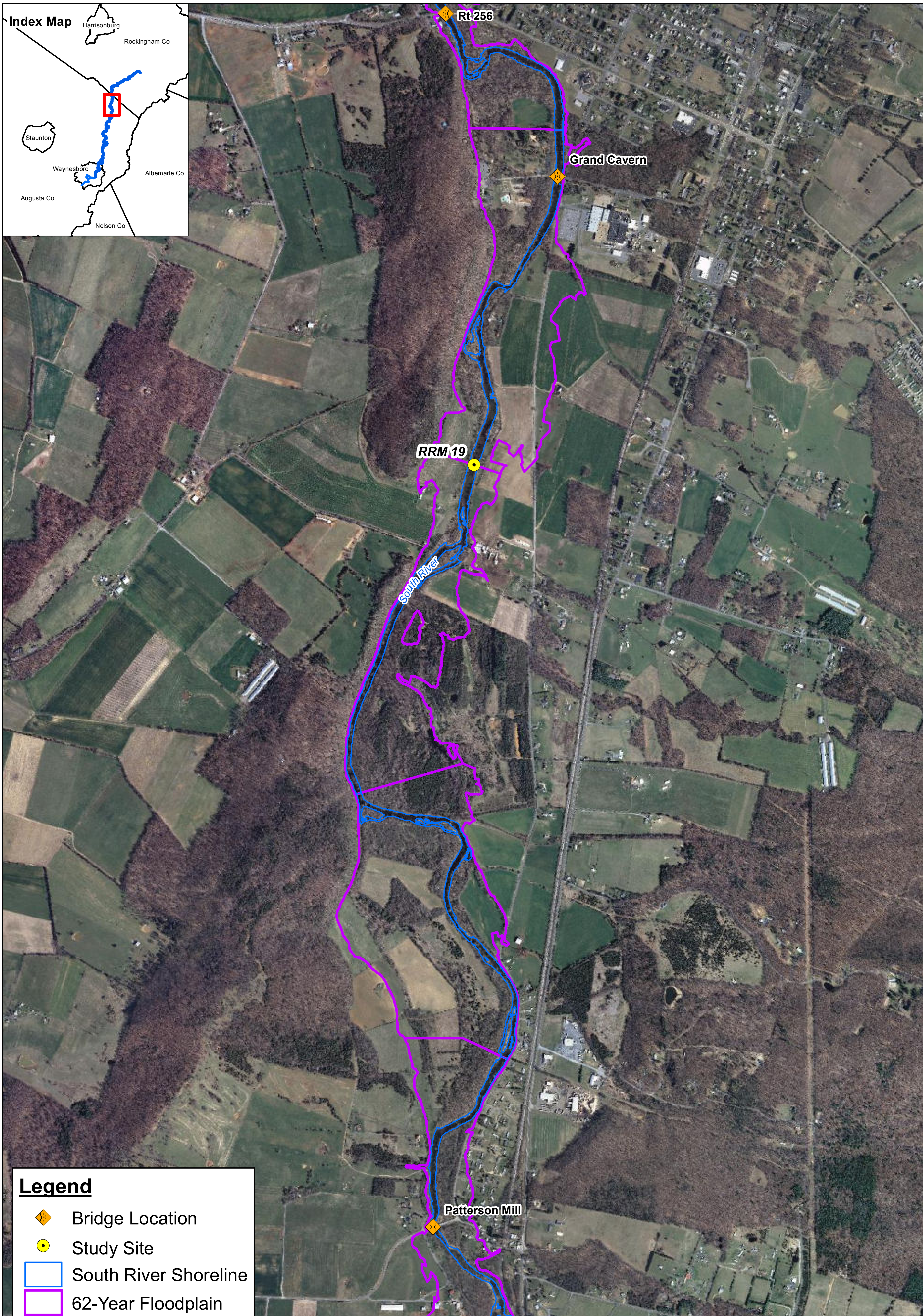
SOUTH RIVER PROJECT

PROJECT NO. 18986307

Figure 1-5
Investigation Area Overview Map – Panel 4
AOC 4 RFI Report
Former DuPont Waynesboro Site
Area of Concern 4
South River and a Segment of the
South Fork Shenandoah River, Va

Path: S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\07302015\Figure 1-5 Investigation Area Overview Map - Panel 4 - 073015.mxd



Source:
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URS Custom Data

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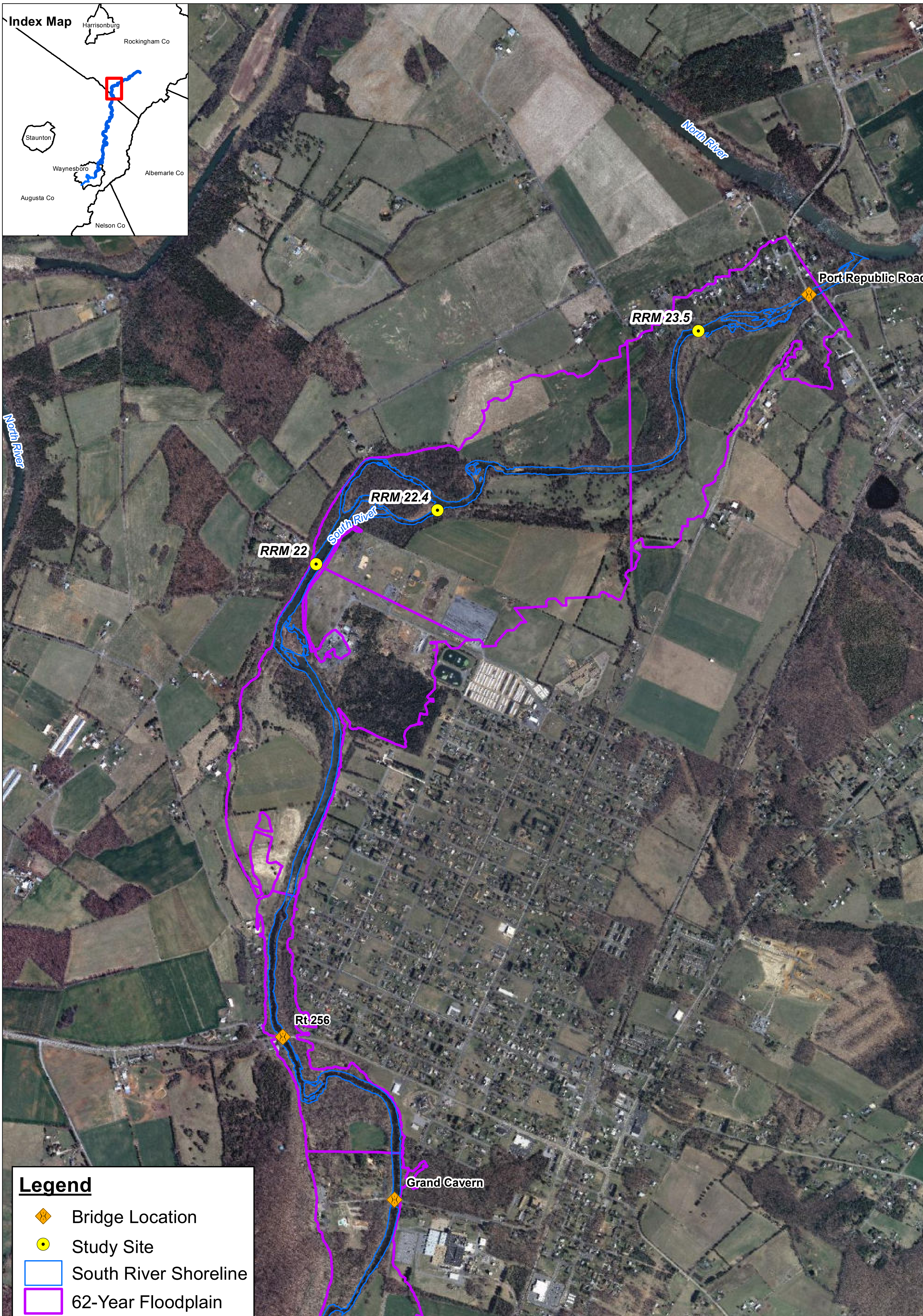
SOUTH RIVER PROJECT

PROJECT NO. 18986307

0 0.125 0.25 0.5
Miles

Figure 1-6
Investigation Area Overview Map – Panel 5
AOC 4 RFI Report
Former DuPont Waynesboro Site
Area of Concern 4
South River and a Segment of the
South Fork Shenandoah River, Va

Path: S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\07302015\Figure 1-6 Investigation Area Overview Map - Panel 5 - 073015.mxd



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Source:
VBMP Most Recent Imagery
URS Custom Data

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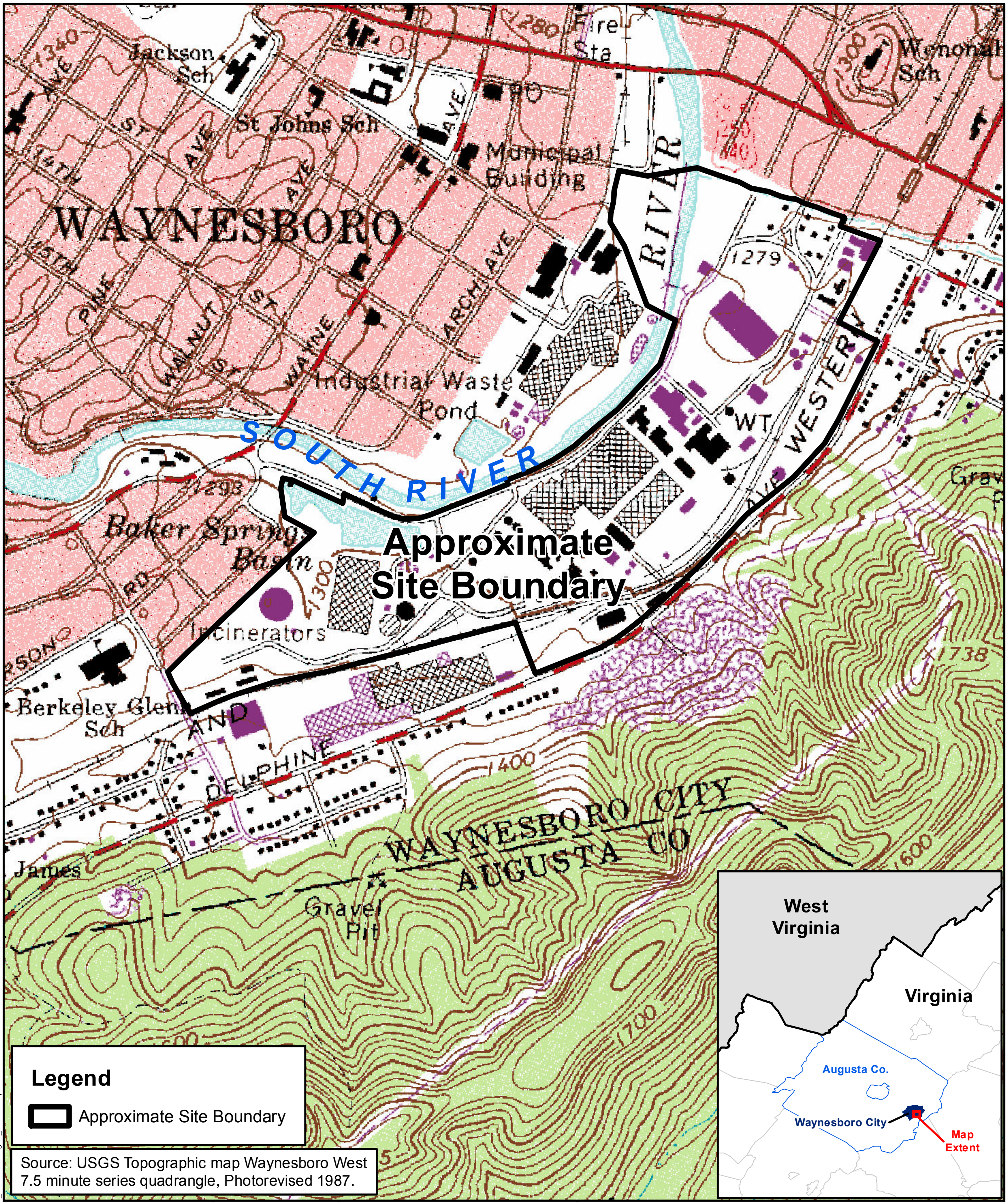
SOUTH RIVER PROJECT

PROJECT NO. 18986307

0 0.125 0.25 0.5
Miles

Figure 1-7
Investigation Area Overview Map – Panel 6
AOC 4 RFI Report
Former DuPont Waynesboro Site
Area of Concern 4
South River and a Segment of the
South Fork Shenandoah River, Va

Path: S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\07302015\Figure 1-7 Investigation Area Overview Map - Panel 6 - 073015.mxd



Source: USGS Topographic map Waynesboro West 7.5 minute series quadrangle, Photorevised 1987.

G:\DuPont\Waynesboro Plant\GIS\Project\18986303_PermitModFigA1_SiteLocMap.mxd

0 250 500 1,000
Feet
1 inch = 1,000 feet

MAP FORMATTED FOR "A" (8.5" X 11") SIZE SHEET.
TEXT SCALE NOT VALID FOR DIFFERENT PAGE SIZE.

FILE NUMBER:

DESIGNED BY: CAD

DRAWN BY: CAD

DATA QUALITY CHECK BY: CAD/RBW

URS

Figure 1-8
Former DuPont Waynesboro Plant
Overview Map
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork
Shenandoah River, Va

Source: Waynesboro RFI Report (URS, 2009).

Figure 2-1
Surrounding Land Use in the South River Watershed
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork
Shenandoah River, Va

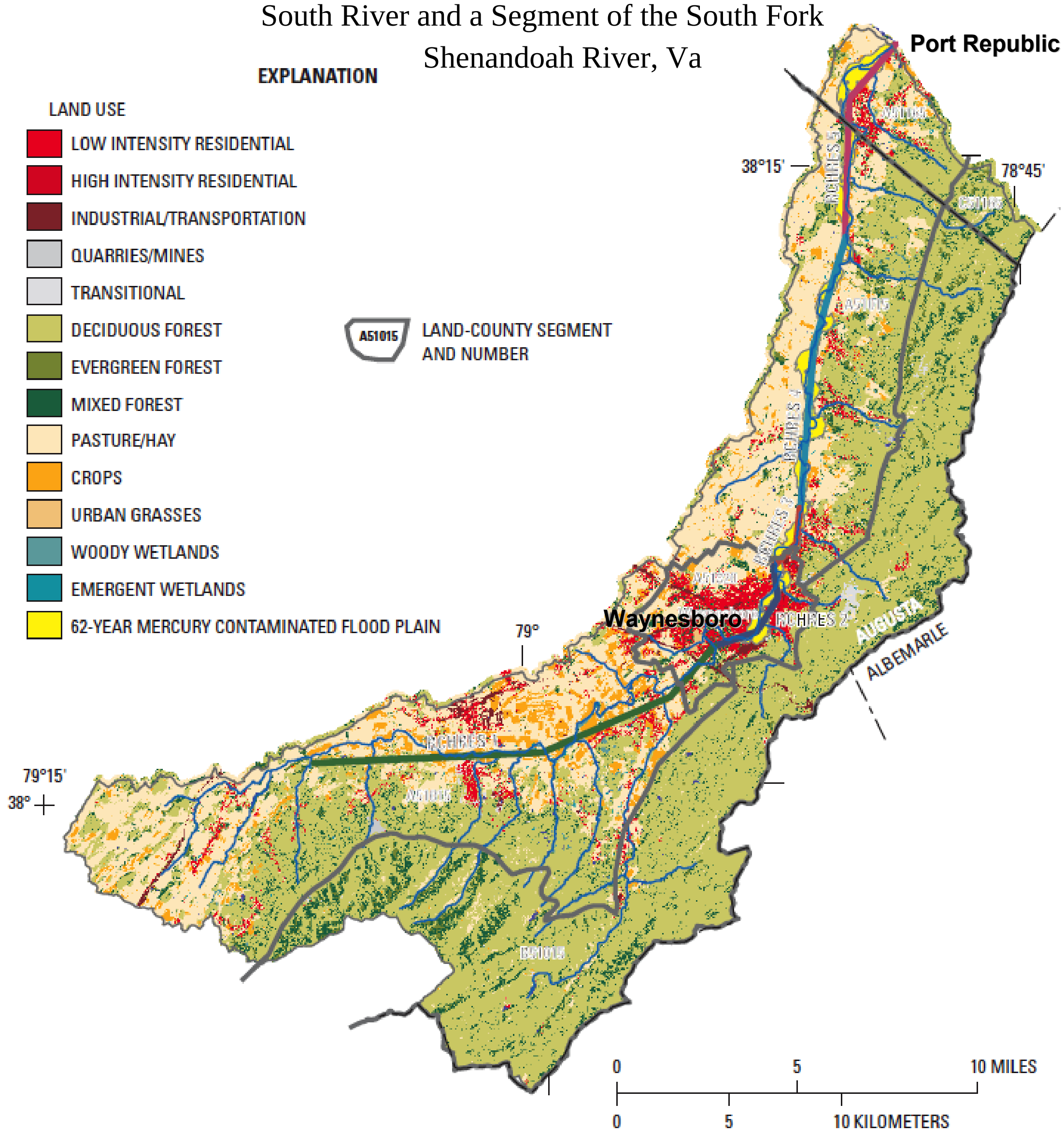
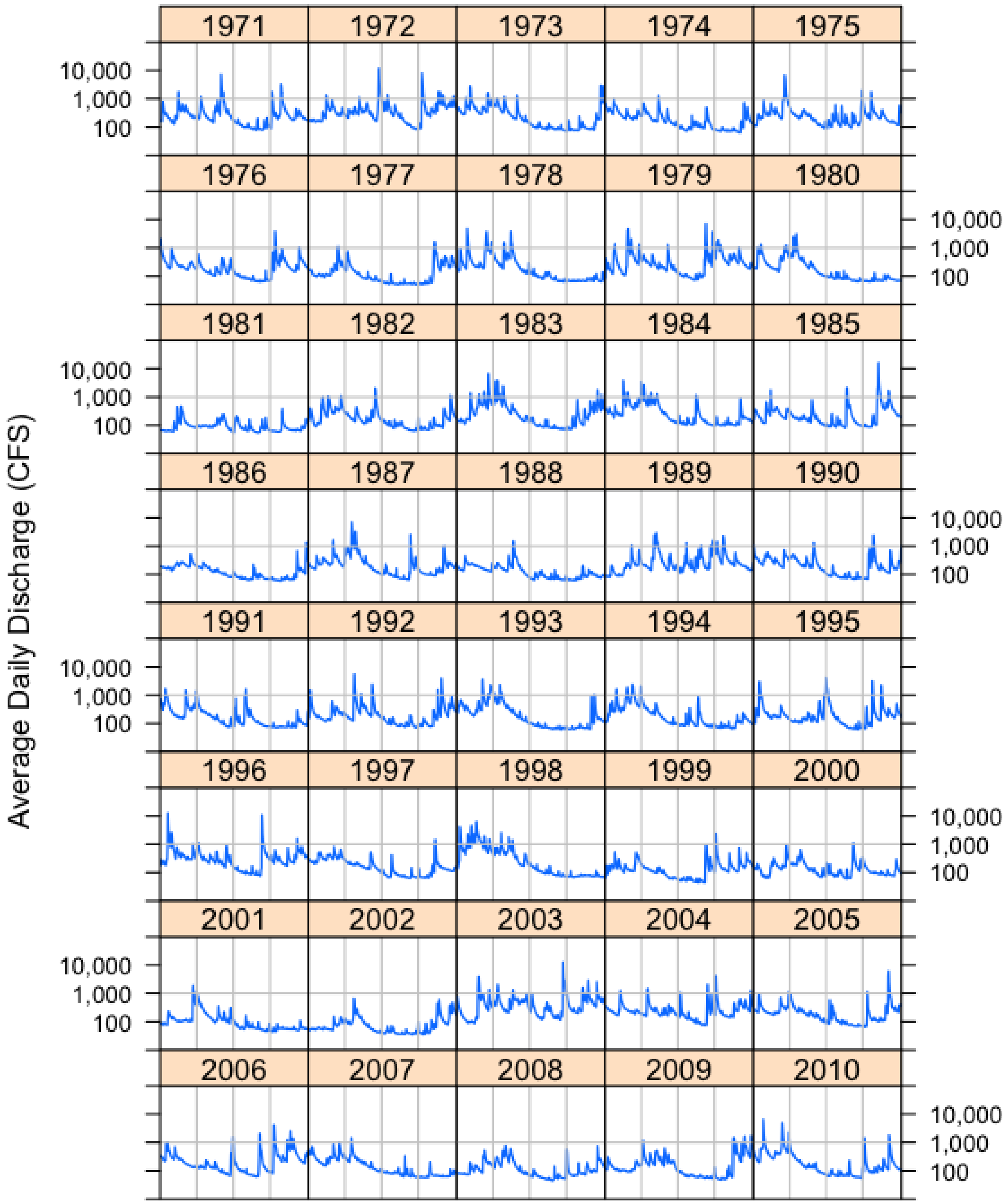
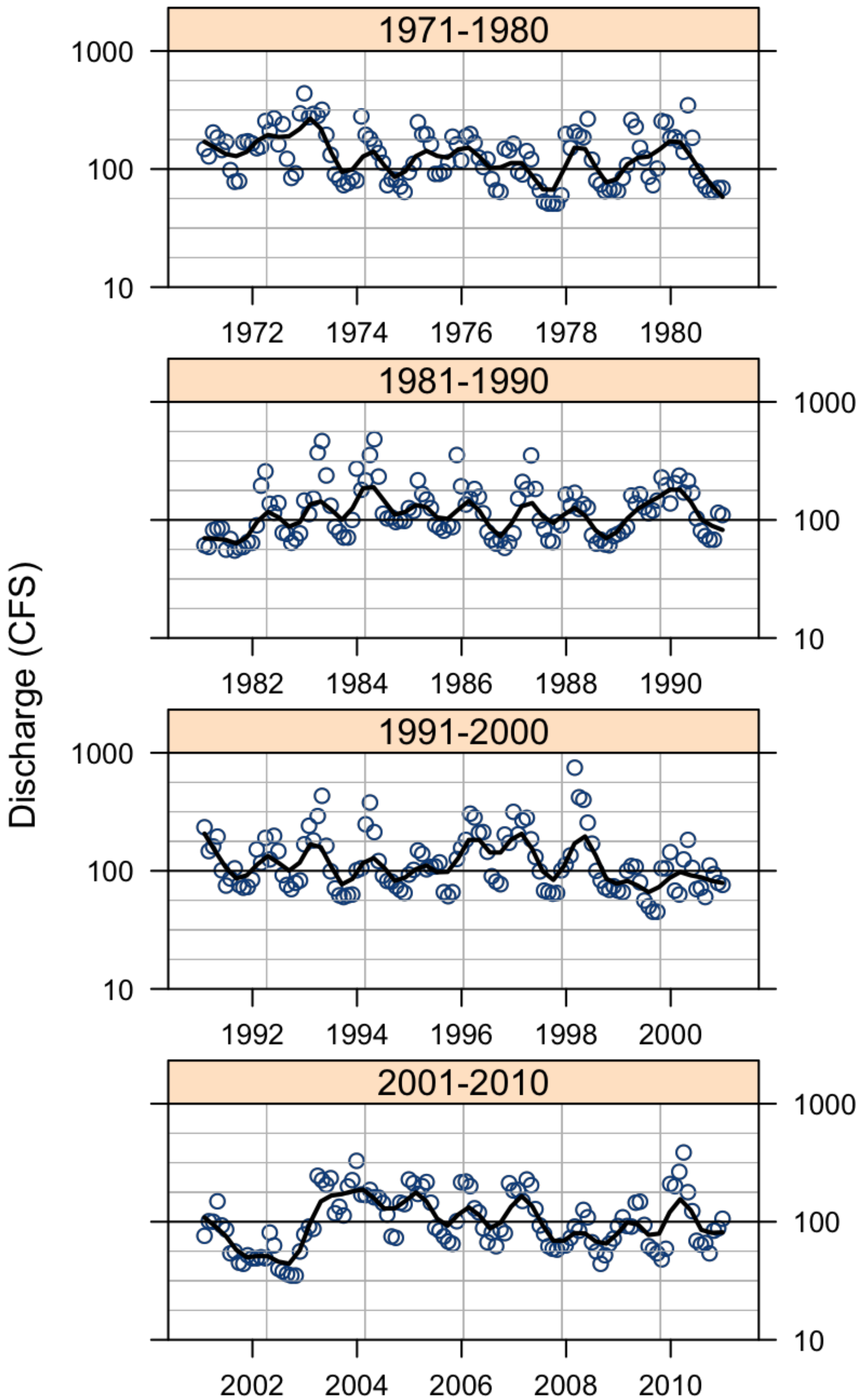


