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FEASIBILITY STUDY

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:

Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:

ENVIRON International Corporation

Anchor QEA, LLC

Date

June 2, 2014

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Executive Summary

1 Introduction

The feasibility study (FS) for the LCP Chemical Superfund Site (the Site) was prepared by ENVIRON International Corporation (ENVIRON) and Anchor QEA (AQ) in accordance with an Administrative Order on Consent (USEPA Docket No. 95-17-C) entered by Honeywell (formerly AlliedSignal, Inc.), the Atlantic Richfield Company, and the Georgia Power Company with the United States Environmental Protection Agency (USEPA), to address the estuarine setting that constitutes Operable Unit 1 (OU1). This document presents remedial alternatives for addressing historical contaminant deposits in marsh sediments at the Site.

Building on historical information, human health and ecological risk assessments (EPS 2011; Black and Veatch 2011; EPS 2011), and information presented in the OU1 Remedial Investigation Report (EPS and ENVIRON 2012), this FS relies on analyses of hydrological, ecological, and sediment conditions within OU1 to support the evaluation of potential remedial measures consistent with USEPA (1988) Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA.

The following are the primary objectives of this FS:

- Identify and screen sediment remediation technologies capable of addressing the occurrence of elevated concentrations of chemicals of concern (COCs) in OU1
- Evaluate viable remedial alternatives against the Remedial Action Objectives (RAOs) and against the full range of National Contingency Plan (NCP) criteria

By completing these objectives in accordance with USEPA guidance (USEPA 2005, 2002, 1999), the FS identifies appropriate remedial alternatives that effectively manage the potential human health and ecological risks associated with the presence of elevated COC concentrations in OU1.

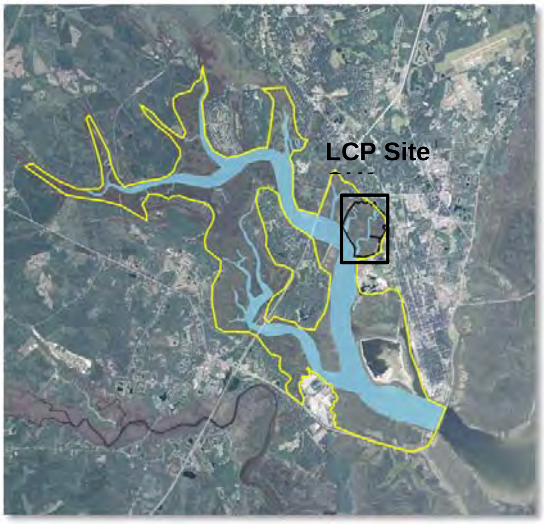

Figure 1. Turtle River/Brunswick Estuary

1.1 Site Overview

OU1 consists of approximately 662 acres of relatively flat, heavily vegetated tidal marsh and approximately 98 acres of tidal creeks within the Turtle River/Brunswick Estuary (Figure 1). The upland area adjacent to OU1 is mostly vacant but was previously the site of a petroleum refinery, power generation facility, paint and varnish manufacturing facility, and a chlor-alkali facility.

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1.2 Previous Investigation Results

The delineation of chemicals in sediment was conducted by USEPA in 1995, Geosyntec in 1995 to 1999, PTI Environmental Services in 1996, National Oceanic and Atmospheric Administration in 1997, and CDR Environmental between 2000 and 2007. ENVIRON and AQ performed additional surface sediment investigations in August and October 2012 as part of the development of this FS. Results from these investigations (Section 2) were used to delineate sediment concentrations of the four COCs: mercury, Aroclor 1268, lead, and total PAHs.

1.3 Conceptual Site Model

The USEPA-led baseline ecological risk assessment (BERA; Black and Veatch 2011) conceptual site model forms the basis for the understanding of potential ecological exposures and risks in this FS. Organisms are exposed to COCs in the creeks as well as the marsh, but those exposures are governed by hydrodynamics (i.e., tidal inundation), organism feeding strategies (i.e., life history, behavior, and diet), and chemical characteristics including both location-specific and surface-weighted average chemical concentrations. Exposures for most aquatic species are proportional to the time they spend in suitable forage habitat where they can find preferred food sources. Due to tidal inundation, this most frequently occurs in the creeks. Exposures for more sessile benthic invertebrates and their predators, however, occur throughout OU1.

2 Remedial Action Objectives and Remedial Goal Options

RAOs and remedial goal options (RGOs) provide the framework for developing implementable and effective remedial alternatives that are protective of human health and the environment. The seven RAOs identified for OU1 (Section 3) focus on mitigating potential COC releases, reducing human health and ecological exposures risks, and protecting aquatic life, wildlife and habitat.

The RGOs support protective management decisions that are consistent with the site-specific human health baseline risk assessment (HHBRA; EPS 2011) and BERA (Black and Veatch 2011)), and with USEPA's (1999) Ecological Risk Assessments and Risk Management Principles for Superfund Sites directive. Two types of RGOs are considered in this FS:

- Surface-weighted average concentration (SWAC) RGOs for mercury and Aroclor 1268 are based on the results of the HHBRA and BERA. They are protective of humans that consume fish, shellfish, and wild game from the Site, and of the mammals, birds, and fish that nest, forage, and breed in the Site and are exposed over relatively large spatial scales.
- Benthic community RGOs for mercury, Aroclor 1268, lead, and total PAHs are based on sediment effect concentrations derived by USEPA from the results of site-specific sediment toxicity tests conducted with benthic invertebrates. They are protective of sediment dwelling organisms exposed over smaller spatial scales.

The following RGOs are based on the results of the USEPA-approved HHBRA and the USEPA-led BERA, and were approved by USEPA for the purposes of evaluating potential remedial alternatives in OU1.

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Constituent	SWAC RGOs (mg/kg)	Benthic Community RGOs (mg/kg)
Mercury	1-2	4 – 11
Aroclor 1268	2-4	6 – 16
Lead	NA	90 – 177
Total PAHs	NA	4

NA: not applicable

The SWAC and benthic community RGOs were established so that concentrations within the ranges meet the overall protectiveness criteria for human health and the environment for this Site. Therefore, remedial alternatives that lie within the SWAC and benthic community RGO ranges meet the National Contingency Plan (NCP) threshold criterion for protectiveness.

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3 Screening of Available Sediment Remedial Technologies and Process Options

The FS identifies and initially screens remedial technologies, or general response actions (GRAs) (Section 4), to be assembled into remedial alternatives for the Site (Section 5). The GRAs evaluated include the following:

1. No action
2. Institutional controls
3. Monitored natural recovery (MNR)
4. Thin-cover placement
5. Sediment capping
6. Sediment removal

Consistent with USEPA guidance (USEPA 1988), the initial screening of GRAs considers effectiveness, implementability, and cost. Innovative technologies, such as the in situ application of reactive amendments, also were evaluated in the screening process.

4 Development of Remedial Alternatives

Remedial alternative development follows a step-wise process beginning with identification of sediment management areas (SMAs) that are informed by RGOs, sediment chemistry, habitat hydrology, and morphology. The SMAs are then merged with the applicable GRAs to develop the remedial alternatives evaluated in the FS. The outcome of this process is the identification of three SMAs and six remedy alternatives, including the No Action alternative required under NCP.

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4.1 Sediment Management Areas

Both the SWAC and benthic community RGOs for the Site are used to delineate SMAs (Section 5). Each SMA represents a different OU1 remediation footprint and all SMAs result in surface sediment concentrations that are within the RGO ranges and are, thus, consistent with the NCP threshold criterion for protectiveness:

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- SMA-1 is 48 acres and encompasses areas where COC concentrations exceed the lower end of the protective range of benthic community RGOs (4 mg/kg mercury, 6 mg/kg Aroclor 1268, 90 mg/kg lead, and 4 mg/kg total PAHs) and the lower end SWAC RGOs for mercury (1 mg/kg) and Aroclor 1268 (2 mg/kg).
- SMA-2 is 18 acres and encompasses areas where COC concentrations exceed the upper end of the protective range of benthic community RGOs (11 mg/kg mercury, 16 mg/kg Aroclor 1268, 177 mg/kg lead, and 4 mg/kg total PAHs). Remediation of SMA-2 also achieves the SWAC RGO ranges for mercury (1 - 2 mg/kg) and Aroclor 1268 (2 - 4 mg/kg).
- SMA-3 encompasses the same areas as SMA 2, and includes additional COC-impacted areas in Purvis Creek and in Domain 1. The total area of SMA-3 is 24 acres. These additional areas were included in the SMA-3 footprint for the following reasons:
    - Addressing areas in Purvis Creek and Domain 1 helps achieve lower SWAC-based RGOs for mercury and Aroclor 1268.
    - Because most of Purvis Creek is permanently submerged, even at low tide, exposure times for fish and piscivorous wildlife are longest in Purvis Creek.
    - Purvis Creek is relatively accessible from water such that remedial actions in the creek will not adversely or significantly impact vegetated marsh areas beyond impacts already contemplated for SMA-2.
    - The area proposed for Domain 1 is located immediately adjacent to areas where other work (i.e., work in LCP Ditch and Eastern Creek) is already planned, making expansion into Domain 1 easily implementable with minimal additional marsh impacts.

4.2 Description of Alternatives

Six (6) alternatives are identified for addressing sediments in OU1 (Section 5). Alternative 1 is the No Action alternative, and is included for comparison to other alternatives and to identify baseline conditions in the absence of remediation, as required by NCP. Alternatives 2 and 3 are based on SMA 1 but are differentiated by the GRAs employed in each alternative. Alternative 2 consists solely of sediment removal, whereas Alternative 3 combines removal, capping, and thin-cover placement to achieve the site-specific RGOs.[1] Similarly, Alternatives 4

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[1] SMA-1 is 48 acres, and is informed by RGOs, sediment chemistry, hydrology, morphology, and the risk of impairment of the existing ecosystem. Relying solely on the most conservative RGO values, an 81-acre dredge remedy was identified and considered by the project team, in consultation with USEPA and GAEPD. However, after weighing contaminant risk reduction against ecosystem impairments—in this case destruction of benthos, marsh vegetation, and wildlife habitat—it was decided that remediation of 81 acres would cause significant marsh damage while providing minimal risk reduction compared to the 48 acre area. For this reason, the 81-acre removal-only remedy was screened from further evaluation.

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and 5 are based on the same SMA—in this case, SMA-2. Like Alternatives 2 and 3, Alternatives 4 and 5 are differentiated by the GRAs employed in each alternative. Alternative 4 consists solely of sediment removal and Alternative 5 combines removal, capping, and thin-cover placement. The final alternative evaluated, Alternative 6, is based on SMA-3 and also combines removal, capping, and thin cover placement. Alternatives 2 through 6 are described in greater detail below.

4.2.1 Alternative 2 – Sediment Removal in SMA-1

Alternative 2 (Figure 2) addresses exceedances of RGOs in the 48-acre SMA-1 by combining sediment removal with institutional controls and long-term monitoring. The estimated in-place sediment volume targeted for removal is approximately 153,000 cubic yards (CY). Following removal, the remedial areas would be backfilled with clean material to manage risks associated with postremoval residuals, accelerate the natural recovery process, and establish a clean sediment surface.

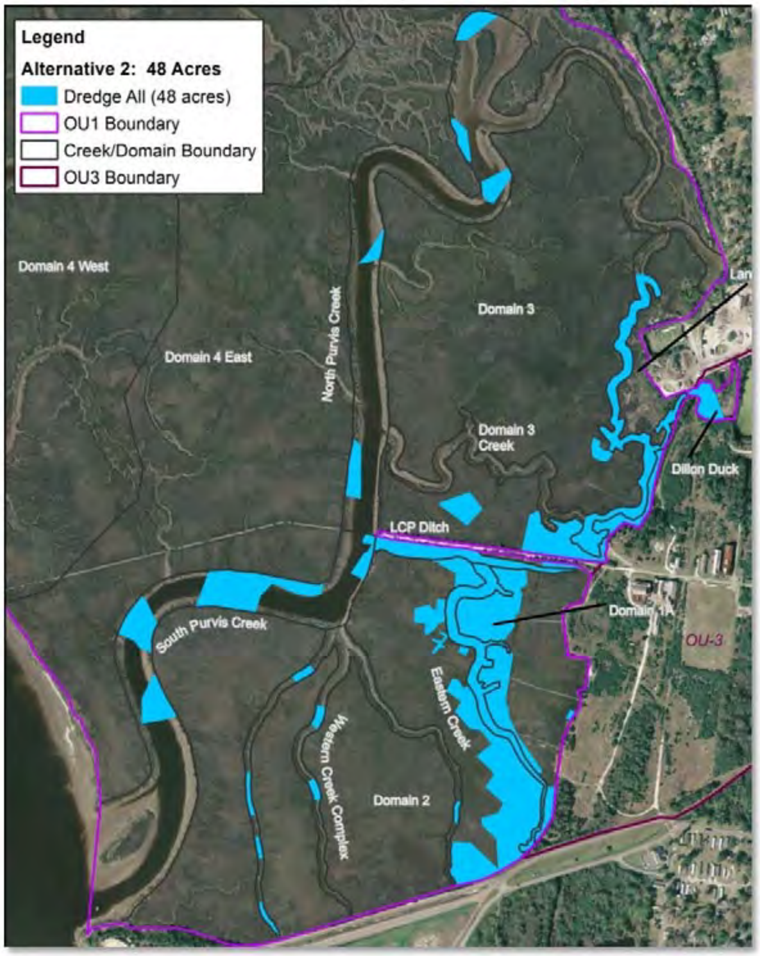

Figure 2. Alternative 2 Remedy Footprint

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4.2.2 Alternative 3 – Sediment Removal, Capping, Thin-Cover Placement in SMA-1

Alternative 3 (Figure 3) addresses exceedances of RGOs in the 48-acre SMA-1 remediation area by combining sediment removal plus backfill, sediment capping, and thin-cover placement with institutional controls and long-term monitoring.

The estimated in-place sediment volume targeted for removal in Alternative 3 is approximately 27,000 CY. Alternative 3 also includes 16 acres of capping and 23 acres of thin-cover placement.

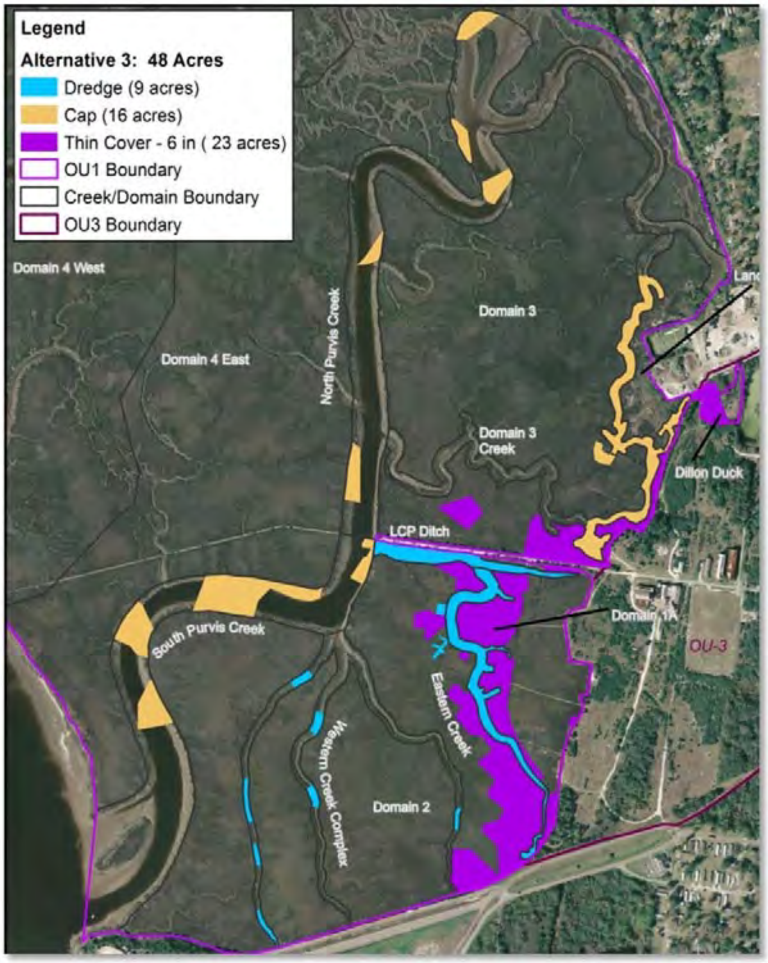

Figure 3. Alternative 3 Remedy Footprint

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4.2.3 Alternative 4 – Sediment Removal in SMA-2

Alternative 4 (Figure 4) addresses exceedances of the upper end of the protective range of benthic community RGOs in the 18-acre SMA-2 remediation area by combining sediment removal plus backfill with institutional controls and long-term monitoring. The estimated in-place sediment volume targeted for removal in Alternative 4 amount to approximately 57,000 CY. Similar to Alternative 2, following removal, the remedial areas would be backfilled with clean material to manage risks associated with postremoval residuals, accelerate the natural recovery process, and establish a clean sediment surface.

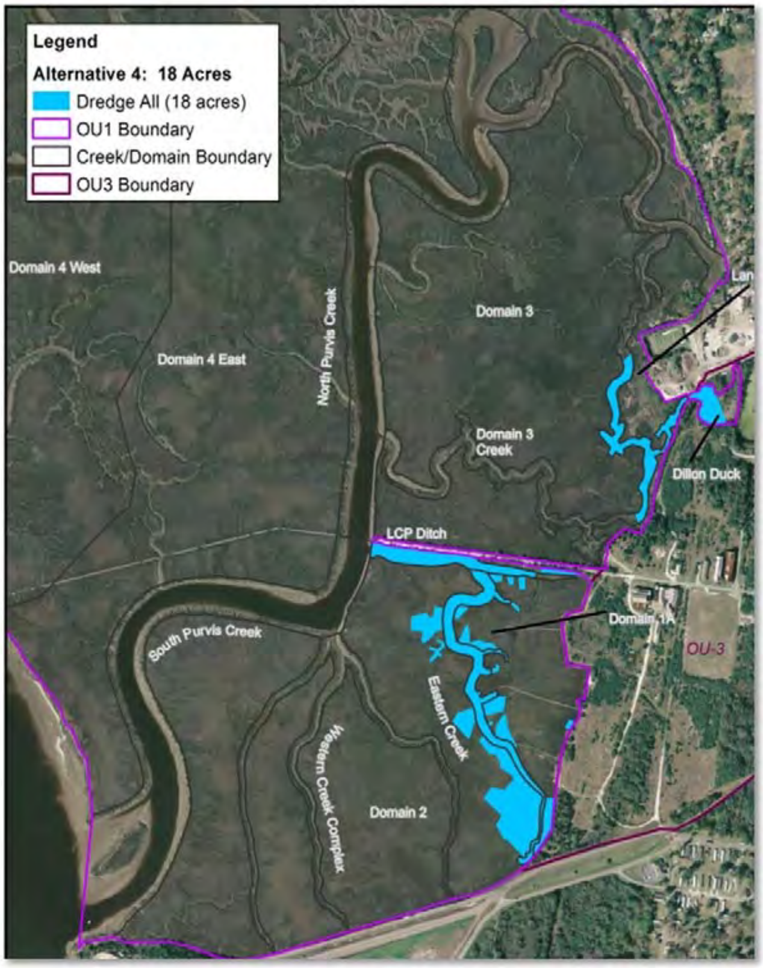

Figure 4. Alternative 4 Remedy Footprint

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4.2.4 Alternative 5 – Sediment Removal, Capping, Thin-Cover Placement in SMA-2

Alternative 5 (Figure 5) addresses exceedances of the upper end of the protective range of benthic community RGOs in the 18-acre SMA-2 remediation area by combining sediment removal plus backfill, sediment capping, and thin-cover placement along with institutional controls and long-term monitoring. Estimated in-place sediment volume targeted for removal in Alternative 5 amount to approximately 22,000 CY. Alternative 5 also includes 3 acres of capping and 8 acres of thin-cover placement.

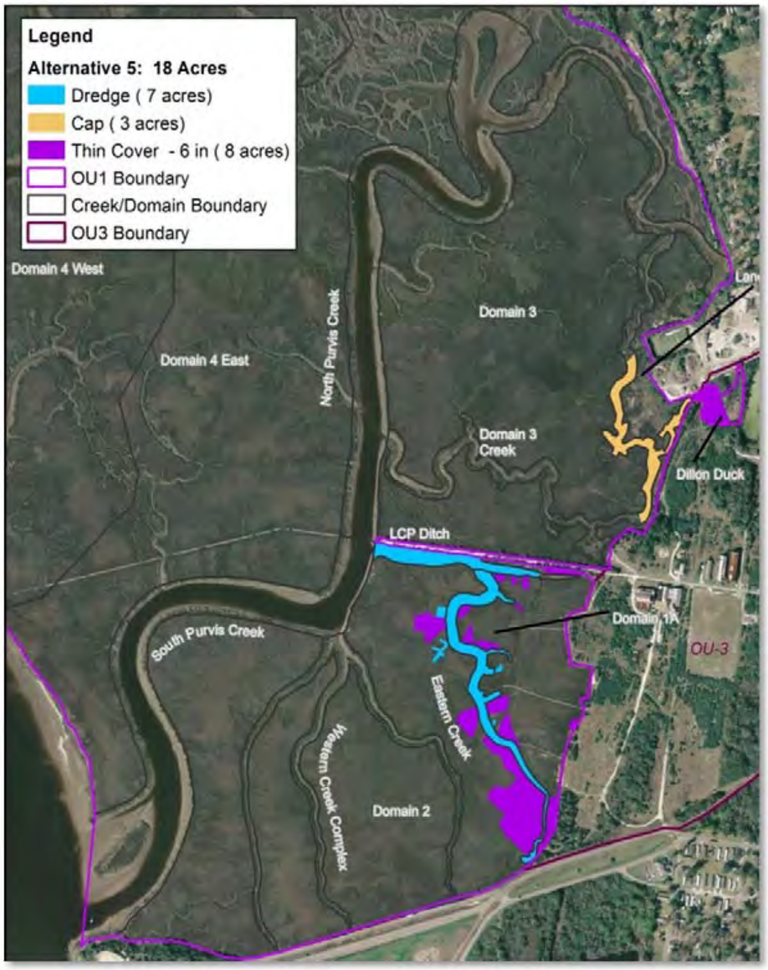

Figure 5. Alternative 5 Remedy Footprint

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4.2.5 Alternative 6 – Sediment Removal, Capping, Thin-Cover Placement in SMA-3

Alternative 6 (Figure 6) addresses RGO exceedances in the 24-acre-SMA-3 remediation area by combining sediment removal plus backfill, sediment capping, and thin-cover placement along with institutional controls and long-term monitoring. The estimated in-place sediment volume targeted for removal in Alternative 6 amount to approximately 22,000 CY. Alternative 6 also includes 6 acres of capping and 11 acres of thin-cover placement.

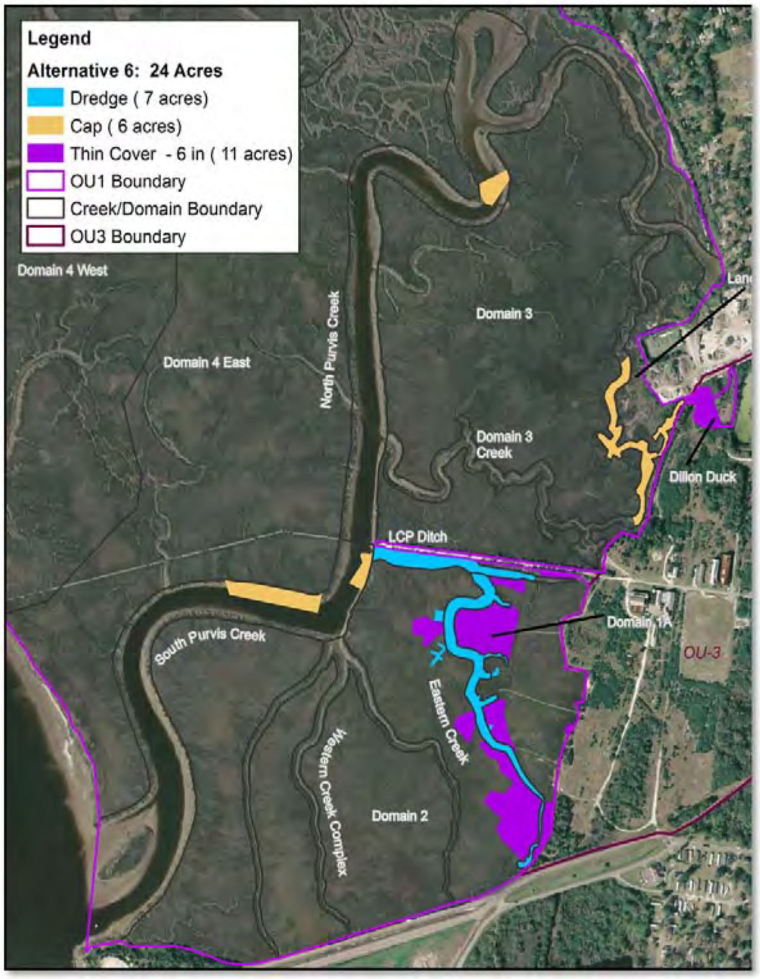

Figure 6. Alternative 6 Remedy Footprint

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5 NCP Evaluation of Alternatives

Alternatives 1 through 6 are evaluated against the nine criteria established under the NCP. This evaluation also serves as a comparison of the 6 alternatives against the RAOs. The results of the alternative evaluation against the nine NCP criteria (Section 6) can be summarized as follows:

- All alternatives, except the no action alternative (Alternative 1) meet the threshold criterion for protectiveness of human health and the environment, because postremedy surface sediment concentrations under all alternatives will lie within the SWAC and benthic community RGO ranges.

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- Alternatives 2 and 4 meet the protectiveness criterion through sediment removal and backfilling areas where COCs exceed the RGOs.
- Alternatives 3, 5, and 6 meet the protectiveness criterion through a mixture of sediment removal, capping, and thin-cover placement. Capping isolates contaminated sediment from contact with human and ecological receptors while thin-cover placement jump starts ongoing natural recovery processes in the marsh and creates a clean sediment surface. Thin-cover placement provides a cleaner sediment surface and benthic environment but it is not intended as an absolute chemical barrier; bioturbation beyond the cover depth does not diminish the effectiveness of the remedy.
- All alternatives include institutional controls such as fish consumption advisories.
- Alternatives 2 through 6 are designed to comply with Applicable or Relevant and Appropriate Requirements (ARARs) and all federal and state permits required for remedy implementation. Other than the No Action Alternative, which would result in no change in conditions in OU1, all alternatives would comply with ARARs.
- Other than the No Action Alternative, all alternatives provide long-term human health and ecological risk reduction by achieving site-specific RGO ranges. Sediment removal, sediment capping, and thin-cover placement have proved reliable and effective at sites similar to OU1. Site-specific modeling and FS-level design calculations lend confidence to the long-term stability of the active remedy components (i.e., removal plus backfill, capping, and thin-cover placement). Institutional controls will be used, as necessary, to control residual risks following remedy implementation. In addition, long-term monitoring ensures long-term protectiveness of the remedy and compliance with ARARs in addition to long-term structural integrity and effectiveness.
- All alternatives, except the No Action Alternative, provide varying degrees of long-term reduction of COC toxicity, mobility, and volume. The No Action Alternative does not reduce toxicity, mobility, or volume of chemicals in OU1 beyond ongoing natural processes. Alternatives 2 through 6 include sediment removal which reduces the volume of COC-impacted sediment in OU1. Alternatives that include sediment capping and thin-cover placement reduce long-term COC toxicity and mobility by creating a clean sediment surface through burial and/or dilution with clean materials.

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- Implementation of any alternative, other than the No Action Alternative, presents short-term construction impacts to the environment and to the surrounding community. The extent of these impacts is proportional to the remedial footprint, the selected remedy components, the time required to complete the remedy, and on-site material handling requirements. Of the GRAs considered, thin covers have the least impact to the existing ecology because, applied accurately, they limit the loss of aquatic habitat and changes in marsh elevations. Capping, limited to marsh creeks in Alternatives 3, 5, and 6, minimally impacts the marsh ecosystem because hydrology is relatively unaffected in areas identified for capping, and capping in creeks does not directly impact marsh vegetation. Sediment removal has the most substantial impact to the marsh ecosystem through the potential changes to hydrology and complete removal of vegetation and the benthic community.
- There are no implementability constraints for the No Action Alternative because no remedial action is taken. Portions of each SMA pose different challenges and technical difficulties associated with remedy implementation. Tides severely impact accessibility of the marsh by equipment, material, and personnel. In addition, implementation of any remedial technology will encounter constraints, such as shallow, narrow, and sinuous creeks, soft sediments necessitating the construction of temporary roads, presence of debris, and material management. Techniques, however, exist to meet many of the challenges associated with working among soft sediments in tidally influenced marsh areas.
- Apart from the No Action Alternative, Alternative 5 has the lowest present-worth cost at approximately $26MM, and Alternative 2 has the highest present worth cost at approximately $65MM. The total estimated present-worth costs of Alternatives 3, 4 and 6 are $39MM, $34MM, and $29MM, respectively.
- The modifying criteria of state and community acceptance are not addressed in this draft FS, but will be in the final FS or the ROD. USEPA and Georgia Environmental Protection Division (GAEPD) have been involved with the various tasks and decisions that have been incorporated into the development of the alternatives presented in this FS, thus USEPA and State acceptance is anticipated. Likewise, community acceptance is anticipated because each alternative, except No Action, is designed to meet RAOs established by USEPA and RGOs.
- All alternatives, except the No Action Alternative, would incorporate sustainable practices, including beneficial reuse of clean dredged material from nearby waterways in lieu of borrowing material from upland sources, using low sulfur fuel or biodiesel in lieu of diesel or incorporating remedial technologies that achieve RGOs while decreasing the short-term and long-term bioavailability of COCs (e.g., sediment capping or thin-cover placement).

5.1 Cost and Ecosystem-Impact Analyses

Alternatives 2 through 6 achieve RAOs and all alternatives achieve the threshold criterion of protection of human health and the environment and compliance with ARARs. All provide long-term human health and ecological risk reduction by decreasing surface sediment COC concentrations, which leads to reduced chemical bioavailability and chemical uptake by human and ecological receptors and reduced risks to human health, mammals, birds, fish, and the

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benthic community. Long-term monitoring ensures long-term remedy integrity and effectiveness.

5.1.1 Cost-Effectiveness Analysis

CERCLA and the NCP require that selected remedies be cost-effective. A remedy is cost effective if its “costs are proportional to its overall effectiveness” (40 CFR 300.430(f)(1)(ii)(D)). Cost effectiveness, defined here as the cost associated with risk reduction following remedy implementation, is evaluated by comparing postremediation residual risks for each alternative against projected remedy costs. Figure 7 shows the risk reduction compared to costs for green heron exposed to mercury and finfish exposed to mercury and Aroclor 1268. The green heron and fish were selected because the BERA identified them as among the most sensitive of wildlife species to COCs in OU1. In all cases, risk reduction is represented by the postremedy hazard quotients (HQs) from individual exposure areas within OU1. The No Action HQs represent baseline conditions reported in the BERA.

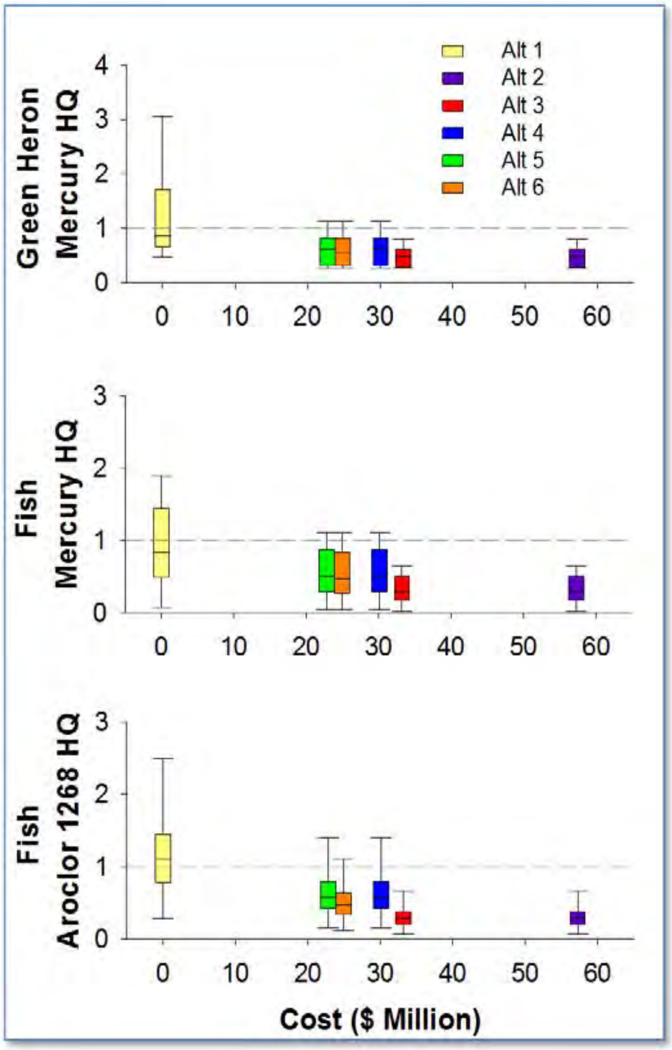

Figure 7. Cost-Effectiveness Evaluation for Alternatives 1 through 6

Although Alternatives 2 and 3 have the greatest predicted COC risk reduction, they do not provide a substantially greater overall risk reduction to bird and fish populations in proportion to their costs. Risk reduction is virtually the same among the remaining alternatives (4, 5, and 6), although the Alternative 6 residual risks are slightly

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lower than those for Alternatives 4 and 5 because Alternative 6 includes areas in Purvis Creek and Domain 1.

Alternatives 1 through 6 also were evaluated for their protection of benthic communities. Except for the No Action alternative, all the alternatives reduce surface sediment concentrations to levels within or below the site-specific RGO ranges to varying levels of protectiveness.. Furthermore, all achieve NOAEL-based HQs at or below 1, even for the most sensitive receptors and pathways identified in the BERA (Figure 7). Thus, although the residual risks associated with SMA-1 (Alternatives 2 and 3) are lower than those associated with SMA-2 (Alternatives 4 and 5) and SMA 3 (Alternative 6), all remedies reduce HQ levels to 1 or below 1; thus, all alternatives are adequately protective of the environment. Therefore, the increased costs associated with the larger sediment footprint (Alternatives 2 and 3) and those associated with removal only (Alternative 2 and 4) are disproportionate to their benefit.

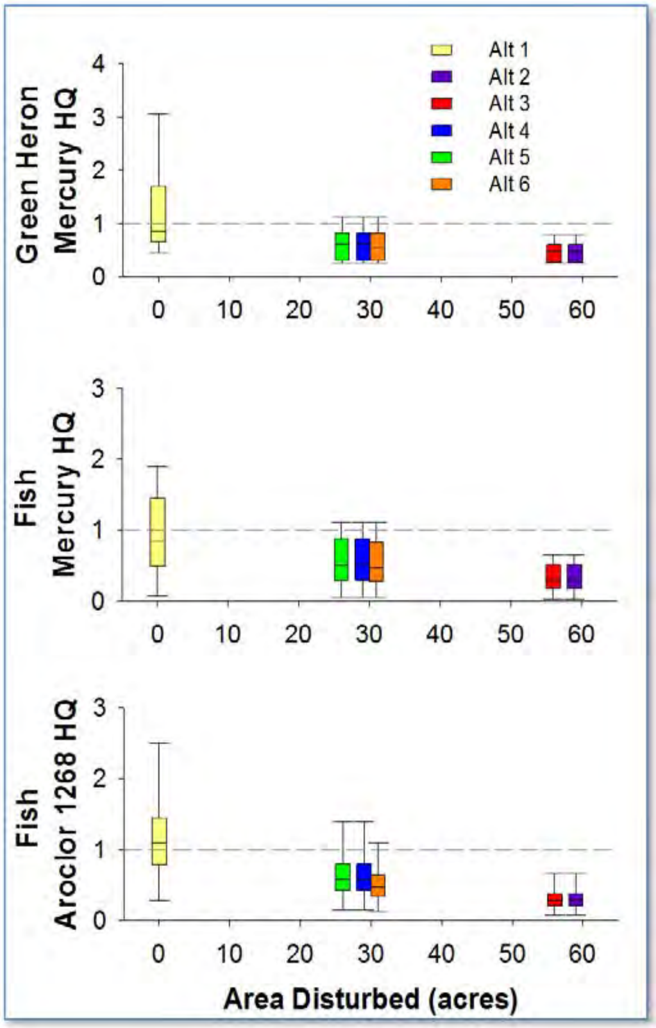

Figure 8. Ecosystem-Impacts Evaluation for Alternatives 1 through 6

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5.1.2 Ecosystem Impacts and Recovery Analysis

Figure 8 shows risk reduction compared to the area impacted by each remedy for the green heron and finfish exposed to Aroclor 1268, and for finfish exposed to mercury. Figure 8 is similar to Figure 7, except that the total area disturbed (remedy footprint plus marsh disturbance for remedy construction) is shown on the x-axis instead of cost. Though similar, the observations between Figures 7 and 8 differ slightly. The

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SMA-1 remedies (Alternatives 2 and 3) have the largest area of impact at 59 and 56 acres, respectively. Alternatives 4 and 5 are comparable and impact approximately 29 and 26 acres, respectively. Alternative 6 impacts approximately 31 acres. Although the residual risks associated with SMA-1 (Alternatives 2 and 3) are lower than those associated with SMA-2 (Alternatives 4 and 5) and SMA 3 (Alternative 6), all remedies reduce HQ levels to 1 or below 1; thus, all alternatives are adequately protective of the environment.

Recovery times also are expected to increase with the area and magnitude of the disturbance. Recovery times are longest for Alternatives 2 and 3, and are longer for the removal-only alternatives (Alternatives 2 and 4) compared to their respective combined remedies (Alternatives 3 and 5).

6 Conclusions

This FS has been prepared following USEPA policy and guidance, including USEPA's (2002) Principles for Managing Contaminated Sediment Risks, USEPA's (2005) Contaminated Sediment Remediation Guidance for Hazard Waste Sites, and USEPA's (1999) Ecological Risk Assessment and Risk Management Principles for Superfund Sites. The FS risk-management analyses were consistent with the HHBRA and BERA documents prepared for the Site, which identified baseline risk conditions and were used to establish site-specific RGOs.

With the exception of the No Action alternative, all remedies considered in the FS are expected to reduce risks to human health and the environment to acceptable levels. With the exception of a few isolated sample stations with elevated concentrations, all five active alternatives (Alternatives 2 through 6) reduce surface sediment concentrations to levels at or below the site-specific RGO ranges established for protection of human health and site-specific sensitive ecological receptors.

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Alternatives 2 through 6 comply with ARARs. Hence, all achieve the threshold criteria of protection of human health and the environment and compliance with ARARs. All active alternatives provide long-term human health and ecological risk reduction by decreasing surface sediment COC concentrations, leading to reduced chemical bioavailability and chemical uptake by human and ecological receptors. This, in turn, leads to reduced risks to human health, mammals, birds, fish, and the benthic community. Long-term monitoring ensures long-term remedy integrity and effectiveness.

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Based on all the remedy selection criteria, including the cost effectiveness and impact analysis summarized above, Alternative 6 is the most effective remedial alternative for OU1. This alternative satisfies the site-specific RAOs, is within the site-specific RGO ranges, and meets the NCP criteria of overall protectiveness, implementability, and permanence while limiting risks associated with disturbing sensitive habitat.

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Acronyms and Abbreviations

%	percent
AET	apparent effects threshold
AOC	Administrative Order on Consent
API	American Petroleum Institute
ARAR	Applicable or Relevant and Appropriate Requirement
BERA	baseline ecological risk assessment
BMP	best management practice
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter(s)
cm/sec	centimeter(s) per second
COC	chemical of concern
CSF	cancer slope factor
CSM	conceptual site model
CTE	central tendency exposure
CY	cubic yards
DoD	Department of Defense
DMCF	dredged material containment facilities
ELCR	excess lifetime cancer risk
ENR	enhanced natural recovery
ENVIRON	ENVIRON International Corporation
FDA	Food and Drug Administration
FFDA	former facility disposal area
FS	feasibility study
ft/sec	feet per second
GADNR	Georgia Department of Natural Resources
GAEPD	Georgia Environmental Protection Division
GIS	geographic information system
GPS	global positioning systems
GRA	general response action
GRC	Georgia Regional Council
HHBRA	human health baseline risk assessment
HI	hazard index
HQ	hazard quotient
kW	kilowatt
LCP	LCP Chemicals of Georgia, Inc.
LiDAR	light detection and ranging
LOAEL	lowest observable adverse effect levels
MHHW	mean high high water
mg/kg	milligram(s) per kilogram

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$(mg/kg\text{-}day)^{-1}$	per milligrams per kilograms per day
MLLW	mean low low water
µg/L	microgram(s) per liter
MNR	monitored natural recovery
MSL	mean sea level
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
ng/L	nanogram(s) per liter
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observable adverse effects levels
NPV	net present value
NRWQC	National Recommended Water Quality Criteria
NTE	not-to-exceed
O&M	operations and maintenance
ODMDS	ocean dredged material disposal sites
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PRP	potentially responsible party
RM	river mile
PTI	PTI Environmental Services
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective
RfD	reference dose
RGO	remedial goal option
RI	remedial investigation
RME	reasonable maximum exposure
ROD	Record of Decision
SEC	sediment effect concentrations
SHEP	Savannah Harbor Expansion Project
SMA	sediment management areas
SWAC	surface-weighted average concentrations
TBC	to be considered
TIE	toxicity identification evaluation
TOC	total organic carbon
TRBE	Turtle River/Brunswick Estuary
TRV	toxicity reference value
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USDOE	United States Department of Energy
VOC	volatile organic compound
WQS	water quality standards

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1 Introduction

In 1995, Honeywell (formerly AlliedSignal, Inc.), the Atlantic Richfield Company, and the Georgia Power Company entered into an Administrative Order on Consent (AOC) (USEPA Docket No. 95-17-C) with the United States Environmental Protection Agency (USEPA) regarding the LCP Chemicals of Georgia, Inc. Site located in Brunswick, Georgia (the Site). Collectively, Honeywell, the Atlantic Richfield Company, and the Georgia Power Company are sometimes referred to as the potentially responsible parties or PRPs. This feasibility study (FS) report has been prepared by ENVIRON International Corporation (ENVIRON) and Anchor QEA in accordance with the requirements of the AOC. The Site is being managed as three operable units (OUs). The estuarine setting for the Site constitutes Operable Unit 1 (OU1) and is the focus of this FS. The other operable units include the upland soils at the Site (OU3) and the groundwater for the Site (OU2). This FS supersedes the March 29, 2013, draft FS, which was modified to address June 20, 2013, comments provided by USEPA and the Georgia Environmental Protection Division (GAEPD).

Building on historical information, human health and ecological risk assessments (EPS 2011a, Black and Veatch 2011), and information presented in the OU1 remedial investigation (RI) report (EPS and ENVIRON 2012), this FS relies on analyses of hydrological, ecological, and sediment conditions within OU1 to support the evaluation of potential remedial measures. Consistent with USEPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (1988), this report does the following:

- Identifies remedial action objectives (RAOs)
- Considers the range of available remediation technologies
- Evaluates technologies considered relevant to remediation of OU1 sediments
- Compares remediation alternatives against both Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and National Oil and Hazardous Substance Pollution Contingency Plan (NCP) criteria to evaluate remedy effectiveness
- Provides USEPA with the information needed to identify a preferred remedy

1.1 Objectives

The work embodied in the FS is based on the following two primary objectives:

- Identify and screen sediment remediation technologies that address the occurrence of elevated concentrations of chemicals of concern (COCs) in the Site surface sediments
- Evaluate viable remedial alternatives against the RAOs and against the NCP criteria

This FS focuses on remedial alternatives that manage the potential risks associated with the presence of elevated concentrations of COCs in OU1 sediments in a cost-effective manner while minimizing, to the extent practicable, the incidental impacts of remediation on the existing estuarine marsh/creek ecosystem. Screening and evaluation are conducted to ensure protection of human health and in accordance with criteria that weigh long-term risk reduction from the COCs against the risks of habitat/ecosystem harm from potential remedies.

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1.2 Report Organization

This introduction to the FS (Section 1) is followed by a summary of OU1 background information (Section 2). Section 3 identifies RAOs and remedial goals for OU1, and Section 4 presents a screening of available remedy technologies and process options. Site-specific remedy alternatives developed for OU1 sediments are presented in Section 5, and evaluations of the remedial alternatives using the criteria established by the NCP are provided in Section 6. Section 7 summarizes key findings and conclusions of the FS. References are provided in Section 8.

The FS also includes the following appendices:

- Appendix A presents the groundwater evaluation.
- Appendix B presents the surface water hydrologic evaluation and the hydrodynamic model.
- Appendix C provides aquatic organism life history information.
- Appendix D provides an analytical data summary for sediment investigations conducted in August and October of 2012.
- Appendix E describes how the data was assessed and includes the resolution of various data handling issues.
- Appendix F provides a graphical summary of contaminants in fish tissues over time, including fish collected and analyzed in 2011.
- Appendix G provides copies of correspondence between USEPA and the potentially responsible parties (PRPs) regarding development of site-specific remedial goal options (RGOs).
- Appendix H presents cost estimates for the remedy alternatives.
- Appendix I provides case studies that discuss the application, precedence, and effectiveness of thin-cover placement remedies.
- Appendix J presents preliminary chemical transport modeling used to evaluate the long-term performance of the chemical isolation caps.
- Appendix K describes the Thiessen polygon and surface-weighted average concentration (SWAC) calculation approaches employed for this FS and provides specific details regarding the delineation of sediment management areas (SMAs) presented in Section 5.
- Appendix L provides remedy effectiveness considerations.

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2 Site Background

This section provides an overview of Site information and historical Site operations (Section 2.1), geology and hydrogeology (Section 2.2), existing habitat conditions and associated wildlife (Section 2.3), and a summary of the RI (Section 2.4). The summary of the RI provides a delineation of chemicals in sediment and surface water and provides an overview of the human health baseline risk assessment (HHBRA; EPS 2011a) and the baseline ecological risk assessment (BERA; Black and Veatch 2011). All of this information serves to inform the conceptual site model (CSM) discussed in Section 2.5. The CSM is a narrative and pictorial communication tool that links sources of contamination, chemical migration pathways, human and ecological receptors, and pathways of exposure (USEPA 2005a). As these elements are closely tied to many of the attributes described in Sections 2.1 through 2.4, the CSM is a logical culmination of OU1 characterization. For example, consistent with USEPA (2002) guidance, sediment stability must be considered in the development of the CSM, since the stability of the sediment will influence the extent to which contaminants are remobilized, resulting in additional migration pathways, receptors, and exposure pathways.

2.1 Site Information and Historical Site Operations

This section includes details on the Site location, historical Site uses, and adjoining land uses. It provides a summary of the available Site information.

2.1.1 Site Area Description

The Site property is located in Glynn County, Georgia, immediately northwest of the city of Brunswick (Figure 2-1). The Site consists of approximately 760 acres of estuary (OU1) and 121 acres of upland area (OU3). The upland area is located east of the estuary and is where former plant operations took place.

OU1 consists of approximately 662 acres of flat, heavily vegetated marsh and approximately 98 acres of tidal creeks within the Turtle River/Brunswick Estuary (TRBE). The marsh elevation is low (approximately 2 to 3 feet (60 to 90 cm) above mean sea level (MSL)), and the numerous channels and creeks traversing the marsh are under tidal influence from the nearby Turtle River (EPS and ENVIRON 2012). As illustrated on Figure 2-1, the marsh is discussed in terms of four domains (Domain 1, Domain 2, Domain 3, and Domain 4).

- Domain 1 is bounded by the uplands to the east, LCP Ditch to the north, and Eastern Creek to the west. A marsh removal action conducted in 1998-1999 addressed sediments in the eastern portion of this domain. The western portion, adjacent to Eastern Creek, is referred to as Domain 1a.
- Domain 2 is bounded on the east by Eastern Creek, in the south by uplands not part of the LCP property, in the west by Purvis Creek, and north by Purvis Creek and LCP Ditch. Domain 2 surrounds Western Creek Complex.
- Domain 3 is bounded to the south by LCP Ditch, to the east by uplands, and to the west and north by Purvis Creek. Dillon Duck is the easternmost portion of Domain 3.

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- Domain 4 is the area west of Purvis Creek and is bounded to the southwest by Turtle River and northwest by uplands not part of the LCP property. Domain 4 is divided into eastern and western portions by the flow divide between creek and river.

Figure 2-1 also identifies the key features of the uplands portion of the Site east of the tidal marsh, which are described in detail in the OU1 RI (EPS and ENVIRON 2012). The eastern boundary of the uplands portion is at an elevation of approximately 15 feet (4.5 meters) above MSL and slopes gently to an elevation of 5 feet (1.5 meters) above MSL along the border with OU1. The east-west entrance road (B Street) divides this area of the Site roughly in half. Chlor-alkali process operations were conducted primarily in the former cell buildings south of B Street, the area of the boiler house north of B Street, and the smaller isolated waste disposal areas dispersed over the northern half of the Site. The area of the former chlor-alkali plant south of B Street is fenced in and covered with a soil cap (EPS and ENVIRON 2012).

A land disposal unit—the former facility disposal area (FFDA)—was located in the southern portion of the Site (Figure 2-1). The FFDA contained elevated concentrations of Site-related chemicals and spent graphite anodes (EPS and ENVIRON 2012).

Refinery operations were present over most of the upland areas until 1935, after which portions of the refinery footprint were demolished and sold for scrap; other portions were used for petroleum storage. Power generation facilities purchased by Georgia Power were located primarily north of B Street. Dixie Paint and Varnish Company operations were primarily south of B Street.

2.1.2 Facility Operating History

The Site was operated as a petroleum refinery from 1919 to the mid-1930s by the Atlantic Refining Company, a predecessor of the Atlantic Richfield Company. In 1922, oil replaced coal as the refinery fuel until 1935 when operations ceased. The Atlantic Richfield Company continued to use the Site for oil storage until 1955. Remnants of these operations exist at the Site including concrete storage tank supports and many buildings. During World War II, much of the steel was salvaged for scrap or moved to other locations (GAEPD 1990).

In 1937, 1942, and 1950, Georgia Power purchased portions of the Site, including two parcels of land and two 750 kilowatt (kW) electric generators, from Atlantic Refining. By 1941, Georgia Power increased the power generation capacity of the Site from 1,500 to 5,500 kW. The source of fuel for the power plant was Bunker C oil (GAEPD 1990).

From 1941 to 1951, the Dixie Paint and Varnish Company operated a paint and varnish manufacturing facility in an area south of the Georgia Power parcel. The Dixie Paint and Varnish Company became the Dixie O'Brien Corporation and eventually a wholly owned subsidiary of the O'Brien Corporation (GAEPD 1990).

In 1955, Allied Chemical and Dye Corporation (now Honeywell) acquired most of the land now referred to as the Site. They established a chlor-alkali facility at the Site producing chlorine gas, hydrogen gas, and caustic solution using the mercury cell process. This involves passing a concentrated brine solution between a stationary graphite or metal anode and a flowing mercury

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cathode. A second reaction is used to produce sodium hypochlorite (bleach) (EPS and ENVIRON 2012).

In 1979 the property, including the chlor-alkali plant, was purchased by LCP, a division of the Hanlin Group. At this time, some modifications were implemented at the chlor-alkali facility. These included the production of hydrochloric acid by reacting chlorine and hydrogen. Operations terminated in 1994 when LCP shutdown the plant (EPS and ENVIRON 2012). Honeywell re-purchased the property again in 1998. Portions of the property are still owned by Honeywell, although parcels have been sold to the County and to Georgia-Pacific Cellulose. Georgia Power also owns a parcel in the northern portion of the Site. Presently, the Honeywell portion of Site is mostly vacant, though it contains several building remnants. On the county portion, construction of a sheriff's complex is underway.

2.1.3 Land Use

Predominantly industrial and commercial properties surround the Site. A county land disposal facility and a pistol firing range border the Site to the north (Figure 2-1). A tidal marsh and the Turtle River lie to the west, and the Georgia-Pacific Cellulose facility is to the south. Commercial property borders the Site to the east.

The area is designated for industrial use according to the Glynn County Planning Commission Land Use Maps. These maps zone the following three areas as "Basic Industrial":

- "Useable" areas of the Site
- Tidal marsh/creek from the eastern bank of Purvis Creek
- Georgia-Pacific Cellulose site

The former Standard Industrial Classification code for the property when last operated by LCP is 2812 (Chemical and Allied Products, Alkalis and Chlorine), which falls within the GAEPD regulatory definition of nonresidential property (391-3-19-02(2)(i)).

2.2 Geology and Hydrology

This section presents the groundwater CSM by describing the Site's hydrogeological setting (Section 2.2.1) and details the groundwater flow into the estuary (Section 2.2.2). It also presents the surface water and sediment transport CSM, describing surface water hydrology (Section 2.2.3) and sediment transport processes (Section 2.2.4) in the estuary. The section closes with an overview of Site surface water uses (Section 2.2.5), including vessel traffic and maintenance dredging activities in the vicinity of the Site.

2.2.1 Hydrogeology

The hydrogeologic CSM is presented in Figure 2-2, adapted from the 1997 RI report (Geosyntec 1997). The figure illustrates the Site stratigraphy and identifies hydraulic conductivities for each of the hydrogeologic units underlying the Site. The Site is underlain by the Satilla Formation, which is Holocene to Pleistocene in age. Beneath the Satilla Formation are the Coosawhatchie Formation and the Berryville Clay Formation, which forms the regional confining layer.

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The Satilla Formation is approximately 55 feet (17 meters) thick in the vicinity of the Site and is divided into two general layers. The upper Satilla sand is the local aquifer and extends to a depth of approximately 45 feet (14 meters). The lower Satilla sand is approximately 10 feet (3 meters) thick and, in the vicinity of the marsh and upland areas of the Site, is variable in texture ranging from sand to dense clayey sand (Geosyntec 1997).

In areas to the west of the Site, marsh sediments overlie the Satilla Formation and provide semiconfined conditions locally for groundwater flow, having a median hydraulic conductivity on the order of 10^{-7} centimeters per second (cm/sec). Marsh sediments in the vicinity of the Site are typically 7 to 8 feet (2.1 to 2.5 meters) thick, though locally they may be thicker, and near the upland areas they may be thinner. The upper Satilla sand is composed of uniform very fine to medium sand with thin, discontinuous layers of clay. The thin clay layers result in an anisotropic hydraulic conductivity for the formation where the vertical permeability of the unit is significantly lower than the horizontal permeability. Slug tests conducted in the upper and lower Satilla sand indicate a horizontal hydraulic conductivity on the order of 10^{-2} cm/sec. The upper Satilla sand primarily discharges to Purvis Creek, which ultimately discharges to Turtle River; some seep discharges also occur, allowing direct discharge into the marsh (which is discussed further in Section 2.2.2). The water in the Satilla Formation at the Site is nonpotable due to naturally occurring high dissolved mineral content.

The Coosawhatchie Formation is Miocene in age and is approximately 180 feet (55 meters) thick. It can be divided roughly into two water-bearing units and two confining layers. The uppermost layer of the Coosawhatchie is approximately 3 to 15 feet (1 to 4.5 meters) of partially cemented sandstone, which acts as a semi-confining layer between the Satilla sand and the Coosawhatchie A/B aquifers (Figure 2-2). The cemented sandstone has an approximate hydraulic conductivity of 10^{-5} cm/sec. The Coosawhatchie A/ B aquifers are approximately 50 feet (15 meters) thick and have an approximate hydraulic conductivity of 10^{-2} cm/sec. The Coosawhatchie C consists of an approximately 30-foot (9-meter)-thick dolomitic marlstone and acts as a confining layer between the Coosawhatchie A/B aquifers and the Coosawhatchie D aquifer.

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The Coosawhatchie D aquifer is approximately 50 feet (15 meters) thick and is composed of variably cemented sandstone. It is the main water-bearing unit in the “rock aquifer” in the vicinity, and many of the potable residential wells in the Brunswick and the Blythe Island areas of Glynn County are completed in this unit.

The Coosawhatchie Formation is underlain by the Berryville Clay, an approximately 80-foot (24-meter)-thick clay layer that forms a regional confining unit. This clay layer separates the surficial water-bearing units from the deeper Brunswick Aquifer and Floridan Aquifer.

2.2.2 Local Groundwater Flow to the Estuary

Local groundwater flows from the uplands into the marsh along four general types of flow paths (Figure 2-3). COCs that are transported along each flow path encounter a sequence of geochemical conditions that affect the fate of the COCs as they are transported and before entering the marsh.

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Shallow groundwater in the Satilla Aquifer, down to the variably cemented sandstone, migrates towards the marsh, approximately perpendicular to the marsh boundary. Groundwater migrating to the marsh from upland areas must cross a vertical plane parallel to the marsh boundary. The groundwater COC contribution across this vertical plane flows through four groundwater pathways as follows from longest to shortest:

- Flow Path to Purvis Creek and Beyond (Flow Path 1): The longest flow path is from upland areas to Purvis Creek and beyond. This path is dominated by water that begins near the bottom of the Satilla sand aquifer at the marsh boundary and is transported more than 1,000 feet (305 meters) within the Satilla sand. The groundwater enters the marsh sediments from below, and discharge may occur as diffuse flow through the marsh sediments or through focused seeps that emanate in Purvis Creek.
- Flow Path to Marsh Flats and Intertidal Channels (Flow Path 2): This flow path begins with groundwater at depth along the marsh boundary. The groundwater is transported within the aquifer and enters the marsh sediments from below. Discharge may diffuse through the marsh sediments or release in focused seeps.
- Flow Path to Restored Marsh Area (Flow Path 3): This flow path begins at shallow depths along the marsh boundary. Groundwater is transported less than 500 feet (152 meters) within the aquifer from upland areas. The groundwater then enters the marsh sediments from below, and discharge diffuses through the marsh sediments or releases in focused seeps.
- Flow Path to Nearshore Seeps (Flow Path 4): The shortest flow path between upland groundwater and the marsh leads to nearshore seeps, such as those that have been identified and sampled by lysimeters. This transport flow path is dominated by the shallowest groundwater in the aquifer along the marsh boundary. The groundwater may be expressed at the surface after intense rainfall events. The distance of transport within the aquifer is short, and the discharge to the surface may be in an area where the marsh sediment layer is thinnest.

All flow paths encompass lithologic and biogeochemical zones that affect the fate of the COCs being transported. The major differences between the flow paths are related to the residence time of the groundwater in the various lithologic and biogeochemical zones. Along each flow path, the zones encountered include the following:

- The aquifer
- The marsh sediments below the root zone
- The marsh sediments within the root zone

The flow paths described above suggest discrete horizontal paths; however, the presence of seeps indicates upward components to groundwater flow in the marsh (Figure 2-3). Upon discharge to the surface, direct mixing with tidal surface water occurs. The more focused the discharge (i.e., as a seep), the higher the potential for elevated COC concentrations, but also the greater the influence of surface water dilution at the point of discharge to surface water and the smaller the area of marsh that is impacted by groundwater flow. Conversely, diffuse

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discharges upwelling through the sediment bed are subject to more attenuation within the sediments resulting in lower potential COC concentrations at the point of discharge. Like focused discharges, diffuse discharges are subject to dilution at the point of discharge to surface water.

In the OU1 RI (EPS and ENVIRON 2012), a transect analysis method was used to evaluate the potential for the groundwater transport of COCs to recontaminate the marsh sediments. In May 2012, the upland wells along the plume transect were resampled. Supplemental groundwater wells were installed and sampled to update the transect analysis. The updated groundwater transport analysis indicates that the potential for the groundwater transport of COCs to recontaminate sediment is minimal and insignificant (Appendix A). Therefore, a decision regarding potential groundwater remediation is not necessary prior to selecting and implementing sediment remedial actions.

2.2.3 Estuary Hydrology

The Site consists of an interconnected complex of tidal creeks and vegetated marshes, with an aerial extent of approximately 760 acres, which is part of the saltwater TRBE that flows eastward into St. Simons Sound. Purvis Creek is the primary tidal channel connecting the Site to the Turtle River, and the creek divides the marsh areas within the Site approximately in half (Figure 2-1). Several secondary channels (i.e., Eastern Creek, the Western Creek Complex, LCP Ditch, Domain 3 Creek) are directly or indirectly connected to Purvis Creek. Numerous small channels provide hydraulic connections between the primary/secondary tidal channels and the intertidal marsh areas. No significant freshwater tributaries flow into the Site.

Tidal hydrodynamics have a significant effect on the transport of waterborne substances (e.g., suspended sediment, chemicals) within the Site. A preliminary modeling study evaluated estuarine hydrodynamic processes within the Site (Appendix B). The model predicted a typical tidal range of about 7 to 8 feet (2 to 2.5 meters), which produces strong vertical mixing in the water column and a relatively long horizontal excursion of water. Density-driven circulation is minimal because there are no significant freshwater inflows to the Site estuary.

Figure 2-4 shows the CSM for surface water hydrology at the Site. Water flows from the Turtle River into Purvis Creek during flood tide and is then conveyed to intertidal marsh through the system of secondary creeks and smaller channels. Tidal flows are mostly confined to the creeks and smaller channels at the beginning of flood tide. Current velocities are relatively high within the tidal creeks during flood tide. Water flows into the marsh once the tidal elevation reaches the bank elevation. The elevation of the marsh is about 2 to 3 feet (0.6 to 1 meter) above MSL. Thus, the marsh is only inundated with water during high tide. Current velocities are relatively low within the marsh area due to increased storage area and high drag induced by plants.

As the maximum tidal elevation is reached at high tide, current velocities are very low throughout the estuary during slack water conditions. During ebb tides, water drains from the marsh into the tidal channels and creeks and eventually back to the Turtle River. During this ebbing stage, the current velocities are relatively high in the creeks.

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The relatively large tidal range within the Site causes a nearly complete exchange of water between the marsh areas and the creeks during each tidal cycle (i.e., marsh areas are filled and drained during one tidal cycle). Dense vegetation has a significant effect on hydrodynamics in the marsh, with relatively low current velocities in those areas.

Historical development within the Site altered marsh drainage patterns, which likely affected local tidal hydrodynamics. These alterations include the construction of causeways and landfills and the marsh removal action during 1998 and 1999. The marsh removal action included backfill to pre-excavation elevations and replanting, so hydrologic changes were temporary. Construction of the causeway, which runs parallel to the northern bank of LCP Ditch, permanently separated the northern and southern marshes; the only surface-water connection between these two areas is now Purvis Creek. These major alterations occurred more than 10 years ago, and the Site is currently assumed to be in a state of geomorphologic equilibrium.

2.2.4 Estuary Sediment Transport Processes

Tidal circulation and rare storm events control sediment transport processes within the Site (Appendix B). Because no tributaries flow directly into the estuary, the dominant source of suspended sediment to the estuary is the Turtle River. Sediment beds in southeastern tidal creek wetlands, like OU1, are composed predominantly of cohesive sediment. The fine-grained particle size distribution of the sediment, which is dominated by silts and clays, supports this characterization. Sediment erosion is likely to occur in some portions of the tidal creeks during spring tide conditions because peak current velocities are high enough (i.e., about 2 feet per second (ft/sec)) to exceed the critical shear stress of surface sediments (generally about 0.1 to 0.5 Pascals). However, bed scour is expected to be minimal, likely 0.04 to 0.08 inches (1 to 2 millimeters) because of bed armoring processes in the cohesive sediment bed. Deeper bed scour may occur in some localized areas of the creek channels during rare storms (e.g., hurricane storm surge).

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Suspended sediment transport is the primary mechanism for sediment movement within the estuary. The transport of suspended sediment particles is controlled by tidal hydrodynamics, which will cause movement of suspended sediment between the marsh areas and creek channels. The intertidal vegetated marshes are a net depositional zone for suspended sediments due to the low current velocities and presence of vegetation within those areas. “Net depositional” means that particles are more likely to settle than to scour from the area. It does not describe the depositional rate.

The characterization of the marsh as net depositional is supported by the hydrodynamic model (Appendix B) which characterizes the vegetated marsh areas as having relatively low velocities and low scour potential. Sediment deposition occurs in the marsh during flood tide and slack water before ebb tide; sediment is not remobilized by tidal currents after initial deposition in the marsh because most flow conveyance occurs in the channels and not on the vegetated marsh areas.

The modeling results show that flood- and ebb-tide velocities in the marsh are too low to substantially scour surface sediment, especially in areas where vegetation further buffers velocities and their corresponding sediment bed shear forces. Despite being characterized as

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net depositional, the rate of deposition is slow, primarily because most natural upland sediment sources have been hydrologically cutoff, leaving transport into the estuary from offshore as the primary source of natural sedimentation.

Consistent with observations in similar saltwater vegetated marshes (Stumpf 1983, Wang et al. 1993, Leonard et al. 1995), higher sedimentation rates are expected along channel banks in the marshes. Various physical processes influence the spatial distribution of net sedimentation rates within the marsh areas, including tidal elevation, current velocity, sediment supply, and vegetation characteristics (i.e., species, biomass, plant density, and height).

2.2.5 Site Uses: Vessel Traffic Patterns, Maintenance Dredging History

Recreational and navigational use of OU1 is infrequent due to the difficulty in navigating small crafts; the effects of remedial actions on those types of uses do not need to be evaluated. However, there are residences on the north end of OU1 that have deep water access to Purvis Creek. Remedial actions within or immediately adjacent Purvis Creek could require temporary access restrictions during remedy implementation for non-project personnel/watercraft.

Information on waterway traffic was obtained from the Port of Brunswick, the US Army Corps of Engineers (USACE), and correspondence with other marine service providers. Two private recreational marinas are located on the Turtle River. Most recreational boat passage in the Turtle River is due to access to or from St. Simons Sound. The primary route of large commercial vessel traffic is from the Atlantic Ocean to the Port of Brunswick, which is located about five miles downstream of the Site. Occasional commercial ship traffic that passes by the Site in the Turtle River consists of oil barges in transit to other industrial uses upstream. Large recreational boats cannot enter the Site due to the narrow, shallow tidal creeks. Small recreational boats (i.e., less than about 14 feet (4 meters) long) can access the Site during high tide.

No active maintenance dredging has occurred to create and maintain a navigational channel in the Site. Maintenance dredging has been limited to the navigation channel from the upper limits of the Brunswick Harbor at river mile (RM) 12.76 in the Turtle River to the entrance of St. Simons Sound; the navigation channel dimensions are maintained at a depth of 30 feet (9 meters) and width of 400 feet (122 meters).

2.3 Existing Habitat Conditions and Associated Wildlife

This section presents information on the habitat and ecology of the Site. It includes an overview of biological characteristics of the marsh and its associated wildlife (Section 2.3.1) with detailed discussions of invertebrate, fish, bird, and mammal communities. Estuary habitat characteristics are described in Section 2.3.2, followed by a discussion of marsh dieback (2.3.3), a phenomenon prevalent in the southeast that affects marsh plant growth cycles. This section closes with an overview of the past remediation and ecological restoration efforts performed in 1998-1999 in Domain 1 (Section 2.3.4).

2.3.1 OU1 and Associated Wildlife

The Site is a tidal estuary that comprises approximately 4 percent (%) of the TRBE (Figure 2-5 and Table 2-1). Approximately 13% of the Site is composed of tidal creeks, with approximately

87% of the marsh composed of indigenous marsh grasses, predominantly smooth cordgrass (*Spartina alterniflora*).

OU1 is comprised of a plant community of *S. alterniflora* and occasional patches of black needle rush (*Juncus roemerianus*) (Figure 2-6; Photos A, B, C, D, E, F, G, H, J, K, M, N, O and P). The productivity of the marsh is especially apparent in areas adjacent to Eastern Creek and LCP Ditch (Figure 2-6; Photos A, B, D, M and N) and Domain 1 and 2 (Figure 2-6; Photos C, D, E and F). *S. alterniflora* is prevalent in the low marsh with plant diversity increasing towards the upland area such as the Dillon Duck area (Figure 2-6; Photos I and J).

Benthic, Epibenthic, and Epiphytic Community Structure

The benthic salt marsh invertebrate community at the Site includes those organisms that live in the sediment of the marsh (benthic infauna) and on top of the sediment (epibenthic fauna). It also includes those organisms that live on the plants of the marsh (epiphytic fauna). Tidal influences and inundation are key factors that govern community structure and function in the marsh system. Site-specific surveys and studies (Black and Veatch 2011, Horne et al. 1999, Wall et al. 2001) have described the critical components of the invertebrate community as follows:

- Fiddler crabs are ubiquitous in salt marshes. Three species of fiddler crabs inhabit the Site: *Uca minax, U. pugilator,* and *U. pugnax.* These crabs appear to have a mutually beneficial interaction with marsh vegetation. Crab burrows increase plant production by moderating soil conditions, and in turn, marsh plants facilitate crab burrows by stabilizing the substrate (Norman and Pennings 1998).
- Grass shrimp (*Palaemonetes pugio*) are a major source of food for crabs and fish and facilitate nutrient cycling.
- Other invertebrates including infaunal, epifaunal, and epiphytic organisms are present at the Site. The benthic community is composed of barnacles, mysids (*Mysidopsis bahia*), penaeid shrimp, ribbed mussel (*Geukensia demissa*), marsh periwinkle (*Littorina irrorata*), mud snail (*Illynassa obsolete*), eastern oyster (*Crassostrea virginica*), blue crab (*Callinectes sapidus*), oligochaetes, polychaetes, and amphipods.

Appendix C provides life history information for several of the classes of benthic invertebrates that live in the estuary and form the base of the food web. The information in this appendix identifies the habitats in which the organisms reside, their lifespans, the movement within an estuary (e.g., burrowing versus free swimming), dietary preferences, foraging patterns within the marsh environment, and the organisms which prey upon them. This information forms the basis for understanding the CSM for COC transport discussed in Section 2.5.

Fish Community

Fish inhabit the LCP creek/marsh system, generally entering into the marsh area with incoming tides. Fish indigenous to the estuary include the mummichog (*Fundulus heteroclitus*), red drum (*Sciaenops ocellatus*), black drum (*Pogonias cromis*), silver perch (*Bairdiella chrysoura*), spotted seatrout (*Cynoscion nebulosus*), striped mullet (*Mugil cephalus*), Atlantic croaker (*Micropogonias undulates*), southern kingfish (*Menticirrhus americanus*), spot (*Leiostomus

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xanthurus), and sheepshead (*Archosargus probatocephalus*) (Black and Veatch 2011). Smaller fish, like mummichog, do not migrate and are a key component of the food web. Many other fish species migrate from the Site to nearby areas. Appendix C provides life history information for the key fish species that live in the estuary and were considered in the HHBRA and the BERA. This appendix identifies the habitats, lifespans, movement, dietary preferences, and foraging patterns for each of the fish life stages. Similar to the sediment-dwelling organisms, this information also is an important component of the CSM for COC transport discussed further in Section 2.5.

Bird Community

Birds indigenous to the estuary include grebes, cormorants, herons, bitterns, ibises, geese, marsh ducks, mergansers, vultures, hawks, ospreys, falcons, rails (including the clapper rail (*Rallus longirostris*)), stilts, plovers, sandpipers, gulls, terns, pelicans, skimmers, kingfishers, and songbirds. The wood stork (*Mycteria americana*), an endangered species, has been observed foraging in tidal creeks of the salt marsh and breeding at several colonies in the vicinity of Brunswick. The upland bird fauna is likely to consist mostly of species adapted to abandoned industrial sites, but may also include hawks that forage in the grassy areas of the upland (USDOI 1995).

Mammal Community

Despite highly variable environmental conditions in salt marshes (related to tidal inundation and salinity), mammals use the marsh and surrounding habitats for food and shelter. At the Site, resident mammal species likely include shrews, bats, raccoon (*Procyon lotor*), mink (*Neovison vison*), river otter (*Lutra canadensis*), marsh rice rat (*Oryzomys palustris*), and marsh rabbit (*Sylvilagus palustris*). The West Indian manatee (*Trichechus manatus*) and the Atlantic bottle-nosed dolphin (*Tursiops truncatus*), both of which are protected under the Marine Mammal Protection Act, have been observed in Purvis Creek. Resident upland mammals that likely inhabit the margins of the marsh include raccoons, various shrews and rodents, Eastern cottontails (*Sylvilagus floridanus*), opossums (*Didelphis marsupialis*), and nine-banded armadillos (*Dasypus novemcinctus*) (USDOI 1995).