Figure 2-2
South River Average Daily Discharge, 1971-2010
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



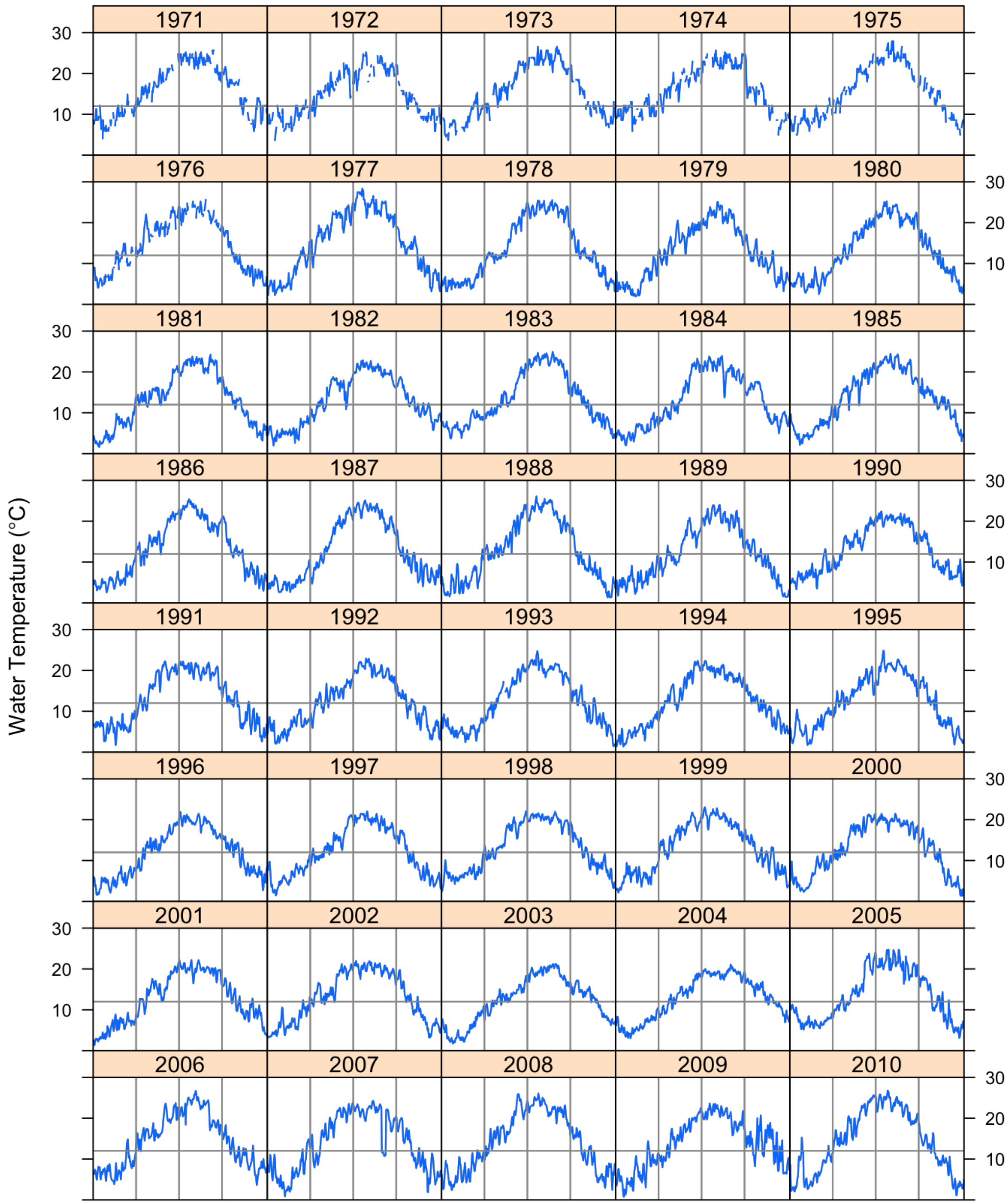
<u>Note:</u> Figure shows discharge, in cubic feet per second (CFS) as measured at Harriston, Virginia (Figure 1-1) by the USGS. The vertical gray lines divide each year into quarters. The horizontal grey line is set at 1,000 CFS for reference. Studies conducted prior to 2000 are not included in the Ecological Study Data Matrix (Table 1-3). Source: Figure 2-2 in Ecological Study Report (URS, 2012)

Figure 2-3
Long-Term Trends in Minimum Monthly Discharge
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



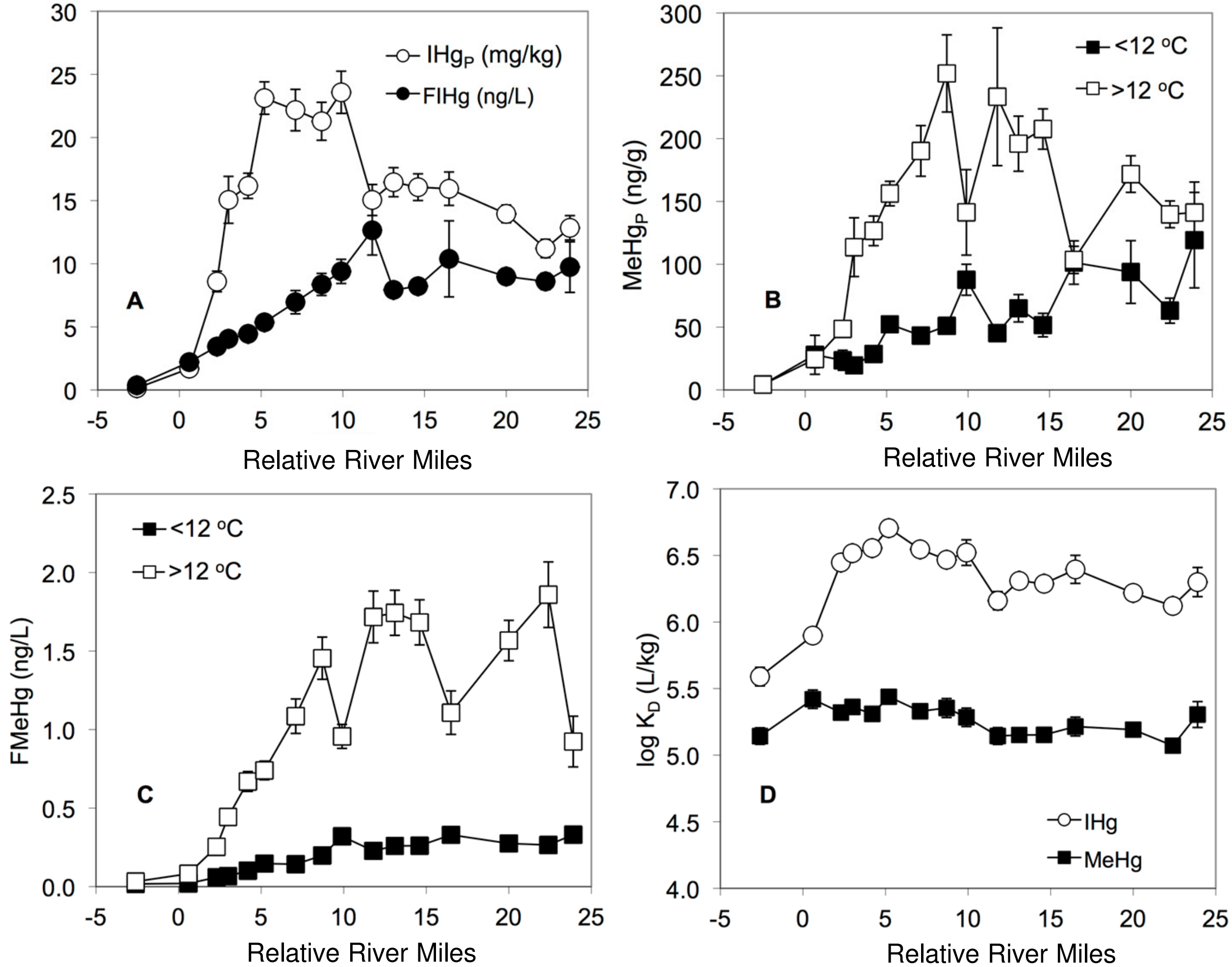
Note: The data shown are the minimum monthly discharge as measured at the USGS stream gage at Harriston, Virginia from 1971 through 2010. The data are fit with a loess curve (span = 0.1) to illustrate interannual trends. Studies conducted prior to 2000 are not included in the Ecological Study Data Matrix (Table 1-3). Source: Figure 2-3 in Ecological Study Report (URS, 2012).

Figure 2-4
Long-Term Average Daily Temperature Record in Surface Water
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



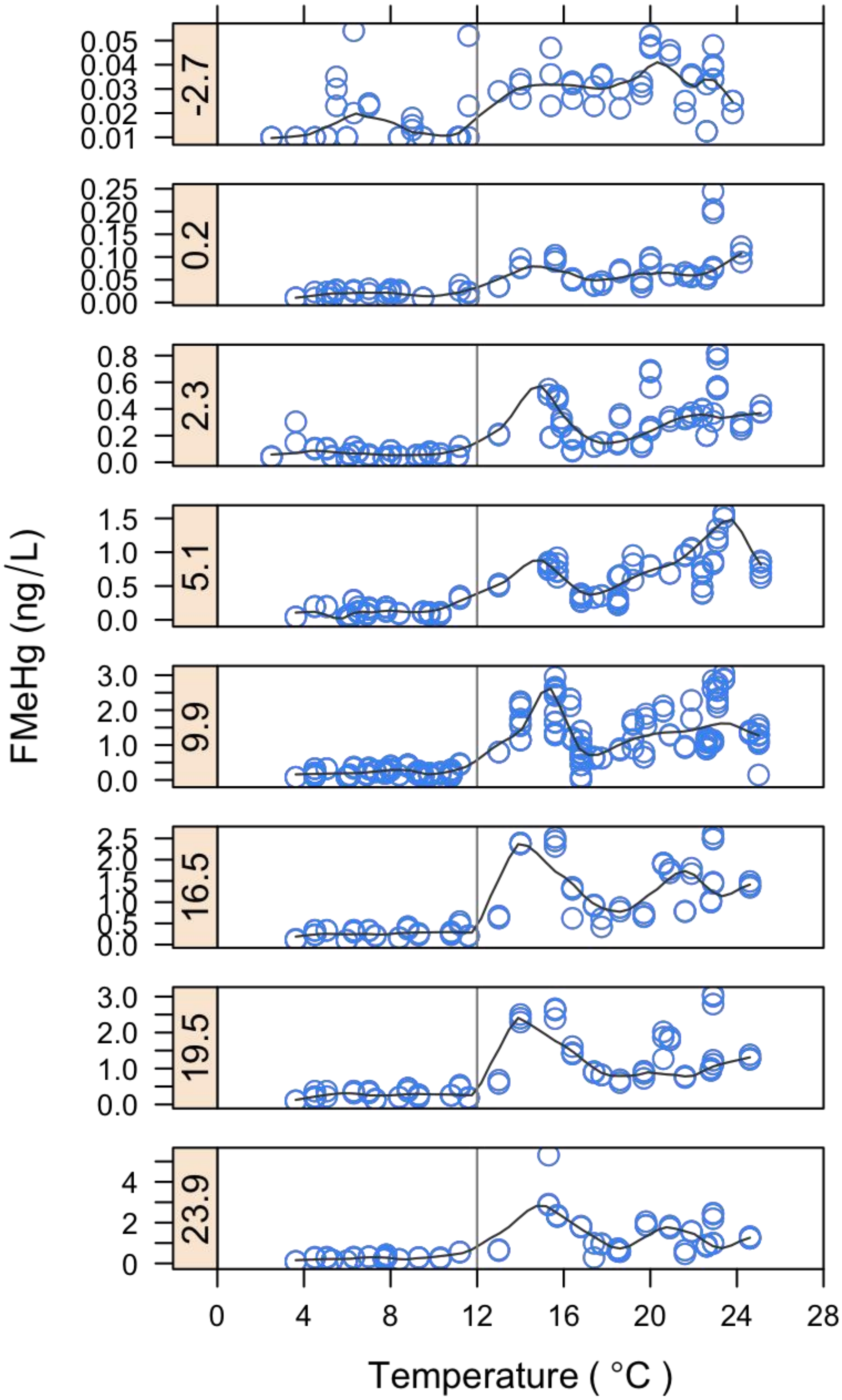
Note: A long-term daily average surface water temperature was constructed using data from USGS stream gages on the South River, Middle River, and Jackson River. The data shown are the mean daily water temperature plotted against the day of the year. The gray horizontal line is equivalent to 12°C. Studies conducted prior to 2000 are not included in the Ecological Study Data Matrix (Table 1-3). Source: Figure 2-5 in Ecological Study Report (URS, 2012).

Figure 3-1
Behavior of Inorganic Mercury and Methylmercury in Surface Water
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



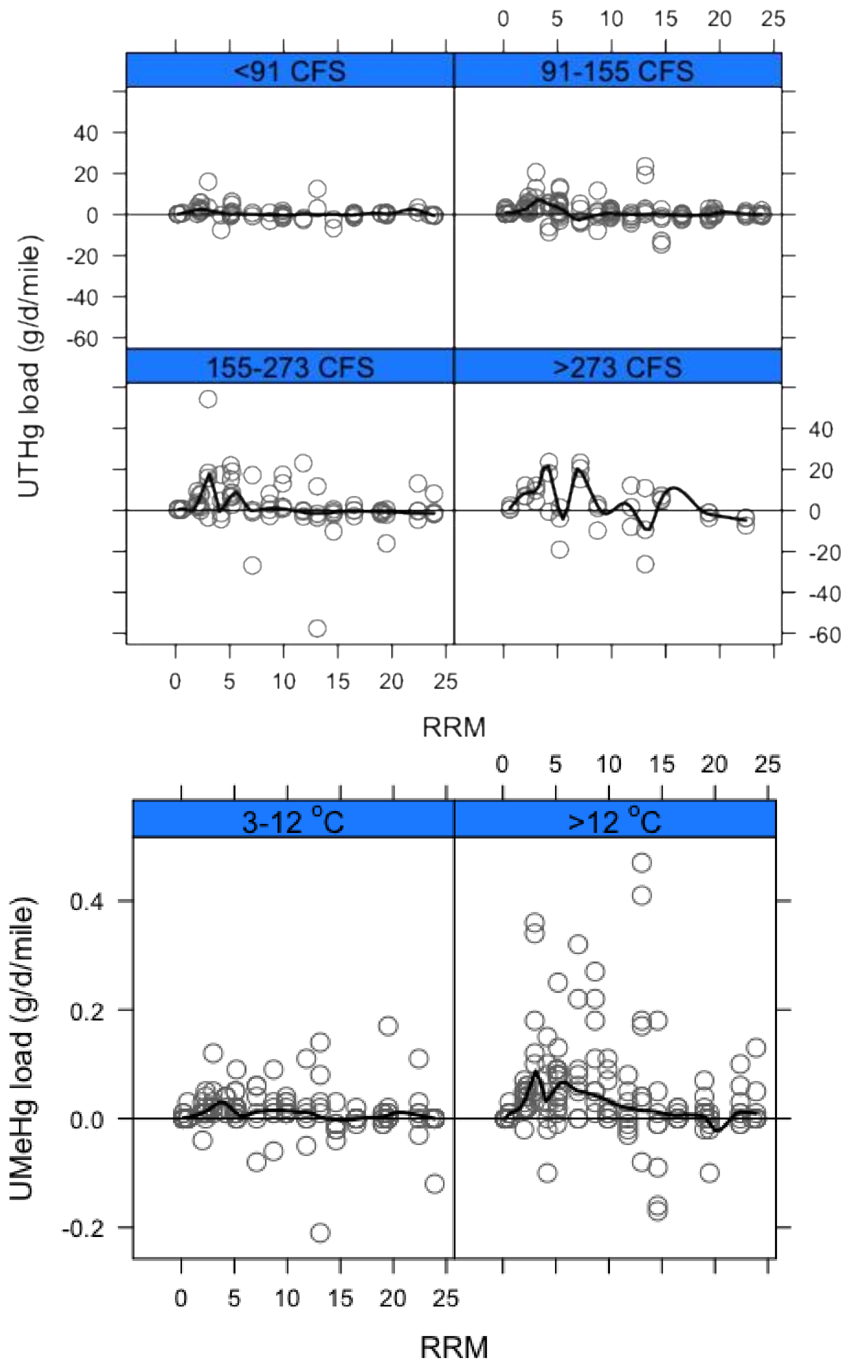
<u>Notes</u>: Behavior of IHg and MeHg in surface water data collected between 2006 and 2010. Symbols represent the mean and the standard error. Panel A: IHg on TSS particles (IHg_P, in mg/kg dry wt.), and in filtered (0.45µm filter) samples (FIHg, in ng/L) as a function of distance, in relative river miles. MeHg on TSS particles ($MeHg_P$, in ng/g dry wt.; Panel B) and in filtered (0.45µm filter) samples (FMeHg; Panel C) as a function of distance and temperature regime. The log of the particle-water distribution coefficient (K_D; Panel D) for IHg and MeHg. See Ecological Study Data Matrix (Table 1-3) for more information regarding study details. Source: Figure 4-3 in Ecological Study Report (URS, 2012).

Figure 3-2
Time Series of Methylmercury in South River Surface Water
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



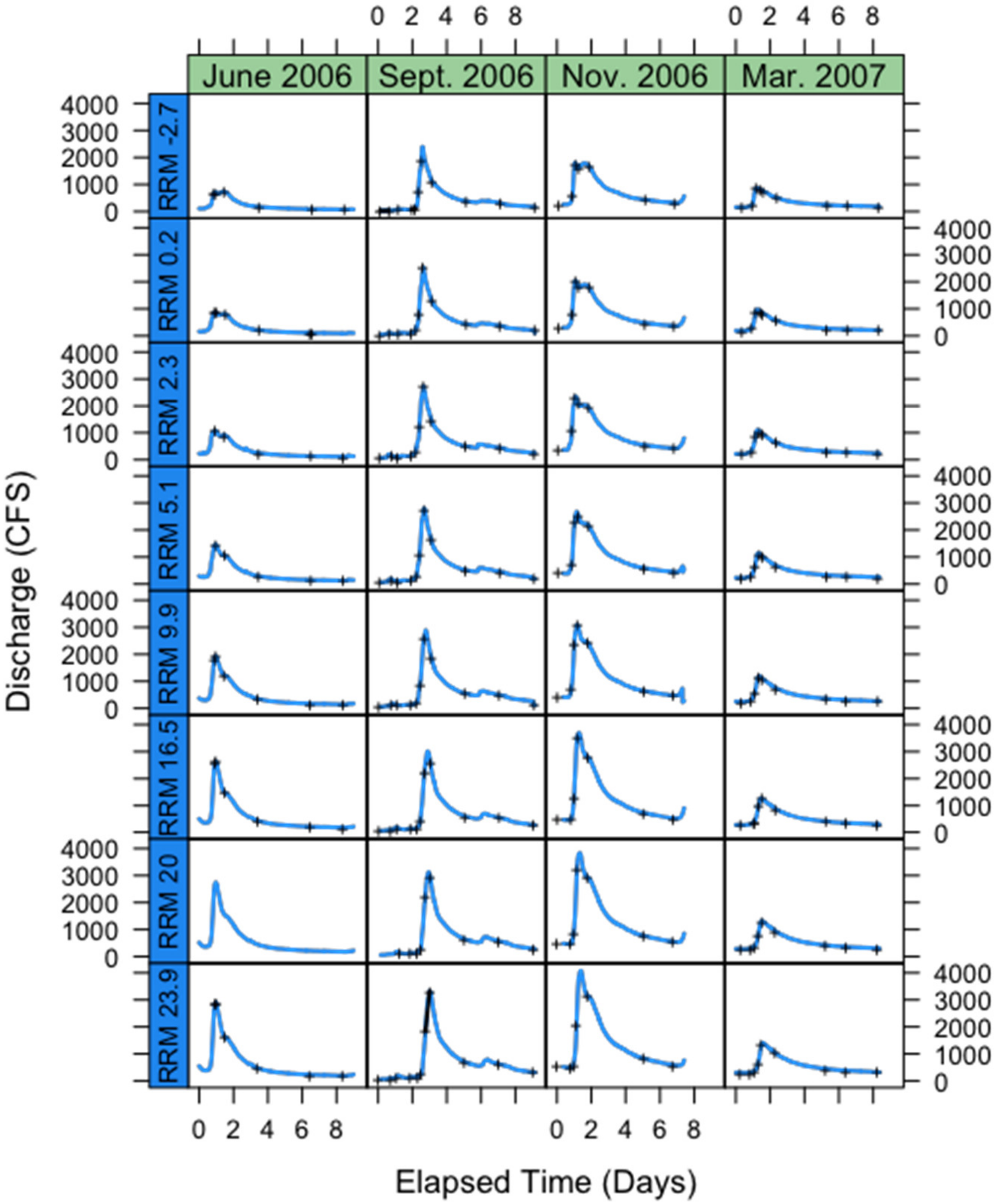
Notes: Data for filtered (0.45µm filter) methylmercury (FMeHg) were collected between 2006 and 2010. Sample locations in RRM are listed on left panel. The figure shows the FMeHg concentration in individual replicates as a function of surface water temperature, fit by a LOESS smoother (span = 0.2) to illustrate the effect of increasing surface water temperature. Surface water temperatures are the mean daily temperature measured at the USGS stream gage at Harriston, Virginia during the period of sampling. See Ecological Study Data Matrix (Table 1-3) for more information regarding study details.

Figure 3-3
Baseline Total Mercury and Methylmercury Incremental Loads, 2006 to 2011
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



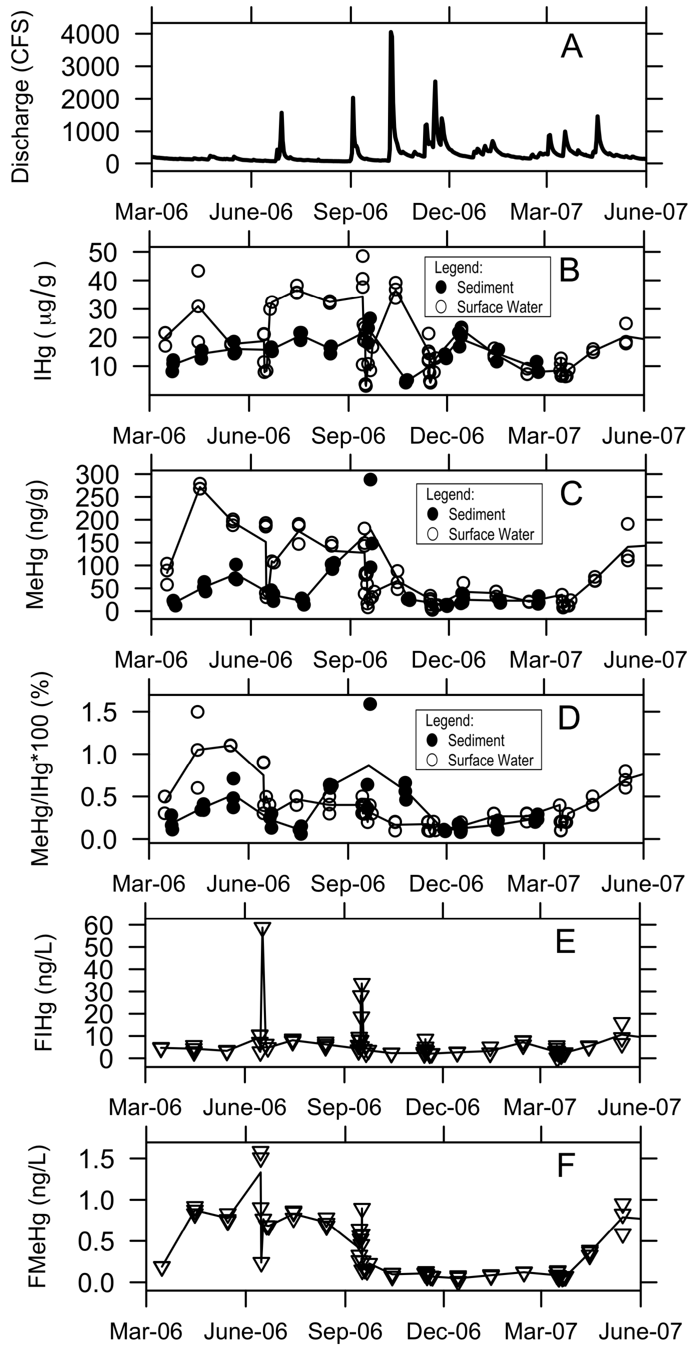
<u>Notes</u>: Data shown are the average (n=2 or 3) incremental unfiltered total mercury (UTHg) and unfiltered methylmercury (UMeHg) load, normalized to the reach length, for locations sampled during the Ecological Study. Data are grouped according to the discharge [in cubic feet per second (CFS)] measured at Harriston during the sampling period. The solid black line was fit by a LOESS procedure to show patterns of incremental load over time. Baseline refers to the periods of time where stream flow increases with distance downstream and the majority of stream flow is supplied by subsurface flow. See Ecological Study Data Matrix (Table 1-3) for more information regarding study details.