Reptile Community

The most common reptile in Atlantic coast salt marshes is the diamondback terrapin (*Malaclemys terrapin*). Several species of threatened or endangered Atlantic sea turtles, including the green turtle (*Chelonia mydas*), Kemp's ridley turtle (*Lepidochelys kempi*), hawksbill turtle (*Eretmochelys imbricata*), loggerhead turtle (*Caretta caretta*), and leatherback turtle (*Dermochelys coriacea*) may visit the estuary, but there is no historical record of occurrence or nesting (Black and Veatch 2011).

2.3.2 Estuary Aquatic Habitat Characteristics

As described in Section 2.2.3, the marsh is only inundated during high tide, which governs how aquatic wildlife use the OU1 estuary. Fish and shellfish predominantly reside in the creeks and make use of the marsh areas only during high tide conditions when the marsh is inundated. Appendix C provides information on wildlife movement patterns relative to the tidal cycle.

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The use of different areas of the marsh by aquatic organisms (e.g., fish, shellfish, grass shrimp) depends on the proportion of time that each area is inundated. The location and duration of inundation depends on bank elevation, which is variable and is illustrated using light detecting and ranging (LiDAR) mapping of mean high high water (MHHW) and mean low low water (MLLW) (Figures 2-7 and 2-8).

During MLLW, vegetated marsh areas and creeks are predominantly exposed; water is present only in portions of the creeks. Figure 2-6 (Photos K, L, M, N, O, and P) shows various locations within OU1 at low and high tide, respectively. Exposed marsh areas are used by nonaquatic organisms such as fiddler crabs, which emerge from their burrows to forage on organic carbon and algae (Figure 2-6; Photo Q). The LiDAR data, along with field observations, and hydrologic estimations were used to characterize the inundation cycle.

Based on the model and an understanding of tidal fluctuations, flooding in the marsh may only be inundated 5% to 20% of the time, which equates to approximately 1 to 4 hours a day, depending on the elevation at any particular point (Table 2-2). This is particularly relevant in understanding the types of ecological exposures that occur for wildlife in the marsh, as aquatic organisms readily move in and out of the marsh with the ebb and flood tides.

2.3.3 Marsh Dieback

Although the majority of the Site has high plant productivity, there are some areas where *Spartina* growth is sparse and this is considered a characteristic of marsh dieback that is afflicting marshes in Georgia and South Carolina. From 2001 to 2002, Georgia and parts of South Carolina experienced a widespread coastal marsh dieback event in which approximately 2,000 acres of marsh were adversely affected. Symptoms of dieback included color change and complete rhizome failure in affected plants (Hurley n.d, Mackinnon 2006). Onset was rapid (one to two growing seasons), but growth impacts were transitory, as indicated in a 2003 study by Ogburn and Alber (2006), which found no significant difference in growth in transplanted *Spartina* between vegetated marshes with and without dieback. However, rhizomes from dieback marshes could not be resprouted when transplanted from affected areas and watered (Mackinnon and Huntington 2005).

To date, no definitive cause of the marsh dieback has been determined (Mackinnon and Huntington 2005). Georgia Regional Council (GRC) continues to monitor eight sites (with and without dieback) quarterly for biological, physical, and chemical parameters (Mackinnon and Huntington 2005). Although plant densities have increased in dieback areas (Mackinnon and Huntington 2005, Alber 2008), new areas of dieback were reported in both Georgia and South Carolina in 2007. One of the GRC's monitoring stations is near the Site, and areas both within and outside the Site were observed to be impacted by the dieback during a January 2012 Site visit (Figure 2-6; Photo R).

2.3.4 1998–1999 Remediation, Restoration, and Recovery in Domain 1

Thirteen acres of the Site in Domain 1 were remediated in 1998 and 1999 (Figure 2-9). The Domain 1 marsh area was excavated and subsequently backfilled with clean sediment to restore the area to preremoval elevations that were within the range for *Spartina* regrowth. In

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addition, dredging was also performed along a portion of the Eastern Creek and in select portions of the LCP Ditch (2,650 linear feet (808 meters)).

Prior to remediation, a temporary sheet pile wall was erected to isolate the area. *Spartina* sprigs were planted in the remediated area three to five days after the temporary piling wall was removed to ensure that tidal fluctuations were well established over the area to aid in regrowth (Figure 2-10; Photo A). As a result of the temporary sheet pile wall, the portion of Eastern Creek located near the southern end of the remediated area adjusted its course. In addition, tidal tributaries to Eastern Creek that extended landward were shortened. These modified natural features and the footprint of the marsh removal are visible in aerial photographs (Figure 2-10; Photo B).

Case studies indicate that salt marshes can become revegetated within 2 to 15 years depending on the elevation and tidal regime (Minello n.d.; Able et al. 2008; Broome et al. 1986, 1988; Webb and Newling 1985; Woodhouse et al. 1976; Leonard et al. 2002; LaSalle et al. 1992; Edwards and Proffitt 2003; Craft et al. 2002, 2003). Within two years after remediation, *Spartina* filled the remediated area of the Site (Figure 2-10; Photo C). After three to four years, the area was visually indistinguishable from the surrounding marsh (Figure 2-6; Photos E and F). These site-specific restoration time frames are consistent with the other observations noted for created salt marsh sites.

Other recovery metrics include the amount of total organic carbon (TOC) in sediment and nitrogen recycling, both of which can take from 5 to more than 10 years to fully recover. This delay relative to *Spartina* regrowth is evident at the remediated area at the Site, as TOC is low (below 2.5%) compared to other areas of the marsh (Figure 2-11). The percent of fine materials in the sediment of the remediated area is also low relative to other areas of the marsh (Figure 2-12); percent fines influence the benthic community habitat.

2.4 Summary of Remedial Investigation Results

This section summarizes the results of prior environmental investigations related to the following:

- Characterization of chemicals in sediment and surface water
- Evaluation of potential human health risks
- Evaluation of potential risks to ecological receptors

This summary focuses on the four COCs addressed in the BERA (Black and Veatch 2011): mercury, Aroclor 1268, lead, and total polycyclic aromatic hydrocarbons (PAHs).

The HHBRA (EPS 2011a) and BERA (Black and Veatch 2011) estimated current risks to human and ecological receptors in the absence of remediation (i.e., baseline). Typically, baseline risks are evaluated to determine the need for remedial action. Risk assessment is a framework that uses information about the toxicity of COCs to estimate a theoretical probability of adverse health effects in humans and ecological receptors potentially exposed to site-related chemicals. This process determines whether concentrations of chemicals in environmental media (i.e., soil, water, sediment, biological tissue) pose an unacceptable risk as defined by threshold

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benchmarks or site-specific studies. When reviewing the results of any risk assessment, it is important to recognize that the risk estimates are intended to facilitate those determinations but are not necessarily predictive of adverse health effects for any person or ecological receptors.

2.4.1 OU1 – Characterization of Chemicals in Sediment and Surface Water

Chemicals in sediment were delineated by USEPA in 1995, Geosyntec in 1995-1999, PTI Environmental Services (PTI) in 1996, the National Oceanic and Atmospheric Administration (NOAA) in 1997, and CDR Environmental in 2000-2007. ENVIRON and Anchor QEA conducted additional surface sediment investigations in August and October 2012 as part of developing this FS. The August and October 2012 sampling events were conducted in accordance with the approved *Sediment Investigation Work Plan* and the *Sediment Investigation Work Plan Addendum* (ENVIRON and Anchor QEA 2012a, 2012b). The 2012 sampling locations, analytical data, laboratory reports, and data validation reports are provided in Appendix D.

Results from these investigations were used to delineate sediment concentrations of the four COCs: mercury, Aroclor 1268, lead, and total PAHs. Data handling methods and decisions regarding data usage are described in Appendix E. Appendix E identifies the general and specific data processing issues. Appendix E also identifies the final actions completed at the LCP Site database with regard to the data management decisions that were identified during the FS process. This section summarizes COC concentrations in the surface and subsurface sediments for investigations from 1995 through 2012.

Surface Sediment COC Concentrations

To be consistent with the BERA sampling, surface sediment samples are defined as samples with a starting depth at the sediment surface and collected from the interval of 0 to 6 inches (0-15 cm) or 0 to 1 foot (0-30 cm) below the sediment surface; the 0 to 1 foot (0-30 cm) interval was used when 6-inch intervals were unavailable. Sample handling for multiple samples collected over space and time are discussed in Appendix E. This appendix also addresses data handling for resampled locations and for those samples with elevated detection limits. Figures 2-13 through 2-17 present the distribution of OU1 surface sediment concentrations for mercury, methylmercury, Aroclor 1268, lead, and total PAHs, respectively. Where neighboring data points overlap in Figures 2-13 through 2-17, the mapping algorithm was programmed so that samples with higher concentrations always overlay samples with lower concentrations. This approach prevents lower-concentration sample locations from obscuring the presence of higher-concentration sample locations.

Mercury in Surface Sediment

Average surface sediment mercury concentrations in OU1 are shown in Figure 2-13. Mercury concentrations greater than 10 milligrams per kilogram (mg/kg) in surface sediment are typically present in Eastern Creek and LCP Ditch. Higher concentrations are found in portions of Eastern Creek and LCP Ditch where limited or no sediment removal was conducted during the remediation of Domain 1 in 1998-1999. Mercury concentrations greater than 10 mg/kg also are observed in surface samples collected from the marsh, near the boundary of Eastern Creek and LCP Ditch. Concentrations of mercury in surface sediment are lower throughout the rest of the estuary, and typically range from 1 to 5 mg/kg, except for isolated areas in the Western Creek

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Complex and Domain 3 Creek. Mercury concentrations are even lower in Domain 4 West which is located west of a tidal divide between Turtle River and Purvis Creek.

Methylmercury in Surface Sediment

Concentrations of methylmercury in surface sediment OU1 are shown in Figure 2-14. Methylmercury concentrations in sediment ranged from below detection to 0.11 mg/kg, with a mean concentration of 0.008 mg/kg. No distinctive relationship is evident with regard to the concentrations of methylmercury in the creek versus marsh areas.

Aroclor 1268 in Surface Sediment

Average concentrations of Aroclor 1268 in surface sediment exhibit a spatial pattern generally consistent with that of mercury, with the highest sediment concentrations observed in LCP Ditch and Eastern Creek (Figure 2-15). Concentrations of Aroclor 1268 in surface sediment in these areas are generally greater than 10 mg/kg. Similar to mercury, Aroclor 1268 concentrations are lowest in the vegetated marsh areas and in Domain 4 West.

Lead in Surface Sediment

Lead concentration in surface sediment is elevated in the Dillon Duck feature, the nearby Domain 3 Creek, and isolated portions of Domain 2 (Figure 2-16). Elevated concentrations of lead in these areas are greater than 100 mg/kg with one location exceeding 1,000 mg/kg in Domain 3 Creek. Concentrations of lead in surface sediment are generally less than 50 mg/kg in other areas of OU1, except for isolated areas in Domain 4 East, Eastern Creek, and Western Creek Complex with concentrations greater than 50 mg/kg.

Total PAHs in Surface Sediment

Concentrations of total PAHs in surface sediment were calculated by summing the concentrations of the 18 individual PAHs[1] analyzed during the RI sediment sampling.

Figure 2-17 shows the distribution of total PAHs in surface sediment. In general, concentrations of total PAHs in surface sediment are less than 5 mg/kg in the majority of the marsh and tidal channels. Concentrations greater than 10 mg/kg are located in isolated locations of LCP Ditch, Domain 3 Creek, Eastern Creek, and the westernmost segment of the Western Creek Complex (headwater portion of the channel).

COC Concentrations in Subsurface Sediment

As part of the 1994 and 1996 sampling investigations, PTI evaluated the vertical distribution of mercury, Aroclor 1268, lead, and total PAHs in the upper few feet of marsh sediment. Cores were collected from Domain 1, Domain 2, Domain 3, Purvis Creek, and LCP Ditch. As described above, cores analyzed for mercury and Aroclor 1268 indicated that higher concentrations were typically observed in the 0 to 0.8-foot (0 to 24-cm) interval and lower concentrations approaching non-detect were below 0.8 feet (24 cm) (0.8 to 1.2 feet (24 to 37 cm) and 0.8 to 1.6 feet (24 to 50 cm)). In these same intervals, cores analyzed for lead and total PAHs typically contained concentrations below 40 mg/kg and 4 mg/kg, respectively.

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[1] Total PAH compounds are listed in Appendix D.

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Additional depth profiling was performed as part of the marsh exploration sampling in 1997. During this investigation, cores were collected to depths of 8 feet (2.4 meters) in the Domain 1 remediation area. At depths greater than 1 foot (30 cm), Aroclor 1268 concentrations were typically non-detect and mercury concentrations were below 10 mg/kg, except for core locations directly adjacent to LCP Ditch and the FFDA. However, as noted in the OU1 RI, four cores had detections of Aroclor 1268 deeper than 1 foot below the estuary bed surface. While lead vertical profiles were confined to a depth of 3 feet (~ 1 meter), at depths greater than 1 foot (30 cm), concentrations of lead were less than 50 mg/kg. Cores from this investigation were not analyzed for total PAHs. Vertical profiles are shown in the OU1 RI report (EPS and ENVIRON 2012).

COC Concentrations in Surface Water

Surface water concentrations for dissolved total mercury and dissolved methylmercury are summarized and compared to the USEPA (2013a) National Recommended Water Quality Criteria (NRWQC) and GAEPD (2013) Water Quality Standards (WQS) on Figure 2-18. Dissolved total mercury and dissolved methylmercury do not exceed the NRWQC of 940 nanograms per liter (ng/L); notably, both also are below the GAEPD WQS of 25 ng/L. The USEPA NRWQC identifies that dissolved-phase data (total mercury or methylmercury) are the appropriate values for comparison to NRWQC, when available. The GAEPD WQS do not state that dissolved-phase data are the appropriate values for comparison but rather compare to total-phase data.

Total mercury concentrations for unfiltered surface water are compared to the GAEPD WQS in Figure 2-19. Some detections of total mercury exceed the GAEPD WQS, including at least one detected concentration from Troup Creek, a reference location. None of the detected concentrations exceed the NRWQC.

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The mercury NRWQC of 940 ng/L is more than an order of magnitude greater than the GAEPD WQS of 25 ng/L. The mercury NRWQC value was derived using the 1995 Great Lakes Initiative Guidelines which was designed to “provide adequate protection to human health and wildlife.” The GAEPD WQS is based on the pre-1995 mercury federal water quality criterion using “Final Residue Value” approach and a bioconcentration factor obtained from a 1974 bioaccumulation study on oysters (Kopfler 1974, as cited in USEPA 1985).

Concentrations of Aroclor 1268 in surface water are compared to the NRWQC and GAEPD WQS for polychlorinated biphenyls (PCBs; Table 2-3). The NRWQC and Georgia WQS use the same value for PCBs of 0.03 micrograms per liter (µg/L). The majority of surface water PCB data to date are non-detected values, and in numerous cases, the detection limits exceed the NRWQC and the GAEPD WQS. In 2006 and 2007, lower detection limits were achieved and some areas showed detections above the NRWQC and GAEPD WQS.

COC Concentrations in Fish and Shellfish Tissue

Concentrations of COCs in edible fish tissue data were summarized in Table 3 of the HHBRA (EPS 2011a). The HHBRA considered fish and shellfish tissue data for the chemicals detected in finfish and shellfish collected from Purvis Creek and the Turtle River adjacent to the Site (EPS 2011a Table 3, Table 2-4 of this FS). Specifically, the HHBRA evaluated samples collected

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from the LCP portion of the Turtle River estuary, identified as Zone D (section of Turtle River from Georgia Highway 303 to Channel Marker 9), Zone H (Purvis Creek), and Zone I (Gibson Creek). The analysis included fish and shellfish samples collected between 2002 and 2006 following guidance provided in *Recommendations for a Fish Tissue Monitoring Strategy for Freshwater Lakes, Rivers, and Streams* from the Georgia Department of Natural Resources (GADNR) (FTAC 1992). The HHBRA tissue datasets were comprised of 8 to 31 composite samples per species and include analytical results for mercury, Aroclor 1268, and other inorganics (EPS 2011a). The HHBRA considered data for red drum, spotted seatrout, mullet, spot, sheepshead, flounder, kingfish, blue crab, and white shrimp.

A variety of biological tissue data were considered in the BERA (EPS 2011a) and analyzed for total mercury, methylmercury, Aroclor 1268, lead, and total PAHs. Whole-body tissue data were considered in the BERA for mummichogs, red drum, spotted seatrout, mullet, spot, sheepshead, flounder, kingfish, blue crab, and fiddler crab. In addition, *Spartina* tissue data were evaluated.

Appendix F presents mercury and Aroclor 1268 fish concentrations over time in OU1 and provides a full report of the 2011 fish collection effort; these data were reported by EPS (2011b) to USEPA, GAEPD, and GADNR. The HHBRA and the BERA did not include the edible tissue and whole-body fish and shellfish tissue from the 2011 collection effort because these data were collected and evaluated after the risk assessment efforts were completed.

Appendix F also compares the fish and shellfish temporal trends to the GADNR (2004) concentration thresholds for fish consumption advisories. The Appendix F fish data were used by GADNR to establish 2012 fish consumption advisories for TRBE. Fish consumption advisories continue to reduce human exposures to PCBs in the Purvis Creek and the Turtle River system (GADNR 2012). These restrictions likely will remain in place until such time that the criteria for delisting are achieved. Table 2-5 lists changes in fish consumption advisories over time, showing that approximately 20 advisories in various areas of the TRBE have been reduced since 1997.

COC Concentrations in Clapper Rail Tissue

The HHBRA also evaluated COC concentrations in clapper rail breast tissue, based on 16 clapper rail samples collected by USEPA from July through August. The birds were collected prior to the 1998-1999 removal action and thus do not represent changes in tissue concentrations resulting from that removal. Therefore, these data likely overestimate current tissue concentrations. Tissue analysis was limited to breast meat which is what is assumed to be consumed by hunters. Samples were analyzed for mercury and Aroclor 1268.

2.4.2 Human Health Risk Assessment Summary

The final OU1 HHBRA (EPS 2011a) was approved by USEPA in a letter dated November 30, 2011 (USEPA 2011), and was conducted in a manner consistent with USEPA's *Risk Assessment Guidance for Superfund (RAGS), Volume I, Human Health Evaluation Manual,* Part A (USEPA 1989) including updates and supplemental guidance. The overall goal of the HHBRA was to evaluate whether chemicals detected in sediment remaining after removal actions and consumable biota present potential exposure and health risks to future Site trespassers or consumers of biota in order to determine the need for remedial action. The

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HHBRA used a four-part process: data analysis, exposure assessment, toxicity assessment, and risk characterization.

HHBRA Data Analysis

USEPA (2010a) used analytical data from surface sediment and biota samples (fish and clapper rail) collected from the Site to identify COCs and to evaluate human exposure to those COCs (Table 2-4). Sediment samples from Purvis Creek and the Turtle River were excluded as these areas remain inundated at low tide and afford no opportunity for human exposure. The biological dataset used in the HHBRA included samples of finfish and shellfish likely to be consumed by humans (e.g., red drum, spotted seatrout), as well as those less likely to be consumed (e.g., spot, striped mullet). The biological dataset also included samples of breast tissue from clapper rail, a small game bird inhabiting coastal marshes, that were collected from the estuary adjacent to the Site in 1995 (i.e., prior to the remediation of Domain 1).

Sediment and biota COCs were identified by comparing the maximum detected concentration of each chemical with the appropriate USEPA Regional Screening Levels (USEPA 2010b, c). The maximum detected concentrations of the inorganic chemicals in sediments also were compared with twice the mean site-specific background concentrations.

HHBRA Exposure Assessment

For risk assessment purposes, the term “exposure” is defined as contact with chemicals in environmental media at the outer boundaries of the body, such as the gastrointestinal tract (for ingestion route) and skin (for the dermal route). Both reasonable maximum exposure (RME) and central tendency exposure (CTE) were evaluated. The HHBRA evaluated the following human receptors:

- Marsh trespasser – the RME assumed an adolescent or adult who visits marsh areas adjacent to the Site for up to 52 days per year for a total of 30 years; the CTE assumed 6 days per year for 8 years. More accessible areas were included in this evaluation.
- Recreational fish consumer – consumes fish from areas proximate to the Site (e.g., 26 meals per year for 30 years for adults). This scenario uses data on the amount of recreationally caught fish consumed by children, adolescents, and adults in the southeastern US (USEPA 1997a) and makes the conservative assumption that all consumption occurs from fish from the Site.
- High-quantity fish consumer – consumes more locally caught fish than the typical recreational angler (e.g., 40 meals per year for 30 years for adults) (DHHS 1999). Similarly, this scenario is based on the conservative assumption that all fish consumption occurs from fish from the Site.
- Shellfish consumer – consumes shellfish (white shrimp and blue crab) directly from the Site (e.g., 19 meals per year for 30 years for adults); estimates are based on the amount of shellfish consumed by children, adolescents, and adults in the US (USEPA 1997a). Again, this is based on the conservative assumption that all of this consumption occurs at the Site.
- Clapper rail consumer – consumes clapper rail. In order to estimate consumption rates for clapper rail, the risk assessment used USEPA consumption rate data for all kinds of wild

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game ingestion for children, adolescents, and adults (USEPA 1997a) as a starting point. The risk assessment then derived a clapper rail consumption rate by assuming that people might eat clapper rail at a rate that was 10% of the total game consumption rate. The risk assessment also assumed that 100% of clapper rail that people might consume would come from the Site. Coupled with the fact that clapper rail is not commonly consumed (Geraghty and Miller 1999) and is unlikely to be hunted at this location due to the proximity of more desirable and accessible areas, this is a very conservative risk approach.

HHBRA Toxicity Assessment

The toxicity assessment provides a description of the relationship between a dose of a chemical and the potential for an adverse health effect. For risk assessment purposes, potential effects of chemicals are separated into two categories: cancer and noncancer. With the exception of Aroclor 1268, cancer slope factor (CSF) and reference dose (RfD) values specific to each COC were obtained from the December 2010 edition of USEPA's Regional Screening Level Table (USEPA 2010b). USEPA has not developed CSFs or RfDs specific to Aroclor 1268. In this assessment, the high- end CSF of 2 per milligrams per kilograms per day (mg/kg-day)$^{-1}$ was applied consistent with USEPA guidance for evaluation of PCBs in biota soil and sediment. For evaluation of noncancer endpoints, the RfD for Aroclor 1016 was applied to evaluate Aroclor 1268 because mammalian studies on Aroclor 1268 were not available at the time of the HHBRA and it was assumed that Aroclor 1016 was the Aroclor most similar to Aroclor 1268.

HHBRA Risk Characterization

The risk characterization integrates the exposure estimates for Site receptors with the representations of the potential toxicity derived for each COC. This integration yields quantitative estimates of theoretical excess lifetime cancer risks (ELCRs) and noncancer hazard quotients (HQs) for COCs. These estimates provide a quantitative representation of the relationship between hypothetical exposures and potential toxic responses.

Theoretical ELCR estimates for receptors are expressed as an upper-bound probability of additional lifetime cancer risk due to exposure to site-related chemicals. These estimates do not reflect an individual's existing lifetime risk of developing cancer—which is, without Site exposure, already between one-in-two (2×10^{-1} or 2E-1) and one-in-three (3×10^{-1} or 3E-1) (ACS 2011)—but only the additional incremental risk that is theoretically related to exposure to Site COCs.

Cancer risk estimates were compared with the USEPA target range of 10^{-4} (1 in 10,000) to 10^{-6} (1 in 1,000,000) for incremental cancer risk identified under the NCP (40 CFR Part 300). Calculated upper-bound ELCR estimates less than 1×10^{-6} are considered to be insignificant, and ELCR estimates greater than 1×10^{-4} require further consideration. However, USEPA guidance indicates that estimates slightly greater than 1×10^{-4} may be protective, depending upon the uncertainties in the estimate (USEPA 1991). Specifically, USEPA (1991) states:

> *"The upper boundary of the risk range is not a discrete line at 1 x 10^{-4}, although [US]EPA generally uses 1 x 10^{-4} in making risk management decisions. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions."*

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Therefore, USEPA may consider risk estimates greater than 10^{-4} to be protective, based on Site-specific conditions.

Potential noncancer risks for individual COCs are expressed as HQs and a hazard index (HI) which is the sum of HQs (USEPA 1989). For each receptor scenario, HQs are calculated as the ratio of the estimated daily intake of each COC to the corresponding RfD for that COC. Where the average daily dose estimated for the COC exceeds the RfD, the HQ exceeds 1. HQ or HI of 1 is typically considered a threshold requiring further evaluation since it indicates that exposure could be higher than the no-effect dose represented by the RfD. However, because of the conservative nature of RfDs and the uncertainties surrounding the RfD, HQ values greater than 1 do not necessarily indicate that harm will occur from this exposure level (USEPA 2013d). USEPA (2013d) says an HQ of 3 is considered a reasonable risk level based on the uncertainty included in USEPA's calculation of RfD values, which is subject to "…uncertainty spanning perhaps an order of magnitude."

HHBRA Risk / Hazard Summary

The theoretical cancer risks and potential noncancer hazards estimated for each receptor are summarized below (Table 2-6[2]):

Carcinogenic effects:

- Only the high-quantity fish consumer scenario has an ELCR estimate that exceeds USEPA's target risk range of 10^{-6} to 10^{-4} and that estimate is 2×10^{-4}.
- The recreational fish consumer and clapper rail consumer scenarios both have ELCR estimates equal to 1×10^{-4}, and as such, are equal to the upper end of USEPA's target risk range.
- All of the receptor scenarios have CTE ELCR estimates below the upper end of USEPA's target risk range and all marsh trespasser RME or CTE ELCR estimates are below the upper end of USEPA's target risk range.

Noncancer effects:

- The marsh trespasser cumulative HI estimate is less than the threshold value of 1.
- All of the RME seafood and wild game consumption scenarios have cumulative HI estimates above 1; however, since all COCs do not share same mode of action, summing across all COCs is overly conservative. When HI values for individual chemicals are considered, HI values are greater than 1 for the high-quantity fish consumption scenario and the recreational fishing scenario.
- The high-quantity fish/shellfish consumer scenarios are the only receptor scenarios with CTE HI estimates above 1.

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[2] This table is a reproduction of Table 22 of the OU1 HHBRA Report (EPS 2011a).

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HHBRA Characterization of Uncertainties

Uncertainties are inherent in the quantitative risk assessment process due to environmental sampling results, assumptions regarding exposure, and the quantitative representation of chemical toxicity. In virtually all cases, conservative assumptions are built into the HHBRA to compensate for unavoidable uncertainty, such that resultant risk estimates are more likely to overestimate risks than to underestimate risks. Examples of uncertainty in the OU1 HHBRA where conservative assumptions were made relate to the exposure assumptions used to characterize the RME receptor scenarios, the COC concentrations in biota tissue used to estimate receptor intake, and the surrogate toxicity values used to characterize the potential cancer risks associated with Aroclor 1268. These assumptions are as follows:

- An individual trespasser would walk through the Site once a week for 30 years (a total of 1,560 separate events), each time getting nearly one-quarter of his body covered in sediment.
- 100% of the fish and shellfish eaten by any individual would come from the areas in the immediate vicinity of the Site.
- A hunter would eat clapper rail obtained from the Site such that this source of clapper rail comprises 10% of the wild game that he eats.
- The potential carcinogenicity of Aroclor 1268 should be evaluated using the upper-bound CSF for high risk/persistence PCBs such as Aroclor 1254, when a comprehensive review of the available carcinogenicity data suggests the tumorigenic potency of Aroclor 1268 may be at least 10-times lower (Warren et al. 2004).

The consistent application of conservative assumptions to address areas of uncertainty in the OU1 HHBRA should be considered when evaluating the need for remedial actions to address human health risks that exceed the USEPA targets. They also should be factored into the evaluation of remedy alternatives against NCP criteria, particularly with regard to the ability of a remedy to meet the NCP “threshold criterion” of protection of human health and the environment.

2.4.3 Summary of the Baseline Ecological Risk Assessment

The OU1 BERA was prepared by Black and Veatch (2011) on behalf of USEPA. The BERA describes the likelihood, nature, severity, and spatial extent of adverse effects to ecological receptors resulting from exposure to chemicals released to the environmental media (i.e., sediment, surface water, and biological tissue) in the estuary as a result of past Site activities. This information provides a basis for decisions regarding the need for remedial actions. USEPA established a general framework for conducting ecological risk assessment (USEPA 1998a), which is an iterative process in which risk questions are asked, data with which to address the questions are collected and analyzed, and additional study is conducted if warranted.

Ecological analyses of the Site estuary have been conducted at various stages of the process with the first assessment submitted to USEPA in 1997 (PTI and CDR 1997), followed by analyses submitted in 2001 (CDR and GeoSyntec 2001) and 2009 (CDR and EPS 2009). The final BERA report was issued in April 2011 and encompasses approximately 1,000 pages of

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text, figures, tables, and appendices (Black and Veatch 2011). The following summary focuses exclusively on the 2011 BERA.

Data Used in the BERA

The data used quantitatively in the OU1 BERA report (Black and Veatch 2011) were generated in the postremoval action ecological monitoring event in 2000 and subsequent annual monitoring events that occurred between 2002 and 2007. The decision to use the entire postremoval action dataset, rather than just the most contemporary data, was based on an evaluation of temporal characteristics of COC concentrations in surface sediment collected from sentinel monitoring stations sampled repeatedly over that period. The BERA concluded that, with a few possible exceptions, there were no discernible concentration trends for the COCs at these sentinel stations. The BERA also concluded that there were no apparent temporal COC concentration trends in biota.

The experimental design for the OU1 BERA was established in the work plan for the 2000 monitoring event (Honeywell 2000), and with the exception of several amphipod toxicity studies conducted in 2006 to address specific risk questions, remained fairly consistent for the 2000 to 2007 monitoring events. The experimental design is summarized in Table 2-7.[3]

BERA Problem Formulation

Problem formulation is a planning step that identifies the major questions to be addressed in an ecological risk assessment, along with the basic approaches that will be used to characterize the potential ecological risks. Here, problem formulation identifies COCs, ecological assessment and measurement endpoints, and ecological exposure and effects evaluation.

Chemicals of Concern

The BERA focuses on the four primary Site chemicals: mercury (including methylmercury), Aroclor 1268, lead, and total PAHs. Information on the ecological toxicity of these chemicals is provided in Section 3.6 of the OU1 BERA (Black and Veatch 2011). Mercury and Aroclor 1268 are of potential concern for both direct toxicological effects to lower trophic level organisms in the sediment and water column (i.e., invertebrates) and upper-trophic-level ecological receptors via bioaccumulation within the food web. Lead and PAHs are of potential toxicological concern only to lower trophic level organisms in the sediment and water column.

These four chemicals remain the primary COCs evaluated quantitatively in the BERA. However, based on subsequent rounds of sampling, the COC screening process was updated to identify other chemicals in sediment and surface water samples that could potentially contribute to ecological risks. This updated screening process involved comparing maximum detected concentrations of all target analytes to conservative screening-level Ecological Effects Values recommended for this purpose by USEPA. No additional COCs were identified.

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[3] This table is a reproduction of Table 3-1 of the OU1 BERA Report. Additional detailed information about the specific analyses conducted at each monitoring station for each monitoring event is provided in Tables 3-2 and 3-3 of the OU1 BERA report. The locations of the ecological monitoring stations in the Site are shown in Figures 3-3, 3-4, and 3-5 of the OU1 BERA (Black & Veatch 2011).

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Detailed information related to the updated chemical screening is provided in Appendix B of the OU1 BERA (Black and Veatch 2011).

<u>Assessment and Measurement Endpoints</u>

Assessment endpoints are the valued attributes of ecological resources or receptors upon which risk management actions are focused. USEPA defines an assessment endpoint as “an explicit expression of the environmental value to be protected, operationally defined as an ecological entity and its attributes” (USEPA 1998a). Measurement endpoints are ecological characteristics that can be measured, interpreted, and related to the valued ecological attributes selected as the assessment endpoints (USEPA 1997b, 1998a). The following assessment and associated measurement endpoints were identified for the OU1 BERA:

- *Assessment Endpoint 1* – Viability of the benthic estuarine community. This assessment endpoint is evaluated by three measurement endpoints:
    1. comparisons of concentrations of COCs in surface sediment to site-specific effects levels
    2. results of toxicity tests conducted with sensitive life stages of benthic biota exposed to surface sediment
    3. evaluation of the indigenous benthic community
- *Assessment Endpoint 2* – Viability of omnivorous reptiles using the estuary. This assessment endpoint is evaluated by HQs derived from food web exposure models for diamondback terrapins.
- *Assessment Endpoint 3* – Viability of omnivorous avian species using the estuary. This assessment endpoint is evaluated by two basic measurement endpoints: 1) HQs derived from food web exposure models for red-winged blackbirds (*Agelaius phoeniceus*) and 2) HQs derived from food web exposure models for clapper rails.
- *Assessment Endpoint 4* – Viability of piscivorous avian species using the estuary. This assessment endpoint is evaluated by HQs derived from food web exposure models for green herons (*Butorides striatus*).
- *Assessment Endpoint 5* – Viability of herbivorous mammalian species using the marsh. This assessment endpoint is evaluated by HQs derived from food web exposure models for marsh rabbits.
- *Assessment Endpoint 6* – Viability of omnivorous mammalian species using the estuary. This assessment endpoint is evaluated by HQs derived from food web exposure models for raccoons.
- *Assessment Endpoint 7* – Viability of piscivorous mammalian species using the estuary. This assessment endpoint is evaluated using HQs derived from food web exposure models for river otters.
- *Assessment Endpoint 8* – Viability of finfishes using the estuarine system. This assessment endpoint is evaluated by five measurement endpoints:

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1. Comparisons of concentrations of COCs in surface water to general literature-based effects levels
2. Results of toxicity tests conducted with early (and sensitive) life stages of aquatic biota exposed to COCs in surface water
3. HQs derived from residue-based toxicity reference values (TRVs) and finfish bioaccumulation models
4. HQs derived from residue-based TRVs and finfishes collected on-site in Purvis Creek
5. Evaluation of the benthic community as a food source for juvenile and adult fishes.

Ecological Exposure and Effects Evaluation
The OU1 BERA describes temporal trends of COCs in surface sediment of the estuary at the Site between 2000 and 2007; the presence of chemicals in various environmental media of the Site; and describes the laboratory, field, and modeling-based analyses that form the basis for the risk characterization for benthic and aquatic invertebrates, fish, and wildlife receptors. The BERA includes discussion of the following lines of evidence:

- Analytical Chemistry Results for Sediment, Surface Water, and Biota
- Surface Water Toxicity Tests
- Sediment Toxicity Tests with Laboratory-Cultured Invertebrates
- Sediment Toxicity Tests with Indigenous Grass Shrimp
- Benthic Community Studies
- Development of HQs for Fish using Multiple Approaches
- Development of HQs for Wildlife

BERA Risk Characterization for Assessment Endpoints

Risk characterization involves the integration of exposure and effects data to evaluate the likelihood of adverse effects. The BERA for the Site evaluates potential risk pertaining to the following eight assessment endpoints using one or more measurement endpoints to evaluate each assessment endpoint: Benthic estuarine community, omnivorous reptiles, omnivorous birds, piscivorous birds, herbivorous mammals, omnivorous mammals, piscivorous mammals, and finfish.

Benthic Estuarine Community (Assessment Endpoint 1)
Three basic measurement endpoints were employed to evaluate the viability of the structure and function of the benthic estuarine community at the Site:

- Comparisons of concentrations of COCs in surface sediment with site-specific sediment effects concentrations (SECs)
- Results of toxicity tests conducted with sensitive life stages of benthic biota exposed to surface sediment
- Evaluation of the indigenous benthic community

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Potential for and causes of sediment toxicity were evaluated in 2006 by a comprehensive set of amphipod studies that included a site-specific toxicity identification experiment (TIE) study, an equilibrium partitioning study for metals, and an apparent effects threshold (AET) study.

The AET study evaluated survival, growth, and/or reproduction of lab-cultured amphipods exposed to surface sediment samples collected from 150 locations in Eastern Creek, LCP Ditch, and Western Creek Complex. Endpoints were often significantly reduced relative to controls and some reference areas. The OU1 BERA concluded that the observed toxicity appeared to be caused by COCs, but also acknowledged that there were no discernible COC exposure-response relationships of high predictive value, and toxicity was substantially influenced by other factors including TOC, sulfide, and grain size. The OU1 BERA concluded that these lines of evidence for collectively evaluating the viability of the structure and function of the benthic estuarine community at the Site indicate that the potential for risk associated with COCs and non-COCs is evident, particularly in LCP Ditch, Eastern Creek and Domain 3 Creek.

Omnivorous Reptiles (Assessment Endpoint 2)
One line of evidence was used to evaluate the viability of omnivorous reptilian species using the Site: HQs derived from food web exposure models for diamondback terrapins. Because all HQs derived for diamondback terrapins were substantially below 1, the OU1 BERA concluded that there is no potential risk to the viability of omnivorous reptiles using the Site.

Omnivorous Birds (Assessment Endpoint 3)
Two lines of evidence were used to evaluate the viability of omnivorous avian species, considering both no observable adverse effects levels (NOAELs) and lowest observable adverse effects levels (LOAELs) as the basis for TRVs: 1) HQs derived from food web exposure models for red-winged blackbirds and 2) HQs derived from food web exposure models for clapper rails. The following is a summary of the findings:

- All food web HQs (NOAEL and LOAEL) for inorganic mercury, Aroclor 1268, and lead were below 1 for both red-winged blackbirds and clapper rails, indicating no significant risk.
- For red-winged blackbirds, modeled NOAEL and LOAEL HQs for methylmercury were at or below 1 in all domains.
- For clapper rails modeled for exposure to methylmercury all LOAEL HQs were less than 1. NOAEL HQs were greater than 1 in Domain 1 (3)[4], Eastern Creek (3), and LCP Ditch (2).

Based on these findings, the OU1 BERA concluded that the overall potential for risk to omnivorous birds at the Site is minimal.

Piscivorous Birds (Assessment Endpoint 4)
One line of evidence was used to evaluate the viability of piscivorous avian species using the Site: HQs derived from food web exposure models for green herons. The following is a summary of the findings:

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[4] HQ values discussed in this section are reported at one significant figure.

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- All food web HQs (NOAEL and LOAEL) for inorganic mercury, Aroclor 1268, lead, and total PAHs were below 1 for green herons, indicating no potential for risk.
- All NOAEL HQs generated by the green heron modeled for exposure to methylmercury exceeded 1 (1 to 11).
- LOAEL HQs for green herons modeled for methylmercury exposure at the Site exceeded 1 in Domain 1 (3), Eastern Creek (4), and LCP Ditch (2).

Based on these findings, the OU1 BERA concluded that potential risk to the viability of piscivorous avian species at the Site from mercury is moderate.

Herbivorous Mammals (Assessment Endpoint 5)
One line of evidence was used to evaluate the viability of herbivorous mammalian species using the Site: HQs derived from food web exposure models for marsh rabbits. The following is a summary of the findings:

- All NOAEL and LOAEL HQs for inorganic mercury, methylmercury, and lead were below 1 for marsh rabbits, indicating no potential for risk.
- For marsh rabbits modeled for exposure to Aroclor 1268 (based on a TRV for Aroclor 1254), all LOAEL HQs were less than 1. The NOAEL HQ of 3 was greater than 1 in Domain 1.

Based on these findings, the OU1 BERA concluded the potential for risk to herbivorous mammals foraging within the Site is minimal.

Omnivorous Mammals (Assessment Endpoint 6)
One line of evidence was used to evaluate the viability of omnivorous mammals foraging within the Site: HQs derived from food web exposure models for raccoons. The following is a summary of the findings:

- All NOAEL and LOAEL HQs for inorganic mercury, methylmercury, and lead, were below 1 for raccoons, indicating no potential for risk.
- For raccoons modeled for exposure to Aroclor 1268 (based on a TRV for Aroclor 1254), all LOAEL HQs were less than 1. Measured at one significant figure, NOAEL HQs were 3 in Domain 1 and 1 in Domain 2.

Based on these findings, the BERA concluded that the potential for risk to the viability of omnivorous mammals using the Site is minimal.

Piscivorous Mammals (Assessment Endpoint 7)
One line of evidence was used to evaluate the viability of piscivorous mammals foraging within the Site: HQs derived from food web exposure models for river otters. The following is a summary of the findings:

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- The modeling study for river otters generated Site NOAEL HQs for Aroclor 1268 (based on a TRV for Aroclor 1254) that ranged from 0.1 to 4.
- No LOAEL-based HQ for Aroclor 1268 exceeded 1. In addition, no risk of adverse effects was predicted for mercury or lead exposures.

Based on these findings, the BERA concluded that the potential risk to the viability of piscivorous mammalian species using the Site is minimal.

Finfish (Assessment Endpoint 8)
Five lines of evidence were used to evaluate the viability of finfish inhabiting the Site:

1. Comparisons of concentrations of COCs in surface water to general literature-based effects levels
2. Results of toxicity tests conducted with sensitive life stages of aquatic biota exposed to COCs in surface water
3. HQs derived from food web exposure models for upper trophic level fish
4. HQs derived from measured residues in field-collected fish
5. Evaluation of the benthic macroinvertebrate community (as a food source for juvenile and adult fishes)

The following is a summary of the findings (HQs are reported to 1 significant figure):

- The maximum concentration of total mercury measured in surface water of the Site (188 ng/L in Eastern Creek in 2000) is less than the Criterion Continuous Concentration of 940 ng/L. The maximum concentration of dissolved lead in water (2.5 µg/L in LCP Ditch during 2000) is below the Criterion Continuous Concentration of 8.1 µg/L. No criteria have been developed for Aroclor 1268. Several unfiltered water samples analyzed for Aroclor 1268 exceeded the GAEPD WQS for total PCBs; filtered samples were consistently below the GAEPD WQS PCB benchmark.
- Laboratory toxicity tests designed to evaluate chronic toxicity of surface water from the Site to mysid shrimp and sheepshead minnows generated similar results. Survival and growth for both species were similar to results seen at the reference locations.
- The mean LOAEL HQ derived using a fish bioaccumulation model for methylmercury was 3. Using three different fish bioaccumulation models for PCBs, mean LOAEL HQ values for Aroclor 1268 ranged from 0.5 to 1. The modeled methylmercury tissue concentrations on which these HQs are based are generally higher than the measured concentrations in most species of fish collected from the Site.
- When HQs were derived based on measured concentrations in field-caught fish from the Site, mean LOAEL HQs for methylmercury was 1 in silver perch and black drum, and 2 for spotted seatrout. Mean LOAEL HQs for Aroclor 1268 were 1 in silver perch and black drum, and 3 for stripped mullet.

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- Evaluation of the benthic macroinvertebrate community in the Site did not identify a limitation of this source of food to fishes, although toxicity to benthic organisms may limit food for fish in portions of LCP Ditch, Eastern Creek, and Western Creek Complex.

Based on an overall evaluation of these five measurement endpoints, the OU1 BERA concluded that that there is no risk to fish in the Site from direct exposure to COCs in the water column. However, the bioaccumulation modeling and field data for finfish suggest that chronic risk from mercury and Aroclor 1268 to viability of finfish indigenous to the Site is of concern.

BERA Uncertainty Analysis

The OU1 BERA (Black and Veatch 2011) examined a variety of uncertainties associated with the components of the BERA process and considered whether these uncertainties tend to over- or underestimate risks. It also presents findings from several independent studies conducted at the Site and evaluates whether those studies lend additional support to, or conflict with, the conclusions of the BERA. The most significant sources of uncertainty in the OU1 BERA are briefly described below. The consistent application of conservative assumptions and interpretations to each of these sources of uncertainty generally results in an overestimation of risks for the assessment endpoints evaluated in the BERA.

- The evaluation of potential adverse effects to the benthic invertebrate community relied on hundreds of site-specific acute and chronic toxicity test measurements using both indigenous and laboratory-cultured organisms. The OU1 BERA notes that the development of RGOs for the protection of benthic invertebrates is “highly uncertain with poor accuracies” and that “only conservative assumptions were used” for this purpose. Although the absence of a clear dose-response relationship resulted in uncertainty in developing the RGOs, there was extensive toxicity in the majority of sediment samples, including the reference locations.
- The evaluation of potential adverse effects to mammalian receptors from Aroclor 1268 is based on a TRV for Aroclor 1254. Appendix J of the OU1 BERA contains a detailed discussion of the relative toxicities of these two PCB mixtures and concludes that representing the toxicity of Aroclor 1268 with Aroclor 1254 TRV overestimates the potential for adverse effects to the mammalian assessment endpoints considered in the OU1 BERA.
- The evaluation of potential adverse effects to upper-trophic level fish from Aroclor 1268 is based on a tissue residue TRV derived by the USEPA for that PCB mixture. This TRV is based on a study published by Matta et al. (2001) in which a statistically significant growth increase was observed in mummichogs with a measured tissue level of 1.3 mg/kg (wet weight) Aroclor 1268. USEPA conservatively determined that this concentration represented a LOAEL rather than a NOAEL, resulting in an overestimation of the potential for adverse effects to this assessment endpoint.
- The evaluation of potential adverse effects to upper-trophic-level fish, birds, and mammals is based on the calculation of HQs. While this has become routine in the realm of regulatory risk assessment, the practice has been criticized by Tannenbaum (2005, 2007) and others. The HQ is simply the ratio of a conservative exposure estimate and a conservative TRV and is not a measure of the probability that an adverse effect will occur. Furthermore, the HQ relates to the response of an individual organism, rather than the population. The HQ method involves the implicit assumption that as exposures and HQs increase, an increasing

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number of individuals could experience adverse effects, and that the higher the number of individuals affected, the greater the risk to the population. In reality, density-dependent biological processes, such as competition for limited food resources, can offset reductions in the reproductive output of individual organisms. In addition, it is well documented that wildlife can acclimate and adapt to elevated levels of chemicals in the environment, thereby mitigating adverse population-level effects.

2.5 Conceptual Site Model

Sections 2.1 through 2.4 present considerable background information regarding OU1. The CSM presented here is a culmination of that broad characterization, organized to facilitate communication and decision making. The CSM illustrates the environmental system in words and pictures in order to help illustrate the following:

- OU1's sources of contamination
- The ways in which COCs move from their original sources through environmental media
- The human and ecological receptors that may contact COCs
- The pathways by which each receptor may be exposed to COCs

Development of CSMs is an iterative process (USEPA 2005a), and CSMs can serve different purposes. The objective of the CSM presented here is to inform remedial decision-making by identifying the migration pathways, exposure media, receptors, and exposure pathways that most strongly influence Site-related risks. By focusing on such risk drivers, an effective and protective remedial alternative can be selected through the identification of pathways that the remedial actions should target to reduce human and ecological exposures to COCs. Like most CSMs, the CSM for OU1 evolved throughout the investigation, as the understanding of sources, COC distribution, receptors, exposures, and risks advanced. Thus, while this CSM is based on the foregoing data and analyses, it also reflects modifications to the CSMs that have been presented in earlier reports.

A variety of schematic illustrations can be used to depict the CSM, as reflected in Figures 2-2 and 2-3 (groundwater transport), 2-4 (surface water CSM), and 2-20 (ecological exposures), which focus on different parts of the CSM. Figure 2-21 offers a fourth schematic illustration of the CSM, developed specifically to parallel the narrative discussion below. Figure 2-21 and the following narrative are organized to reflect the four main components of the CSM:

- Sources
- Migration pathways
- Receptors
- Exposure pathways

Sediment stability, which is critical to the overall understanding of the CSM, is discussed within the subsection on migration pathways.

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2.5.1 COC Sources

The primary sources of COCs to OU1—mercury, lead, PAHs, and Aroclor 1268—are upland historical industrial activities that date back to the early 1900s. Industrial facilities that historically operated at the Site include a petroleum refinery, power plant, paint manufacturer, chlor-alkali plant, landfill, and adjacent shooting range. Each facility engaged in different types of industrial and waste management activities, resulting in point and nonpoint source discharges from process lines, wastewater lines, storm sewer lines, smoke stacks, and direct disposal. COCs also spread by surface runoff and outfall discharges. Routine tidal inundation washed the contaminated sediments out into the nearshore marsh. Hydrodynamic processes within the marsh focused the deposition of contaminated particles in the creeks, where the highest COC concentrations have been measured—much lower concentrations appear in the vegetated marsh areas.

All known primary sources associated with historical industrial discharges and overland runoff have been controlled (EPS and ENVIRON 2012). The RI (EPS and ENVIRON 2012) discusses source control and mitigation activities that were undertaken from the early 1970s through 1997 to eliminate the potential for recontamination from upland sources. Source control activities, and the years in which they were undertaken, are listed below:

- Diversion of surface water to sumps (1970s)
- Construction of surface water containment berms (1994)
- Installation of cap on former mercury cell building slabs (1995 - 1997)
- Removal of process waste impoundments and FFDA (1995 to 1997)
- Removal and backfilling (with clean fill) uplands areas including south American Petroleum Institute (API) separator and Quadrant 3 area (1997)
- Sealing of sewer network using flowable fill (1997)
- Excavation and restoration of approximately 13 acres of marsh flats bordering the FFDA and sewer discharge points (1998-1999) (Figure 2-9)
- Dredging of portions of the LCP Ditch and Eastern Creek (1998-1999) (Figure 2-9)

Soil and groundwater were the primary environmental media that historically received COCs from the sources listed above, via disposal, releases, and discharges. Upland soil sources have been controlled through the remedial actions described above. Hence, upland soil is not an ongoing source to the marsh. The extent to which groundwater is an ongoing secondary source of COCs to surface water, sediment, and biota is discussed in Section 2.5.2, which describes the migration pathways by which COCs move between environmental compartments.

2.5.2 Migration Pathways

Historically, upland sources conveyed COCs to the marsh through outfall discharges or surface water runoff. Resuspension from sediment to surface water and deposition from surface water to sediment contributed to the broad distribution of COCs in the marsh. As discussed in the preceding section, sources from the past industrial operations and upland soils have been controlled, such that migration pathways from the past industrial operations and upland soils no

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longer drive exposure. This section therefore focuses on migration pathways that may be ongoing—namely, surface water-sediment flux—in order to focus the CSM on matters relevant to remedial action decision-making. Groundwater transport to surface water and surface sediments also are discussed, though groundwater is not considered a significant chemical transport pathway.

Groundwater Transport

The question of whether groundwater transport is a significant ongoing migration pathway has been the focus of considerable analysis. The OU1 RI (EPS and ENVIRON 2012) evaluated the potential for groundwater migration through the marsh clay layers using a transect analysis; further analysis was performed in support of this FS and is reported in Appendix A.

Local, sporadic groundwater seepages were observed along the marsh edge, where the marsh clay was absent and the underlying sand was exposed. A seepage analysis identified the occurrence of seeps in the marsh. As detailed in Appendix A, porewater analyses were performed at identified seep locations, and a transect analysis was performed using shoreline/nearshore groundwater wells installed along the length of the Site; wells along the transect were sampled in May 2012. Based on the results of the seep analysis and the shoreline transect analysis, groundwater was found to be a minor contributor of COCs to sediment in the marsh.

The groundwater analysis was expanded to evaluate the potential for groundwater migration to surface water to influence surface water COC concentrations and to measure water quality criteria exceedances (Section 2.4.1). The groundwater dilution factor was conservatively estimated to be 1,800 (i.e., groundwater is diluted approximately 1,800 times upon discharging to surface water). The combined effects of low groundwater concentrations, non-detect seep concentrations, limited and localized seepages, and high dilution upon discharge to surface water together indicate that groundwater is a negligible ongoing source of COCs to sediment and surface water.

Based on results of the groundwater analyses, a decision regarding the need for groundwater remediation is not required prior to the sediment remediation decision.

Surface Water-Sediment Flux and Sediment Stability

COC migration within OU1 is influenced by the chemical-physical properties of the COCs, as well as marsh hydrodynamics and sediment characteristics. Specifically, the low solubility of the COCs causes them to preferentially adsorb to sediment particles. Consequently, COCs predominantly move with suspended sediments, rather than in dissolved phase. However, because the sediment bed in the creeks is largely composed of cohesive clayey silts, it is likely that minimal erosion occurs during typical tidal conditions. Due to natural bed armoring processes in these cohesive sediment beds (Sections 2.2.1 and 2.2.4), it is likely that minimal erosion occurs during typical tidal conditions within the creek channel. Bed scour is anticipated to be most significant in localized areas of the creek channels during rare severe storms (e.g., hurricane storm surge). Nonetheless, the dominant erosional and depositional pattern reflects tidal forces that continuously rework only the top few millimeters of the sediment. This process

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of continuous reworking of the upper millimeters of sediment also contributes to the current distribution of contaminants in the creeks and marsh areas. In the presences of high COC concentrations in LCP Ditch, Eastern Creek, and Domain 3 Creek, recovery of other creeks and marsh areas is slowed.

Suspended sediments present in the water column as a result of tidal action are transported between the intertidal marsh areas and creek channels with the tides and as a function of the complex network of tidal creeks. During flood tide, water flows from the Turtle River into the Purvis Creek and is then conveyed to the marsh through the system of secondary creeks and smaller channels. At the beginning of flood tide, flows are mostly confined to the creeks and smaller channels. Once the tidal elevation reaches the bank elevation, water flows into the marsh, where current velocities are relatively low due to increased storage area and high drag induced by plants. Due to the low current velocities and presence of vegetation, the intertidal vegetated marshes are a depositional zone. Salt marshes are net depositional coastal features and, thus, act as sediment sinks, particularly when viewed on larger spatial scales and over multiyear periods. Over time, sediment cohesion and consolidation processes reduce the susceptibility of particles to resuspension and transport.

During ebb tide, water drains from the intertidal marsh into the tidal channels and creeks, and eventually back to the Turtle River. The relatively large tidal prism within OU1 causes nearly complete exchange of water between the intertidal marsh areas and the creeks during each tidal cycle (i.e., marsh areas are filled and drained every tidal cycle). Thus, the larger creek channels play an important role in the exchange of water and sediment between intertidal vegetated marshes and the Turtle River during the tidal cycle.

2.5.3 Receptors

Section 2.3 describes existing habitat and wildlife of OU1 and ecological receptors are summarized in Section 2.4.3. Human receptors are described in Section 2.4.2. Given the detailed descriptions of receptors that have already been presented in Section 2 and in order to avoid repetition, those receptors are simply listed below.

Ecological Receptors

With the exception of the benthic estuarine community, individual representative species are listed below for each feeding guild. The selection of representative species is not meant to imply that these are the only representatives of those feeding guilds present or that these are the only species of interest. On the contrary, the representative species serve as proxies for all species in that feeding guild that use the estuary. Also, due to space constraints, some receptors are omitted from Figure 2-21.

- Benthic estuarine community
- Finfish community
- Omnivorous reptiles, as represented by diamondback terrapins
- Omnivorous birds, as represented by red-winged blackbirds and clapper rails
- Piscivorous birds, as represented by green herons
- Herbivorous mammals, as represented by marsh rabbits

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- Omnivorous mammals, as represented by raccoons
- Piscivorous mammals, as represented by river otters

Human Receptors

- Marsh trespasser
- Recreational fish consumer
- High-quantity fish consumer
- Shellfish consumer
- Clapper rail consumer

2.5.4 Exposure Pathways

Exposure pathways describe the ways in which ecological and human receptors contact COCs in OU1. As illustrated in the pictorial CSM (Figure 2-21), biological exposures occur through prey ingestion, surface water contact and ingestion, and surface sediment contact and ingestion. The exposure pathways presented in this CSM are consistent with those described in the RI, HHBRA, and BERA (EPS and ENVIRON 2012, EPS 2011a, Black and Veatch 2011). These same exposure pathways were considered relevant during USEPA efforts to develop a range of potential remedial goals for human health and ecological receptors (USEPA 2011). As detailed in the HHBRA, the BERA, and this FS, exposures of organisms to COCs are governed by marsh hydrodynamics (i.e., tidal inundation), organism feeding strategies (i.e., life history, behavior, and diet), and chemical characteristics (i.e., both location-specific and weighted average chemical concentrations). Consistent with the HHBRA and the BERA, and for reasons discussed below, exposures for most aquatic species like fish, grass shrimp, and blue crabs are proportional to the time they spend in suitable forage habitat where they can find their preferred food sources.

The Effects of Tidal Inundation on Exposure

The tidal cycle is the dominant hydrogeological condition that governs how biological organisms use OU1. Some areas of OU1 are inundated only during limited portions of the tidal cycle. Domain 1, for example, is inundated 5% to 20% of the time (or 1 to 4 hours a day). This understanding of the marsh hydrogeology is consistent with information in the BERA, which states “the high marsh is covered by tidal water for only about an hour or less each day” and “the low marsh is inundated by tides for several hours each day” (Black and Veatch 2011). Conversely, water is present in Purvis Creek, portions of the Eastern Creek, and the LCP Ditch 100% of the time. Consequently, aquatic animals can use most creeks throughout the tidal cycles, while they can only use portions of the marsh (e.g., Domains 1 and 2) when sufficient water is present.

The amount of water required varies across species and age classes; only a few inches of water is needed to support small fish and grass shrimp, while larger fish require 1 or more feet (30 or more centimeters) of water. Thus, exposure duration in marshes varies with the tides and across receptors. The mature finfish evaluated in the HHBRA and BERA exceed 10 inches

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(25 cm) in length, with exception of silver perch, which is approximately 6 inches (15 cm) when mature (Appendix C provides information on mature fish sizes and minimum capture sizes for anglers while Figure 2-22 provides photographs showing mature fish sizes for fish captured in the Brunswick estuary). Because of their size, large mature fish have only limited access to many vegetated marsh areas and shallow creeks due to the low frequency of water depths that would allow their use of the marsh.

The Effects of Feeding Strategies on Exposure

Organism life history characteristics also influence exposures to COCs in OU1. Most species have exposures to both vegetated marsh and creek habitats. Such exposures may be a result of direct contact with sediment and surface water in the marsh and creeks or indirectly from the consumption of prey. Section 2.5.3 and Appendix C provide life history information for a variety of organisms that live in the estuary and form the base of the food web. This appendix identifies the following:

- The preferred habitats in which the organisms reside
- Their lifespans
- The movement within an estuary (e.g., burrowing versus free swimming)
- Their dietary preferences
- Foraging patterns within the marsh environment
- The organisms that prey upon them

Information in Appendix C demonstrates that chemical uptake into biological organisms occurs from both the creek and marsh sediments, and therefore, remedial actions that focus on both types of habitats can effectively reduce chemical exposures for human health and the environment.

The Effects of Chemical Characteristics on Exposure

The chemical characteristics of the COCs influence their bioavailability and potential to bioaccumulate, which in turn influence exposure to ecological and human receptors. The chemical forms of the COCs and the mixtures present also influence their toxicity (EPS 2011a, USEPA 2011, Black and Veatch 2011). The chemical characteristics of methylmercury and Aroclor 1268 are sufficiently complex to warrant expanded discussion, as follows.

<u>Chemical Characteristics of Methylmercury</u>

In most aquatic systems, mercury exists in several forms, including elemental mercury, inorganic mercury compounds (usually as divalent mercury, Hg(II)), and organomercury (methylmercury or dimethylmercury) (Benoit et al. 2001, Mason and Lawrence 1999, Naimo et al. 2000, Sjoblom et al. 2000, Hsu-Kim et al. 2013). In sediments, elemental mercury is typically a small proportion of total mercury present and is not directly available for organism uptake (Bouchet et al. 2011, Rodriguez Martin-Doimeadios et al. 2004). Inorganic Hg(II), present as a cation (Hg2+), usually predominates in mercury-contaminated sediment environments. Only a

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small portion of Hg2+ is truly dissolved and readily bioavailable; the majority is bound in mercury-ligand complexes with chloride, dissolved organic matter, and reduced sulfur (e.g., organic thiols and sulfhydryl groups; Belzile et al. 2008, Kelly et al. 2003, Benoit et al. 1999) or associated within or adsorbed to solid mineral particles (Hsu-Kim et al. 2013). Inorganic mercury compounds may be transformed to organomercury (i.e., methylated) by biotic and abiotic oxidation and reduction, bioconversion of inorganic and organic forms, and photodegradation of organomercurials (ATSDR 1999). Compared to inorganic mercury, methylmercury has a higher tendency to bioaccumulate and is more toxic.

Because of the complexities of mercury partitioning and methylation processes, an equilibrium partition model for mercury has not been developed to the level of certainty associated with mechanistic models for divalent metals (Ankley et al. 1996, USEPA 2005b,c) or hydrophobic organic chemicals (Di Toro et al. 1991, USEPA 2003, 2008a). Mercury bioavailability and bioaccumulation are site-specific and difficult to predict. As a consequence, risk assessments, like those for OU1 (Black and Veatch 2011, EPS 2011a), often rely on simplifying conservative assumptions (discussed below) regarding mercury exposure and risk.

In the OU1 marsh sediments, methylmercury was detected in creek sediments and in vegetated marsh areas (Section 2.4.1). Dissolved methylmercury also was detected in surface water, and mercury was measured in biological tissues (mercury in biological tissues was assumed to be methylmercury). While the exact mechanisms that control methylation are still not fully understood by scientists and regulatory decision-makers, the data for OU1 do not suggest that mercury methylation was more prevalent in either the creeks or the marsh areas.

Some studies of methylmercury suggest a higher rate of methylation occurs in wetlands (e.g., Hall et al. 2008, Selvendiran et al. 2008). A recent study suggests that the presence of biological organisms, such as polychaetes, increase methylation because polychaetes influence factors like the aerobic condition of sediments, the presence of sulfide-reducing bacteria, and the aerobic condition of the sediments (Sizmur et al. 2013). Research also suggests that freshly deposited mercury from the global atmospheric pool is more prone to methylation than historically released mercury bound to sulfides in sediments (USEPA 2006, Babiarz et al. 2002). The dissolved methylmercury and dissolved total mercury concentrations in OU1 surface water and porewater are similar to surface water and porewater mercury concentrations in saltwater/brackish wetlands in Louisiana where atmospheric deposition is the primary source of mercury (Hall et al. 2008). Specifically, OU1 surface water mercury concentrations were within a factor of 5 and porewater concentrations were within a factor of 2 of the dissolved methylmercury and dissolved total mercury concentrations reported by Hall et al. (2008). This similarity between Hall et al. (2008) locations and OU1 suggests that a significant portion of OU1 mercury is tightly bound due to the geochemistry of the sediments.

Given the complexity and variability of mercury methylation, the HHBRA made the simplified and conservative assumption that all mercury contacted by human receptors was methylmercury. When this assumption is applied to direct contact with methylmercury in sediment, it is particularly conservative, given that only a small percentage of total mercury is present as methylmercury. In contrast, for dietary exposures, this assumption is reasonably

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accurate, as fish tissue data confirmed that the vast majority of the mercury present in tissue is methylated.

The BERA used measured methylmercury tissue data for a variety of dietary food items that each receptor group consumes. Based on Site methylmercury and total mercury analyses, the BERA calculated the fraction of total mercury present as methylmercury is 0.75% in sediment and from 10% (*Spartina*) to 100% (spotted seatrout) in tissue.[5] These percentages were used to establish remedial goals that would be protective of wildlife exposures through the bioaccumulation of mercury. The BERA also evaluates extensive sediment toxicity testing results to identify site-specific SECs for sediment-dwelling organisms exposed to mercury through direct contact. SECs were derived from samples that were predominantly collected from the creeks, but also included locations in the marsh.

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Chemical Characteristics of Aroclor 1268

Before PCBs were banned in the US in 1977, they were sold in mixtures, known as Aroclors, which were composed of large numbers of individual congeners and classified by percentage of chlorine. Aroclor 1268 is highly chlorinated, extremely stable, slow to degrade, bioaccumulative, and less toxic than other Aroclors. Aroclor 1268 is one of only two Aroclors (the other being Aroclor 1270) to exist in a solid form, as contrasted to viscous oil (Aroclor 1254), mobile oil (Aroclors 1221, 1232, 1242, and 1248), or sticky resin (Aroclors 1260 and 1262). A general conclusion in the scientific literature is that Aroclor 1268 is less mobile and less toxic than other, lower-chlorinated Aroclor mixtures (e.g., Simon et al. 2007, EPS 2011a, Black and Veatch 2011).

Exposures to PCBs are influenced by a number of chemical properties common across all PCBs, including Aroclor 1268. All PCBs are extremely hydrophobic. Volatilization and sedimentation are the major processes that determine the fate of PCBs in aquatic systems (Black and Veatch 2011). Both processes remove PCBs from the water, but the amount transferred depends on partitioning between dissolved and particulate-bound phases. That partitioning determines the relative sizes of the soluble pool available for volatilization and the particulate pool available for sedimentation.

All PCBs are highly lipophilic, which enhances their bioaccumulation. The bioaccumulation of Aroclor 1268 in fish, shellfish, and clapper rail was closely examined in the HHBRA and was the basis of the development of remedial goals protective of human health (USEPA 2011). Specifically, USEPA considered uptake from the creeks to the finfish as the dominant pathway for fish and shellfish. USEPA considered uptake from the creek and marsh the dominant pathway for the clapper rail (USEPA 2011). Similarly, the BERA focuses on bioaccumulative pathways for fish, mammals, and birds using measured Aroclor 1268 tissue data for a variety of dietary food items each receptor group consumes from creek and marsh habitats. As with mercury, the direct contact pathway was considered important in the derivation of potential remedial goals for sediment-dwelling organisms.

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[5] Data provided on Table 7-9 of the BERA (Black and Veatch 2011).

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2.5.5 Conceptual Site Model Summary

The CSM presented in this section described the environmental system in words and pictures in order to help illustrate the following:

- OU1 source control measures that manage historical upland sources
- COCs migration pathways that led to the current distribution of COCs in creeks and marshes
- Human and ecological receptors of concern in this FS
- The pathways by which those receptors may be exposed to COCs

The tidal cycle is the dominant hydrogeological condition that governs how biological organisms use OU1. Aquatic animals can use most creeks throughout the tidal cycles, while they can only use portions of the marsh when sufficient water is present.

Historical releases led to the accumulation of elevated COC levels in surface sediments in the OU1 marsh. The highest concentrations appear in creeks in proximity to historical releases, namely the LCP Ditch, Eastern Creek, and Domain 3 Creek. Sediment stability helps resist the substantial erosion of sediment from creeks, though minor erosive forces that affect the upper millimeters of sediment contribute to the current distribution of COCs in other creeks and in the marsh areas.

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The OU1 BERA concluded that that there is no risk to fish in the Site from direct exposure to COCs in the water column. However, the bioaccumulation modeling and field data for finfish suggest that chronic risk from mercury and Aroclor 1268 to viability of finfish indigenous to the Site is of concern. Bioaccumulation into fish and shellfish is a pathway of concern for the humans that consume fish and shellfish. In addition, the HHBRA indicated that the bioaccumulation pathway is a concern for the consumption of clapper rail. The BERA showed that LOAEL HQs were less than 1 for all mammal and bird species except the green heron, which is used as the indicator species for this FS. The BERA indicated that all four COCs contribute to the risk for the sediment dwelling organism community.

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3 Potentially Applicable or Relevant and Appropriate Requirements

This section provides information regarding the cleanup objectives of the Site. Section 3.1 discusses potentially applicable or relevant and appropriate requirements (ARARs) considered in developing this FS. RAOs are identified and discussed in Section 3.2. The basis for RGOs is summarized, and RGO values are identified in Section 3.3.

3.1 Potentially Applicable, or Relevant and Appropriate Requirements

In accordance with federal CERCLA guidance, consideration must be given to ARARs and to other relevant information when planning a response action. Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. ARARs, while not specifically applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, are those requirements that address problems or situations sufficiently similar to those encountered at the CERCLA site, such that their use applies to the particular site. Guidance that may or may not be legally enforceable, but may contribute to the development and implementation of effective and protective sediment remedy alternatives, is to be considered (TBC) in the FS and remedy selection process.

ARARs and TBC guidance information that may contribute to defining remedial alternatives for the Site are summarized in Tables 3-1 through 3-3 and grouped into chemical-specific, location-specific, and action-specific categories. Chemical-specific ARARs specify concentration limits for environmental media defined by the state of Georgia or federal regulations. Location-specific ARARs place constraints on or define requirements for remedial activities that occur in environmentally sensitive areas (e.g., wetlands, floodplains), disposal of sediment-derived wastes, navigational constraints, and permitting requirements for treatment and disposal facilities (e.g., landfills). Action-specific ARARs govern the design, performance, or operational aspects of contaminated materials management and may be used to establish safe concentration levels for discharge of materials during implementation of a remedial action.

3.2 Remedial Action Objectives

RAOs provide general descriptions of what the cleanup is expected to accomplish (USEPA 2005a). Derived from the CSM, RAOs address the significant exposure pathways and risks associated with sediment contaminants. RAOs and RGOs should reinforce each other, leading to the selection of a remedial action that meets the NCP threshold criteria by being protective of human health and the environment and meeting ARARs, while also providing the best balance among the remaining NCP criteria (USEPA 2005a). The RAOs for this FS which were used to guide the development of remedy alternatives are listed below.

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RAO 1**:** *Mitigate potential COC releases of contaminated instream sediment deposits and prevent such releases from entering Purvis Creek.*

This RAO applies to elevated sediment COCs in Eastern Creek, LCP Ditch, the Domain 3 Creek that may contribute COCs into Purvis Creek. The goal of this RAO is to achieve, in the future, lower concentrations of COCs throughout the Site, particularly in Purvis Creek.

RAO 2: *Reduce exposure to piscivorous bird and mammal populations from ingestion of COCs in prey exposed to contaminated sediment in the estuary to acceptable levels considering spatial forage areas of the wildlife and movement of forage prey.*

This RAO addresses ecological exposures based on COCs in sediment, and will be evaluated for the ability each remedy has to meet the NCP threshold criterion of protectiveness of the environment. This RAO also attends to the NCP criteria that address short- and long-term effectiveness and reduced toxicity, mobility, and/or volume of contaminants in sediments. Remedy evaluation should consider not only long-term risk reduction associated with reduced human and ecological exposure to chemicals in sediment, but also short-term impacts of remedy implementation (USEPA 2005a).

Evaluation of this RAO includes monitoring of biological organisms and ecosystem recovery following remedy implementation.

RAO 3: *Reduce human exposure to COCs, through the ingestion of fish and shellfish, that could result in a cumulative HI greater than 1 or exceed the acceptable range for cancer risk, defined as an added health risk between 1 in 10,000 (1 x 10^{-4}) and 1 in 1,000,000 (1 x 10^{-6}).*

This RAO addresses the NCP threshold criterion of human health protection. Sediment remedies will be evaluated for their ability to reduce long-term human health risk at the Site with regard to the ingestion of fish and shellfish. The remedies also will consider the uncertainties associated with the various conservative assumptions used in the HHBRA to quantify potential health risks.

GAEPD issues advisories on eating fish and shellfish because some of these contain chemicals at levels that may be harmful to health. When reviewing fish contaminant data to derive fish advisories, GAEPD considers the fish contaminant levels and fish physical characteristics, health risks and health benefits, populations at greater potential risk, US food marketplace standards, and risk communication issues. This FS assumes that the current fish advisories will be used in conjunction with other remedial actions. The most recent fish consumption advisories for the Turtle River/Brunswick Estuary were updated in 2012. Table 2-5 summarizes fish consumption advisory improvements since 1995, including the most recent updates in 2012 (GADNR 2004, 2012).

Evaluation of this RAO includes monitoring of fish and shellfish following remedy implementation to assess changes in residual biological tissue chemical concentrations.

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RAO 4: *Reduce ecological risks to benthic organisms exposed to contaminated sediment to levels that will result in self-sustaining benthic communities with diversity and structure comparable to that in appropriate reference areas.*

> This RAO addresses ecological exposures to all four COCs in sediment—mercury, Aroclor 1268, lead, and total PAHs—and will be evaluated for the ability of each remedy to meet the NCP threshold criterion of protectiveness of the environment. This RAO also attends to the NCP criteria that address short-term effectiveness, long-term effectiveness, as well as reduction in toxicity, mobility, and/or volume of contaminants in sediments. Remedy evaluation should consider not only long-term risk reduction associated with reduced human and ecological exposure to chemicals in sediment, but also short-term risks introduced by implementing a remedy alternative (USEPA 2005a).
>
> Evaluation of this RAO involves monitoring ecosystem recovery following remedy implementation.

RAO 5: *Reduce finfish exposures from ingestion of COCs in food items exposed to contaminated sediment in the estuary to support conditions within OU1 that do not pose unacceptable adverse effects on fish.*

> Like RAO 2, this RAO addresses ecological exposures to mercury and Aroclor 1268 in sediment and each will be evaluated for the ability to meet the NCP threshold criteria of protectiveness of the environment. In addition, the NCP criteria that address short- and long-term effectiveness, as well as reductions in toxicity, mobility, and/or volume of sediments, will impact this RAO. Remedy evaluation should consider not only long-term risk reduction associated with reduced human and ecological exposure to chemicals in sediment but also short-term risks introduced by implementing a remedy alternative (USEPA 2005a).
>
> Evaluation of this RAO includes monitoring of biological organisms and ecosystem recovery following remedy implementation.

RAO 6: *Meet and sustain the applicable USEPA National Recommended Water Quality Criteria and State of Georgia Water Quality Standards for protection of aquatic life in the estuary.*

> This RAO applies to total and dissolved phase sediment COCs that may be suspended in the water column. Evaluation of this RAO would include surface water monitoring for relevant COCs.

3.3 Remedial Goal Options

The RGOs identified for this FS are used as part of the designation of SMAs. The RGOs described herein support protective management decisions that are consistent with the USEPA's *Ecological Risk Assessments and Risk Management Principles for Superfund Sites* directives (OSWER 1999).

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3.3.1 Remedial Goal Correspondence with USEPA

Two types of RGOs are considered in this FS and these reflect the manner in which human health and ecological receptors may be exposed to chemicals in the Site, SWAC RGOs, and benthic community RGOs. SWAC RGOs are concentrations averaged over site-specific exposure areas for bioaccumulative COCs. For OU1, SWAC RGOs are applied to mercury and Aroclor 1268, because these COCs are related via food web bioaccumulative pathways. Benthic community RGOs are protective of sediment-dwelling communities and reflect direct-contact exposures that occur over smaller spatial scales. For OU1, benthic community RGOs are applied to mercury, Aroclor 1268, lead, and total PAHs because these RGOs are related to the direct contact pathway.

RGOs developed for OU1 are based on the findings of the BERA and HHBRA, along with the following series of communications between the Agencies and the PRPs, which are described below and attached in Appendix G.

- Letter regarding "Approval of the Human Health Risk Assessment for the Estuary, OU1 (Estuary): LCP Chemicals Superfund Site, Brunswick, Glynn County, GA" (USEPA 2011) and associated memorandum.
  - Provide a range of RGOs deemed protective of human health and the environment
  - Allow the use of other RGO values as long as the FS provides "justification for using such ranges in its development and screening of remedial action alternatives"
  - Define the area of the benthic community over which RGOs should be applied as 50-meter by 50-meter areas (which allows for averaging of multiple results in the 50-meter by 50-meter area)
- Letter and memorandum regarding "Response to EPA's November 2011 Letter regarding Remedial Goal Option (RGO) Ranges for the Remedial Action Alternatives for OU1 (Estuary) – LCP Chemicals Site, Brunswick, GA" (Honeywell 2012).
  - Honeywell, on behalf of the PRPs, proposed a range of protective risk-based RGOs to be employed by risk managers in the FS.
  - Justification for the RGO ranges is provided.
- Agency Reply Letter "Remedial Goal Option (RGO) Ranges for the Remedial Action Alternatives for OU1 (Estuary): LCP Chemicals Superfund Site (Site), Brunswick, Glynn County, Georgia" (USEPA 2012).
  - USEPA and the GAEPD agreed to consider the broader RGO range established in the November 2, 2012, PRP letter during their review of the remedial alternatives developed for OU1 in the FS.
- Letter from USEPA, "Remedial Goal Option (RGO) Ranges for the Remedial Action Alternatives of OU1 (Estuary): LCP Chemicals Superfund Site, Brunswick, Glynn County, GA" (USEPA 2013b).

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  - USEPA and GAEPD accept the use of a range of benthic community RGOs for developing and screening remedial alternatives in the FS.

- Letter from USEPA, “Remedial Goal Option (RGO) Ranges for Remedial Action Alternatives for OU1 (Estuary): LCP Chemicals Superfund Site, Brunswick, Glynn County, GA” (USEPA 2013c).
  - Confirms that the SWAC RGOs are acceptable to USEPA and GAEPD for use in developing and screening remedial alternatives in the FS.
  - Reiterates the benthic community RGOs identified in the February 20, 2013, correspondence and the range of SWAC RGOs that are acceptable to USEPA and GAEPD for use in developing and screening remedial alternatives in the FS.

3.3.2 Site-Specific Remedial Goal Options

Consistent with USEPA (2005a) guidance, the RGOs developed for OU1 represent “a range of values within acceptable risk levels so that the project manager may consider the other NCP criteria when selecting the final cleanup levels.” The development of ecologically based RGOs should provide “a range of risk levels based on the receptors of concern identified in the ecological risk assessment.”

The following RGOs are used in this FS:

Chemical	SWAC RGOs (mg/kg)	Benthic Community RGOs (mg/kg)
Mercury	1 - 2	4 - 11
Aroclor 1268	2 - 4	6–16
Lead	NA	90 - 177
Total PAHs	NA	4

NA: Not applicable
mg/kg: milligram(s) per kilogram

3.3.3 Technical Basis for the Site-Specific RGOs

The technical basis and protectiveness of the SWAC and benthic community RGOs is described in the BERA and the RGO correspondence letters described in Section 3.3.1. Table 3-4 shows the range of preliminary RGOs identified in the BERA for mercury and Aroclor 1268, for birds, mammals, and fish; this range extends between the NOAEL and the LOAEL for each ecological receptor. Both NOAEL-based and LOAEL-based RGOs can be used to inform risk management decisions that meet the threshold criteria of protection of fish, mammal, and bird populations. Shading on Table 3-4 illustrates where the OU1 FS SWAC RGOs fall along the NOAEL and LOAEL range identified in the BERA. In all cases, the SWAC RGOs are at or

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below the respective LOAEL preliminary RGOs established in the BERA, and for several species, the range falls below the preliminary NOAEL RGO value.

Ultimately, using information from the BERA and information from the communications provided in Appendix G, the USEPA (2011 and 2013c) determined that a SWAC range of 1 to 2 mg/kg is protective of ecological receptors exposed to mercury. As seen in Table 3-4, the shading shows that this range is well within the NOAEL and LOAEL-based preliminary RGOs established in the BERA. Similarly, USEPA also established that SWAC RGOs for mercury of 1 to 2 mg/kg are protective of human exposures for the consumption of fish and shellfish. Thus, achieving the mercury RGO range of 1 to 2 mg/kg is expected to meet the threshold criterion of environmental protectiveness for human and ecological receptors.

For Aroclor 1268, and using assumptions based on the HHBRA and the communications provided in Appendix G, USEPA determined that a SWAC range of 2 to 4 mg/kg is protective of ecological receptors and human exposures. As seen in Table 3-4, the shading shows that this range is well within the NOAEL and LOAEL-based preliminary RGOs established in the BERA. The 2 to 4 mg/kg RGO range also encompasses USEPA's RGO goal for Aroclor 1268 of 3 mg/kg in the four creeks combined (Main Canal, Eastern Creek, Western Creek Complex, and Purvis Creek) (USEPA 2011 letter, Appendix G). Thus, achieving the Aroclor 1268 RGO range of 2 to 4 mg/kg and the USEPA RGO of 3 mg/kg in the four creeks combined meets the threshold criterion of environmental protectiveness for human and ecological receptors.

The technical basis for the benthic community RGOs for mercury, Aroclor, lead, and total PAHs are discussed in the BERA and in the 2012 Honeywell letter provided in Appendix G. The 2012 Honeywell letter explains how and why the benthic community RGO range is protective of sensitive organisms in the estuary and therefore meets the threshold criteria for protectiveness of the environment.

3.3.4 Current Conditions Relative to SWAC and Benthic Community RGOs

The current SWAC conditions for mercury and Aroclor 1268 are summarized on Table 3-5. The SWAC derivation approach is described in Section 5.1.

- Mercury SWAC conditions range from 0.7 mg/kg to 4.8 mg/kg in the marsh areas, with a total domain SWAC of 1.7 mg/kg. The mercury SWAC conditions range from 1.2 mg/kg to 14.6 mg/kg in the creeks, with a total creek SWAC of 2.6 mg/kg. The total estuary mercury SWAC in current conditions is 1.8 mg/kg.
- Aroclor SWAC conditions range from 0.8 mg/kg to 3.1 mg/kg in the marsh areas, with a total domain SWAC of 1.6 mg/kg. The Aroclor SWAC conditions range from 3.0 mg/kg to 43.5 mg/kg in the creeks, with a total creek SWAC of 6.0 mg/kg. The total estuary Aroclor SWAC in current conditions is 2.2 mg/kg.

Sediment COC concentrations are compared to benthic community RGOs in Figures 3-1 through 3-4 for mercury, Aroclor 1268, lead, and total PAHs, respectively. Each figure is presented in two parts: Part A maps the entire OU1 sample area and Part B focuses on the Western Creek Complex area. These figures illustrate the 50-meter averaging that was conducted for Purvis Creek and Western Creek Complex, when more than one sample was

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present within a 50-meter interval. The individual data points used for averaging and the averaged concentrations for the 50-meter x 50-meter polygons are illustrated.

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4 Identification and Screening of Remedial Technologies

This section identifies and initially screens remedial technologies to be assembled into remedial alternatives for the Site (Section 5). The technology and process screening approach described in this section is consistent with USEPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA 1988), and the technologies screened are consistent with USEPA sediment remediation guidance (USEPA 1998b, 2005a).

The evaluation of technologies potentially applicable to remedial alternatives for the Site was conducted in two steps consistent with CERCLA guidance (USEPA 1988). The first evaluation step, presented in this section, identifies an array of possible remedial technologies and evaluates these technologies based on technical effectiveness, implementability, and cost. Technologies and process options that 1) have clearly not been demonstrated as effective in addressing similar conditions at other sediment sites; 2) cannot be implemented due to site-specific conditions; or 3) do not meet the RAOs specified in Section 3 are eliminated from further consideration for the purposes of this FS. The exception is the No Action alternative, which is retained per the NCP in Title 40 Code of Federal Regulations Part 300 (NCP 1994) to serve as a basis for comparison to other effective and implementable technologies. The second evaluation step, presented in Sections 5 and 6, assembles the retained remedial technologies into a range of potentially viable remedial alternatives that are further evaluated based on the NCP criteria (USEPA 1988).

4.1 General Response Actions

Remedial technologies evaluated for possible application to OU1 at the Site were organized under general response actions (GRAs). GRAs are broad categories of conceptual sediment remediation. Consistent with USEPA (2005a), the following GRAs were identified:

1. No action serves as a basis for comparison to other effective and implementable technologies (NCP 1994).
2. Institutional controls include instruments such as administrative and legal controls, to minimize the potential for exposure and to ensure the long-term integrity of the remedy.
3. Monitored natural recovery (MNR) documents the effectiveness of natural physical, chemical, or biological processes in reducing contaminant concentrations to achieve RAOs.
4. Thin-cover placement uses sand, soil, or previously dredged sediment to enhance the process of natural recovery by placing the material on the sediment bed surface.
5. Sediment capping isolates contaminants from the water column and biological receptors by placing clean material on the sediment bed surface and armoring the cap as needed to withstand erosive forces.
6. Sediment removal includes removal of sediment via dredging or excavation, often followed by placement of a clean backfill layer, and subsequent material management, such as dewatering and disposal of the excavated sediment.

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Consistent with CERCLA guidance (USEPA 1988), this initial screening of remedial alternatives evaluates the GRAs against the following NCP Criteria: effectiveness, implementability, and cost.

Effectiveness is evaluated based on the relative ability of the technology or process option to meet the RAOs in a reasonable timeframe, ensure long-term human health and environmental protection, protect against short-term human and environmental effects during construction, and proven reliability at other sites with chemicals and conditions similar to those at the Site. Effectiveness also considers the potential for implementation of a technology or process option to generate higher, different, or unanticipated adverse human health effects or ecological impacts. Projected activities are evaluated for negative impact to community residents, changes such as disruption of baseline sediment geochemical or biological conditions that alter chemical bioavailability, increased erosion, or increased likelihood of off-site migration of contaminated sediment.

Implementability encompasses both the technical and administrative feasibility of implementing a technology or process option. Technical feasibility refers to the ability to construct, operate, maintain, and monitor the action during and after construction and meet technology-specific regulations during construction. Technical feasibility also applies to the availability of necessary equipment, personnel, and services for implementation or construction, and industry experience in implementing the remedy. Administrative feasibility refers to the ability to obtain approvals to construct the remedy (on-site response actions defined under CERCLA are exempt from the procedural requirements of federal, state, and local environmental laws, though the action must nevertheless comply with the substantive requirements of such laws).

Costs are used to compare different technologies or alternatives. While the total cost of a given technology is not normally estimated during the initial screening described in this section, relative costs of technologies (i.e., whether they are low, moderate, or high) are evaluated and compared during the initial screening phase. For this section, costs (including overall construction, operation, maintenance, and monitoring costs) are based on vendor information, cost-estimating guides, available historical information (for the Site, as well as from other similar sites), and engineering experience and judgment associated with each option. In many cases, more efficient and cost-effective remedies can accomplish the same result or can outperform less efficient, more costly remedies. Detailed costs for each alternative are developed for the comparative evaluation (Sections 6 and 7) and presented in Appendix H.

The evaluation and initial screening of potentially applicable remedial technologies for each GRA is described below and summarized on Figure 4-1.

4.2 Screening of Remedial Technologies

This section preliminarily evaluates possible remedial technologies based on technical effectiveness, implementability, and cost. Other than the No Action alternative, which is retained as a basis for comparison to other effective and implementable technologies (NCP 1994), only technologies and process options that 1) have been demonstrated as effective in addressing similar conditions at other sediment sites; 2) can be implemented at the Site; or 3) meet the RAOs specified in Section 3 are evaluated in this section.

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4.2.1 No Action

The No Action GRA is required by the NCP as the baseline case to which all other response actions and alternatives are compared.

Applicability to the Site

Under the No Action response, no remedial activities are conducted and there is no short- or long-term monitoring. No Action reflects the Site sediment conditions as they currently exist. No Action may be appropriate if a site currently meets all of the RAOs or if a previous response (e.g., upland remedial activities and source control) eliminated the need for further action.

Evaluation Against Major Screening Criteria

Initial evaluation of the No Action response against the following major NCP screening criteria can be summarized as follows:

- *Effectiveness.* This response would not change baseline sediment conditions reported in the RI report (EPS and Environ 2012), except for changes that occur naturally (e.g., natural deposition of sediments). Construction hazards and health risks to remediation workers and residential communities during remediation would be nonexistent because no action is taken as part of this alternative. However, as a result of the No Action alternative, chemical concentrations exceeding the remedial targets developed for the increased protection of ecological and human health would be left in place in sediments in both the marsh and creek areas of OU1.
- *Implementability*. Because no action is taken, this response is readily implementable.
- *Cost.* Because no action is taken, no costs apply to this option.

No Action is retained for further evaluation to serve as a baseline alternative for comparison with other remedial alternatives as required by the NCP.

4.2.2 Institutional Controls

Institutional controls are instruments (e.g., administrative or legal controls or restrictions, and informational devices) included as part of a remedial action to minimize, limit, or prevent potentially unacceptable human health or ecological exposures to contaminated media and/or protect the long-term integrity of the remedial action (USEPA 2010d). USEPA guidance on institutional controls is provided in OSWER Directive 9355.0-74FS-P, *Institutional Controls: A Site Manager's Guide to Identifying, Evaluating, and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups* (USEPA 2000a) and OSWER Directive 9355.0-106, *Strategy to Ensure Institutional Control Implementation at Superfund Sites* (USEPA 2004). Institutional controls are typically designed to work by one or both of the following approaches:

- Limiting land or resource use through land use or deed restrictions, maintenance agreements, physical restrictions (e.g., fencing or security guards) or permit conditions for future activities, and enforcement.

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- Providing information that helps modify or guide human behavior and enhance protectiveness at a site, such as notices, signage, and fish consumption advisories that may be required until RAOs are met.

Applicability to the Site

Fish consumption advisories have been issued by the GADNR for Purvis Creek and the Turtle River system due to mercury and PCB contamination of fish and shellfish in these water bodies (GADNR 2012). In addition, a commercial fishing ban was issued in Purvis Creek due to mercury and PCB levels in fish tissue that exceed Food and Drug Administration (FDA) action levels. These restrictions will likely be maintained by GAEPD until such time that the criteria for delisting are attained. This FS assumes that the current fish advisories will be used in conjunction with other remedial actions at the Site.

Permits are currently required for dredging, capping, or other in-water construction activities in OU1. USACE administers Section 404 of the Clean Water Act, which requires that a permit be obtained for the discharge of fill or dredged material in waters of the US. Section 401 of the Clean Water Act requires certification that Section 404 discharges comply with applicable WQS. The USACE also administers Section 10 of the Rivers and Harbors Act, which requires that a permit be obtained for dredging and other activities in navigable waters.

Evaluation against Major Screening Criteria

Initial evaluation of institutional controls as a response against the following major NCP screening criteria can be summarized as follows:

- *Effectiveness.* Institutional controls may supplement other engineering controls or response actions during development and evaluation of the remedial alternatives.
- *Implementability.* This response action is readily implementable.
- *Cost.* Only administrative actions are taken for this response action; therefore, capital and operations and maintenance (O&M) costs are low.

Based on the initial evaluation against the major NCP screening criteria, institutional controls are not retained as a sole remedy, but may be evaluated as a component in the development of remedial alternatives. This FS assumes that institutional controls will be used in conjunction with other remedial actions in OU1.

4.2.3 Monitored Natural Recovery

Under MNR, contaminant concentrations in sediment are reduced over time through a combination of existing environmental processes (physical, chemical, or biological) to contain, destroy, alter, or otherwise reduce the bioavailability and toxicity of contaminants (Magar et al. 2009, NRC 1997). MNR involves monitoring this process and is one of the three primary sediment remediation technologies recognized by USEPA (USEPA 2005a).

A variety of natural processes can contribute to MNR, including natural sedimentation over impacted sediments in depositional environments (e.g., off-channel areas such as river banks, marshes and turning basins), chemical transformation of contaminants (e.g., chemical reduction

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or biodegradation by native bacteria), and sequestration and stabilization (e.g., the precipitation of metals and hydrophobic chemical partitioning). Natural sedimentation and mixing can create a surface sediment layer with lower chemical concentrations through the physical burial of contaminated sediments over time (USEPA 2005a, Brenner et al. 2004, Magar and Wenning 2006). Natural sedimentation can form a protective barrier that inhibits diffusion of chemicals into the water column, minimizes the potential of contaminated sediment resuspension, and helps isolate contamination from contact with ecological and human receptors.

Predictive modeling of natural recovery processes using site-specific tools (such as sediment transport models) can be performed to predict sediment recovery rates by assessing the rate at which new sediments from upstream areas mix with existing sediments within a particular deposit, as long as uncertainties associated with such predictions are adequately addressed. Performance monitoring of sediments at specified intervals is an integral component of the MNR remedy and is used to verify model predictions and to document the presence and effectiveness of the natural processes in reducing risks. Long-term monitoring of environmental restoration recognizes that uncertainty is inherent to any cleanup activity and must be managed through data collection and monitoring (US Department of Energy (USDOE) 1997).

Provided there is source reduction or control, MNR can be implemented as a sole remedy. However, it typically is part of a larger remedial strategy incorporating other sediment alternatives for areas where natural recovery alone cannot achieve site-specific goals within a reasonable period. Institutional or engineering controls are commonly employed in conjunction with MNR, such as navigational restrictions, physical access restrictions, and future dredging restrictions. These controls minimize the potential for disruption of the natural recovery processes.

The USEPA *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA 2005a) and the US Department of Defense *Technical Guide: Monitored Natural Recovery at Contaminated Sediment Sites* (Magar et al. 2009) discuss advantages and limitations of MNR. MNR is readily implementable and reduces disturbances to the ecosystem that may jeopardize habitat and sensitive aquatic species. In addition, at sites where MNR satisfies risk-based remedial goals, MNR can effectively manage human and ecological risks. However, with MNR, contaminants are left in place and the timeframe to achieve remedial goals is typically slower than that for other remedies, such as capping or removal.

Applicability to the Site

MNR is applicable to areas where contamination is buried below cleaner stable sediment that does not exceed threshold criteria or areas where natural sediment transport may provide a source of clean sediment deposition within impacted areas.

MNR relies on source reduction, which occurred at the Site. However, high concentration deposits in the marsh, along with the potential intramarsh redistribution of sediment, can act as a secondary source and can undermine natural recovery processes.

The dominant source of uncontaminated suspended sediment to the estuary is the Turtle River; no upland tributaries flow directly into the estuary. Although the Site, and especially the

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vegetated marsh areas, are characterized as net depositional (i.e., the general propensity is for sediment particles to deposit in the marsh), deposition rates are low. The basis for this assessment is the characterization of vertical sediment profiles (EPS and ENVIRON 2012). Most of the sediment contamination resides close to the sediment surface (i.e., within the upper 2 ft.), which indicates a relatively low historical net deposition rate in the marsh. Furthermore, the general observation that surface sediment COC concentrations continue to exceed RAOs in portions of the marsh indicates that MNR alone has not adequately reduced surface sediment COC concentrations to achieve RAOs in those areas.

Evaluation against Major Screening Criteria

Initial evaluation of MNR as a response against the following major NCP screening criteria can be summarized as follows:

- *Effectiveness.* MNR is effective at sites with strong evidence for natural recovery processes. However, in areas of the Site with high residual COC levels, estimated sediment deposition rates, and other attenuation processes alone are unlikely to reduce risks within an acceptable time frame. If combined with other remedial technologies that are effective at reducing exposures to COCs, the effectiveness of MNR can be targeted for less-contaminated areas and can be demonstrated by long-term monitoring of sediment, chemical, geochemical, and biological conditions.
- *Implementability.* MNR is readily implementable for the Site because upland contaminant sources have been controlled, and because it requires no action beyond detailed Site characterization, monitoring, and possible execution and maintenance of institutional or engineering controls.
- *Cost.* MNR has a relatively low cost compared to other, more active remedial technologies. However, monitoring costs associated with MNR can be significant, particularly if monitoring is required over a large area and long duration. Even when considering monitoring and institutional control costs, costs for MNR are generally low compared to other sediment remedies.

Based on the initial evaluation against the major NCP screening criteria, MNR is not retained as a sole remedy but may be evaluated as a component of other remedies in the development of alternatives, particularly for long-term management of areas with relatively low COC concentrations.

4.2.4 Thin-Cover Placement

Thin-cover placement refers to the placement of a clean sediment layer on the sediment surface to accelerate risk reduction and to achieve RAOs. In general, thin-cover placement techniques emulate natural deposition events that occur in marsh systems during extreme storm surges. Thin-cover placement provides a cleaner sediment surface and benthic environment and thus contributes to the rapid dilution of surface sediment chemical concentrations (USEPA 2005a). The thickness of the thin cover is optimized to provide risk reduction and ecological protection while minimizing impacts to the habitat including elevation changes and severe plant/animal

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burial. Thin covers generally are less than 6 inches (15 centimeters (cm)) thick and typically are constructed using clean sediment or sand.[6] Given their shallow profile, thin-cover placement minimizes adverse impacts to the marsh hydrology and ecology associated with remedy implementation.

Bioturbators such as oligochaetes and polychaetes ingest sediments at depth and deposit materials at the surface. Bioturbation associated with these organisms is primarily confined to the upper 4 inches (10 cm) of sediment and thus does not contribute to substantial mixing of buried contaminated sediment with the clean cover material when the thin-layer cover is 6 inches (15 cm) thick (Appendix I). However, some mixing with underlying contaminants can occur—the intent of most thin-cover placement remedies is to create an acceptably clean sediment surface, not to create an impenetrable surface sediment barrier.

In many cases, clean materials can be dredged from nearby waterways instead of upland sources (e.g., quarries or mines). Dredged sediment is more likely to be organic-rich and will likely contain nutrients that support plant and wildlife growth, whereas quarried sands tend to be virtually absent of natural organic matter. For example, potential sources of material local to the Site include material from navigational dredging of both the Brunswick Harbor and the Savannah Harbor Expansion Project (SHEP), which are ongoing projects managed by the USACE Savannah District (USACE 2012 a,b). Currently, dredged materials from both projects are managed at upland dredged material containment facilities (DMCF) and ocean dredged material disposal sites (ODMDS). If the sediment from these sites are determined to be suitable for beneficial reuse at the Site, using dredged material from either project offers multiple benefits:

- Reduced energy uses because new raw material does not need to be quarried, crushed, processed, cleaned, and transported to the Site
- Increased DMCF or ODMDS capacity
- Potentially lower project costs
- Better suited material - Dredged sediment is likely to be better suited for marsh restoration than quarried sand.

Thin-cover placement has been implemented in a number of recent projects, both as part of a remedial program and for marsh restoration. Though initial impacts to marsh ecology may occur from material placement, vegetated marshes typically recover vigorously in one to two growing seasons (Appendix I).

Key case studies where thin-layer capping was used for sediment remediation are presented in Appendix I and summarized below.

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[6] Modeling was performed to predict long-term thin-cover chemical concentrations; results showed that a 15-cm (6-inch) sand cap with nominal organic content (i.e. 0.1%) would maintain chemical concentrations below RGOs for more than 100 years. Considering the protection provided by a nominal organic content, it is determined that organic amendments are not needed with the thin-cover material. Specifications for the thin-cover material, including organic carbon content, if required, will be defined during the detailed design phase. (Appendix J)

- At the East 11th Street tide flats restoration project in Washington, over 10 years of monitoring has shown successful performance of clean sand placement; low fines and reduction of COC levels below project thresholds have been documented at this site.
- At the Bremerton Naval Complex in Bremerton, Washington, the investigation of physical isolation processes supported the selection of thin-cover placement as well as dredging to address PCB- and mercury-contaminated sediments. Monitoring results over subsequent years (2003 to 2007) indicated minimal change to bathymetry and reduced concentrations in mercury when compared to native sediment over time (Magar et al. 2009, Merritt et al. 2009).
- Several remedy options (source control, institutional controls, dredging, isolation capping, thin-layer cover, and MNR) were used in Commencement Bay, Tacoma, Washington, in the nearshore tide flats (Magar et al. 2009) which had sediments impacted with PCBs, PAHs, 4-methylphenol, and volatile organic compounds (VOCs). Thin-cover placement was used in areas of moderate concern. Results indicate that remedial goals in areas where thin cover was used have been achieved. The long-term monitoring was considered complete in 2004.
- At the nearshore tidal flats in Middle Harbor, Washington, long-term monitoring demonstrated that silt and/or wood debris has naturally accumulated over the cover and the cover was found to be stable.
- At the Grasse River site in New York, postconstruction monitoring showed that average PCB concentration in the surface of the thin-layer cover was 99% lower than the preremediation value. Further, there appeared to be little mixing of the cover with underlying sediments.
- A 6-inch (15-cm) cap was placed over mercury- and PAH-impacted sediment in Wyckoff/Eagle Harbor, Puget Sound, Washington, in areas of moderate concern (Merritt et al. 2009). Postremediation monitoring events occurred between 1999 and 2007. Results indicate that the cap has remained stable. In addition, results indicate that COCs remain below criteria for most of the area except for a small area which has shown an increase in mercury concentrations in 2005. This increase is believed to be the result of lateral transport of chemicals in the absence of wider harbor source control.
- A thin cover of clean material (sand) was placed over a 4-acre PCB-impacted area in the Lower Duwamish Waterway, Seattle, Washington (Anchor 2007). The thickness of the layer was between 9 and 12 inches (23 - 30 cm). Monitoring results over subsequent years indicate that the thin-cover placement achieved its remedial goals and suggests that underlying sediments have not mixed in with surface sediments. Results of the thin-cover placement were compared with the monitoring results from an adjacent site which was remediated with MNR. Results from both techniques indicate that the final surface concentration is dominated by the waterway loading rather than by the initial treatment (MNR or enhanced natural recovery (ENR)); however, ENR is reported as having increased the recovery rate so that cleanup goals will be achieved earlier than anticipated.
- Herrenkohl et al. (2006) reports on the long-term success of thin-cover placement at a site in Ward Cover, Alaska in 2001 that was impacted with ammonia, sulfide, and 4-methylphenol. Approximately 6 inches (15 cm) of clean sand was applied over 27 acres of sediment in Ward Cove, Alaska. The effectiveness of the remedial technique was monitored three years

after initial placement of the thin cover. Results indicate that areas subjected to thin-cover placement had reduced toxicity and increased abundance and diversity of benthic communities.

Following is a summary of the case studies presented in Appendix I where thin-layer capping was used for marsh restoration:

- Leonard et al. (2002) and Croft et al. (2006) examined the effects of manually applied clean dredged materials (primarily medium sand) of varying thickness (0 to 4 inches (10 cm)) to sparsely vegetated *Spartina* and reference plots in Masonboro Island, North Carolina. Both studies found that the placement of dredged material on sparsely vegetated plots stimulated plant growth.
- Cahoon and Cowan (1987, 1988) investigated the response of salt marsh wetlands to the application of thin layers of dredged material using high-pressure spraying at Lake Coquille and Dog Lake, Louisiana. Sediment layers of 4-6 inches (10-15 cm) and 7-15 inches (18-38 cm) were applied to salt marshes at Dog Lake and Lake Coquille, respectively, and growth of vegetation was monitored. The authors found that although vegetation on the plots was still buried after 14 months, recolonization of representative marsh species was apparent.
- LaSalle (1992) revisited the Lake Coquille and Dog Lake thin-cover placement sites originally sampled by Cahoon and Cowan five years after the project began. At this time, the salt marsh at Dog Lake was no longer distinguishable from nearby references sites with regard to percent coverage of *Spartina*.
- DeLaune et al. (1990) looked at the effect of adding dredged material onto salt marsh plots in Barataria Bay, Louisiana. Dredged material was manually placed onto deteriorated salt marsh plots in two applications. The authors reported that the addition of thin layers of sediment increased aboveground biomass and density of *Spartina* shoots when compared to control areas.
- Ford et al. (1999) examined the effects of spraying sediment material onto a salt marsh in Venice, Louisiana, as a method of disposal for dredged material. Sediment was applied to a 0.5-hectare (1.2 acres) salt marsh using a high-pressure spray to a thickness of approximately 1 inch (2.3 cm). Although the high-pressure spray initially flattened vegetation, plants quickly recovered with the percent coverage of *Spartina* increasing to above preapplication coverage values. Results indicated that the treated marsh was indistinguishable from control areas with respect to sediment and vegetation properties.

Thin-cover placement is a readily implementable technology, particularly in low-energy areas not subject to scour or erosion, and as shown above, extensive research on marsh restoration projects in coastal environments has been conducted and demonstrates success in achieving remediation goals. Thin-cover placement generally is most appropriate for locations where routine disturbance (e.g., maintenance dredging) is not required to support local functions such as navigation and where institutional controls can be implemented to restrict activities that could potentially impact long-term stability. Various methods for placement of material are shown on Figure 4-2 and discussed further in Appendix I. These methods include broadcasting from land, aerial deposition, and hydraulic or pneumatic placement.

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Thin-cover placement leaves contaminants in place and could result in potential restrictions on future Site use. Such restrictions should pose little concern because state laws already protect saltwater marshes by restricting construction.

Because placement of material in vegetated marshes can potentially impact the Site hydrology and ecology if bed elevations change (e.g., subtidal areas may be converted to intertidal areas and intertidal areas may be converted to upland areas), hydrodynamic modeling was used to evaluate the impact of thin-cover caps on water flow in the marsh. Concerns about hydrology are addressed in Appendix B, through the evaluation of hydrodynamic conditions using a surface water transport model. Results of the modeling analysis show that thin-cover placement does not significantly impact tidal hydrodynamics within the marsh areas, so that wetting and drying cycles for marsh areas remain effectively unchanged.

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A monitoring program is commonly required when a thin cover is placed to remediate contaminated sediment sites. Monitoring may include visual observation (e.g., camera or video profiling) to evaluate thin-cover integrity and the potential for displacement, shifting, or erosion. Biological monitoring may be conducted to evaluate biological recovery of the thin-cover surface, and surface sediment sampling may be conducted to monitor surface sediment deposition and recontamination potential.

Applicability to the Site

Thin-cover placement is applicable to low-energy areas not subject to scour or erosion or areas where natural sediment transport may provide a source of clean sediment deposition within impacted areas. In OU1, only the existing creeks are subject to tidal erosion. The vegetated marsh areas are net depositional and are subject to a slow sediment deposition process, which make them well suited for thin-cover placement. In addition, cover materials could be placed in most, if not all areas, from land or water. Thin-cover placement minimizes adverse impacts to the marsh associated with remedy construction/implementation, which helps accelerate ecosystem recovery and minimizes some of the more permanent hydrological and biological impacts that can occur under more aggressive remedies. This is especially true if thin-cover placement relies on construction methods that do not require substantial intrusion of heavy equipment into the marsh and if thin-cover placement relies on materials that support plant growth and ecosystem recovery.

As for all remedies, thin-cover placement relies on source control, and can potentially be undermined if ongoing sources of sediment contamination are not completely eliminated. Potential Site sources that may contribute to the release of contaminants to OU1 have been identified and controlled. However, recovery of OU1 sediments also can be limited by high-concentration secondary source areas, particularly in channels, which cause persistent elevated COC levels in marsh areas. To the extent that these secondary sources are controlled, thin-cover placement can be effectively implemented within marsh areas.

Evaluation Against Major Screening Criteria

Initial evaluation of thin-cover placement as a response against the following major NCP screening criteria can be summarized as follows:

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- *Effectiveness.* Placement of a thin cover accelerates the natural recovery process and can reduce risks within a shorter, acceptable time frame. Thin-cover placement is most effective in depositional areas within vegetated marshes not subject to scouring or erosive forces. If combined with other remedial technologies that are effective at controlling secondary contaminant sources, the effectiveness of thin-cover placement can be reinforced by long-term monitoring of sediment, chemical, geochemical, and biological conditions.
- *Implementability.* Thin covers are implementable in marsh areas as these areas are accessible from land and, to a lesser extent, water.
- *Cost.* Thin-cover placement is higher in cost than MNR due to the need to purchase/acquire, transport, and place a thin layer of material on the sediment surface; however, this remedy is relatively low in cost compared to other remedial technologies such as capping or sediment removal. Like MNR, monitoring costs can be significant, but are lessened due to the acceleration of the natural recovery process; further, costs for thin-cover placement are generally low compared to other sediment remedies, even when considering monitoring and institutional control costs.

Based on the initial evaluation against the major NCP screening criteria, thin-cover placement is retained for further evaluation in the development of remedial alternatives. This FS assumes thin-cover placement is an effective and implementable technology in vegetated marsh areas to be used in conjunction with other remedial actions that address tributaries, creeks, and ditches.

4.2.5 Sediment Cap

Sediment capping involves the controlled placement of suitable materials over contaminated sediment. USEPA (2005a) identifies the following three primary cap functions: physical isolation, chemical isolation, and stabilization/erosion protection. Physical and chemical isolation separate contaminants from the surrounding environment, protect human or ecological receptors from chemical exposures, and minimize the potential for resuspension and transport. Sediment capping is a relatively mature, proven, and readily implementable technology and experience in coastal environments is extensive. However, sediment capping is generally most appropriate for locations where routine disturbance (e.g., maintenance dredging) is not required to support local functions such as navigation and where the institutional controls can be implemented to restrict activities that could potentially impact long-term stability. Some methods for placement of material are shown on Figure 4-3 and include hydraulic and mechanical placement.

Sediment caps typically comprise at least two layers—an isolation layer and an erosion protection layer—with a total thickness of at least 6 inches (15 cm). Erosion protection is employed, where required, to stabilize the isolation materials, and generally consists of the placement of gravel or riprap over the clean sand. In situations where the grain size differences between the armor and native sediments are significant, an additional filter layer may also be necessary to provide hydraulic protection. Armoring is used to stabilize caps under site-specific hydrodynamic conditions so that sediment caps may be used in higher-energy environments where currents, waves, or mechanical disturbance (e.g., propeller wash) could potentially scour the cap material. A schematic cross-section of an armored cap is shown on Figure 4-4.

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Materials commonly used in conventional capping include clean sediment, sand, or gravel (USEPA 1998b). As with thin-cover placement (Section 4.2.4), in many cases capping materials can be dredged from nearby waterways instead of relying on upland sources (e.g. quarried sands). If chemically and physically suitable for reuse at the Site, capping materials could consist of beneficial reused dredged materials from ongoing USACE dredging projects discussed in Section 4.2.4.

Optimum material thickness is determined on the basis of site-specific characterization information, natural recovery characteristics, and RAOs. The characteristics of the clean sediment used in sediment caps, such as grain size and organic carbon content, are considerations in the choice of materials to be used and are evaluated during the design.

The thickness and configuration of each cap layer is determined based on site-specific conditions, including COCs, and material properties and hydrodynamic conditions. If warranted, geosynthetics (e.g., geomembranes or geotextiles) may be incorporated into the capping system to serve as a filter layer between dissimilar materials, reinforce the cap, or decrease contaminant flow through the cap. For complex contaminants, reactive caps involving reagents (e.g., activated carbon, organoclays, or other natural or synthetic sorbents) typically added to the capping materials to decrease contaminant flow through the cap, enhance certain physical or geochemical properties or otherwise treat target contaminants may be considered. In the LCP marsh system, cap modeling results (Appendix J) indicate that reagents such as activated carbon or geosynthetics are not required to achieve the RAOs. Thus, reactive cap materials are not considered necessary and are not included in the evaluation of sediment caps at the Site. However, for areas where a sediment cap is the selected remedy, geosynthetics or reactive materials may be reconsidered during design, as long as they enhance and do not undermine cap performance, as evaluated herein.

A monitoring program is commonly required when a cap is used to remediate contaminated sediment sites. Monitoring may include bathymetric surveying and visual observation (e.g., camera or video profiling) to evaluate cap integrity and the potential for cap displacement, shifting, or erosion. Biological monitoring may be conducted to evaluate biological recovery of the cap surface, and surface sediment sampling may be conducted to monitor surface sediment deposition and recontamination potential.

Sediment capping can be implemented as a sole remedy, or in conjunction with other remedial techniques. Institutional or engineering controls, such as navigational restrictions, physical access restrictions, and future dredging restrictions, are commonly employed in conjunction with caps. Such controls minimize the potential for cap disturbance and subsequent exposure to sediment contamination by human or ecological receptors.

USEPA (2005a) discusses advantages and limitations of sediment capping. Sediment capping immediately provides a clean sediment surface and quickly reduces exposure to chemicals in surface sediments. The clean sediment surface reduces exposure to contaminants without material handling, treatment, and disposal, and often provides a clean substrate for the recolonization of benthic organisms.

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Sediment capping leaves contaminants in place and could result in potential restrictions on future use of the Site. Because sediment caps are thicker than thin covers, impacts to site hydrology and ecology[7] can be more significant and can have a longer lasting impact than MNR or thin-cover placement. The sediment cap may also alter water depths, reducing available habitat, navigation depths, and floodway conveyance. Some of these hydrology challenges can be overcome by optimizing cap design and applying caps in areas where impacts are minimized; these conditions are best evaluated using a site-specific hydrodynamic model.

Sediment capping results in unavoidable disruption of the benthic environment and usually includes at least a temporary destruction of the aquatic community and habitat within the remediation area. Sediment caps incorporating reagents or geosynthetics add implementation challenges (e.g., placement of geosynthetics or reagents, blending of reagents with cap materials). Sediment caps could also require routine repair or periodic replenishment if damaged and require long-term monitoring of its structural integrity and effectiveness.

Concerns about hydrology are addressed in Appendix B through the evaluation of hydrodynamic conditions using a surface water transport model. Concerns about marsh ecology may be addressed by minimizing capping, to the extent practicable, in vegetated marsh areas.

Applicability to the Site

Sediment capping satisfies the RAOs that seek risk reduction while minimizing construction hazards and implementation risks to construction workers and the environment. Sediment capping physically and chemically isolates site contaminants from the environment while enhancing natural recovery processes via stabilization and containment of in situ sediment.

OU1 exhibits conditions suitable for sediment capping, including the relatively high- and low-energy environments along the sediment banks within the creeks of OU1. In addition, cap materials could be placed in most, if not all areas, from land or water using a combination of approaches (e.g., hydraulic, mechanical, broadcasting).

Evaluation against Major Screening Criteria

Initial evaluation of sediment capping as a response against the following major NCP screening criteria can be summarized as follows:

- *Effectiveness.* Capping isolates contaminants and decreases surface sediment contaminant concentrations, thereby reducing risks to human health and the environment. Capping may be effective in areas that cannot be dredged due to limited accessibility or protection of sensitive habitat where the benefits of conserving existing habitat outweigh the benefits of dredging. Capping reduces risks within an acceptable time frame. Cap effectiveness is reinforced by long-term monitoring of cap integrity and biological recovery following remedy implementation.

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[7] Sediment capping can impact the Site hydrology and ecology if bed elevations change (e.g., subtidal areas may be converted to intertidal areas and intertidal areas may be converted to upland areas). Initial impacts to marsh ecology would result from placement of material, though the marsh could recover with time.

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- *Implementability*. In general, sediment capping is readily implementable, as areas are accessible from land and, to a lesser extent, water. Capping is field proven, and can be implemented in the relatively low-energy marsh environments and the high- and low-energy environments along the sediment banks within the creeks of OU1. Implementation may require executing and maintaining institutional or engineering controls.
- *Cost.* Capping costs are generally moderate. Capping usually has a lower cost than dredging and is more expensive than No Action, MNR, and thin-cover placement. Costs for reactive caps can be significantly higher than those of an engineered cap due to the additional costs of the reactive media, installation, long-term monitoring, and in some cases, replacement. Monitoring costs associated with capping can be appreciable, particularly if monitoring is required over a large area and a long duration and if extensive chemical and biological monitoring are required. Initial monitoring determines whether cap installation meets design specifications. Long-term monitoring assesses long-term remedy effectiveness.

Based on the initial evaluation against the major NCP screening criteria, sediment capping is retained for further evaluation in the development of remedial alternatives.

4.2.6 Sediment Removal and Disposal/Treatment

Sediment dredging and excavation can be performed while the sediment is submerged (mechanical or hydraulic dredging) or after water has been diverted or drained (excavation). Both methods typically necessitate transporting the sediment to an on-site location for treatment and to an on-site or off-site location for disposal.

The primary function of sediment dredging is to physically remove contaminated sediment from the aquatic environment. By removing contaminants from an impacted environment, both dredging and excavation have the potential to reduce mobility and exposure of contaminants to humans and ecological receptors. However, dredging often is confounded by the difficulty to achieve very low target chemical concentrations due to concurrent surface sediment mixing and the unavoidable resuspension, release, and subsequent deposition of resuspended sediments (residuals). To address dredged residuals, sediment removal often relies on backfilling or natural deposition to meet target remediation goals. A conceptual illustration of the hydraulic dredging processes is provided on Figure 4-5. Hydraulic and mechanical sediment removals are shown on Figure 4-6.

USACE (2008a)—*Technical Guidelines for Environmental Dredging of Contaminated Sediments*—discusses advantages and limitations of sediment removal. If sediment removal achieves cleanup levels for the site, uncertainty regarding long-term cleanup effectiveness can be reduced. Sediment removal also provides flexibility for future use of the water body without institutional controls that limit dredging or marine construction activities.

Removal can lead to surface-sediment residuals and short-term releases via resuspension, dissolution, and release to the water column. Even the most state-of-the-art dredging and excavation equipment methods have technical limitations that may result in contaminant residuals and off-site release. Sediment residuals may limit the amount of risk reduction achieved by the remedy, and consequently reduce the effectiveness of dredging (NRC 2007).

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Research has shown that sediment residuals remaining on the surface after dredging typically range from 2% to 9% of the remaining contaminated sediment mass prior to the final production dredge pass (USACE 2008b). There is a level of uncertainty associated with estimating the extent of residual contamination following removal, often making the sediment removal processes and achievement of risk-based remediation goals difficult and costly. Management of potential postremoval residuals by placement backfill material or natural recovery is commonly considered to help ensure that RAOs are achieved.

Resuspension of contaminants (dissolved or sorbed to suspended sediment particles) into the water column and potential downstream transport can result in downstream impacts, even if the removal area is enclosed by turbidity control devices. Experience at similar sites indicates that an estimated 2% to 4% of the dredged contaminant mass is typically resuspended in the water column and transported (often as dissolved-phase contaminants) out of the removal area (USACE 2008a). Sediment turbidity impacts in the removal area can be minimized in certain applications through best management practices (BMPs) such as silt curtains or temporary sheet piling. However, such BMPs are generally ineffective in reducing the downstream release of dissolved contaminants.

More so than capping and thin-cover placement, dredging plus backfill can significantly impact marsh hydrology, primarily by removing and filling small creeks and tributaries that contribute to water conveyance during flood and ebb tides. Some of these hydrology challenges can be overcome by optimizing the use of dredging so that dredging is applied in areas where impacts are minimized; these conditions are best evaluated using a site-specific hydrodynamic model.

Sediment removal unavoidably disrupts the benthic environment and usually includes at least a temporary destruction of the aquatic community and habitat within the remediation area. In addition, removal requires additional handling of dredged or excavated sediment including dewatering, transport, and disposal, each of which involves additional costs and the potential for further releases. Sediment removal also may be more complex and costly than other approaches due to accommodating equipment maneuverability, portability/site access, presence of utilities and other infrastructure, surface and submerged structures (e.g., piers, bulkheads, or pilings), overhead restrictions, and narrow creek widths.

The following subsections discuss aspects of dredging that require consideration when evaluating dredging as a component of a sediment remedy.

Sediment Dredging and Excavation

Dredging is used to describe the removal of sediment without water diversion or draining (i.e., “in the wet” under submerged-sediment conditions). Dredging is generally accomplished using one of two technologies: hydraulic (generally involves pumping sediment and water in a slurry) or mechanical (typically involves employing an excavator or crane with a clamshell bucket on a derrick barge). Photographs of hydraulic and mechanical dredging operations are shown on Figure 4-6. In contrast with sediment dredging, excavation is used to describe the removal of sediment “in the dry,” and relies on the use of excavators, backhoes, and other conventional earthmoving equipment to remove contaminated sediment after water has been diverted or drained from the site (or from portions of the site). Water diversion from the

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excavation area can be facilitated through installing temporary cofferdams, sheet piling, or other water management structures and subsequently lowering the surface water elevation within the excavation area. It should be noted that installing sheet pile or temporary cofferdams to support dry excavation could cause erosion adjacent to the work area due to constricted flow or other hydrodynamic forces. In addition, sheet pile installation may be inhibited by the presence of debris and/or other natural obstructions, and sheet pile installation and removal require heavy equipment that can be disruptive of marsh ecology.

Sediment dredging and excavation have been implemented at many sites. However, in general, dredges cannot operate in very shallow water and typically require water depths of at least 2 feet (60 cm). On the other hand, mechanical excavation typically is limited to nearshore areas accessible by conventional earthwork equipment or by the practicability of diverting flow from the remediation area to facilitate excavation.

Sediment Transportation, Dewatering, Treatment, and Disposal

Apart from actual dredging or excavating, sediment removal involves transportation of dredged material from the area being remediated to an upland staging area (i.e., barge, truck, or pipeline), usually in close proximity to the dredge area. Dewatering, treating, and disposing of dredged materials account for a major proportion of the total cost of sediment removal projects, and the ability to process the sediment may be the rate-limiting step when planning the overall schedule (USACE 2008a). In a designated staging area, sediments can be segregated, solidified, dewatered, treated, or handled for disposal. Shoreline and marine construction upgrades may be required, permits procured, and concerns with potential disruption of navigable waterways addressed to support dredging operations.

Dredged sediments can be dewatered using passive (e.g., gravity dewatering, confined disposal facilities, or geotextile tubes) or active methods (e.g., belt presses, hydrocyclones). Additives (polymers) may enhance dewaterability, but may increase the net sediment volume for disposal and are expensive. The degree of dewatering effort necessary prior to transport depends on the physical properties (e.g., grain size and permeability) of the removed sediment and the amount of free water entrained during the removal process.

The management of water removed from wet sediments is inherent to the dewatering approach. The magnitude and extent of water management requirements depends on the dredging or excavation method and the dewatering method employed. Water generated by sediment dewatering activities typically requires treatment to meet discharge requirements. Additionally, water discharges must be permitted.[8]

Treating the dredged/excavated sediment can remove, destroy, or reduce the mobility of contaminants, making the treated material suitable for beneficial reuse as structural or nonstructural fill. However, ex situ sediment treatment technologies have limited proven

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[8] As per USEPA OSWER Directive 9355.7-03, “CERCLA response actions are exempted by law from the requirement to obtain Federal, State or local permits related to any activities conducted completely on-site.” However, consultation with the permitting authority is part of the process of evaluating against the NCP criteria, and is needed to assure that the substantive requirements of relevant permits are met.

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reliability at full scale and tend to have very high costs. In addition, given the COCs at OU1, multiple treatment processes would be required, as well as pilot tests, to demonstrate effectiveness. Treatment also results in additional waste streams, such as undesirable emissions from thermal treatment processes (e.g., dioxin formation and greenhouse gases).

Removed sediment can be disposed on-site or off-site with or without pretreatment. Disposal in controlled facilities reduces contaminant mobility and human and environmental exposure to contaminants. On-site disposal entails the construction of an engineered disposal area requiring periodic inspection and maintenance to ensure its integrity and function. On-site disposal reduces risks and emissions associated with trucking for off-site disposal, and—depending on the nature of sediments to be managed—can be more cost-effective than off-site disposal. However, creating an on-site disposal area requires real property to be subject to future land use restrictions and long-term operation and maintenance. Off-site disposal alternatives are based on the types and levels of contaminant and the proximity and availability of approved and appropriate disposal facilities. In certain cases, the off-site disposal facility may impose additional specific acceptance requirements pertaining to moisture content, chemical concentration, or other physical/chemical criteria.

For the purposes of this FS, only off-site disposal is retained for further evaluation as a component of the sediment removal and disposal alternative. During design, on-site disposal may be considered if supported by the Agencies. In addition, considering the challenges associated with ex situ treatment, ex situ treatment is not retained for further evaluation as a component in the development of alternatives.

Applicability to the Site

Sediment removal satisfies the RAO goals that seek risk reduction while minimizing construction hazards and implementation risks to construction workers and the environment. Sediment removal eliminates site contaminants from the environment, thereby reducing contaminant mobility and human and ecological receptor exposure to contaminants. Both dredging and excavation are mature technologies used primarily for sediment mass removal. Though removal may have little positive impact on short-term risk reduction and would result in removal of the existing benthic community, the removal of target sediment mass is expected to effectively reduce long-term risks.

Potential postremoval residuals could be addressed by placing backfill over removal areas to enhance the natural recovery process. Construction BMPs, such as controlling removal rates, or using global positioning system (GPS) to monitor removal progress, and backfilling soon after removal is complete, can be implemented to minimize turbidity and the downstream release of dissolved contaminants.

OU1 constraints (e.g., tidal effects, drained and inundated areas, soft sediments) will impede sediment removal, and a combination of removal methods (e.g., water or land-based dredging, excavation from shorelines, or using amphibious equipment) may be required. The Site can accommodate the dredged material handling areas and operations (e.g., dewatering or solidification/stabilization), although improvements to create haul roads for transfer of sediments and a dock/berthing area may be necessary.

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Evaluation against Major Screening Criteria

Initial evaluation of sediment removal as a response against the following major NCP screening criteria can be summarized as follows:

- *Effectiveness.* Removal of sediment by dredging or excavation has been demonstrated at numerous sites. As a mass-removal or source-removal technology, dredging and excavation are both effective process options. However, sediment removal typically relies on natural recovery processes or postremoval backfill to achieve long-term, site-specific RGOs. However, considering that natural deposition rates at OU1 are slow, the removal alternatives proposed for the Site do not rely on natural recovery. Instead, backfilling is proposed to accelerate natural recovery and achieve RGOs.
- *Implementability*. Both sediment dredging and sediment excavation can be implemented within OU1 at the Site. With the exception of ex situ sediment treatment, the industry and the region have substantial experience with each of the unit processes associated with such removal approaches and all are considered implementable, though different unit processes present unique challenges at the Site. A combination of sediment dredging or excavation techniques may be required to accomplish removal of sediments within OU1.

  Monitoring of dredge depth compliance and water quality during dredging could be required to determine attainment of cleanup goals. Monitoring dredging performance and monitoring sediments after dredging is readily implementable.

  Backfilling after dredging is implementable and is expected to achieve low-concentration residuals. However, backfilling to grade is challenging and likely would achieve elevations of approximately ±6 inches (15 cm) of the original elevation. Dredging and backfilling of vegetated marsh areas also will smooth out the contours of the marsh, eliminating small tributaries and creeks that contribute to the microhydrology of the marsh.
- *Cost.* Sediment removal is generally more costly than MNR, thin-cover placement, or capping. Dredging costs can be reduced by focusing dredging to target areas, such as areas with elevated chemical concentrations, while relying on other remedies to achieve overall risk reduction. Such an approach greatly reduces the removal volume requiring dewatering and off-site disposal. Costs also are controlled by establishing an elevation-based dredging program that acknowledges the presence of residuals and manages those residuals using backfill rather than targeting low concentrations when dredging.

Based on the initial evaluation against the major NCP screening criteria, sediment removal with subsequent backfilling is retained for further evaluation as a sole remedy and also as a component in the development of remedial alternatives. This FS does not critically evaluate dredging or excavation methods or processes for sediment removal and assumes that excavation or dredging by mechanical or hydraulic means are implementable.

4.3 Overview Results of Technology Screening

The technologies and process options that are retained from the screening process are listed on Figure 4-7. These technologies and process options are carried forward for the development of remedial alternatives in Section 5. The following are the screened sediment remedy

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technologies to be evaluated as part of remedial alternatives for addressing sediment contamination in OU1 at the Site:

1. No action
2. Institutional controls
3. Thin-cover placement
4. Sediment cap
5. Sediment removal and backfill, and disposal/treatment

The No Action alternative was identified and retained as required by the NCP and will serve as a baseline condition against which other remedies are compared. Although institutional controls are not expected to serve as stand-alone remedies, they may be combined with other technologies to enhance human health protectiveness. The thin-cover placement remedy would enhance the natural recovery process, particularly in marsh areas not subject to erosion and after secondary contaminant sources are controlled by other remedial actions. Sediment capping may be employed as a sole remedy or a component of a remedial alternative, because it rapidly reduces surface sediment COC concentrations, thereby reducing or eliminating chemical exposures. Sediment dredging and/or excavation could be employed as a sole remedy or a component of a remedial alternative, because it removes the contaminant mass from the estuary. Its long-term effectiveness is enhanced when combined with natural sedimentation processes or placement of backfill over postremoval residuals, which reduces surface sediment concentrations with time. The sediment removal alternatives encompass sediment dewatering and solidification, process water management, sediment transport, and sediment disposal.

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5 Development of Remedial Alternatives

This section presents potentially viable remedial alternatives for addressing OU1 sediments and attaining the RGOs discussed in Section 3.3. The development of remedial alternatives follows a step-wise process beginning with the identification of SMAs informed by RGOs, sediment chemistry, habitat hydrology and morphology, and the risk of impairment of sensitive ecosystems. The next step in the process is the identification of remedial technologies applicable to the different habitat types in OU1 (e.g., creeks, vegetated marsh areas), considering both the effectiveness of different remedies for each of the different habitat types and the risk of impairment of sensitive ecosystems. The final step involves merging the SMAs and applicable remedial technologies to develop remedial alternatives, while accounting for the CERCLA criteria of effectiveness, implementability, and cost.

This FS evaluates SMAs and process options simultaneously with the development and evaluation of remedy process options (i.e., removal, capping, and thin-cover placement). Comparing SMAs facilitates an understanding of how achieving different RGOs results in different remedy footprints. Comparing different process options facilitates an evaluation of the risk reduction achieved by different remedy process options and the relative impacts of remediation to the marsh ecosystem. The simultaneous comparison of SMAs and process options is particularly useful when considering sensitive sites like the OU1 marsh estuary, where it is important to ensure that the steps taken to achieve risk reduction do not unnecessarily impair valuable ecological resources.

This section is organized to be consistent with the step-wise process described above:

- Section 5.1 provides the basis for the identification of three SMAs for OU1.
- Section 5.2 presents the remedial technologies applicable to the different habitats common to each SMA, based on the technologies presented and screened in Section 4.
- Section 5.3 merges the three SMAs presented in Section 5.1 with the habitat-specific remedial technologies presented in Section 5.2, creating six site-specific sediment remedy alternatives for OU1.

5.1 Delineate Sediment Management Areas

The development of remedy alternatives begins with defining three SMAs that, when remediated, will achieves the RGOs presented in Section 3.3. This section describes how the three SMAs are delineated and the decisions that went into defining each SMA, beginning with a description of the approach used for all three SMAs (Section 5.1.1), followed by a discussion of each respective SMA in Sections 5.1.2 through 5.1.4. Further details are provided in Appendix K.

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5.1.1 SMA Identification Approach

Figure 5-1 shows the delineation process used to develop the SMAs. This process is discussed in greater detail in Appendix K and in the remainder of this section.

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The OU1 SMAs were delineated by comparing the sediment data reported in Section 2.5 to the SWAC and benthic community surface sediment RGOs presented in Section 3. Each SMA represents the remedial extent necessary to meet a specified set of RGOs. Other considerations that influenced the delineation of SMAs included OU1 morphology, a risk-based evaluation of the remedy versus existing risks of COCs, and spatial (area) averaging performed on a 50-meter x 50-meter grid in accordance with the November 11, 2011, RGO letter (USEPA 2011). Each of these considerations is described in more detail below.

Defining the extent of each SMA began with identifying the areas that exceed the RGOs, as follows:

- *Direct Comparison to Benthic RGOs* – Benthic RGOs are not-to-exceed (NTE) goals. At each location, measured concentrations are compared to the RGO value for each respective COC. At each location, sediment mercury, Aroclor 1268, lead, and total PAH concentrations were compared to the range of NTE RGOs to determine whether sampled concentrations were above, below, or within the RGO range for each respective COC.
- *Spatial Averaging* – Spatial averaging was applied to tidal creeks where more than one sample was collected within a 50-meter x 50-meter area. This approach is consistent with USEPA's November 11, 2011, RGO letter (USEPA 2011) and is conservatively protective when the movement of many of the most sensitive benthic organisms is considered, as described in the November 2, 2012, Honeywell letter and memorandum (Honeywell 2012). The following approach to averaging in the creeks was employed:
    - Determine the length and width of the creeks
    - Divide the creek into 50-meter x 50-meter segments
    - Average the samples that fall within each 50-meter x 50-meter segment

  The averaging results are illustrated for the Western Creek Complex and Purvis Creek in Figures 3-1 through 3-4. For the Western Creek Complex and Purvis Creek, 50-meter x 50-meter average COC concentrations were calculated where possible, based on the data density. For each COC, the 50-meter x 50-meter average concentrations were compared to their respective benthic RGOs. Benthic RGO exceedances were defined by locations where the 50-meter x 50-meter average concentrations were greater than at least one of the Site-specific benthic RGOs.
- *Calculation of SWAC* – SWACs were calculated for mercury and Aroclor 1268 as follows:
    - SWACs were calculated using the Thiessen polygon approach as described in Appendix K.
    - Preremediation SWACs were calculated for current conditions using the existing data set presented in Section 2.4.1.
    - Postremediation SWACs were estimated by replacing current surface sediment concentrations in areas targeted for remediation with values representing postremedy surface sediment conditions. For postremedy surface sediment COC concentrations, regional background values were employed. The regional background value was based on data from the Blythe Island marsh located across the Turtle River. Regional

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background values were 0.3 mg/kg for mercury and 0.2 mg/kg for Aroclor 1268. Baseline surface SWACs for each domain, each of the creeks, and the total estuary are summarized in Table 5-1. Table 5-1 also includes postremedy SWACs for each SMA, based on further discussions below.

- *Comparison to SWAC RGOs* – Remedies that targeted only the benthic RGOs did not necessarily achieve the SWAC RGOs for Aroclor 1268 or mercury. Thus, the areas established on the basis of benthic RGO exceedances had to be expanded to further reduce site-wide surface sediment concentrations to levels that would achieve the SWAC RGOs. The expansion of SMAs to achieve the SWAC RGOs was an iterative process.
  - After identifying areas where COC levels exceeded one or more benthic RGOs, a single map was created, merging all of the polygon areas for all four COCs. The areas on the new map associated with benthic RGO exceedances were assumed remediated, so that mercury and Aroclor 1268 SWACs could be recalculated.
  - The recalculated SWACs were compared to their respective SWAC RGOs. If SWAC RGOs were not achieved, additional remediation areas were added. Additional locations were identified iteratively until each of the SWAC RGOs was achieved. Generally, this process began with locations containing the elevated residual sediment concentrations, and included other considerations such as proximity to areas already targeted for remediation, the relative sizes of the polygon areas, whether one or more COCs exceeded their respective target RGOs in a polygon, and the local hydrology and morphology of the different areas.
  - This process was performed for each of the various creeks and each of the various vegetated marsh areas and continued until the site-specific SWAC RGOs were met.

Once the SMAs meeting the range of benthic RGOs, spatial averaging, and SWAC RGOs were established, the SMAs were refined further based on the following considerations:

- *Morphology* – Marsh morphology, including the location of creek banks and the presence of small tributaries to LCP Ditch and Eastern Creek, were considered when delineating surface sediment concentrations near the boundaries of the creeks. For example, a surface concentration from a sample collected within a small tributary was confined to the boundaries of the tributary and was not extrapolated to represent a larger area in the marsh. Changes in marsh topography and vegetation also were considered when delineating surface sediment concentrations between sample points. Visual observations, LiDAR information, and geographic information system (GIS) aerial images were tools used to understand marsh morphological changes and characteristics.
- *Thiessen Polygons* – In the absence of changes in morphology, Thiessen polygon boundaries were used to delineate surface sediment chemical concentrations between sample locations. The size and shape of the Thiessen polygons were based on the position of neighboring sediment sample locations within each domain or creek.
- *Risk-of-Remedy Considerations* – Each SMA was refined based on remedy effectiveness and implementation considerations that reflect NCP balancing criteria discussed further in Section 6. Specifically, these considerations are consistent with the USEPA Superfund

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Sites Directive (1999) requiring consideration of whether “the cleanup [will] cause more ecological harm than the current site contamination?” Specifically, EPA (1999) says:

> At some sites, especially those that have rare or very sensitive habitats, removal or in-situ treatment of the contamination may cause more long-term ecological harm (often due to wide spread physical destruction of habitat) than leaving it in place. Conversely, leaving persistent and/or bioaccumulative contaminants in place where they may serve as a continuing source of substantial exposure, may also not be appropriate.

- This question considers whether removal or in situ treatment of the sediment contaminants might cause more long-term ecological harm than no remedial action due to widespread physical destruction of habitat and removal of species. Construction in the marsh involving removal or capping will result in the removal or burial of marsh plants and benthic animals, and backfilling of removal areas and small tributaries. Construction would impact hydrology, possibly in ways that are not readily anticipated or predictable, and would require construction of temporary access roads and staging areas across the marsh to access the marsh areas, further impacting the marsh ecosystem. Thus, the impacts of remediation on the marsh were weighted against the benefits of risk reduction achieved through active sediment remediation. This resulted in the identification of isolated areas that exceed RGOs but are not included in the final SMA footprint when the following conditions apply:
  - An area is defined by a single detection above the RGO and is relatively isolated with respect to other areas exceeding RGOs.
  - It is possible that damage to a large portion of the marsh may occur, even in areas without chemical concentrations exceeding RGOs, in order to access areas where concentrations exceeded or only marginally exceeded RGOs.

  Although excluding these areas reduced the spatial extent of the SMAs, the final SMAs and corresponding remedial alternatives are still designed to meet the NCP Threshold Criteria of 1) overall protectiveness of human health and the environment and 2) achievement of ARARs (Section 6).

5.1.2 Sediment Management Area 1

SMA-1 (Figure 5-2) encompasses areas where COC concentrations exceed the lower end of the benthic community RGOs (i.e., where concentrations are greater than 4 mg/kg mercury, 6 mg/kg Aroclor 1268, 90 mg/kg lead, or 4 mg/kg total PAHs), and achieves the low-end SWAC RGOs for mercury (1 mg/kg) and Aroclor 1268 (2 mg/kg). By applying these criteria, and using spatial averaging, morphology, and Thiessen polygons, remediation of 81 acres is required to achieve the most conservative RGO criteria for all four chemicals, considering both NTE and SWAC criteria (Figure 5-2).

In accordance with USEPA’s (1999) Superfund Sites Directive, each polygon area was further evaluated from a risk-of-remedy perspective to consider whether sediment removal/treatment might cause more long-term ecological harm than good, that is, the impacts of remediation on the marsh are weighted against the benefits of risk reduction achieved through active sediment remediation. Figure 5-2 also identifies the following areas within the 81-acre footprint that were excluded to minimize impacts to the marsh where the expected risk reduction is small:

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- Domain 4 –OU1 comprises a number of vegetated marshes bounded by creeks or other waterways, and remedy implementation must consider the impacts of remediation on those vegetated marsh areas.

  Five locations in Domain 4 were identified with concentrations above the low-end NTE RGOs for mercury or total PAHs. Each location is relatively isolated in the marsh with low chemical concentrations above the RGOs applied to this SMA. For example, the four Domain 4 mercury concentrations exceedances of 4.6 to 6.8 mg/kg and the single total PAH exceedance of 8.0 mg/kg only slightly exceeded the benthic community RGOs of 4 mg/kg for mercury and 4 mg/kg for total PAHs, and the locations of these concentrations were surrounded by sample locations with concentrations below their respective RGO values. Remediation of these areas solely for the protection of the benthic community would cause significant damage to the marsh vegetation and wildlife habitat with minimal contaminant risk reduction. Therefore, the negative impacts of remediation in Domain 4 outweigh the benefits of risk reduction.

- Dillon Duck – Increased topographic elevations and vegetation changes characterize the upstream (eastern) end of Dillon Duck. Though the eastern half of Dillon Duck is characterized by a single sample (located on the western edge of the subject area) with a lead concentration of 280 mg/kg, this area (0.77 acres) is not expected to have elevated chemical concentrations because of its higher topographic elevations and overall location relative to the adjacent upland features. Figure 3-3 shows sediment sample results in Dillon Duck, located adjacent to this area and at lower elevations that are consistent with adjacent marsh areas. Remediation of this area would potentially jeopardize the stability of the adjacent freshwater pond and provide minimal additional protection of benthic organisms of the adjacent marsh.

- Domain 1 Nearshore Remediated Area – A single shoreline sample in the remediated area of Domain 1 was defined by a detection of lead at 210 mg/kg; this lead sample is located in the marsh near the eastern shoreline of Domain 1 (Figure 3-3). Ecological exposures at this 1.6 acre polygon area are low, because the area is inundated with water approximately one to two hours per day at high tide. Because exposure times to sediment-dwelling organisms upon which the RGOs are based are limited, and because this single sample was surrounded by samples below the low-end RGO for lead (i.e., <90 mg/kg), remediation of this location would cause significant damage to the marsh with minimal contaminant risk reduction.

- An initial scenario was conducted to compare reduction of SWACs between the 81 acre footprint and the remaining 48 acre footprint. The scenario assumed dredging of all 81 acres. Table 5-1 shows that the postremediation SWAC of the 81-acre scenario is not significantly different from the remaining 48-acre SWAC.

SMA-1, as defined solely by RGOs, encompasses a total of 81 acres. A dredge-all remedy would involve removal of sediments occupying the entire 81-acre SMA, plus the construction of temporary roads to access remote areas of the marsh. Postremediation SWAC values for SMA-1, based on the 48-acre footprint, are included in Table 5-1 for comparison with postremediation SWAC values for the 81-acre footprint.

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An 81-acre dredge remedy was considered by the project team and in consultation with USEPA and GAEPD. As discussed above, however, SMAs are not solely defined by RGOs. Remedies must weigh contaminant risk reduction against ecosystem impairments—in this case, including destruction of benthos, marsh vegetation, and wildlife habitat. Because remediating 33 of the 81 acres would cause significant damage to the marsh while providing minimal contaminant risk reduction (Table 5-1), the SMA-1 footprint is defined as 48 acres rather than 81 acres. The green shading on Figure 5-2 identifies areas that were excluded from the 81-acre remediation footprint.

5.1.3 Sediment Management Area 2

SMA-2 (Figure 5-3) encompasses areas where COC concentrations exceed the upper end of the protective range of benthic community RGOs (i.e., where concentrations are greater than 11 mg/kg mercury, 16 mg/kg Aroclor 1268, 177 mg/kg lead, or 4 mg/kg total PAHs). SMA-2 also achieves the SWAC RGO ranges for mercury (1-2 mg/kg) and Aroclor 1268 (2-4 mg/kg). By applying these criteria, and using spatial averaging, morphology, and Thiessen polygons, the areal extent of SMA-2 is 25 acres (Figure 5-3).

Similar to SMA-1 and in accordance with USEPA’s (1999) Superfund Sites Directive, each polygon area was evaluated from a risk-of-remedy perspective to consider whether sediment removal/treatment might cause more long-term ecological harm than anticipated risk reduction; that is, the impacts of remediation on the marsh are weighted against the benefits of risk reduction achieved through active sediment remediation. Figure 5-3 identifies the following areas within the 25-acre footprint of SMA-2 where the degree of risk reduction was small relative to the marsh impacts:

- Domain 4 Total PAH Polygon – West of Purvis Creek in Domain 4, a single polygon recorded a total PAH concentration of 8 mg/kg, which is above the 4 mg/kg RGO. Surrounding samples were below 4 mg/kg. For the same reasons described for SMA-1, remediation of this single polygon would cause significant damage to the marsh with little contaminant risk reduction.
- Purvis Creek – On the northern side of Purvis Creek, Aroclor 1268 was detected at a concentration of 18 mg/kg, which is only slightly higher than the benthic community RGO of 16 mg/kg. At a second location, on the south side of Purvis Creek, total PAHs were detected at a concentration of 7.2 mg/kg, as compared to the RGO of 4 mg/kg. Both sample locations were surrounded by polygons with measured concentrations below their respective RGOs. Remediation of these locations would result in minimal reduction of the overall risk to sediment-dwelling organisms in Purvis Creek and thus would contribute little to improving the benthic community.
- Domain 3 Creek – At the northern end of Domain 3 Creek, mercury was detected at a concentration of 13 mg/kg and Aroclor 1268 was detected at 17 mg/kg; both conditions only slightly exceed their respective benthic community RGOs of 11 mg/kg and 16 mg/kg. Furthermore, both are surrounded by chemical concentrations below the benthic community RGOs. Remediation of these locations would do little to reduce the overall risk in the Domain 3 Creek, causing significant damage to the marsh with minimal contaminant risk reduction.

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- Dillon Duck – The eastern end of Dillon Duck was excluded from SMA-2 for the same reasons as described for SMA-1 (Section 5.1.2).
- Domain 1 Nearshore Remediated Area – The single lead exceedance in the marsh along the eastern shoreline of Domain 1 is excluded from SMA-2 for the same reasons as described for SMA-1 (Section 5.1.2).

SMA-2, as defined solely by RGOs, encompasses a total of 25 acres. As discussed above, however, SMAs are not solely defined by RGOs. Remedies must weigh contaminant risk reduction against ecosystem impairments—in this case, including destruction of benthos, marsh vegetation, and wildlife habitat.

Postremediation SWAC values for SMA-2, based on the 18-acre footprint, are included in Table 5-1, along with postremediation SWAC values for the 25-acre remedy. As described above and depicted in Figure 5-3, the benefits of risk reduction was considered small relative to impacts to the marsh ecosystem in areas represented by isolated polygons where COC concentrations were only marginally above their respective site-specific RGOs and were surrounded by polygons with concentrations below the RGOs, and in the upstream (eastern) end of Dillon Duck. This exercise identified 7 of the 25 acres that would cause significant damage to the marsh while providing minimal contaminant risk reduction. Thus, the SMA-2 footprint is defined as 18 acres rather than 25 (Figure 5-3). The green shading on Figure 5-3 identifies areas that were excluded from the 25-acre remediation footprint.

5.1.4 Sediment Management Area 3

SMA-3 (Figure 5-4) encompasses the same area as SMA-2, and includes additional potential COC-impacted areas in Purvis Creek and Domain 1. These additional areas were identified for the following reasons:

- Addressing areas in Purvis Creek and Domain 1 helps achieve lower SWAC-based RGOs for mercury and Aroclor 1268 in both areas.
- Because most of Purvis Creek is permanently submerged, even at low tide, ecological exposure times are longest in Purvis Creek. Consequently, a reduction in Purvis Creek SWAC levels is expected to contribute to a commensurate improvement in fish COC concentrations.
- SMA-2 considers that remediation in locations in Purvis Creek would result in minimal reduction of the overall risk in Purvis Creek and thus would contribute little to improving the ecosystem. However, SMA-3 identifies additional locations in Purvis that result in beneficial SWAC reductions. If accessed by water or coordinated with the LCP Ditch work, dredging in south Purvis Creek and an area in north Purvis Creek will not adversely impact vegetated marsh areas beyond that which is already expected in order to address SMA-2.
- The area proposed for Domain 1 is located immediately adjacent to areas were other work (i.e., work in LCP Ditch and Eastern Creek) is already planned, making an expansion into Domain 1 easily implementable with minimal additional impacts to vegetated marsh areas beyond the areas targeted for remediation in Domain 1.