Figure 3-4
Sample Collection and Storm Discharge Summary
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



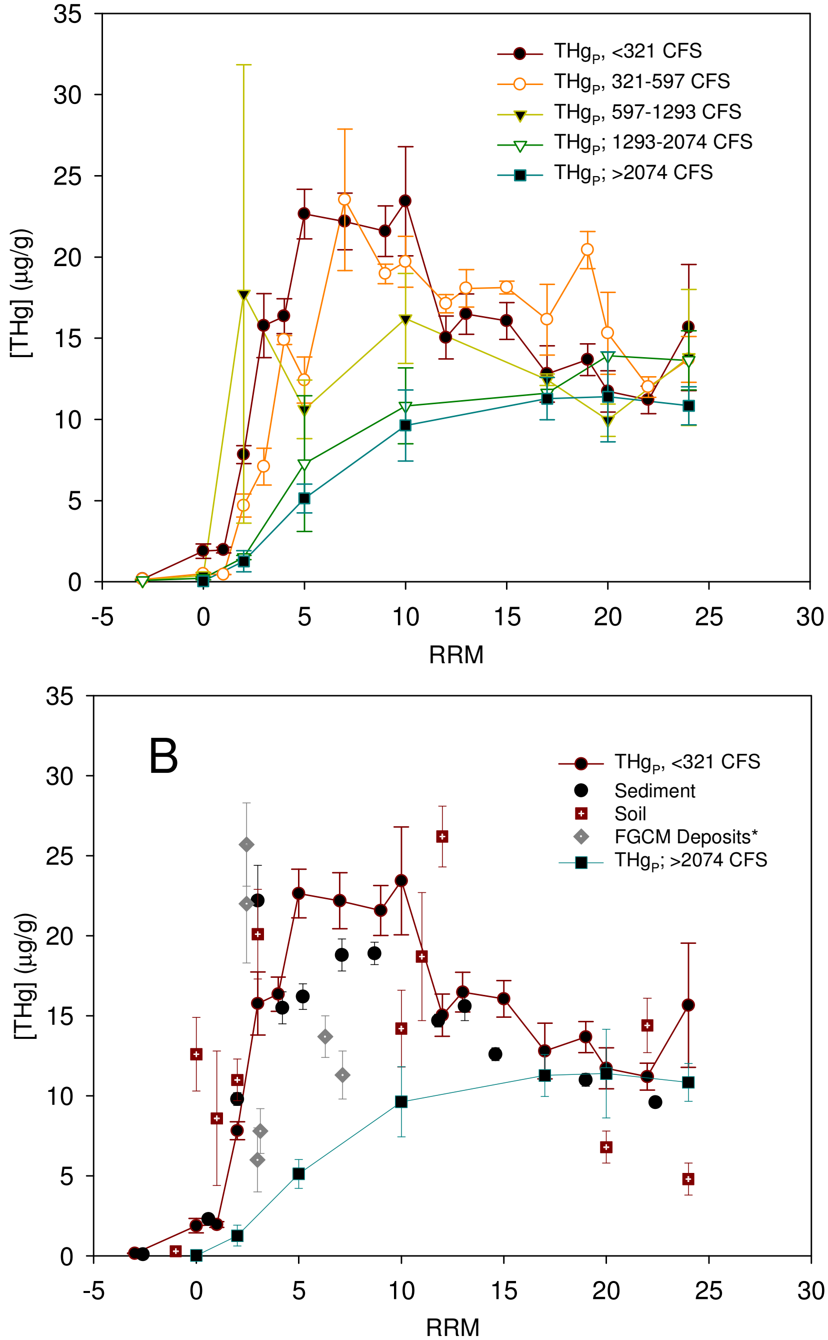
Notes: RRM – Relative river mile; Blue lines represent discharges [in cubic feet per second (CFS)] based on USGS measurements and interpolations at 15 minute intervals. Crosses represent sample collection times for each of the four storm events comprehensively sampled in Phase I (2005-2007). USGS measured the discharges at RRM -2.7, 2.3, and 16.5; Discharges at other locations were interpolated. Location RRM 20 was not included in the June 2006 sampling event during Phase I. Source: Figure 4-6 in Ecological Study Report (URS, 2012).

Figure 3-5
2006-2007 Time Series of Mercury in Surface Water and Sediment
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



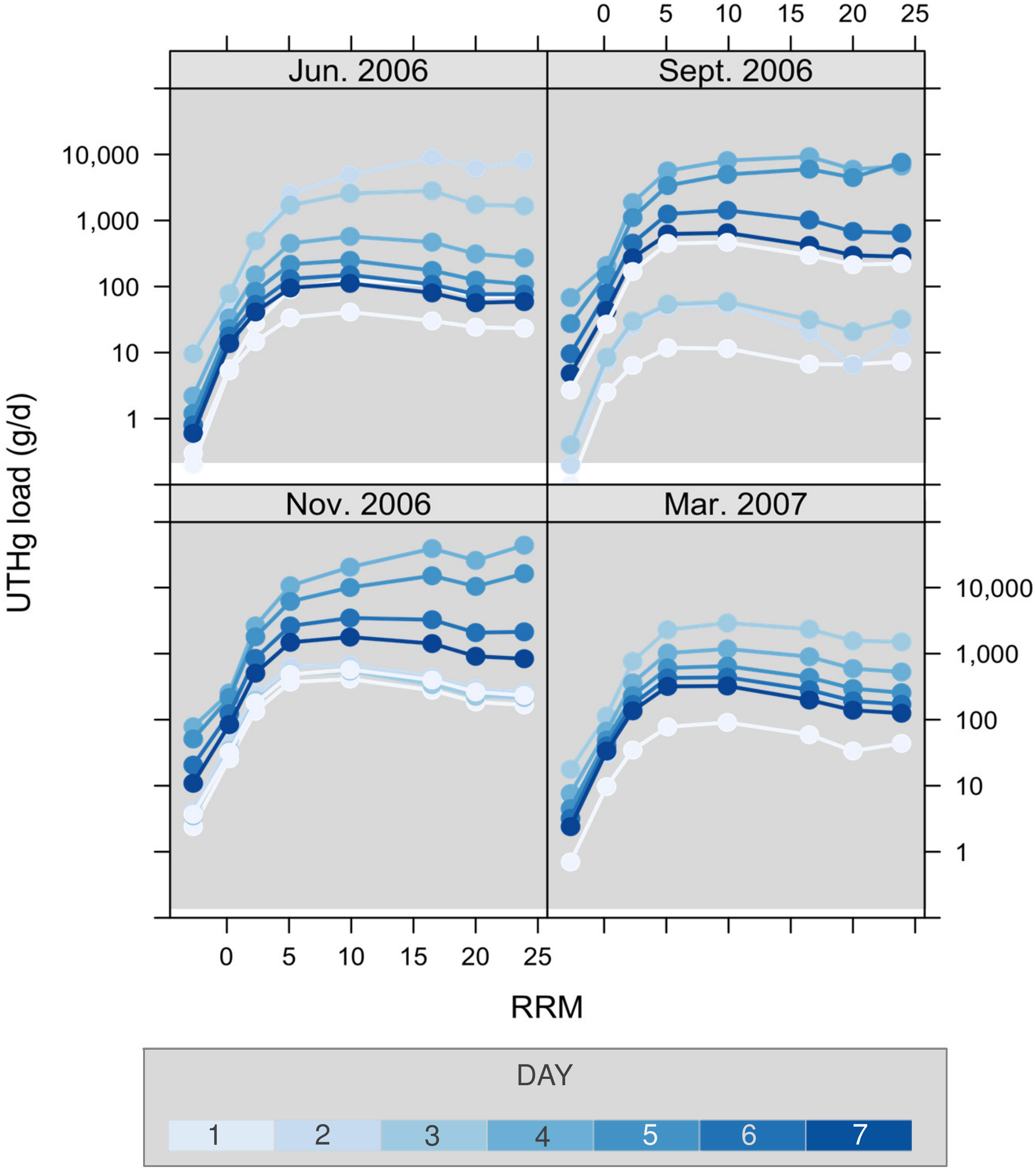
Notes: Behavior of IHg and MeHg over time at RRM 5.1 between March 2006 and June 2007. Panel A: River discharge (Q) at Harriston, VA in cubic feet per second. IHg (Panel B), MeHg (Panel C) and percentage of IHg as MeHg (Panel D) on TSS particles and in sediment (dry wt.). Panels E and F show concentrations of IHg (FIHg) and MeHg (FMeHg) in filtered (0.45µm filter) surface water, respectively. Other locations and complete record are shown in Flanders et al. 2010. Figure reprinted with permission from Flanders et al. (2010). See Ecological Study Data Matrix (Table 1-3) for more information regarding study details. Source: Figure 4-7 in Ecological Study Report (URS, 2012).

Figure 3-6
Total Mercury Concentrations on Solids During Four Storm Events
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



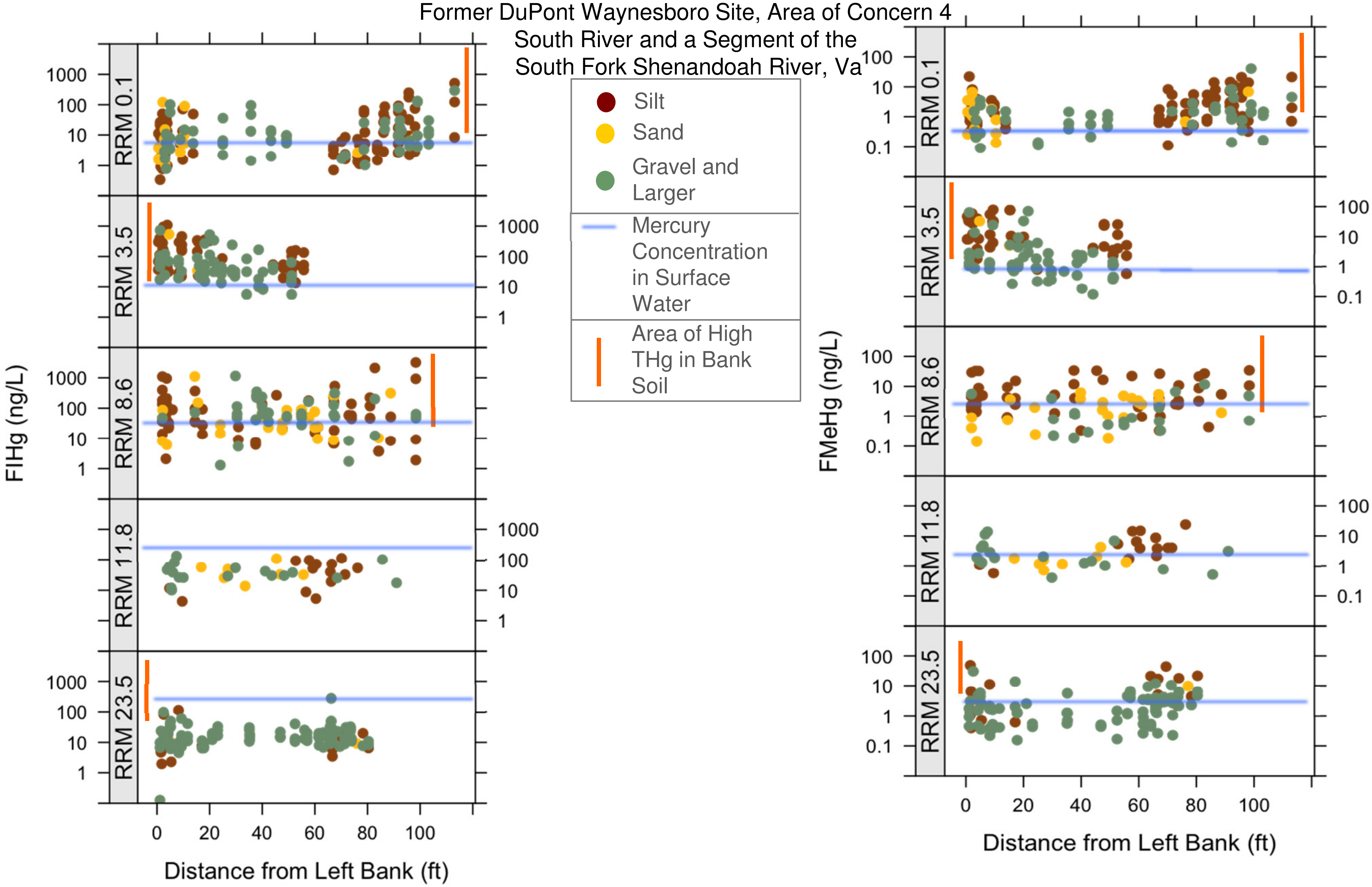
Notes: Panel A: Concentrations of THg on particles (THg_P, µg/g) under increasing discharge regimes. As discharges increases, the concentration of THg_P decreases. Note that as river mile (RRM) increases, the THg_P concentrations converge to a value around 10-15 µg/g. Panel B: The average [THg] in soil, fine-grained channel margin deposits (FGCM) and low (THg_P; <321 CFS) and high (THg_P; >2074 CFS) discharges. Note the similarity between THg_P at low flows (<321 CFS) are similar to sediment concentrations and soils. Values for FGCM are averages. Concentrations are as dry weight. One core, not shown due to scale, had an average concentration of 126±43 µg/g and a maximum of 620 µg/g at RRM 2.5. See Ecological Study Data Matrix (Table 1-3) for more information regarding study details. Source: Figure 4-8 in Ecological Study Report (URS, 2012).

Figure 3-7
Spatial Profile of Unfiltered Total Mercury Loads During Storms
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



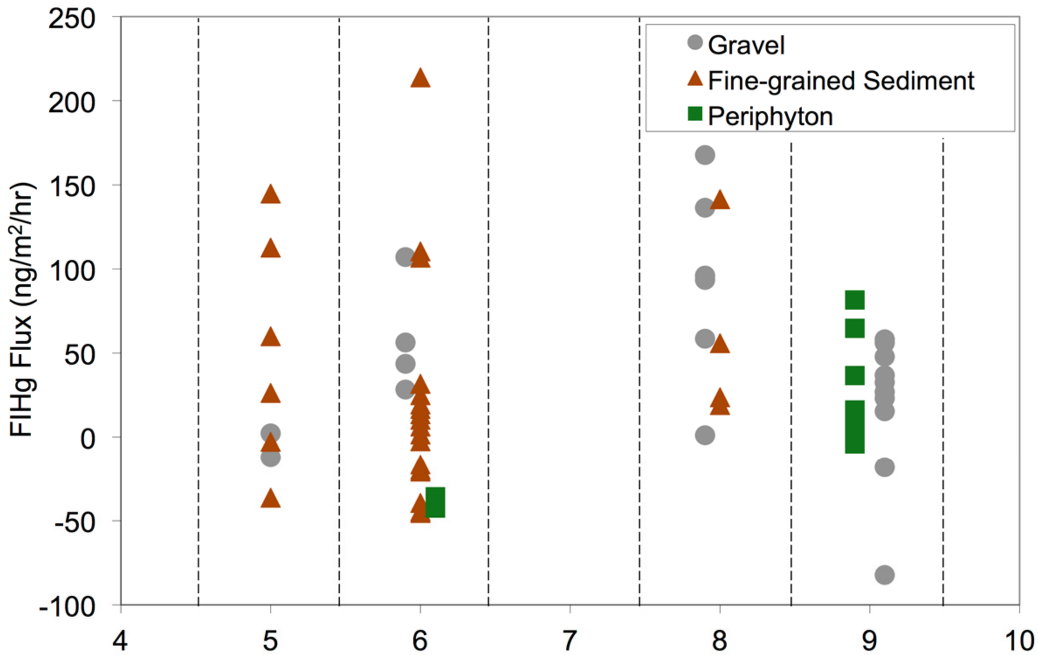
Notes: The data shown are the spatial profile of the daily sum of unfiltered total mercury (UTHg) loads in grams per day (g/d) for four storms sampled between June 2006 and March 2007. Each data point is the daily sum of the UTHg load at the sampling location; the location of the sample is indicated by the value on the x-axis, in relative river miles (RRM). The different colored lines correspond to the day of sampling. Each storm was sampled for up to seven days following the peak of the storm. These loads were used to compute the incremental loads for each reach of the river. See Ecological Study Data Matrix (Table 1-3) for more information regarding study details. Source: Figure 4-10 in Ecological Study Report (URS, 2012).

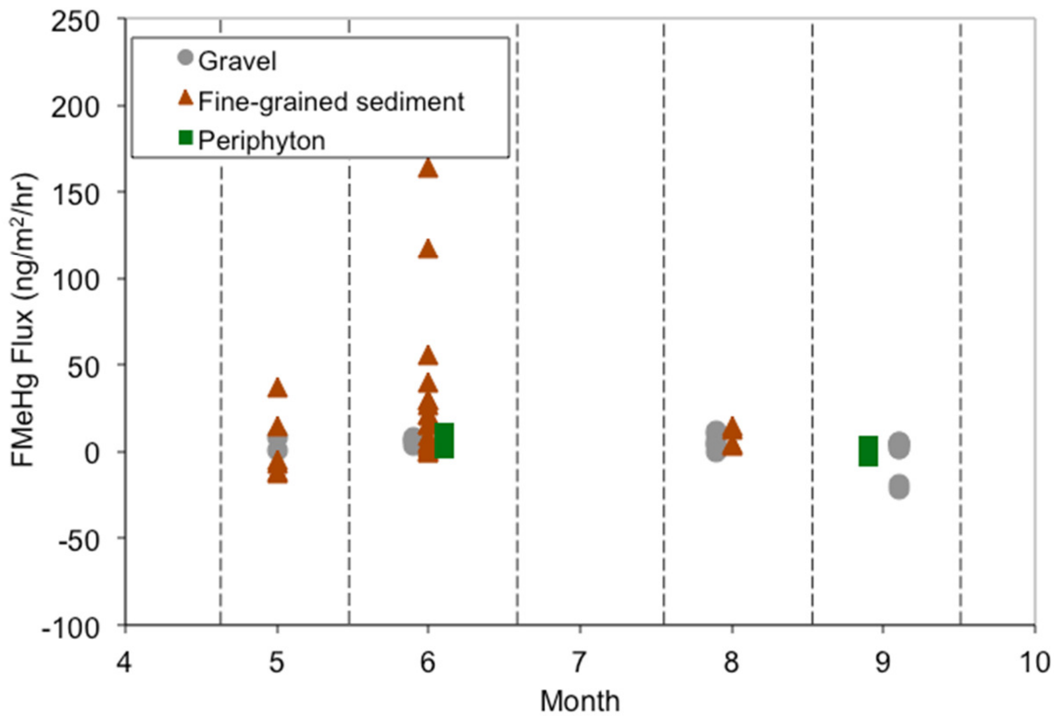
Figure 3-8
Relationship Between Filtered Inorganic and Methylmercury in Pore Water, Surface Water, and Bank Soil
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the
South Fork Shenandoah River, Va



Notes: The data shown are the concentrations of filtered (0.45µm filter) inorganic mercury (FIHg) and methylmercury (FMeHg) in pore water at five study sites, identified by their position in relative river miles on the left side of the plot and distance from the bank on the x-axis. Data were collected from substrates dominated by silt, sand or gravel and larger (e.g., cobble), via a Henry probe, between June 2009 and June 2010. The horizontal blue line is the average surface water concentration measured between 2006 and 2010. The orange bar indicates the general location of river banks with high total mercury (THg) concentrations in soil. See Ecological Study Data Matrix (Table 1-1) for more information regarding study details. Source: Figure 4-13 in Ecological Study Report (URS, 2012).

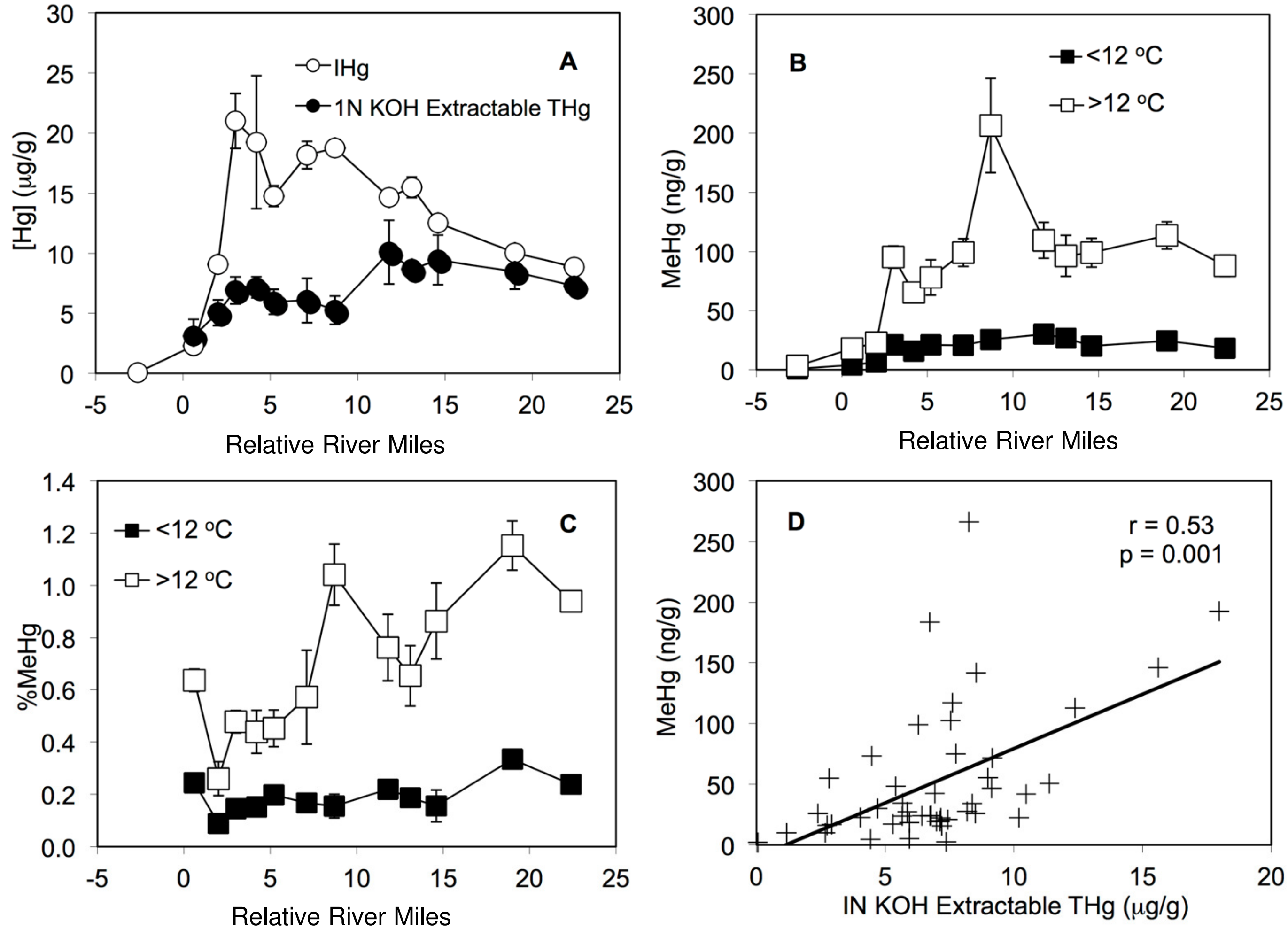
Figure 3-9
Filtered Inorganic Mercury and Methylmercury Flux Rates
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



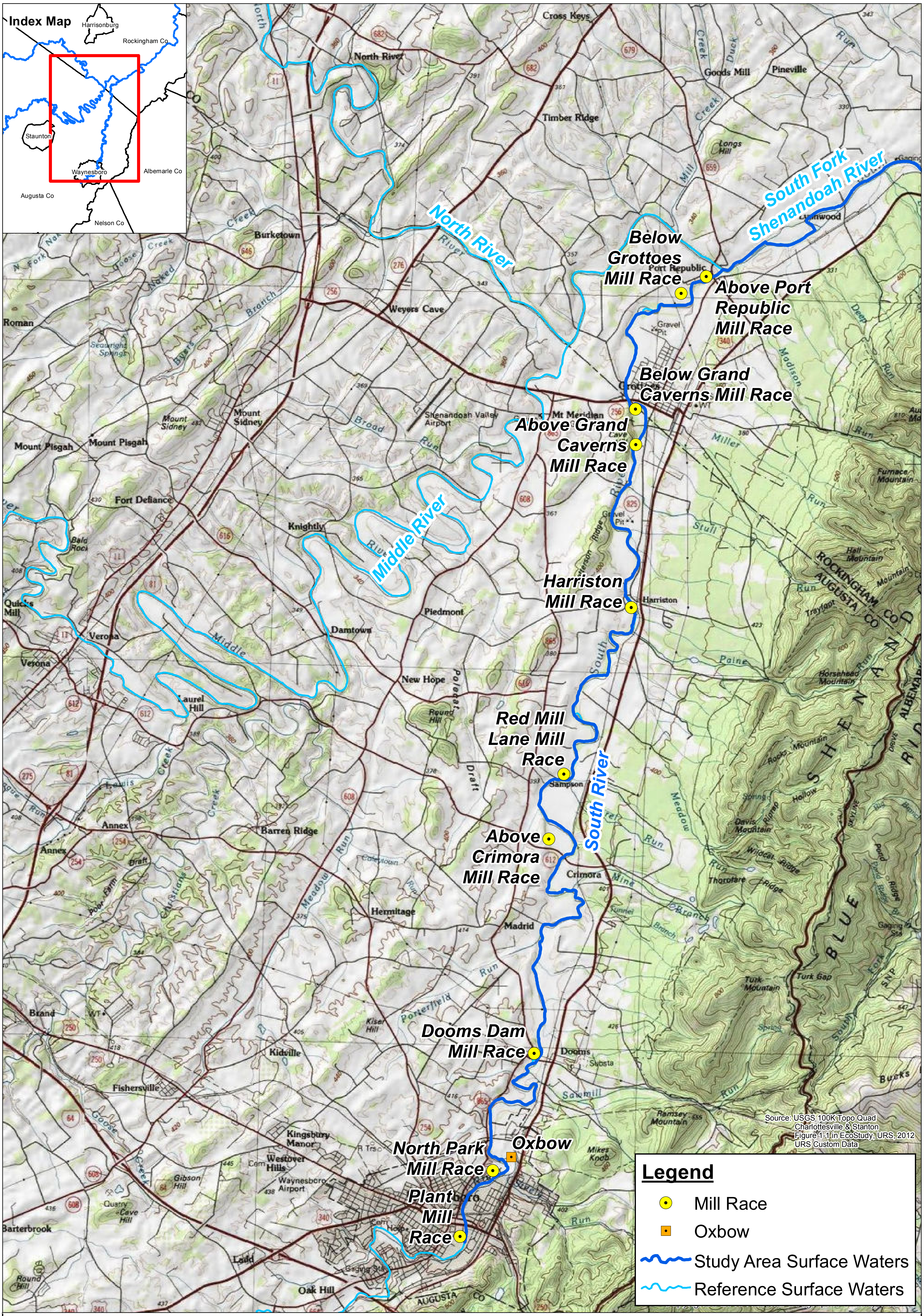


Notes: Each data point is the flux rate for filtered methylmercury (FMeHg) and filtered inorganic mercury (FIHg), in nanograms per square meter per hour ($ng/m^2/hr$), calculated from a four-hour deployment of a benthic flux chamber on either a gravel bed, fine-grained sediment deposit, or experimental substrate colonized by native periphyton and solids. Flux data were collected at 31 locations between May and September 2006 and 2008, between RRM 3 and 13. See Ecological Study Data Matrix (Table 1-3) for more information regarding study details. Source: Figure 4-16 in Ecological Study Report (URS, 2012).