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The total area of SMA-3 is 24 acres and is presented in Figure 5-4. Postremediation SWAC values for SMA-3 are included in Table 5-1. The SMA-3 area is shown using brown shading and the expansions into Purvis Creek and Domain 1a are shown using yellow shading.

5.2 Remedial Technologies Applicable to Remedial Subareas

In Section 5.1, the SMAs were defined to target the range of RGOs, while considering morphology, hydrology, and habitat. Adjustments were made to the SMAs to minimize the impacts to vegetated marsh areas by refining areas where RGO exceedances 1) were only marginally above the target RGO value, 2) were surrounded by polygons with concentrations below the target RGO range, 3) occurred in relatively remote areas (e.g., deep in Domain 4) where construction access would further destroy vegetated marsh habitat, and 4) were overall located relative to adjacent upland features. The outcome of this exercise was the development of two SMAs (SMA-1 and SMA-2). After the development of SMA-1 and SMA-2, additional adjustments were made to expand the SMA-2 remediation area by incorporating areas in Purvis Creek and in Domain 1, leading to the identification of SMA-3.

This section focuses on the applicability of the screened remedial technologies (Section 4) to remedial subareas identified in the SMAs. Geographic, morphologic, hydrologic, and other physical characteristics are used to subdivide the SMA remedial areas into vegetated marsh areas (Section 5.2.1) and marsh creeks (Section 5.2.2). The applicability of screened remedial technologies to each specific marsh area and creek is evaluated in consideration of both site-specific risk criteria and physical conditions to assess remedy effectiveness and implementability of the removal, capping, or thin-cover process options. The area-specific analysis in this section provides a basis for the development of sediment remedial alternatives in Section 5.3.

5.2.1 Vegetated Marsh Areas

OU1 comprises a number of vegetated marshes bounded by creeks or other waterways, including Domain 1a, Domain 2, Domain 3, and Dillon Duck. Remedial technology implementation is impacted by accessibility to the vegetated marshes; in some areas, potential short- and long-term ecological impacts of the remedy may outweigh the limited risk reduction benefits of implementing a remedial technology, as discussed below. The following is an evaluation of remedial technology effectiveness and implementability for vegetated marsh areas within SMAs 1, 2, and 3.

Remedy Implementability Considerations

Vegetated areas are considered for remediation within Domain 1a, Domain 2, Domain 3, and Dillon Duck. The areas in Domain 1a, Domain 2, and Domain 3 are located around Eastern Creek, LCP Ditch, Western Creek Complex, and Domain 3 Creek. The Dillon Duck area is bound by upland areas to the north, east, and south, and the Domain 3 Creek to the west.

Tidal cycles result in diurnal flooding and drainage of the vegetated marsh areas, limiting accessibility for both land-based and aquatic-based equipment. Areas along LCP Ditch, Eastern Creek, Western Creek Complex, and Domain 3 Creek are accessible only from upland areas because the creeks are narrow and completely drain at low tide making aquatic access from Purvis Creek impracticable. Land-based access to the Domain 1a, Domain 2, and Domain

3 remedial areas requires constructing temporary access roads to establish surface elevations at least 1 foot (30 cm) above the mean high water elevation so operations can be performed above water. These roads would be used to access remedial areas and facilitate material (e.g., excavated material, backfill material, cover or capping material) transport to and from each remediation area. Upon completion of construction activities, the roads would be removed or integrated into the remedial action, such as using the road material as backfill after sediment removal.

Work also could be performed using low-ground-pressure earthmoving equipment staged on upland areas or temporary access roads; however, tide conditions would limit the time permitted to perform work without temporary access roads even if using low-pressure equipment. Where water-based operations are possible (i.e., in areas that are adequately submerged for sufficiently long periods to be able to efficiently mobilize and implement the remedy), work could be performed during flood tide. Multiple staging areas would be required to facilitate and optimize material handling, access, and management. Movement of materials in and out of the marsh areas must be coordinated around the tide cycle, whether using land-based or aquatic-based equipment.

The configuration and location of Dillon Duck makes this area accessible only by land. Given the relatively soft nature of wetlands materials, land-based access to the Dillon Duck remedial area would require constructing temporary access roads with surface elevations at least 1 foot (30 cm) above the existing ground surface. These roads would be spaced about 100 feet (30 meters) apart and used to access remedial areas and facilitate the transfer of construction materials (e.g., excavated material, backfill material, cover or capping material). Upon completion of the construction activities, the roads would be dismantled or integrated as part of the remedial action. The shallow water depths in Dillon Duck do not permit water-based operations without damming or otherwise controlling surface water elevations in the creek.

Remedy Effectiveness Considerations

The following discussion considers the effectiveness of thin-cover placement, capping, and removal in the vegetated marsh areas. The evaluation of thin-cover placement, capping, and sediment removal in marsh areas involved consideration of the benefits of risk reduction achieved by each remedy, physical and ecological impacts to the marsh ecosystem, and physical impacts to marsh hydrology. Most of the vegetated marsh areas exhibit relatively low-risk conditions, with COC concentrations infrequently above the upper end of the RGO range (these areas are captured in SMA-2).

Thin-Cover Placement. Thin-cover placement achieves the project-specific RAOs with the least physical impact on the marsh ecosystem, and thus with minimal unintended negative impacts, due to the following:

- A thin cover of clean sediment immediately reduces surface sediment chemical concentrations and achieves levels below the low-end RGOs in the upper 6 inches (15 cm).
- The introduction of heavy equipment on the marsh can be minimized, compared to dredging and capping.

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- Given their shallow profile, thin covers do not substantially change the marsh bed elevations and thus do not substantially impact hydrology, so that wetting and drying cycles for marsh areas remain effectively unchanged. Minimizing the potential for impacts on hydrology helps minimize ecological impacts.
- Though initial impacts to marsh ecology may occur from material placement, vegetated marshes typically recover vigorously in one to two growing seasons (Appendix I).
- The thin-cover material can be selected and specified to optimize ecological conditions for plant growth and benthic colonization.

Based on these considerations, thin-cover placement is retained for consideration in the Domain 1, Domain 2, and Domain 3 marsh areas.

Capping. Similar to thin-cover placement, capping achieves the project-specific RAOs by reducing surface sediment chemical concentrations to levels below the target RGOs. Capping involves placement of clean sediment material—an engineered chemical isolation layer—to establish a low-concentration sediment surface. Cap armoring is used to maintain cap stability under a range of current velocities.

The thickness of an engineered cap is expected to be greater than the thickness of a thin cover, though in some cases the two may be relatively comparable depending on design requirements. Thicker caps more negatively impact surface water hydrology and habitat. Additional cap considerations include the following:

- Heavy equipment is required to install an engineered cap so that the chemical isolation material is carefully placed according to remedy design specifications. Roads also must be built to access cap areas, further impacting the marsh ecosystem.
- Capping impacts the existing ecosystem due to its potential to fill small tributaries, change surface sediment elevations and corresponding hydrology and ecology, and bury existing vegetation and benthos.
- Marsh plants and benthic animals are covered by capping, and recovery generally is slower than with thin-cover placement. Restoration efforts, such as replanting, may accelerate recovery after remediation.
- For marsh areas, armoring can hinder the pace or extent of habitat restoration over capped areas.

Capping is likely to impact the marsh ecosystem in vegetated areas more substantially than thin-cover placement. Capping can substantially alter elevations, fill tributaries, and cover marsh plants and benthos. In vegetated marsh areas, capping would cause more damage to the marsh ecosystem than thin-cover placement while achieving minimal additional risk reduction. Therefore, capping is not carried forward for further consideration in the vegetated marsh areas.

Removal. For the marsh areas of OU1, removal involves the excavation of sediment, followed by backfilling with a clean sediment layer. Because removal alone may not achieve low surface sediment chemical concentrations due to the presence of residuals, backfilling is used to create

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a relatively clean sediment surface. When combined with backfilling, sediment removal is expected to meet the RGO criteria. This remedial technology achieves the project-specific RAOs but may cause short-term impacts on the marsh ecosystem, including the following:

- Removal must be performed with heavy equipment to excavate and backfill marsh areas. Roads also must be built to access sediment removal areas, further impacting the marsh ecosystem.
- Removal completely excavates the existing sediment surface and established benthic community. While backfilling would fill the removal areas, small tributaries would be removed and backfilled, temporarily impacting hydrology in ways that are not readily anticipated or predictable.
- Backfilling returns sediment removal areas to grade, and thus helps minimize changes to the marsh bed elevations, which in turn minimizes potential impacts to hydrology. However, backfilling exactly to an existing grade is challenging. Removal and placement of materials in an aquatic environment is generally performed within a level of precision of ± 6 inches (15 cm), depending on site-specific conditions and contractor capabilities and skills. An elevation change of ± 6 inches (15 cm) is within the tolerance of the thin-cover placement technology and capping, and thus is not expected to impact hydrologic conditions more than thin-cover placement, assuming that dredging and backfilling are conducted within a ± 6-inch tolerance.
- Marsh plants and benthic animals are removed with sediment removal. Restoration efforts, such as replanting, accelerate recovery after remediation and minimize short-term impacts on the ecosystem. However, the success of replanting efforts varies depending on site-specific conditions, and generally is slower than for thin-cover placement.

Because it is the only technology that removes contamination from the marsh environment, removal is retained for further evaluation in the marsh areas. In summary, thin-cover placement and sediment removal are retained for evaluation as remedial technologies for the vegetated marsh areas within OU1.

5.2.2 Marsh Creeks and Ditches

Four main creeks (i.e., Eastern Creek, Western Creek Complex, Domain 3 Creek, and Purvis Creek) and a constructed ditch (LCP Ditch) subdivide OU1 east of Purvis Creek. Sediment removal is a viable technology for all creeks and ditches, and sediment capping is feasible for creeks and ditches provided that its implementation does not restrict water conveyance. Although all creeks and ditches are net depositional, they are subject to periods of high flow during flood and ebb tides. Tidal flows in the marsh have been modeled (Appendix B) to predict the range of velocities that can occur in the creeks and ditches and to assess the stability and need for cap armoring. The results of the model analysis indicate that cap armoring is generally needed in the creeks, rendering thin-cover placement inapplicable to creeks and ditches.

Both sediment removal with subsequent backfilling and capping achieve the project-specific RAOs by creating a clean sediment surface that meets the RGO target concentrations:

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- Removal involves excavating sediment followed by backfilling with a clean sediment layer to address dredge residuals and to create a relatively clean sediment surface.
- Capping, which involves the placing a clean isolation layer on the sediment surface followed by an armoring layer, also creates a clean sediment surface.
- Implementing both sediment removal/backfilling and sediment capping must be performed with heavy equipment. Roads also must be built to access remedial areas, impacting the creek ecosystem beyond the areas targeted for remediation. Though sediment removal/backfilling and capping can impact the existing ecosystem, confining activities to the channel areas minimizes impacts to the vegetated marshes and other habitat areas.
- Capping with armoring and sediment removal with backfill will temporarily impact marsh habitat during construction. Short-term impacts could be minimized by controlling placement methods, material selection, and reducing the cap profile to the extent practicable while still achieving site-specific RAOs.
- The hydrologic impacts of capping with armoring and sediment removal with backfill have been examined using the hydrodynamic model. The model demonstrated that neither technology will permanently and adversely influence surface water hydrodynamics, as measured by flow velocities and wetting/drying cycles (Appendix B). However, capping with armoring and removal with backfilling have the potential to fill small creeks and tributaries, potentially impacting hydrology in ways that may not be anticipated or predictable. To the degree possible, impacts to creek hydrology will be minimized during design.
- Backfilling of sediment removal areas to grade minimizes changes to the marsh bed elevations, thus minimizing potential impacts to hydrology. Removal and placement of materials in an aquatic environment is generally performed within a level of precision of ± 6 inches (15 cm), depending on site-specific conditions.
- Some impacts to marsh plants and benthic animals cannot be avoided, as access roads are required for both sediment removal/backfilling and sediment capping. Restoration of vegetated areas, such as replanting, is used to accelerate recovery after remediation and minimize short-term impacts on the ecosystem.

The following sections evaluate remedial technology implementation and ecological impacts for specific creeks and ditches of OU1.

Purvis Creek

Purvis Creek is the primary tidal channel that connects the Site to the Turtle River. Purvis Creek subdivides the marsh areas approximately in half and connects to several secondary creeks (e.g., Eastern Creek, the Western Creek Complex, LCP Ditch, Domain 3 Creek). Purvis Creek is subject to relatively high flows and elevated velocities approaching 2 ft/sec during peak tidal flows. Under these flow conditions, conventional thin covers are not stable without adequate armoring. For this reason, only capping and removal are evaluated for Purvis Creek.

Both sediment removal and armored sediment capping are technically viable technologies for Purvis Creek. While both remedial options produce temporary impacts to the benthic communities, these communities are expected to recover over time. Both sediment

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removal/backfilling and sediment capping incorporate the placement of a clean streambed surface.

Areas within south Purvis Creek could be accessed by water. Work in south Purvis Creek would not be interrupted by tides, whereas work in north Purvis Creek would be interrupted by tides. In north Purvis Creek, tides would impact ingress and egress of equipment, material and personnel transport, and construction schedules. Because remediation areas in north Purvis Creek are isolated from other remedial areas, access via land requires construction of a network of temporary access roads and procurement of access agreements from adjoining property owners, possibly making land access even more difficult than aquatic access. Construction of these roads would impact vegetated marshes, including areas where remediation is not required.

Both sediment removal and capping can be performed using equipment staged on shallow draft barges. Sediment can be excavated during ebb tide and mechanically or hydraulically dredged during high tide. Similarly, sediment caps can be mechanically or hydraulically constructed. For either operation, a single staging area is required to facilitate and optimize material handling, access, and management. This staging area could be located near the causeway, which runs parallel to the northern shore of LCP Ditch, to support water-based operations and material management (either sediment removed or capping materials).

In summary, sediment capping and sediment removal are retained for evaluation as remedial technologies for Purvis Creek, both to be implemented as water-based operations supported by staging near the causeway. Productivity and accessibility of equipment, material and personnel from work areas would be limited by tidal effects, particularly in the isolated remedial areas of north Purvis Creek.

Eastern Creek and LCP Ditch

The Eastern Creek is connected to LCP Ditch (a constructed channel that connects the Site to Purvis Creek along the southern edge of the causeway). The Eastern Creek and LCP Ditch exhibit some of the highest COC concentrations, thereby potentially acting as secondary sources to other creeks and marsh areas. Although capping could effectively prevent exposure and future migration, because of the high COC concentrations and the need to prevent future transport to other areas of marsh, sediment removal is deemed the most appropriate remedy for Eastern Creek and LCP Ditch.

Remedial work within Eastern Creek and LCP Ditch can be conducted by land or water; tides will limit productivity and accessibility of equipment, material, and personnel in either case. Land-based access to Eastern Creek and LCP Ditch requires constructing temporary access roads across the soft sediments of Domain 1a and may require improving the causeway to facilitate access to remedial areas and the transfer of materials (e.g., excavated material, backfill material). Temporary access roads across the soft sediments of the marshes would be spaced about 100 feet (30 meters) apart, with surface elevations at least 1 foot (30 cm) above the mean high water elevation. The same roads could be used for marsh area remedy implementation and upon completion of construction activities, removed or integrated in the remedial action (e.g., used as backfill).

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In summary, only sediment removal is retained for evaluation as a remedial technology for Eastern Creek and LCP Ditch, to be implemented as land-based or water-based operation supported by staging near the mouth of LCP Ditch or the mouth of Eastern Creek. Due to tidal effects, productivity and accessibility of equipment, material, and personnel from work areas may be limited.

Western Creek Complex

The Western Creek Complex is the southernmost secondary channel connected to Purvis Creek and is composed of three main branches. Because remedial areas within the Western Creek Complex are discontinuous and isolated from other remedial areas within the creek, capping discrete areas would likely result in the creation of troughs and valleys within the narrow and shallow Western Creek Complex; these troughs would likely restrict flow conveyance, especially at low tides, and thus could negatively impact the vegetated marshes surrounding the creek. Therefore, sediment capping is not retained for evaluation for the Western Creek Complex, and sediment removal is considered the only viable remedial alternative in this area.

Remedial areas within the Western Creek Complex could be accessed by land or water, although tides would affect ingress or egress of equipment, material, and personnel from work areas. Access via land requires constructing a network of temporary access roads and procuring access agreements from adjoining property owners. Construction of these roads would impact surrounding marshes, including those where remediation is not required, to access remedial areas and transfer materials (e.g., excavated material, backfill material). The temporary access roads across the soft sediments of the marshes would have surface elevations at least 1 foot above the mean high water elevation. The roads would be removed upon completion of the construction activities or integrated as part of the remedial action.

In summary, sediment removal is the only remedial technology evaluated for the isolated and discontinuous remedial areas of the narrow and shallow channels comprising the Western Creek Complex. Sediment removal would be implemented with a land-based operation supported by staging near the mouth of LCP Ditch. Productivity and accessibility of equipment, material, and personnel from work areas may be limited by tidal effects.

Domain 3 Creek

The Domain 3 Creek is the northernmost secondary channel connected to Purvis Creek. The northern portion of this creek is directly connected to the upper reaches of Purvis Creek. The southern reach of the Domain 3 Creek is indirectly connected to the central portion of Purvis Creek. Domain 3 Creek also is connected to the Dillon Duck marsh. Both sediment removal and armored sediment capping are applicable to the Domain 3 Creek.

The impact of potential remedies on surface water hydrology was investigated using the hydrodynamic model (Appendix B). Placement of 12 inches (30 cm) of material is required for sediment capping and armoring, and additional thickness may result from construction tolerances. Model results show that the placement of a cap along the Domain 3 Creek is not expected to substantially impact the marsh hydrology.

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Remedy areas within Domain 3 Creek could be accessed by land or water, though land-based access is more likely due to the creeks' proximity to land. Tides will affect ingress or egress of equipment, material, and personnel from work areas. Land-based access to the Domain 3 Creek requires constructing a number of temporary access roads across the soft sediments of Domain 3 marshes and upland areas. These roads would be used to access remediation areas and to transfer materials (e.g., excavated material, backfill material). The temporary access roads across the soft sediments of the marshes would need to have surface elevations at least 1 foot above the mean high water elevation. Upon completion of construction activities, the roads would be dismantled or integrated as part of the remedial action.

To overcome tidal effects and upland area accessibility constraints, sediments can be excavated or capped using low-ground-pressure earthmoving equipment staged on upland areas or the temporary access roads. However, to facilitate and optimize material handling, access, and management, multiple staging areas may be required.

In summary, sediment excavation and sediment capping are evaluated for remedial areas within the Domain 3 Creek.

5.3 Development of Remedial Alternatives

Six remedy alternatives were developed for this FS, including the No Action alternative. The five other alternatives were developed by combining SMAs (Section 5.1) and the remedial technologies process options (i.e., thin-cover placement, capping, and sediment removal) applicable to each remedial area (Section 5.2), as appropriate to achieve the site-specific RAOs. In this section, the six remedial alternatives are characterized briefly based on the CERCLA criteria of effectiveness, implementability, and cost. The six remedial alternatives listed below incorporate source control, monitoring, and institutional controls. The alternatives are summarized in Table 5-2 and are discussed in the following Sections 5.3.1 through 5.3.6, respectively. Common elements to all alternatives are presented in Section 5.3.7.

- Remedy Alternative 1: No Action
- Remedy Alternative 2: Sediment Removal in SMA-1
- Remedy Alternative 3: Sediment Removal, Capping, and Thin-Cover Placement in SMA-1
- Remedy Alternative 4: Sediment Removal in SMA-2
- Remedy Alternative 5: Sediment Removal, Capping, and Thin-Cover Placement in SMA-2
- Remedy Alternative 6: Sediment Removal, Capping and Thin-Cover Placement in SMA-3

Sections 5.3.1 through 5.3.6 describe the general engineering scope and implementation considerations of each remedial alternative. The evaluation process presented in this section is consistent with USEPA guidance (1988, 2005a) and CERCLA requirements to evaluate a range of remedial strategies for a given site. In Section 6, the alternatives are evaluated against the full range of NCP evaluation criteria.

The sediment remedies will be required to meet substantive Georgia and federal permit requirements for waterfront activities associated with disturbance to state and federal navigable

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waters. It is possible that state and/or federal substantive permitting requirements could alter the remedies described in this section. The nature of changes to one or more of the sediment remedy alternatives cannot be ascertained until the permitting process has been completed and regulatory requirements are known. However, at this time, it is not anticipated that permitting requirements would fundamentally alter the overall conclusions and recommendations presented in this FS.

5.3.1 Sediment Remedy Alternative 1: No Action

Pursuant to the requirements of the NCP to identify baseline environmental conditions in the absence of remediation, the No Action remedial alternative is included in the analysis for comparison to other alternatives. This remedial alternative reflects baseline river sediment conditions as described in the OU1 RI (EPS and ENVIRON 2012), and entails no further action for remediation of the OU1 sediments. With the No Action remedial alternative, natural recovery processes are expected to continue and institutional controls—namely fish advisories already in place for Purvis Creek and the Turtle River system, an existing commercial fishing ban for Purvis Creek, and permitting requirements or restrictions—are maintained.

5.3.2 Sediment Remedy Alternative 2: Sediment Removal in SMA-1

Remedy Alternative 2 combines sediment removal, institutional controls, and long-term monitoring in the 48-acre SMA-1 remediation area. Specifically, this remedy alternative calls for sediment removal and backfilling within Eastern Creek, Western Creek Complex, LCP Ditch, Purvis Creek, the Domain 3 Creek, Dillon Duck, and the vegetated marshes of Domain 1a, Domain 2, and Domain 3 (Figure 5-5 and Table 5-3).

Sediment Removal and Backfilling

The limits of dredging and backfilling for Remedy Alternative 2 are shown on Figure 5-5. The proposed sediment removal area is approximately 48 acres, distributed as summarized in Table 5-3.

In proposed sediment removal areas, removal targets a depth of 18 inches (46 cm), where the sediment chemistry is expected to meet the RGOs. For the purpose of this FS, the estimated in-place sediment volume targeted for removal in Remedy Alternative 2 is approximately 153,000 cubic yards (CY). Following removal, the remedial areas are backfilled with 12 inches (30 cm) (or approximately 96,000 CY) of clean material (e.g., sand) to manage risks associated with postremoval residuals, accelerate the natural recovery process, and establish a clean sediment surface. Vegetated marsh areas would be replanted with native plants to promote and accelerate habitat recovery.

Remedy Alternative 2 relies on dredging and/or sediment excavation to remove sediments, followed placement of backfill to control residuals. The construction of various sediment management/staging areas and temporary access roads is required to facilitate material management and sediment excavation. Debris must be removed during sediment removal, either during excavation/dredging or as part of a separate debris removal operation, which may hinder or slow sediment removal. The distribution of submerged debris is expected to be relatively high, particularly in sediment removal areas that have not been historically dredged or

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maintained and in nearshore areas. Debris will be disposed off-site at licensed facilities. Sediments will be dewatered on-site and disposed at licensed off-site facilities.

Short- and Long-Term Monitoring Requirements for Remedy Alternative 2

As part of the remedy design process, both short- and long-term maintenance and monitoring programs will be developed to ensure long-term remedy protectiveness. Short-term monitoring determines whether remedy implementation meets design specifications. Long-term monitoring recognizes that uncertainty is inherent to any cleanup activity and must be managed through data collection and monitoring (USDOE 1997).

Short-term monitoring activities will span the construction phase and will be defined during the remedy design phase. Monitoring could include soundings and surveys to verify removal depths, depth verification measurements to document backfill material placed, and/or backfill material coverage assessments.

Long-term remedy monitoring measures the remedy's long-term effectiveness in enhancing ecosystem recovery and reducing risks to human health and the environment. Details of the long-term monitoring program will be developed during remedial design, and may include the following:

- Physical measurements to monitor the integrity of backfilled areas (e.g., bathymetric surveys, push cores, or visual observation via camera or video profiling)
- Visual observations and surveys of marsh recovery, including plant growth and plant density
- Chemical measurements in fish and shellfish
- Chemical measurements in sediment
- Surface water quality measurements, as necessary to comply with ARARs

5.3.3 Sediment Remedy Alternative 3: Sediment Removal, Capping and Thin-Cover Placement in SMA-1

Remedy Alternative 3 combines sediment removal, sediment capping, and thin-cover placement with institutional controls and long-term monitoring (Figure 5-6 and Table 5-3) to address the 48-acre SMA-1 remediation area. This alternative includes sediment removal and backfilling in Eastern Creek, Western Creek Complex, and LCP Ditch and capping in Purvis Creek and Domain 3 Creek. Thin covers would be placed within Dillon Duck and the vegetated marshes of Domain 1a, Domain 2, and Domain 3.

Sediment Removal and Backfilling

The limits of dredging and backfilling for Remedy Alternative 3 are shown on Figure 5-6. The proposed sediment removal area is approximately 9 acres, distributed as summarized in Table 5-3.

In proposed sediment removal areas, removal targets a depth of 18 inches (46 cm), where the sediment chemistry is expected to meet the RGOs. For the purpose of this FS, the estimated in-place sediment volume targeted for removal in Remedy Alternative 3 is approximately

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27,000 CY. Following removal, the remedial areas will be backfilled with 12 inches (30 cm) (or approximately 17,000 CY) of clean material (e.g., sand) to manage risks associated with postremoval residuals, accelerate the natural recovery process, and establish a clean sediment surface. Marsh areas would be replanted with native plants to promote and accelerate habitat recovery.

Remedy Alternative 3 relies on dredging and/or sediment excavation to remove sediments, followed by placement of backfill to control residuals. The construction of various sediment management/staging areas and temporary access roads is required to facilitate material management and sediment excavation. Debris must be removed during sediment removal, either during excavation/dredging or as part of a separate debris removal operation, which may hinder or slow sediment removal. The distribution of submerged debris is expected to be relatively high, particularly in sediment removal areas that have not been historically dredged or maintained and in nearshore areas. Debris is disposed off-site at licensed facilities. Sediments will be dewatered on-site and disposed at licensed off-site facilities.

Sediment Capping

The limits of sediment capping for Remedy Alternative 3 are shown on Figure 5-6. The proposed sediment capping area is approximately 16 acres, distributed as summarized in Table 5-3.

Sediment caps isolate underlying sediment contaminants; control chemical migration, physical erosion, and biological contact with underlying sediment contaminants; and provide a clean sediment surface for habitat restoration. As detailed in Appendix J, preliminary cap design evaluations were performed in general accordance with USEPA guidance and using conservative assumptions (e.g., maximum sediment concentrations and peak shear stresses). These evaluations were used to conceptually design the thickness and material size for the cap armor layer to ensure that the cap retains its integrity under worst-case shear stress conditions. The analysis in Appendix J shows that a 6-inch base chemical isolation layer with up to 6 inches (15 cm) of coarse sand-to-gravel armoring adequately protects against chemical migration through the cap as well as erosive forces resulting from storm events.

Cap material placement could be performed as a water-based operation (north and south Purvis Creek) and a land-based operation (Domain 3 Creek). Given shallow water depths, narrow creeks, and tidal effects, the cap may need to be placed by small mechanical equipment (e.g. backhoe or similar excavator with a fixed arm or a telescoping conveyor belt) operating from the shoreline and/or a shallow-draft barge. The construction of various material staging areas and temporary access roads is required to facilitate material management and sediment cap placement. While the anticipated distribution of submerged debris is expected to be relatively high because the proposed sediment removal areas have not been periodically maintained, debris will remain in place unless it interferes with capping operations. Any removed debris will be disposed off-site at licensed facilities.

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Thin-Cover Placement

The limits of thin-cover placement for Remedy Alternative 3 are shown on Figure 5-6. The proposed thin-cover placement area is approximately 23 acres, distributed as summarized in Table 5-3.

Thin cover placement targets the low-energy/lower-risk vegetated marsh areas to reduce risks to human health and the environment and provide a clean sediment surface for habitat recovery while minimizing construction impacts to the marsh environment. For this site, thin-cover placement is best suited for the vegetated marsh environments as they minimize the negative ecological impacts of sediment capping (e.g., loss of aquatic habitat, potential changes in marsh inundation patterns) and implementation concerns with sediment removal (e.g., destruction of marsh habitat, areas of limited accessibility). Based on a literature review of thin-cover placement in marsh and wetlands restoration case studies (Ray 2007), it is anticipated that remediated areas will recover within two growing seasons. A detailed summary of research related to thin-cover placement, including marsh recovery time and issues related to bioturbation, is provided in Appendix I.

Thin-cover materials could be placed as a water-based operation and/or a land-based operation, in which materials are broadcast mechanically or pneumatically or sprayed hydraulically. If placement is a water-based operation (e.g., portions of vegetated marshes abutting the Eastern Creek or LCP Ditch), the equipment is staged along the shoreline and/or from shallow-draft barges. Land-based placement of thin covers (e.g., Dillon Duck or inland portions of all other vegetated marshes) requires constructing a limited number of temporary access roads to place thin-cover materials. Both land- and water-based operations require constructing a limited number of staging areas to facilitate material transport and manage operations. Submerged debris, if any, will remain in place.

Short- and Long-Term Monitoring Requirements for Remedy Alternative 3

As part of the remedy design process, both short- and long-term maintenance and monitoring programs will be developed to ensure long-term remedy protectiveness. Short-term monitoring determines whether remedy implementation meets design specifications. Long-term monitoring recognizes that uncertainty is inherent to any cleanup activity and must be managed through data collection and monitoring (USDOE 1997).

Short-term monitoring activities will span the construction phase and will be defined during the remedy design phase. Monitoring could include soundings and surveys to verify removal depths, depth verification measurements to document material placed, and/or material coverage assessments.

Long-term remedy monitoring measures the remedy's long-term effectiveness in enhancing ecosystem recovery and reducing risks to human health and the environment. Details of the long-monitoring program will be developed during remedial design, and may include the following:

- Physical measurements to monitor cap integrity (e.g., push cores, bathymetric surveys, or visual observation via camera or video profiling)

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- Visual observations of marsh recovery and surveys, including plant growth and plant density
- Chemical measurements in fish and shellfish
- Chemical measurements in sediment
- Surface water quality measurements, as necessary to comply with ARARs

Although caps are designed to withstand high-energy event flows, they may require repair if damaged by erosion or unexpected environmental conditions (e.g., extreme storm events), particularly if such events occur before marsh grasses are restored in remediated areas. The extent of these potential repairs will be evaluated during programmed Site inspections (e.g. annual, biennial or triennial) or Site inspections following major storm events.

5.3.4 Sediment Remedy Alternative 4: Sediment Removal in SMA-2

Remedy Alternative 4 combines sediment removal with institutional controls and long-term monitoring in the 18-acre SMA-2 remediation area. Specifically, this remedy alternative calls for sediment removal and backfilling within Eastern Creek, LCP Ditch, the Domain 3 Creek, Dillon Duck, and vegetated marsh areas of Domain 1a and Domain 2 (Figure 5-7 and Table 5-3).

Sediment Removal and Backfilling

The limits of dredging and backfilling for Remedy Alternative 4 are shown on Figure 5-7. The proposed sediment removal area is approximately 18 acres, distributed as summarized in Table 5-3.

In proposed sediment removal areas, removal targets a depth of 18 inches (46 cm), where the sediment chemistry is expected to be compliant with the RGOs. For the purpose of this FS, the estimated in-place sediment volume targeted for removal in Remedy Alternative 4 is approximately 57,000 CY. Following removal, the remedial areas will be backfilled with 12 inches (or approximately 36,000 CY) of clean material (e.g., sand) to manage risks associated with postremoval residuals, accelerate the natural recovery process, and establish a clean sediment surface. Vegetated marsh areas would be replanted with native plants to promote and accelerate habitat recovery.

Remedy Alternative 4 relies on dredging and/or sediment excavation to remove sediments, followed by placement of backfill to control residuals. The construction of various sediment management/staging areas and temporary access roads is required to facilitate material management and sediment excavation. Debris must be removed during sediment removal, either during excavation/dredging or as part of a separate debris removal operation, which may hinder or slow sediment removal. The distribution of submerged debris is expected to be relatively high, particularly in sediment removal areas that have not been dredged or maintained and in nearshore areas. Debris is disposed off-site at licensed facilities. Sediments will be dewatered on-site and disposed at licensed off-site facilities.

Short- and Long-Term Monitoring Requirements for Remedy Alternative 4

As part of the remedy design process, both short- and long-term maintenance and monitoring programs will be developed to ensure long-term remedy protectiveness. Short-term monitoring

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determines whether remedy implementation meets design specifications. Long-term monitoring recognizes that uncertainty is inherent to any cleanup activity and must be managed through data collection and monitoring (USDOE 1997).

Short-term monitoring activities will span the construction phase and will be defined during the remedy design phase. Monitoring could include soundings and surveys to verify removal depths, depth verification measurements to document backfill material placed, and/or backfill material coverage assessments.

Long-term remedy monitoring measures the remedy's long-term effectiveness in enhancing ecosystem recovery and reducing risks to human health and the environment. Details of the long-monitoring program will be developed during remedial design, and may include the following:

- Physical measurements to monitor backfilled areas or recovery processes (e.g., push cores, bathymetric surveys, or visual observation via camera or video profiling)
- Visual observations and surveys of marsh recovery, including plant growth and plant density
- Chemical measurements in fish and shellfish
- Chemical measurements in sediment
- Surface water quality measurements, as necessary to comply with ARARs

5.3.5 Sediment Remedy Alternative 5: Sediment Removal, Capping and Thin-Cover Placement in SMA-2

Remedy Alternative 5 combines sediment removal, sediment capping, and thin-cover placement with institutional controls and long-term monitoring (Figure 5-8 and Table 5-3) to address the 18-acre SMA-2 remediation area. This alternative includes sediment removal and backfilling in Eastern Creek and LCP Ditch, capping in Domain 3 Creek, and thin-cover placement in Dillon Duck and the vegetated marshes of Domain 1a and Domain 2.

Sediment Removal and Backfilling

The limits of dredging and backfilling for Remedy Alternative 5 are shown on Figure 5-8. The proposed sediment removal area is approximately 7 acres, distributed as summarized in Table 5-3.

In proposed sediment removal areas, removal targets a depth of 18 inches (46 cm), where the sediment chemistry is expected to meet the RGOs. For the purpose of this FS, the estimated in-place sediment volume targeted for removal in Remedy Alternative 5 is approximately 22,000 CY. Following removal, the remedial areas are backfilled with 12 inches (30 cm) (or approximately 14,000 CY) of clean material (e.g., sand) to manage risks associated with postremoval residuals, accelerate the natural recovery process, and establish a clean sediment surface. Vegetated marsh areas would be replanted with native plants to promote and accelerate habitat recovery.

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Remedy Alternative 5 relies on dredging and/or sediment excavation to remove sediments, followed by placement of backfill to control residuals. The construction of various sediment management/staging areas and temporary access roads is required to facilitate material management and sediment excavation. Debris must be removed during sediment removal, either during excavation/dredging or as part of a separate debris removal operation, which may hinder or slow sediment removal. The distribution of submerged debris is expected to be relatively high, particularly in sediment removal areas that have not been historically dredged or maintained and in nearshore areas. Debris is disposed off-site at licensed facilities. Sediments will be dewatered on-site and disposed at licensed off-site facilities.

Sediment Capping

The limits of sediment capping for Remedy Alternative 5 are shown on Figure 5-8. As summarized in Table 5-3, the proposed sediment capping area is approximately 3 acres of the Domain 3 Creek.

Sediment caps isolate underlying sediment contaminants, control chemical migration, physical erosion, and biological contact with underlying sediment contaminants, and provide a clean sediment surface for habitat restoration. As detailed in Appendix J, preliminary cap design evaluations were performed in general accordance with USEPA guidance and using conservative assumptions (e.g., maximum sediment concentrations and peak shear stresses). These evaluations were used to conceptually design the thickness and material size for the cap armor layer to ensure that the cap retains its integrity under worst-case shear stress conditions. The analysis in Appendix J shows that a 6-inch base chemical isolation layer with up to 6 inches (15 cm) of coarse sand-to-gravel armoring adequately protects against chemical migration through the cap, as well as erosive forces under extreme storm events.

Cap placement could be performed as a land-based operation due to the creeks' proximity to land. Given shallow water depths, narrow creeks, and tidal effects, cap placement may require small mechanical equipment (e.g., backhoe or similar excavator with a fixed arm, or a telescoping conveyor belt). Land-based access to the Domain 3 Creek requires constructing a small number of temporary access roads across the soft sediments of Domain 3 marshes and upland areas. Constructing various material staging areas is also required to facilitate material management and sediment cap placement. While the anticipated distribution of submerged debris is relatively high since the proposed sediment removal areas have not been periodically maintained, debris will remain in place unless it interferes with capping operations. Debris is disposed off-site at licensed facilities.

Thin-Cover Placement

The limits of thin-cover placement for Remedy Alternative 5 are shown on Figure 5-8. The proposed thin-cover placement area is approximately 8 acres, distributed as summarized in Table 5-3.

Thin-cover placement targets the low-energy/lower-risk vegetated marsh areas to reduce risks to human health and the environment and provide a clean sediment surface for habitat recovery, while minimizing construction impacts to the marsh environment. For this site, thin covers are best suited for the vegetated marsh environments as they minimize the negative

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ecological impacts of sediment capping (e.g., loss of aquatic habitat, potential changes in marsh inundation patterns) or implementation concerns with sediment removal (e.g., destruction of marsh habitat, areas of limited accessibility). Based on a literature review of thin-cover placement in marsh and wetlands restoration case studies (Ray 2007), it is anticipated that remediated areas will recover within two growing seasons.

Thin-cover materials could be placed as a water-based operation and/or a land-based operation, in which materials are broadcast mechanically or pneumatically, or sprayed hydraulically. If placement is a water-based operation (e.g., portions of vegetated marshes abutting the Eastern Creek or LCP Ditch), the equipment is staged along the shoreline and/or from shallow-draft barges. For land-based placement of thin covers (e.g., inland portions of vegetated marshes), constructing a limited number of temporary access roads is required. For both water- and land-based operations, constructing a limited number of staging areas to facilitate material transport and management operations is required. Submerged debris, if any will remain in place.

Short- and Long-Term Monitoring Requirements for Remedy Alternative 5

As part of the remedy design process, both short- and long-term maintenance and monitoring programs will be developed to ensure long-term remedy protectiveness. Short-term monitoring determines whether remedy implementation meets design specifications. Long-term monitoring recognizes that uncertainty is inherent to any cleanup activity and must be managed through data collection and monitoring (USDOE 1997).

Short-term monitoring activities will span the construction phase and will be defined during the remedy design phase. Monitoring could include soundings and surveys to verify removal depths, depth verification measurements to document material placed, and/or material coverage assessments.

Long-term remedy monitoring measures the remedy’s long-term effectiveness in enhancing ecosystem recovery and reducing risks to human health and the environment. Details of the long-monitoring program will be developed during remedial design, and may include the following:

- Physical measurements to monitor cap integrity (e.g., push cores, bathymetric surveys, or visual observation via camera or video profiling)
- Visual observations and surveys of marsh recovery, including plant growth and plant density
- Chemical measurements in fish and shellfish
- Chemical measurements in sediment
- Surface water quality measurements, as necessary to comply with ARARs

Although caps are designed to withstand high-energy event flows, they may require repair if damaged by erosion or unexpected environmental conditions (e.g., extreme storms), particularly if such events occur before marsh grasses are restored. The extent of these potential repairs will be evaluated during programmed Site inspections (e.g., annual, biennial or triennial) or Site inspections following major storm events.

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5.3.6 Sediment Remedy Alternative 6: Sediment Removal, Capping and Thin-Cover Placement in SMA-3

Remedy Alternative 6 combines sediment removal, sediment capping, and thin-cover placement with institutional controls and long-term monitoring (Figure 5-9 and Table 5-3) to address the 24-acre SMA-3 remediation area. This alternative includes sediment removal and backfilling in Eastern Creek and LCP Ditch, capping in Purvis Creek and Domain 3 Creek, and thin-cover placement in Dillon Duck and the vegetated marshes of Domain 1a and Domain 2.

Sediment Removal and Backfilling

The limits of dredging and backfilling for Remedy Alternative 6 are shown on Figure 5-9. The proposed sediment removal area is approximately 7 acres, distributed as summarized in Table 5-3.

In proposed sediment removal areas, removal targets a depth of 18 inches (46 cm), where the sediment chemistry is expected to meet the RGOs. For the purpose of this FS, the estimated in-place sediment volume targeted for removal in Remedy Alternative 6 is approximately 22,000 CY. Following removal, the remedial areas will be backfilled with 12 inches (30 cm) (or approximately 14,000 CY) of clean material (e.g., sand) to manage risks associated with postremoval residuals, accelerate the natural recovery process, and establish a clean sediment surface. Vegetated marsh areas would be replanted with native plants to promote and accelerate habitat recovery.

Remedy Alternative 6 relies on dredging and/or sediment excavation to remove sediments, followed by placement of backfill to control residuals. The construction of various sediment management/staging areas and temporary access roads is required to facilitate material management and sediment excavation. Debris must be removed during sediment removal, either during excavation/dredging or as part of a separate debris removal operation, which may hinder or slow sediment removal. The distribution of submerged debris is expected to be relatively high, particularly in sediment removal areas that have not been dredged or maintained and in nearshore areas. Debris is disposed off-site at licensed facilities. Sediment is dewatered on-site and disposed at licensed off-site facilities.

Sediment Capping

The limits of sediment capping for Remedy Alternative 6 are shown on Figure 5-9. The proposed sediment capping area is approximately 6 acres, distributed as summarized in Table 5-3.

Sediment caps isolate underlying sediment contaminants; control chemical migration, physical erosion, and biological contact with underlying sediment contaminants; and provide a clean sediment surface for habitat restoration. As detailed in Appendix J, preliminary cap design evaluations were performed in general accordance with USEPA guidance and using conservative assumptions (e.g., maximum sediment concentrations and peak shear stresses). These evaluations were used to conceptually design the thickness and material size for the cap armor layer to ensure that the cap retains its integrity under worst-case shear stress conditions. The analysis in Appendix J shows that a 6-inch base chemical isolation layer with up to 6 inches

(15 cm) of coarse sand-to-gravel armoring adequately protects against chemical migration through the cap as well as erosive forces under extreme storm events.

Cap placement could be performed as a water-based operation (north and south Purvis Creek) and a land-based operation (Domain 3 Creek due to proximity to land). Given shallow water depths, narrow creeks, and tidal effects, cap placement may require small mechanical equipment (e.g., backhoe or similar excavator with a fixed arm, or a telescoping conveyor belt) operating from the shoreline and/or a shallow-draft barge. Land-based access to the Domain 3 Creek requires construction of a small number of temporary access roads across the soft sediments of Domain 3 marshes and upland areas. Construction of various material staging areas and temporary access roads is required to facilitate material management and sediment cap placement. While the anticipated distribution of submerged debris is expected to be relatively high since the proposed sediment removal areas have not been periodically maintained, debris will remain in place unless it interferes with capping operations. Any removed debris will be disposed of off-site at licensed facilities.

Thin-Cover Placement

The limits of thin-cover placement for Remedy Alternative 6 are shown on Figure 5-9. The proposed thin-cover placement area is approximately 11 acres, distributed as summarized in Table 5-3.

Thin-cover placement targets low-energy/lower-risk vegetated marsh areas to reduce risks to human health and the environment and provide a clean sediment surface for habitat recovery, while minimizing construction impacts to the marsh environment. For this site, thin-cover placement is best suited for the vegetated marsh environments as they minimize the negative ecological impacts of sediment capping (e.g., loss of aquatic habitat or potential changes in marsh inundation patterns) and implementation concerns with sediment removal (e.g., destruction of marsh habitat and areas of limited accessibility). Based on a literature review of thin-cover placement in marsh and wetlands restoration case studies (Ray 2007), it is anticipated that remediated areas will recover within two growing seasons.

Thin-cover materials could be placed as a water-based operation and/or a land-based operation in which materials are broadcast mechanically or pneumatically or sprayed hydraulically. If placement is a water-based operation (e.g., portions of marshes abutting the Eastern Creek or LCP Ditch), equipment would be staged along the shoreline and/or from shallow-draft barges. For land-based placement of thin cover (e.g., inland portions of marshes), construction of a limited number of temporary access roads is required. Both land- and water-based operations require construction of a limited number of staging areas to facilitate material transport and management operations. Submerged debris, if any, will remain in place.

Short- and Long-Term Monitoring Requirements for Remedy Alternative 6

As part of the remedy design process, both short- and long-term maintenance and monitoring programs will be developed to ensure long-term remedy protectiveness. Short-term monitoring determines whether remedy implementation meets design specifications. Long-term monitoring of environmental restoration recognizes that uncertainty is inherent to any cleanup activity and must be managed through data collection and monitoring (USDOE 1997).

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Short-term monitoring activities will span the construction phase and will be defined during the remedy design phase. Monitoring could include soundings and surveys to verify removal depths, depth verification measurements to document material placed, and/or material coverage assessments.

Long-term remedy monitoring measures the remedy's long-term effectiveness in enhancing ecosystem recovery and reducing risks to human health and the environment. Details of the long-monitoring program will be developed during remedial design, and may include the following:

- Physical measurements to monitor cap integrity (e.g., push cores, bathymetric surveys, or visual observation via camera or video profiling)
- Visual observations and surveys of marsh recovery, including plant growth and plant density
- Chemical measurements in fish and shellfish
- Chemical measurements in sediment
- Surface water quality measurements, as necessary to comply with ARARs

Although caps are designed to withstand high-energy event flows, they may require repair or if damaged by erosion or unexpected environmental conditions (e.g., extreme storms), particularly if such events occur before marsh grasses are restored. The extent of these potential repairs will be evaluated during programmed Site inspections (e.g., annual, biennial or triennial) or Site inspections following major storm events.

5.3.7 Elements Common to All Remedial Alternatives

Several common elements are relevant to OU1 remedial alternatives including source controls, existing regulatory requirements, existing institutional controls, and site-wide monitoring. Related assumptions that are also common to all remedial alternatives, other than Alternative 1 (No Action), include the following:

- Known upland sources of contamination to OU1 (i.e., sources associated with historical industrial discharges and overland runoff and identified in Table 7-1 of the RI report; EPS and ENVIRON 2012) have been controlled.
- A hydrodynamic assessment was performed (Appendix B) to determine whether modifications to the marsh and channel areas resulting from remedy implementation have the potential to adversely affect the hydrologic characteristics of the marsh. Remedies were analyzed to minimize the potential for negative hydrologic impacts while achieving RGOs. Under all conditions evaluated, the analysis indicated that likely hydrologic impacts to the marsh resulting from remedy implementation are minimal.
- Physical constraints across Purvis Creek (e.g., remnants of a bulkhead and bridge, potential cross-channel utilities, and debris) can hinder remedy implementation and must be evaluated during remedy design.
- Institutional controls will be maintained as necessary—namely fish advisories already in place for Purvis Creek and the Turtle River system, and an existing commercial fishing ban

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for Purvis Creek. With time, when fish chemical concentrations fall below the criteria to maintain the fish advisories and/or commercial fishing ban, the state of Georgia may elect to remove the advisories and/or commercial fishing ban. Current USACE permit requirements for dredging, capping, or other construction activities under Section 401 and 404 of the Clean Water Act will also serve as institutional controls for future construction in and adjacent to OU1 at the Site.

- Where incorporated as part of a remedial alternative, thin-cover placement consists of a nominal 6 inches (15 cm) of sand to be broadcast or placed mechanically.
- Where incorporated as part of a remedial alternative, sediment caps are assumed to consist of a chemical isolation layer (approximately 6 inches (15 cm)) of sand based on preliminary chemical flux evaluations presented in Appendix J) overlain with 6 inches (15 cm) of coarse sand-to-gravel armor material for physical isolation. Based on the preliminary hydrodynamic modeling presented in Appendix B, the sediment cap will be armored as needed to resist peak flow velocities in the marsh creeks and ditches. For the purpose of this FS, it is also assumed that the sediment cap requires no amendments, reagents or geosynthetics, based on the results of preliminary cap modeling (Appendix J).
- Where incorporated as part of a remedial alternative, sediment removal designs will be "elevation-based." Removal entails the excavation or dredging of 18 inches (46 cm) of sediment and backfilling with 12 inches (30 cm) of clean material.
- The exact methods to be used to reduce potential sediment suspension and contaminant release will be assessed during remedy design. Construction BMPs, such as operational controls (controlling the bite size or limiting the removal rates) and specialty equipment (e.g., environmental clamshell buckets with open/closed sensors and GPS tracking to track progress) will be used during sediment removal operations to reduce potential contaminant release. BMPs will be specified in the detailed design phase.
- Where required, dewatering and water treatment will be performed as practicable at an on-site dewatering area. Removed materials (e.g., dewatered sediment) will be disposed at licensed off-site disposal facilities in conformance with applicable federal and state environmental laws and regulations.
- To the extent that materials dredged from nearby waterways (e.g., Brunswick Harbor and Savannah Harbor) meet state criteria, these materials could be reused beneficially at the Site as backfill, capping, or cover materials.
- Material and equipment staging areas and dock/berthing facilities for loading/offloading of materials (backfill, capping materials, cover materials, or dredged/excavated materials) will be constructed. In addition, shoreline and marine construction upgrades may be implemented, permits procured, and concerns about potential disruption of navigable waterways addressed.
- Construction activities within OU1 are anticipated to take place over a 1-to-2-year period (depending on the alternative), following remedial alternative selection, remedial design, and to meet substantive permit requirements. To the extent that water-based operations are implemented, accessibility of equipment, material, and personnel from work areas is limited by tidal effects and consequently will extend the implementation schedule.

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- Where required and as detailed for the selected remedial alternative, maintenance and monitoring will be performed. Future remedial design evaluations may be required for any remedial alternative selected. Details of the construction monitoring will be developed during remedial design.
- The time to achieve remediation goals (i.e. RGOs) for removal, capping, and thin-cover placement coincides with the time to implement each remedy. That is, because all three technologies rely on the placement of clean material on the sediment bed surface to achieve RGOs, the RGOs are achieved as soon as implementation is complete; approximately 2 years for SMA-2 and SMA-3 and approximately 3 to 4 years for SMA-1. Shellfish and fish concentration reductions will require much longer (years or decades, respectively) to reach equilibrium with reduced surface sediment concentrations. The time for habitat recovery also is expected to be much longer. Within approximately 2 years after construction, *Spartina* growth is expected to recover. However, full functionality of the marsh ecosystem will require more time—years to decades depending on the remedy. For example, thin-cover placement will recover more quickly than removal because it retains the natural organic matter in the sediments.

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6 Detailed Evaluation and Comparative Analysis of Alternatives

This chapter evaluates and compares the six remedy alternatives identified in Section 5 according to NCP 40 CFR 300.430(e)(9)) criteria. The NCP criteria are introduced in Section 6.1, including an introduction to USEPA (2008b) environmental sustainability principles for remediation projects. Section 6.2 contains a detailed comparative analysis of the six alternatives in accordance with the NCP, as well as a discussion of how remedial action in OU1 can support environmental sustainability objectives consistent with USEPA (2008b) guidance. Section 6.3 discusses Site-specific environmental sustainability goals and how they may impact remedy implementation.

6.1 Overview of NCP Evaluation Criteria and Assessment Method

This section provides an overview of the nine evaluation criteria established under NCP (40 CFR 300.430(e)(9)). The nine NCP evaluation criteria provide a basis for comparing proposed alternatives to select the most appropriate remedy for a site (USEPA 1988). The nine criteria include two threshold criteria, five balancing criteria, and two modifying criteria.

Threshold Criteria

1. Overall protection of human health and the environment
2. Compliance with ARARs

Balancing Criteria

3. Long-term effectiveness and permanence
4. Reduction of toxicity, mobility, or volume
5. Short-term effectiveness
6. Implementability
7. Cost

Modifying Criteria

8. State acceptance
9. Community acceptance

Alternatives must meet threshold criteria to be considered viable. Balancing criteria support detailed comparative evaluation of five measures of remedy suitability. Modifying criteria generally must be met before alternative selection can be finalized. The discussion of each criterion below summarizes the assessment method.

6.1.1 Overall Protection of Human Health and the Environment

This threshold criterion measures how the alternative achieves and maintains protection of human health and the environment. Overall protection of human health and the environment is

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assessed by determining the extent to which the alternative is able to achieve RAOs and maintain adequate short- and long-term protection of human health and the environment. The evaluation of this criterion relies on assessments of the balancing criteria discussed below, particularly effectiveness and implementability (USEPA 1988). This criterion also is assessed by reviewing potential short-term and cross-media impacts associated with the alternative.

6.1.2 Compliance with ARARs

Compliance with ARARs is the second threshold criterion. Its evaluation involves summarizing applicable requirements and describing how the alternative meets these requirements. Chemical-specific, location-specific, and action-specific ARARs are considered. When an ARAR cannot be met, justification for one of the six waivers permitted by CERCLA is considered and evaluated (USEPA 1988).

6.1.3 Long-Term Effectiveness and Permanence

Long-term effectiveness—a balancing criterion—measures long-term risk reduction and remedy permanence. This criterion is assessed by determining the adequacy and reliability of the proposed alternative to manage human health and ecological risks associated with COCs that remain on-site following remedy implementation (USEPA 2005a). Evaluation of long-term effectiveness and permanence includes assessing residual risks after RAOs have been met. For each proposed alternative, the magnitude of residual risk is defined. A permanent and effective alternative limits exposure to human and environmental receptors to within protective levels in the long term (USEPA 1988).

Assessing reliability includes evaluating the effectiveness of the alternative’s remedial technologies at sites with similar chemical constituents and conditions. The permanence of the alternative is determined by evaluating the aspects of the remedy that result in the physical and chemical stability of COCs that remain in place (USEPA 1988).

6.1.4 Reduction of Toxicity, Mobility, or Volume

When selecting a remedial alternative for a site, there is an inherent preference for techniques that permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances through treatment (USEPA 1988)—the second balancing criterion of the NCP assessment method.

For this FS, each alternative is evaluated based on the extent to which it reduces the total mass, mobility, and volume of COCs present at the sediment surface, the extent to which the alternative and its effects are irreversible, and the type and quantity of residuals that remain following implementation. As part of this assessment, a distinction is made between the portion of contaminated material removed and the portion controlled by the alternative. Additionally, the risks posed by postremedy residuals are quantified.

6.1.5 Short-Term Effectiveness

Assessing short-term effectiveness—the third balancing criterion—includes evaluating positive and negative environmental impacts of remedy implementation, potential impacts to the community and site workers during remedy implementation, and the time until the RAOs are achieved (Magar et al. 2008; Wenning et al. 2005, 2007).

This criterion primarily assesses whether the proposed alternative minimizes short-term risks to human health and the community, and whether those risks can be eliminated or controlled by remedy design and BMPs. Assessing short-term effectiveness includes identifying short-term risks that cannot be readily controlled, such as the following:

1. Quality-of-life impacts: noise, odors, and traffic
2. Effects on on-site workers: safety risks associated with remedy implementation
3. Temporary physical disturbance of the environment: destruction of vegetation beds and benthic organisms, alteration of the marsh hydrology, elimination of possible shallow habitat within the creeks and marsh, and reduced water quality

6.1.6 Implementability

Implementability— the fourth balancing criterion of the NCP assessment method— encompasses both the technical and administrative feasibility of implementing a remedial alternative. Assessment of this criterion incorporates evaluating the technical challenges associated with constructing and operating the remediation system, the reliability of the selected technologies, the ability to implement all facets of the alternative, and challenges associated with process options that support each remedy, such as treatment, storage and disposal services, transportation, and equipment availability. This evaluation also considers whether specialized equipment or personnel is required for implementation, and whether such equipment and personnel are readily available. This includes the likelihood that technical or implementation problems or constraints will lead to schedule delays.

Evaluation of implementability also considers the ability to monitor the effectiveness of the alternative and the difficulty in undertaking additional future remedial actions. Migration or exposure pathways that cannot be monitored adequately are identified.

Assessing administrative feasibility focuses on the ability to obtain necessary permits, the impact of state and local regulations on remedy implementation (USEPA 1988), and the steps required to coordinate implementation with appropriate regulatory agencies.

6.1.7 Cost

Assessing cost—the fifth balancing criterion—includes an evaluation of direct and indirect and O&M costs (USEPA 1988, 2000b). Direct costs are those costs associated with equipment, land and site-development, construction materials, building and service, relocation, and disposal. Indirect costs include engineering, licenses and permits, and contingency allowances. Annual O&M costs include labor, maintenance materials, monitoring, and rehabilitation. Costs also are estimated for remedy maintenance and repair if there is a reasonable expectation that a component of the alternative will require future work.

Costs are calculated as present-value-worth costs for comparison of alternatives. O&M costs are estimated for a 30-year period, discounted to a net present value (NPV) in 2013 dollars. The overall cost for each alternative is the sum of capital and discounted annual costs. The discounted costs are calculated based on the NPV methods described in the USEPA guidance document, *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study*

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(USEPA 2000b). The discount rate selected for the net present-worth calculations is 7% (USEPA 2000b).

FS-level cost estimates provide an accuracy of +50% to -30% (USEPA 1988). The present-value-worth costs are used to compare alternatives. Where there is sufficient uncertainty associated with the alternative, a sensitivity analysis may be conducted.

6.1.8 State Acceptance

Evaluating state acceptance—the first modifying criterion of the NCP—involves securing USEPA and state agency acceptance. Though briefly addressed in Section 6.2, this criterion will be more fully addressed in the Record of Decision (ROD) following public review of the FS.

6.1.9 Community Acceptance

Community acceptance—the second modifying criterion—addresses the general public's issues and concerns. This evaluation considers whether the alternative is consistent with community preferences and concerns. Evaluation also determines the extent to which the alternative minimizes impacts on the following:

- Community safety during implementation
- Quality of life, such as the generation of odors, light, diesel emissions, and noise during construction
- Ease of access to and use of areas in the vicinity of the remediation

Finally, the assessment considers whether the alternative adequately addresses technical and administrative issues raised by the community. Though briefly addressed in Section 6.2, this criterion will be more fully addressed in the ROD following public review of the FS.

6.1.10 Environmental Sustainability

USEPA has begun "examining opportunities to integrate sustainable practices into the decision-making processes and implementation strategies that carry forward to reuse strategies" (USEPA 2008b, 2010e). Federal Executive Order 13423 (Federal Register 2007) defines sustainability as

> "…the capacity to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations of Americans."

Sustainable practices for site remediation emphasize six core elements (USEPA 2008b):

1. Energy requirements of the treatment system
2. Air emissions
3. Water requirements and impacts on water resources
4. Land and ecosystem impacts
5. Material consumption and waste generation

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6. Long-term stewardship actions

The primary goal of the sustainability evaluation is to identify alternatives that minimize the environmental and energy footprints of site remediation while still achieving short- and long-term risk management goals specified in the RAOs and RGOs. This assessment also evaluates whether:

- Passive-energy technologies can be used
- Equipment will operate at peak efficiency
- The use of fossil-fueled equipment can be minimized
- Renewable energy systems can replace or offset utility electricity requirements

In addition, this assessment evaluates the ability to minimize the release of dust and toxins through waste generation, air emissions, and greenhouse gas production relative to short-term effectiveness; the alternative’s ability to minimize freshwater consumption and maximize reuse; recycling practices during daily operations; and factors such as the potential for soil and habitat disturbances.

Examples of long-term environmental sustainability measures incorporated in remedial alternatives include the installation of renewable energy systems to power long-term cleanup and future activities and the incorporation of passive sampling devices for long-term monitoring.

6.2 Analysis of Alternatives against NCP Criteria

This section evaluates Alternatives 1 through 6 against the nine NCP criteria discussed in Section 6.1. This discussion is organized by criterion, starting with an overview that assesses the remedial technologies that comprise each alternative (i.e., sediment removal, capping, and thin-layer placement), followed by a detailed assessment of the alternatives. Alternatives are grouped together in the detailed discussions when common features (such as remedial footprint or remedial technology) render them highly similar in terms of the criterion being assessed.

6.2.1 Overall Protection of Human Health and Environment

Other than the No Action alternative, all remedy alternatives would achieve long-term reduction of risks to protect both human health and the environment based on their ability to achieve RGOs and the functionality of each general response action (removal, capping, thin-cover placement, ,and institutional controls).

RGO Range. The range of SWAC and NTE RGOs described in Section 3 reflect concentrations that protect human health and the environment. The RGO concentrations at the lower end of the range contribute to a larger area of cleanup in the marsh than those at the upper end of the range. However, despite these differences in cleanup areas, Alternatives 2 through 6 all meet the threshold criterion of overall human health and the environmental protection, because all fall within the risk range established by the RGOs to be protective of human health and ecological receptors. Alternative 1, the No Action alternative, does not achieve the RGOs and thus is not considered adequately protective of human health and the environment. The manner in which Alternatives 2 through 6 achieve the SWAC and NTE RGOs is further discussed in this section,

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including consideration of how risk management decisions identified in Section 5 influence the understanding of overall protectiveness and residual risks.

Sediment Removal. Sediment removal is incorporated in Alternatives 2 through 6 and targets the removal of contaminants exceeding the RGOs for mercury, Aroclor 1268, lead, and total PAHs, thus immediately reducing the COC mass in OU1. Sediment removal coupled with backfilling improves long-term surface sediment conditions that reduce risks to human health, mammals, birds, fish, and benthic organisms. Backfilling in sediment removal areas and, to a lesser extent, natural surface sediment deposition processes, accelerates recovery of the natural environment and contributes to reduced chemical concentrations to achieve RAOs and RGOs.

Sediment Capping. Sediment capping is incorporated in Alternatives 3, 5, and 6. Capping reduces and controls risks by isolating contaminated sediment from contact with ecological and human receptors. Capping improves long-term surface sediment conditions by creating a clean sediment surface, thereby immediately reducing risks to human health, mammals, birds, fish, and benthic organisms. Sediment capping temporarily disrupts the natural environment. However, recovery of the natural environment is anticipated within approximately two to four years. Generally, capping is used to target sediment contamination in creeks.

Thin-Cover Placement. Thin-cover placement is incorporated into Alternatives 3, 5, and 6. Thin-cover placement reduces risks by reducing surface sediment COC concentrations and thus reducing contaminated sediment contact with ecological and human receptors. Thin-cover placement improves long-term surface sediment conditions by creating a cleaner sediment surface, thereby immediately reducing risks to human health, mammals, birds, fish, and benthic organisms. Thin-cover placement temporarily disrupts the natural environment. However, recovery of the natural environment is anticipated within approximately two years. Generally, thin-cover placement is used to target vegetated marsh areas where chemical risks are relatively low, to minimize construction impacts on the existing natural habitat and to minimize changes to the marsh hydrology. Additional information related to the effectiveness of thin covers is provided in Appendix I.

Institutional Controls. Institutional controls are incorporated into all alternatives, as needed, and are designed to protect human health and the environment. Institutional controls include land use or deed restrictions, maintenance agreements, permit conditions limiting land use for future activities, and advisories.

- The Coastal Marshlands Protection Act (OCGA§ 12-5-280 et seq) protects marshland areas against construction alterations in the state of Georgia without first obtaining a permit from the Coastal Marshlands Protection Committee.
- Fish consumption advisories exist to prevent human exposures to PCBs in the Purvis Creek and the Turtle River system (GADNR 2012). These restrictions likely will remain in place until such time that the criteria for delisting are achieved. Table 2-5 lists changes in fish consumption advisories over time, showing that approximately 20 advisories in various areas of the TRBE have been reduced since 1997. However, there are still advisories in most of the areas of the TRBE. Edible (fillet) fish and shellfish tissue data are compiled in Appendix F. Appendix F illustrates the concentrations of mercury and Aroclor 1268 over time in OU1 and provides a full report of the 2011 fish collection effort. EPS reported these

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data to USEPA, GAEPD, and GADNR in tabular form (EPS 2011b). GADNR used these data to establish 2012 fish consumption advisories for TRBE. Appendix F also shows time trends in fish and shellfish compared to the GADNR (2004) concentration thresholds for fish consumption advisories.

In evaluating overall protectiveness of human health and the environment, the following environmental components are considered:

- Human health risk reduction
- Mammal and bird population risk reduction
- Finfish population risk reduction
- Risk reduction for the sediment-dwelling organism community
- Ability of alternatives to achieve surface water quality ARARs

Alternative 1: No Action

The No Action alternative results in no change in conditions in OU1 and relies on existing institutional controls and advisories to meet RAOs. These controls and advisories alone do not meet the RAOs. The HHBRA concludes that unacceptable risks to human health exist from the ingestion of fish and shellfish (Section 2.4.2). The fish tissue data show concentration reductions in the majority of species over time when all data and all areas sampled within the TRBE are considered collectively. For some species, the tissue reductions have reached an apparent asymptotic plateau, or have shown slightly variable results that oscillate between higher and lower concentrations from one sample event to another.

The detected concentrations of mercury and Aroclor 1268 in many species continue to exceed fish consumption advisories for the TRBE, including at some locations in OU1. Thus, while existing fish consumption advisories minimize the potential adverse impacts on human health and a continuing trend in fish tissue reduction for some species is anticipated, the timeframe to achieve RAOs and fish-consumption criteria is uncertain and could be lengthy. Therefore, the No Action alternative does not achieve some of the RAOs identified Section 3.2.

The SWAC RGOs for mercury and Aroclor 1268 are concentrations that are protective for humans who consume fish, shellfish, and wild game from OU1 (Section 3.3). Although the No Action alternative achieves the SWAC RGOs in some areas, SWAC RGOs are not achieved for either mercury or Aroclor 1268 when measured in all the tidal creeks (i.e., total creeks), suggesting that No Action is not adequately protective for the fish-consumption pathway (Tables 6-1A and 6-1B). Human health exposure to sediment from direct contact (incidental ingestion and dermal skin) was not found to be a significant risk in the HHBRA even when very conservative exposure assumptions were applied (i.e., 52 visits per year). Therefore, the No Action alternative is protective of this pathway.

SWAC RGOs are protective of the mammals, birds, and fish that nest, forage, and breed in OU1 (Sections 3.2). The No Action alternative results in no change in conditions in OU1 that currently pose a risk to piscivorous avian populations and viability of indigenous finfish populations (Section 2.4.3).

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- Figure 6-1A (mercury) and Figure 6-1B (Aroclor 1268)[9] show that the No Action alternative is reasonably protective for most species, particularly when balancing the harm to receptor populations from residual chemical exposures and harm from the remedy itself. Among the seven species evaluated for mercury in Figures 6-1A and 6-1B, only the green heron HQ was greater than 1.[10] None of the HQs are greater than 1 among the seven species evaluated for Aroclor 1268, including the green heron.
- HQs in Figure 6-2A and 6-2B are less than 1 for the green heron in a number of areas around OU1 (e.g., Western Creek Complex, Dillon Duck, Domain 4, Domain 2). However, the HQs exceed the value of 1 elsewhere. Thus, for the green heron, the No Action alternative does not meet the RAOs or RGOs.
- Figure 6-3 shows the mercury HQs for finfish. The HQ exceeds a value of 1 for the No Action alternative for spotted seatrout and silver perch. Figure 6-4A shows the Aroclor 1268 HQs for finfish. The HQ exceeds a value of 1 for the No Action alternative for black drum, silver perch, and striped mullet. Figure 6-4B illustrates the reduction of Aroclor 1268 in fish tissue over time.
- Table 6-1C shows current SWAC values relative to NOAEL and LOAEL-based SWAC RGO values reported in the BERA; these current SWACs reflect baseline conditions of the No Action alternative. The current SWACs (i.e., the No Action alternative) exceed the LOAEL-based RGOs for piscivorous birds, piscivorous mammals, and several finfish species. SWACs exceeding the LOAEL-based SWAC RGOs indicate that the No Action alternative would not be adequately protective of the environment, and therefore fails to meet this threshold criterion.

The benthic community RGOs described in Section 3.3 are designed to protect sediment-dwelling organisms. The No Action alternative results in no change in conditions in OU1, which poses some risk of toxicity to the benthic community (Section 2.4.3). Many areas of OU1 exceed benthic community RGOs (Figures 3-1, 3-2, 3-3, and 3-4 for mercury, Aroclor 1268, lead, and total PAHs, respectively). Figure 6-5 shows whether any of the four COCs falls within or outside the range of benthic community RGOs:

- Whether all four COCs have concentrations below the range of benthic community RGOs
- Whether any COC has a concentration within the range of benthic community RGOs
- Whether any COC has a concentration exceeding the range of COCs

Given the prevalence of locations that exceed the range of benthic community RGOs (Figure 6-5), the No Action alternative is not adequately protective of the sediment-dwelling community.

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[9] Risk reduction for the river otter exposed to Aroclor 1268 is not provided because LOAEL HQs do not exceed the value of 1. NOAEL HQs for the river otter (and other species) is provided in Appendix L.

[10] Discussion in this section is focused on LOAEL HQs because, both NOAEL-based and LOAEL-based RGOs are considered to meet the threshold criteria of overall protectiveness. Whereas LOAEL HQs greater than 1 show areas where unacceptable risks to wildlife populations may be considered likely, it is less clear what degree of adverse impacts (if any) may exist when NOAEL HQs exceed the value of 1. Therefore, LOAEL HQs are discussed here. NOAEL HQ (including graphics similar to those provided in Figures 6-1A and 6-1B) are provided in Appendix M.

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RAO 6 in Section 3.2 considers surface water quality criteria based on total and dissolved mercury and PCBs. The No Action alternative does not meet the state WQS when total mercury data are considered because measurements to date have shown exceedances. The locations where measurements have identified exceedances of surface water quality criteria are identified in Appendix C and Figure 2-19. Measurements of total PCBs also have shown exceedances of the federal and state water quality criteria, in OU1 and in reference locations. As with mercury, the No Action alternative does not meet the federal and state water quality criteria when total PCB data are considered.

Alternatives 2 and 3 (SMA-1), 4 and 5 (SMA-2), and 6 (SMA-3)

Alternatives 2 through 6 are protective of human health and environment, as these alternatives are designed to comply with ARARs, RAOs, and RGOs set forth in Section 3. Therefore, these remedy alternatives meet the threshold criteria of protectiveness for human health. Each alternative results in SWACs that lie within the RGO ranges. Therefore, the SWAC reductions achieved by each alternative result in commensurate reductions of mercury and Aroclor 1268 in fish and shellfish concentrations and are expected to lead to reductions in fish and shellfish consumption advisories within the TRBE. Table 6-1A identifies the SWACs for each of the SMAs and demonstrates that postremedy SWACs generally fall within the range of RGOs identified in Section 3.

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Figure 6-2A shows green heron risks in all creeks and marsh areas for the No Action alternative (i.e., baseline risks) and for remediation of SMAs 1-3. Figure 6-2B shows the same information focused on the highest-concentration areas (Eastern Creek, LCP Ditch, Domain 2, and Domain 3 Creek, plus the average of all creeks combined including Purvis Creek).   Each of the areas in OU1 is predicted to have HQs at or below 1 for the green heron. Because the green heron was deemed most sensitive in the BERA, these results indicate that conditions in OU1 after implementation of Alternatives 2 through 6 would result in conditions that are protective for all mammal and bird populations likely to be present.

Alternatives 2 through 6 also are effective for finfish risk reduction for mercury (Figure 6-3) and Aroclor 1268 (Figure 6-4A). For each alternative of the SMAs, postremedy mercury HQs are at or below a value of 1 (Figure 6-3). Similar postremedy conditions are expected for Aroclor 1268 (Figure 6-4A); measured at one significant figure, fish HQs are at or below 1 for Aroclor 1268. Using the 2005 to 2007 data (Figure 6-4A), the highest postremedy Aroclor 1268 HQs are for striped mullet; however, more recent data collected in 2011 show that striped mullet concentrations decreased between 2005/2007 and 2011 (Figure 6-4B), suggesting that the 2005/2007 data conservatively estimate mullet HQs.

Tables 6-1D, 6-1E, and 6-1F present the SWACs for SMAs 1, 2, and 3 (i.e., Alternative 2 through Alternative 6) in comparison to the NOAEL- and LOAEL-based SWAC RGOs discussed in Section 3. The areas used to calculate SWAC in these tables were defined in accordance with how each class of organisms uses the marsh (e.g., piscivorous species are based on total creek SWACs, herbivorous species are based on total domain SWACs, and omnivorous species are based on total estuary SWACs). SWACs are below the NOAEL-based SWAC RGOs or are within the NOAEL- and LOAEL-based SWAC range for each of the organism-

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specific area footprints; therefore, each footprint is protective of mammals, birds, and fish populations. These results are consistent with the results seen in Figures 6-1 through 6-4.