Figure 3-10
Inorganic Mercury, Methylmercury, and Organo-Complexed Mercury in Sediment
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



Notes: IHg, 1N KOH extractable THg and MeHg in fine-grained sediment collected from cobble/gravel interstices. Symbols represent the mean and the standard error. Panel A: IHg and 1N KOH extractable THg as a function of distance, in relative river miles (RRM). MeHg (Panel B) and the percentage of IHg as MeHg (Panel C) as a function of distance and water temperature. Panel D: (+) represents the correlation between 1N KOH extractable THg and MeHg. Concentrations are as dry weight. Figure reprinted with permission from Flanders et al. (2010). See Ecological Study Data Matrix (Table 1-3) for more information regarding study details. Source: Figure 4-12 in Ecological Study Report (URS, 2012).



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E. I. du PONT de NEMOURS & COMPANY

SOUTH RIVER PROJECT

PROJECT NO. 18986307

0 0.5 1 2 3 Miles

Figure 4-1
Mill Race and Oxbow Location Overview Map - AOC 4 RFI Report
Former DuPont Waynesboro Site
Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Path: S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\04172015\Figure 4-1 Mill Race and Oxbow Location Overview Map - URS.mxd

Legend

Soil Sample Location

Within Mill Race Buffer (sample year)

- 2004
- 2006
- 2008
- 2011
- 2013
- 2014
- RRM Intervals (Mile)
- Stream
- Mill Race (Approximate)
- Mill Race 50ft Buffer
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain

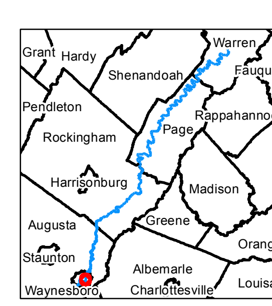
0 150 300 600
Feet

N

Notes:
Sample location may have multiple samples for a single point.

Reference:
VBMP Most Recent Imagery

NAD 1983 StatePlane Virginia North
Projection: Transverse Mercator
Linear Unit: Foot US



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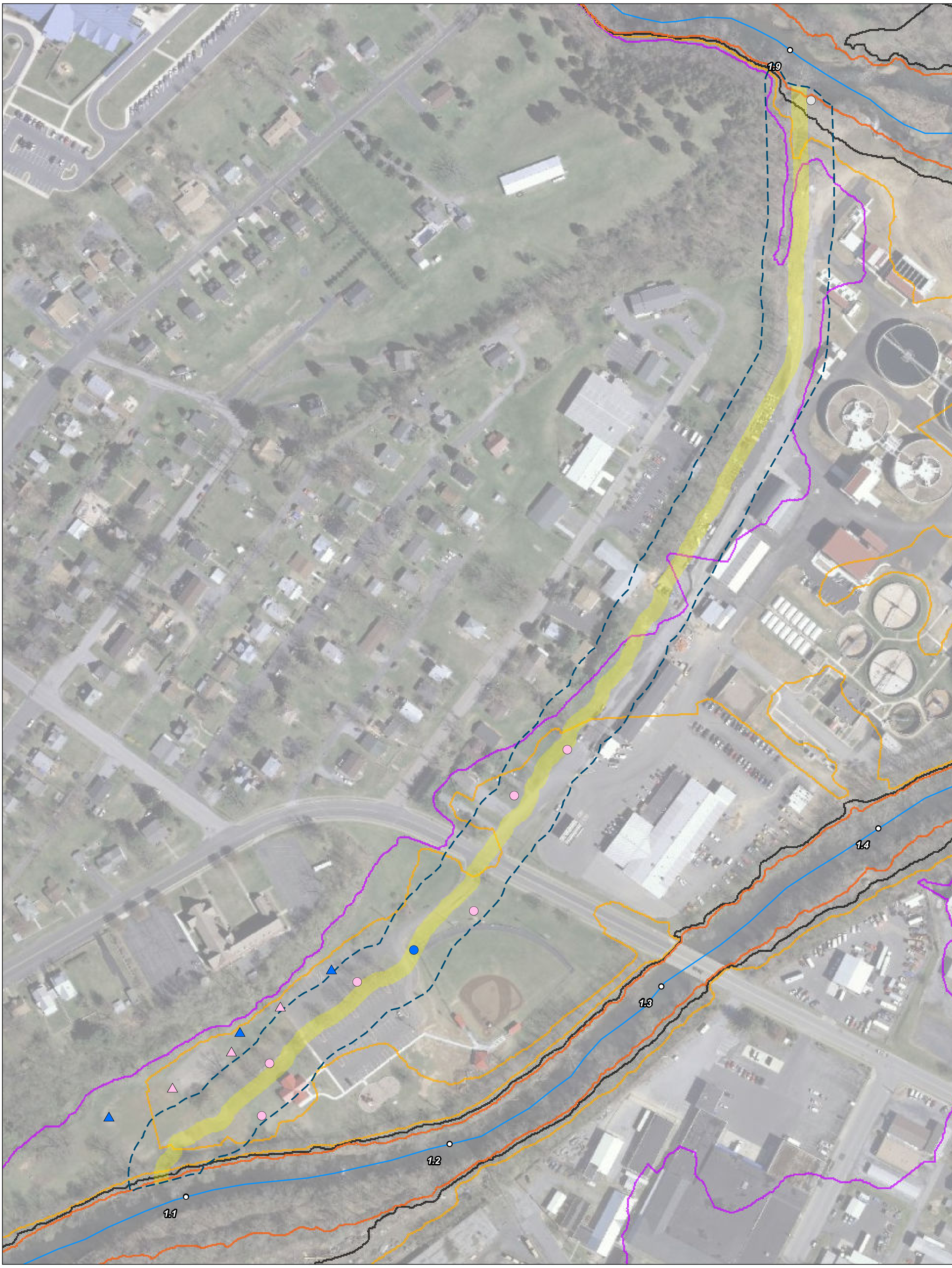
Prepared by: RRM III

Checked by: BR

Date: 7/15/2015

Figure 4-2
Panel 1 of 11: Plant Mill Race
Mill Race and Oxbow Soil Sample Location Map - AOC 4 RFI Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\04172015\Figure 4-2 Mill Race and Oxbow Soil Sample Location Map - URS.mxd



Legend

Soil Sample Location

Within Mill Race Buffer (sample year)
- 2004
- 2006
- 2008
- 2011
- 2013
- 2014

Outside Mill Race Buffer (sample year)
- 2008
- 2011

- RRM Intervals (Mile)
- Stream
- Mill Race (Approximate)
- Mill Race 50ft Buffer
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain

0 150 300 600 Feet

N

Notes:
Sample location may have multiple samples for a single point. Soil sample locations outside Mill Race buffer are potentially associated with historic Mill Race.

Reference:
VBMP Most Recent Imagery

NAD 1983 StatePlane Virginia North
Projection: Transverse Mercator
Linear Unit: Foot US

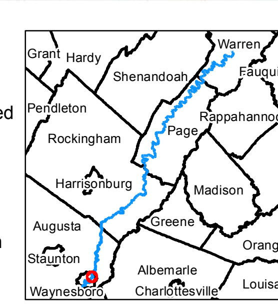


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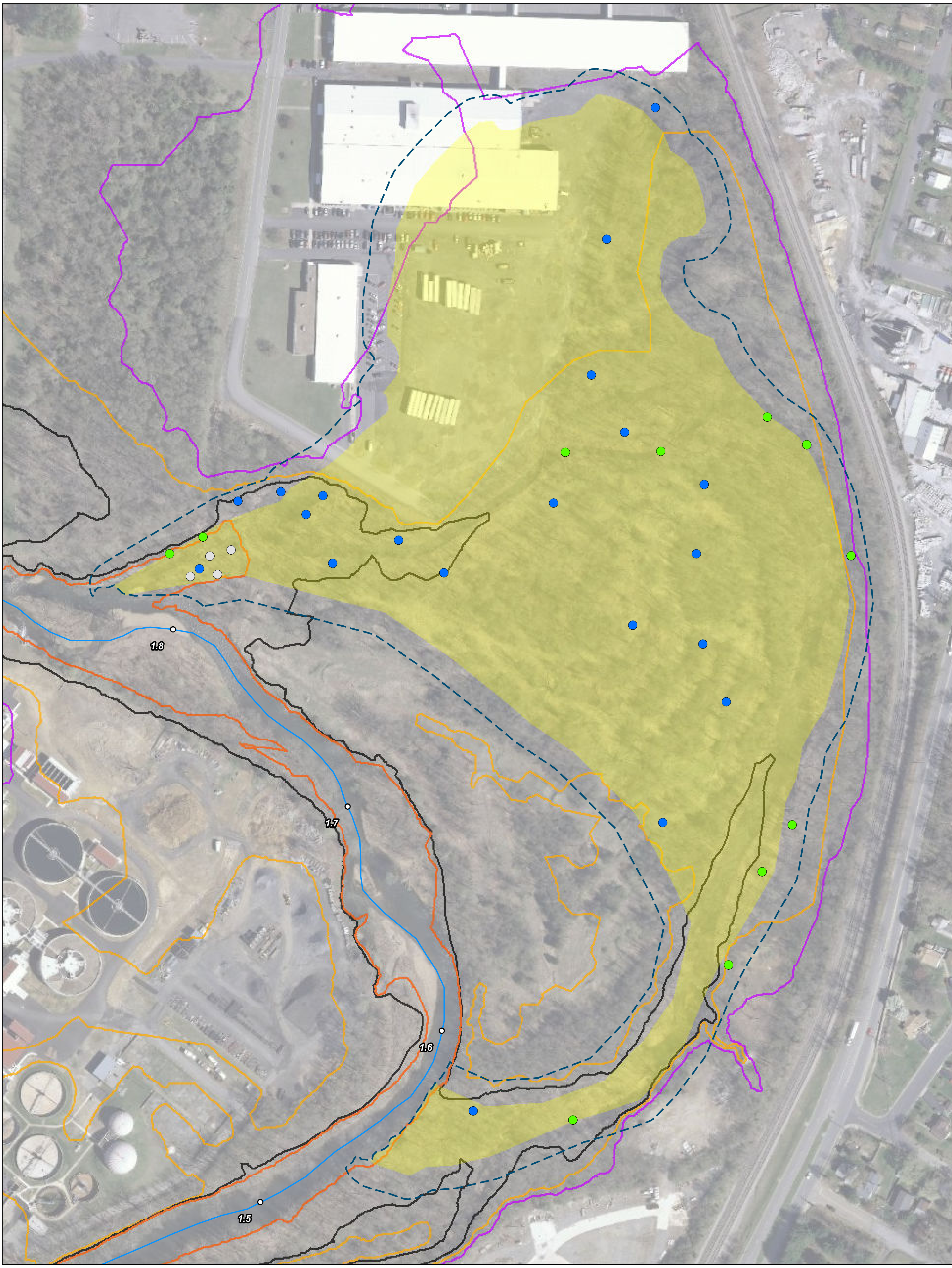
Figure 4-2
Panel 2 of 11: North Park Mill Race
Mill Race and Oxbow Soil Sample Location Map - AOC 4 RFI Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\04172015\Figure 4-2 Mill Race and Oxbow Soil Sample Location Map Sheet 2 - URS.mxd



Legend

Soil Sample Location

Within Oxbow Buffer (sample year)

- 2004
- 2006
- 2008
- 2011
- 2013
- 2014
- RRM Intervals (Mile)
- Stream
- Oxbow
- Oxbow 50ft Buffer
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain

0 150 300 600 Feet

N

Notes:
Sample location may have multiple samples for a single point.

Reference:
VBMP Most Recent Imagery

NAD 1983 StatePlane Virginia North
Projection: Transverse Mercator
Linear Unit: Foot US

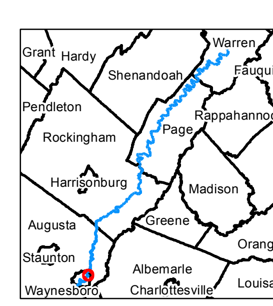


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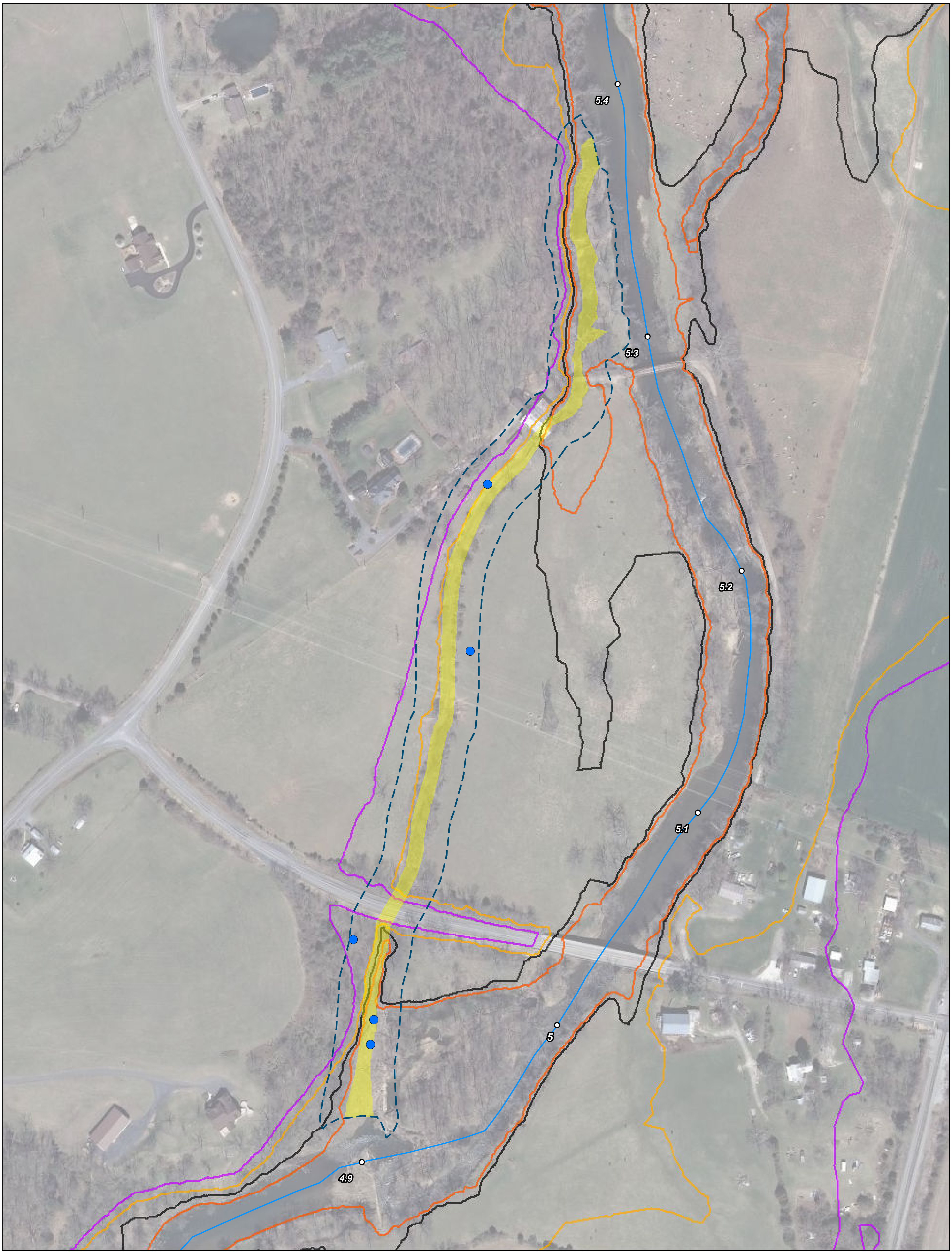
Figure 4-2
Panel 3 of 11: Oxbow
Mill Race and Oxbow Soil Sample Location Map - AOC 4 RFI Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\04172015\Figure 4-2 Mill Race and Oxbow Soil Sample Location Map Sheet 3 - URS.mxd



Legend

Soil Sample Location

Within Mill Race Buffer (sample year)

- 2004
- 2006
- 2008
- 2011
- 2013
- 2014
- RRM Intervals (Mile)
- Stream
- Mill Race (Approximate)
- Mill Race 50ft Buffer
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain

0 150 300 600 Feet

N

Notes:
Sample location may have multiple samples for a single point.

Reference:
VBMP Most Recent Imagery

NAD 1983 StatePlane Virginia North
Projection: Transverse Mercator
Linear Unit: Foot US

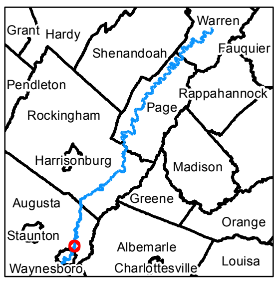


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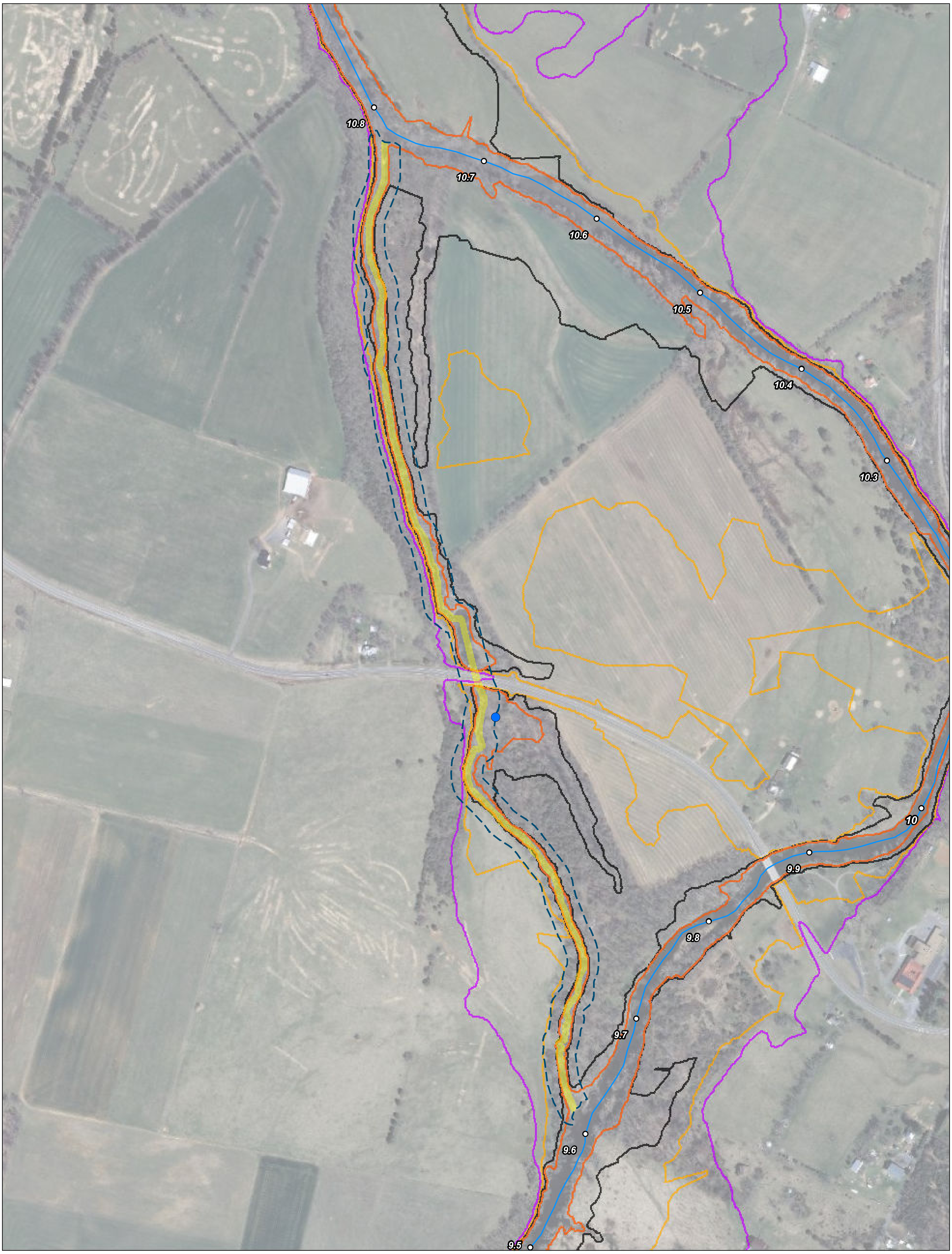
Figure 4-2
Panel 4 of 11: Dooms Dam Mill Race
Mill Race and Oxbow Soil Sample
Location Map - AOC 4 RFI Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\04172015\Figure 4-2 Mill Race and Oxbow Soil Sample Location Map - URS.mxd



Legend

Soil Sample Location

Within Mill Race Buffer (sample year)

- 2004
- 2006
- 2008
- 2011
- 2013
- 2014
- RRM Intervals (Mile)
- Stream
- Mill Race (Approximate)
- Mill Race 50ft Buffer
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain

0 150 300 600 Feet

N

Notes:
Sample location may have multiple samples for a single point.

Reference:
VBMP Most Recent Imagery

NAD 1983 StatePlane Virginia North
Projection: Transverse Mercator
Linear Unit: Foot US

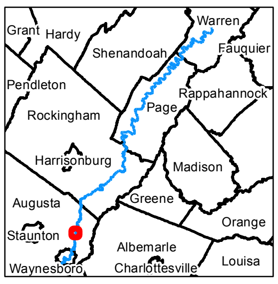


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Figure 4-2
Panel 5 of 11: Above Crimora Mill Race
Mill Race and Oxbow Soil Sample
Location Map - AOC 4 RFI Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\04172015\Figure 4-2 Mill Race and Oxbow Soil Sample Location Map - URS.mxd

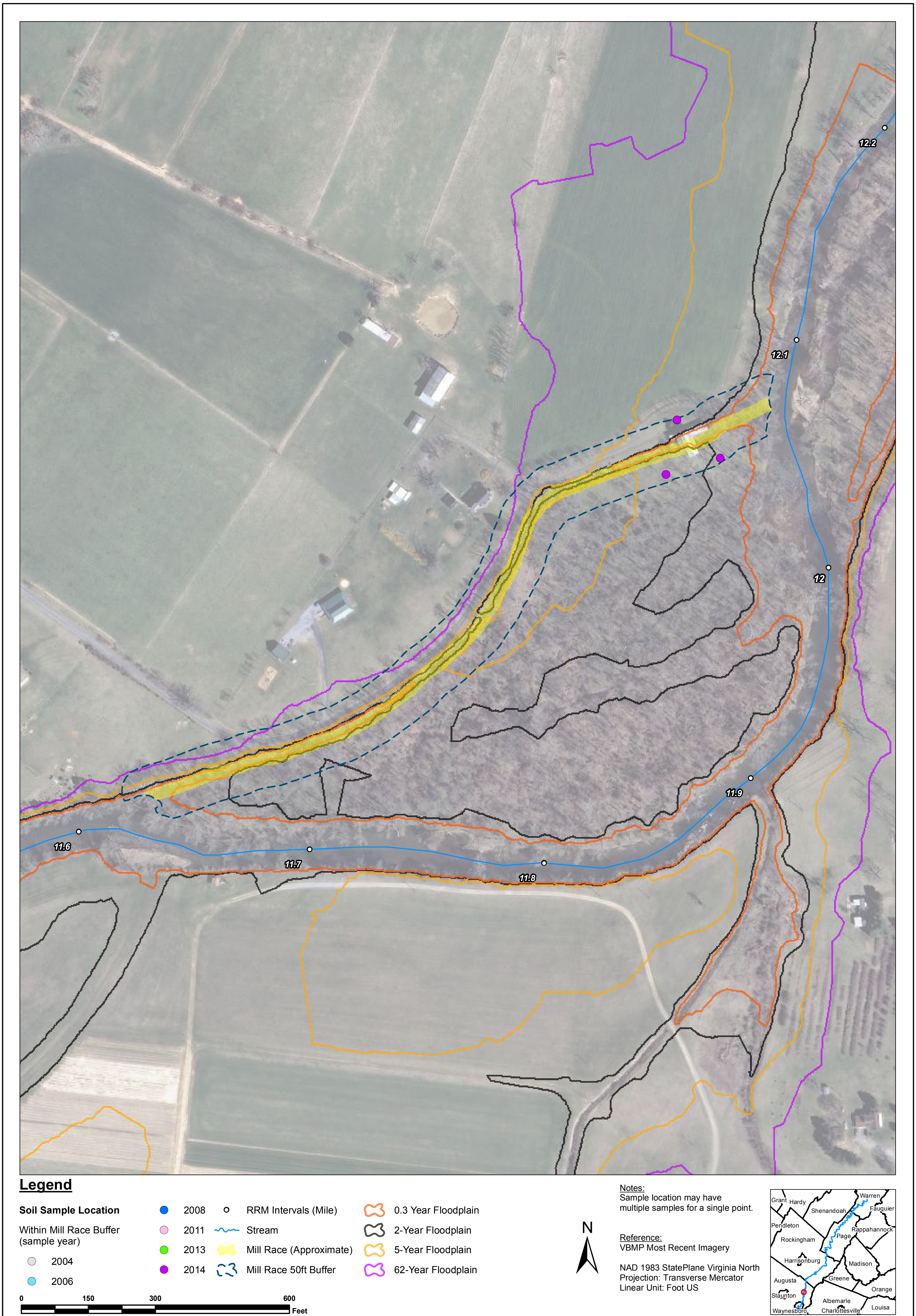

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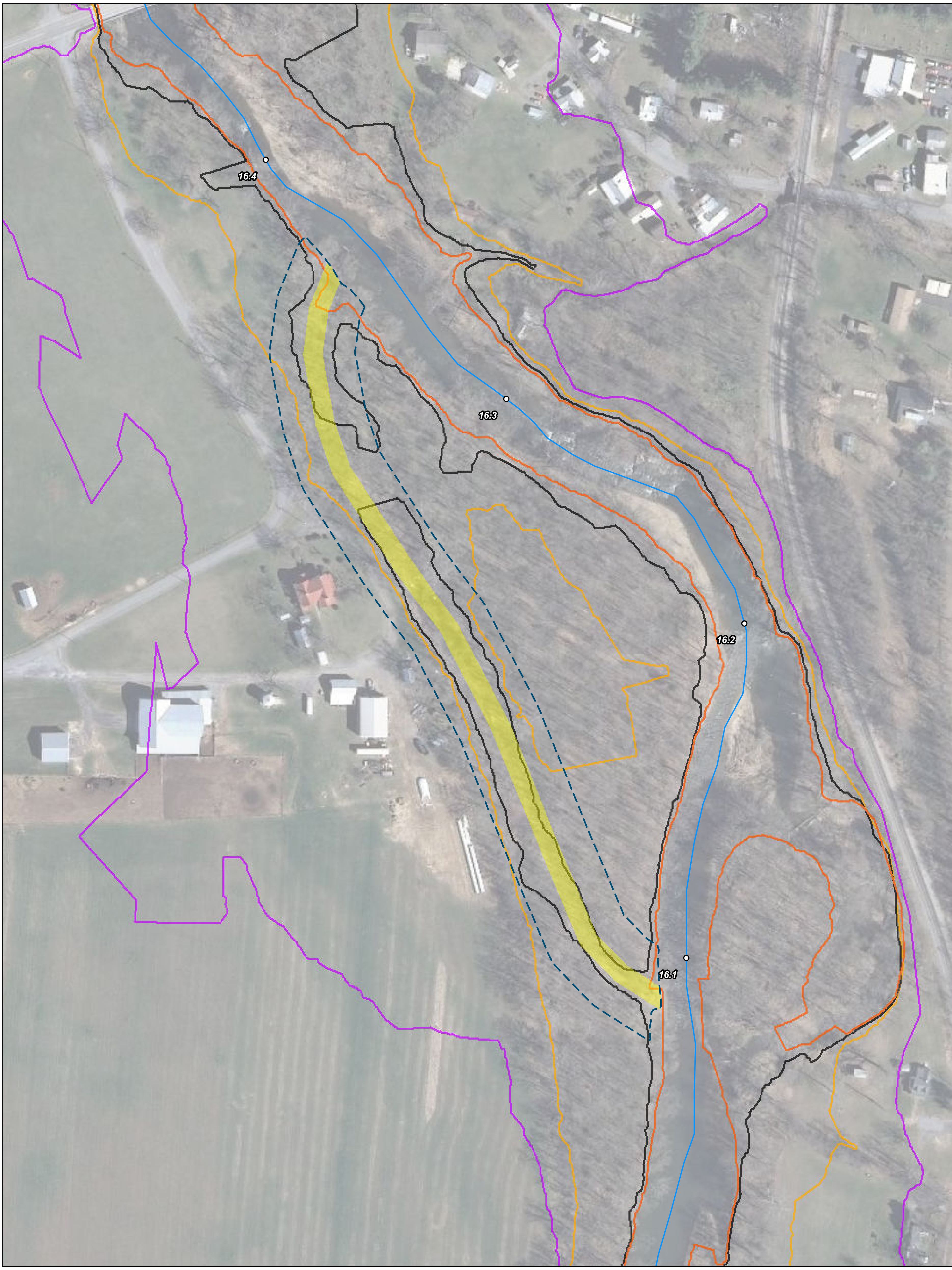
Figure 4-2
Panel 6 of 11: Red Mill Lane Mill Race
Mill Race and Oxbow Soil Sample Location Map - AOC 4 RFI Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\04172015\Figure 4-2 Mill Race and Oxbow Soil Sample Location Map - URS.mxd



Legend

Soil Sample Location

Within Mill Race Buffer (sample year)

- 2004
- 2006
- 2008
- 2011
- 2013
- 2014
- RRM Intervals (Mile)
- Stream
- Mill Race (Approximate)
- Mill Race 50ft Buffer
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain

0 150 300 600 Feet

N

Notes:
Sample location may have multiple samples for a single point.

Reference:
VBMP Most Recent Imagery

NAD 1983 StatePlane Virginia North
Projection: Transverse Mercator
Linear Unit: Foot US

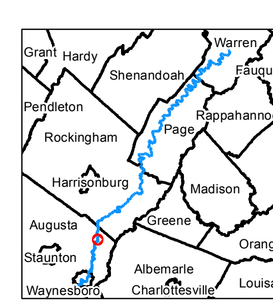


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Figure 4-2
Panel 7 of 11: Harriston Mill Race
Mill Race and Oxbow Soil Sample Location Map - AOC 4 RFI Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\04172015\Figure 4-2 Mill Race and Oxbow Soil Sample Location Map - URS.mxd

Legend

Soil Sample Location

Within Mill Race Buffer (sample year)

- 2004
- 2006
- 2008
- 2011
- 2013
- 2014
- RRM Intervals (Mile)
- Stream
- Mill Race (Approximate)
- Mill Race 50ft Buffer
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain

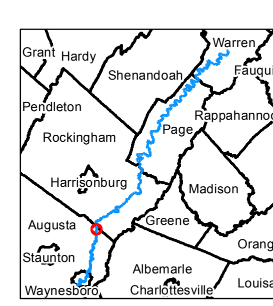
0 150 300 600 Feet

Notes:
Sample location may have multiple samples for a single point.

N

Reference:
VBMP Most Recent Imagery

NAD 1983 StatePlane Virginia North
Projection: Transverse Mercator
Linear Unit: Foot US



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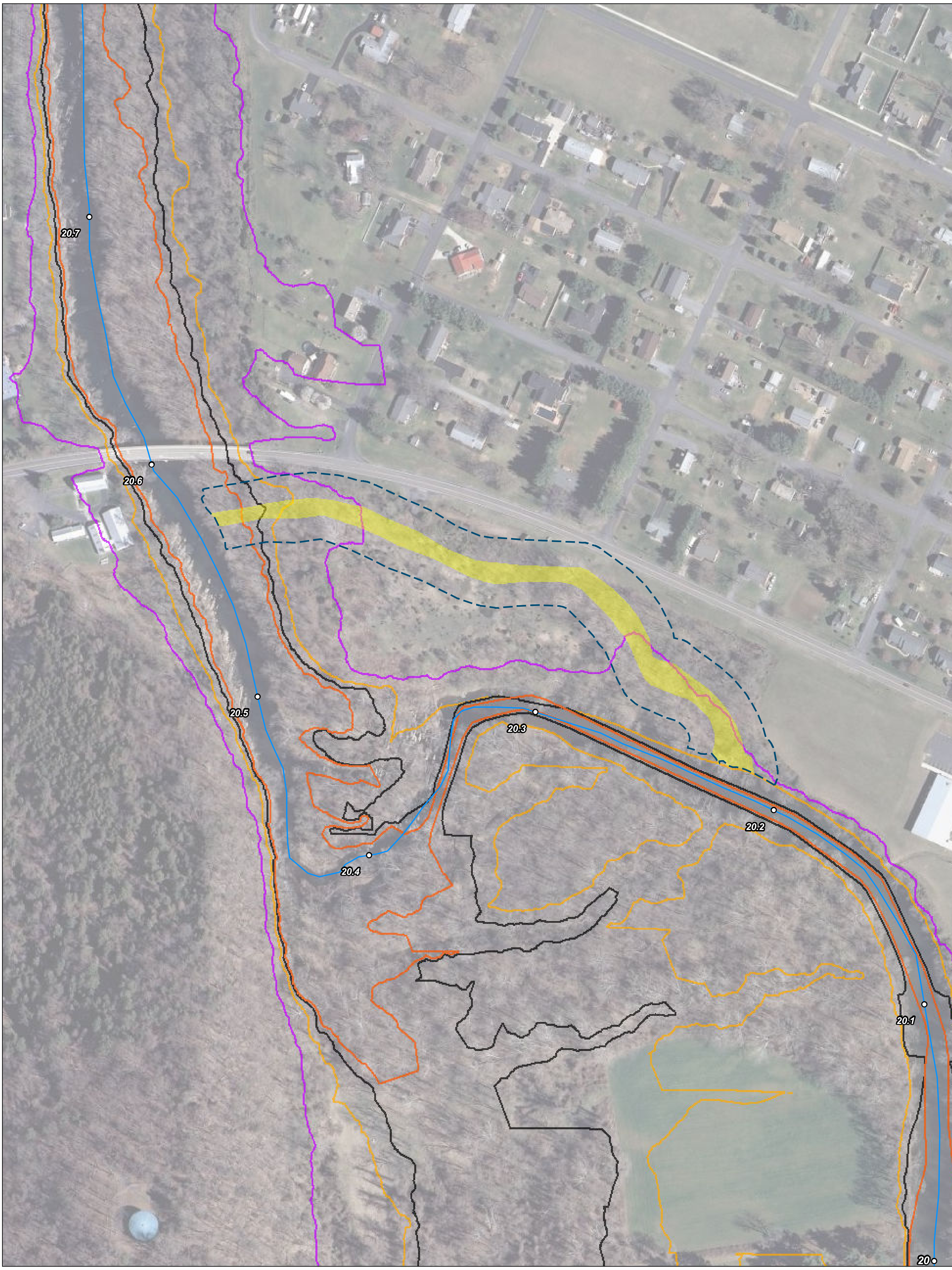
Checked by: BR

Date: 7/15/2015

Figure 4-2
Panel 8 of 11: Above Grand Caverns Mill Race
Mill Race and Oxbow Soil Sample Location Map - AOC 4 RFI Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\04172015\Figure 4-2 Mill Race and Oxbow Soil Sample Location Map - URS.mxd



Legend

Soil Sample Location

Within Mill Race Buffer (sample year)

- 2004
- 2006
- 2008
- 2011
- 2013
- 2014
- RRM Intervals (Mile)
- Stream
- Mill Race (Approximate)
- Mill Race 50ft Buffer
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain

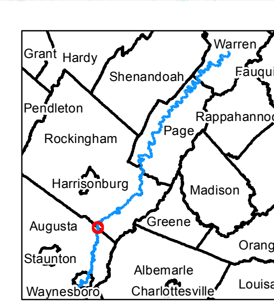
0 150 300 600 Feet

N

Notes:
Sample location may have multiple samples for a single point.

Reference:
VBMP Most Recent Imagery

NAD 1983 StatePlane Virginia North
Projection: Transverse Mercator
Linear Unit: Foot US



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Checked by: BR

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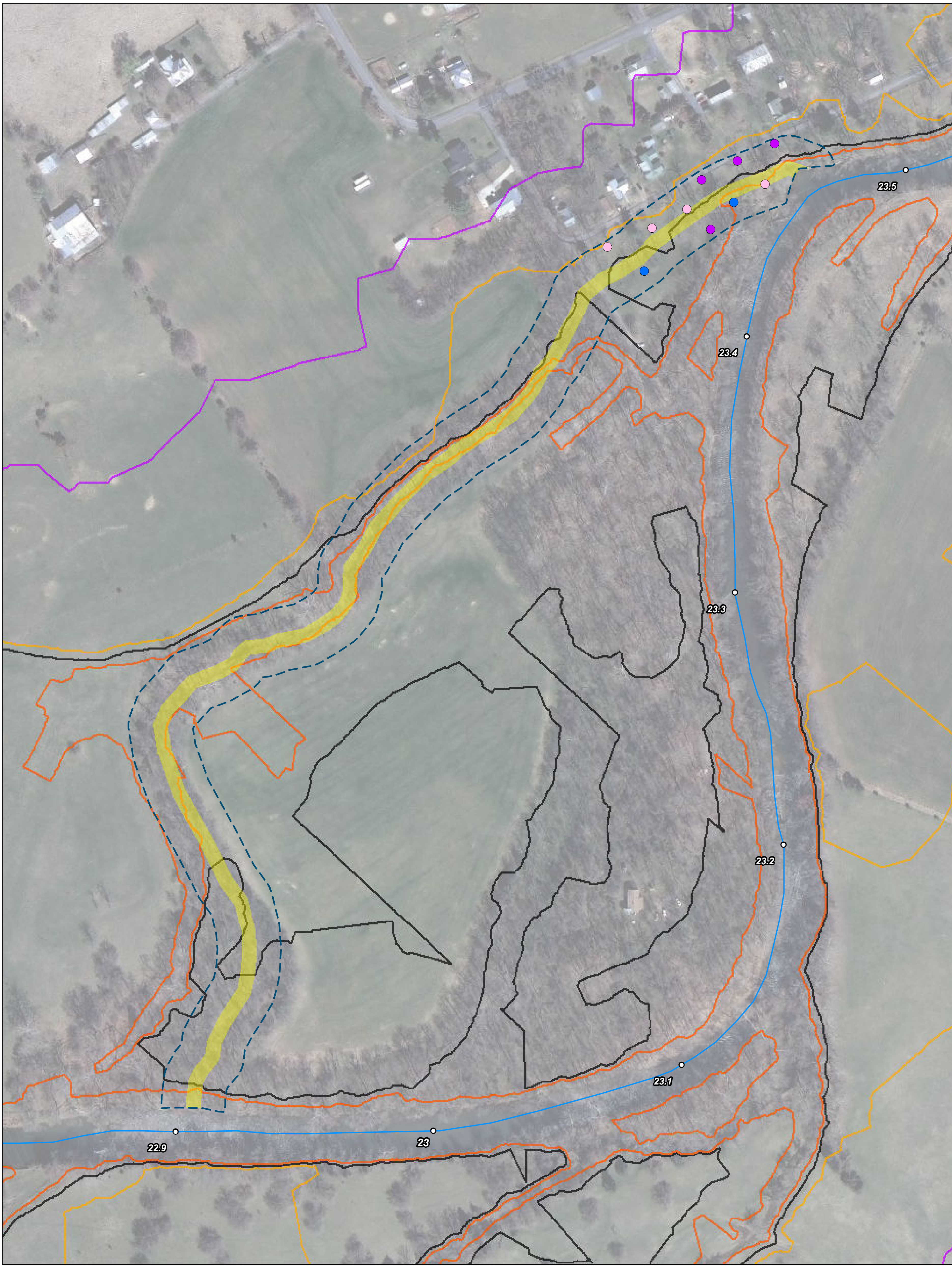
Figure 4-2
Panel 9 of 11: Below Grand Caverns Mill Race
Mill Race and Oxbow Soil Sample Location Map - AOC 4 RFI Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\04172015\Figure 4-2 Mill Race and Oxbow Soil Sample Location Map - URS.mxd



Legend

Soil Sample Location

Within Mill Race Buffer (sample year)

- 2004
- 2006
- 2008
- 2011
- 2013
- 2014
- RRM Intervals (Mile)
- Stream
- Mill Race (Approximate)
- Mill Race 50ft Buffer
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain

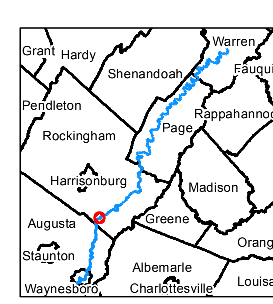
0 150 300 600 Feet

N

Notes:
Sample location may have multiple samples for a single point.

Reference:
VBMP Most Recent Imagery

NAD 1983 StatePlane Virginia North
Projection: Transverse Mercator
Linear Unit: Foot US



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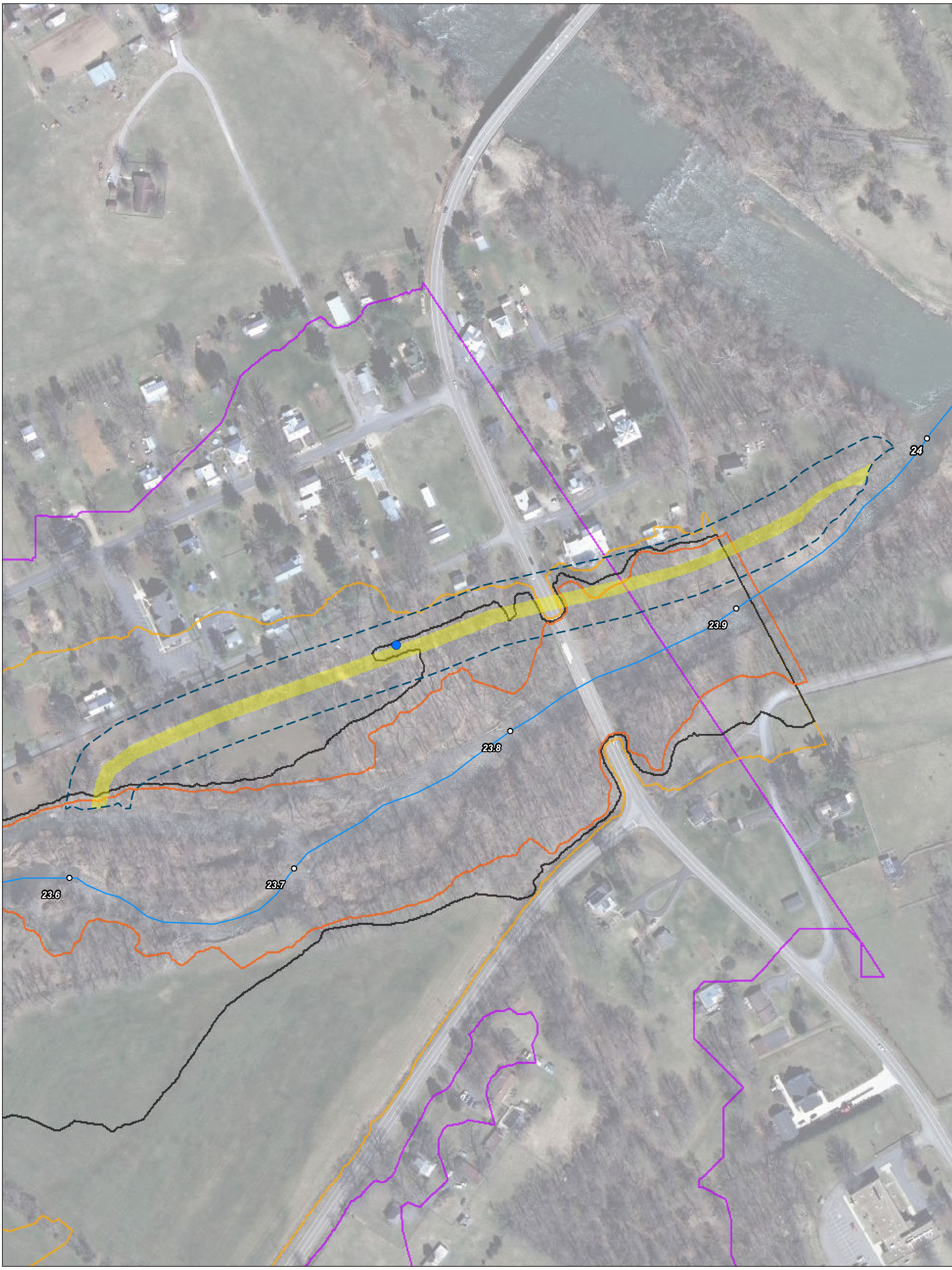
Prepared by: RRM III

Checked by: BR

Date: 7/15/2015

Figure 4-2
Panel 10 of 11: Below Grottoes Mill Race
Mill Race and Oxbow Soil Sample Location Map - AOC 4 RFI Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\04172015\Figure 4-2 Mill Race and Oxbow Soil Sample Location Map - URS.mxd



Legend

Soil Sample Location

Within Mill Race Buffer (sample year)

- 2004
- 2006
- 2008
- 2011
- 2013
- 2014
- RRM Intervals (Mile)
- Stream
- Mill Race (Approximate)
- Mill Race 50ft Buffer
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain

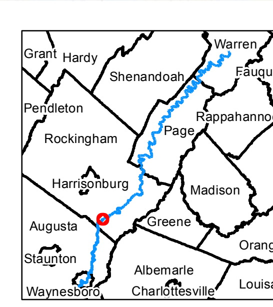
0 150 300 600 Feet

N

Notes:
Sample location may have multiple samples for a single point.