In Table 6-1B, SWACs are presented for the total marshes combined (total domain), total creeks combined, and total estuary, in addition to each of the individual marsh, creek, and domain areas. When measured at one significant figure, each alternative achieves the SWAC RGOs whether considering the total creek areas, the total vegetated marsh areas, or the entire estuary. Alternatives 2 through 6 also lie within the SWAC RGO ranges for individual areas, except in Domain 3 Creek. However, as illustrated in Figure 6-2A and 6-2B, when the conditions of Domain 3 Creek, Domain 3, and Purvis Creek are averaged, the postremedy SWAC conditions for Alternatives 2 through 6 are similarly protective even for species with a small home range, like the green heron.

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Alternatives 2 through 6 address toxicity to sediment-dwelling organisms and each of these alternatives are protective of the sediment-dwelling community. The following observations are made regarding each alternative.

Alternatives 2 and 3. SMA-1 (Figure 5-2) is the basis for Alternatives 2 and 3 and is delineated according to the lower boundary of the RGO range. Figures 6-6A and 6-6B identify Alternatives 2 and 3 and show whether postremedy residual COC concentrations are above (black dots), within (yellow dots), or consistently below (white dots) the benthic community RGO range. Several locations in Domain 4 are within the range of benthic community RGOs, and one location in Domain 4 exceeds the benthic community RGOs. These locations were briefly described in Section 5, and an explanation was provided in Section 5 as to why these locations were excluded from the final SMA-1 footprint.

The residual risks in Domain 4 would not adversely impact the entire sediment-dwelling community. The RGO exceedances in Domain 4 are small and represent isolated samples surrounded by much lower COC concentrations throughout the remainder of Domain 4. The overall community in this Domain as a whole would not be adversely impacted. Therefore, Alternatives 2 and 3 are protective of the sediment-dwelling community.

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Alternatives 4 and 5. SMA-2 (Figure 5-3) is the basis for Alternatives 4 and 5 and is delineated according to the upper boundary of the benthic community RGOs and intermediate values within the range of SWAC RGOs. Figures 6-7A and 6-7B identify Alternatives 4 and 5 and show whether postremedy residual COC concentrations are above (black dots), within (yellow dots), or consistently below (white dots) the benthic community RGO range. Domain 4 conditions, discussed above, are the same in Alternatives 4 and 5 as in Alternatives 2 and 3. Alternatives 4 and 5 differ with regard to the number of postremedy locations in OU1 that remain within the RGO range. However, as noted previously, concentrations within the RGO range are considered protective. The concentrations within the RGO range may not be as protective as concentrations below the RGO range, but nevertheless, they are protective. Alternatives 4 and 5 also have one additional location in the Domain 3 Creek that exceeds the RGO range. This location was briefly described in Section 5, and an explanation was provided in Section 5 as to why the location was excluded from the final SMA-2 footprint.

In summary, although Alternatives 4 and 5 do not directly address two locations in Domain 4 and the Domain 3 Creek location that exceed the RGO range, indicating there may be some

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residual risks to sediment-dwelling organisms, the potential residual risks would not adversely impact the entire sediment-dwelling community because these locations are located far apart and are surrounded by other locations within or below the RGO range. While the lower end of the RGO range may be considered more protective than the upper end of the RGO range, the adverse impacts of achieving the lower end of the RGO range must be balanced against the benefits. In this case, the residual risk to the benthic community associated with three isolated samples is small compared to the impact of remediation at these relatively remote locations.

Alternative 6. SMA-3 (Figure 5-4) is the basis for Alternative 6 and encompasses SMA-2 as well as some SMA-1 areas that could reduce the overall SWAC in Purvis Creek and Domain 1. Figure 6-8 identifies Alternative 6 and shows whether postremedy residual COC concentrations are above (black dots), within (yellow dots), or consistently below (white dots) the benthic community RGO range. Alternative 6 remediates approximately 20 locations that are not addressed by Alternatives 4 and 5. Similar to Alternatives 4 and 5, two locations exceed the RGO range: one in Domain 3 Creek and one in Domain 4. Therefore, the residual benthic community risks associated with Alternative 6 are similar to those described for Alternatives 4 and 5. In addition, Alternative 6 also has the same residual risks in Domain 4 as was described for Alternative 2 and 3.

The larger remedy footprint associated with SMA-1 achieves lower residual COC concentrations than the smaller remedy footprints associated with SMA-2 and SMA-3. However, the larger footprint also results in substantial destructive impacts to the existing benthic habitat resulting from remedial construction. The need to remediate to the lower end of the RGO range must be balanced against the physical impacts of the remedy to ensure that the remedy itself does not do more harm than good to the marsh ecosystem.

Appendix L summarizes indigenous grass shrimp, sediment-dwelling community studies, and provides a brief overview of extensive sediment toxicity testing that was identified in the BERA. The indigenous shrimp toxicity tests evaluated stations within OU1 during six events from 2000 to 2007 (Appendix L; Figure L-5A). Benthic community assessments were conducted from only four stations within OU1 during one event in 1995 (Horne et al. 1999) and one event in 2000 (as cited in Black & Veatch 2011). Extensive sediment toxicity testing (i.e., more than 200 tests on two species using multiple endpoints) was also conducted using sediments from OU1 from 2000 to 2007 (Appendix L). Results of the laboratory sediment testing were used in the BERA to derive several COC-specific sediment effects concentrations, such as probable effect levels and apparent effects thresholds (AETs).

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The indigenous and laboratory-raised grass shrimp toxicity tests, benthic community, and amphipod sediment toxicity studies, collectively suggest that the RGOs are not thresholds above which adverse effects are definitive and absolute. For example, the BERA indicates that locations with residual mercury concentrations above the AET of 11 mg/kg are expected to be toxic to grass shrimp, based on testing that continuously exposed developing shrimp to sediment for two months, which is conservative and may not necessarily be representative of how grass shrimp are exposed in OU1 in-situ. Nevertheless, Alternatives 2 and 3 address locations with mercury and Aroclor 1268 that exceed their respective mercury AETs.

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Although toxicity to laboratory-raised grass shrimp was evident at many stations in the estuary, toxicity to indigenous grass shrimp were observed only in LCP Ditch and Eastern Creek, where OU1 COC concentrations are highest. No significant differences in indigenous grass shrimp toxicity were seen in other areas, even in areas where in situ COC concentrations were above the RGO range (Appendix L; Figure L-5A). Similarly, benthic community impacts were observed in Eastern Creek, also where COC concentrations were well above the RGO range (Appendix L; Figure L-6). Alternatives 2 and 3 capture the areas where differences were observed in grass shrimp, amphipods, and the benthic community, and the areas that exceed the lower end of the RGO range developed using the site specific toxicity testing data. Alternatives 4 and 5 capture the majority of areas above the RGO range except in the Western Creek Complex, upper Domain 3 Creek, and in Purvis Creek. Alternative 6 captures the majority of areas in Purvis Creek above the RGO range.

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Alternatives 2 through 6 Summary

Alternatives 2 and 3 (SMA-1) address the largest SMA footprint. The larger footprints contribute to a greater level of risk reduction for ecological receptors compared to Alternatives 4 and 5 (SMA-2) and 6 (SMA-3). However, all remedies achieve acceptable risk levels, insofar as all achieve HQ levels at or below 1. This is particularly relevant when considering, including fish, bird, and mammal populations, and the benthic community.

6.2.2 Compliance with ARARs

Alternatives 2 through 6 are designed to comply with ARARs and all federal and state permits required for remedy implementation. ARARs for the LCP Brunswick Site are provided in Tables 3-1 through 3-3. Other than the No Action alternative, which would result in no change in conditions in OU1, all alternatives comply with ARARs as described below:

- Location-specific, chemical-specific, and action-specific ARARs will be met by obtaining or complying with appropriate federal, state, and local permits and approvals required to implement the remedial activities.
- Chemical-specific ARARs will be met through waste characterization of materials designated for off-site disposal and ensuring that licensed haulers and disposal facilities are used in the management of such materials.
- Sediment removal may disturb contaminated sediments during implementation. Such disturbances may result in short-term exceedances of chemical-specific ARARs. However, these short-term exceedances would be mitigated in large part by backfilling sediment removal areas, which accelerates recovery of the natural environment, and by using various BMPs to minimize the potential for contaminants suspension and off-site transport. BMPs help ensure compliance with action-specific ARARs, such as those directing the disposal of materials.
- Work will be scheduled to minimize impacts to fish species in the LCP estuary during remedy implementation by adhering to fish windows (i.e., designated significant timeframes associated with fish or shellfish spawning and larval development under the Magnuson Stevens Act, if listed species are identified for the LCP estuary), if any, and employing BMPs to minimize ecological impacts to the extent practicable.

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- Surface water quality is expected to improve with each alternative so that water quality criteria are achieved, meeting the requirements of RAO 6. The lower surface-sediment COC concentrations associated with Alternatives 2 through 6, compared to the No Action alternative, will substantially decrease the potential for the suspension and transport of contaminated sediment particles.

  Alternatives 2 through 6 are expected to achieve federal and state WQS for dissolved-phase and total mercury and PCBs because each alternative will limit suspended particles that may transport COCs through OU1, particularly from the high-concentration areas that will be dredged or capped. However, as indicated in Figures 2-18 and 2-19, considering that Troup Creek (one of the water quality sampling reference locations) had an exceedance of the Georgia WQS for total mercury and Crescent River (another water-quality-sampling reference location) had an exceedance of both the federal and state WQS for PCBs, total mercury, and total PCB concentrations alone cannot define overall protectiveness of the alternatives.

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The following is a comparative discussion on the ability of each of the alternatives to comply with all chemical-specific, location-specific, and action-specific ARARs.

Alternative 1 – No Action

Alternative 1 is expected to comply with location-specific ARARs because it requires no construction and thus requires no permitting or access. There are no action-specific ARARs associated with the No Action alternative. Surface water quality conditions are not expected to change beyond current ongoing trends under this alternative. Under this alternative, there are exceedances of chemical-specific ARARs for surface water.

Alternatives 2 (SMA-1) and 4 (SMA-2) – Removal Only

Alternatives 2 and 4 are designed to comply with all ARARs and will comply with all appropriate federal, state, and local permits and approvals required to implement each alternative. Implementing Alternatives 2 or 4, which only incorporate sediment removal, could potentially result in temporary noncompliance of certain chemical-specific ARARs, such as impacts to water quality. Potential water quality impacts associated with sediment removal for Alternative 2 are greater than for Alternative 4 because of the larger area associated with Alternative 2—Alternative 2 includes sediment removal in 48 acres while Alternative 4 includes removal in 18 acres. The reduced remedial footprint associated with Alternative 4 also shortens the construction schedule from 18 months to 9 months, thereby reducing the time during which potential water quality impacts can occur.

Alternatives 3 (SMA-1), 5 (SMA-2), and 6 (SMA-3) – Combined Remedies

Alternatives 3, 5, and 6 are designed to comply with all ARARs and will comply with all appropriate federal, state, and local permits. These alternatives incorporate sediment removal, sediment capping, and thin-cover placement, portions of which could potentially result in temporary noncompliance of certain chemical-specific ARARs, such as impacts to water quality. The sediment removal components of the remedy raise similar concerns to those discussed for Alternatives 2 and 4, except that Alternatives 3, 5, and 6 minimize the removal-area footprint by

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integrating removal of high-concentration areas in the marsh creeks with capping and thin-cover placement in lower-concentration and vegetated marsh areas.

Sediment capping and thin covers require placement of clean material over respective target areas. They can result in the generation of turbidity plumes if placed under submerged conditions. However, most turbidity during capping is associated with the cap material itself and is not contaminated; contemporary capping techniques greatly minimize the potential for contaminated sediment resuspension during cap placement (Lyons et al. 2006). Because turbidity plumes associated with capping are made up mostly of clean sediment, these temporary plumes are expected to comply with chemical-specific ARARs.

The smaller footprints associated with Alternatives 5 and 6 result in shorter construction schedules for these remedies, thereby reducing the time during which water quality impacts may occur. Alternatives 3, 5, and 6 have estimated construction durations of approximately 17, 10, and 11 months, respectively.

6.2.3 Long-Term Effectiveness and Permanence

Other than the No Action alternative, all alternatives provide long-term human health and ecological risk reduction by targeting site-specific RGOs. As part of Alternatives 2 through 6, sediments contributing to RGO exceedances are targeted for removal, capping, or thin-cover placement, thus reducing or eliminating potential risk of exposure to contaminated material. Sediment removal, sediment capping, and thin-cover placement have proved reliable and effective at sites similar to OU1. Sediment removal removes COCs from the Site permanently. Cap armoring and cover material are designed to ensure permanence. Institutional controls (e.g., land use or deed restrictions, maintenance agreements, permits limiting land use for future activities, and fish consumptions advisories) will be used, as necessary, to control residual risks following remedy implementation. In addition, long-term monitoring is conducted to ensure long-term protectiveness of the remedy and compliance with ARARs, in addition to long-term structural integrity and effectiveness.

Risk Reduction and Residual Risk

Alternative 1 provides no reduction in risk to humans or the environment beyond current ongoing natural processes. Fish and shellfish tissue concentrations have decreased over time and future fish and shellfish concentrations are reasonably expected to continue on a downward trajectory. Therefore, Alternative 1 could eventually satisfy the RAO goals over the long term. However it is not clear how long this would take, and without monitoring, risk reduction cannot be confirmed. Therefore, No Action does not provide adequate risk reduction and does not adequately address residual risks for human health and some ecological receptors.

In Alternatives 2 through 6, sediments contributing to RGO exceedances would be targeted for removal, capping, and/or thin-cover placement, thus reducing potential risk of exposure to contaminated material. Sediment removal permanently removes contaminated material; backfilling addresses dredge residuals that otherwise pose risks. Capping and thin-cover placement leave contaminants in place. Capping isolates COCs and reduces bioavailability through burial with clean material; caps are armored against erosion, and thus can be placed in relatively high-energy areas. Thin-cover placement creates a clean sediment surface in low-

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risk, low-energy areas; the clean sediment surface allows for the colonization of plants and animals that are then exposed to lower COC levels. Alternatives 2 through 6 have varying degrees of risk reduction and residual risks.

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Although Alternatives 2 and 3 (SMA-1) have the largest SMA footprint and result in the lowest residual-risk levels, they do not provide a substantially greater overall risk reduction when compared to Alternatives 4 and 5 (SMA-2) or 6 (SMA-3) (Section 6.2.1). Consideration of potential residual risks and more conservative footprints must be balanced against considerations of damage to the marsh from remedial actions, which is defined both by the size of the SMA footprint and incidental areas that are damaged in efforts to access remediation areas (Table 6-2). Thus, whereas the lower end of the SWAC RGO range provides lower residual COC levels, the overall recovery time would be faster with the upper end of the SWAC RGO range which has a much smaller immediate impact on the ecosystem. Construction activities that impact the marsh also impact long-term ecological recovery. Larger surface sediment recovery times are required for larger-scale remedies. Similarly, sediment removal and capping are far more intrusive to vegetated marsh areas than thin-cover placement, and thus require longer recovery periods. Marsh recovery times associated with thin-cover placement are generally less than two years (Appendix I), largely because the biomass is not destroyed and provides a basis for recovery.

Permanence

Except for Alternative 1 (No Action), all alternatives provide permanent risk reduction by targeting sediment concentrations that exceed RGOs and through remedy design.

Sediment removal permanently removes COCs from OU1 and backfilling permanently addresses postremoval residuals. Capping and thin covers are engineered to account for hydrodynamic conditions to ensure their permanence; capping relies on armoring for protection in relatively high-energy areas whereas thin-cover placement relies on the appropriate specification of the cover material when placed in relatively low-energy areas. Overall OU1 is characterized as stable and relatively resistant to scour and sediment resuspension. The results from hydrodynamic model simulations (Appendix B) demonstrated relatively low velocities (less than 2 ft/sec) throughout the OU1 during spring-neap tidal cycles, 100-year flood conditions, and hurricane storm surge conditions. Velocities that could result in cap material instability are addressed through armoring to resist erosion.

Materials for sediment capping and thin-cover placement will be sized to ensure protection against erosion and scour. However, because the thin cover is not an armored barrier, some burrowing and other types of biological activity will occur in the thin-cover layer, but this activity is not expected to adversely impact the overall effectiveness of the thin cover (Appendix I). Monitoring and maintenance will be performed as necessary to ensure long-term remedy effectiveness.

6.2.4 Reduction of Toxicity, Mobility, or Volume

All alternatives, except No Action (Alternative 1), provide varying degrees of long-term reduction of COC toxicity, mobility, and volume. The No Action alternative does not reduce toxicity, mobility, or volume of chemicals in OU1 beyond ongoing natural processes.

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All of the alternatives include sediment removal which reduces of the volume of COC-impacted sediment in OU1 following remedy implementation. However, short-term increases in COC mobility and toxicity can result from sediment removal via materials management.

Where alternatives include sediment capping and thin-cover placement, long-term COC toxicity and mobility are reduced by creating a clean sediment surface through burial with clean materials. The thin cover is not intended as an absolute chemical barrier, but as a layer to jump start ongoing natural recovery processes. Therefore, some bioturbation beyond the cover depth does not diminish the effectiveness of this remedy and thus does not preclude its beneficial use as a protective remedy. Residual risks posed by COCs left unremediated are addressed through institutional controls (e.g., permit requirements, which already exist, limiting use or future activities in the marsh and fish consumption advisories) and long-term monitoring to ensure the long-term structural integrity and effectiveness of the remedy.

Alternatives 2 (SMA-1) and 4 (SMA-2)

Alternatives 2 and 4 rely only on removing sediments with high COC concentrations from areas within SMA-1 (Alternative 2) and SMA-2 (Alternative 4) to achieve RAOs. Removal reduces the volume of COCs, thereby reducing COC toxicity and mobility. Alternatives 2 and 4 reduce COC-impacted sediment by volumes of approximately 153,000 CY and 57,000 CY, respectively. The estimated mass of COCs removed from OU1 is provided in Table 6-3. The resulting SWACs for the COCs as a result of Alternatives 2 and 4 are presented in Table 6-1a and Table 6-1b; both alternatives achieve the RGO SWACs established in Section 3.3.

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Experience at other sites indicates that sediment removal does not completely remove all contaminated sediments, leaving behind a layer of residuals on the surface after dredging. Because the residual sediment reduces the overall effectiveness of the sediment removal remedy (NRC 2007, Bridges et al. 2010). Alternatives 2 and 4 rely on backfilling to manage residuals by reducing exposures. Experience at other dredge sites also indicates that an estimated 2% to 4% of dredged contaminant mass typically resuspend into the water column and is transported out of the removal area (USACE 2008a, Bridges et al. 2010).

Thus, whereas both Alternatives 2 and 4 reduce the long-term toxicity and mobility associated with elevated concentrations of COCs in sediments by removing contaminated material from the environment, some contaminated material is left behind and some may resuspend and migrate to other areas during construction.

Alternatives 3 (SMA-1), 5 (SMA-2), and 6 (SMA-3)

Alternatives 3, 5, and 6 achieve RAOs through a combination of sediment removal, sediment capping, and thin-cover placement within SMA-1, SMA-2, and SMA-3 respectively. Removal of sediment with the highest concentrations of COCs from the SMAs reduces the volume of COCs in OU1, thereby reducing COC toxicity and mobility. Alternative 3 reduces the COC-impacted sediment volume by approximately 27,000 CY, and Alternatives 5 and 6 reduce the volume of COC-impacted sediment by approximately 22,000 CY. Table 6-3 shows the estimated mass of COCs removed from OU1. The sediment removal components of the remedy raise similar concerns to those discussed previously for Alternatives 2 and 4, except that Alternatives 3, 5, and 6 minimize the removal-area footprint by integrating removal of high-concentration areas in

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the marsh creeks with capping and thin-cover placement in lower-concentration and vegetated marsh areas.

Capping and thin-cover placement reduce COC toxicity and mobility by isolating contaminants through burial with clean materials. All three alternatives that rely on capping and thin-cover placement achieve the RGO SWACs established in Section 3.3.

Unlike removal, contaminant mass does not substantially resuspend during cap placement (Lyons et al. 2006), thus reducing the potential for contaminant mobility during construction. Therefore, Alternatives 3, 5, and 6 reduce the long-term toxicity and mobility associated with the off-site transport of elevated concentrations of COCs in sediments.

6.2.5 Short-Term Effectiveness

Implementing any alternative, other than the No Action alternative (Alternative 1), presents short-term impacts associated with on-site construction and remediation operations. The extent of these impacts is proportional to the remedial footprint, the sediment removal volume, the selected remedy components, the time required to complete the remedy, and on-site material handling requirements.

Sediment removal provides the opportunity to achieve risk reduction by removing sediment contaminants from OU1. However, depending on the size and complexity of the project, sediment removal increases the potential for negative short-term impacts to the environment and to the surrounding community. The following short-term risks relate to sediment removal:

- Sediment excavation, handling, transportation, and disposal increase community impacts, including traffic, odors, and noise. Community impacts are in proportion to the volume of material removed, on-site sediment handling requirements, and time required to complete remedy implementation.
- Sediment removal poses adverse risks to the community and construction workers via potential exposures to contaminated sediment, prolonged construction impacts to the community, and increased transportation to and from the Site. The risks of sediment suspension and accidental spills of site-related materials increase during excavation and transportation. Transportation of contaminated material increases human exposure risks due to extended sediment handling. Although these risks are reduced by BMPs and site-specific health and safety plans, the risks cannot be eliminated entirely. Sediment removal increases the risk of sediment resuspension and short-term impacts on water quality. Minimizing the sediment removal component of the remedy reduces the potential for sediment scouring and off-site contaminant transport and minimizes ecological exposures to chemicals in surface water resulting from sediment resuspension and dissolved-phase partitioning of compounds. These risks also are minimized by employing BMPs and adhering to site-specific permitting requirements, but risks cannot be eliminated entirely.
- Sediment removal requires extensive heavy equipment use, including barge- or shoreline-mounted excavation equipment and on-site sediment handling equipment (e.g., backhoes or cranes). Though the construction industry has extensive experience working with such heavy equipment, the increased risk of worker injury cannot be eliminated entirely.

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Sediment capping and thin-cover placement bury contaminants through depositing a layer of clean material on the sediment bed surface. The short-term risks associated with capping and thin-cover placement include the following:

- Clean material transportation to the Site increases community impacts, including traffic, noise, and diesel exhaust. Community impacts are in proportion to the volume of material delivered and time required to complete remedy implementation. Additionally, clean material transport is necessary for the backfill component of the removal alternatives. Depending on tidal conditions and contractor preferences, some material may be transported by water.
- Sediment capping and thin-cover placement require extensive heavy equipment use, including barge- or shoreline-mounted excavation equipment, and on-site material handling equipment. Though the construction industry has extensive experience working with heavy equipment, the increased risk of injury to workers cannot be eliminated entirely.

Sediment removal, sediment capping, and thin-cover placement will result in short-term ecological impacts to the marsh. Marsh plants and benthic animals will be covered by capping or thin covers and will be excavated with sediment removal.

- Thin covers have the least impact to the existing ecology. Based on a literature review of thin-layer placement in marsh and wetlands restoration case studies (Appendix I), areas remediated with thin covers are expected to recover within approximately two growing seasons. While restoration efforts, such as replanting, may accelerate recovery after sediment capping or removal, restoration is expected to be slower. However, recovery is not completely certain. Marsh dieback is prevalent in portions of the estuary and throughout TRBE. In some cases, dieback may hinder marsh vegetation recovery; under these conditions, replanting and maintenance may not necessarily accelerate recovery to overcome dieback and thus may not beget positive results.
- Thin covers, applied accurately, limit the loss of aquatic habitat and changes in marsh elevations; hydrodynamic modeling (Appendix B) shows that thin-cover placement would not adversely impact hydrology in OU1.
- Capping, limited to marsh creeks in Alternatives 3, 5, and 6, minimally impacts the marsh ecosystem. Hydrology is relatively unaffected (Appendix B), and capping within the creeks would not impact marsh vegetation directly.
- Removal has the most substantial impact to the marsh ecosystem. Besides the risk of chemical residuals and chemical release during construction, removal is the most damaging to the existing habitat because it destroys the existing marsh ecosystem (i.e., marsh plants and the benthic community). When confined to the marsh creeks in Alternatives 3, 5, and 6, the impacts of removal to the ecosystem are minimized by targeting only those areas with the highest COC levels.
- Short-term risks associated with sediment removal should be commensurate with the long-term gains of removal. Because contamination is confined primarily to surface sediment deposits, and because surface concentrations (as opposed to concentrations in deeply buried sediments) are the most relevant to risk (NRC 2007), focus of this FS is on

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remediation of surface sediment deposits. Targeting buried chemical deposits may exacerbate risks associated with sequestered sediment that is not currently bioavailable or bioaccessible.

Alternatives 2 (SMA-1) and 4 (SMA-2)

Alternatives 2 and 4 only feature sediment removal, resulting in the most substantial potential negative short-term impacts to the environment and surrounding community. The extent of these impacts is proportional to the remedial footprint, the use of removal only, the time required to implement the remedy, and on-site material handling requirements.

Alternative 2 (SMA-1) requires the removal, transportation, and disposal of 153,000 CY of contaminated sediment material from 48 acres of OU1 and construction is estimated to span 18 months. Alternative 4 (SMA-2) includes the removal of 57,000 CY of contaminated sediment material from 18 acres of OU1 and construction is estimated to span 12 months. Thus, Alternative 2 poses greater short-term risks and potential impacts to human health and the environment than Alternative 4.

Alternatives 3 (SMA-1), 5 (SMA-2), and 6 (SMA-3)

Alternatives 3, 5, and 6 incorporate sediment removal, sediment capping, and thin-cover placement resulting in potential negative short-term impacts to the environment and surrounding community. In comparison to Alternatives 2 and 4, Alternatives 3, 5, and 6 minimize short-term risks by reducing the scope of sediment removal through removing only those sediments that exceed the RGOs and cannot be remediated via capping or thin-cover placement.

Alternative 3 includes the removal of 27,000 CY of contaminated sediment from 48 acres of OU1, while Alternatives 5 and 6 require the removal, transportation, and disposal of 22,000 CY of contaminated material from 18 and 24 acres of OU1, respectively. These volumes represent approximately 18% (Alternative 3) and 14% (Alternatives 5 and 6) of the volume considered for removal in Alternative 2. Based strictly on the volume of contaminated materials to be removed, Alternative 3 poses greater community impacts and risks to human health and the environment than either Alternatives 5 or 6.

The short-term human-health and ecological impacts of sediment capping and thin-cover placement are generally limited to transportation of clean material and heavy equipment usage, so risks strongly correlate to the duration of construction activities and can be managed by BMPs and site-specific safety plans. The estimated construction duration for Alternatives 3, 5, and 6 is 23, 13, and 16 months, respectively. Thus, Alternative 3 poses a greater short-term risk than Alternative 6, which poses a marginally greater short-term risk than Alternative 5.

6.2.6 Implementability

There are no implementability constraints for the No Action alternative because no remedial action is taken.

Portions of each SMA pose different challenges and technical difficulties associated with remedy implementation (Section 5.1 and Table 6-4). Tides severely impact accessibility of the marsh by equipment, material, and personnel. Thus, tides severely impact productivity,

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regardless of whether a land- or water-based operation is employed. Implementation of any remedial technology (whether sediment removal, sediment capping, or thin-cover placement), will encounter the following constraints:

- Marsh areas and creeks (except for portions of Purvis Creek) completely fill and drain during one tidal cycle (Figure 6-9; Photos A through H). This condition limits water-based operations to north Purvis Creek, LCP Ditch, Eastern Creek, and Western Creek Complex. Water-based operations are restricted further by the shallow, narrow, and sinuous nature of Eastern Creek, Western Creek Complex, and Domain 3 Creek (Figure 6-9; Photos I and J).
- Land-based operations require construction of temporary access roads across the soft sediments in the marshes and creeks (Figure 6-9; Photos J through L). These roads will access remedial areas and allow material (e.g., excavated material, backfill material) transfer. The temporary access roads must have surface elevations at least 1 foot above the mean high water elevation to avoid flooding. Staging areas are needed to facilitate and optimize material handling, access, and management. The roads and staging areas are to be removed upon completion of construction activities, or integrated into the remedial action as appropriate (e.g., road material may be used as backfill after sediment removal). Access via land to some isolated remedial areas, such as the Western Creek Complex or even north Purvis Creek and Domain 3 Creek, may require access agreements from adjoining property owners, possibly making land access even more difficult than aquatic access.
- As with other sediment remediation projects, the removal, transportation, off-loading, dewatering/solidification, and disposal of contaminated sediment and debris presents implementation challenges, such as traffic management, noise, and suitable disposal facility capacity.
- Scattered debris has been observed throughout OU1, including large stone lining of the banks of the LCP Ditch (Figure 6-9; Photos M through Q). The distribution of submerged debris is unknown, but is expected to be present, particularly in sediment removal areas that have not been dredged or maintained historically. Debris within removal areas will be removed and disposed off-site during remedy implementation. Debris removal also may be required for capping, in the event that debris prevents or obstructs cap placement and cover. Debris removal is not anticipated for thin-cover placement, except perhaps to groom nearshore marsh areas where surface debris is prevalent.
- Marsh recovery will be monitored. However, recovery is not completely certain as marsh dieback, which may hinder marsh vegetation recovery, is prevalent in portions of the estuary, and throughout TRBE (Figure 6-9; Photo R). Thus, replanting and maintenance may not necessarily accelerate recovery to overcome dieback and thus may not beget positive results.

Techniques exist to meet the challenges associated with working among soft sediments in tidally influenced marsh areas. These include the use of low-ground-pressure earthmoving equipment, telescoping conveyor belts for cap placement, water-based sediment removal and sediment capping using shallow draft barges, and hydraulic placement of thin-cover material. Most of these considerations will be resolved during design and the construction bidding process.

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Alternatives 2 (SMA-1) and 4 (SMA-2)

Alternatives 2 and 4 face similar implementation challenges as they both feature only sediment removal (Table 6-4). In addition to the implementation constraints discussed above, Alternatives 2 and 4 face the following challenges:

- Generally, creek sediments will be removed in water- or land-based operations; sediments from the marshes likely will be removed in land-based operations
- Implementing a land-based operation requires access with owners of adjacent off-site properties
- The pier remnants across Purvis Creek (Figure 6-9; Photo Q) may require removal (particularly for Alternative 2)
- The soft marsh sediments require substantial fill material to construct temporary access roads and staging areas capable of supporting anticipated loads

Since Alternative 2 has a footprint that is approximately 30 acres larger than that of Alternative 4, Alternative 2 will result in greater implementation challenges, such as those listed below:

- More temporary access roads and staging areas
- More sediments requiring removal, dewatering/solidification, management, transport and off-site disposal, resulting in more substantial community impacts due to traffic, noise, and overburdened disposal facilities
- More debris to be removed and disposed off-site
- Greater magnitude of temporary short-term ecological impacts to remediated marshes
- Greater magnitude of short-term ecological impacts to marshes not targeted for remediation (e.g., footprints of access roads and staging areas)

Remedy effectiveness is evaluated through the implementation of short-term and long-term monitoring plans. These monitoring programs and potential future corrective actions are implementable.

Alternatives 3 (SMA-1), 5 (SMA-2), and 6 (SMA-3)

Alternatives 3, 5, and 6 face similar implementation challenges as they combine sediment removal, sediment capping, and thin-cover placement. In addition to the implementation constraints discussed above (Section 6.2.6, Table 6-4), Alternatives 3, 5, and 6 face the following challenges:

- Generally, creek sediments will be removed in water- or land-based operations; sediments from the marshes will be removed in land-based operations
- Implementation of a land-based operation requires access agreements with owners of adjacent off-site properties

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- Portions of the pier remnants (Figure 6-9; Photo Q) across Purvis Creek may require removal (particularly for Alternatives 3 and 6)
- Soft marsh sediments require substantial fill material to construct temporary access roads and staging areas capable of supporting anticipated loads
- Thin-cover placement may require equipment which may not be as prevalent as typical earthmoving equipment, but nonetheless generally available (e.g., equipment to broadcast mechanically or pneumatically, or spray hydraulically)

Because Alternative 3 has a footprint that is approximately 30 acres larger than Alternative 5, and approximately 24 acres larger than Alternative 6, Alternative 3 will result in greater implementation challenges. Similarly, Alternative 6 is approximately 6 acres larger than Alternative 5, so it will encounter comparatively greater implementation challenges such as those listed below:

- More temporary access roads and larger staging areas
- Limited access and productivity (water-based operation) or need for access agreements (i.e., land-based operation) to remediate isolated and discontinuous areas in the Western Creek Complex (Alternative 3 only)
- Construction of temporary roads and staging areas to remediate the Domain 3 marsh (Alternative 3 only)
- More sediments requiring removal, dewatering/solidification, management, transport, and off-site disposal, resulting in higher community impacts due to traffic, noise, and overburdened disposal facilities
- More debris to be removed and disposed off-site
- Greater magnitude of temporary short-term ecological impacts to remediated marshes
- Greater magnitude of short-term ecological impacts to marshes not targeted for remediation (e.g., footprints of access roads and staging areas)
- Alternatives 3 and 6 require access to the upper reaches of north Purvis Creek, which are tidally influenced and will have limited access during low tides.

Alternatives 4 (Removal SMA-2), 5 (Combined SMA-2), and 6 (Combined SMA-3)

Alternative 4, removal only in SMA-2, faces different implementation challenges than Alternatives 5 and 6, as these combine sediment removal, sediment capping, and thin-cover placement. Since Alternative 4 has a sediment removal footprint that is approximately 11 acres larger than that of Alternatives 5 or 6 (Table 6-5), Alternative 4 will result in greater implementation challenges, such as those listed below:

- More sediments requiring removal, dewatering/solidification, management, transport, and off-site disposal, resulting in more substantial community impacts due to traffic, noise, and overburdened disposal facilities
- More debris to be removed and disposed off-site
- Greater magnitude of temporary short-term ecological impacts to remediated marshes

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Both sediment removal and sediment capping require construction of temporary access roads and staging areas. Since Alternative 5 has a combined sediment removal/sediment capping footprint that is 8 acres and 3 acres smaller than Alternatives 4 and 6, respectively (Table 6-5), Alternatives 4 and 6 will result in greater implementation challenges, such as those listed below:

- More temporary access roads and staging areas
- The soft marsh sediments require substantial fill material to construct temporary access roads and staging areas capable of supporting anticipated loads.
- Greater magnitude of short-term ecological impacts to marshes not targeted for remediation (e.g., footprints of access roads and staging areas)

Since Alternative 6 incorporates sediment capping of the upper reaches of north Purvis Creek, which are tidally influenced and will have limited access during low tides, accessibility may pose additional implementation challenges.

Remedy effectiveness is evaluated through the implementation of short-term and long-term monitoring plans (Section 5.2.1). These monitoring programs and potential future corrective actions are implementable.

6.2.7 Cost

Cost estimate details are provided in Appendix H, including material and construction unit costs and assumptions used to develop the cost estimates, such as monitoring assumptions. Although considered reasonable to provide sufficient detail to compare technology costs, monitoring assumptions (e.g., quantities, frequencies, and durations) are not intended to be prescriptive.

Remedy costs are summarized in Table 6-5. Besides the No Action alternative (Alternative 1), Alternative 5 has the lowest total estimated present-worth cost—approximately $26MM. Alternative 2 has the highest total estimated present-worth cost—approximately $65MM. The total estimated present-worth costs of Alternatives 3, 4, and 6 are $39MM, $34MM, and $29MM, respectively. Alternative 2 is approximately 1.6 to 2.5 times more expensive than Alternatives 3, 4, 5, and 6.

6.2.8 State Acceptance

The modifying criterion of state acceptance is not been addressed in this draft FS. It may be addressed in the final FS or the ROD. USEPA and GAEPD have been involved with the various tasks and decisions that have been incorporated into the development of the alternatives presented in this FS and will continue to participate in the review and evaluation of the alternatives and in the selection of the most appropriate sediment remedy for the Site. The alternatives identified in this FS aim to balance remediation to reduce risks to human health and the environment, while preserving the existing habitat and ecological communities, both of which are important criteria for USEPA and GADEP.

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6.2.9 Community Acceptance

The modifying criterion of community acceptance is not addressed in this draft FS. It may be addressed in the final FS or the ROD. The Site is surrounded primarily by commercial and industrial property (EPS and ENVIRON 2012). The Glynn County Planning Commission Land Use Maps show the area designated as industrial for both present and future use. Nonetheless, remedial activities for any alternatives except the No Action alternative may increase short-term impacts to neighboring communities through construction noise, odors, and diesel emissions related to Site activities and off-site material transport. Other effects of remedy implementation on the community include safety issues associated with implementation, which could restrict use of areas in the vicinity of the remediation.

Remediation will ultimately improve the marsh ecosystem as a community resource, by lowering sediment contaminant concentrations, contaminant bioavailability, and chemical concentrations in fish; this in turn will lessen fish restrictions associated with OU1. However, by destroying existing marsh habitat, all of the remedies will temporarily diminish the aesthetic value of the marsh for the local community. Larger remedies will have a more substantial impact on the existing marsh habitat than smaller remedies, and alternatives that require sediment removal of vegetated marsh areas will have a more substantial impact than the thin-cover placement alternatives.

Public education is necessary to build support of remedial action. Public education informs the public, adjacent businesses, and other stakeholders of the physical and visual impacts that construction activities will have on the estuary and the short- and long-term benefits that are expected.

This FS anticipates community acceptance because each alternative, except No Action, is designed to meet RAOs established by USEPA and RGOs established for OU1. The FS will undergo public review before being finalized.

6.3 Environmental Sustainability

The evaluation of alternatives for environmental sustainability is focused primarily on maximizing the net environmental benefit of remediation while optimizing the use of resources (e.g., energy and water) and minimizing the impact on the ecosystem (e.g., minimizing waste generation and impacts on land and habitat). For OU1, the following are environmentally sustainable practices:

- Reusing clean dredged material from nearby waterways in lieu of borrowing material from upland sources (e.g., quarries or mines). Potential sources of material local to OU1 include material from navigational dredging of both the Brunswick Harbor and SHEP, which are ongoing projects managed by the USACE Savannah District (USACE 2012 a,b). Currently, dredged materials from both projects are managed at upland DMCFs and ODMDS. If the sediment from these sites are determined to be suitable for beneficial reuse at the LCP OU-1 Site, dredged material from either project would result in the following sustainability benefits:
    - Reduce the space consumed in the DMCF or ODMDS

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  - Reduce the energy required to generate newly quarried cap material, which must be mined, crushed, processed, cleaned, and transported to the Site
  - Provide material better suited for marsh restoration than quarried sand; dredged sediment is more organic-rich and contains natural nutrients that support plant and wildlife growth, whereas quarried sands tends to lack natural organic matter

- Ensuring that equipment is operating at peak efficiency, thereby minimizing fossil fuel usage, air emission, and waste generation
- Using low-sulfur fuel or biodiesels in lieu of diesel to reduce air emissions and greenhouse gas contributions
- Using mufflers and sound attenuation equipment, where possible (e.g., pump enclosures) to reduce noise
- Minimizing temporary road and staging area footprints to limit habitat disturbance
- Incorporating remedial technologies that achieve RGOs while decreasing the short-term and long-term bioavailability of COCs (e.g., sediment capping or thin-cover placement)
- Evaluating, as part of the remedial design, the possibility of incorporating passive sampling devices for long-term monitoring

All alternatives, except the No Action alternative (Alternative 1), would incorporate sustainable practices. The extent to which these environmentally sustainable practices are incorporated depends on the selected remedy components and the remedy footprint (e.g., incorporating technologies that decrease the short-term and long-term bioavailability of COCs), the project duration (e.g., sustainable equipment and operational practices), and the volumes of clean fill required for remedy implementation (e.g., beneficial reuse of clean dredged material from nearby waterways).

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7 Feasibility Study Summary

This FS identified six remedial alternatives, which have been screened (Section 5) and evaluated against NCP criteria (Section 6). Alternative 1 (No Action)—included in the screening and evaluation as required by NCP to provide a baseline—is not carried forward for the comparative analysis because, while it is readily implementable and low-cost, Alternative 1 does not accomplish the following:

- Achieve some of the RAOs or RGOs
- Adequately protect human health or the environment
- Comply with the ARARs
- Reduce COC toxicity, mobility, or volume
- Mitigate long-term risks within a reasonable time frame

This section summarizes the comparative analysis of Alternatives 2 through 6 against the RGOs and RAOs identified in Section 3 (Section 7.1), reviews the FS against USEPA guidance (Section 7.2), and provides cost and risk-of-remedy analysis in support of remedy selection (Section 7.3).

7.1 Summary of the Comparative Analysis

With the exception of the No Action alternative, all remedies considered in the FS are expected to significantly reduce risks to human health and the environment. The SWAC RGOs were developed to be protective of receptors/pathways that integrate exposure over larger areas (e.g., fish and wildlife), while the benthic community RGOs were developed to assess protectiveness to receptors exposed over relatively small areas (e.g., benthic invertebrates). With the exception of a few isolated sample locations with elevated COC concentrations, all five active alternatives reduce surface sediment concentrations to levels at or below the site-specific RGO range that provides varying degrees of protectiveness. Alternatives 2 through 6 also comply with ARARs and achieve the threshold criteria of protection of human health and the environment.

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Alternatives 2 and 3 capture the areas exceeding the low range of the RGOs but may result in more destructive impacts to the estuary from implementing their proposed remedies. Alternatives 4 and 5 capture the majority of areas above the RGO range except in the Western Creek Complex, upper Domain 3 Creek, and in Purvis Creek. Alternative 6 captures the majority of areas in Purvis Creek above the RGO range. Each of these alternatives provide for long-term human health and ecological risk reduction by decreasing surface sediment COC concentrations, which leads to reduced chemical bioavailability and chemical uptake by human and ecological receptors, which in turn leads to reduced risks to human health, mammals, birds, fish, and the benthic community. Long-term monitoring measures long-term remedy integrity and effectiveness.

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To varying degrees, the remedies achieve the RAOs established in Section 3 by dredging and backfilling, capping, or covering sediments. Alternatives 2 through 6 achieve RAOs 1 through 6 as follows:

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- RAO 1: *Mitigate potential COC releases of contaminated instream sediment deposits and prevent such releases from entering Purvis Creek.*

  Alternatives 2 through 6 mitigate potential COC releases of contaminated instream sediment deposits and help prevent releases into Purvis Creek. All five alternatives remediate the highest COC concentrations in OU1 (i.e., all five include LCP Ditch, Eastern Creek, and Domain 3 Creek) and substantially reduce the potential for transport from instream deposits to Purvis Creek.

- RAO 2: *Reduce exposure to piscivorous bird and mammal populations from ingestion of COCs in prey exposed to contaminated sediment in the estuary to acceptable levels considering spatial forage areas of the wildlife and movement of forage prey.*

  Lower surface sediment concentrations reduce exposures to piscivorous bird and mammal populations from ingestion of COCs in prey exposed to contaminated sediment in the estuary. Alternatives 2 through 6 achieve the site-specific remedial goals insofar as all achieve the RGO range for the target COCs. Furthermore, postremediation HQs for all species, including the most sensitive species (green heron), are at or below 1 for all alternatives. Thus, the five remedies reduce sediment concentrations to acceptable levels, especially when considering spatial forage areas of wildlife and movement of forage prey.

- RAO 3: *Reduce human exposure to COCs, through the ingestion of fish and shellfish, that could result in a cumulative HI greater than 1 or exceed the acceptable range for cancer risk, defined as an added health risk between 1 in 10,000 (1 x 10^{-4}) and 1 in 1,000,000 (1 x 10^{-6}).*

  Alternatives 2 through 6 reduce human exposure to COCs through ingestion of fish and shellfish associated with Site contaminants. Each alternative results in total creek and total marsh SWACs that meet the SWAC RGOs, leading to reductions of mercury and Aroclor 1268 in fish and shellfish concentrations that is expected to reduce fish and shellfish consumption advisories within the TRBE. Moreover, the analysis provided in Section 5 shows that the individual areas lie within the SWAC RGOs, which were based on protection of human health, as well as ecological receptors.[12] Sediment concentrations in Purvis Creek are not reduced by Alternatives 4 and 5 which may underestimate human health protection for the high finfish consumer. However, Alternatives 2, 3, and 6 are protective of this receptor group.

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- RAO 4: *Reduce ecological risks to benthic organisms exposed to contaminated sediment to levels that will result in self-sustaining benthic communities with diversity and structure comparable to that in appropriate reference areas.*

  Alternatives 2 through 6 reduce ecological risks to benthic organisms exposed to contaminated sediment to levels that are consistent with the benthic community RGOs. The remedies address the areas containing the highest COC concentrations in the marsh and reduce surface sediment concentrations to levels at or below the site-specific RGO range.

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[12] The exception to this was in the Domain 3 Creek, which was above the SWAC RGOs for mercury. However, because the Domain 3 Creek is not large enough to support finfish, risks to finfish from the Domain 3 Creek are not significant. When average conditions of the Domain 3 Creek are considered with other nearby creeks, the postremedy SWAC conditions for Alternatives 2 through 6 are protective of human health.

Alternatives 2 and 3 would result in the lowest residual risks to the benthic community; however disturbing the large areas for remediation may significantly impact not only the sediment-dwelling communities, but the habitat structure for many other organisms. Alternatives 4 and 5 would result in greater residual risk, but would be the least destructive to the environment. Alternative 6 provides a blend, and targets some of the higher contaminated sediments in Purvis Creek

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- RAO 5: *Reduce finfish exposures from ingestion of COCs in food items exposed to contaminated sediment in the estuary to support conditions within OU1 that do not pose unacceptable adverse effects on fish.*

  Alternatives 2 through 6 reduce finfish exposures to COCs to acceptable levels. In all five remedies, the postremedy residual finfish HQs are at or below 1.

- RAO 6: *Meet and sustain the applicable USEPA National Recommended Water Quality Criteria and State of Georgia Water Quality Standards for protection of aquatic life in the estuary.*

  Alternatives 2 through 6 are expected to meet the applicable USEPA and Georgia WQS for protection of aquatic life in the estuary, using total and dissolved-phase mercury and PCB measures. The five remedies address the highest concentrations in the estuary, including elevated concentrations in major creeks. These actions will reduce the potential for contaminated sediment particle transport throughout the estuary and thereby limit future ambient water quality criteria exceedances.

In summary, Alternatives 2 through 6 meet the RAOs and are designed to achieve the SWAC-based and benthic-community-based RGOs.

7.2 Analysis of FS Consistency with USEPA Guidance

Preparation of the FS was consistent with USEPA policy and guidance, including *Principles for Managing Contaminated Sediment Risks (*USEPA 2002)*, Contaminated Sediment Remediation Guidance for Hazard Waste Sites* (USEPA 2005a), and *Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (USEPA 1999). The FS also was consistent with the HHBRA and BERA documents prepared for the Site.

7.2.1 USEPA's 11 Principals for Managing Contaminated Sediment Risk

USEPA prepared the *Principles for Managing Contaminated Sediment Risks* (USEPA 2002) to "help [US]EPA site managers make scientifically sound and nationally consistent risk management decisions at contaminated sediment sites." The 11 principles, which were reiterated in the USEPA guidance document (USEPA 2005a) were incorporated into the FS as follows.

1. *Control sources early*

   Sources have been controlled. Source control is discussed in Section 3.

2. *Involve the community early and often*

   Though not explicitly discussed in this FS, PRPs have engaged community groups to help them understand the scope of the work planned for the Brunswick site.

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3. *Coordinate with states, local governments, Indian tribes, and natural resource trustees*

   Though not explicitly discussed in this FS, PRPs have engaged the state and local governments and trustees to help them understand the scope of the work planned for the Brunswick site.

4. *Develop and refine a conceptual site model that considers sediment stability*

   A robust CSM was developed (Section 2) and included the development of a hydrodynamic model (Appendix B) that was used to examine sediment and remedy stability.

5. *Use an iterative approach in a risk-based framework*

   The FS evaluated a range of RGOs (Section 3) and remedy alternatives (Section 5), and over time the PRPs have engaged USEPA Region 4 and GAEPD in an iterative approach to design and refine remedies that are applicable and that meet the threshold criteria of protection of human health and the environment and compliance with ARARs (Section 6).

6. *Carefully evaluate the assumptions and uncertainties associated with site characterization data and site models*

   The FS carefully considered and evaluated assumptions and uncertainties of the HHBRA and the BERA, as well as uncertainties in the remedy alternatives. Various conservative assumptions were used when calculating risks in the HHBRA and the BERA, in order to account for unavoidable uncertainty (Section 6). The groundwater transport analysis (Appendix A) and the surface water hydrologic model (Appendix B) were conservatively applied (Section 5) to account for uncertainties with regard to remedy stability and cap design requirements.

7. *Select site-specific, project-specific, and sediment-specific risk management approaches that will achieve risk-based goals*

   Site-specific RAOs and RGOs (Section 3) were based on the site-specific HHBRA and BERA analyses and conclusions.

8. *Ensure that sediment cleanup levels are clearly tied to risk management goals*

   Remedy Alternatives 2 through 6 were clearly tied to the RGOs established in Section 3, and were evaluated against NCP criteria in Section 6 and against RAOs in Section 7.

9. *Maximize the effectiveness of institutional controls and recognize their limitations*

   Although institutional controls can be used to limit human exposures and transport of contamination, when used alone at the Site, they may not be sufficient in significantly reducing or eliminating human or ecological exposures (Section 6). The existing institutional controls for the estuary (i.e., fish consumption advisories, commercial fishing ban) will be maintained until criteria for delisting are attained. Requirements applicable to permits obtained during construction activities may be used as institutional controls during construction.

10. *Design remedies to minimize short-term risks while achieving long-term protection*

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The advantages and disadvantages of a remedy should be assessed based on the long-term protection of that remedy versus its short- and long-term impacts during and after implementation (USEPA 2002). The FS evaluates the six remedial alternatives for the Site with respect to NCP 40 CFR 300.430(e)(9) criteria, which include long-term effectiveness and permanence and short-term effectiveness. Except for the No Action alternative, all alternatives provide long-term human health and ecological risk reduction by targeting site-specific RGOs. However, the remedies differ in the amount of risk reduction achieved and with regard to their respective impacts on the existing habitat. Alternatives 4, 5 and 6, which rely on the upper-end RGOs remediate a smaller footprint than Alternatives 2 and 3, but also minimize impacts to the ecosystem by targeting remediation of those areas where COC levels are above the acceptable RGO range. Similarly, when employing combined remedies that include removal plus capping plus thin-cover placement, Alternative 3 and Alternatives 5 and 6 have a smaller environmental impact compared to Alternatives 2 and 4, respectively, because the combined remedies remove only those areas with the highest COC levels that cannot be remediated via capping or thin-cover placement and rely on less intrusive approaches for lower-risk areas.

11. *Monitor during and after sediment remediation to assess and document remedy effectiveness*

    Monitoring will occur during and after implementation of the remedy. The monitoring requirements specific to each alternative are described briefly (Sections 5) and will be developed further as part of remedy design.

7.2.2 USEPA Contaminated Sediment Remediation Guidance for Hazardous Waste Sites

Consistent with USEPA's (2005a), *Contaminated Sediment Remediation Guidance for Hazard Waste Sites*, the FS evaluates capping, thin-cover placement, sediment removal, and MNR. No action and institutional controls are considered, as well. USEPA (2005a) policy is

> "there is no presumptive remedy for any contaminated sediment site, regardless of the contaminant or level of risk. At many sites, but especially at large sites, a combination of sediment cleanup methods may be the most effective way to manage the risk."

The FS evaluates dredge-only remedies (Alternatives 2 and 4) and remedies that combine removal, capping, and thin-cover placement (Alternatives 3, 5, and 6).

The FS carefully evaluated the in-place options (i.e., capping and thin-cover placement) for long-term effectiveness and permanence. A groundwater analysis of contaminant transport (Appendix A), surface water modeling (Appendix B), and detailed cap modeling (Appendix J) were performed to evaluate the physical and chemical stability of both approaches, adding confidence that they can be designed and implemented effectively, and that they will provide long-term risk reduction. Appendix I, the review of thin-cover placement approaches and precedents, was provided to demonstrate the maturity of the thin-cover placement technology to protect human and ecological receptors.

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Consideration also was given not only to risk reduction associated with reduced human and ecological exposure to contaminants, but also to risks introduced by implementing the alternatives (Sections 6 and 7; USEPA *Principal 10*, above).

7.2.3 USEPA Risk Management Principles and Consistency with Site-Specific Risk Assessments

The BERA, the FS, and Alternative 2 through 6 are consistent with *Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (USEPA 1999). The principles provided in the guidance are "intended to help Superfund risk managers make ecological risk management decisions that are based on sound science, consistent across Regions, and present a characterization of site risks that is transparent to the public" (USEPA 1999). The following are key principles discussed in this directive:

- Superfund's goal is to reduce ecological risks to levels that will result in the recovery and maintenance of healthy local populations and communities of biota
- Use site-specific ecological risk data to support cleanup decisions
- Characterize site risks
- Remediate unacceptable ecological risks

The guidance also includes questions that should be addressed by risk managers and risk assessors:

- What ecological receptors should be protected?
- Is there an unacceptable risk at the site?
- Will the cleanup cause more ecological harm than the current site contamination?
- What cleanup levels are protective?

These principles and questions are fully addressed in the BERA and the FS. The BERA defines the ecological receptors that should protected (Black and Veatch 2011; Section 3.0) and concludes that under baseline conditions, there are unacceptable risks at the Site (Black and Veatch 2011; Section 5.0). The RGOs presented in Section 3 are protective cleanup levels based on the findings of the HHBRA and BERA. SWAC RGOs are protective of the humans and other mammals, birds, and fish in the Site. Benthic community RGOs are protective of sediment-dwelling organisms.

Alternatives 2 through 5 reduce ecological risks to acceptable levels by targeting the site-specific RGOs. By targeting the site-specific RGOs in all five of the active remedies, ecological risks will be reduced to levels that will result in recovery and maintenance of healthy local populations and communities of biota. Furthermore, site-specific ecological risk data were used to support cleanup decisions, Site risks are characterized, and unacceptable ecological risks will be remediated.

The final key question raised by USEPA (1999) is whether the cleanup will cause more ecological harm than the current Site contamination. The range of alternatives included in the

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FS provides an opportunity to consider approaches that achieve acceptable levels while minimizing harm to the marsh. Except for the No Action alternative, all alternatives provide long-term human health and ecological risk reduction by targeting site-specific RGOs. However, as discussed above, some alternatives disproportionately impact the existing habitat, while others have a much lesser impact on existing habitat. Because the physical impact of the remedies on the existing marsh habitat is in proportion to the size and scope of the remedy, Alternatives 2 through 6 balance human and ecological risk reduction with sustaining and protecting existing habitat and wildlife to varying degrees. The SMA-1 alternatives (Alternatives 2 and 3) address larger areas and thus have the potential for greater risk reduction, but more substantially impact the existing vegetated marsh habitat than the SMA-2 alternatives (Alternatives 4 and 5) and the SMA 3 alternative (Alternative 6). Furthermore, whereas the dredging-only remedies (Alternatives 2 and 4) remove a larger mass of contaminants from the Site than the remedies that integrate dredging, capping, and thin-cover placement (Alternatives 3, 5, and 6), the dredge-only remedies also have a more destructive impact on the vegetated marsh habitat. In summary, habitat disturbance is proportional to the remedial footprint and is more substantial for removal and capping compared to thin-cover placement. Section 7.3 compares risk reduction among all six alternatives with impacts to the marsh.

7.3 Cost and Risk-of-Remedy Analysis in Support of Remedy Selection

CERCLA and the NCP require that every selected remedy be cost-effective (USEPA 1996). A remedy is cost-effective if its "costs are proportional to its overall effectiveness" (40 CFR 300.430(f)(1)(ii)(D)). Overall effectiveness of a remedial alternative is determined by evaluating long-term effectiveness and permanence; reduction in toxicity, mobility, and volume through treatment; and short-term effectiveness. Overall effectiveness is then compared to cost to determine whether the remedy is cost-effective (USEPA 1996).

The evaluation of alternatives with respect to long-term effectiveness and cost (Sections 6.2.3 and 6.2.7) can be summarized as follows:

- While Alternatives 2 and 3 (SMA-1) include the remediation of the largest areas, they do not provide a significantly greater overall risk reduction than Alternatives 4 and 5 (SMA-2) or 6 (SMA-3).
- Though residual COC concentrations in the estuary differ among the remedies, most are within the benthic community RGO range. There may not be greater improvement in risk reduction to the benthic community when achieving the lower end of the RGO range, particularly given the adverse impacts from the remedy itself to the benthic community in efforts to address the larger footprints that correspond to the lower NTE values.
- Costs are presented in Table 6-5 and in Appendix H. Alternative 5 has the lowest total estimated present-worth cost of approximately $26MM. Remedy Alternative 2 has the highest total estimated present-worth cost of $65MM. The total estimated present-worth costs of Alternatives 3, 4, and 6 are $39MM, $34MM and $29MM, respectively.

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7.3.1 Cost-Effectiveness Analysis

Remedy cost-effectiveness, defined herein as the cost associated with risk reduction following remedy implementation, is evaluated by comparing postremediation residual risks for each

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alternative against remedy costs. The figure 7-1 series shows risk reduction compared to total costs for the green heron exposed to mercury (Figure 7-1A), finfish exposed to Aroclor 1268 (Figure 7-1B), and finfish exposed to mercury (Figure 7-1C). These figures present total costs for each of the remedy alternatives, understanding that the degree of risk reduction and costs differ for each of the various portions of the overall footprints. For example, risk reduction and costs associated with remediation of the LCP Ditch differ from the risk reduction and costs associated with Domain 1 remediation. The amount of risk reduction for each creek or domain area is represented by the individual data points for each alternative plotted on the graphs.

Alternatives 2 through 6 achieve HQs at or below 1. Although Alternatives 2 and 3 have the greatest predicted COC risk reduction, they do not provide a substantially greater overall risk reduction in proportion to their greater costs when compared to Alternatives 4 and 5 or 6, for bird and fish populations. Therefore, Alternatives 2 and 3 have the lowest cost-effectiveness (i.e., the highest cost relative to effectiveness) because they provide only an incremental increase in risk reduction at a significantly greater cost than Alternatives 4, 5, and 6.

Risk reduction is virtually the same among Alternatives 4, 5, and 6, although the Alternative 6 residual risks are slightly lower than those for Alternatives 4 and 5 because Alternative 6 includes areas in Purvis Creek and Domain 1. Alternatives 5 and 6 are more cost-effective than Alternative 4 because they achieve the same degree of risk reduction at lower costs. The uncertainty in costs and risk reduction make it impossible to compare Alternatives 5 and 6, so both are considered comparably cost-effective.

Except for the No Action alternative, each of the remedial alternatives addresses concentrations in various areas that are above the RGO range and reduce ecological risks to benthic organisms exposed to contaminated sediment. Figures 6-6 through 6-8 identify differences among the footprints relative to the RGO range, and show where residual chemical risks may remain. Thus, the increased cost associated with the larger sediment footprint (SMA-1, Alternatives 2 and 3) and those associated with removal only (Alternative 2 and 4) are disproportionate to their benefit. Cost-effective remedies are those that are protective of the benthic community at the lowest cost and the lowest negative impact to the ecosystem. Accordingly, Alternatives 5 and 6 are the most cost-effective remedies for the Site.

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In summary, Figures 7-1A through 7-1C, and the remedy effectiveness discussions in Section 6, indicate that the marginal improvement in risk reduction for mammals, birds, fish, and sediment-dwelling organisms under Alternatives 2 and 3 is disproportionately expensive compared to Alternatives 4, 5, and 6. Furthermore, much higher costs are associated with removal only when compared to remedies that combine and optimize the use of removal, capping, and thin-cover placement. Because these higher costs do not achieve correspondingly reduced risks, the combined remedies are considered more cost effective than the removal-only remedies.

7.3.2 Ecosystem Impacts Analysis

Long-term ecological recovery of the estuary is a time-dependent process, with longer recovery times required for larger-scale remedies (Alternatives 2 and 3 vs. Alternatives 4, 5, and 6), and for dredging remedies (Alternatives 2 and 4) compared to remedies that rely on a combination of dredging plus backfill, capping, and thin-cover placement (Alternatives 3, 5, and 6).

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Predictions of ecological impacts such as damage to the vegetated marsh areas are driven by the size of the SMA footprint plus incidental areas not targeted for remediation but damaged as part of the construction process (e.g., road construction in the marshes to access areas targeted for remediation).

Figure 7-2 plots remedy cost versus area disturbed by each remedy, as this area of disturbance is related to impacts to the marsh and the sediment-dwelling organism community. Alternatives 2 and 3 impact the largest areas (59 and 56 acres, respectively); Alternatives 4 and 5 impact the smallest areas (29 and 26 acres, respectively); and Alternative 6 falls between those alternatives (31 acres impacted).

Figures 7-3A, 7-3B, and 7-3C show risk reduction compared to the area remediated and impacted by each remedy for the green heron exposed to mercury, finfish exposed to Aroclor 1268, and finfish exposed to mercury, respectively. These figures are similar to Figures 7-1A through 7-1C, except that the impacted area is shown on the x-axis instead of cost. Though similar, the observations between Figures 7-3 and 7-1 differ slightly. The SMA-1 remedies (Alternatives 2 and 3) have the largest area of impact at 56-59 acres. Alternatives 3, 4, and 5 are comparable and impact 26-31 acres. Although the residual risks associated with SMA-1 (Alternatives 2 and 3) are lower than those associated with SMA-2 (Alternatives 4 and 5) and SMA 3 (Alternative 6), all remedies reduce HQ levels to 1 or below 1; thus, all alternatives are adequately protective of the environment.

With the exception of a few isolated sample stations with elevated concentrations, Alternatives 2 through 6 meet the ARARs, RAOs, and are within the RGO ranges. Alternatives 4, 5 and 6 are most cost-effective in achieving goals while minimizing vegetated marsh disturbance and recovery. These alternatives will comply with project goals and limit vegetated marsh disturbance to approximately half of what would result from implementing Alternatives 2 or 3 (Figure 7-2). Among Alternatives 4, 5, and 6, Alternatives 5 and 6 combine removal, capping, and thin-cover placement; specifically, thin-cover placement is targeted for marsh areas where risks are moderate and where dredging would severely impact the existing marsh habitat; areas remediated using thin-cover placement are expected to recover more quickly (i.e., within approximately two growing seasons).

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7.3.3 Marsh Recovery Analysis

Predictions of ecological recovery time frames depend on the remediation approach as well as on the remediation footprint. Sediment removal is much more intrusive to vegetated marsh areas than thin-cover placement, leading to longer recovery times. As a result, the alternatives that incorporate only sediment removal (i.e., Alternatives 2 and 4) require longer periods for ecological recovery than remedies that combine removal with sediment capping and thin-cover placement for vegetated marsh areas (Alternatives 3, 5, and 6).

7.3.4 Conclusion

Throughout the preparation of the FS, practices employed were well aligned with USEPA guidance and policy. Based on all the remedy selection criteria—including the ecosystem impact analysis, marsh recovery analysis, and cost-effectiveness analysis discussed above—Alternative 6 appears to be the most effective remedial alternative for OU1. This alternative

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satisfies the site-specific RAOs, is within the site-specific RGO ranges, and meets the NCP criteria of overall protectiveness, implementability, and permanence while limiting risks associated with disturbing sensitive habitat.

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Tables

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:
Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:
ENVIRON International Corporation

Anchor QEA, LLC

Date:
June 2, 2014

Table 2-1
Names and Areas of Site Estuary Domains
LCP Chemical Site, Brunswick, Georgia

Name	Approximate Area (acres)
Domain	
Dillon Duck	1.8
Domain 1	21
Domain 2	115
Domain 3	108
Domain 4 East	192
Domain 4 West	224
Creek	
Domain 3 Creek	12
Eastern Creek	4.2
LCP Ditch ("Main Canal")	2.5
Purvis Creek	70
Western Creek Complex	9
Total Domains	**662**
Total Creeks	**98**

Table 2-2
Range of Percent Inundation Times for Areas within the LCP Marsh Based on Elevation
LCP Chemical Site, Brunswick, Georgia

Domain/Creek Name	Average Thalweg Depth (ft)	Range in Bank Elevation (ft)	Range in Percent Time of Water in Marsh Land (%)
Purvis Creek	-12.3	2-3	4-13
Eastern Creek	-3.35	2-3	4-13
Domain 3 Creek	-2.43	2-3	4-13
LCP Ditch	-1.5	1.5-2.5	10-20

%	percent
ft	feet

Table 2-3

Total Aroclor 1268 Concentrations in Surface Water Compared to GAEPD WQS and USEPA NRWQC
LCP Chemical Site, Brunswick, Georgia

Year	Mouth of Eastern Creek C-9	Mouth of Western Creek C-15	Upper Purvis Creek C-36	Mid-Stretch Purvis Creek C-29	Mouth of Purvis Creek C-16	Control TC	Control CR
2000	0.19	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	0.33
2002	---	---	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*
2003	---	---	*0.25*	*0.25*	1	*0.25*	*0.25*
2004	---	---	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*
2005	---	---	*0.01*	*0.01*	*0.01*	*0.5*	*1.4*
2006	0.18	0.026	0.021	0.044	0.029	0.0012	*0.0005*
2007	0.44	0.22	0.024	0.031	0.037	0.0024	---

---	not analyzed
GAEPD	Georgia Environmental Protection Division
NRWQC	National Recommended Water Quality Criteria
PCB	polychlorinated biphenyl
µg/L	microgram(s) per liter
USEPA	United States Environmental Protection Agency
WQS	water quality standard

All results in micrograms per liter (µg/L).
GAEPD and USEPA WQS for Aroclor 1268 in Coastal and Marine Estuarine Waters is 0.03 µg/L.

Numbers italicized and in gray were non-detected values that were assigned a value of 1/2 of detection limit.

Cells shaded in yellow were above the WQS. Please note that PCB detection limit was above the threshold level of 0.03 µg/L.

Control locations were Troop Creek (TC) and Crescent River (CR).
Surface water results taken from Table 4-2b of the BERA (Black and Veatch 2011).

Table 2-4
Human Health COCs Identified in Sediment and Biological Tissue
LCP Chemical Site, Brunswick, Georgia

Chemical	Sediment	Fish	Shellfish	Clapper Rail
Aluminum	X			
Aroclor 1268 (a)	X	X	X	X
B(a)P TEQ	X			
Copper			x	
Chromium (b)	X			
Lead	X			
Manganese	X			
Mercury (c)	X	X	X	X
Thallium	X			
Zinc			X	

B(a)P TEQ	benzo(a)pyrene toxic equivalents
COC	chemical of concern
HHBRA	human health baseline risk assessment
TEQ	toxic equivalent

(a) Aroclor 1268 was identified as a COC based on comparisons to the regional screening levels for Aroclor 1254.

(b) As a conservative assumption, chromium in sediment and biota was assumed to be in the hexavalent state, despite the reducing conditions of the sediment.

(c) Although mercury and methylmercury were considered separately for sediment exposure in the HHBRA, both chemical forms were assessed conservatively as methylmercury.

Table 2-5
Fish Consumption Advisories for Turtle River/Brunswick Estuary over Time
LCP Chemical Site, Brunswick, Georgia

Values in table correspond to number of meals allowable per month.[a]

	Purvis & Gibson Creeks (Zones H and I)			Middle Turtle River (Zone D)			Upper Turtle and Buffalo Rivers (Zones A, B, and C)			Lower Turtle and S. Brunswick Rivers (Zones E, F, and G)		
Species	1997 Survey	2002 Survey	**2011 Survey**	1997 Survey	2002 Survey	**2011 Survey**	1997 Survey	2002 Survey	**2011 Survey**	1997 Survey	2002 Survey	**2011 Survey**
Atlantic Croaker	0	0	0	1	1	1	1	1	1	4	1	1
Black Drum	0	1	1	1	1	4	0	1	4	1	4	4
Blue Crab	0	1	4	1	1	4	4	4	4	4	4	NR
Red Drum	0	4	4	1	4	4	4	4	4	NR	4	NR
Sheepshead	NC	1	1	NC	1	1	NC	1	4	NC	4	NR
Southern Flounder	0	4	4	4	4	4	4	4	NR	NR	NR	NR
Southern Kingfish	NC	1	1	NC	1	1	NC	1	1	NC	1	4
Spot	NC	1	1	NC	0	0	NC	1	1	NC	1	1
Spotted Seatrout	0	1	1	1	1	1	1	4	1	1	4	4
Striped Mullet	NC	0	4	NC	0	1	NC	0	4	NC	1	NR
Penaeid Shrimp	0	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

Notes:

FCG	fish consumption guidelines
NC	species not collected (no FCG)
NR	no restrictions to consumption

(a) GADNR 2012

Summary:

2002	11 cases show improvement. 2 cases more restrictive.	
2011	15 cases show improvement. 1 case more restrictive.	

→ Arrow denotes improvement from one survey period to another.

🟩 Green highlight denotes where FCG improved from previous survey event.

🟧 Orange highlight denotes where FCG worsened from previous survey event.

🟨 Yellow highlight denotes where data shows improvement but previous FCG is carried forward due to insufficient number of fishes caught.