Reference:
VBMP Most Recent Imagery

NAD 1983 StatePlane Virginia North
Projection: Transverse Mercator
Linear Unit: Foot US



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Conshohocken, PA 19428
Phone: (215) 367-2500 Fax: (215) 367-1000

Job: 18986307.01340

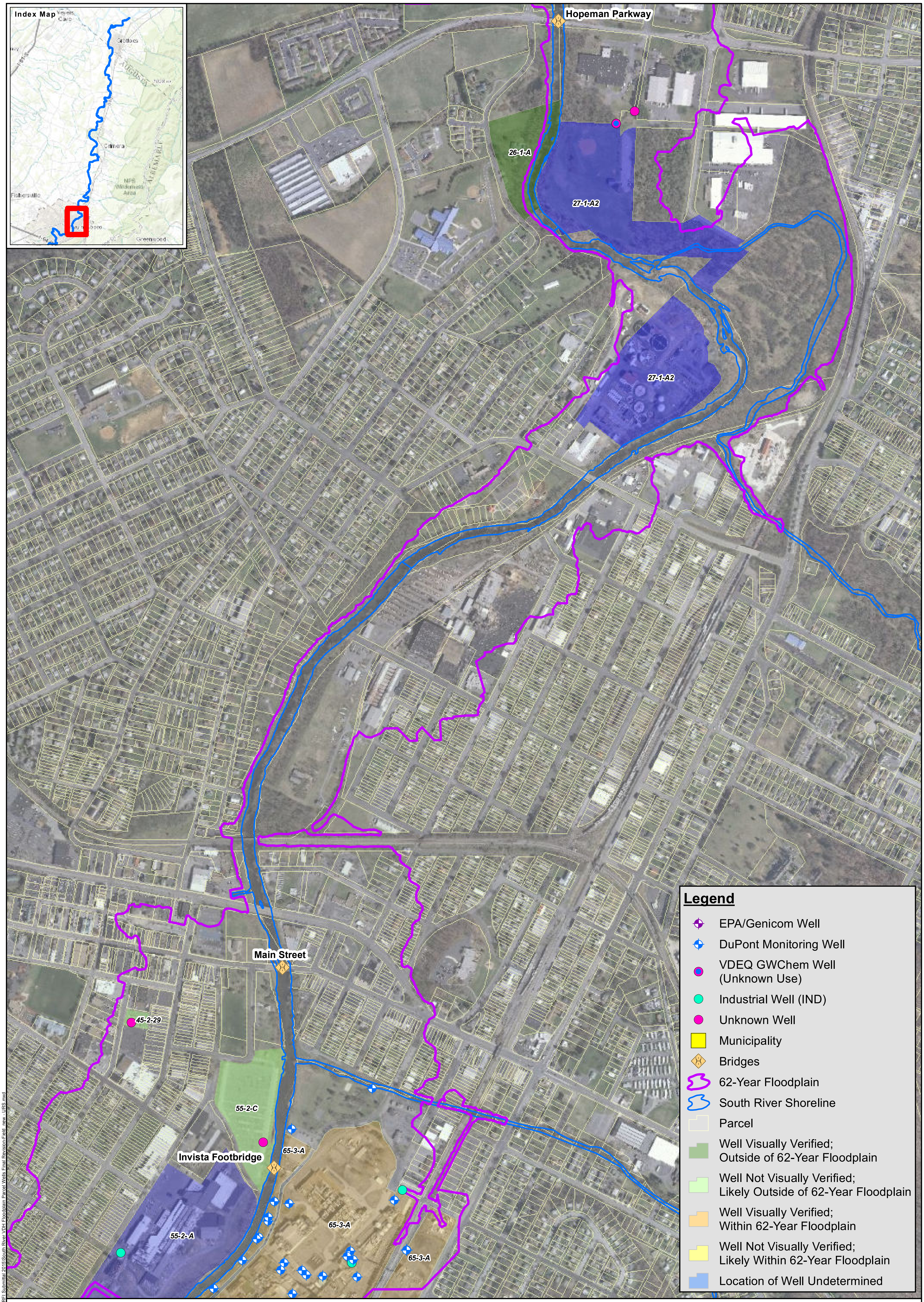
Prepared by: RRM III

Checked by: BR

Date: 7/15/2015

Figure 4-2
Panel 11 of 11: Above Port Republic Mill Race
Mill Race and Oxbow Soil Sample Location Map - AOC 4 RFI Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\AOC 4 RFI Report\04172015\Figure 4-2 Mill Race and Oxbow Soil Sample Location Map - URS.mxd



Source:
VBMP Most Recent Imagery Virginia DEQ Well Data

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N

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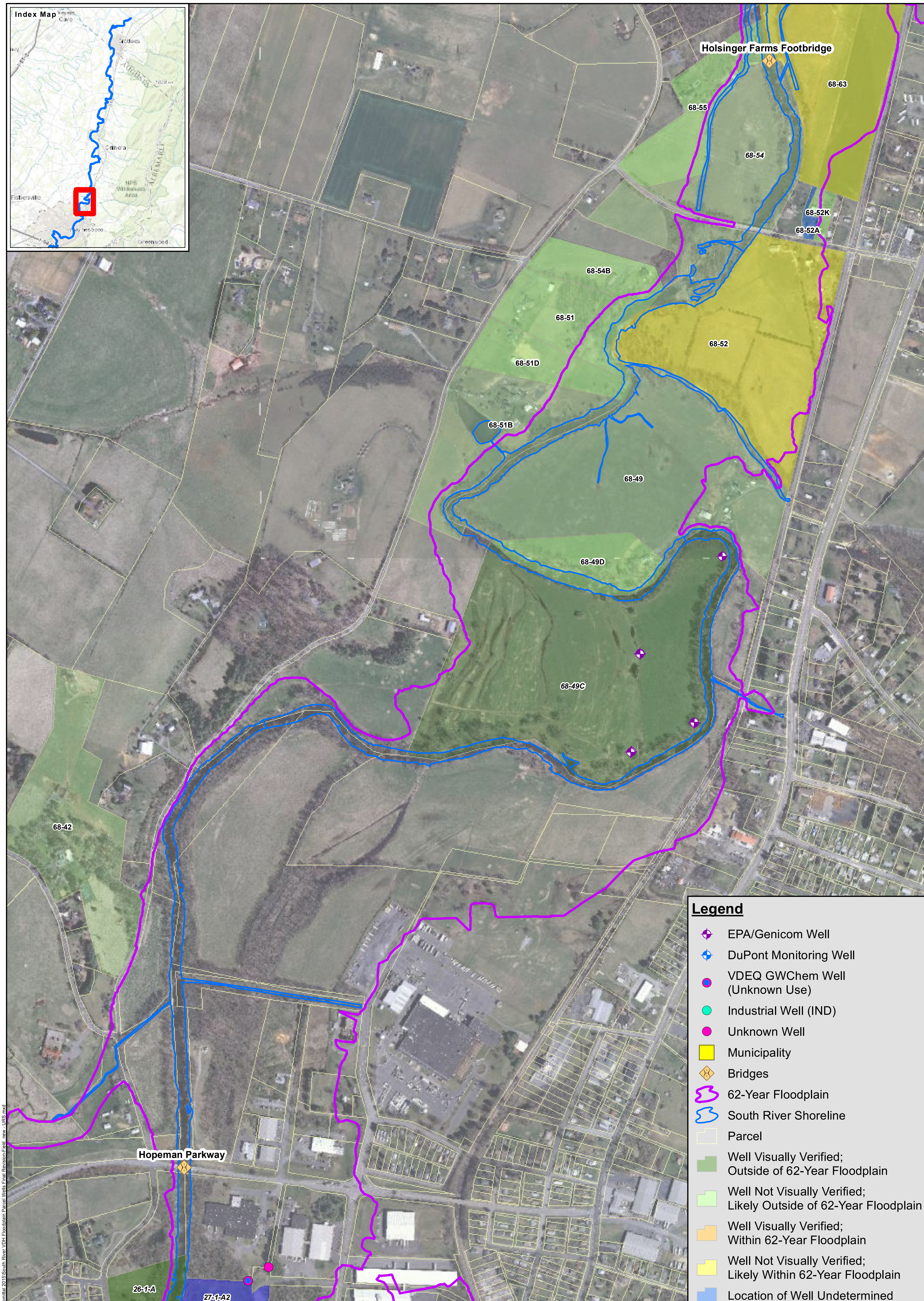
SOUTH RIVER PROJECT

URS PROJECT NO. 18986308

0 250 500 1,000
Feet

Figure 4-3
Well Search Results
Reach 1
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork
Shenandoah River, Va



Source:
VBMP Most Recent Imagery Virginia DEQ Well Data

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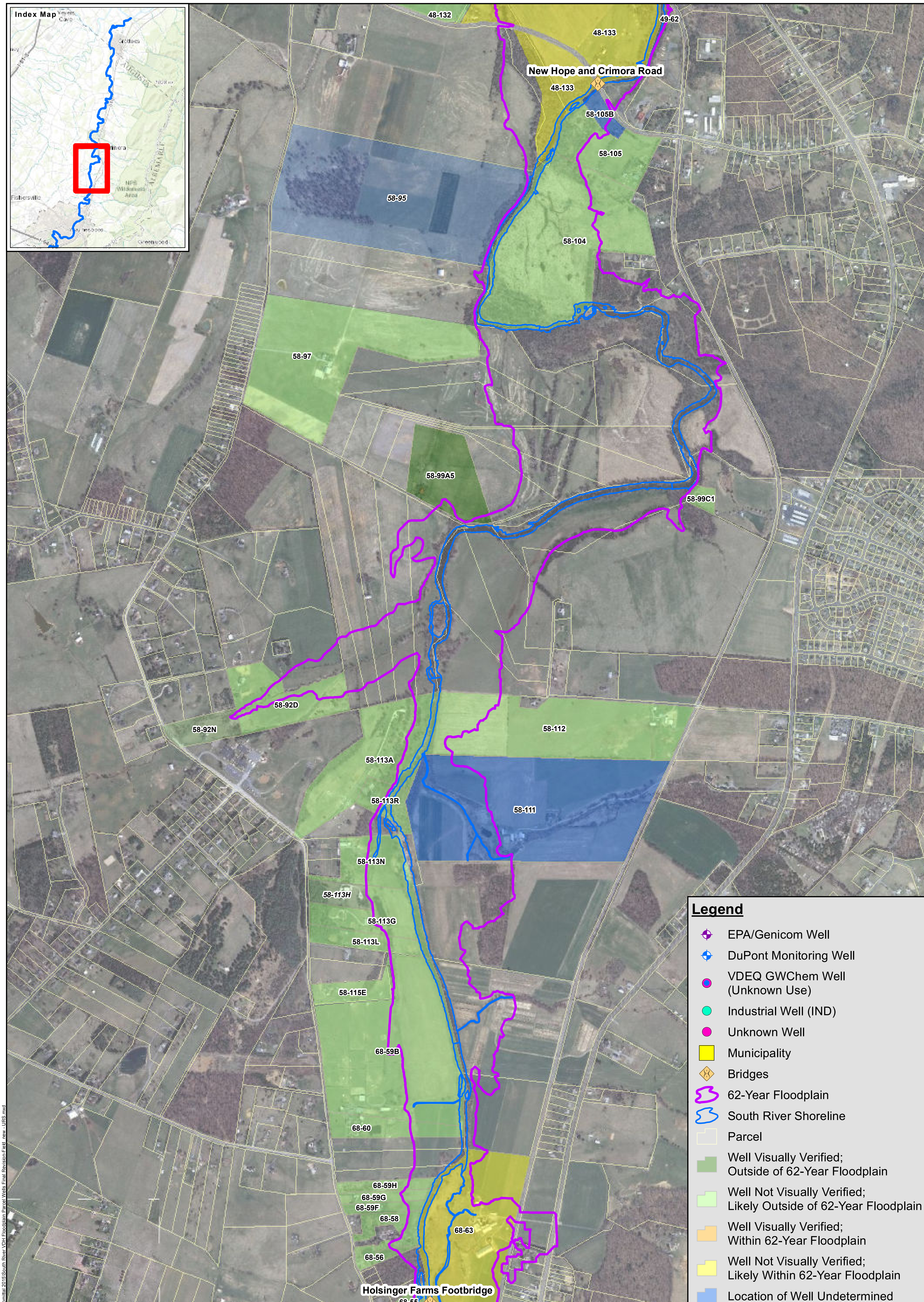
SOUTH RIVER PROJECT

URS PROJECT NO. 18986308

0 250 500 1,000
Feet

Figure 4-3
Well Search Results
Reach 2
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork
Shenandoah River, Va



Source:
VBMP Most Recent Imagery Virginia DEQ Well Data

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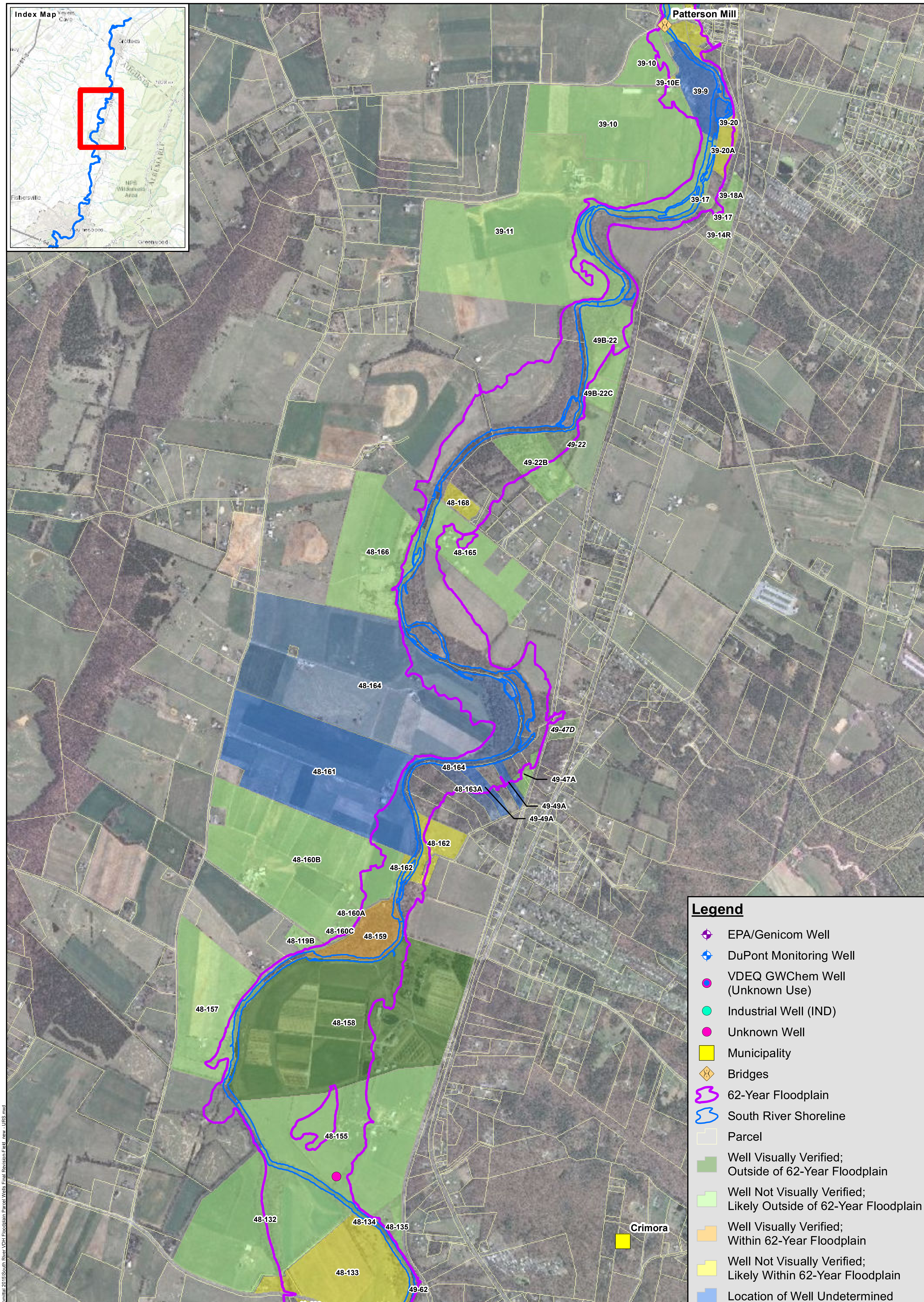
URS PROJECT NO. 18986308

0 250 500 1,000
Feet

Figure 4-3
Well Search Results
Reach 3
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork
Shenandoah River, Va



Source:
VBMP Most Recent Imagery Virginia DEQ Well Data

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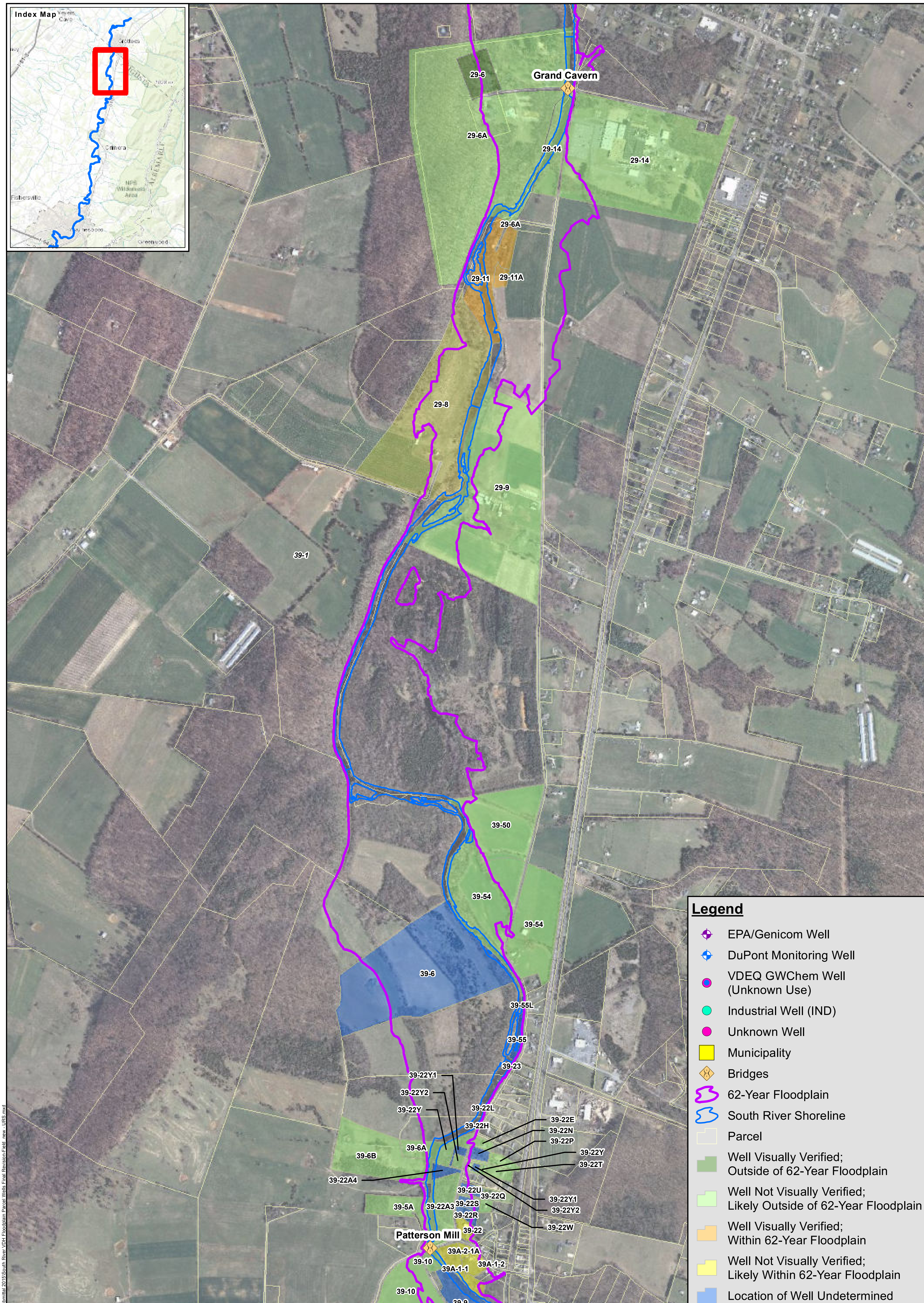
SOUTH RIVER PROJECT

URS PROJECT NO. 18986308

N

0 250500 1,000
Feet

Figure 4-3
Well Search Results
Reach 4
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



Source:
VBMP Most Recent Imagery Virginia DEQ Well Data

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SOUTH RIVER PROJECT

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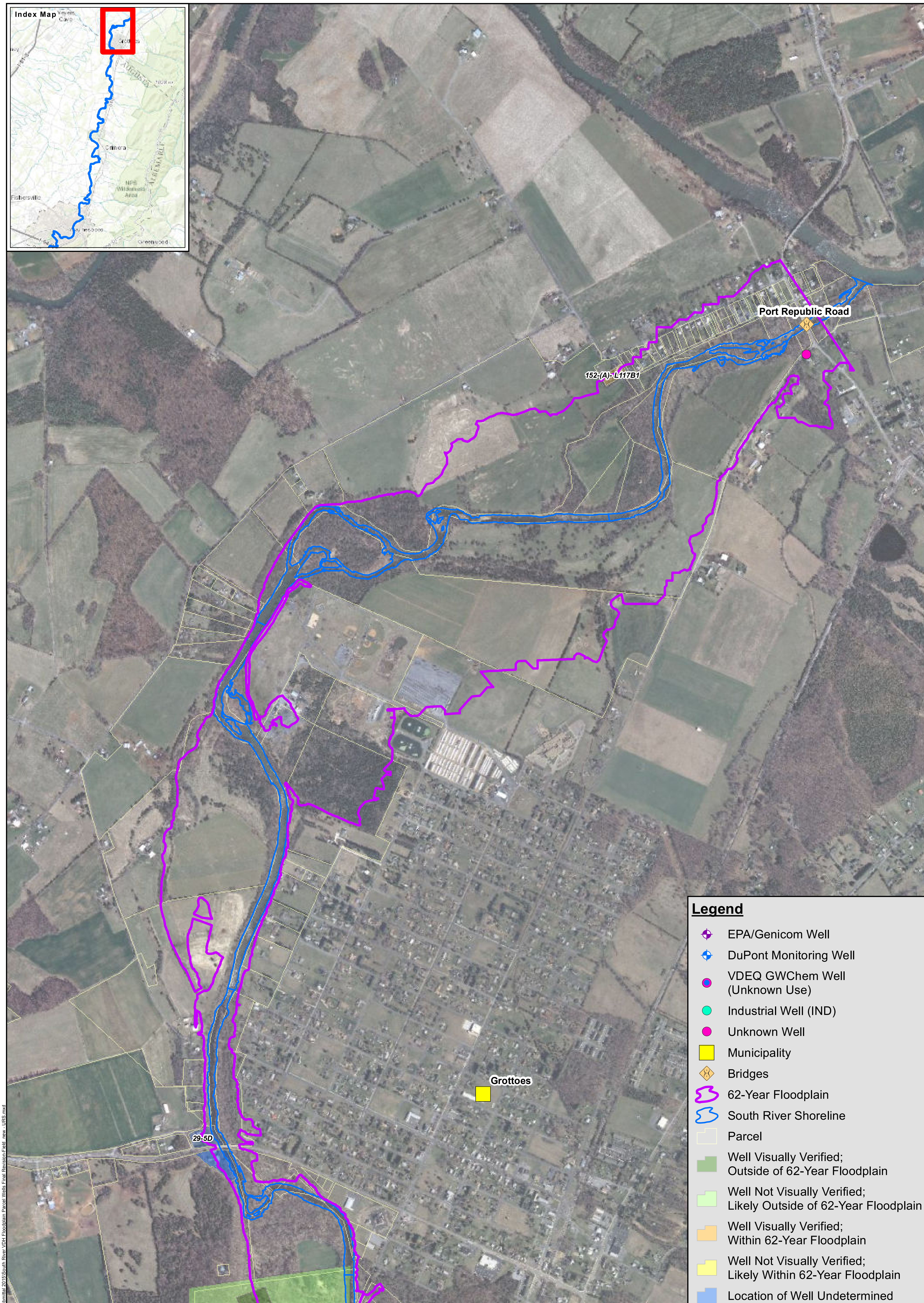
0 250 500 1,000
Feet

Figure 4-3
Well Search Results
Reach 5
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork
Shenandoah River, Va



Source:
VBMP Most Recent Imagery Virginia DEQ Well Data

URS

N

0 250 500 1,000
Feet

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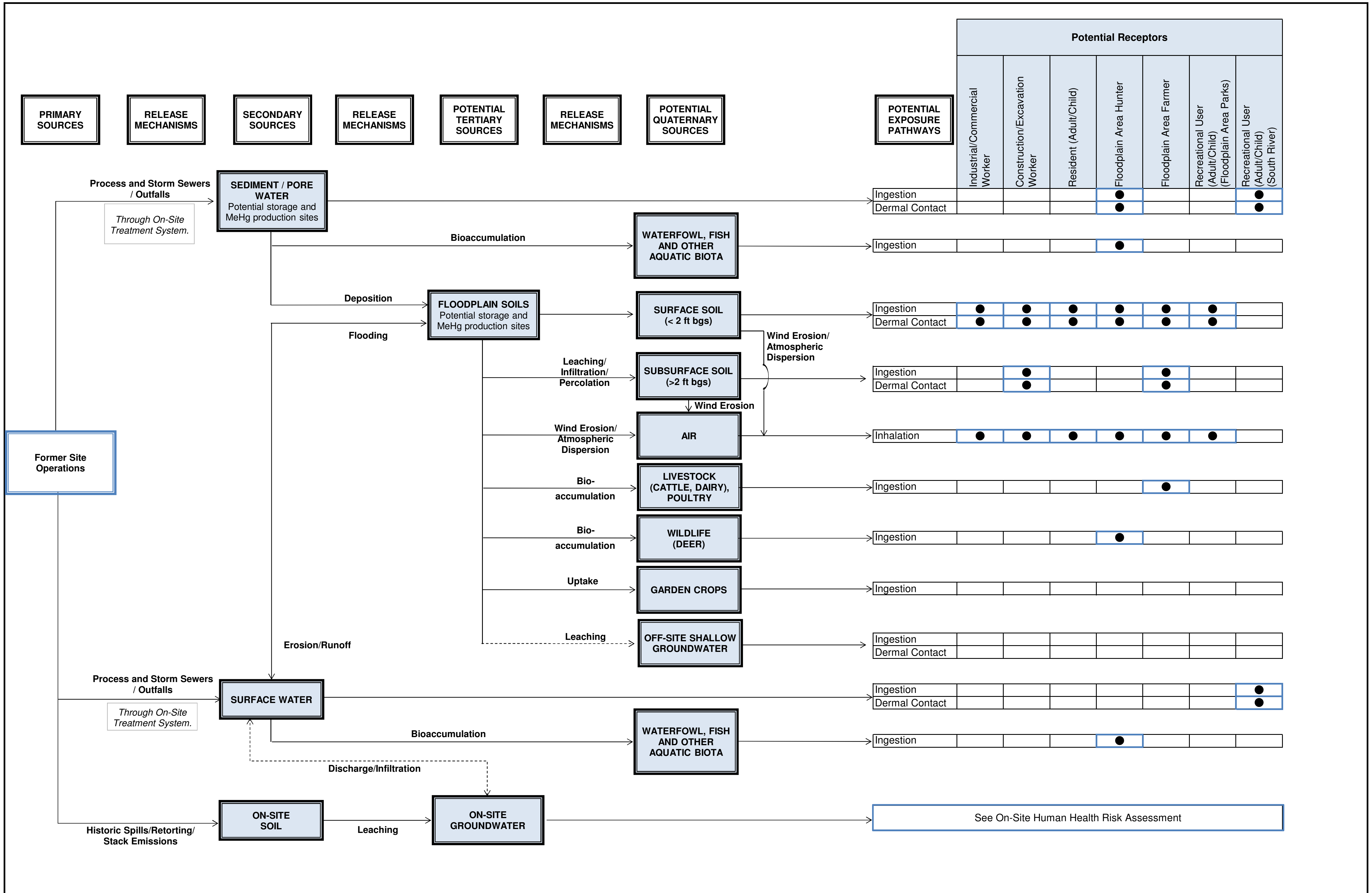
SOUTH RIVER PROJECT
URS PROJECT NO. 18986308

Figure 4-3
Well Search Results
Reach 6
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Document Path: S:\Projects\IMS\DUPONT\STHRIVER\Projects\RFI Submittal 2015\South River VDH Floodplain Parcel Wells Final Revision-Field_new - URS.mxd



Potential Exposure Pathways	Industrial/Commercial Worker	Construction/Excavation Worker	Resident (Adult/Child)	Floodplain Area Hunter	Floodplain Area Farmer	Recreational User (Adult/Child) (Floodplain Area Parks)	Recreational User (Adult/Child) (South River)
Ingestion				●			●
Dermal Contact				●			●
Ingestion				●			
Ingestion	●	●	●	●	●	●	
Dermal Contact	●	●	●	●	●	●	
Ingestion		●			●		
Dermal Contact		●			●		
Inhalation	●	●	●	●	●	●	
Ingestion					●		
Ingestion				●			
Ingestion							
Ingestion							
Dermal Contact							
Ingestion							●
Dermal Contact							●
Ingestion				●			

Notes: ● POTENTIALLY COMPLETE EXPOSURE PATHWAY
BLANK = INCOMPLETE EXPOSURE PATHWAY
- - → LIMITED OR INSIGNIFICANT CONTAMINANT MIGRATION PATHWAY
→ CONTAMINANT MIGRATION PATHWAY
ITEMS WITH BLUE OUTLINES ARE LINKS TO ACCESS THE CONCEPTUAL SITE MODEL REFERENCE LIBRARY

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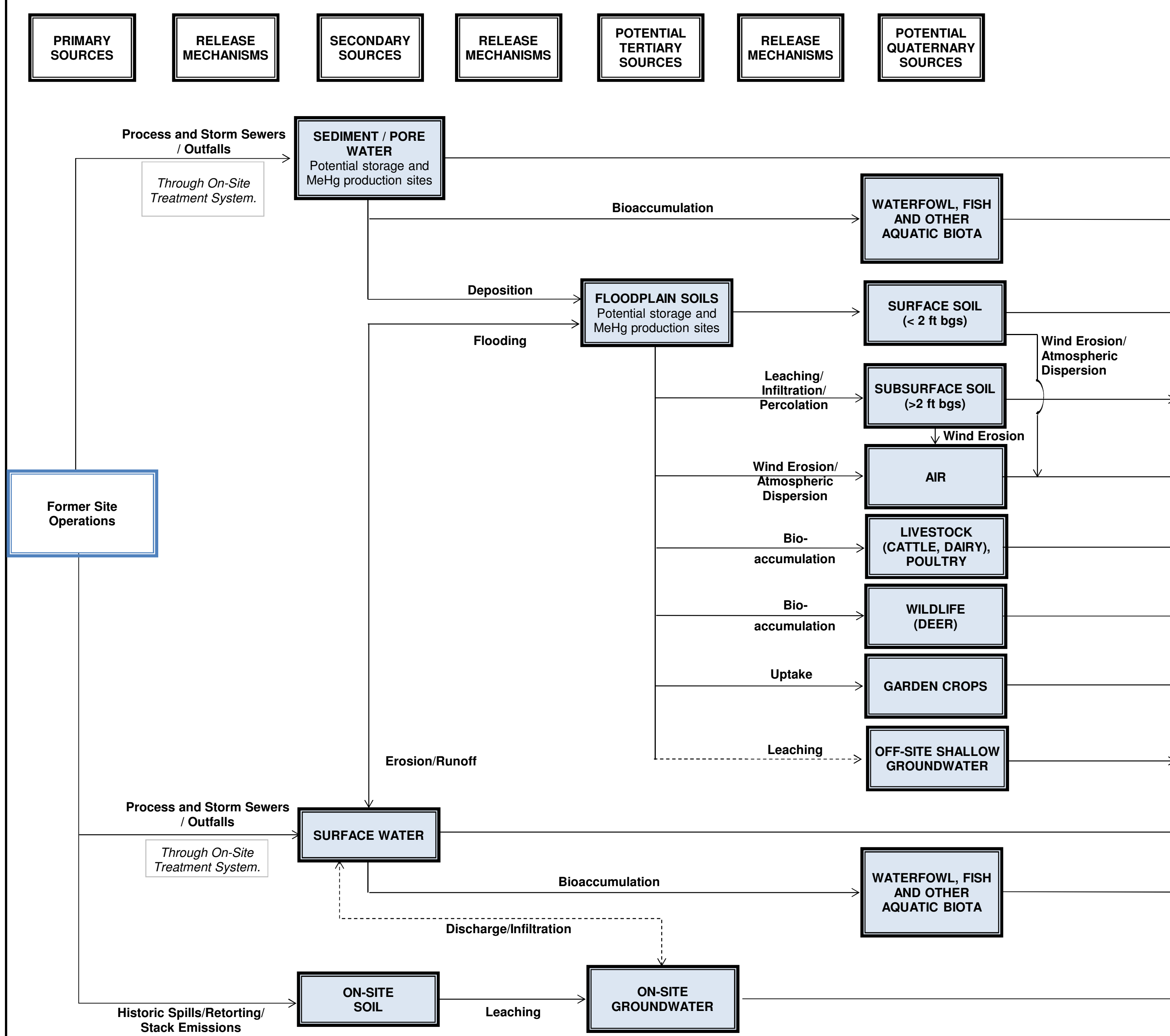
AOC 4 Human Health Conceptual Site Model: Current/Future Land Use

Former DuPont Waynesboro Sute, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

1/27/2014 Fig. 5-1a



Source	POTENTIAL EXPOSURE PATHWAYS	Industrial/Commercial Worker	Construction/Excavation Worker	Resident (Adult/Child)	Floodplain Area Hunter	Floodplain Area Farmer	Recreational User (Adult/Child) (Floodplain Area Parks)	Recreational User (Adult/Child) (South River)
Sediment / Pore Water	Ingestion				●			●
	Dermal Contact				●			●
Waterfowl, Fish and Other Aquatic Biota	Ingestion				●			●
Surface Soil	Ingestion	●	●	●	●	●	●	
	Dermal Contact	●	●	●	●	●	●	
Subsurface Soil	Ingestion	●	●	●[1]	●	●	●	
	Dermal Contact	●	●	●[1]	●	●	●	
Air	Inhalation	●	●	●[1]	●	●	●	
Livestock	Ingestion					●		
Wildlife	Ingestion				●			
Garden Crops	Ingestion			●		●		
Off-Site Shallow Groundwater	Ingestion			●[3]		●[3]		
	Dermal Contact			●[3]		●[3]		
Surface Water	Ingestion							●[2]
	Dermal Contact							●[2]
Waterfowl, Fish and Other Aquatic Biota	Ingestion				●			
On-Site Groundwater	See On-Site Human Health Risk Assessment							

1 = Subsurface soil samples have not been collected at the 17 properties identified for current/future residential use

2 = Surface water is included for completeness even though current surface water data does not indicate concentrations exceeding screening criteria

3 = Groundwater is included for completeness even though available groundwater data does not indicate concentrations exceeding screening criteria

Notes: ● POTENTIALLY COMPLETE EXPOSURE PATHWAY
BLANK = INCOMPLETE EXPOSURE PATHWAY
- -→ LIMITED OR INSIGNIFICANT CONTAMINANT MIGRATION PATHWAY
→ CONTAMINANT MIGRATION PATHWAY
ITEMS WITH BLUE OUTLINES ARE LINKS TO ACCESS THE CONCEPTUAL SITE MODEL REFERENCE LIBRARY

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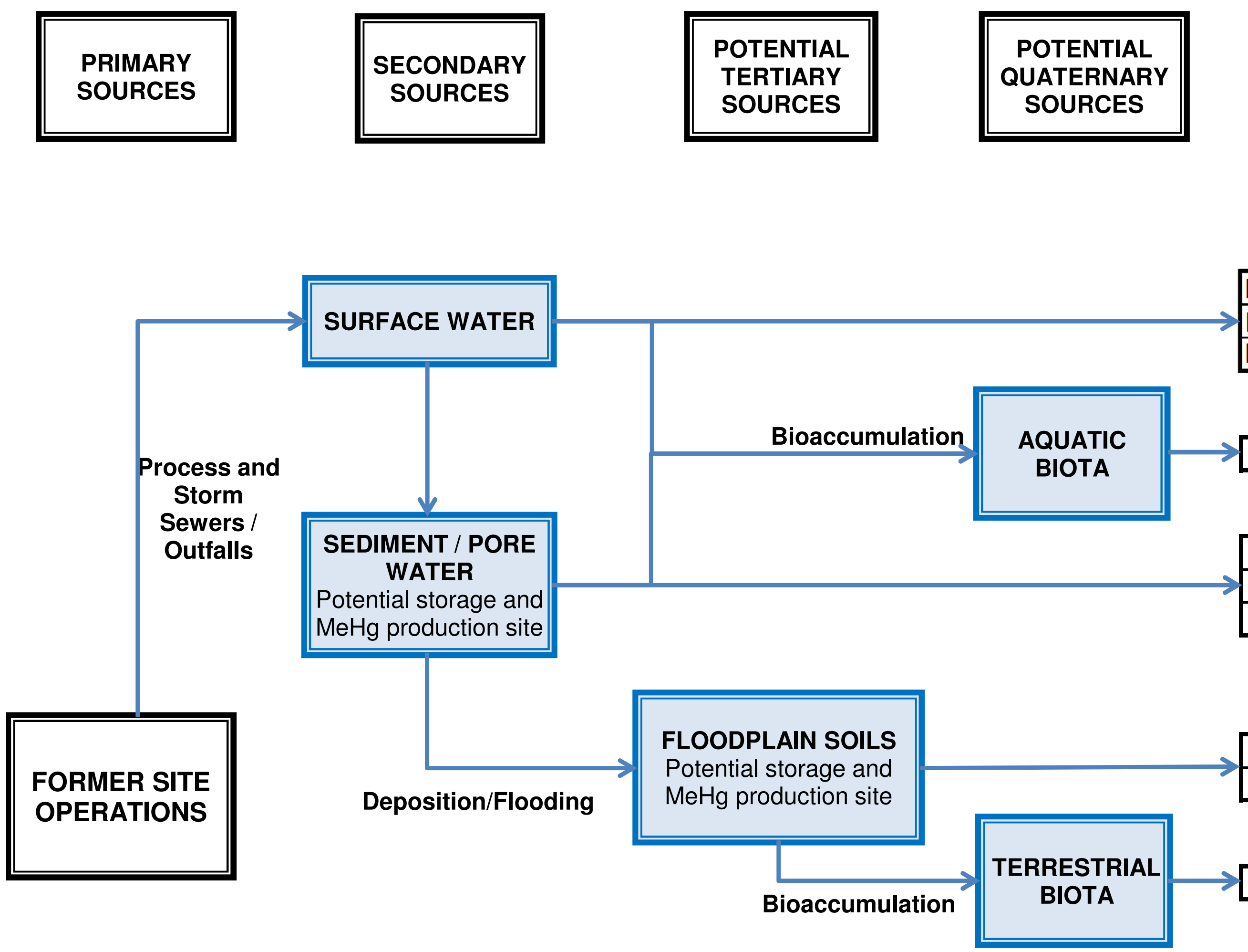
AOC 4 Human Health Conceptual Site Model: Hypothetical Future Land Use

Former DuPont Waynesboro Sute, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

7/14/2015

Fig. 5-1b

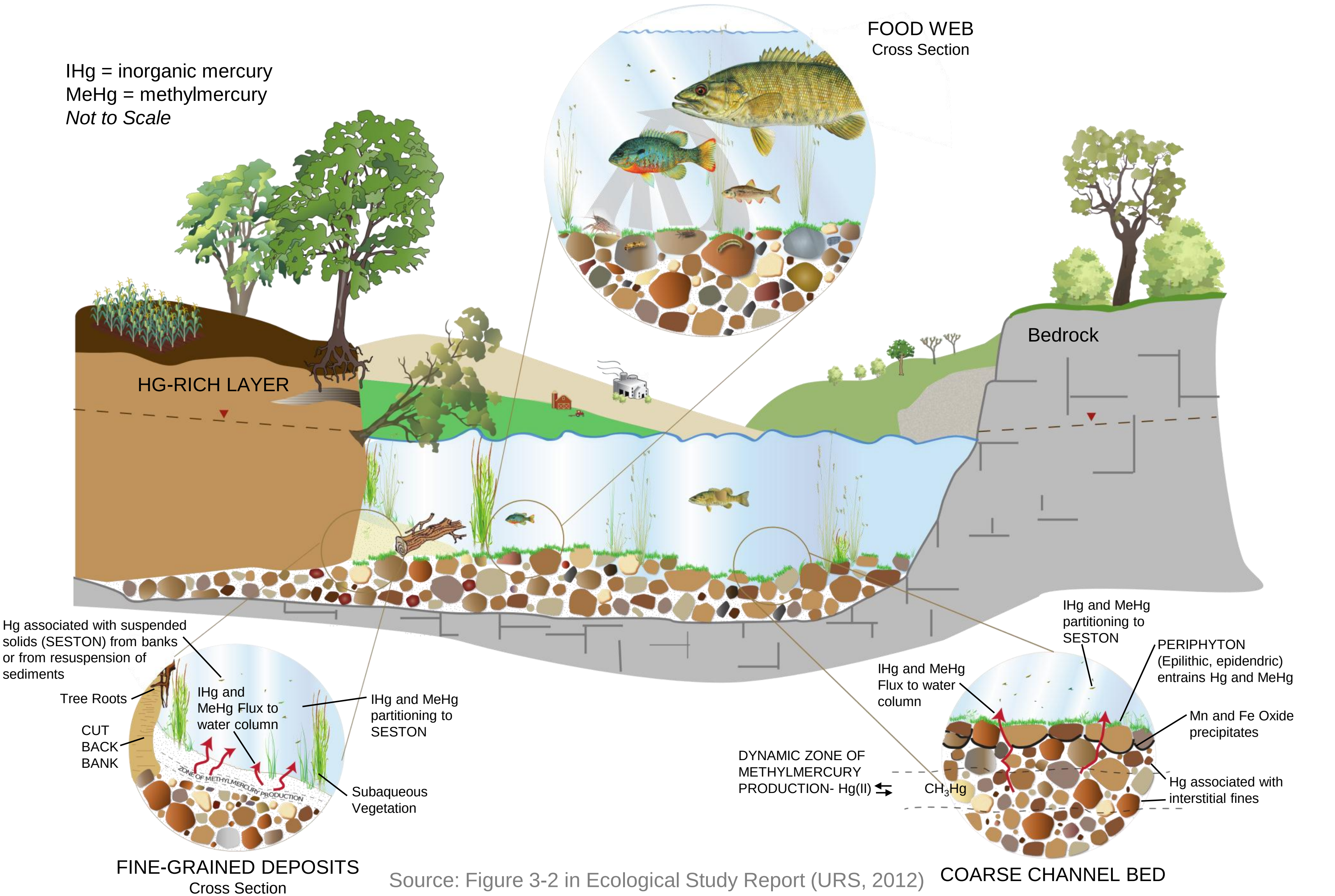
Figure 5-2
AOC 4 Ecological Conceptual Site Model
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



		Potential Receptors															
		Aquatic			Semi-Aquatic					Terrestrial							
Source	Potential Exposure Pathways	Benthic Macroinvertebrates	Fishes	Submerged Aquatic Vegetation	Amphibians	Reptiles	Piscivorous Birds	Omnivorous Birds	Piscivorous Mammals	Terrestrial Vegetation	Soil Invertebrates	Insectivorous Birds (Aerial)	Insectivorous Birds (Terrestrial)	Carnivorous birds	Aerial Insectivorous Mammals	Invertivorous Mammals	Herbivorous Mammals
SURFACE WATER	Direct Contact/Absorption	●	●	●	●	●	--	--	--			--	--	--	--		
	Incidental Ingestion	○	○		○	○	●	●	●			--	--	--	--	--	--
	Direct Ingestion	--	--				●	●	●			●	●	●	●	●	●
AQUATIC BIOTA	Direct Ingestion	○	●		●	●	●	●	●			●		●	●		
SEDIMENT / PORE WATER	Direct Contact/Absorption	●	○	●	●	●	--	--	--					--			
	Incidental Ingestion	○	○		○	○	●	●	●					●			
	Direct Ingestion																
FLOODPLAIN SOILS	Direct Contact/Absorption				○	○	--	--	--	●	●	--		--		--	--
	Incidental Ingestion				○	○	●	●	●		○	--		●		●	●
TERRESTRIAL BIOTA	Direct Ingestion		○		●	●	--	●	●		○	●		●	●	●	●

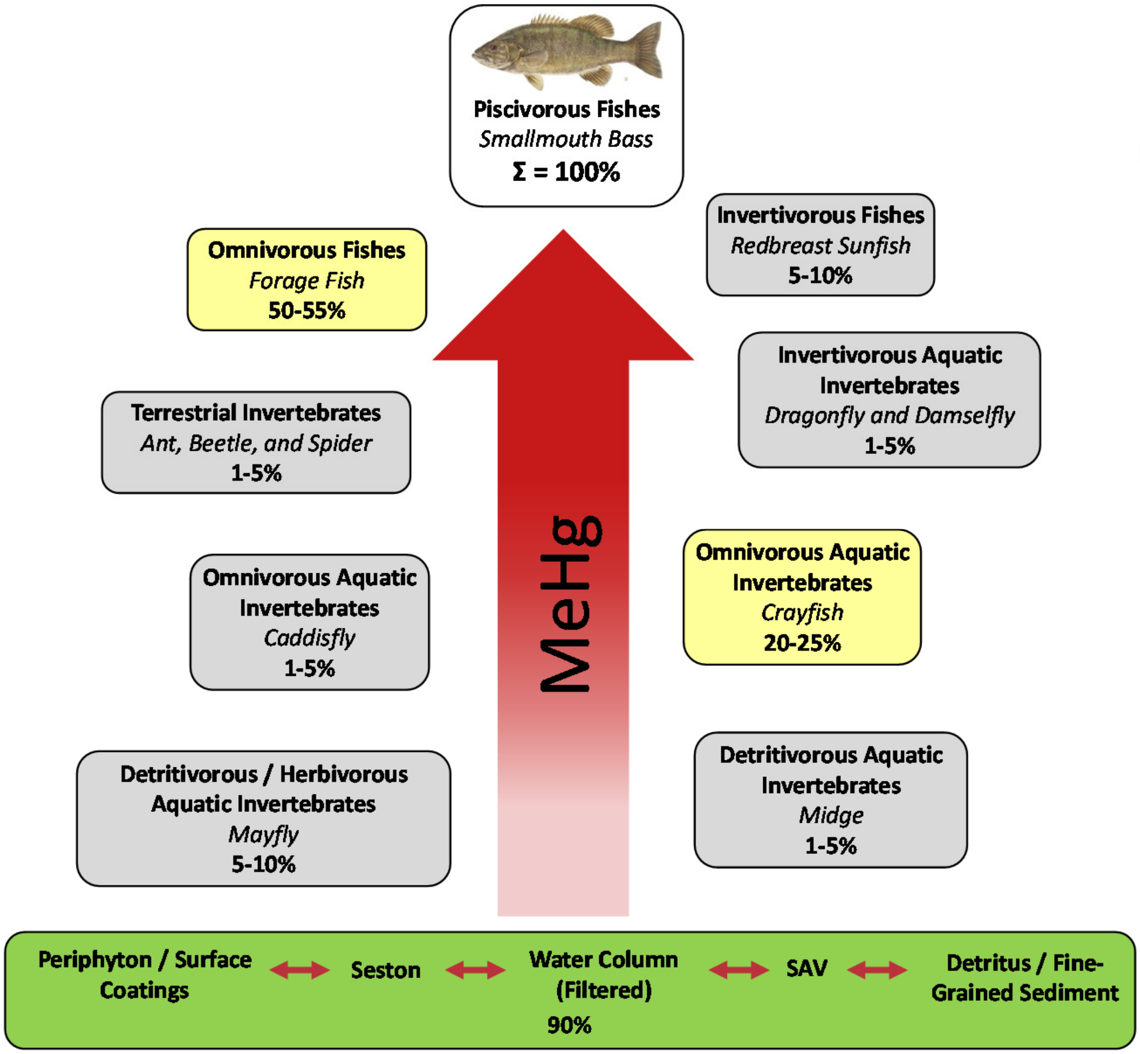
Notes:
→ CONTAMINANT MIGRATION PATHWAY
● POTENTIALLY COMPLETE EXPOSURE PATHWAY
○ SECONDARY EXPOSURE PATHWAY; NOT DIRECTLY QUANTIFIED
-- EXPOSURE PATHWAY IS POTENTIALLY COMPLETE BUT INSIGNIFICANT
BLANK = INCOMPLETE EXPOSURE PATHWAY
INCIDENTAL INGESTION OF SURFACE WATER DURING FEEDING IS NOT AN APPLICABLE PATHWAY

Figure 7-1
Aquatic Mercury Conceptual System Model (Aquatic HgCSM)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