Table 2-6
Summary of Calculated Risks and Hazards from the HHBRA
LCP Chemical Site, Brunswick, Georgia

	Cancer Risk		Noncancer HI	
Exposure Scenario / Receptor	**RME**	**CTE**	**RME**	**CTE**
Marsh Trespasser				
Lifetime	1E-05	2E-07		
Adult			0.06	0.005
Adolescent			0.08	0.006
Recreational Finfish Consumer				
Lifetime	1E-04	2E-05		
Adult			3	0.8
Adolescent			3	0.9
Child			4	1
High Quantity Finfish Consumer				
Lifetime	2E-04	4E-05		
Adult			5	2
Adolescent			5	3
Child			8	2
Shellfish Consumer				
Lifetime	6E-05	9E-06		
Adult			2	0.6
Adolescent			0.7	0.2
Child			4	2
Clapper Rail Consumer				
Lifetime	1E-04	8E-06		
Adult			2	0.4
Adolescent			1	0.1
Child			5	0.4

CTE	central tendency exposure
HHBRA	human health baseline risk assessment
HI	hazard index
RME	reasonable maximum exposure

Table 2-7
Experimental Design of the BERA
LCP Chemical Site, Brunswick, Georgia

Measurement [a]	Number of Sampling Stations [b, c]	Method [d]	Typical Detection Limit	Other Details
Surface Water Chemistry -- Creek Water				
General water quality characteristics	12	Hydrolab	-----	Temperature, salinity, specific conductance, turbidity, pH, and dissolved oxygen evaluated
Total mercury	12 + 29 (2005)	1631E	0.07 ng/L	Total and dissolved mercury evaluated by "clean-hands" technique
Methylmercury (2005)	28	Bloom 1989	0.02 ng/L	Evaluated by "clean-hands" technique; all 28 data employed in analysis.
Aroclor 1268	12	8082	0.001 µg/L	-----
Lead	12	200.8	0.002 µg/L	Total and dissolved lead evaluated
Surface Water Toxicity -- Creek Water				
Mysids	6 (2000)	1007	-----	7-day test designed to evaluate chronic effects; 8 replicates per sampling station; evaluation of survival and growth of mysids exposed to water in laboratory
Sheepshead minnows	6 (2000)	1004	-----	7-day test designed to evaluate chronic effects; 4 replicates per sampling station; evaluation of survival and growth of fish exposed to water in laboratory
Surface Sediment Chemistry -- Creek Sediment[e]				
Grain-size distribution	27	ASTM D-422	1% passing sieve	-----
Total organic carbon	27	ASTM D4129-82M	0.02% (dry wt)	-----
Total mercury	27 +150 + 31 (2005)	1631E	0.001 mg/kg (dry wt)	-----
Methylmercury (2005)	31	Bloom, 1989	0.008 µg/kg (dry wt)	
Aroclor 1268	27 +150	8082	0.003 mg/kg (dry wt)	-----
Lead	27 +150	6020	0.02 mg/kg (dry wt)	-----
Total PAHs	27 +150	8270C	0.001 mg/kg (dry wt)	18 different PAHs evaluated
Secondary metals	20	6010B/6020	<1 mg/kg (dry wt)	21 different metals evaluated
Simultaneously extracted metals (SEM)	20	6010B-SEM	1 mg/kg (dry wt)	6 different metals (cadmium, copper, lead, nickel, silver, and zinc) evaluated
Acid-volatile sulfide (AVS)	20	USEPA 1991	0.5 mg/kg (dry wt)	-----

Table 2-7
Experimental Design of the BERA
LCP Chemical Site, Brunswick, Georgia

Measurement [a]	Number of Sampling Stations [b, c]	Method [d]	Typical Detection Limit	Other Details
Surface Sediment Chemistry -- Marsh Sediment)[e]				
Grain-size distribution	26	ASTM D-422	1% passing sieve	-----
Total organic carbon	26	ASTM D4129-82M	0.02% (dry wt)	-----
Total mercury	26 + 29 (2005)	1631E	0.001 mg/kg (dry wt)	
Methylmercury (2005)	29	Bloom 1989	0.008 µg/kg (dry wt)	
Aroclor 1268	26	8082	0.003 mg/kg (dry wt)	-----
Lead	26	6020	0.02 mg/kg (dry wt)	-----
Total PAHs	26	8270C	0.001 mg/kg (dry wt)	18 different PAHs evaluated
Secondary metals	4	6010B/6020	1 mg/kg (dry wt)	21 different metals evaluated
Simultaneously extracted metals (SEM)	4	6010B-SEM	1 mg/kg (dry wt)	6 different metals (cadmium, copper, lead, nickel, silver, and zinc) evaluated
Acid-volatile sulfide (AVS)	4	USEPA 1991	0.5 mg/kg (dry wt)	-----
Surface Sediment Toxicity -- Creek and Marsh Sediment(e)				
Amphipods	24	EPA/600/R-01/020	-----	Main Amphipod Study. 28-day chronic test; 5 replicates per sampling station; evaluation of survival, growth, and reproduction of amphipods exposed to sedime in laboratory
Amphipods	150	EPA/600/R-01/020	-----	Apparent Effects Threshold (AET) Study. As above, except only 1 replication per sampling station.
Amphipods	3	Metals: usually 6020A; Aroclors: 8082; Total PAHs: 8270-SIM	Various	Toxicity Identification Evaluation (TIE): Analytical methods pertain to porewater analyses.
Grass shrimp	9	Special Lee test	-----	Direct evaluation of reproduction and DNA strand damage (Comet Test) of shrimp collected in field (no laboratory exposure to sediment)

Table 2-7
Experimental Design of the BERA
LCP Chemical Site, Brunswick, Georgia

Measurement [(a)]	Number of Sampling Stations [(b, c)]	Method [(d)]	Typical Detection Limit	Other Details
Benthic Community -- Creek Surface Sediment				
Benthic macroinvertebrates	6 (2000)	Relative numerical abundance	-----	Evaluation of number of taxa, taxonomic groups, and individuals; density of individuals; diversity of equitability indices
Biota Collected for Evaluation of Chemical Body Burdens (Residue) -- Creek and Marsh Stations				
Cordgrass (2005)	20	-----	-----	1 replicate (>100 g) per sampling station collected above 15 cm from ground
Eastern oysters	8	-----	-----	3 replicates of about 100 composited young-of-year (Year 0) oysters and 20 composited older (Years I and II) oysters per sampling station
Fiddler crabs	15	-----	-----	4-7 replicates of about 15-50 composited crabs (mostly males) per sampling station; replicate weight = about 16-55 g
Grass shrimp	9	-----	-----	3 replicates of about 50 composited shrimp per sampling station
Blue crabs	3	-----	-----	7 replicates of individual male crabs per sampling station; crab length (point-to-point on carapace) = about 130-170 mm (155-352 g)
Mummichogs	13	-----	-----	1-3 replicates of 5-30 composited fish (about 45-100 mm in length) per sampling station; replicate weight = 18.4-59.6 g
Silver perch	2	-----	-----	8 replicates of individual silver perch per sampling station; fish length (total length) = 155-185 mm (50 - 89 g)
Red drum	1	-----	-----	3 replicates of individual red drum at sampling station; fish length (total length) = 355-415 mm (527-832 g)
Black drum	2	-----	-----	8 replicates of individual black drum per sampling station; fish length (total length) = 170-220 mm (87-158 g)
Spotted seatrout	2	-----	-----	8 replicates of individual spotted seatrout per sampling station; fish length (total length) = 290-390 mm (236-627 g)
Striped mullet	2	-----	-----	5-8 replicates of individual striped mullet per sampling station; fish length (total length) = 230-340 mm (177-497 g)

Table 2-7
Experimental Design of the BERA
LCP Chemical Site, Brunswick, Georgia

Measurement [a]	Number of Sampling Stations [b, c]	Method [d]	Typical Detection Limit	Other Details
Chemical (Residue) Analyses Performed on Biota (Whole Bodies Analyzed)				
Total mercury	-----	1631E	0.0001 mg/kg (wet wt)	-----
Methyl mercury (2005)	-----	1630 (mod)	0.0004 mg/kg (wet wt)	-----
Aroclor 1268	-----	8082	0.0006 mg/kg (wet wt)	-----
Lead	-----	6020	0.001 mg/kg (wet wt)	-----
Lipids	-----	NOAA NOS ORCA 71	0.05% (wet wt)	Evaluated in just blue crabs and large finfishes (not reported).

AET	apparent effects threshold	NOAA	National Oceanic and Atmospheric Administration
AVS	acid-volatile sulfide	NOS	National Ocean Service
BERA	baseline ecological risk assessmen	ng/L	nanogram(s) per liter
cm	centimeter(s)	ORCA	Ocean Resources Conservation and Assessmen
g	gram(s)	PAH	polycyclic aromatic hydrocarbon
µg/kg	microgram(s) per kilogram	SEM	simultaneously extracted metals
µg/L	microgram(s) per liter	USEPA	United States Environmental Protection Agenc
mg/kg	milligram(s) per kilogram	wt	weight
mm	millimeter(s)		

(a) All measurements (studies) were performed in 2006 except those identified as occurring in 2000 or 2005.

(b) Number of sampling stations includes reference locations -- Crescent River and/or Troop Creek.

(c) The 150 creek sediment samples are associated exclusively with the AET study conducted during this investigation. Evaluation of sediment for secondary metals, SEM, and AVS was performed on just those sediment samples also tested for toxicity in the main amphipod study.

(d) Analytical methods are USEPA methods unless otherwise indicated.

(e) Surface sediment is defined as between 0 and 15 cm in depth.

Table 3-1
Chemical-Specific ARARs and TBC Items
LCP Chemical Site, Brunswick, Georgia

Requirement	Citation (Statutory and Regulatory)	Requirement Synopsis	Status for LCP Brunswick OU1
Clean Water Act, Section 301-302	33 USC §§ 1251, Section 301-302 40 CFR 129	Toxic Pollutant Effluent Standards	ARAR
Instream Water Quality Standards	O.C.G.A. 12-5-20 391-3-6.03	Adopted Federal National Recommended Water Quality Criteria to protect water uses.	ARAR
Clean Water Act 40, Section 304	USEPA Federal Register, Volume 57, No. 246, December 22, 1992 and subsequent updates; current list:http://water.epa.gov/scitech/swguidance /standards/current/index.cfm	Establishes ambient water quality criteria (National Recommended Water Quality Criteria) which provide guidance for states and tribes to use in adopting water quality standards.	ARAR
Total Maximum Daily Load (TMDL) - PCBs	July 2001, USEPA TMDL Development for Fish Consumption Guidelines & Commercial Fishing Ban due to PCBs	Establishes TMDL 0.00045 ug/L (Gibson Creek, Terry Creek, Purvis Creek, Turtle River System)	TBC

Table 3-1
Chemical-Specific ARARs and TBC Items
LCP Chemical Site, Brunswick, Georgia

Requirement	Citation (Statutory and Regulatory)	Requirement Synopsis	Status for LCP Brunswick OU1
TMDL - Mercury	July 2001 TMDL Development for Mercury	Establishes Satilla Watershed TMDL for Mercury at 3.76 kg/yr to achieve 2.5 ng/L	TBC
NOAA Sediment Quality Guidelines [SQGs]	Screening Quick Reference Tables for Organics (SQRTs)	Tables with screening concentrations for inorganic and organic contaminants.	TBC

ARAR	applicable or relevant and appropriate requirement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
FEMA	Federal Emergency Management Agency
kg/yr	kilogram(s) per year
ng/L	nanogram(s) per liter
NOAA	National Oceanic and Atmospheric Administration
OCGA	Official Code of Georgia Annotated
OSWER	Office of Solid Waste and Emergency Response
PCB	polychlorinated biphenyl
TBC	to be considered
TMDL	total maximum daily limit
USACE	United States Army Corps of Engineers
USC	United States Code
USEPA	United States Environmental Protection Agency
µg/L	microgram(s) per liter

Table 3-2
Location-Specific ARARs and TBC Items
LCP Chemical Site, Brunswick, Georgia

Requirement	Citation (Statutory and Regulatory)	Requirement Synopsis	Status for LCP Brunswick OU1
Rivers and Harbors Act, Section 10	33 USC § 403 33 CFR Parts 320, 322, 323, 325, 329 and 330	USACE approval is generally required to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of the channel of any navigable water of the US.	ARAR
Clean Water Act, Section 404	33 USC § 1344 33 CFR Parts 320, 322, 323, 325, 328 and 330	These regulations apply to discharges of dredged or fill materials into U.S. waters, which include wetlands. Includes special policies, practices, and procedures to be followed by the USACE in connection with the review of applications for permits to authorize the discharge of dredged or fill material into waters of the US pursuant to Section 404 of the Clean Water Act.	ARAR
Clean Water Act, Section 404	33 USC § 1344 40 CFR Parts 230 and 231	No activity which adversely affects aquatic ecosystems, including wetlands, shall be permitted if a practicable alternative that has less adverse impacts is available. If there is no other practical alternative, impacts must be minimized.	ARAR
Endangered Species Act	16 USC § 1531 et. seq.	Federal statute establishing programmatic protection for endangered and threatened species.	ARAR
FEMA Operation Regulations and National Flood Insurance Program Regulations	42 USC 4001 et seq; 42 USC 4101	Prohibits alterations to river or floodplains that may increase potential for flooding; provides federal flood insurance to local authorities and requires that the local authorities not allow fill in the river that would cause an increase in water levels associated with floods.	ARAR
Fish and Wildlife Coordination Act	16 USC § 662 40 CFR 6.302	Whenever the waters of any stream or other body of water are proposed or authorized to be impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified for any purpose, by any department or agency of the US, such department or agency first shall consult with the United States Fish and Wildlife Service, Department of the Interior, and with the head of the agency exercising administration over the wildlife resources of the particular state in which the impoundment, diversion, or other control facility is to be constructed, with a view to the conservation of wildlife resources by preventing loss of and damage to such resources.	ARAR
Migratory Bird Treaty Act	16 USC §§703-712 50 CFR 10.12	Makes it unlawful to take, import, export, possess, buy, sell, purchase, or barter any migratory bird. “Take” is defined as pursuing, hunting, shooting, poisoning, wounding, killing, capturing, and trapping and collecting.	ARAR

Table 3-2
Location-Specific ARARs and TBC Items
LCP Chemical Site, Brunswick, Georgia

Requirement	Citation (Statutory and Regulatory)	Requirement Synopsis	Status for LCP Brunswick OU1
Bald and Golden Eagle Protection Act	16 USC §668a-d	Makes it unlawful to take, import, export, possess, buy, sell, purchase, or barter any bald or golden eagle, nest, or egg. "Take" is defined as pursuing, hunting, shooting, poisoning, wounding, killing, capturing, trapping and collecting, molesting, or disturbing.	ARAR
Marine Mammal Protection Act	16 USC 1361 et seq	Makes unlawful the harassment, hunting, capturing, or killing of marine mammals and the importation of marine mammals and marine mammal products without a permit from either the Secretary of the Interior or the Secretary of Commerce, depending upon the species of marine mammal involved.	ARAR
National Historic Preservation Act	16 USC § 470 et seq. 36 CFR Part 800	Proposed remedial actions must take into account effect on properties in or eligible for inclusion in the National Registry of Historic Places. Federal agencies undertaking a project having an effect on a listed or eligible property must provide the Advisory Council on Historic Preservation a reasonable opportunity to comment pursuant to section 106 of the National Historic Preservation Act of 1966 (NHPA), as amended. While the Advisory Council comments must be taken into account and integrated into the decision-making process, program decisions rest with the agency implementing the under-taking. A Stage 1A cultural resource survey may be necessary for any active remediation to identify historic properties along the lakeshore to determine if any areas should be the subject of further consideration under NHPA.	ARAR
Coastal Zone Management Act	16 USC 1451 15 CFR § 923	Specifies requirements for state coastal management program approval by the Assistant Administrator for Ocean Services and Coastal Zone Management	ARAR
Shore Protection Act (Georgia)	O.C.G.A. 12-5-230	Limits activities in shore areas and requires a permit for certain activities and structures on the beach.	ARAR
Coastal Marshlands Protection Act (Georgia)	O.C.G.A. 12-5-280	Provides the Coastal Resources Division with the authority to protect tidal wetlands. The Coastal Marshlands Protection Act limits certain activities and structures in marsh areas and requires permits for other activities and structures.	TBC
Protection of Tidewaters Act (Georgia)	O.C.G.A. 52-1-1	Establishes the State of Georgia as the owner of the beds of all tidewaters within the state, except where title by a private party can be traced to a valid British Crown or State land grant.	TBC

Table 3-2
Location-Specific ARARs and TBC Items
LCP Chemical Site, Brunswick, Georgia

Requirement	Citation (Statutory and Regulatory)	Requirement Synopsis	Status for LCP Brunswick OU1
USEPA Office of Solid Waste and Emergency Response	Policy on Floodplains and Waste and Wetland Assessments for CERCLA Actions, August 1985	This memorandum discusses situations that require preparation of a floodplain or wetlands assessment and the factors that should be considered in preparing an assessment for response actions taken pursuant to Section 104 or 106 of CERCLA. For remedial actions, a floodplain/wetlands assessment must be incorporated into the analysis conducted during the planning of the remedial action.	ARAR
Flood Damage Prevention (Glynn County)	Glynn County Code, Section 2-5-120	Establishes requirements to minimize public and private losses due to flood conditions	TBC
Executive Order No. 11988, 42 Fed. Reg. 26951 (May 25, 1977)	Floodplain Management	Executive Order describes the circumstances where federal agencies should manage floodplains.	TBC
Executive Order No. 11990, 42 Fed. Reg. 26961 (May 25, 1977)	Protection of Wetlands	Executive Order describes the circumstances where federal agencies should manage wetlands.	ARAR
Coastal Management Act (Georgia)	O.C.G.A. 12-5-320	Provides enabling authority for the State to prepare and administer a coastal management program	TBC

ARAR	applicable or relevant and appropriate requirement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
FEMA	Federal Emergency Management Agency
NOAA	National Oceanic and Atmospheric Administration
OCGA	Official Code of Georgia Annotated
OSWER	Office of Solid Waste and Emergency Response
TBC	to be considered
USACE	United States Army Corps of Engineers
USC	United States Code
USEPA	United States Environmental Protection Agency

Table 3-3
Action-Specific ARARs and TBC Items
LCP Chemical Site, Brunswick, Georgia

Requirement	Citation (Statutory & Regulatory)	Requirement Synopsis	Status for LCP Brunswick OU1
Clean Water Act, Section 401	33 USC 1341 40 CFR Part 121	State Water Quality Certification Program	ARAR
Toxic Substances Control Act	Title 1,15 USC § 2601 40 CFR §§ 761.65 – 761.75	TSCA facility requirements: Establishes siting guidance and criteria for storage (761.65), chemical waste landfills (761.75), and incinerators (761.70).	ARAR
Resource Conservation and Recovery Act	40 CFR Part 257	Establishes criteria for classification of waste disposal facilities and practices	ARAR
Resource Conservation and Recovery Act 42 USC s/s 6901 et seq. (1976)	40 CFR Part 261	Identification and listing of hazardous waste	ARAR
Resource Conservation and Recovery Act 42 USC s/s 6901 et seq. (1976)	40 CFR Part 262	Standards applicable to generators of hazardous waste	ARAR
Resource Conservation and Recovery Act 42 USC s/s 6901 et seq. (1976)	40 CFR § 262.11	Hazardous waste determination	ARAR
Resource Conservation and Recovery Act, 42 USC s/s 6901 et seq. (1976)	40 CFR Part 262.34	Standards for Hazardous Waste Generators, 90-Day Accumulation Rule	ARAR
Resource Conservation and Recovery Act, 42 USC s/s 6901 et seq. (1976)	40 CFR Part 263	Standards for Transporters of Hazardous Waste	ARAR
Resource Conservation and Recovery Act, 42 USC s/s 6901 et seq. (1976)	40 CFR Part 264 and 265, Subparts	Standards for Owners/Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities.	ARAR
	B-264.10 - .19	B- General Facility Standards	
	F-264.90 - .101	F- Releases from Solid Waste Management Units	
	G-264.110 - .120	G- Closure and Post Closure	
	J-264.190 - .200	J- Tank Systems	
	S-264.550 - .555	S- Special Provisions for Cleanup	
	X-264.600 - .603	X- Miscellaneous Units	
Section 3004 of the Resource Conservation and Recovery Act (Solid Waste Disposal Act, as amended),	40 CFR § 264. 13(b)	Owner or operator of a facility that treats, stores, or disposes of hazardous wastes must develop and follow a written waste analysis plan.	ARAR
Resource Conservation and Recovery Act, 42 USC s/s 6901 et seq. (1976)	40 CFR Part 264 and 265, Subparts	Standards for Owners/Operators of Hazardous Waste Treatment, Storage and Disposal Facilities.	ARAR
	K-264.220 - .232	K- Surface Impounds	
	L-264.250 - .259	L- Waste Piles	
	N – 264.300 - .317	N- Landfills, Subtitle C	

Table 3-3
Action-Specific ARARs and TBC Items
LCP Chemical Site, Brunswick, Georgia

Requirement	Citation (Statutory & Regulatory)	Requirement Synopsis	Status for LCP Brunswick OU1
Section 3004 of the Resource Conservation and Recovery Act, as amended, 42 USC § 6924	40 CFR § 264.232	Owners and operators shall manage all hazardous waste placed in a surface impoundment in accordance with 40 CFR Subparts BB (Air Emission Standards for Equipment Leaks) and CC (Air Emission Standards for Tanks, Surface Impoundments and Containers).	ARAR
Resource Conservation and Recovery Act, 42 USC s/s 6901 et seq. (1976)	40 CFR Part 268	Land disposal restrictions C- Prohibitions on land disposal	ARAR
Hazardous Materials Transportation Act, as amended, 49 USC §§ 5101 – 5127	49 CFR Part 170	Transport of hazardous materials program procedures	ARAR
Hazardous Materials Transportation Act, as amended, 49 USC §§ 5101 – 5127	49 CFR Part 171	Department of Transportation Rules for Transportation of Hazardous Materials, including procedures for the packaging, labeling, manifesting, and transporting of hazardous materials.	ARAR
Occupational Safety and Health Act	29CFR 1904, 1910, and 1926	Specifies minimum requirements to maintain worker health and safety during hazardous waste operations, including training and construction safety requirements.	ARAR
Control of Erosion and Sedimentation (Georgia & Glynn County)	O.C.G.A. 12-7-1 391-3-7 Glynn County Code, Section 2-5-100	Establishes a statewide comprehensive soil erosion and sedimentation control program to be administered by local issuing authorities	ARAR
Air Pollution Control Act (Georgia)	O.C.G.A. 12-9-1 391-3-1	Provides regulations pertaining to control of air pollution and emissions. May have specific requirements regarding odor thresholds or particulate matter	ARAR
Clean Water Act, Section 402	33 USC §§ 1251- 1387 40 CFR 122, 125 & 401	Authorizes issuance of a permit for discharge of pollutants or combination of pollutants, not withstanding other CWA requirements. Provisions related to the implementation of the NPDES program, including wastewater Discharge Permits; Effluent Guidelines, and Best Available Technology.	TBC
Clean Air Act Section 109	U.S.C. 7409 40 CFR Part 50	Clean Air Act, National Ambient Air Quality Standards	TBC
Water Quality Control Act (Georgia) NPDES Program	O.C.G.A. 12-5-30 391-3-6.06	Specifies requirements for issuing NPDES permits associated with a discharge of pollutants into waters of the state	ARAR

Table 3-3
Action-Specific ARARs and TBC Items
LCP Chemical Site, Brunswick, Georgia

Requirement	Citation (Statutory & Regulatory)	Requirement Synopsis	Status for LCP Brunswick OU1
Hazardous Waste Management Act & Hazardous Sites Response Act (Georgia)	O.C.G.A. 12-8-60 O.C.G.A. 12-8-90 391-3-.04, 391-3-11, 391-3-19, 391-3-4 (C.S.W.M.A. 12-8-20)	Requires owner to report and remediate a release of a regulated substance to soil or groundwater	TBC
USEPA Rules of Thumb for Superfund Remedy Selection	EPA 540-R-97- 013, August 1997	Describes key principles and expectations, as well as "best practices" based on program experience for the remedy selection process under Superfund. Major policy areas covered are risk assessment and risk management, developing remedial alternatives, and groundwater response actions.	TBC
USEPA Land Use in the CERCLA Remedy Selection Process	OSWER Directive No. 9355.7-04, May 1995	Presents information for considering land use in making remedy selection decisions at NPL sites.	TBC
USEPA Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites	OSWER Directive 9285.6-08, February 2002	Presents risk management principles that site managers should consider when making risk management decisions at contaminated sediment sites.	TBC
USEPA Ecological Risk Assessment and Risk Management Principles	OSWER Directive 9285.7-28P, USEPA	Presents risk management principles that site managers should consider when making risk management decisions at contaminated sediment sites. Specific to consider the ecological impacts.	TBC
USEPA Contaminated Sediment Strategy	EPA-823-R-98- 001, April 1998	Establishes an Agency-wide strategy for contaminated sediments, with the following four goals: 1) prevent the volume of contaminated sediments from increasing; 2) reduce the volume of existing contaminated sediment; 3) ensure that sediment dredging and dredged material disposal are managed in an environmentally sound manner; and 4) develop scientifically sound sediment management tools for use in pollution prevention, source control, remediation, and dredged material management.	TBC
USEPA Contaminated Sediment Remediation Guidance for Hazardous Waste Sites	EPA-540-R-05-012, December 2005	Provides technical and policy guidance for addressing contaminated sediment sites nationwide primarily associated with CERCLA actions.	TBC

Table 3-3
Action-Specific ARARs and TBC Items
LCP Chemical Site, Brunswick, Georgia

Requirement	Citation (Statutory & Regulatory)	Requirement Synopsis	Status for LCP Brunswick OU1
USEPA Five-Year Review Guidance	Structure and Components of Five-Year Reviews (OSWER Directive 9355.7-02, May 1991) Supplemental Five-Year Review Guidance (OSWER Directive 9355.7-02A, July 1994) Second Supplemental Five-Year Review Guidance (OSWER 9355.7-03A, December 1995)	Provides guidance on conducting Five-Year Reviews for sites at which hazardous substances, pollutants, or contaminants remain on-site above levels that allow for unrestricted use and unlimited exposure. The purpose of the Five-Year Review is to evaluate whether the selected response action continues to be protective of public health and the environment and is functioning as designed:	TBC
USEPA Remedial Design/Remedial Action Handbook	USEPA 540-R-95-059, OSWER Directive 9355.0-4B	General reference manual that provides remedial project managers with an overview of the remedial design and remedial action processes.	TBC
USEPA Area of Contamination Policy	OSWER Directive 9347.3-05FS	Guidance outlines the process used to determine whether RCRA land disposal restrictions established under the Hazardous and Solid Waste Amendments are "applicable" to a CERCLA response action.	TBC
USEPA Off-site Disposal Policy	OSWER Directive 9834.11a	The off-site policy describes procedures that should be observed when a response action under CERCLA involves off-site storage, treatment, or disposal of CERCLA waste.	TBC
USEPA Region 4 Clean and Green Policy	USEPA Region 4 Memorandum, 2/17/2010	Memo defines USEPA Region 4's policy to enhance environmental benefits of federal cleanup programs by promoting technologies and practices that are sustainable.	TBC

ARAR	applicable or relevant and appropriate requirement
BMPPT	best management practices with preferred technologies
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CWA	Clean Water Act
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
RCRA	Resource Conservation and Recovery Act
TBC	to be considered
TSCA	Toxic Substances Control Act
USEPA	United States Environmental Protection Agency

Table 3-4
Preliminary SWAC Remedial Goal Options from the BERA
LCP Chemical Site, Brunswick, Georgia

COC Receptor Group	SWAC RGO Range for OU1 FS (a)	<NOAEL RGO	NOAEL RGO	Rule of 5 Range of RGOs					LOAEL RGO	RGO Range Identified in the BERA	Is OU1 RGO within or below Preliminary RGO Range Identified in BERA?
Mercury (mg/kg)											
Omnivorous Birds	1 - 2	Yes	2.2	3.2	4.7	7	10	15	22	1 - 3	Yes
Piscivorous Birds	1 - 2		0.44	0.6	0.8	1.1	1.5	2	2.7		Yes
Piscivorous Mammals	1 - 2	Yes	1.7	2	2.4	2.8	3.3	3.9	4.2		Yes
Aroclor 1268 (mg/kg)											
Herbivorous Mammals	2 - 4	Yes	8	12	17	25	37	55	80	5 - 10	Yes
Omnivorous Mammals	2 - 4	Yes	4.3	6	10	14	21	32	47		Yes
Piscivorous Mammals	2- 4		0.27	0.4	0.7	1.1	1.8	2.9	4.6		Yes
Mercury (mg/kg)											
Black Drum	1 - 2		0.7	1	1.3	1.7	2.2	3	4.0	1 - 3	Yes
Red Drum	1 - 2		0.9	1.1	1.5	2	2.6	3.5	4.7		Yes
Silver Perch	1 - 2		0.4	0.6	0.8	1	1.4	1.9	2.6		Yes
Spotted Seatrout	1 - 2		0.4	0.5	0.7	0.9	1.1	1.4	1.9		Yes
Striped Mullet	1 - 2	Yes	11	14	17	21	26	32	39		Yes
Aroclor 1268 (mg/kg)											
Black Drum	2 - 4	Yes	2.5	3.7	5.6	8.3	12.4	18.4	27.6	3 - 6	Yes
Red Drum	2 - 4		0.55	0.8	1.3	2	3	4.6	7.1		Yes
Silver Perch	2 - 4		0.58	0.9	1.3	2	3.1	4.6	7		Yes
Spotted Seatrout	2 - 4		0.67	1	1.5	2.3	3.5	5.3	8		Yes
Striped Mullet	2- 4		0.39	0.5	0.8	1.1	1.5	2.1	3		Yes

Source: Section 7 of the baseline ecological risk assessment

(a)	SWAC RGO range for ecological receptors agreed upon by USEPA, as specified in correspondence provided in Appendix E and discussed in Section 3.3.1.
BERA	baseline ecological risk assessment
COC	chemical of concern
LOAEL	lowest observable adverse effect level
mg/kg	milligram(s) per kilogram
NOAEL	no observable adverse effects level
RGO	remedial goal options
SWAC	surface-weighted average concentration
🟩	Green shading shows where the OU1 mercury RGO range of 1 to 2 mg/kg falls along the range of NOAEL and LOAEL preliminary RGOs for mammals, birds, and finfish.
🟦	Blue shading shows where the OU1 Aroclor 1268 RGO range of 2 to 4 mg/kg falls along the range of NOAEL and LOAEL preliminary RGOs for mammals, birds, and finfish.

Table 3-5
Current Condition SWACs for Mercury and Aroclor 1268
LCP Chemical Site, Brunswick, Georgia

Domain	Domain Area (acres)	Current SWAC (mg/kg)
Mercury		
Dillon Duck	1.8	1.4
Domain 1	21.0	4.8
Domain 2	114.6	2.5
Domain 3	107.7	1.7
Domain 4 East	191.9	2.0
Domain 4 West	224.5	0.7
Total Domains	**661.5**	**1.7**
Domain 3 Creek	12.4	5.9
Eastern Creek	4.2	14.6
LCP Ditch	2.5	7.7
Purvis Creek	70.5	1.2
Western Creek Complex	9.0	2.1
Total Creek	**98.5**	**2.6**
Mercury Total Estuary	**760.0**	**1.8**
Aroclor 1268		
Dillon Duck	1.8	2.1
Domain 1	21.0	3.1
Domain 2	114.6	1.9
Domain 3	107.7	1.7
Domain 4 East	191.9	2.1
Domain 4 West	224.5	0.8
Total Domains	**661.5**	**1.6**
Domain 3 Creek	12.4	5.7
Eastern Creek	4.2	43.5
LCP Ditch	2.5	25.4
Purvis Creek	70.5	3.6
Western Creek Complex	9.0	3.0
Total Creeks	**98.5**	**6.0**
Aroclor 1268 Total Estuary	**760.0**	**2.2**

mg/kg	milligram(s) per kilogram
SWAC	surface-weighted average concentration

Table 5-1
Mercury and Aroclor 1268 SWACs
LCP Chemical Site, Brunswick, Georgia

Domain	Domain Area (acres)	Current SWAC (mg/kg)	Postremediation SWAC (mg/kg)				
			81-Acre	48-Acre (SMA-1)	25-Acre	18-Acre (SMA-2)	24-Acre (SMA-3)
Mercury							
Dillon Duck	1.8	1.4	0.3	0.3	0.3	0.3	0.3
Domain 1	21.0	4.8	0.6	0.6	1.6	1.6	1.1
Domain 2	114.6	2.5	0.9	0.9	1.3	1.3	1.3
Domain 3	107.7	1.7	1.5	1.5	1.7	1.7	1.7
Domain 4 East	191.9	2.0	1.2	2.0	2.0	2.0	2.0
Domain 4 West	224.5	0.7	0.7	0.7	0.7	0.7	0.7
Total Domains	**661.5**	**1.7**	**1.0**	**1.2**	**1.4**	**1.4**	**1.3**
Domain 3 Creek	12.4	5.9	1.0	1.0	2.5	3.7	3.7
Eastern Creek	4.2	14.6	0.3	0.3	0.3	0.3	0.3
LCP Ditch	2.5	7.7	0.3	0.3	0.4	0.4	0.4
Purvis Creek	70.5	1.2	0.9	0.9	1.1	1.2	1.1
Western Creek Complex	9.0	2.1	1.2	1.2	2.1	2.1	2.1
Total Creek	**98.5**	**2.6**	**0.9**	**0.9**	**1.3**	**1.5**	**1.4**
Mercury Total Estuary	**760.0**	**1.8**	**1.0**	**1.2**	**1.4**	**1.4**	**1.4**
Aroclor 1268							
Dillon Duck	1.8	2.1	0.2	0.2	0.2	0.2	0.2
Domain 1	21.0	3.1	0.6	0.6	1.2	1.2	0.9
Domain 2	114.6	1.9	1.4	1.4	1.5	1.5	1.5
Domain 3	107.7	1.7	1.5	1.5	1.7	1.7	1.7
Domain 4 East	191.9	2.1	1.6	2.1	2.1	2.1	2.1
Domain 4 West	224.5	0.8	0.8	0.8	0.8	0.8	0.8
Total Domains	**661.5**	**1.6**	**1.2**	**1.4**	**1.5**	**1.5**	**1.4**
Domain 3 Creek	12.4	5.7	1.1	1.1	1.8	3.4	3.4
Eastern Creek	4.2	43.5	0.2	0.2	0.2	0.2	0.2
LCP Ditch	2.5	25.4	0.2	0.2	0.3	0.3	0.3
Purvis Creek	70.5	3.6	1.7	1.7	3.3	3.6	2.7
Western Creek Complex	9.0	3.0	1.7	1.7	3.0	3.0	3.0
Total Creeks	**98.5**	**6.0**	**1.6**	**1.6**	**2.9**	**3.3**	**2.7**
Aroclor 1268 Total Estuary	**760.0**	**2.2**	**1.3**	**1.4**	**1.6**	**1.7**	**1.6**

mg/kg	milligram(s) per kilogram
No Action	remedy alternative 1
SMA-1	remedy alternatives 2 and 3
SMA-2	remedy alternatives 4 and 5
SMA-3	remedy alternatives 6
SWAC	surface-weighted average concentration

Table 5-2
Summary of Remedial Footprints
LCP Chemical Site, Brunswick, Georgia

Remedial Area	Remedy Alternative 2 - Sediment Removal in SMA-1	Remedy Alternative 3 - Sediment Removal, Capping, and Thin-Cover Placement in SMA-1	Remedy Alternative 4 - Sediment Removal in SMA-2	Remedy Alternative 5 - Sediment Removal, Capping, and Thin-Cover Placement in SMA-2	Remedy Alternative 6 - Sediment Removal, Capping, and Thin-Cover Placement in SMA-3
Purvis Creek	Dredge (10)	Cap (10)	--	--	Cap (3.0)
Western Creek Complex	Dredge (1.5)	Dredge (1.5)	--	--	--
Eastern Creek	Dredge (4.3)	Dredge (4.3)	Dredge (4.3)	Dredge (4.3)	Dredge (4.3)
LCP Ditch	Dredge (2.4)	Dredge (2.4)	Dredge (2.2)	Dredge (2.2)	Dredge (2.2)
Domain 3 Creek	Dredge (6.0)	Cap (6.0)	Dredge (3.0)	Cap (3.0)	Cap (3.0)
Dillon Duck	Dredge (1.0)	Thin-Cover (1.0)	Dredge (1.0)	Thin-Cover (1.0)	Thin-Cover (1.0)
Marsh 1a	Dredge (7.2)	Thin-Cover (7.2)	Dredge (2.1)	Thin-Cover (2.1)	Thin-Cover (5.1)
Marsh 2	Dredge (10.6)	Thin-Cover (10.6)	Dredge (5.0)	Thin-Cover (5.0)	Thin-Cover (5.0)
Marsh 3	Dredge (4.5)	Thin-Cover (4.5)	--	--	--

(number)	number in parentheses is number of acres
SMA-1	remedy alternatives 2 and 3
SMA-2	remedy alternatives 4 and 5
SMA-3	remedy alternatives 6

Table 5-3
Summary of Remedial Alternatives
LCP Chemical Site, Brunswick, Georgia

Remedial Alternative	Remedy Description	Total Remedy Area (acres)	Sediment Removal Areas (acres)	Removal Volume (cubic yards)	Backfill Volume (cubic yards)	Capping Area (acres)	Thin Cover Area (acres)
1	No Action	0	0	0	0	0	0
2	Sediment Removal in SMA-1	48	48	153,000	96,000	0	0
3	Sediment Removal, Capping, and Thin Cover in SMA-1	48	9	27,000	17,000	16	23
4	Sediment Removal in SMA-2	18	18	57,000	36,000	0	0
5	Sediment Removal, Capping, and Thin Cover in SMA-2	18	7	22,000	14,000	3	8
6	Sediment Removal, Capping, and Thin Cover in SMA-3	24	7	22,000	14,000	6	11

No Action	remedy alternative 1
SMA-1	remedy alternatives 2 and 3
SMA-2	remedy alternatives 4 and 5
SMA-3	remedy alternatives 6

Table 6-1A
Remedy Effectiveness for Human Health: Total Creeks and Total Marsh
LCP Chemical Site, Brunswick, Georgia

Domain	SWAC RGO (a, b)	No Action SWAC (mg/kg)	Postremediation SWAC (mg/kg)		
			SMA 1	SMA 2	SMA 3
Mercury					
Total Domains (Marsh)	NA	1.7	1.2	1.4	1.3
Total Creek	1-2	2.6	0.9	1.5	1.4
Total Estuary	NA	1.8	1.2	1.4	1.4
Aroclor 1268					
Total Domains (Marsh)	NA	1.6	1.4	1.5	1.4
Total Creeks	2-4	6.0	1.6	3.3	2.7
Total Estuary	2-4	2.2	1.4	1.7	1.6

NA	not applicable
mg/kg	milligram(s) per kilogram
No Action	remedy alternative 1
RGO	remedial goal option
SMA-1	remedy alternatives 2 and 3
SMA-2	remedy alternatives 4 and 5
SMA-3	remedy alternatives 6
SWAC	surface-weighted average concentration

(a) The mercury SWAC is based on finfish exposures in the Total Creeks.

(b) The Aroclor 1268 SWAC is based on finfish exposed to the Total Creeks and clapper rail exposed to the Total Estuary.

🟩 Green highlight indicates conditions achieve the SWAC RGO.

🟦 Blue highlight notes that the SWAC RGO is achieved even though the RGO is not directly applicable because the conditions are not directly related to the human health exposures or risks.

Table 6-1B
Remedy Effectiveness for Human Health and the Environment:
Area-Specific SWACs for Alternatives 2 though 6
LCP Chemical Site, Brunswick, Georgia

Domain	Domain Area (acres)	Preliminary SWAC FS Goals	Current SWAC (No Action)	SMA-1 (Alternatives 2 and 3)	SMA-2 (Alternatives 4 and 5)	SMA-3 (Alternative 6)
Mercury (units in mg/kg)						
Dillon Duck	1.8	1-2	1.4	0.3	0.3	0.3
Domain 1	21.0	1-2	6.2	0.6	1.6	1.1
Domain 2	114.6	1-2	2.5	0.9	1.3	1.3
Domain 3	107.7	1-2	1.7	1.5	1.7	1.7
Domain 4 East	191.9	1-2	2.0	2.0	2.0	2.0
Domain 4 West	224.5	1-2	0.7	0.7	0.7	0.7
Total Domains	661.5	1-2	1.7	1.2	1.4	1.3
Domain 3 Creek	12.4	1-2	5.9	1.0	3.7 (a)	3.7 (a)
Eastern Creek	4.2	1-2	14.6	0.3	0.3	0.3
LCP Ditch	2.5	1-2	7.7	0.3	0.4	0.4
Purvis Creek	70.5	1-2	1.2	0.9	1.2	1.1
Western Creek Complex	9.0	1-2	2.1	1.2	2.1 (a)	2.1 (a)
Total Creek	**98.5**	**1-2**	**2.6**	**0.9**	**1.5**	**1.4**
Mercury Total Estuary	760.0	1-2	1.8	1.2	1.4	1.4
Aroclor 1268 (units in mg/kg)						
Dillon Duck	1.8	2-4	2.1	0.2	0.2	0.2
Domain 1	21.0	2-4	3.9	0.6	1.2	0.9
Domain 2	114.6	2-4	1.9	1.4	1.5	1.5
Domain 3	107.7	2-4	1.7	1.5	1.7	1.7
Domain 4 East	191.9	2-4	2.1	2.1	2.1	2.1
Domain 4 West	224.5	2-4	0.8	0.8	0.8	0.8
Total Domains	661.5	2-4	1.6	1.4	1.5	1.4
Domain 3 Creek	12.4	2-4	5.7	1.1	3.4	3.4
Eastern Creek	4.2	2-4	43.5	0.2	0.2	0.2
LCP Ditch	2.5	2-4	25.4	0.2	0.3	0.3
Purvis Creek	70.5	2-4	3.6	1.7	3.6	2.7
Western Creek Complex	9.0	2-4	3.0	1.7	3.0	3.0
Total Creeks	**98.5**	**2-4**	**6.0**	**1.6**	**3.3**	**2.7**
Aroclor 1268 Total Estuary	760.0	2-4	2.2	1.4	1.7	1.6

FS	feasibility study
mg/kg	milligram(s) per kilogram
No Action	remedy alternative 1
SMA-1	remedy alternatives 2 and 3
SMA-2	remedy alternatives 4 and 5
SMA-3	remedy alternative 6
SWAC	surface-weighted average concentration
BOLD	Bold text indicates the Total Creek concentrations that are most relevant for fish and shellfish exposures and exposures for human health.
🟨	Yellow highlight indicates a condition in OU1 that exceeds the preliminary FS SWACs.
🟩	Green highlight indicates conditions achieve the SWAC RGO.
(a)	The Domain 3 Creek and Western Creek Complex ~~are very small and cannot support significant exposures to finfish.~~ represent a relatively small portion of the total creek area. Hence, these creeks have a relatively small contribution to the SWAC. Therefore in consideration of protectiveness of human health and finfish, the Total Creeks are most relevant (i.e., current conditions SWAC vs. Total Creek SWAC). SWAC conditions for the individual areas are most relevant for small-home-range species, like green heron. Therefore, the individual areas, including the Domain 3 Creek and Western Creek Complex, are considered further with wildlife remedy effectiveness Figures 6-2A and 6-2B and Tables 6-1C through 6-1E.

Table 6-1C
Remedy Effectiveness for the Environment: Postremedy SWACs for the No Action Alternative
LCP Chemicals, Brunswick, Georgia

COC Receptor Group	No Action SWACs (a)		NOAEL RGO (b)	Rule of 5 Range of RGOs (b)					LOAEL RGO (b)	SWAC Exceeds LOAEL RGO? (c)
Mercury (mg/kg)										
Omnivorous Birds	1.8	(d)	2.2	3.2	4.7	7	10	15	22	No
Piscivorous Birds	2.6	(e)	0.44	0.6	0.8	1.1	1.5	2	2.7	No
Piscivorous Birds	14.6	(g)	0.44	0.6	0.8	1.1	1.5	2	2.7	**Yes**
Piscivorous Mammals	2.6	(e)	1.7	2	2.4	2.8	3.3	3.9	4.2	No
Aroclor 1268 (mg/kg)										
Herbivorous Mammals	1.6	(f)	8	12	17	25	37	55	80	No
Omnivorous Mammals	2.2	(d)	4.3	6	10	14	21	32	47	No
Piscivorous Mammals	6	(e)	0.27	0.4	0.7	1.1	1.8	2.9	4.6	**Yes**
Mercury (mg/kg)										
Black Drum	2.6	(e)	0.73	1	1.3	1.7	2.2	3	3.95	No
Red Drum	2.6	(e)	0.85	1.1	1.5	2	2.6	3.5	4.65	No
Silver Perch	2.6	(e)	0.43	0.6	0.8	1	1.4	1.9	2.55	**Yes**
Spotted Seatrout	2.6	(e)	0.42	0.5	0.7	0.9	1.1	1.4	1.85	**Yes**
Striped Mullet	2.6	(e)	11	14	17	21	26	32	39	No
Aroclor 1268 (mg/kg)										
Black Drum	6	(e)	2.5	3.7	5.6	8.3	12.4	18.4	27.6	No
Red Drum	6	(e)	0.55	0.8	1.3	2	3	4.6	7.1	No
Silver Perch	6	(e)	0.58	0.9	1.3	2	3.1	4.6	7	No
Spotted Seatrout	6	(e)	0.67	1	1.5	2.3	3.5	5.3	8	No
Striped Mullet	6	(e)	0.39	0.5	0.8	1.1	1.5	2.1	3	**Yes**

COC	chemical of concern
LOAEL	lowest observable adverse effect level
mg/kg	milligrams per kilogram
NOAEL	no observable adverse effects level
RGO	remedial goal option
SMA-1	sediment management area 1
SWAC	surface-weighted average concentration

(a) SWACs provided on Table 5-1. The type of SWAC selected reflects the types of exposures expected for wildlife (e.g., herbivorous mammals SWAC reflects the total domains, piscivorous mammals reflects total creeks).

(b) RGOs sourced from Section 7 of the Baseline Ecological Risk Assessment.

(c) No indicates a condition that meets the threshold criterion and yes indicates that it does not meet the threshold criterion of protectiveness for the wildlife receptors noted.

(d) SWAC for Total Estuary.

(e) SWAC for Total Creek.

(f) SWAC for Total Domains.

(g) Eastern Creek SWAC, reflecting a potentially small-home-range condition for a potentially small-home-range species.

BOLD Indicates condition that does not meet the threshold criteria of protectiveness for the wildlife receptors noted.

🟦 Comparison of Current Condition SWAC (i.e., the No Action Alternative) to the RGO Range for wildlife. Blue indicates where within the range of RGOs the SWAC for SMA-1 (no action) falls.

🟧 Current Condition SWAC is Below NOAEL RGO.

Table 6-1D
Remedial Goal Options Achieved with Postremedy SWACs for SMA-1 (Alternatives 2 and 3)
LCP Chemicals, Brunswick, Georgia

COC Receptor Group	SMA-1 SWACs (a)		NOAEL RGO (b)	Rule of 5 Range of RGOs (b)					LOAEL RGO (b)	SWAC Exceeds LOAEL RGO? (c)
Mercury (mg/kg)										
Omnivorous Birds	1.2	(d)	2.2	3.2	4.7	7	10	15	22	No
Piscivorous Birds	0.9	(e)	0.44	0.6	0.8	1.1	1.5	2	2.7	No
Piscivorous Birds	0.3	(g)	0.44	0.6	0.8	1.1	1.5	2	2.7	No
Piscivorous Mammals	0.9	(e)	1.7	2	2.4	2.8	3.3	3.9	4.2	No
Aroclor 1268 (mg/kg)										
Herbivorous Mammals	1.4	(f)	8	12	17	25	37	55	80	No
Omnivorous Mammals	1.4	(d)	4.3	6	10	14	21	32	47	No
Piscivorous Mammals	1.6	(e)	0.27	0.4	0.7	1.1	1.8	2.9	4.6	No
Mercury (mg/kg)										
Black Drum	0.9	(e)	0.73	1	1.3	1.7	2.2	3	3.95	No
Red Drum	0.9	(e)	0.85	1.1	1.5	2	2.6	3.5	4.65	No
Silver Perch	0.9	(e)	0.43	0.6	0.8	1	1.4	1.9	2.55	No
Spotted Seatrout	0.9	(e)	0.42	0.5	0.7	0.9	1.1	1.4	1.85	No
Striped Mullet	0.9	(e)	11	14	17	21	26	32	39	No
Aroclor 1268 (mg/kg)										
Black Drum	1.6	(e)	2.5	3.7	5.6	8.3	12.4	18.4	27.6	No
Red Drum	1.6	(e)	0.55	0.8	1.3	2	3	4.6	7.1	No
Silver Perch	1.6	(e)	0.58	0.9	1.3	2	3.1	4.6	7	No
Spotted Seatrout	1.6	(e)	0.67	1	1.5	2.3	3.5	5.3	8	No
Striped Mullet	1.6	(e)	0.39	0.5	0.8	1.1	1.5	2.1	3	No

COC	chemical of concern	RGO	remedial goal option
LOAEL	lowest observable adverse effect level	SMA-1	sediment management area 1
mg/kg	milligram(s) per kilogram	SWAC	surface-weighted average concentration
NOAEL	no observable adverse effects level		

(a) SWACs provided on Table 5-1. The type of SWAC selected reflects the types of exposures expected for wildlife.
(b) RGOs sourced from Section 7 of the baseline ecological risk assessment (Black and Veatch 2011).
(c) No indicates a condition that meets the threshold criterion and yes indicates that it does not meet the threshold criterion of protectiveness for the wildlife receptors noted.
(d) Postremedy SWAC for Total Estuary
(e) Postremedy SWAC for Total Creek
(f) Postremedy SWAC for Total Domains
(g) Eastern Creek SWAC, reflecting a potentially small-home-range condition for a potentially small-home-range species.
BOLD Indicates condition that does not meet the threshold criteria of protectiveness for the wildlife receptors noted.
🟦 Comparison of Current Condition SWAC to RGO Range. Blue indicates where within the range of RGOs the SWAC for Alternatives 2 and 3 (SMA-1) falls.
🟨 Current Condition SWAC is below NOAEL RGO

Table 6-1E
Remedial Goal Options Achieved with Postremedy SWACs for SMA-2 (Alternatives 4 and 5)
LCP Chemical Site, Brunswick, Georgia

COC Receptor Group	SMA-2 SWACs (a)		NOAEL RGO (b)	Rule of 5 Range of RGOs (b)					LOAEL RGO (b)	SWAC Exceeds LOAEL RGO? (c)
Mercury (mg/kg)										
Omnivorous Birds	1.4	(d)	2.2	3.2	4.7	7	10	15	22	No
Piscivorous Birds	1.5	(e)	0.44	0.6	0.8	1.1	1.5	2	2.7	No
Piscivorous Birds	0.3	(g)	0.44	0.6	0.8	1.1	1.5	2	2.7	No
Piscivorous Mammals	1.5	(e)	1.7	2	2.4	2.8	3.3	3.9	4.2	No
Aroclor 1268 (mg/kg)										
Herbivorous Mammals	1.5	(f)	8	12	17	25	37	55	80	No
Omnivorous Mammals	1.7	(d)	4.3	6	10	14	21	32	47	No
Piscivorous Mammals	3.3	(e)	0.27	0.4	0.7	1.1	1.8	2.9	4.6	No
Mercury (mg/kg)										
Black Drum	1.5	(e)	0.73	1	1.3	1.7	2.2	3	3.95	No
Red Drum	1.5	(e)	0.85	1.1	1.5	2	2.6	3.5	4.65	No
Silver Perch	1.5	(e)	0.43	0.6	0.8	1	1.4	1.9	2.55	No
Spotted Seatrout	1.5	(e)	0.42	0.5	0.7	0.9	1.1	1.4	1.85	No
Striped Mullet	1.5	(e)	11	14	17	21	26	32	39	No
Aroclor 1268 (mg/kg)										
Black Drum	3.3	(e)	2.5	3.7	5.6	8.3	12.4	18.4	27.6	No
Red Drum	3.3	(e)	0.55	0.8	1.3	2	3	4.6	7.1	No
Silver Perch	3.3	(e)	0.58	0.9	1.3	2	3.1	4.6	7	No
Spotted Seatrout	3.3	(e)	0.67	1	1.5	2.3	3.5	5.3	8	No
Striped Mullet	3.3	(e)	0.39	0.5	0.8	1.1	1.5	2.1	3	No (h)

COC	chemical of concern	RGO	remedial goal option
LOAEL	lowest observable adverse effect level	SMA-2	sediment management area 2
mg/kg	milligram(s) per kilogram	SWAC	surface-weighted average concentration
NOAEL	no observable adverse effects level		

(a) SWACs provided on Table 5-1. The type of SWAC selected reflects the types of exposures expected for wildlife.

(b) RGOs sourced from Section 7 of the Baseline Ecological Risk Assessment.

(c) No indicates a condition that meets the threshold criterion and yes indicates that it does not meet the threshold criterion of protectiveness for the wildlife receptors noted.

(d) Postremedy SWAC for Total Estuary

(e) Postremedy SWAC for Total Creek

(f) Postremedy SWAC for Total Domains

(g) Eastern Creek SWAC, reflecting a potentially small-home-range condition for a potentially small-home-range species.

(h) A value of 3.3 is equivalent to 3 given the uncertainties of this type of evaluation.

BOLD Indicates condition that does not meet the threshold criteria of protectiveness for the wildlife receptors noted.

🟦 Comparison of Current Condition SWAC to RGO Range. Blue indicates where within the range of RGOs the SWAC for Alternatives 4 and 5 (SMA-2) falls.

🟧 Current Condition SWAC is below NOAEL RGO

Table 6-1F
Remedial Goal Options Achieved with Postremedy SWACs for SMA-3 (Alternative 6)
LCP Chemical Site, Brunswick, Georgia

COC Receptor Group	**SMA-3 SWACs (a)**		**NOAEL RGO (b)**	**Rule of 5 Range of RGOs (b)**					**LOAEL RGO (b)**	**SWAC Exceeds LOAEL RGO? (c)**
Mercury (mg/kg)										
Omnivorous Birds	1.4	(d)	2.2	3.2	4.7	7	10	15	22	No
Piscivorous Birds	1.4	(e)	0.44	0.6	0.8	1.1	1.5	2	2.7	No
Piscivorous Birds	0.3	(g)	0.44	0.6	0.8	1.1	1.5	2	2.7	No
Piscivorous Mammals	1.4	(e)	1.7	2	2.4	2.8	3.3	3.9	4.2	No
Aroclor 1268 (mg/kg)										
Herbivorous Mammals	1.4	(f)	8	12	17	25	37	55	80	No
Omnivorous Mammals	1.6	(d)	4.3	6	10	14	21	32	47	No
Piscivorous Mammals	2.7	(e)	0.27	0.4	0.7	1.1	1.8	2.9	4.6	No
Mercury (mg/kg)										
Black Drum	1.4	(e)	0.73	1	1.3	1.7	2.2	3	3.95	No
Red Drum	1.4	(e)	0.85	1.1	1.5	2	2.6	3.5	4.65	No
Silver Perch	1.4	(e)	0.43	0.6	0.8	1	1.4	1.9	2.55	No
Spotted Seatrout	1.4	(e)	0.42	0.5	0.7	0.9	1.1	1.4	1.85	No
Striped Mullet	1.4	(e)	11	14	17	21	26	32	39	No
Aroclor 1268 (mg/kg)										
Black Drum	2.7	(e)	2.5	3.7	5.6	8.3	12.4	18.4	27.6	No
Red Drum	2.7	(e)	0.55	0.8	1.3	2	3	4.6	7.1	No
Silver Perch	2.7	(e)	0.58	0.9	1.3	2	3.1	4.6	7	No
Spotted Seatrout	2.7	(e)	0.67	1	1.5	2.3	3.5	5.3	8	No
Striped Mullet	2.7	(e)	0.39	0.5	0.8	1.1	1.5	2.1	3	No

COC	chemical of concern	RGO	remedial goal option
LOAEL	lowest observable adverse effect level	SMA-3	sediment management area 3
mg/kg	milligram(s) per kilogram	SWAC	surface-weighted average concentration
NOAEL	no observable adverse effects level		

(a)	SWACs provided on Table 5-1. The type of SWAC selected reflects the types of exposures expected for wildlife.
(b)	RGOs sourced from Section 7 of the baseline ecological risk assessment (Black and Veatch 2011).
(c)	No indicates a condition that meets the threshold criterion and yes indicates that it does not meet the threshold criterion of protectiveness for the wildlife receptors noted.
(d)	Postremedy SWAC for Total Estuary
(e)	Postremedy SWAC for Total Creek
(f)	Postremedy SWAC for Total Domains
(g)	Eastern Creek SWAC, reflecting a potentially small-home-range condition for a potentially small-home-range species.
BOLD	Indicates condition that does not meet the threshold criteria of protectiveness for the wildlife receptors noted.
🟦	Comparison of Current Condition SWAC to RGO Range. Blue indicates the RGO achieved for Alternative 6 (SMA-3).
🟧	Current Condition SWAC is below NOAEL RGO.

Table 6-2
Estimated Marsh Disturbance Associated with Remedy Alternatives
LCP Chemical Site, Brunswick, Georgia

Alternative	Remedy Footprint (Acres)	Marsh Disturbance within Remedy Footprint (Acres)	Marsh Disturbance Beyond Remedy Footprint (Acres)	Total Disturbance (Remedy Footprint + Beyond Remedy Footprint) (Acres)
NO ACTION				
Alternative 1	0	0	-	-
SMA-1 (48 Acres)				
Alternative 2	48	48	11	59
Alternative 3	48	48	8	56
SMA-2 (18 Acres)				
Alternative 4	18	18	11	29
Alternative 5	18	18	8	26
SMA-3 (24 Acres)				
Alternative 6	24	24	7	31

No Action	remedy alternative 1
SMA-1	remedy alternatives 2 and 3
SMA-2	remedy alternatives 4 and 5
SMA-3	remedy alternative 6

Table 6-3
Summary of Remedial Quantities
LCP Chemical Site, Brunswick, Georgia

Alternative	Volume Removed (CY)	Mass of Aroclor 1268 Removed (kg)	Mass of Mercury Removed (kg)	Mass of Lead Removed (kg)	Mass of tPAH Removed (kg)
NO ACTION					
Alternative 1	--	--	--	--	--
SMA-1 (48 Acres)					
Alternative 2	153,000	1,730	1,480	15,740	160
Alternative 3	27,000	760	260	910	30
SMA-2 (18 Acres)					
Alternative 4	57,000	980	1,190	12,820	80
Alternative 5	22,000	720	240	730	20
SMA-3 (24 Acres)					
Alternative 6	22,000	720	240	730	20

CY	cubic yards
kg	kilogram(s)
No Action	remedy alternative 1
SMA-1	remedy alternatives 2 and 3
SMA-2	remedy alternatives 4 and 5
SMA-3	remedy alternative 6
tPAH	total polycyclic aromatic hydrocarbon

Table 6-4
Remedy Alternative Implementation Constraints
LCP Chemical Site, Brunswick, Georgia

Implementation Limitation or Constraint	Remedy Alternative 1 (0 acres)	Remedy Alternative 2 (48 acres)	Remedy Alternative 3 (48 acres)	Remedy Alternative 4 (18 acres)	Remedy Alternative 5 (18 acres)	Remedy Alternative 6 (24 acres)
General						
Water-based equipment access and production affected by tide cycles?	NA	Yes	Yes	Yes	Yes	Yes
Land-based equipment access and production affected by tide cycles?	NA	Yes	Yes	Yes	Yes	Yes
Result in temporary short-term ecological impacts to marshes not targeted for remediation?	NA	Substantial	Substantial	Moderate	Moderate	Moderate
Debris removal required for remedy implementation?	NA	Yes	Yes	Yes	Yes	Yes
Requires removal of pier remnants across Purvis Creek?	NA	Yes	Yes	Likely	Likely	Yes
Specialized or non-readily available equipment required?	NA	No	Possibly	No	Possibly	Possibly
Purvis Creek						
Implementation likely to be land-based or water-based?	NA	Water-based	Water-based	NA	NA	Water-based
Staging areas required?	NA	One	One	NA	NA	One
Improvements to the causeway required?	NA	Possibly	Possibly	NA	NA	Possibly
Result in temporary short-term ecological impacts to creeks?	NA	Substantial	Substantial	NA	NA	Substantial
LCP Ditch and Eastern Creek						
Implementation likely to be land-based or water-based?	NA	Either	Either	Either	Either	Either
Soft sediment conditions present that could affect implementation?	NA	Yes	Yes	Yes	Yes	Yes
Improvements to the Causeway required?	NA	Possibly	Possibly	Possibly	Possibly	Possibly
Construction of temporary roads required to implement land-based remedy?	NA	Possibly	Possibly	Possibly	Possibly	Possibly
Staging areas required?	NA	One	One	One	One	One
Result in temporary short-term ecological impacts to creeks?	NA	Substantial	Substantial	Substantial	Substantial	Substantial
Western Creek Complex						
Implementation likely to be land-based or water-based?	NA	Either	Either	NA	NA	NA
Remedial areas isolated and discontinuous?	NA	Yes	Yes	NA	NA	NA
Access agreements required for land-based operations?	NA	Yes	Yes	NA	NA	NA
Soft sediment conditions present that could affect implementation?	NA	Yes	Yes	NA	NA	NA
Construction of temporary roads required to implement land-based remedy?	NA	Yes	Yes	NA	NA	NA
Staging areas required?	NA	No	No	NA	NA	NA
Result in temporary short-term ecological impacts to creeks?	NA	Substantial	Substantial	NA	NA	NA
Ecological impact to marshes significantly greater than remedial areas?	NA	Yes	Yes	NA	NA	NA
Domain 3 Creek						
Implementation likely to be land-based or water-based?	NA	Land-based	Land-based	Land-based	Land-based	Land-based
Access agreements required for land-based operations?	NA	Possibly	Possibly	Possibly	Possibly	Possibly
Soft sediment conditions present that could affect implementation?	NA	Yes	Yes	Yes	Yes	Yes
Construction of temporary roads required to implement land-based remedy?	NA	Yes	Yes	Yes	Yes	Yes
Staging areas required?	NA	Multiple	Multiple	Multiple	Multiple	Multiple
Result in temporary short-term ecological impacts to creeks?	NA	Substantial	Substantial	Substantial	Substantial	Substantial
Domain 1A and Domain 2 Marsh						
Implementation likely to be land-based or water-based?	NA	Land-based	Land-based	Land-based	Land-based	Land-based
Soft sediment conditions present that could affect implementation?	NA	Yes	Yes	Yes	Yes	Yes
Large earthmoving equipment required?	NA	Yes	No	Yes	No	No
Construction of temporary roads required to implement land-based remedy?	NA	Yes	Possibly	Yes	Possibly	Possibly
Staging areas required?	NA	Multiple	Some	Multiple	Some	Some
Result in temporary short-term ecological impacts to marshes?	NA	Substantial	Minimal	Substantial	Minimal	Minimal

Table 6-4
Remedy Alternative Implementation Constraints
LCP Chemical Site, Brunswick, Georgia

Implementation Limitation or Constraint	Remedy Alternative 1 (0 acres)	Remedy Alternative 2 (48 acres)	Remedy Alternative 3 (48 acres)	Remedy Alternative 4 (18 acres)	Remedy Alternative 5 (18 acres)	Remedy Alternative 6 (24 acres)
Domain 3 Marsh						
Implementation likely to be land-based or water-based?	NA	Land-based	Land-based	NA	NA	NA
Soft sediment conditions present that could affect implementation?	NA	Yes	Yes	NA	NA	NA
Large earthmoving equipment required?	NA	Yes	No	NA	NA	NA
Construction of temporary roads required to implement land-based remedy?	NA	Yes	Possibly	NA	NA	NA
Staging areas required?	NA	Multiple	Some	NA	NA	NA
Result in temporary short-term ecological impacts to marshes?	NA	Substantial	Minimal	NA	NA	NA
Dillon Duck						
Implementation likely to be land-based or water-based?	NA	Land-based	Land-based	Land-based	Land-based	Land-based
Soft sediment conditions present that could affect implementation?	NA	Yes	Yes	Yes	Yes	Yes
Large earthmoving equipment required?	NA	Yes	No	Yes	No	No
Construction of temporary roads required to implement land-based remedy?	NA	Yes	Yes	Yes	Yes	Yes
Staging areas required?	NA	One	One	One	One	One
Result in temporary short-term ecological impacts to marshes?	NA	Substantial	Minimal	Substantial	Minimal	Minimal

Table 6-5
Summary of Remedial Alternative Costs
LCP Chemical site, Brunswick, Georgia

Alternative		Area (Acres)	Total Estimated Indirect Costs (Present Day $MM)	Total Estimated Direct Costs (Present Day $MM)	Total Estimated Recurring Costs (Present Day $MM)	Contingency Costs ($MM)	Total Estimated Cost ($MM)
NO ACTION							
ALT 1	**No Action**	-	$0.0	$0.0	$0.0	$0.0	$0.0
SMA 1 (48 Acres)							
ALT 2	**Dredge:** All Areas	48	$8.6	$48.6	$0.4	$7.3	$64.8
ALT 3	**Dredge:** LCP Ditch, Eastern Creek and Western Creek Complex	8	$5.3	$27.9	$1.4	$4.2	$38.7
	Cap: Domain 3 Creek, Purvis Creek North and Purvis Creek South	16					
	Thin Cover: Domain 1A, Domain 2, Domain 3 and Dillon Duck	23					
SMA 2 (18 Acres)							
ALT 4	**Dredge:** All Areas	18	$4.9	$25.2	$0.3	$3.8	$34.1
ALT 5	**Dredge:** LCP Ditch and Eastern Creek	7	$3.9	$18.9	$0.5	$2.8	$26.0
	Cap: Domain 3 Creek	3					
	Thin Cover: Dillon Duck, Domain 1A and Domain 2	8					
SMA 3 (24 Acres)							
ALT 6	**Dredge:** LCP Ditch and Eastern Creek	7	$4.2	$20.7	$0.7	$3.1	$28.6
	Cap: Domain 3 Creek & Purvis Creek South	6					
	Thin Cover: Dillon Duck, Domain 1A and Domain 2	11					

Note:
Recurring Costs include operation and maintenance and long-term monitoring.

No Action	remedy alternative 1
$MM	million(s) of dollars
SMA-1	remedy alternatives 2 and 3
SMA-2	remedy alternatives 4 and 5
SMA-3	remedy alternative 6

Figures

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:
Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:
ENVIRON International Corporation

Anchor QEA, LLC

Date:
June 2, 2014

Note: OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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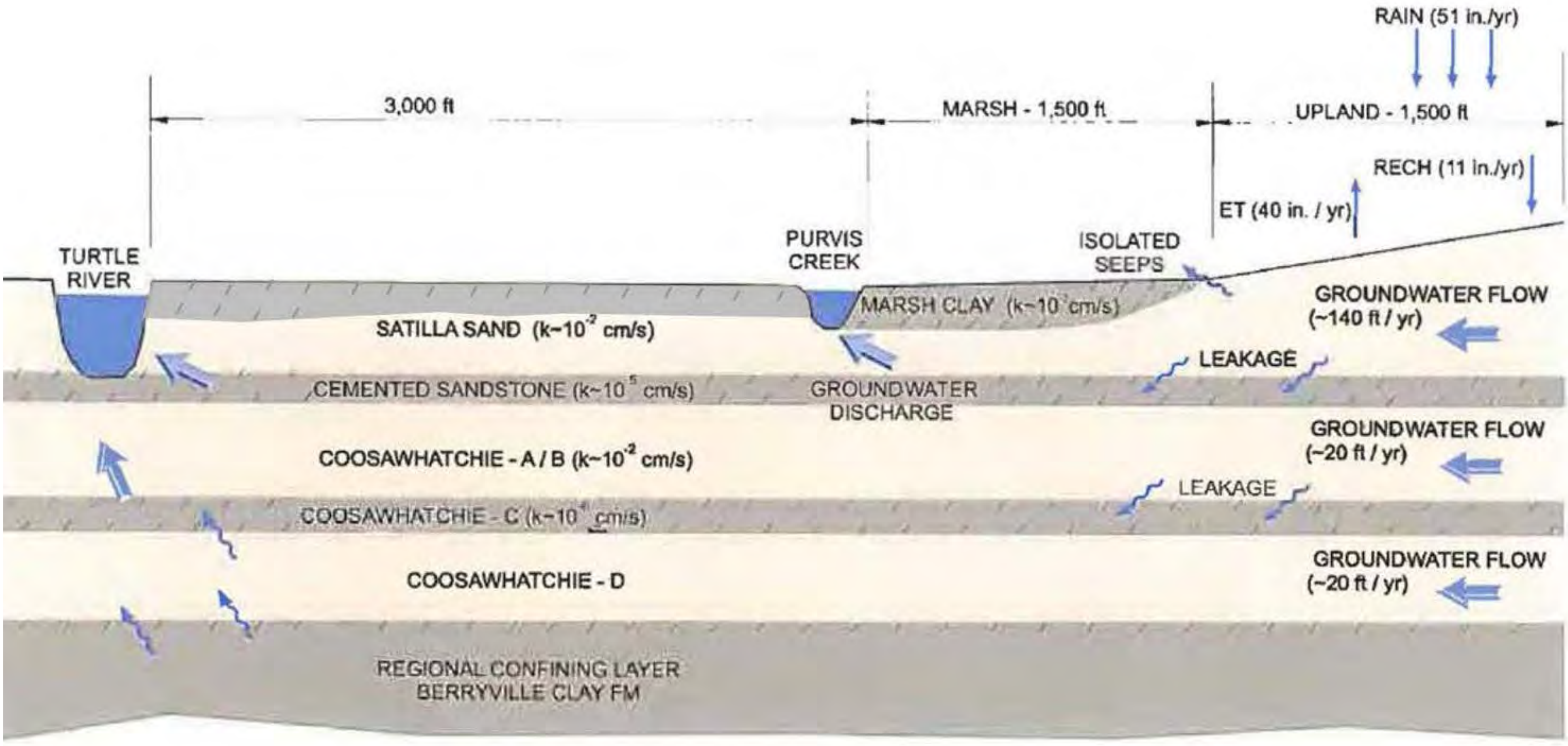
Site Location Map

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 2-1



Source: Adapted from Figure 2.1.1 1997 RI Report (GeoSyntec Consultants, 1997)

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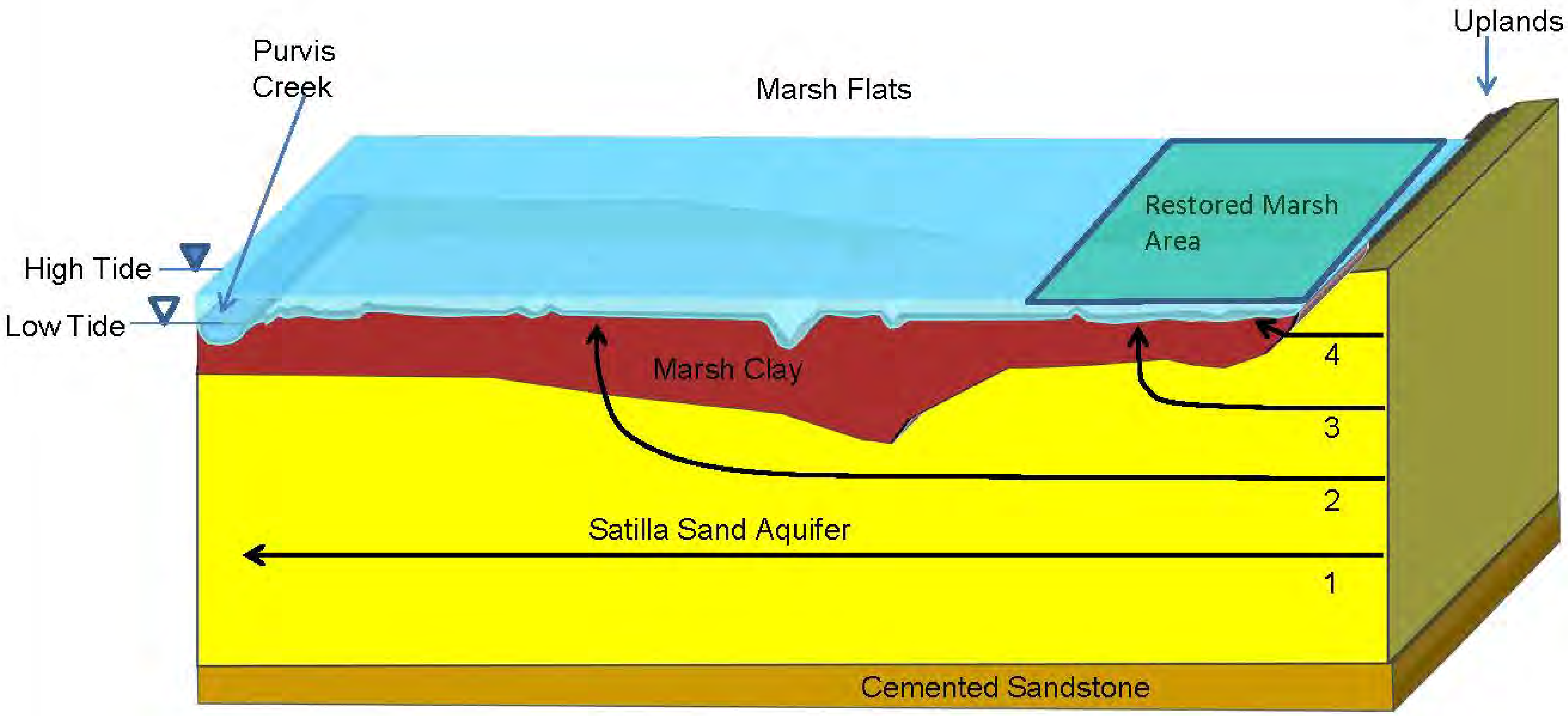
Hydrogeologic Conceptual Site Model

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

2-2



1 Net Flow Path to Purvis Creek and Beyond
2 Net Flow Path to Marsh Flats and Intertidal Channels
3 Net Flow Path to Restored Marsh Area
4 Net Flow Path to Nearshore Seeps

Note: Tidal forces can reverse groundwater flows beneath the marsh

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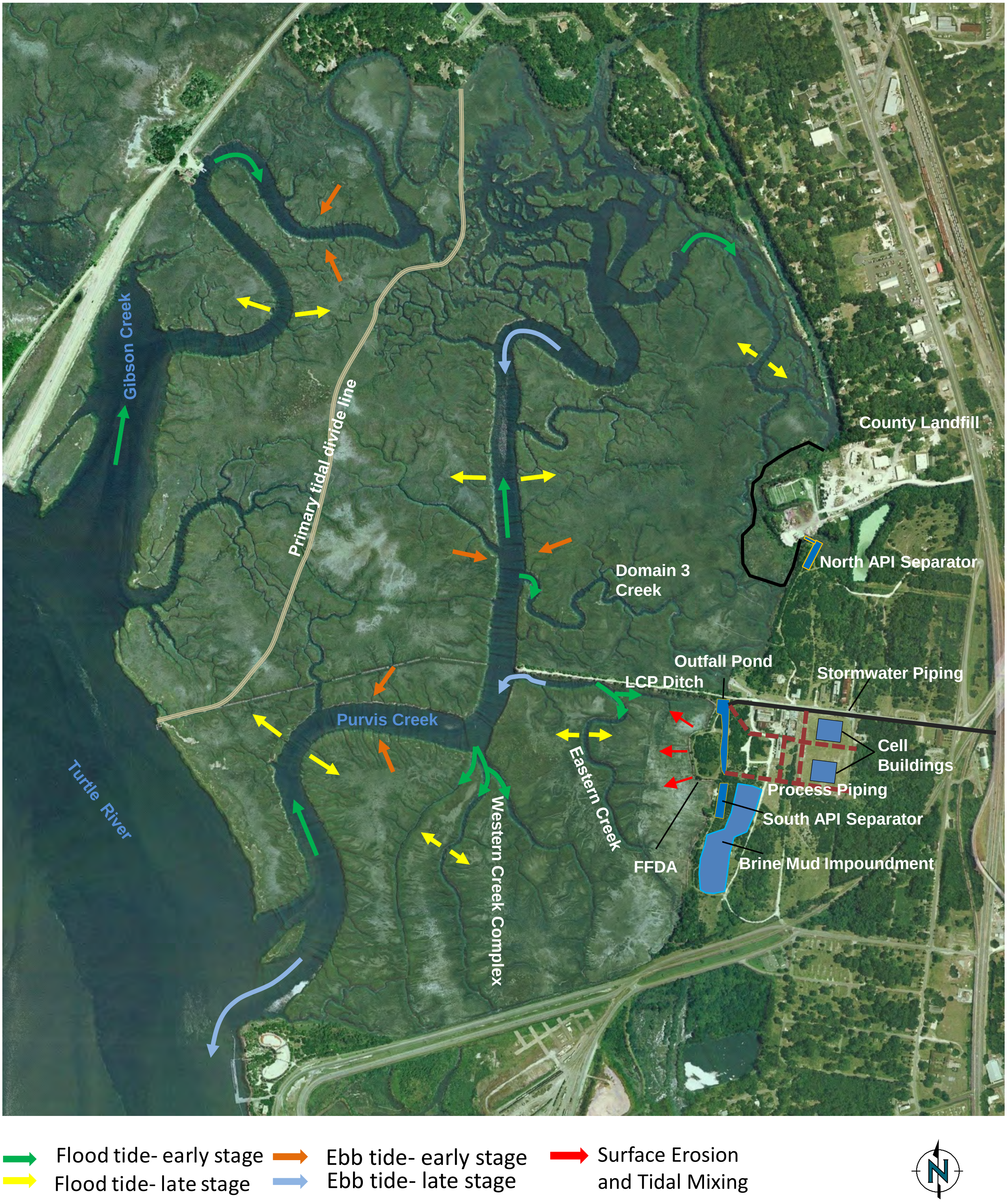
Groundwater Conceptual Site Model: Flow Paths

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 2-3



Source: Figures 2-2, 7-1 and 7-5 of the Remedial Investigation Report Operable Unit One – Estuary LCP Chemical Site (EPS and ENVIRON, October 2012)

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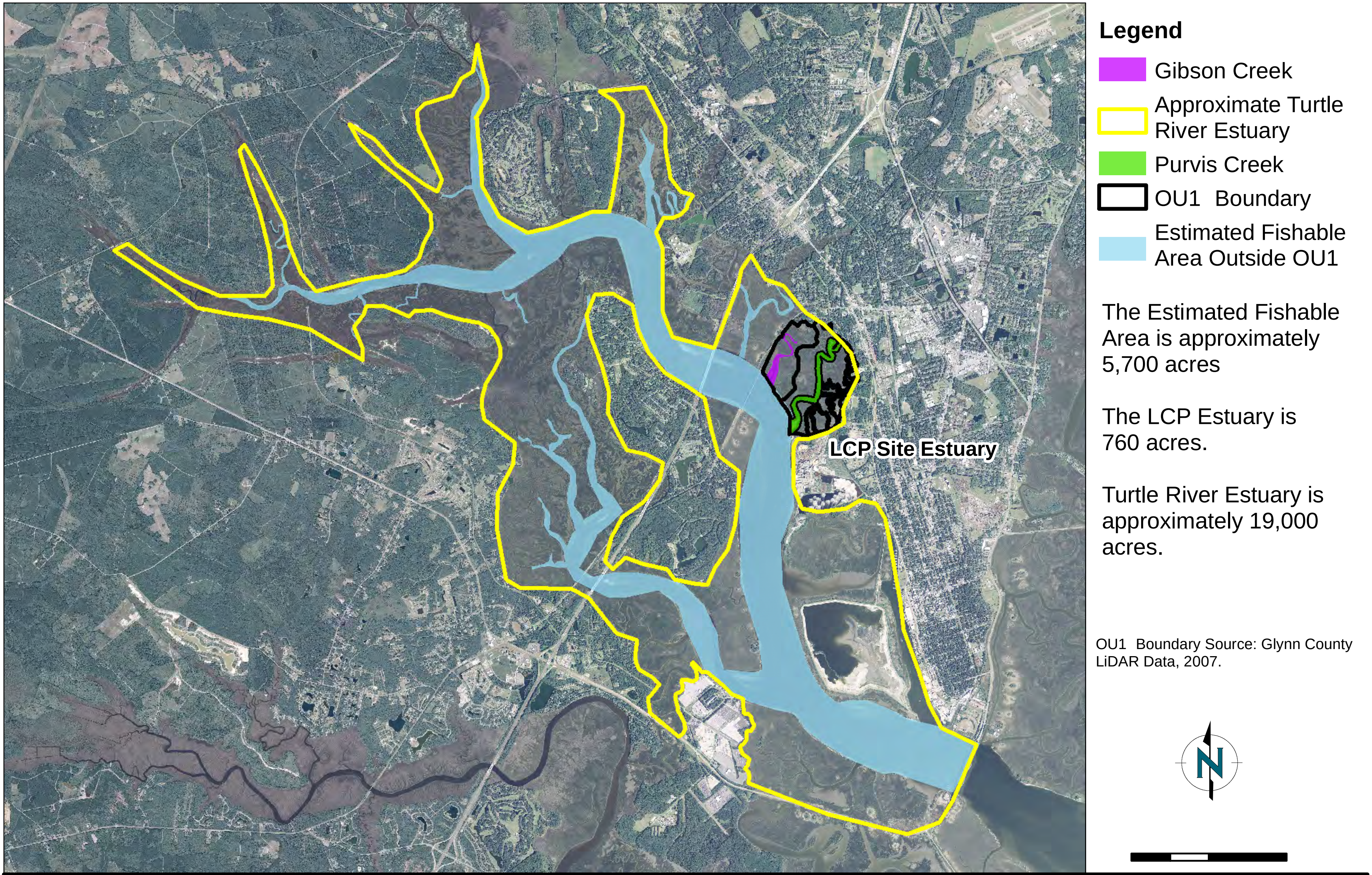
Surface Water
Conceptual Site Model

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 2-4



Legend

- 🟪 Gibson Creek
- ☐ Approximate Turtle River Estuary
- 🟩 Purvis Creek
- ☐ OU1 Boundary
- 🟦 Estimated Fishable Area Outside OU1

The Estimated Fishable Area is approximately 5,700 acres

The LCP Estuary is 760 acres.

Turtle River Estuary is approximately 19,000 acres.

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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Turtle River/Brunswick Estuary

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 2-5

A. Eastern Creek

This picture is representative of the eastern creek at high tide.

.

B. Eastern Creek

This picture is representative of the eastern creek at low tide.

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LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

FIGURE

2-6

C. Domain 2

This picture is oriented north and depicts the typical marsh community at Domain 2.

D. Domain 2

This picture is oriented south. Eastern Creek is in the foreground and Domain 2 is the marsh in the background.

E. Domain 1A

This picture is oriented south. LCP Ditch is in foreground and Domain 1A is in background.

F. Domain 1

This picture is oriented south from the northern edge of Domain 1 and is a close-up of the marsh ecosystem found at the site.

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LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

FIGURE
2-6

G. Marsh

This picture is oriented west. Purvis Creek is in the foreground and Domain 4 East is in the background.

H. Marsh

This picture is oriented north along Purvis Creek. Domain 4 East is the marsh on the left of Purvis Creek and Domain 3 is the marsh on the right. Domain 3 Creek is also visible in the background on the right.

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LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

FIGURE
2-6

I. Dillon Duck

This picture is representative of the western portion of the Dillon Duck area which is east of Domain 3 and in the upland area of the site.

J. Dillon Duck

This picture is representative of the southeastern portion of the Dillon Duck area which is east of Domain 3 and in the upland area of the site.

K. Eastern Creek

This picture is representative of the southern end of eastern creek at high tide. At this time there is less than 1 foot of water in the marsh.

L. Eastern Creek

This picture is representative of the southern end of eastern creek at low tide.

M. LCP Ditch

This picture is representative of the LCP ditch at mid-tide.

N. LCP Ditch

This picture is representative of the LCP ditch at low tide..

O. Domain 1

This picture is representative of the Domain 1 marsh at high tide.

P. Domain 1

This picture is representative of the Domain 1 marsh at low tide.

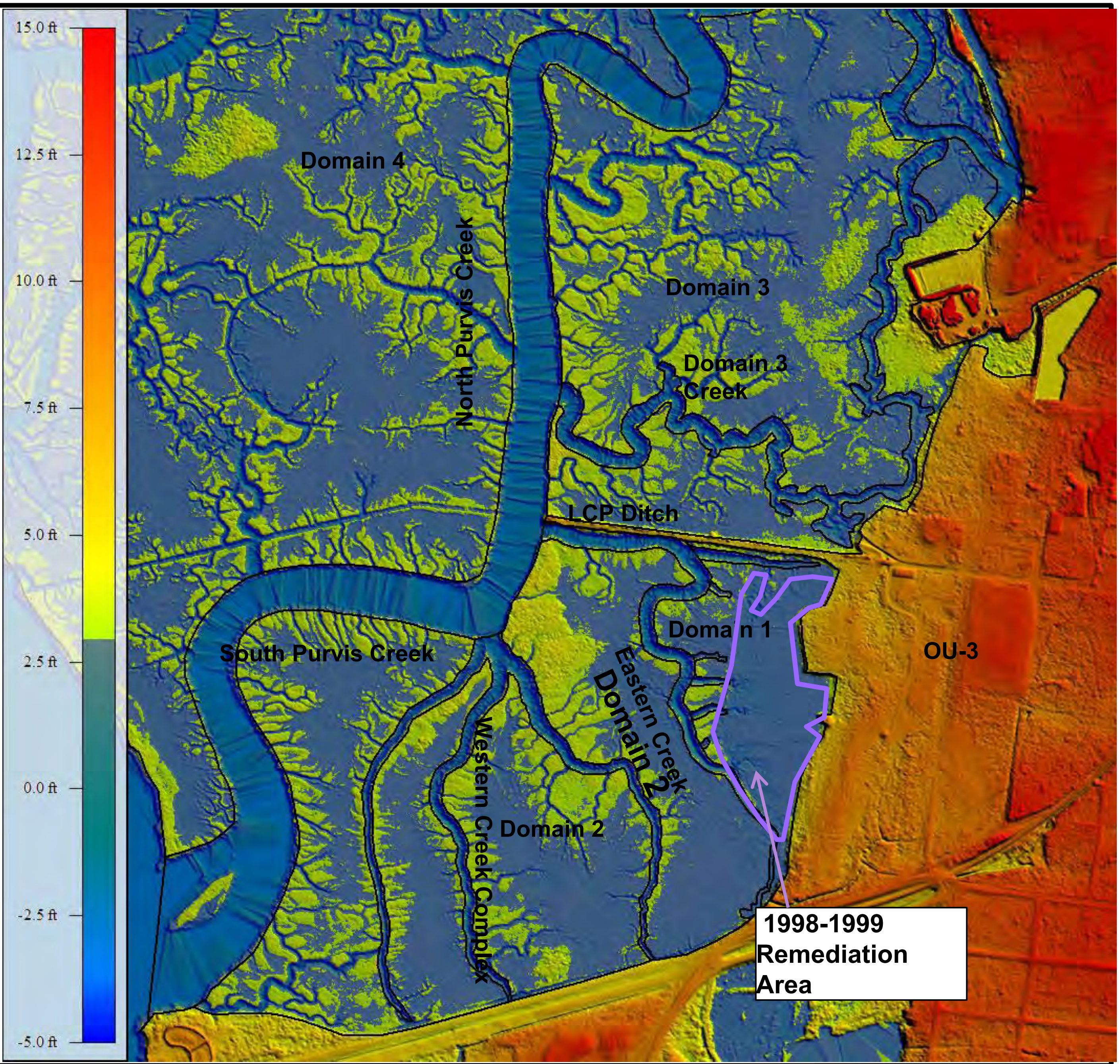
Q. Epibenthic Community

This picture is a close-up of the abundant epibenthic community of fiddler crabs located at in Domain 1 along the shoreline.

R. Dieback Area

This picture is oriented west from the eastern portion of Domain 1, and is representative of a dieback area at the site.

Marsh areas in the LCP estuary are only inundated for one to five hours a day depending on the tidal cycle.



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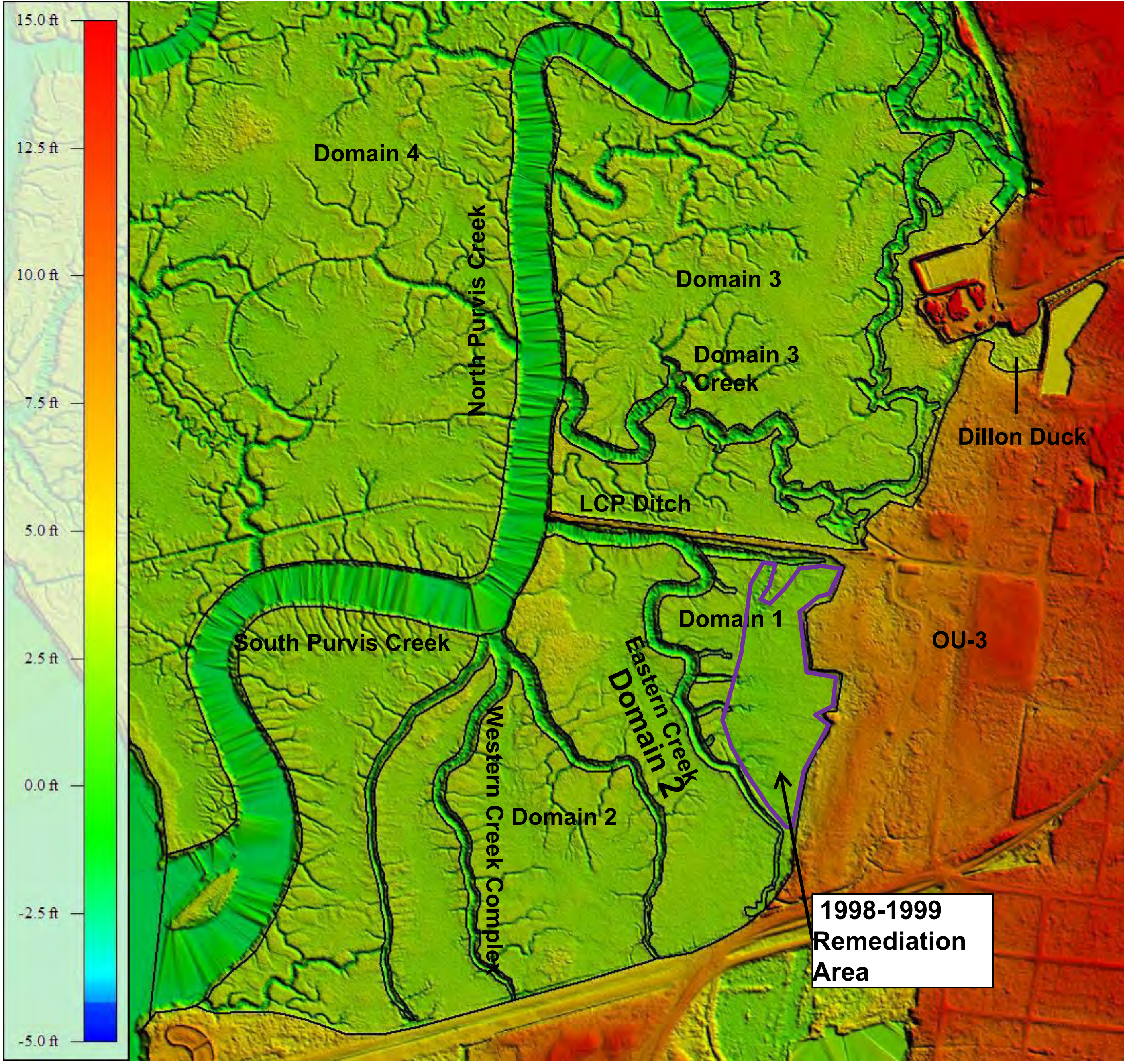
Marsh Inundation – Mean High High Water

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 2-7

Marsh areas in the LCP estuary are only inundated for one to five hours a day depending on the tidal cycle.



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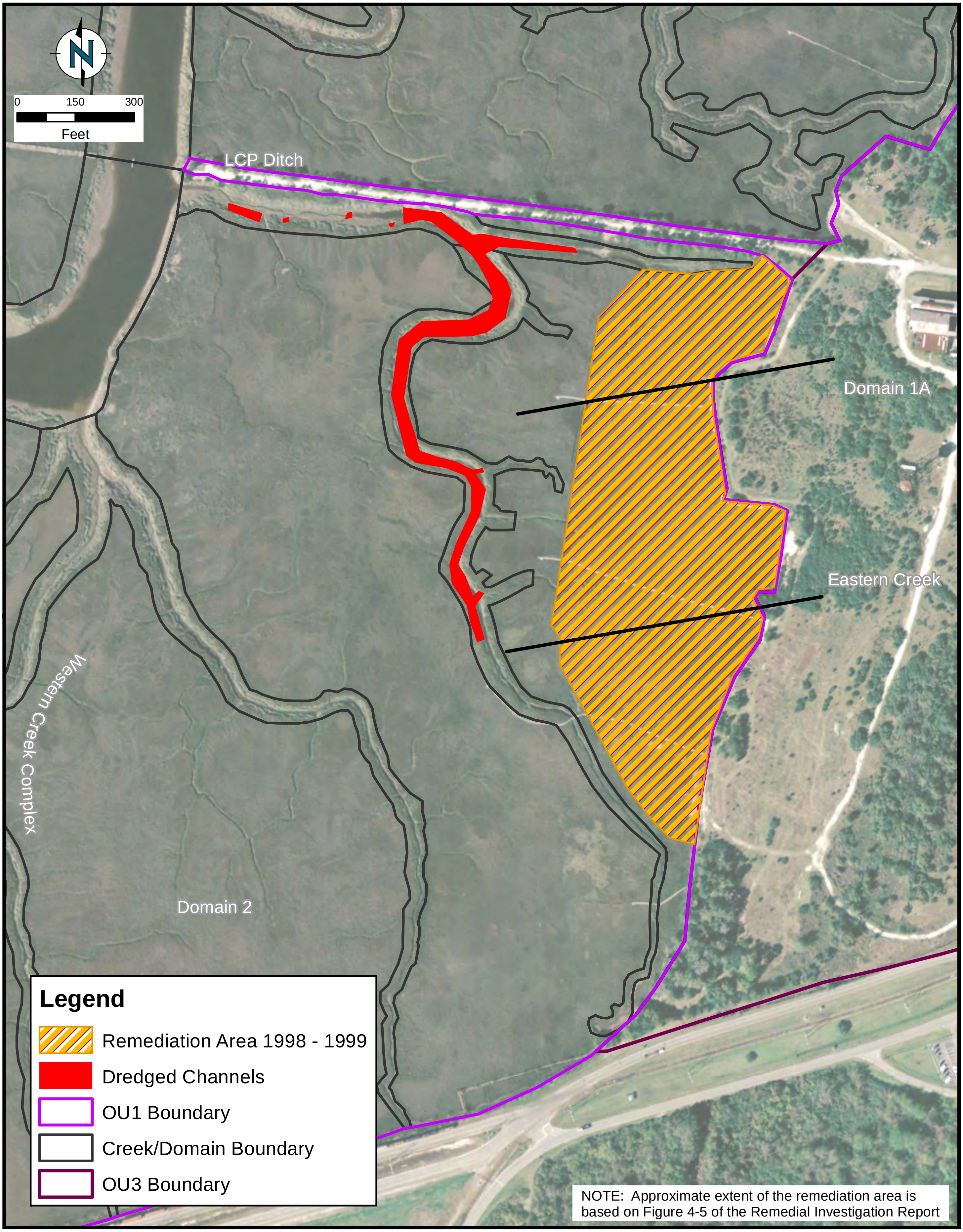
Marsh Inundation – Mean Low Low Water

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

2-8



NOTE: Approximate extent of the remediation area is based on Figure 4-5 of the Remedial Investigation Report

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Approximate Extent of 1998 - 1999 Remediation Area

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 2-9

A. Initial Revegetation of Remediated Marsh Flats at the LCP Marsh

B. Aerial Photograph of Marsh Remediation Activities

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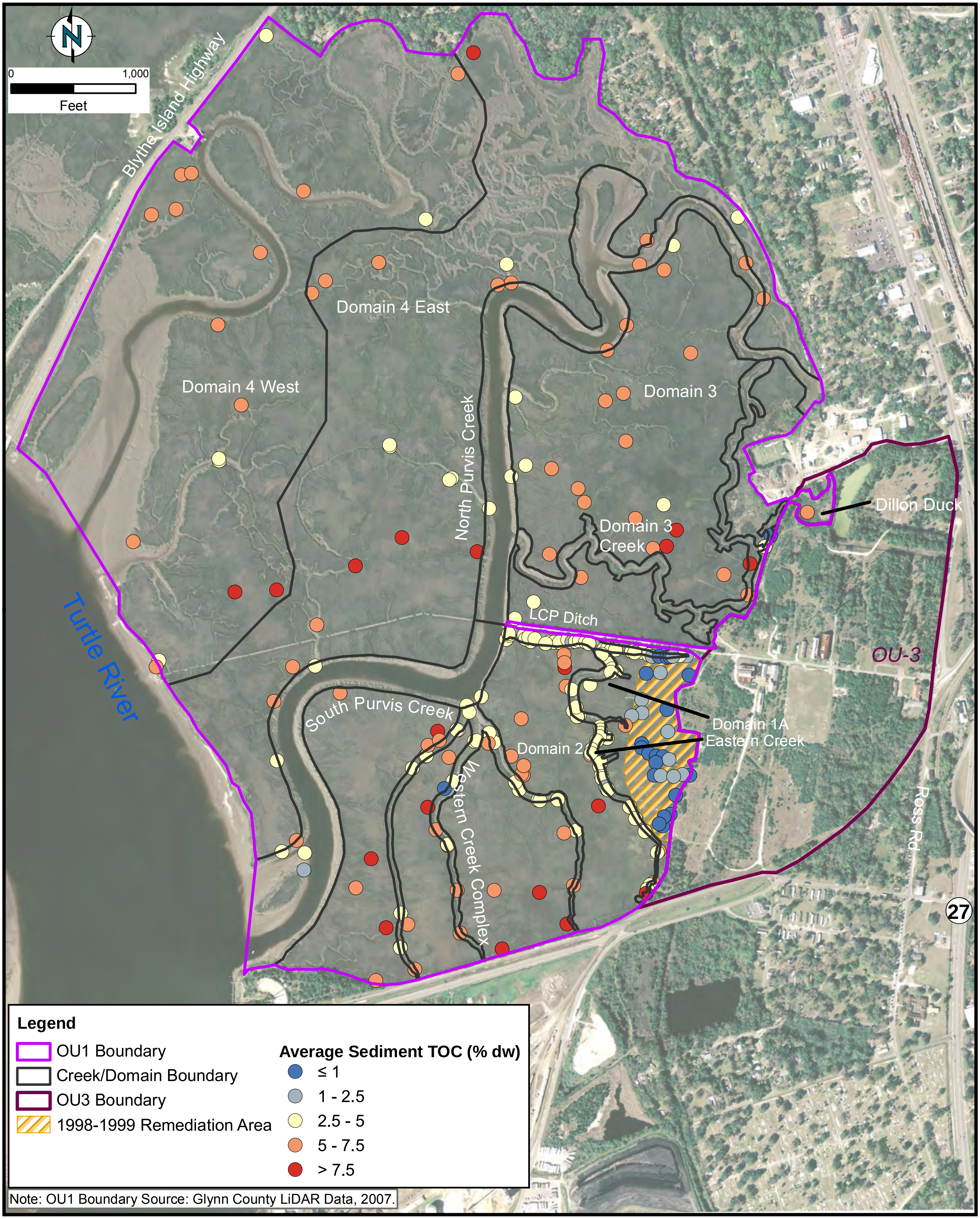
Remediation Photographs

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

FIGURE **2-10**

C. Revegetation of Remediated Marsh Flats at the LCP Marsh After Two Years



Note: OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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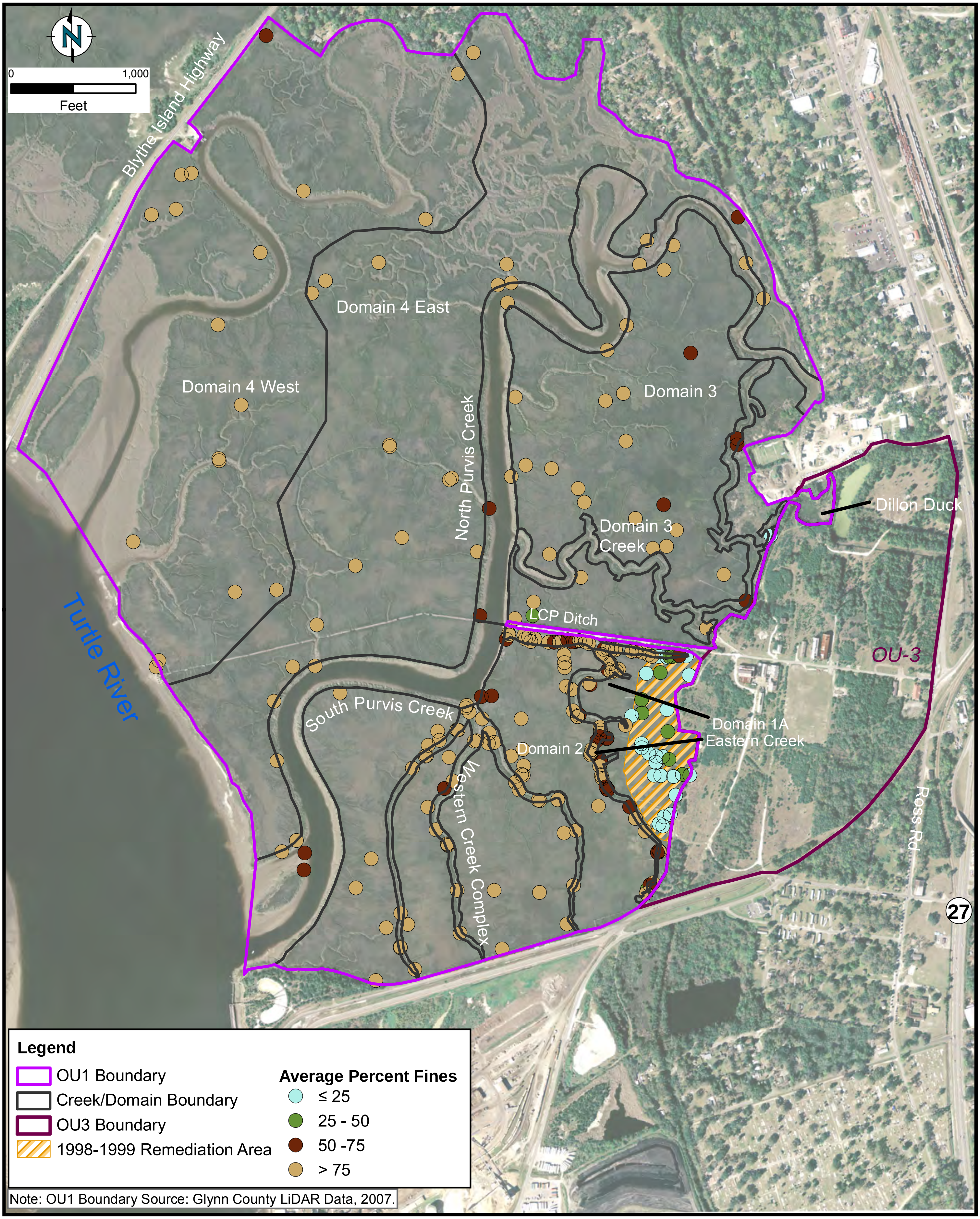
Average Total Organic Carbon in Sediment

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 2-11



Note: OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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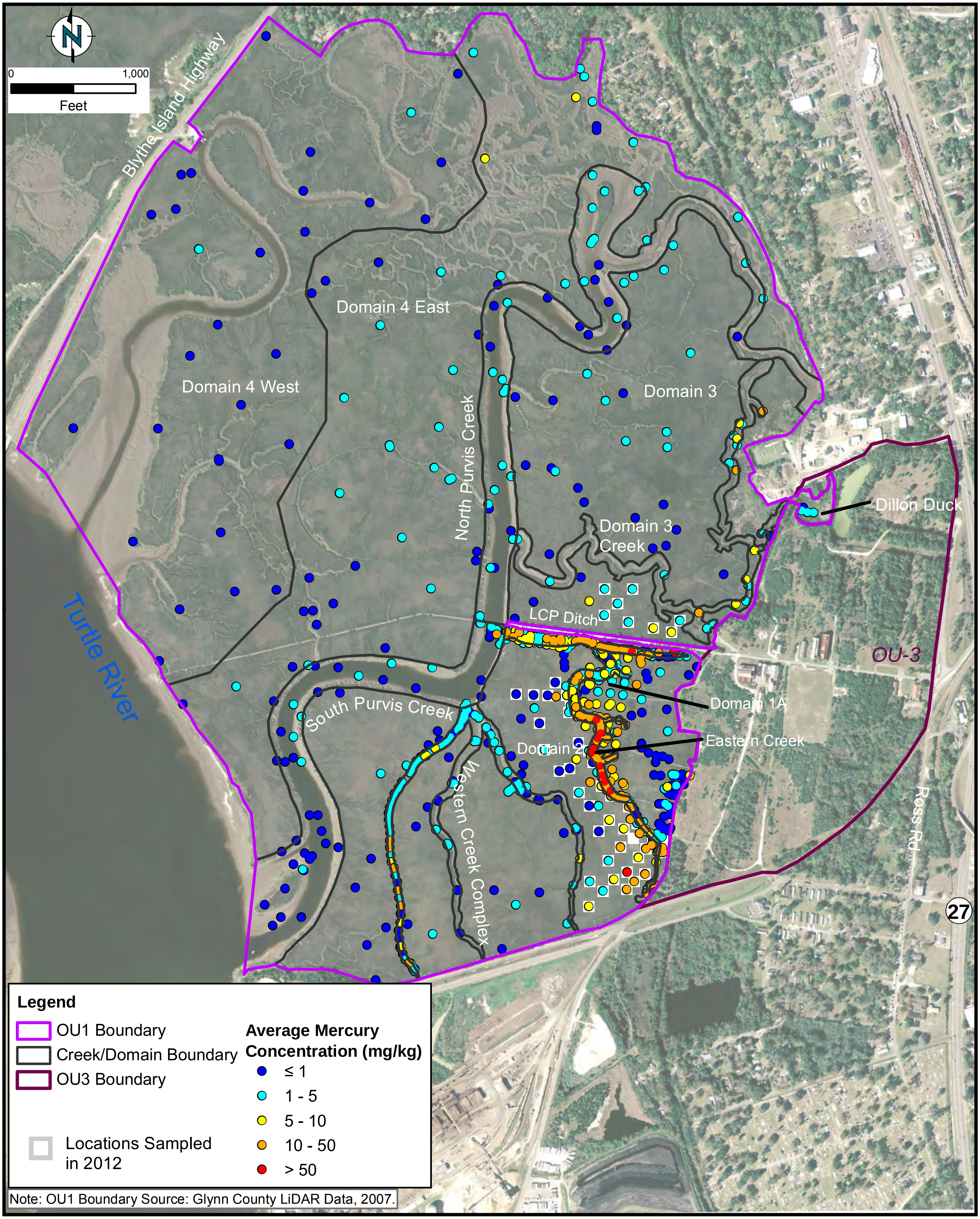
Average Percent Fines

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 2-12



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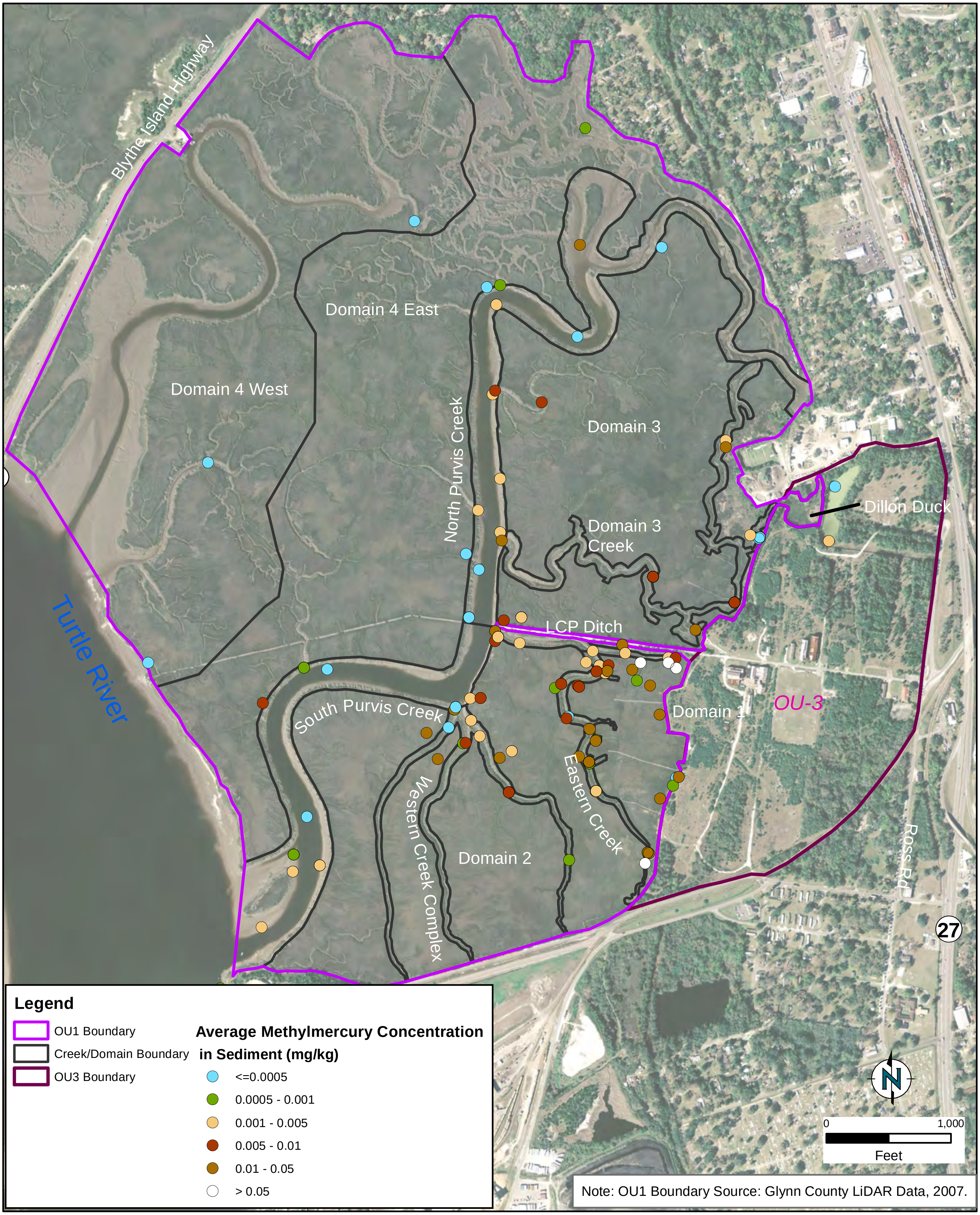
Average Mercury Concentration in OU1 Surface Sediments

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 2-13



Note: OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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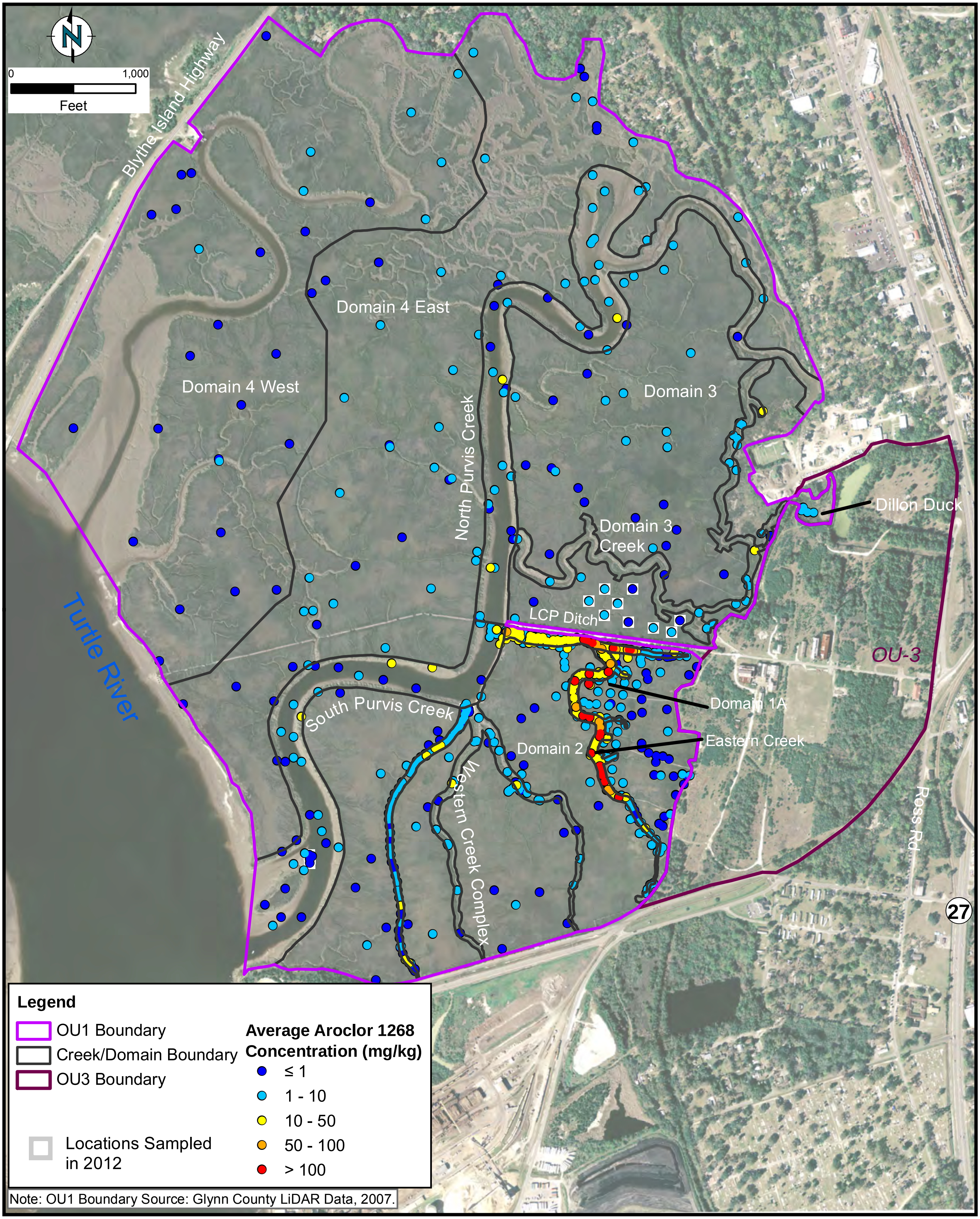
Average Methylmercury Concentration in Surface Sediments

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure
2-14



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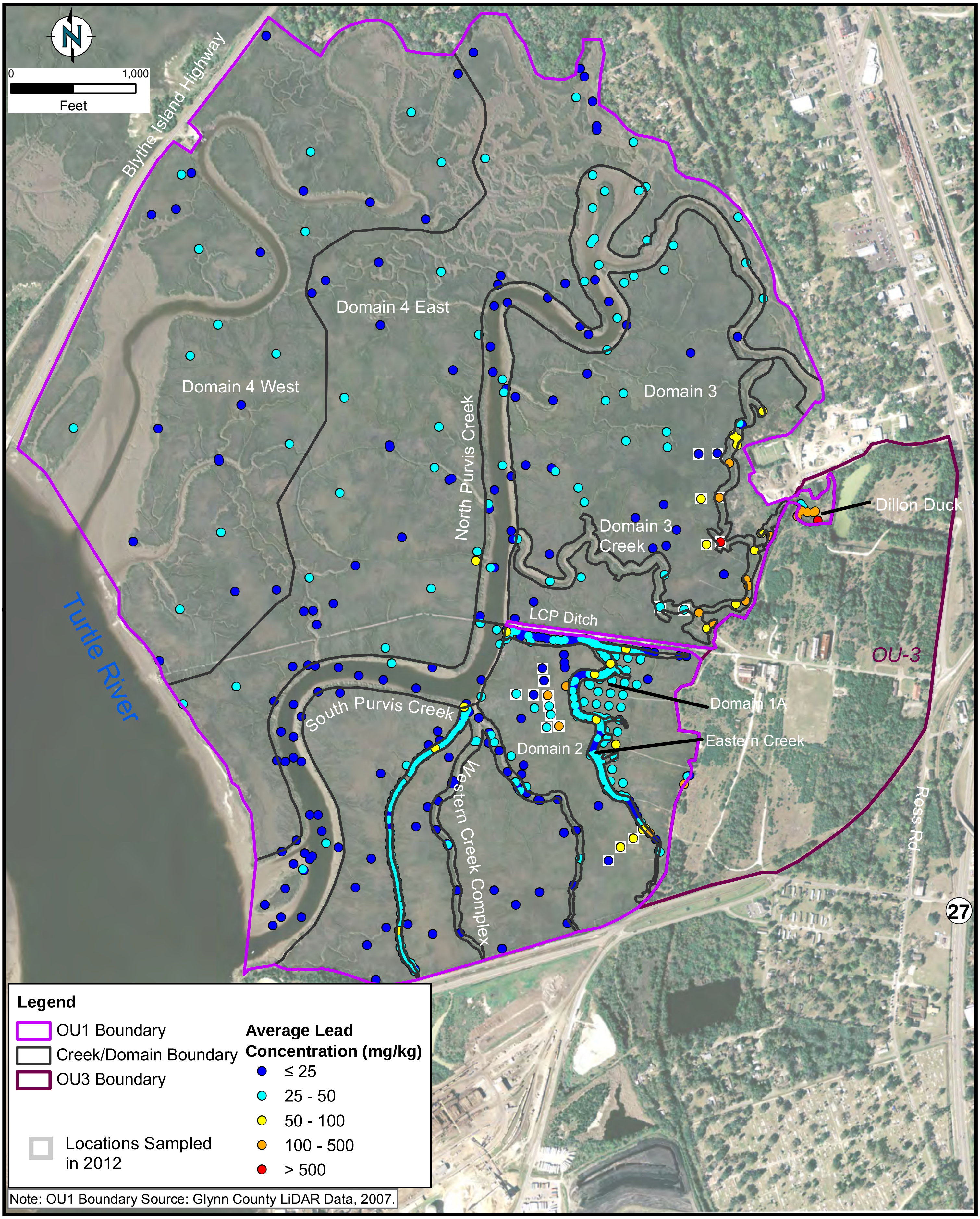
Average Aroclor 1268 Concentration in OU1 Surface Sediments

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 2-15



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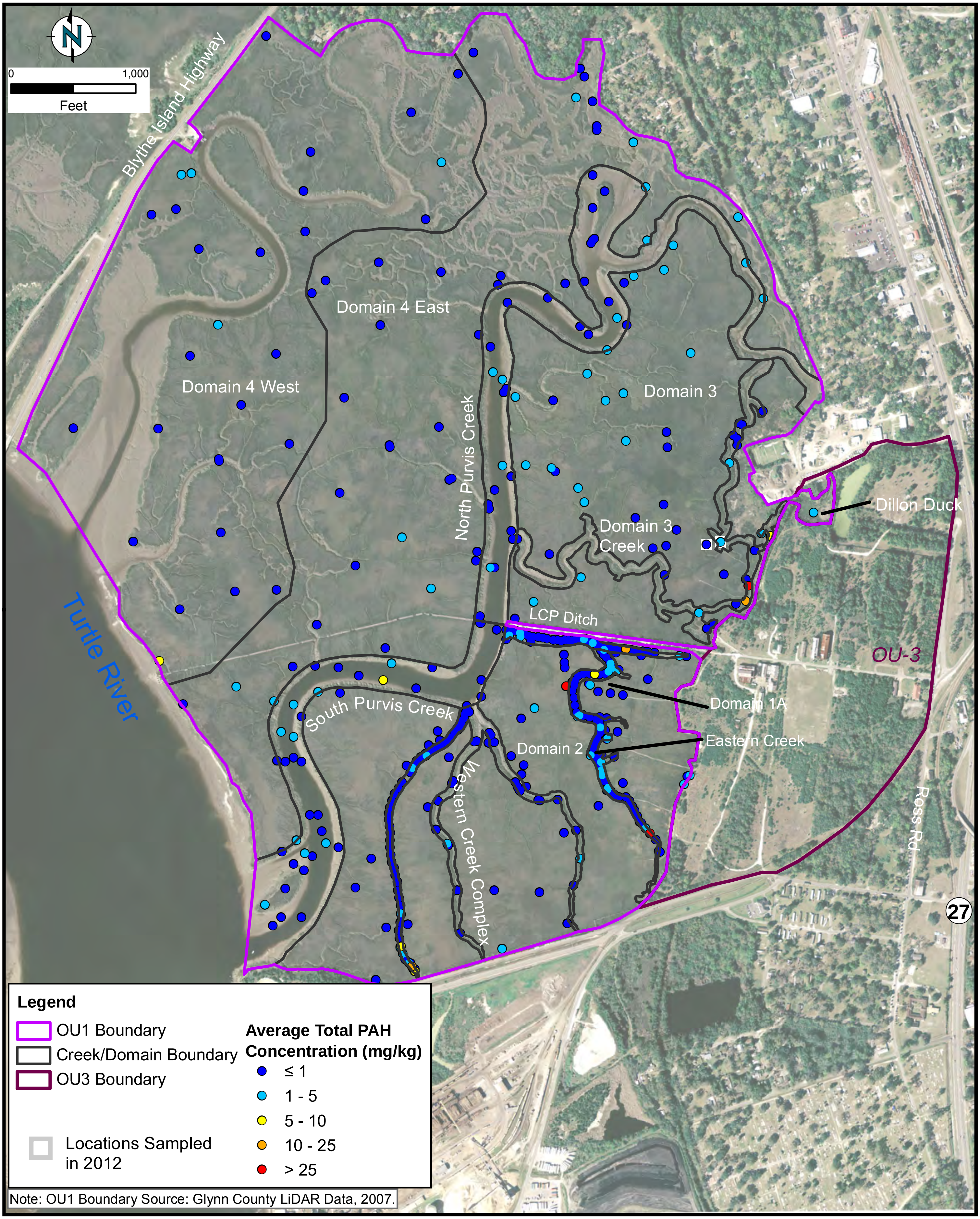
Average Lead Concentration in OU1 Surface Sediments

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 2-16



Note: OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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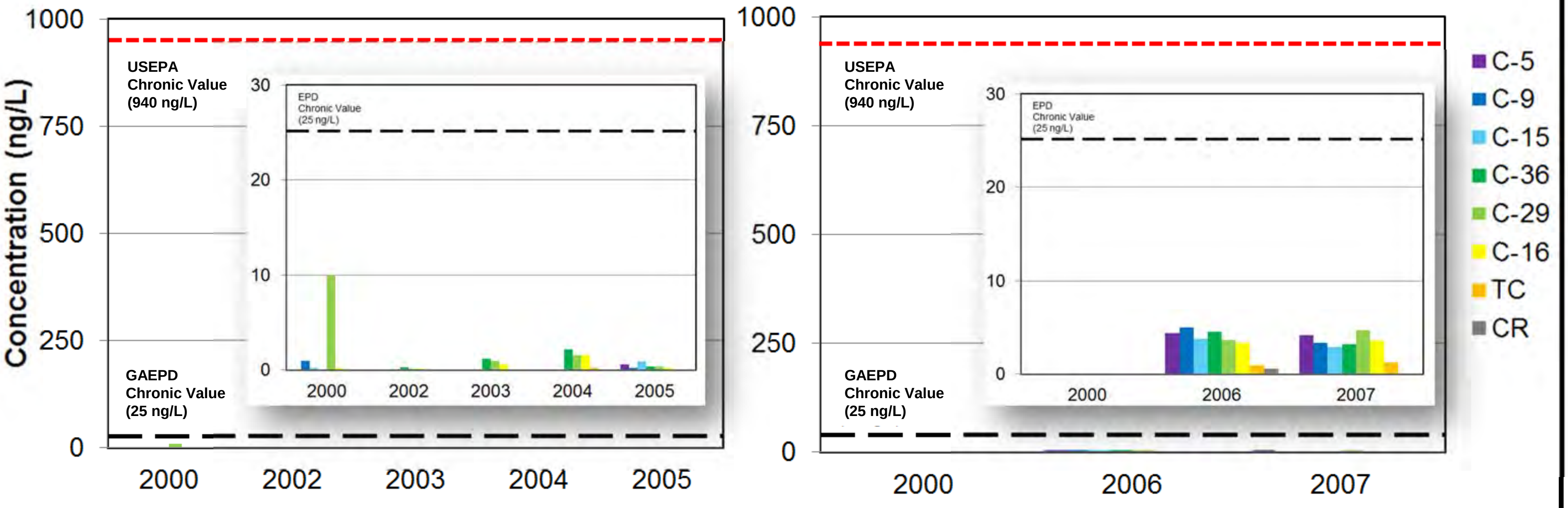
Average Total PAH Concentration in OU1 Surface Sediments

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 2-17



Year	Mouth of Main Canal	Mouth of Eastern Creek	Mouth of Western Creek	Upper Purvis Creek	Mid-Stretch Purvis Creek	Mouth of Purvis Creek	Control	Control
	C-5	C-9	C-15	C-36	C-29	C-16	TC	CR
2000	*0.1*	0.94	0.22	0.1	10	0.2	***0.036***	***0.012***
2002	---	---	---	0.28	0.15	0.18	0.05	0.043
2003	---	---	---	1.2	1	0.61	***0.012***	*0.012*
2004	---	---	---	2.2	1.6	1.6	0.22	0.047
2005	0.59	0.22	0.89	0.35	0.36	0.25	0.088	***0.008***
2006	4.4	5	3.8	4.6	3.7	3.4	1	*0.6*
2007	4.2	3.4	2.9	3.2	4.7	3.6	1.3	---

Blue text reflects dissolved methylmercury. Black text reflects dissolved total mercury. Data in italics are non-detects.
Data reported in ng/L and is the data source for the two figures graphed. Non-detects are treated as ½ the detection limit.

CR	Crescent River (Control)
GAEPD	Environmental Protection Division
ng/L	Nanogram per liter
NRWQC	National Recommended Water Quality Criteria
TC	Troup Creek (Control)
USEPA	Environmental Protection Agency

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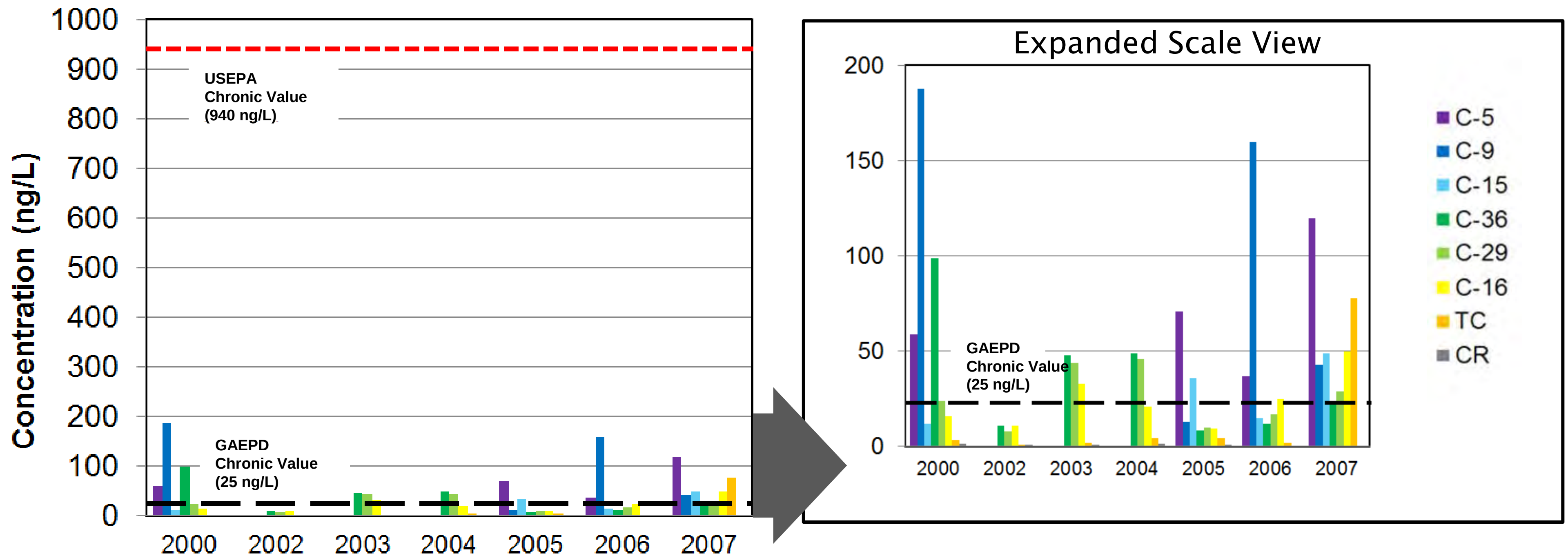
Surface Water Quality Dissolved Total Mercury and Dissolved Methylmercury Compared to GAEPD WQS and USEPA NRWQC Chronic Values

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

2-18



Year	Mouth of Main Canal	Mouth of Eastern Creek	Mouth of Western Creek	Upper Purvis Creek	Mid-Stretch Purvis Creek	Mouth of Purvis Creek	Control	Control
	C-5	C-9	C-15	C-36	C-29	C-16	TC	CR
2000	59	188	12	99	24	16	3.3	1.7
2002	---	---	---	11	8.1	11	1.1	1.2
2003	---	---	---	48	44	33	2.1	1.2
2004	---	---	---	49	46	21	4.6	1.6
2005	71	13	36	8.4	9.8	9.6	4.7	1.2
2006	37	160	15	12	17	25	1.8	0.7
2007	120	43	49	23	29	50	78	---

CR	Crescent River (Control)
GAEPD	Georgia Environmental Protection Division
ng/L	Nanograms per liter
NRWQC	National Recommended Water Quality Criteria
TC	Troup Creek (Control)
USEPA	United States Environmental Protection Agency

Yellow highlighted cells exceed the GAEPD chronic Water Quality Standard (WQS).

Data is in ng/L and is the data source of the above graph.

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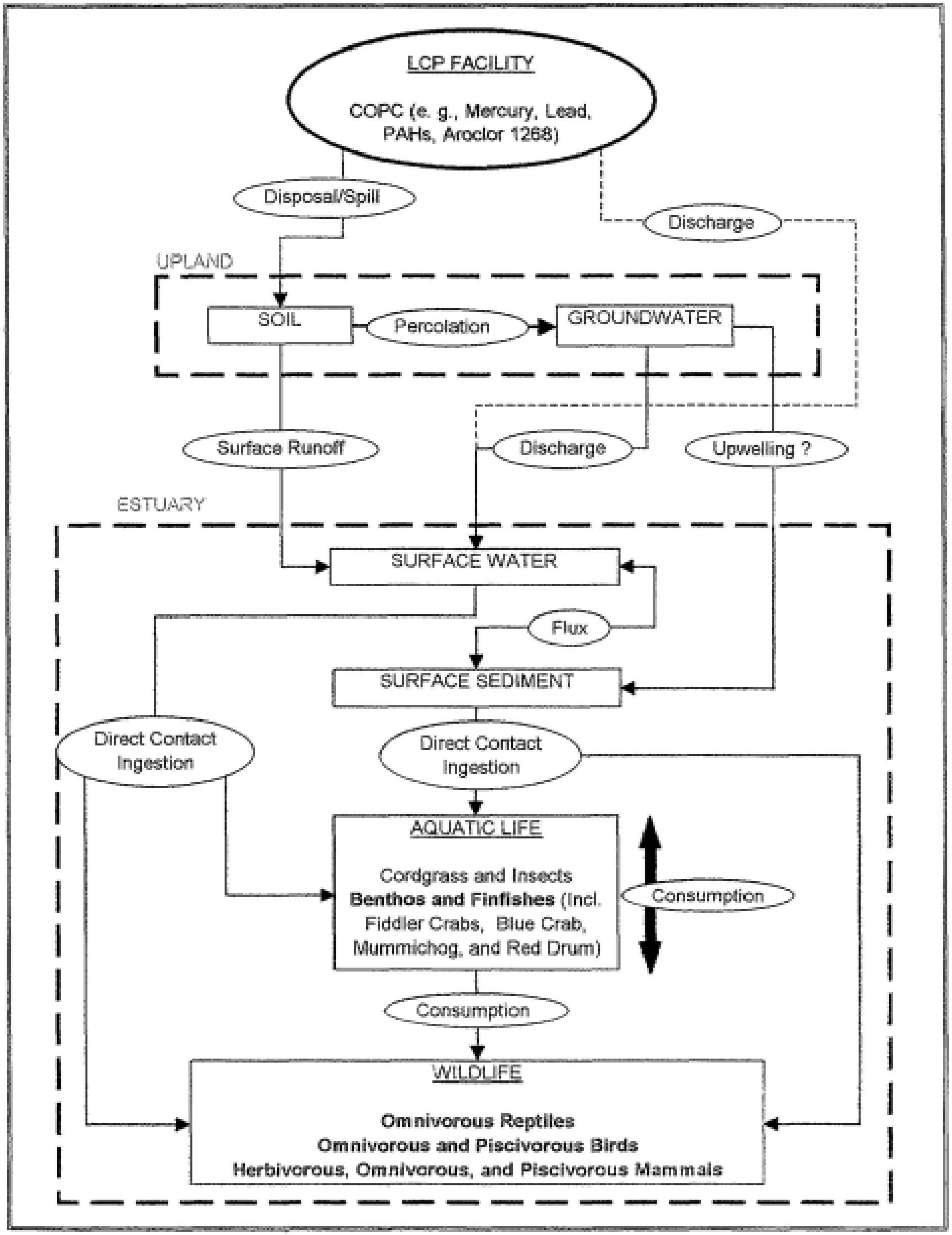
Surface Water Quality Total Mercury Compared to GAEPD WQS and USEPA NRWQC Chronic Values

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

2-19



Source: Baseline Ecological Risk Assessment (Black and Veatch 2011, Figure 3-2)

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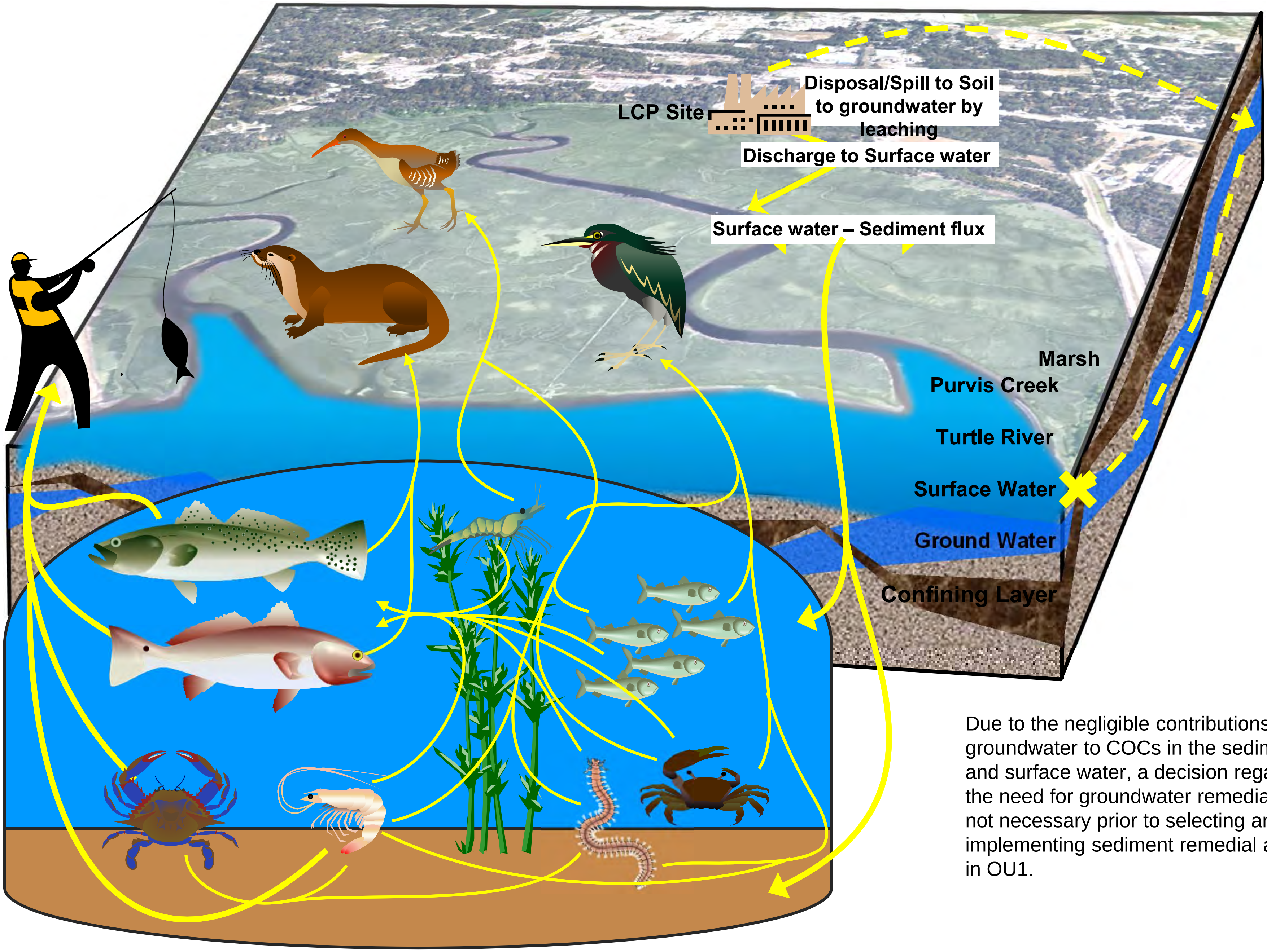
Conceptual Model for Ecological Exposures

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

FIGURE
2-20



Due to the negligible contributions of groundwater to COCs in the sediments and surface water, a decision regarding the need for groundwater remediation is not necessary prior to selecting and implementing sediment remedial actions in OU1.

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Conceptual Site Model for OU1

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

2-21

Mummichog
Fundulus heteroclitus

Silver Perch
Bairdiella chrysoura.

Striped Mullet
Mugil cephalus

Spotted Seatrout
Cynoscion nebulosus

Black Drum
Pogonias cromis.

Red Drum
Sciaenops ocellatus.

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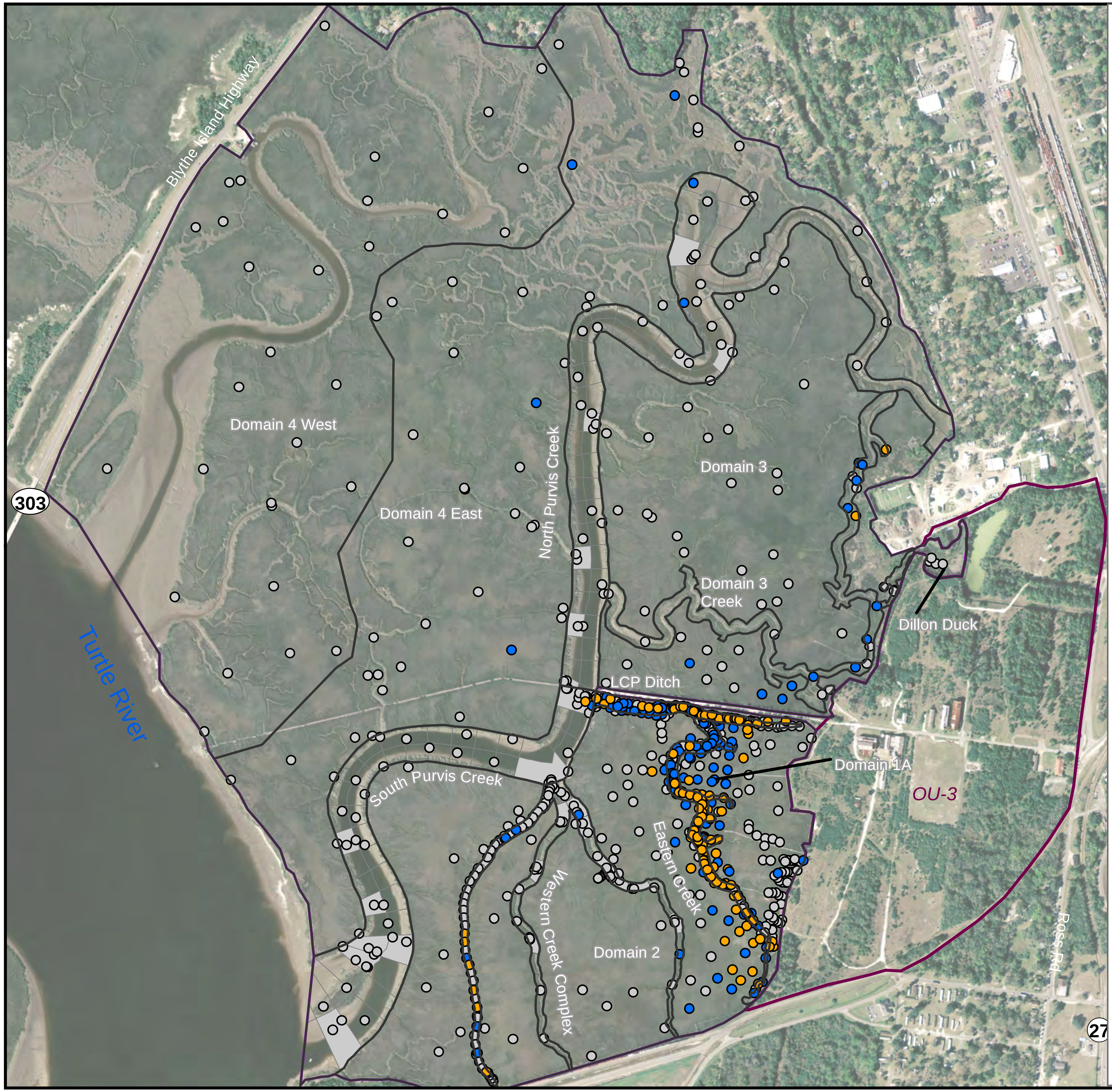
Example Fish Photographs

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

FIGURE
2-22



Legend

Mercury Concentration (mg/kg)

- ● < = 4
- ● 4 -11
- ● > 11
- ▨ < = 4
- ▨ 4 - 11
- ▨ > 11
- ☐ OU1 Boundary
- ☐ Creek/Domain Boundary
- ☐ OU3 Boundary

Notes:
-Colored boxes in Purvis Creek and Western Creek Complex reflect locations where averaging along approximately 50 meter polygons was conducted when more than one sample was collected within the approximate 50 meter interval.
-Units for all RGOs is mg/kg.

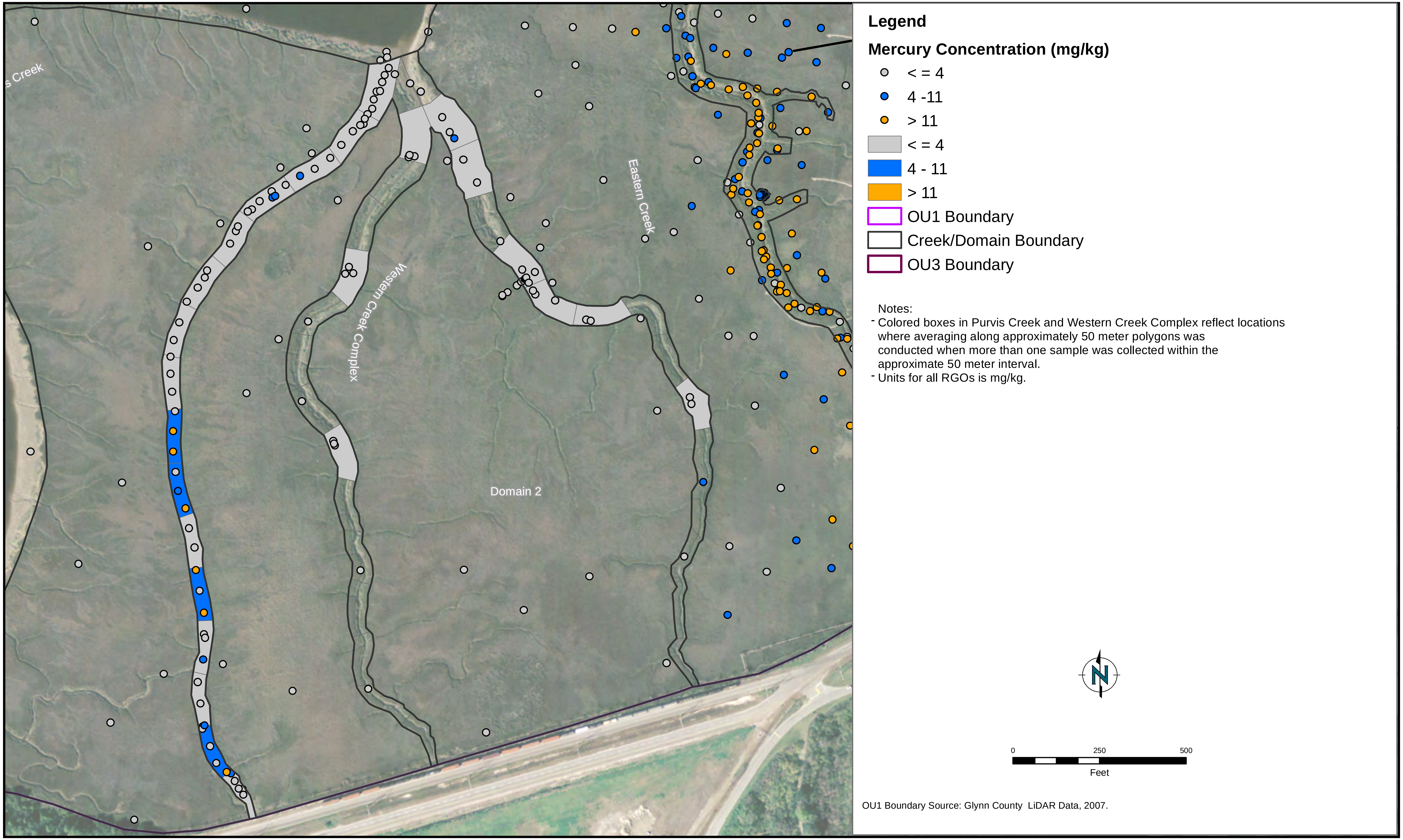
0 800 1,600
Feet

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

Average Mercury Concentration in OU1 Surface Sediments Compared to Benthic RGOs (OU1)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure
3-1A



Legend

Mercury Concentration (mg/kg)

○ < = 4
● 4 -11
● > 11
⬜ < = 4
🟦 4 - 11
🟧 > 11
▭ OU1 Boundary
▭ Creek/Domain Boundary
▭ OU3 Boundary

Notes:
- Colored boxes in Purvis Creek and Western Creek Complex reflect locations where averaging along approximately 50 meter polygons was conducted when more than one sample was collected within the approximate 50 meter interval.
- Units for all RGOs is mg/kg.