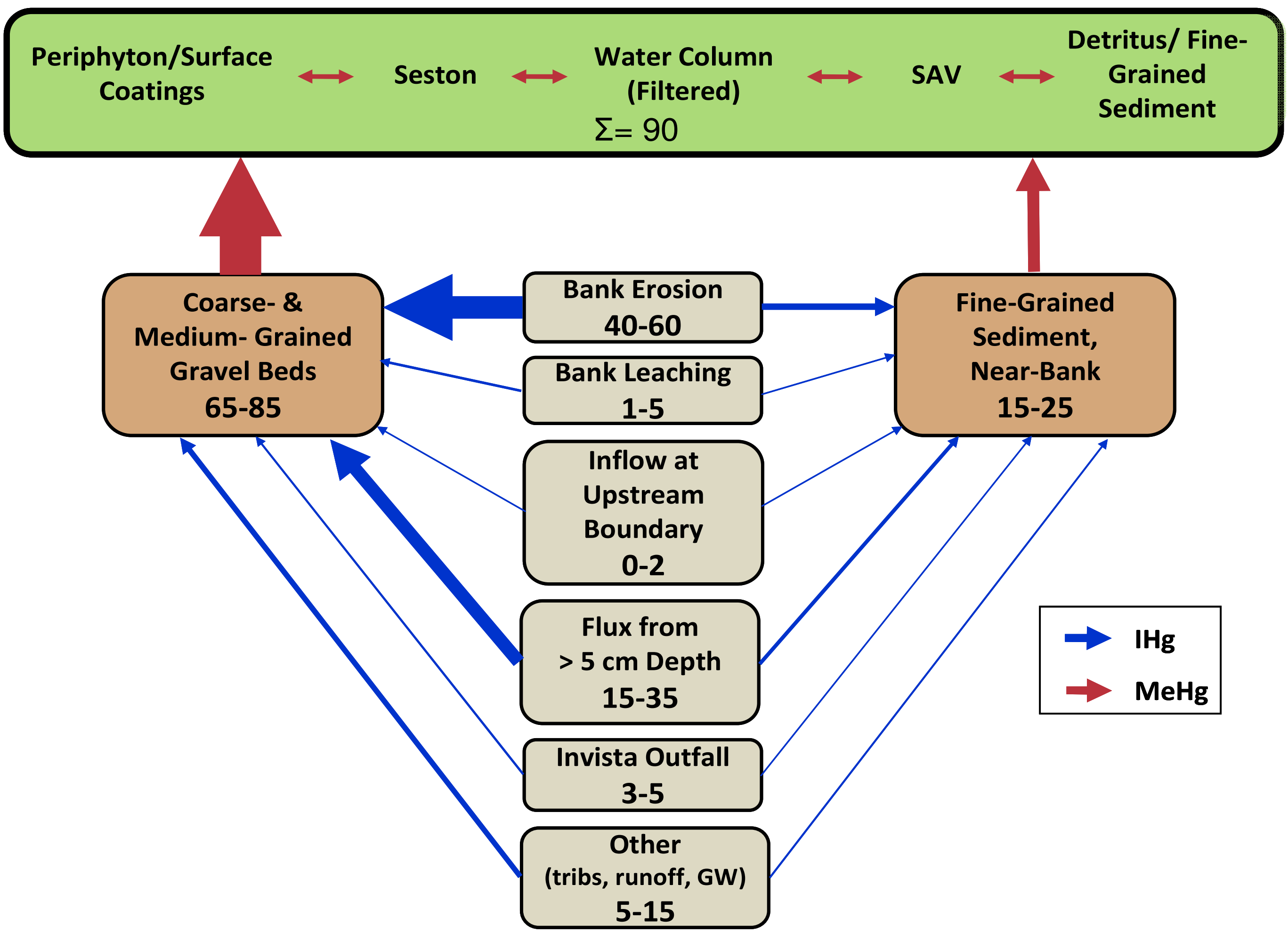
Source: Figure 3-2 in Ecological Study Report (URS, 2012)

Figure 7-2
MeHg Flow through the Food Web to Smallmouth Bass in the South River
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



Notes: The schematic describes the movement of methylmercury (MeHg) from the base of the food web (green box) through the food web to a piscivorous fish (e.g., smallmouth bass). Each box represents a component of the food web, described by the feeding type, an example of that feeding type, and the approximate percentage of the total MeHg that feeding type contributes to smallmouth bass. The grey boxes represent relatively small sources of MeHg to smallmouth bass; the major sources, omnivorous invertebrates and omnivorous fish, which contribute up to 80% of the MeHg to smallmouth bass are in yellow boxes. The items in the green box are important dietary items for the other organisms of the food web. The structure of the food web is based on bioenergetics modeling and field data including stable carbon and nitrogen isotopic ratios, mercury concentrations, and stomach content analysis. See Ecological Study Data Matrix (Table 1-3) for more information regarding study details.
Source: Figure 6-20 in Ecological Study Report (URS, 2012)

Figure 7-3
Pathways and Sources of IHg to Areas of Methylation Under Baseflow Conditions
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



<u>Notes</u>: The schematic depicts the movement of inorganic mercury (IHg; blue arrows) from the sources (gray boxes) in the South River to areas of mercury methylation (brown boxes); the red arrows show the movement of methylmercury from areas of methylation to the base of the food web (green box). The thickness of the arrow and the range of values within each box represents the magnitude of the IHg or MeHg flux. This schematic describes the important sources between RRM 0 and 10 under baseflow conditions.
Source: Figure 6-21 in Ecological Study Report (URS, 2012)

Figure 7-4
Terrestrial Mercury Conceptual System Model (Terrestrial HgCSM)
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

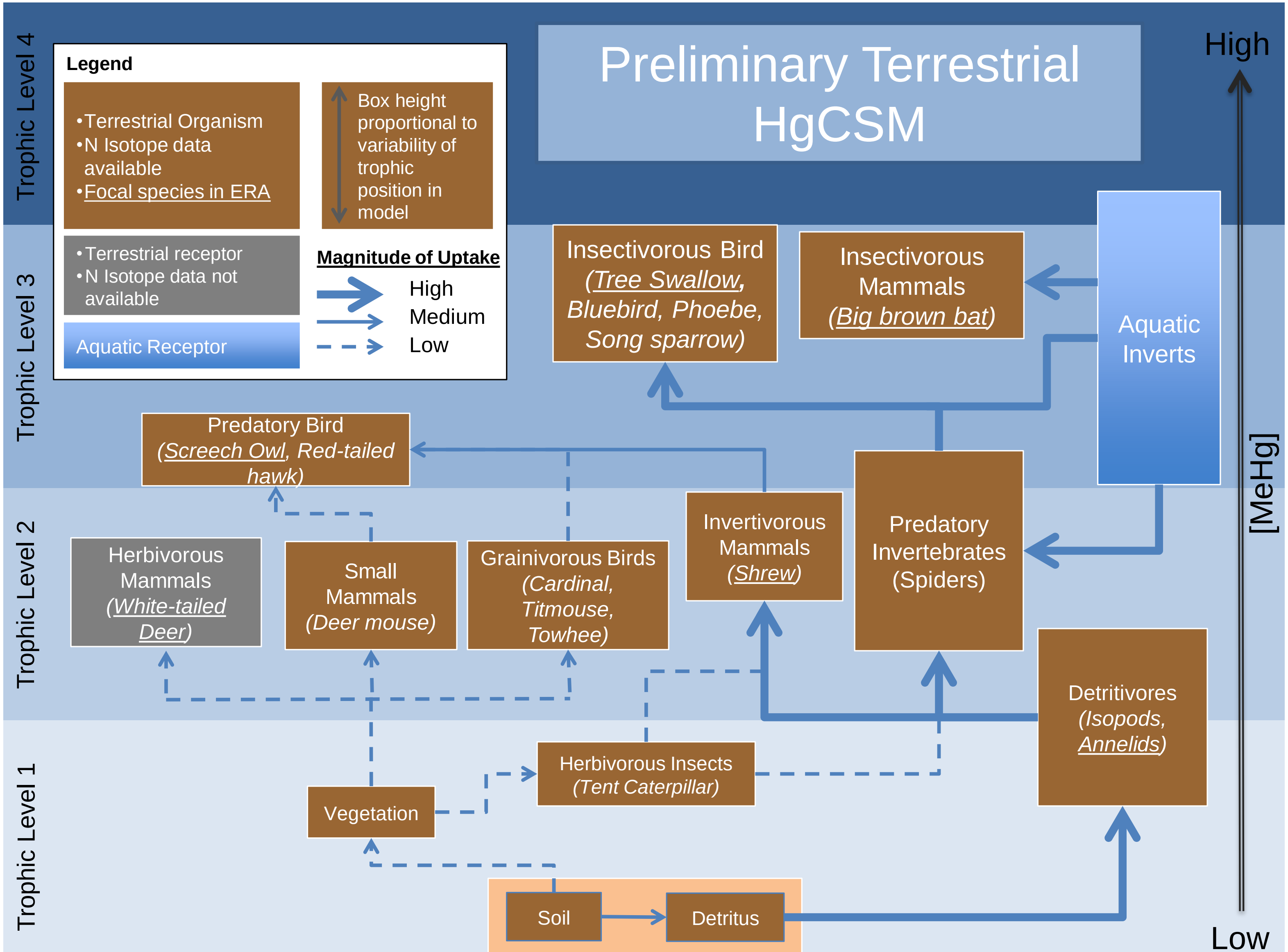
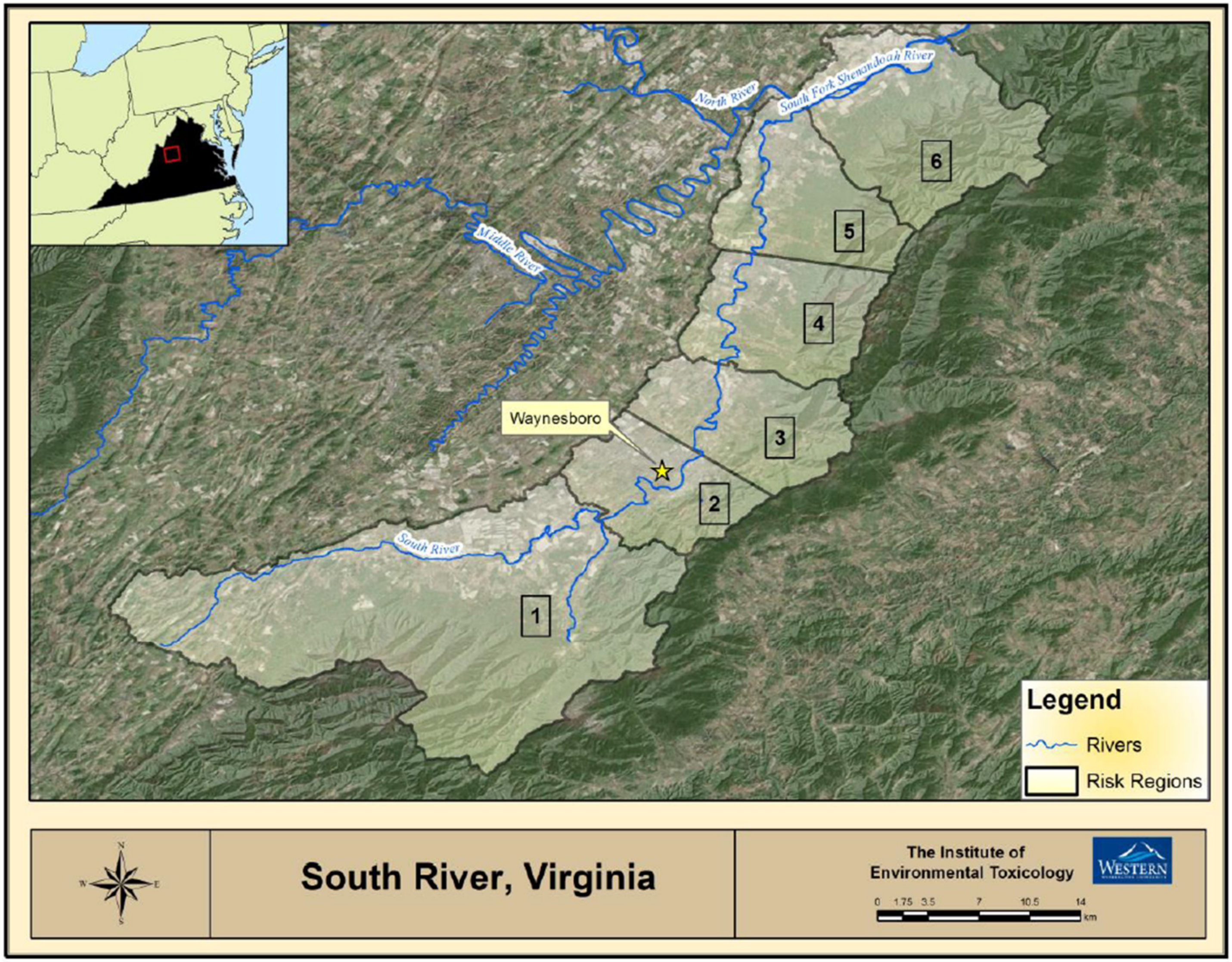


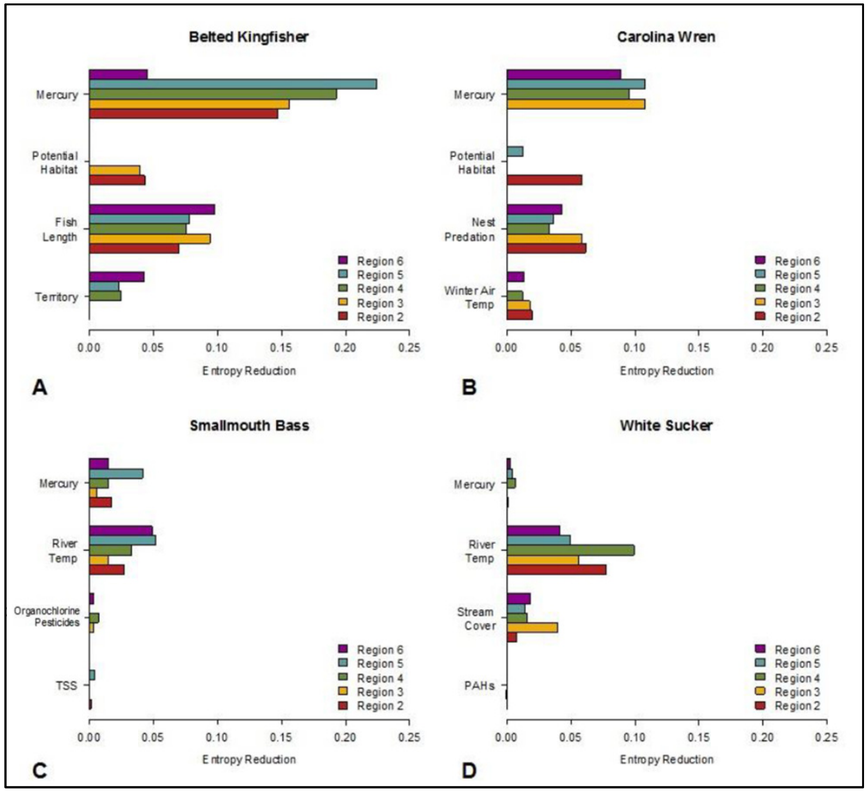
Figure 7-5
Risk Regions for the Relative Risk Model
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



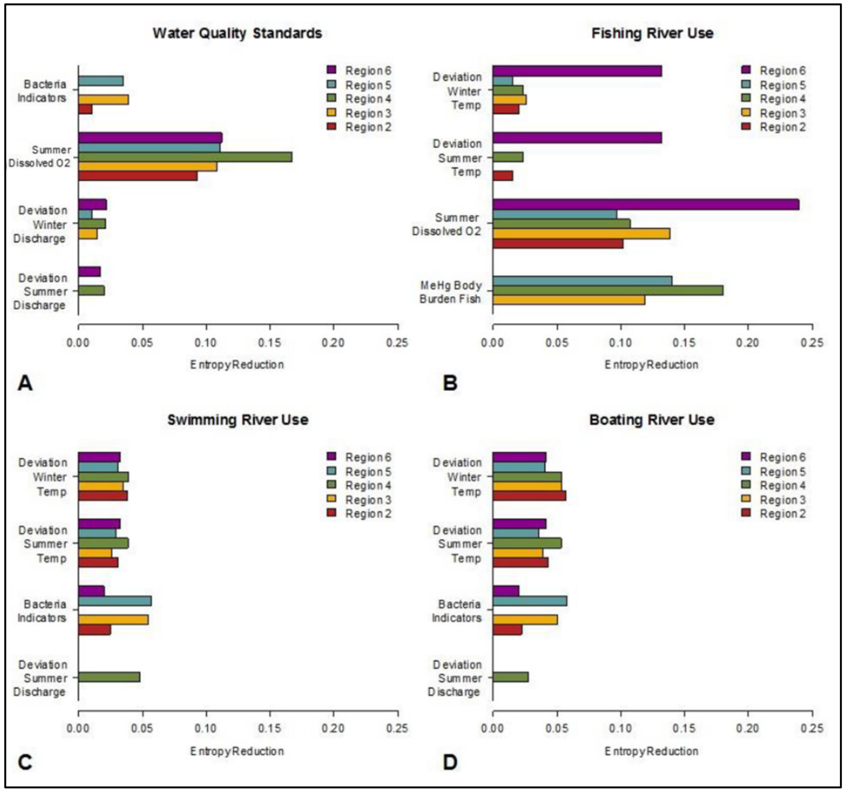
Source: Figure 2-1 in the Integrated Regional Risk Assessment (Landis, 2015)

Figure 7-6
Summary of Findings from Relative Risk Modeling
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va

Biotic Endpoints

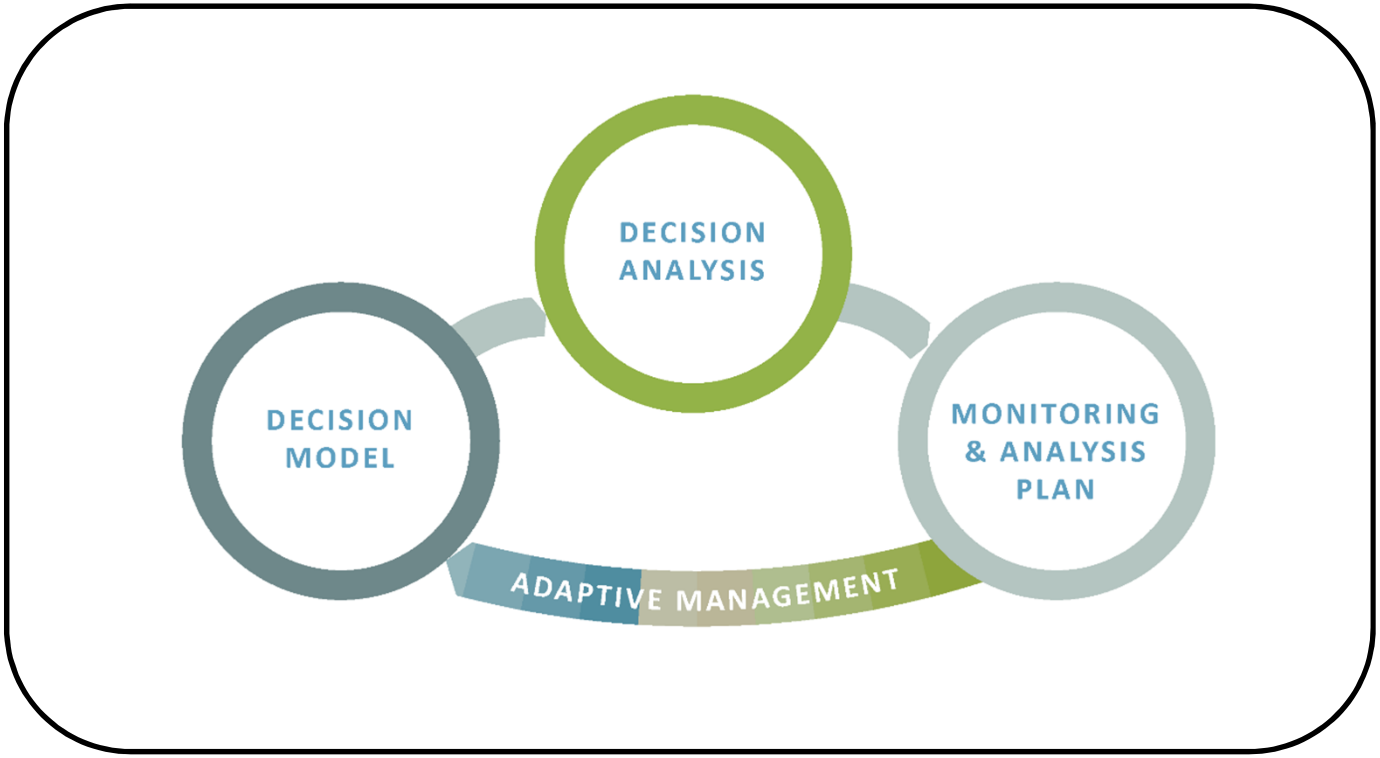


Abiotic Endpoints



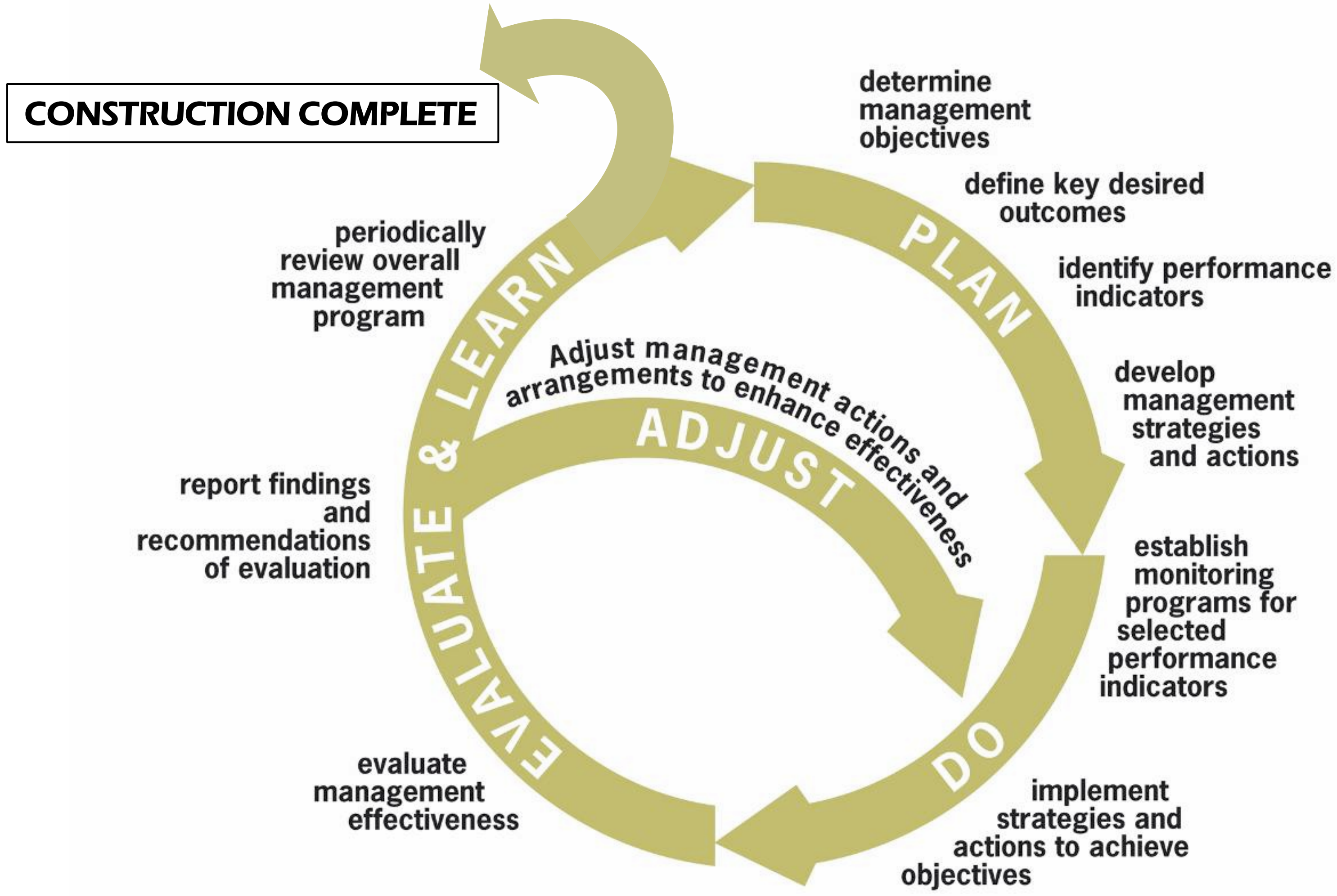
Source: Figure 2-14 (Biotic Endpoints) and Figure 2-15 (Abiotic Endpoints) in the Integrated Regional Risk Assessment (Landis, 2015)

Figure 9-1
Enhanced Adaptive Management Components
AOC 4 RFI Report
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



Source: Remediation Proposal (Anchor QEA and URS, 2013)

Figure 9-2
Enhanced Adaptive Management Cycle*
AOC 4 RFI
Former DuPont Waynesboro Site, Area of Concern 4
South River and a Segment of the South Fork Shenandoah River, Va



*Adapted from Anchor QEA and URS (2013) and Jones (2005).

Appendices

See AOC4_Final_RFI_31AUG2015SR_EcoStudy_Final_Report-Vol_II.pdf and AOC4_Final_RFI_31AUG2015SR_RemediationProposal-Vol_III.pdf