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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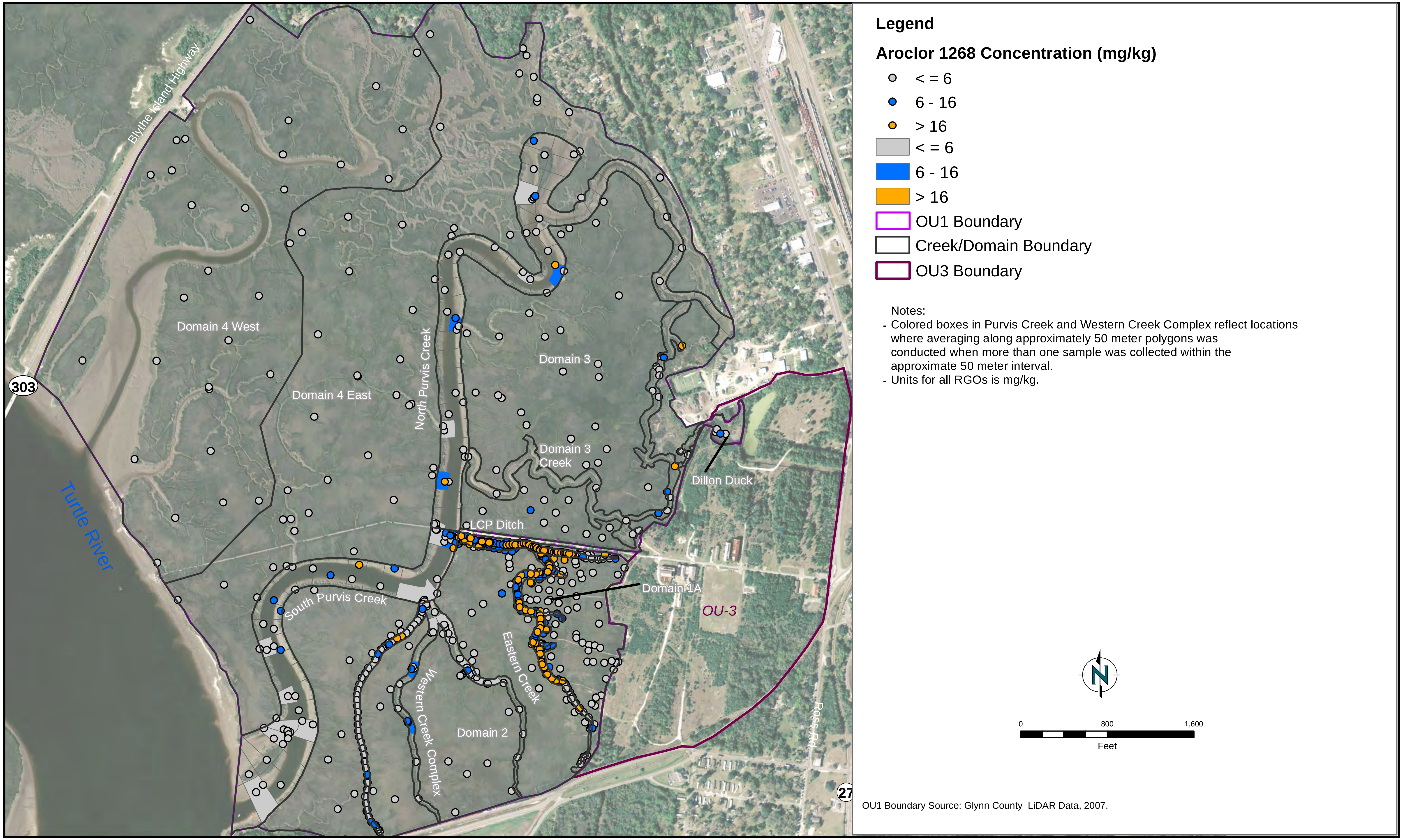
Average Mercury Concentration in OU1 Surface Sediments Compared to Benthic RGOs (Western Creek Complex)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure
3-1B



Notes:
- Colored boxes in Purvis Creek and Western Creek Complex reflect locations where averaging along approximately 50 meter polygons was conducted when more than one sample was collected within the approximate 50 meter interval.
- Units for all RGOs is mg/kg.

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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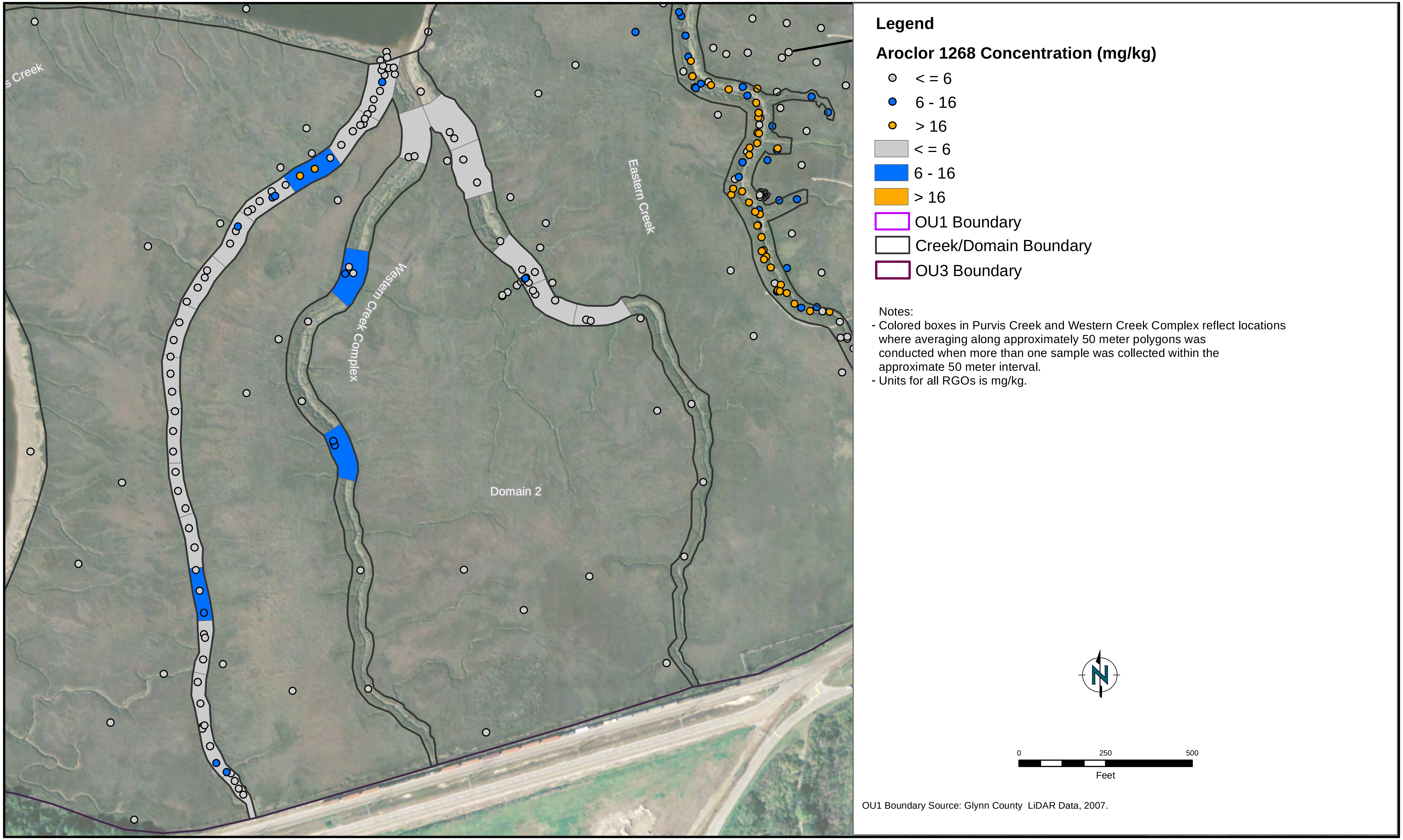
Average Aroclor 1268 Concentration in OU1 Surface Sediments Compared to Benthic RGOs (OU1)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 3-2A



Notes:
- Colored boxes in Purvis Creek and Western Creek Complex reflect locations where averaging along approximately 50 meter polygons was conducted when more than one sample was collected within the approximate 50 meter interval.
- Units for all RGOs is mg/kg.

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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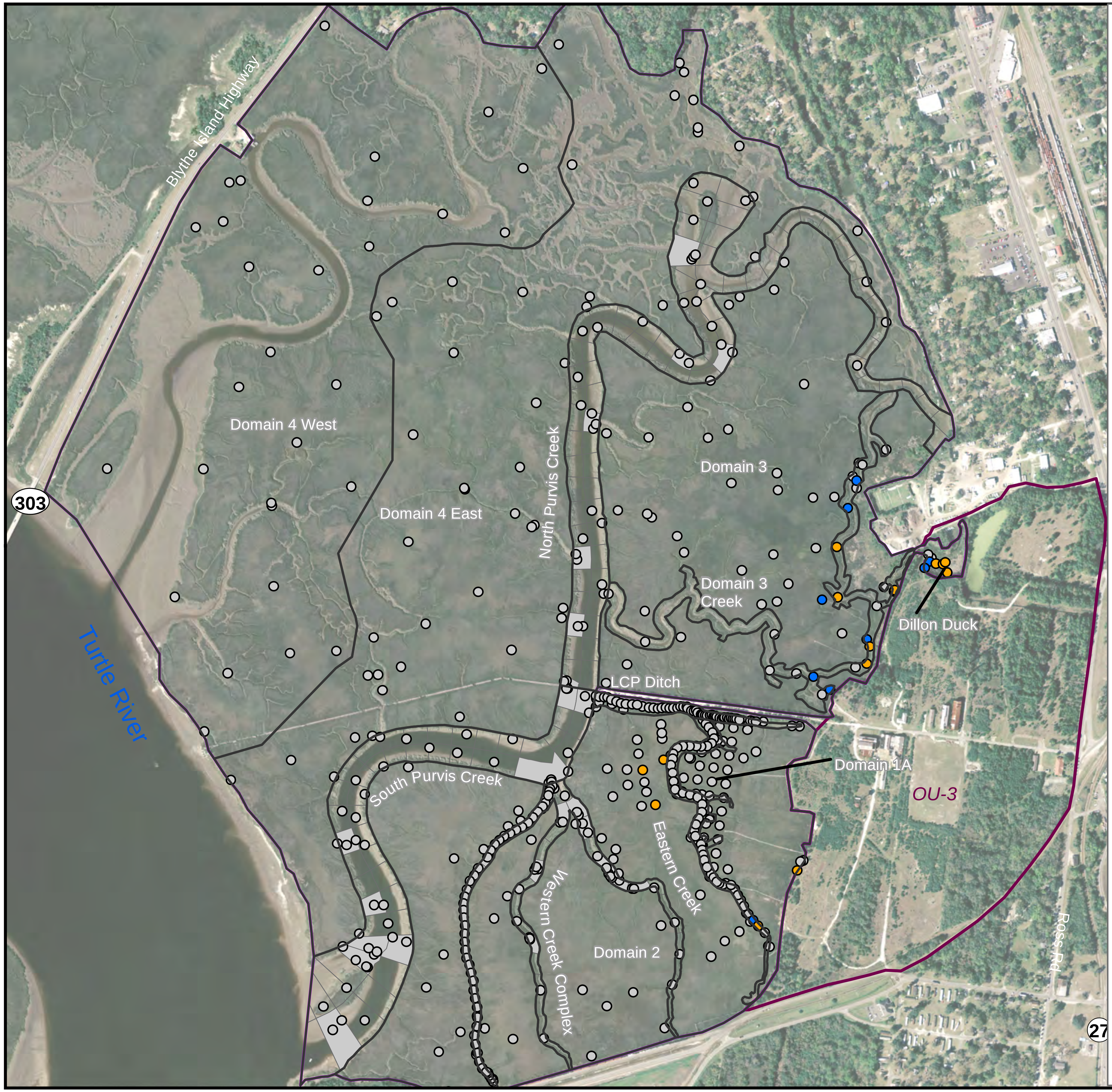
Average Aroclor 1268 Concentration in OU1 Surface Sediments Compared to Benthic RGOs (Western Creek Complex)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure
3-2B



Legend

Lead Concentration (mg/kg)

○ < = 90
● 90 - 177
● > 177
⬜ < = 90
🟦 90 - 177
🟧 >177
☐ OU1 Boundary
☐ Creek/Domain Boundary
☐ OU3 Boundary

Notes:
- Colored boxes in Purvis Creek and Western Creek Complex reflect locations where averaging along approximately 50 meter polygons was conducted when more than one sample was collected within the approximate 50 meter interval.
- Units for all RGOs is mg/kg.

N

0 800 1,600
Feet

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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Average Lead Concentration in OU1 Surface Sediments Compared to Benthic RGOs (OU1)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure
3-3A

Legend

Lead Concentration (mg/kg)

- ○ < = 90
- ● 90 - 177
- ● > 177
- ▭ < = 90
- 🟦 90 - 177
- 🟧 >177
- ▭ OU1 Boundary
- ▭ Creek/Domain Boundary
- ▭ OU3 Boundary

Notes:
- Colored boxes in Purvis Creek and Western Creek Complex reflect locations where averaging along approximately 50 meter polygons was conducted when more than one sample was collected within the approximate 50 meter interval.
- Units for all RGOs is mg/kg.

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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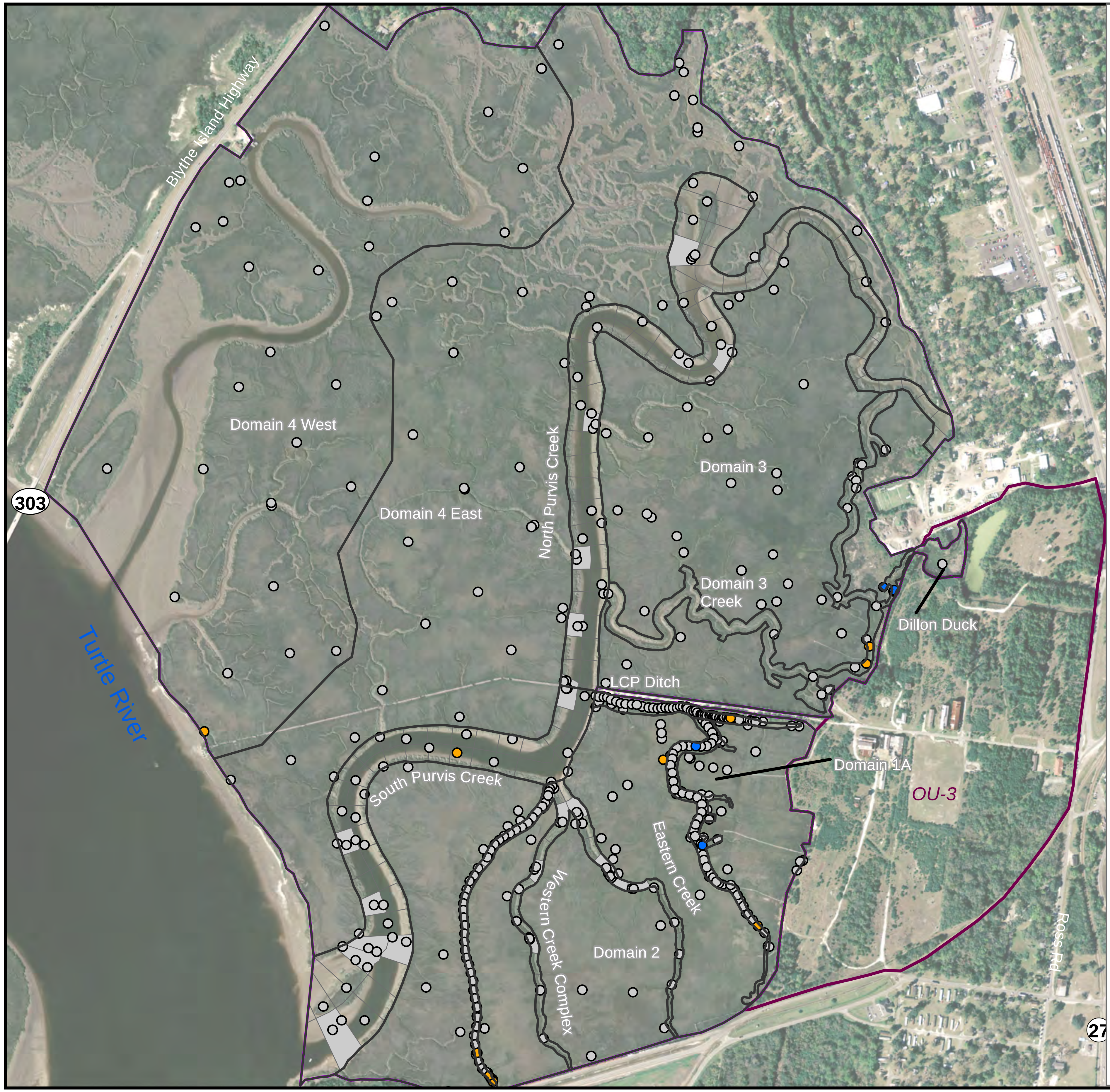
Average Lead Concentration in OU1 Surface Sediments Compared to Benthic RGOs (Western Creek Complex)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 3-3B



Legend

Total PAH Concentration (mg/kg)

- ● < = 4
- 🔵 4 - 6
- 🟠 > 6
- ⬜ < = 4
- 🟦 4 - 6
- 🟧 > 6
- ☐ OU1 Boundary
- ☐ Creek/Domain Boundary
- ☐ OU3 Boundary

Notes:
- Colored boxes in Purvis Creek and Western Creek Complex reflect locations where averaging along approximately 50 meter polygons was conducted when more than one sample was collected within the approximate 50 meter interval.
- Units for all RGOs is mg/kg.

N

0 800 1,600
Feet

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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Average Total PAH Concentration in OU1 Surface Sediments Compared to Benthic RGOs (OU1)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 3-4A

Legend

Total PAHs Concentration (mg/kg)

○ < = 4
● 4 - 6
● > 6
□ < = 4
🟦 4 - 6
🟧 > 6
▭ OU1 Boundary
▭ Creek/Domain Boundary
▭ OU3 Boundary

Notes:
- Colored boxes in Purvis Creek and Western Creek Complex reflect locations where averaging along approximately 50 meter polygons was conducted when more than one sample was collected within the approximate 50 meter interval.
- Units for all RGOs is mg/kg.

0 250 500
Feet

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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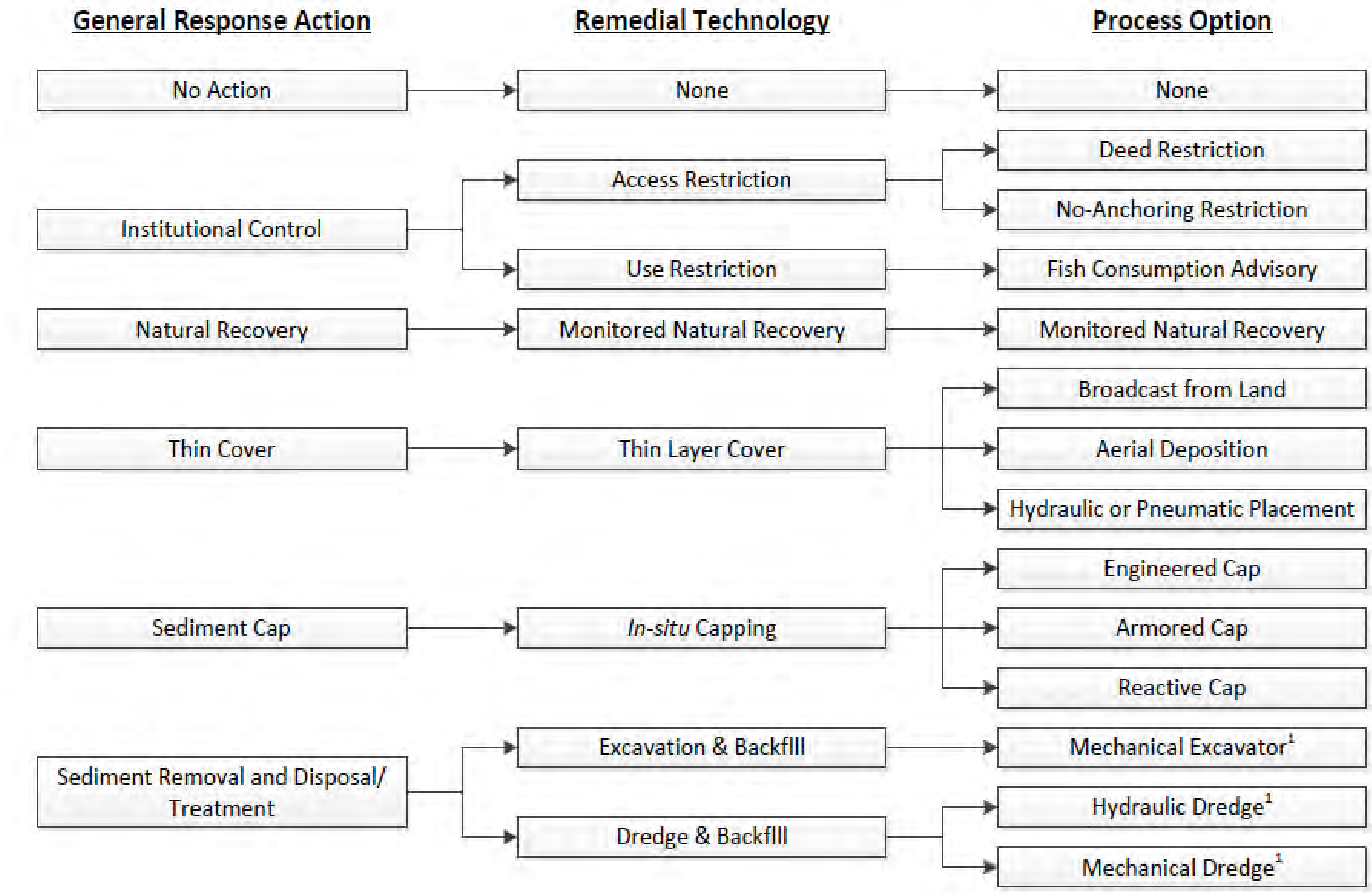
Average Total PAH Concentration in OU1 Surface Sediments Compared to Benthic RGOs (Western Creek Complex)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure
3-4B



[1] Following removal, materials need to be solidified/ stabalized and deposited on-site or off-site

Identification of Technologies

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

4-1

Photo 1.

Telebelt placement of capping material

Photo 2.

Hydraulic dredge spraying a thin layer of dredged material to restore a wetland at the Blackwater Wildlife Refuge, Dorchester County, Maryland.

(Source: USACE, Baltimore District, Baltimore Harbor & Channels, Dredged Material Management Plan. Available at: http://www.nab.usace.army.mil/projects/Maryland/DMMP/photos.html

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Examples of Thin-Layer Cover Placement

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

FIGURE
4-2

Photo 1.

Mechanical placement of a subaqueous cap with a clamshell

Photo 2.

Hydraulic placement of a subaqueous cap with a spreader barge

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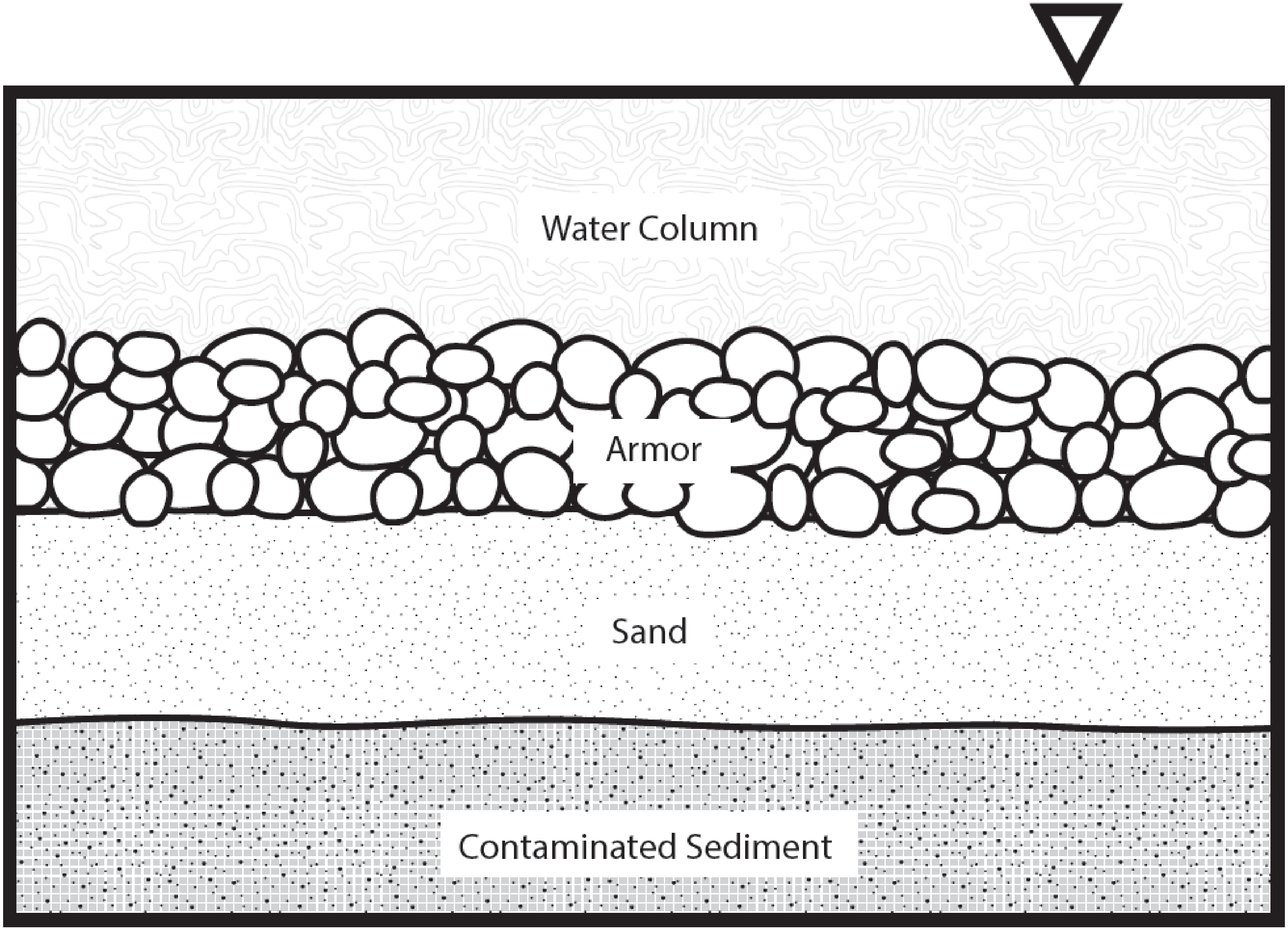
Examples of Engineered Cap Placement

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

FIGURE
4-3



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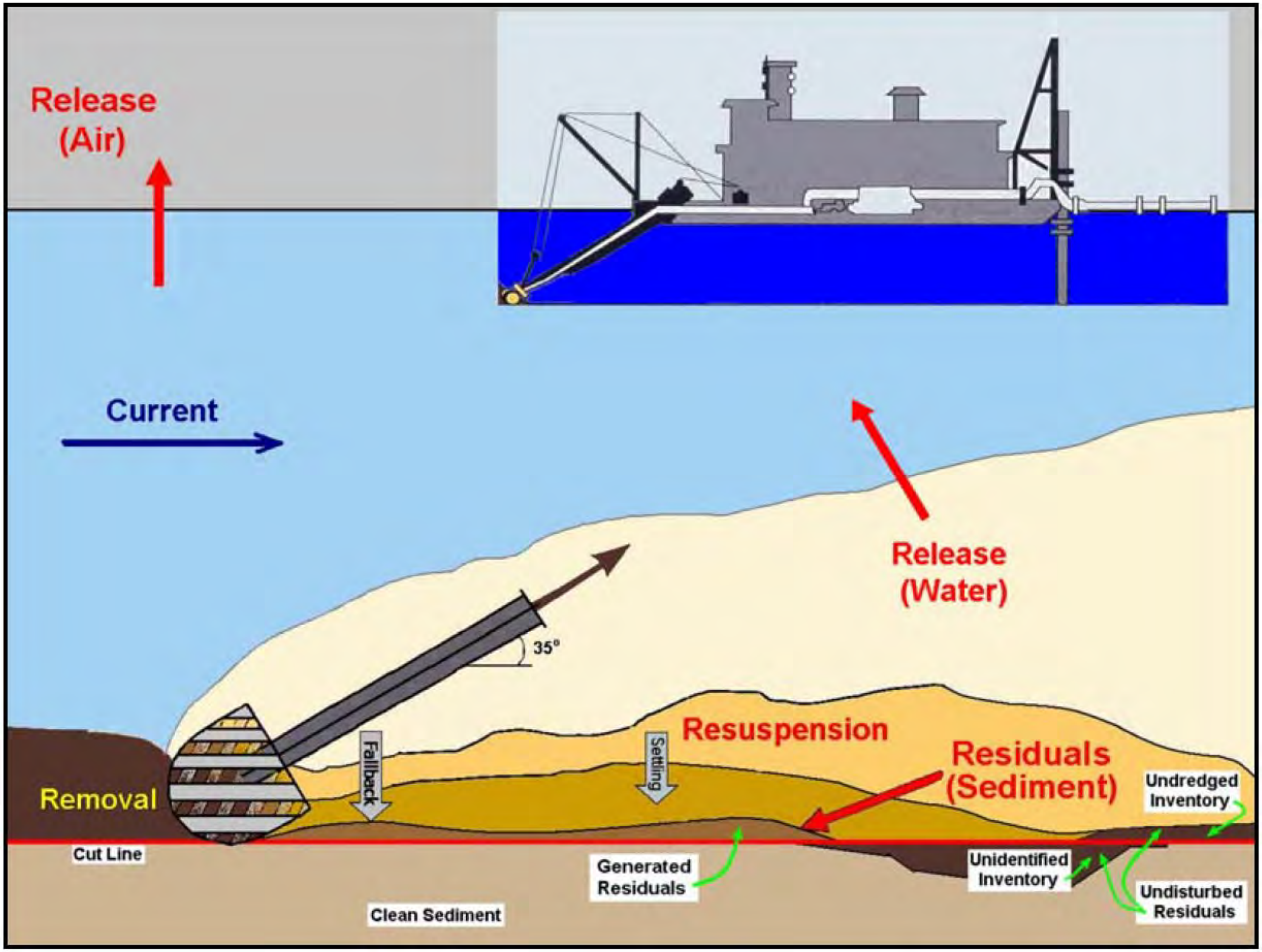
Schematic Cross-Section of Armored Cap

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 4-4



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Conceptual Illustration of Hydraulic Dredging and Processes

(Palermo et al. 2005)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

4-5

Photo 1.

Hydraulic Dredging

Photo 2.

Mechanical Dredging

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Examples of Hydraulic and Mechanical Dredging

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

FIGURE

4-6

	Remedial Technology / Process Option	Effectiveness	Implementability	Cost	Summary
4.2.1	No Action	–	+	L	R[1]
4.2.2	Institutional Controls				
	Deed Restriction	-	+	L	R[2]
	No-Anchoring Restriction	-	+	L	R[2]
	Fish Consumption Advisory	-	+	L	R[2]
4.2.3	Monitored Natural Recovery (MNR)	-	+	L	NR
4.2.4	Thin Cover				
	Broadcast from Land	O	+	L	R[3]
	Aerial Deposition	O	+	M	NR
	Hydraulic or Pneumatic Placement	O	+	L	R[3]
4.2.5	Sediment Cap				
	Engineered Cap	+	O	M	R
	Armored Cap	+	O	M	R
	Reactive Cap	+	O	H	NR
4.2.6	Sediment Removal and Disposal/Treatment				
	Mechanical Excavator	+	+	H	R
	Hydraulic Dredge	+	+	H	R
	Mechanical Dredge	+	+	H	R

Notes:
+ = generally able to meet the evaluation criteria
– = generally unable to meet the evaluation criteria
O = ability to meet the evaluation criteria may be dependent on site-specific factors to be evaluated during the detailed development of alternatives
L = low; M = medium; H = high
R = technology/process option retained for further evaluation
R[1] = No action as a technology is retained per the NCP to serve as a baseline for comparison with other effective and implementable technologies.
R[2] = technology would not be effective on its own; must be combined with other technologies to be effective
R[3] = technology would be effective on its own in some areas; in other areas it must be combined with other technologies to be effective
NR = technology does not meet the evaluation criteria and is not retained for further consideration

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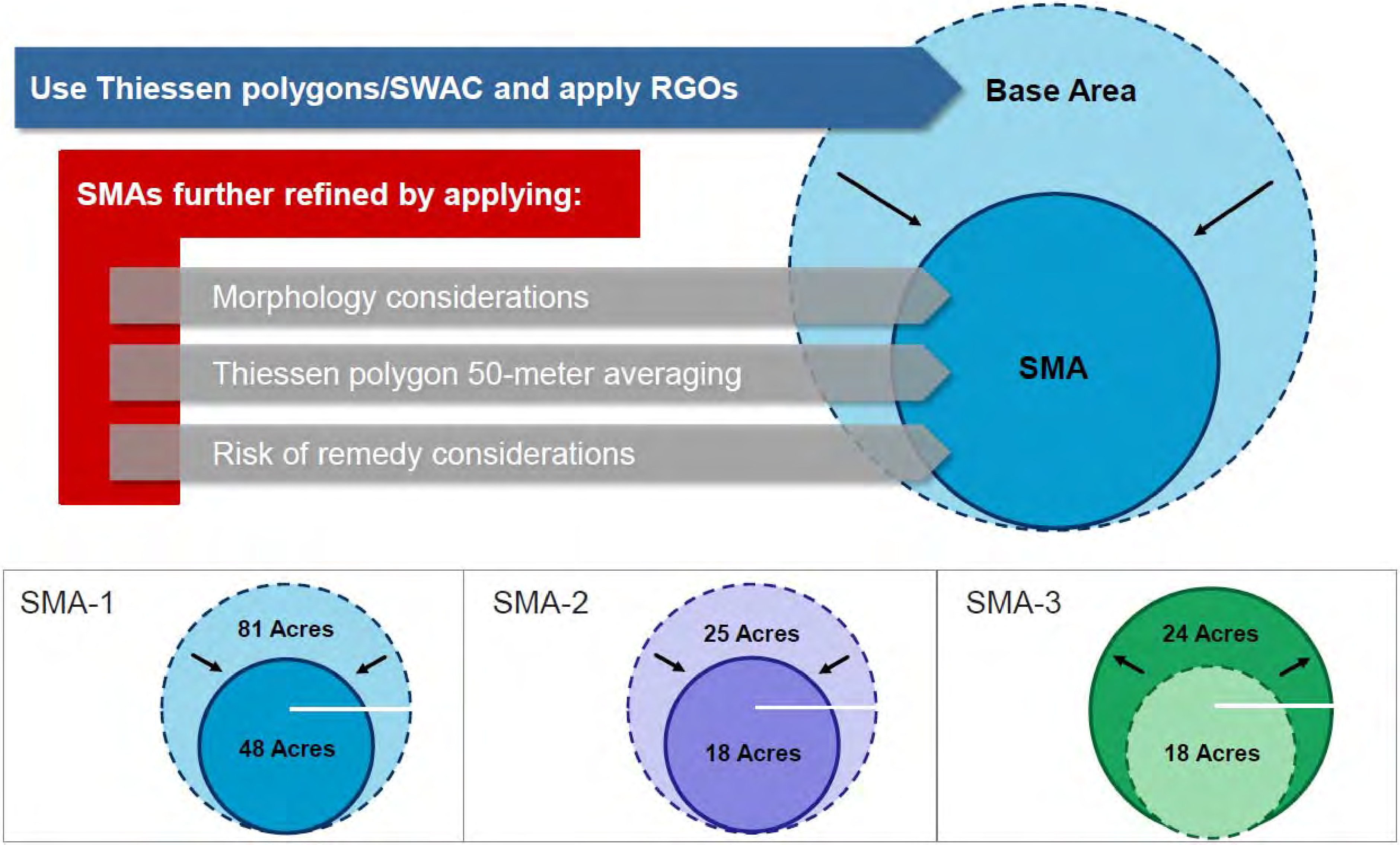
Summary of Feasibility Study Technology Screening Results

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

4-7



Use Thiessen polygons/SWAC and apply RGOs

Base Area

SMAs further refined by applying:

- Morphology considerations
- Thiessen polygon 50-meter averaging
- Risk of remedy considerations

SMA

SMA-1

81 Acres

48 Acres

SMA-2

25 Acres

18 Acres

SMA-3

24 Acres

18 Acres

More detailed information about SMA delineation is provided in Appendix K

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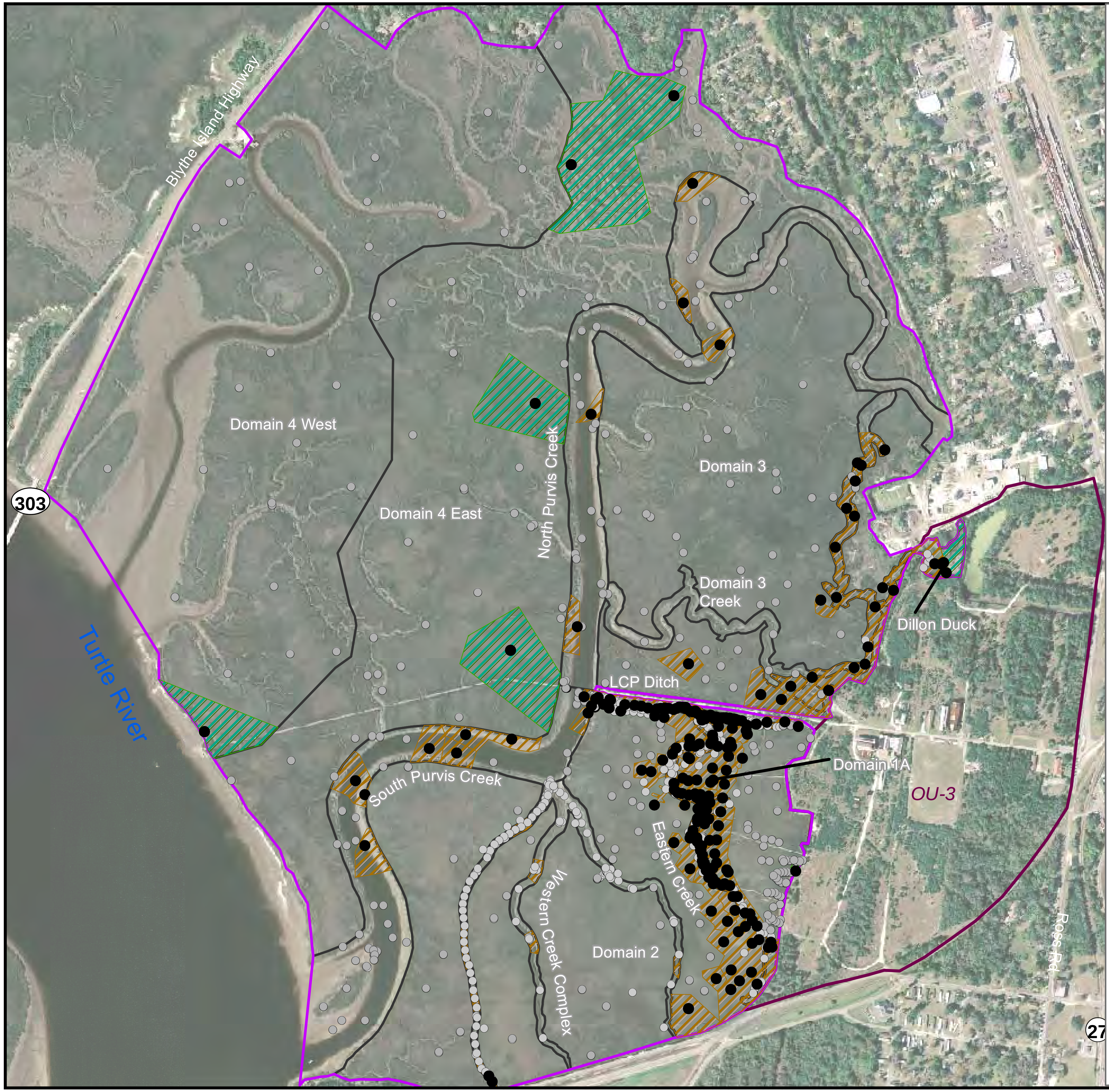
SMA Delineation Overview

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure
5-1



Legend

● Exceeds Benthic Community RGOs Shown Below

● No Exceedance of Benthic Community RGOs Shown Below

▨ Remediation Area (48 acres)

▨ Excluded Area (33 acres)

☐ OU1 Boundary

☐ Creek/Domain Boundary

☐ OU3 Boundary

Constituent	SWAC RGOs	Benthic Community RGOs
Hg	1	4
Ar1268	2	6
Pb	--	90
TPAHs	--	4

Notes:
- Units for all RGOs is mg/kg.

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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Sediment Management Area 1

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 5-2

Legend

● Exceeds Benthic Community RGOs Shown Below

○ No Exceedance of Benthic Community RGOs Shown Below

▨ Remediation Area (18 acres)

▨ Excluded Area (7 acres)

☐ OU1 Boundary

☐ Creek/Domain Boundary

☐ OU3 Boundary

Constituent	SWAC RGOs	Benthic Community RGOs
Hg	1-2	11
Ar1268	2-4	16
Pb	--	177
TPAHs	--	4

Notes:
- Units for all RGOs is mg/kg.

0 800 1,600
Feet

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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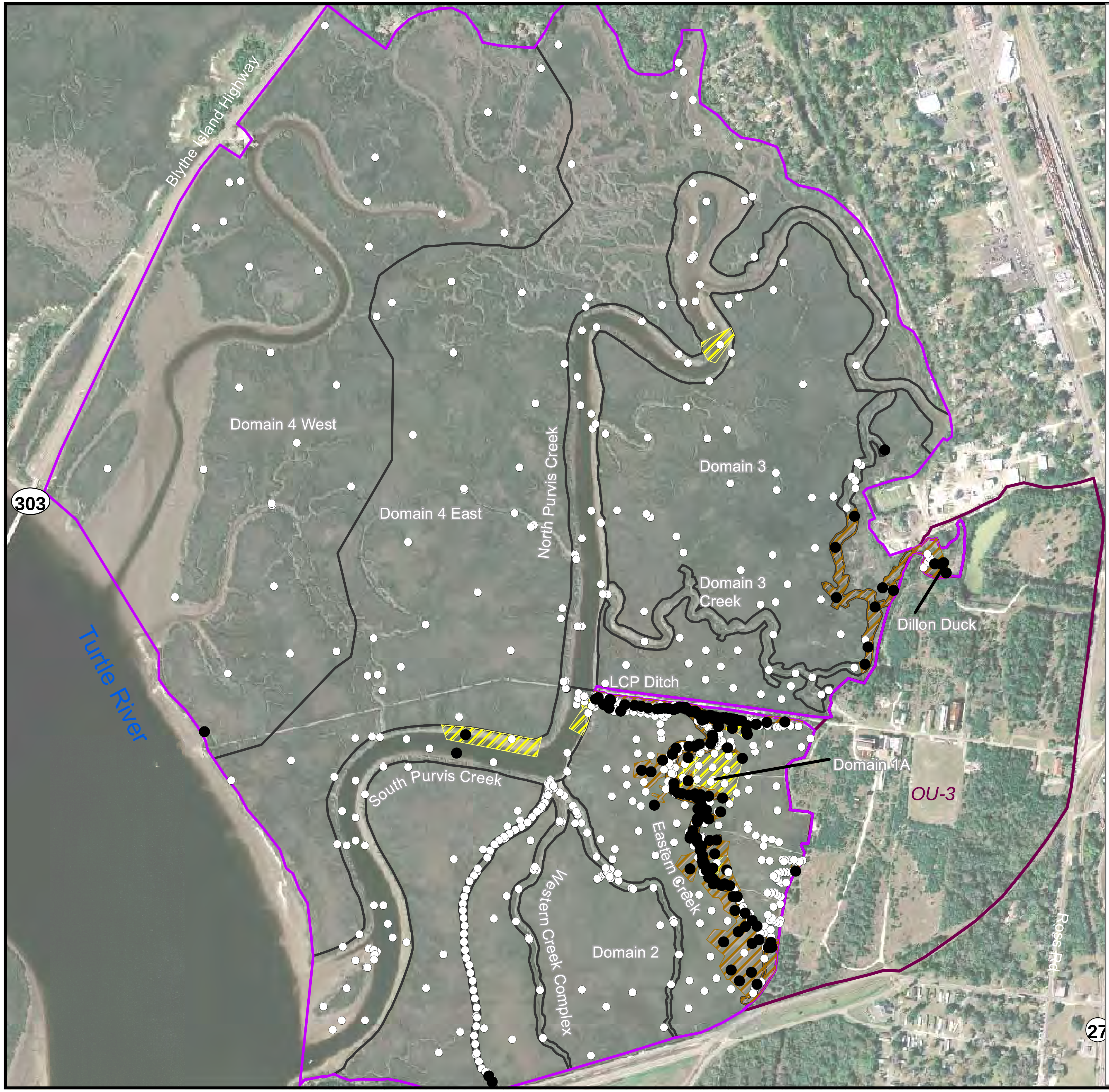
Sediment Management Area 2

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure
5-3

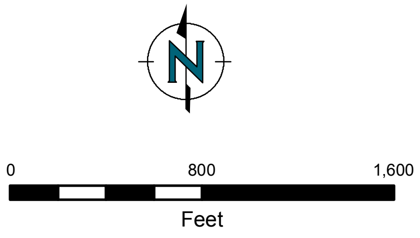


Legend

- ● Exceeds Benthic Community RGOs Shown Below
- ○ No Exceedance of Benthic Community RGOs Shown Below
- ▨ Remediation Area (18 acres)
- ▨ Domain 1A and Purvis Creek Addition (6 acres)
- ☐ OU1 Boundary
- ☐ Creek/Domain Boundary
- ☐ OU3 Boundary

Constituent	SWAC RGOs	Benthic Community RGOs
Hg	1-2	11
Ar1268	2-4	16
Pb	--	177
TPAHs	--	4

Notes:
- Units for all RGOs is mg/kg.



OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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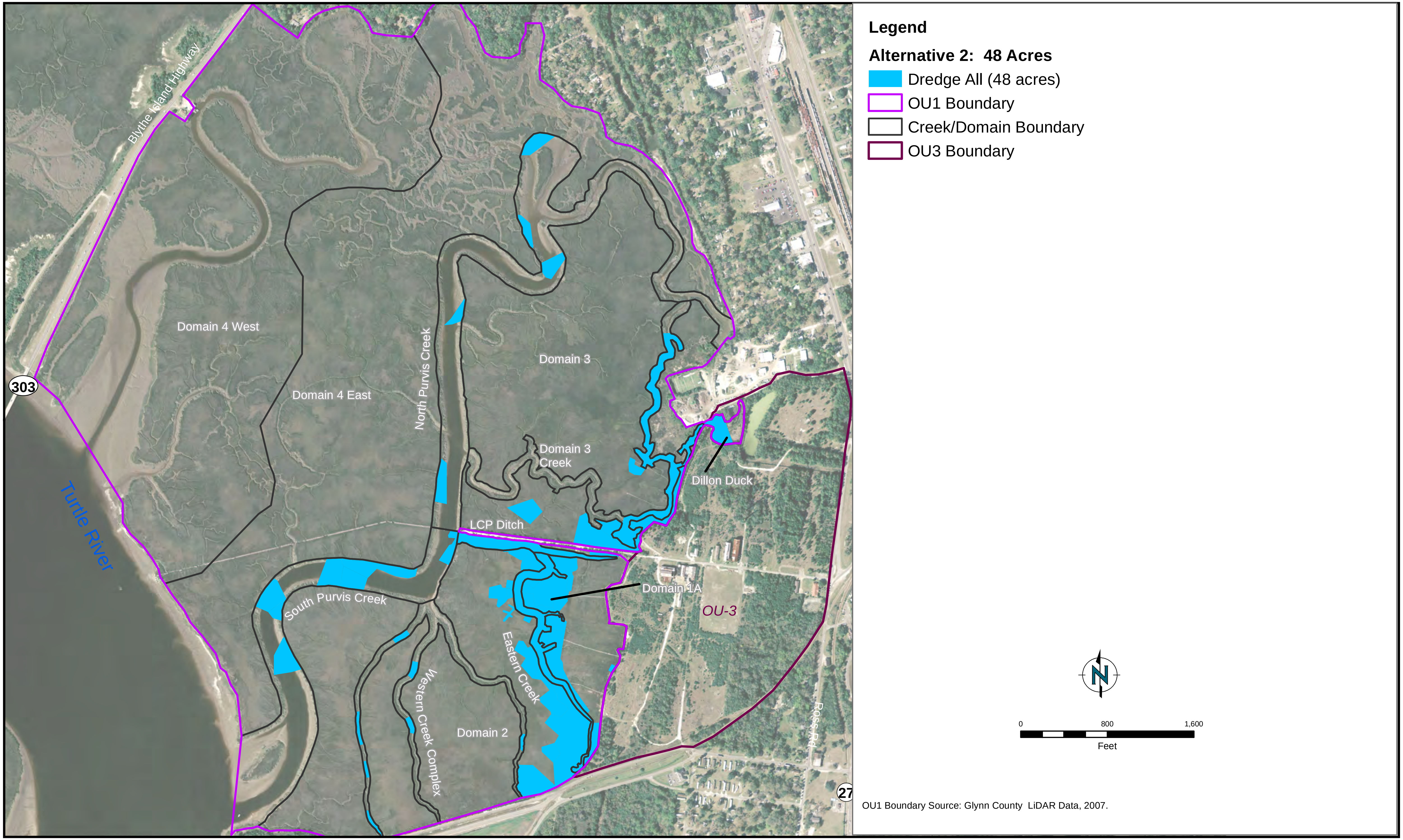
Sediment Management Area 3

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 5-4



OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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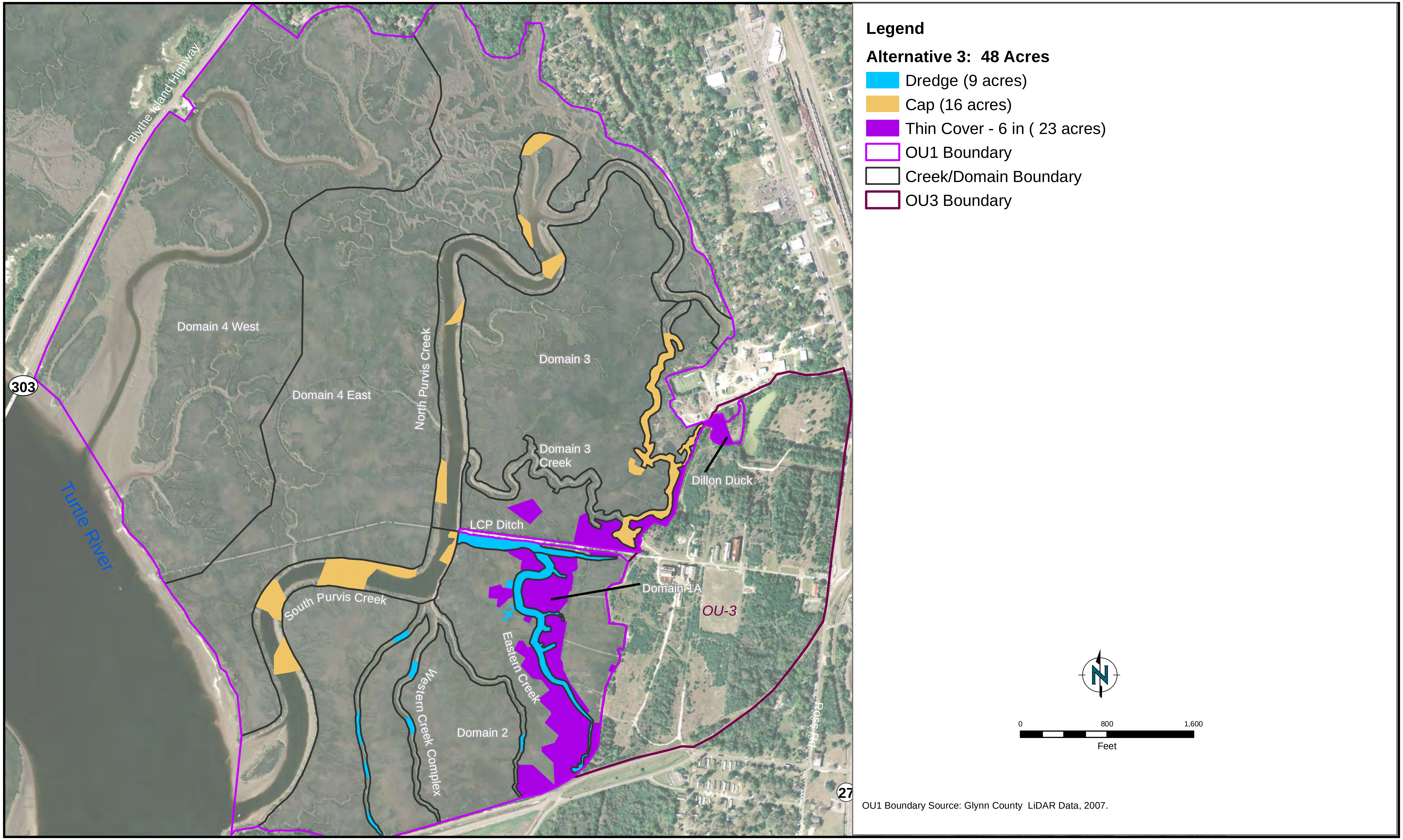
Sediment Remedy Alternative 2: Sediment Removal in SMA-1

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure
5-5



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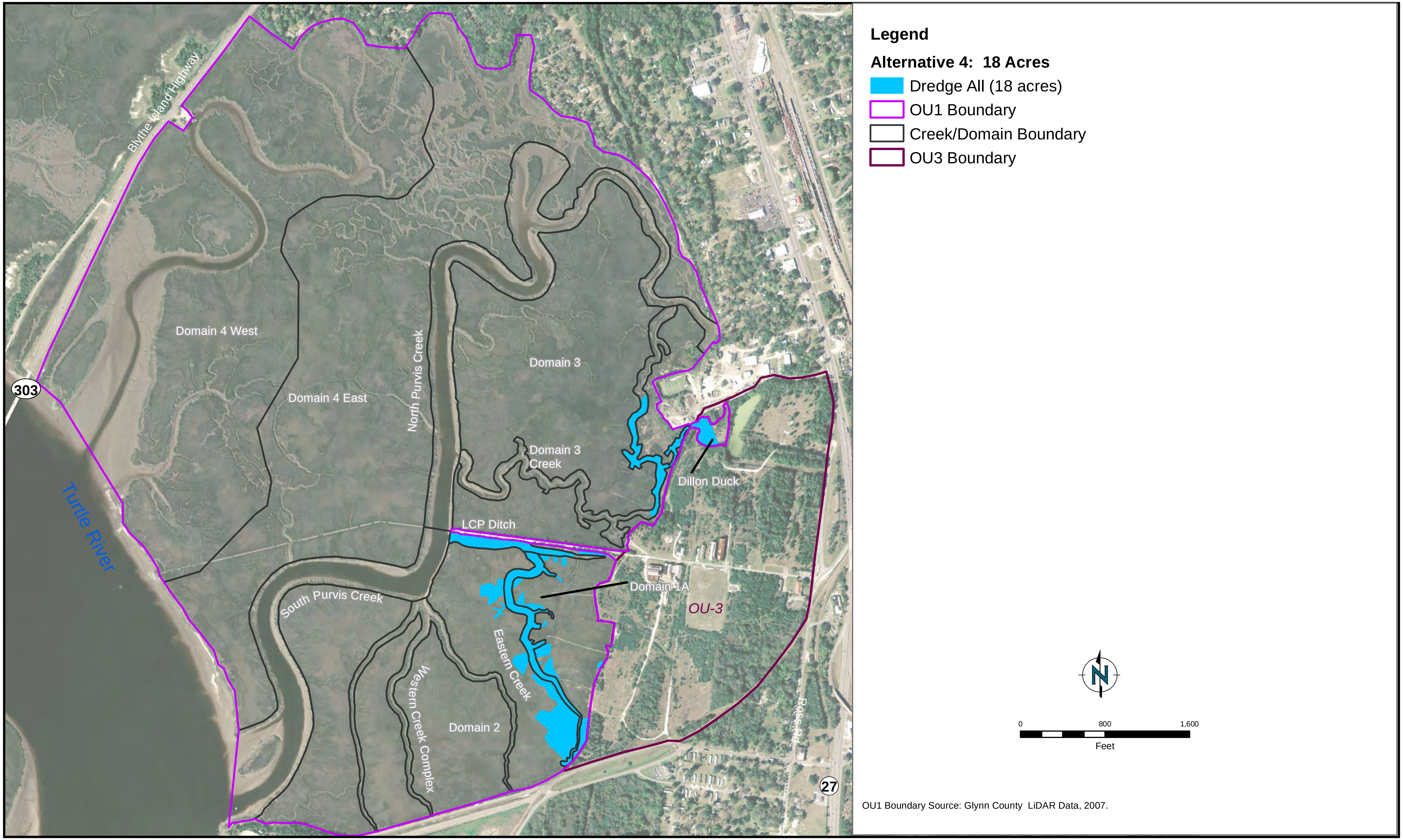
Sediment Remedy Alternative 3: Sediment Removal, Capping, and Thin Cover in SMA-1

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 5-6



Legend

Alternative 4: 18 Acres

- 🟦 Dredge All (18 acres)
- ☐ OU1 Boundary
- ☐ Creek/Domain Boundary
- ☐ OU3 Boundary

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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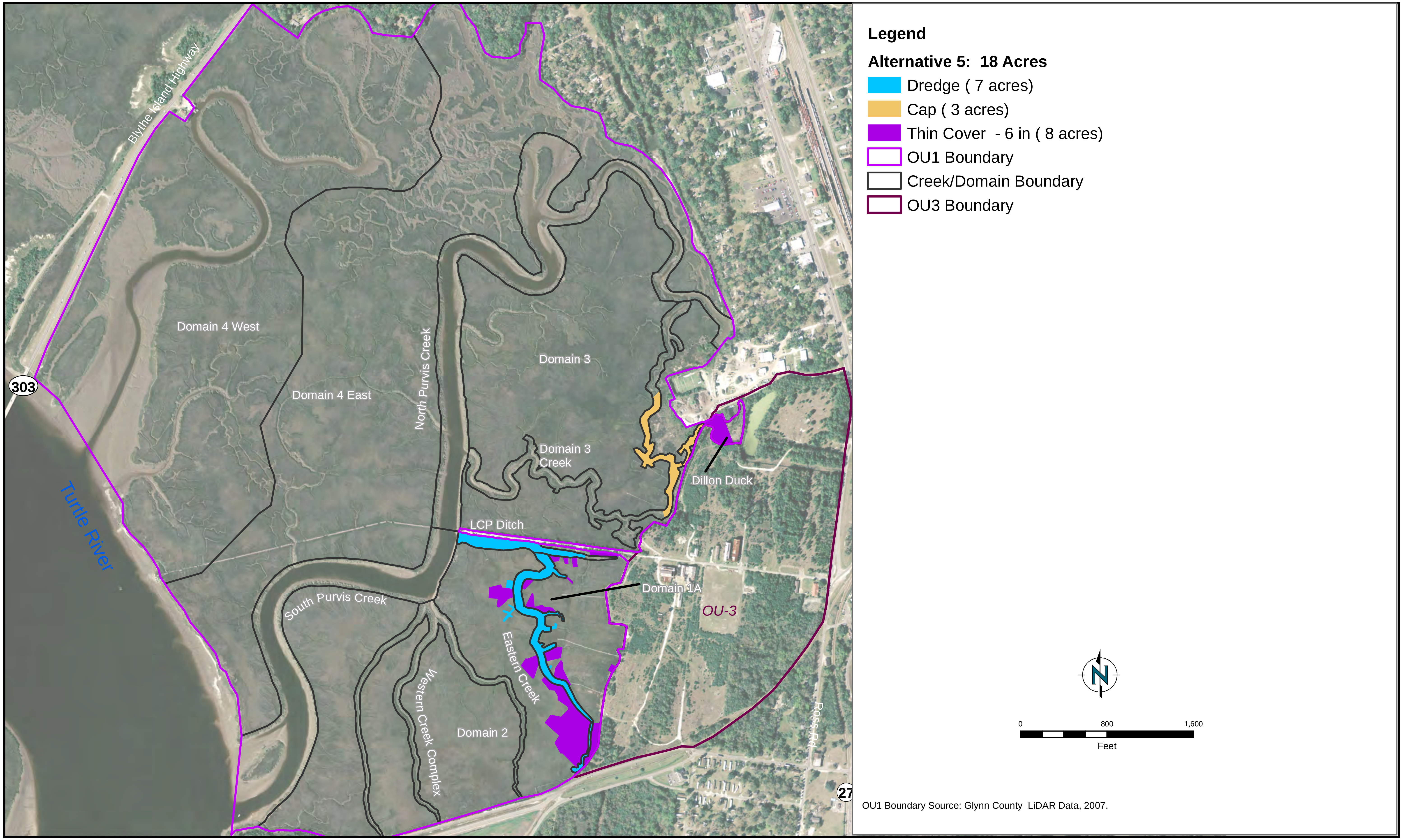
Sediment Remedy Alternative 4: Sediment Removal in SMA-2

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 5-7



OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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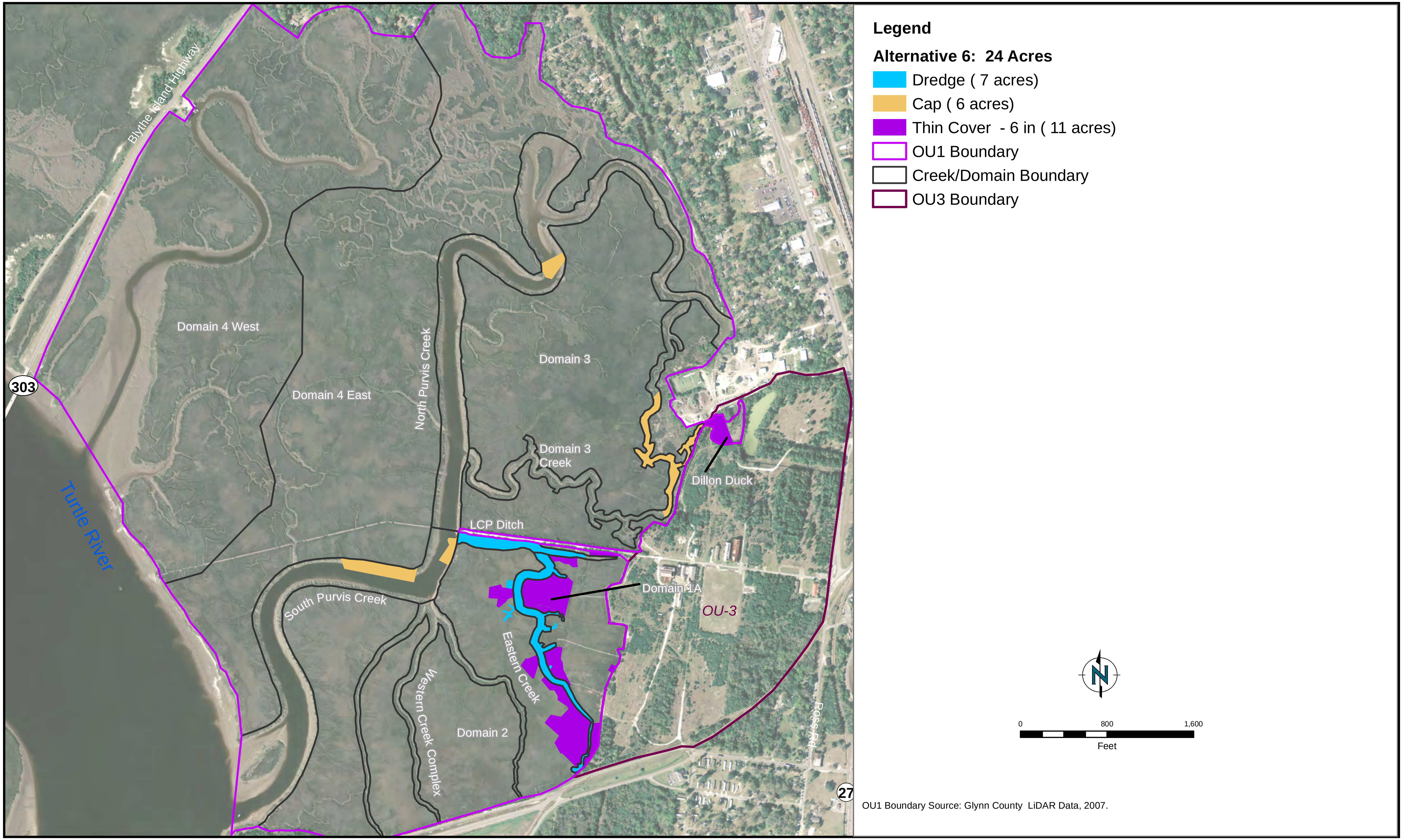
Sediment Remedy Alternative 5: Sediment Removal, Capping, and Thin Cover in SMA-2

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 5-8



OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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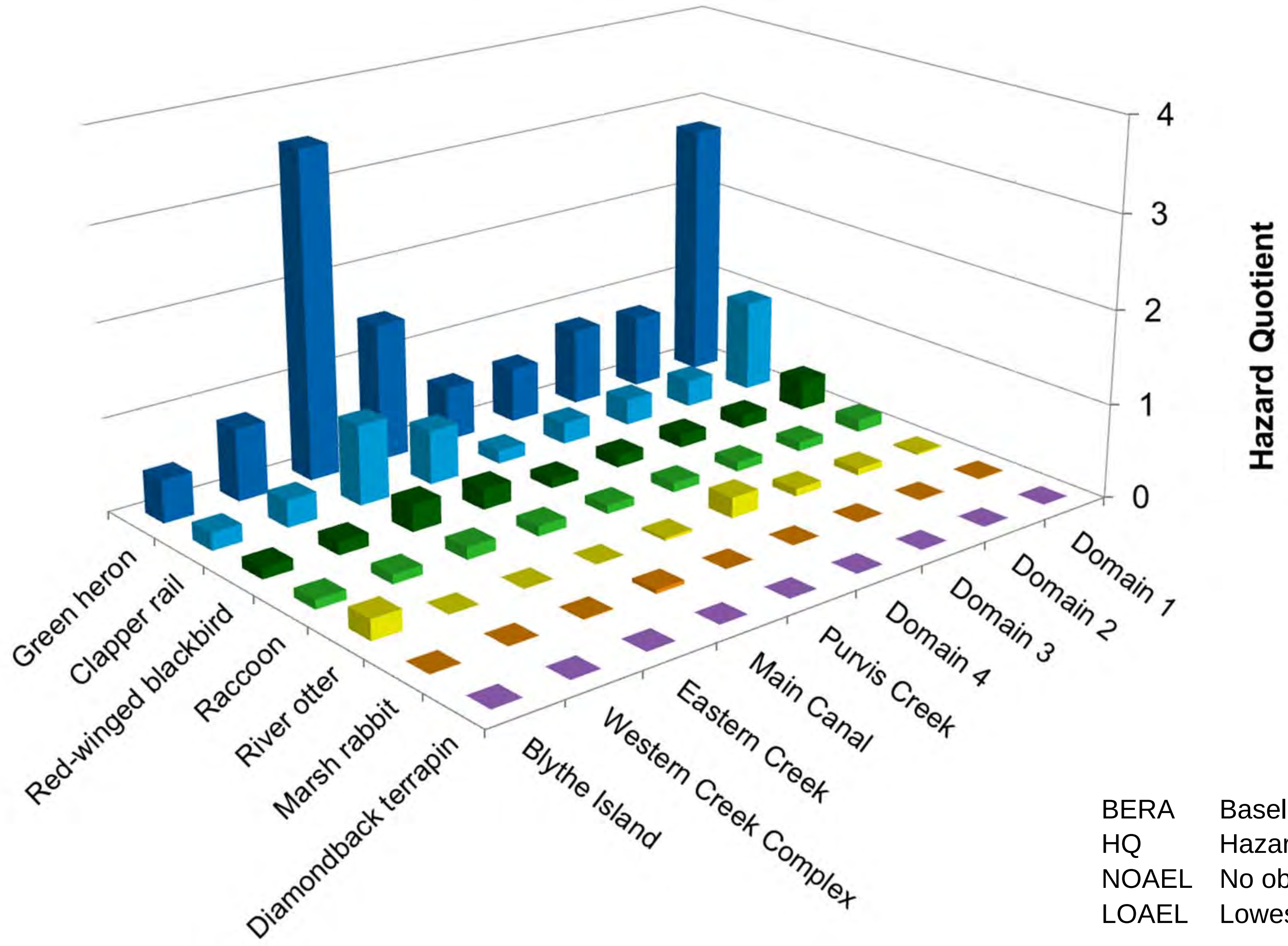
Sediment Remedy Alternative 6: Sediment Removal, Capping, and Thin Cover in SMA-3

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure
5-9



- HQs are based on the LOAEL from the BERA (Black and Veatch 2011).
- The results show that HQs are below the level of 1 for all receptors except the green heron, under current conditions.
- The green heron is considered the most sensitive species and is the focus of further discussion related to remedy effectiveness.

BERA	Baseline Ecological Risk Assessment
HQ	Hazard quotient
NOAEL	No observable adverse effects levels
LOAEL	Lowest observable adverse effects levels

Appendix L provides the technical supporting information for this figure and the NOAEL values.

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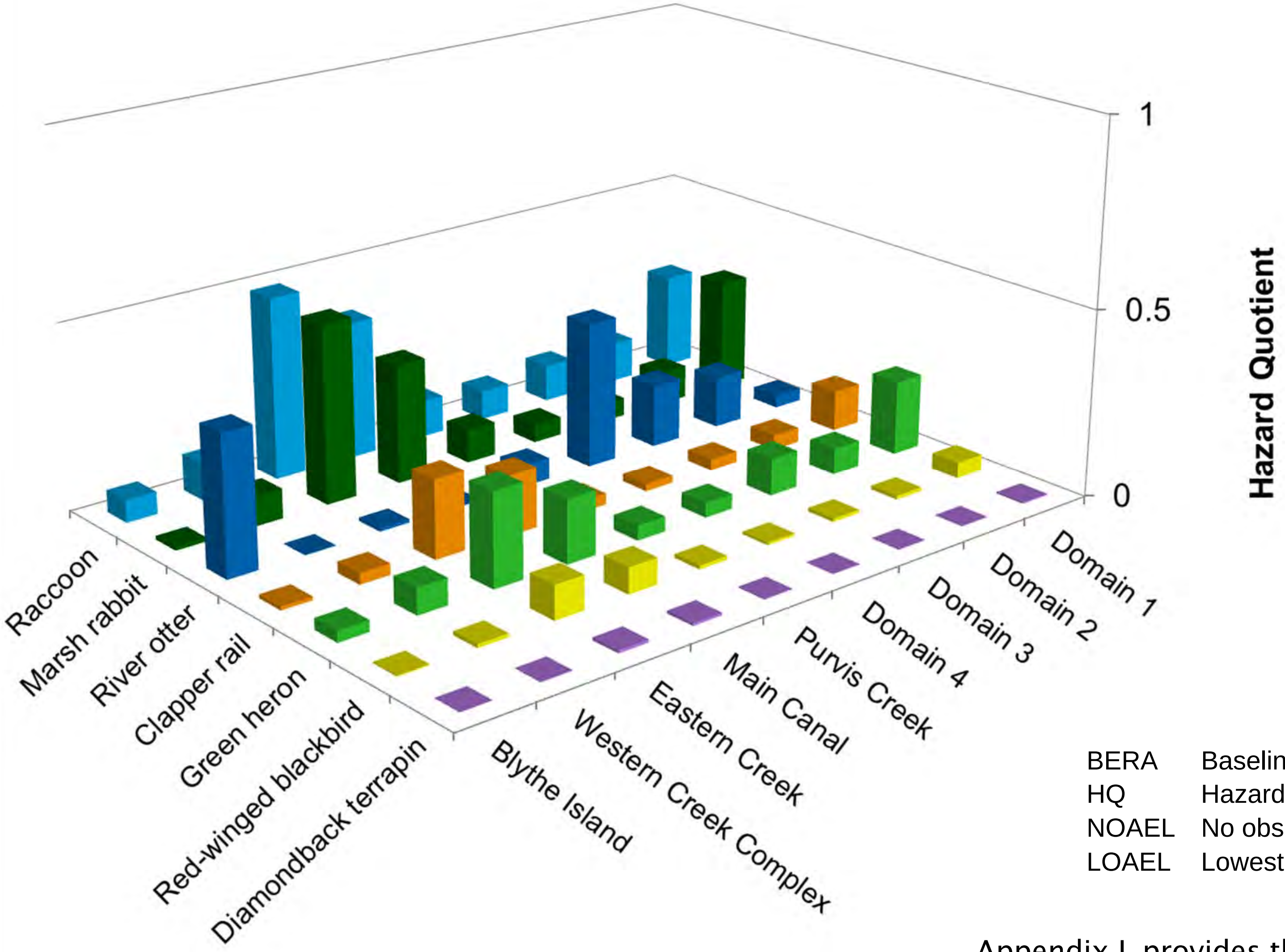
Current Conditions and Baseline Ecological Risk Assessment Findings for Mammals and Birds for Mercury

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

6-1A



- HQs are based on the LOAEL from the BERA (Black and Veatch 2011).
- The results show that HQs are below the level of 1 for all receptors, under current conditions.

BERA	Baseline Ecological Risk Assessment
HQ	Hazard quotient
NOAEL	No observable adverse effects levels
LOAEL	Lowest observable adverse effects levels

Appendix L provides the technical supporting information for this figure and the NOAEL values.

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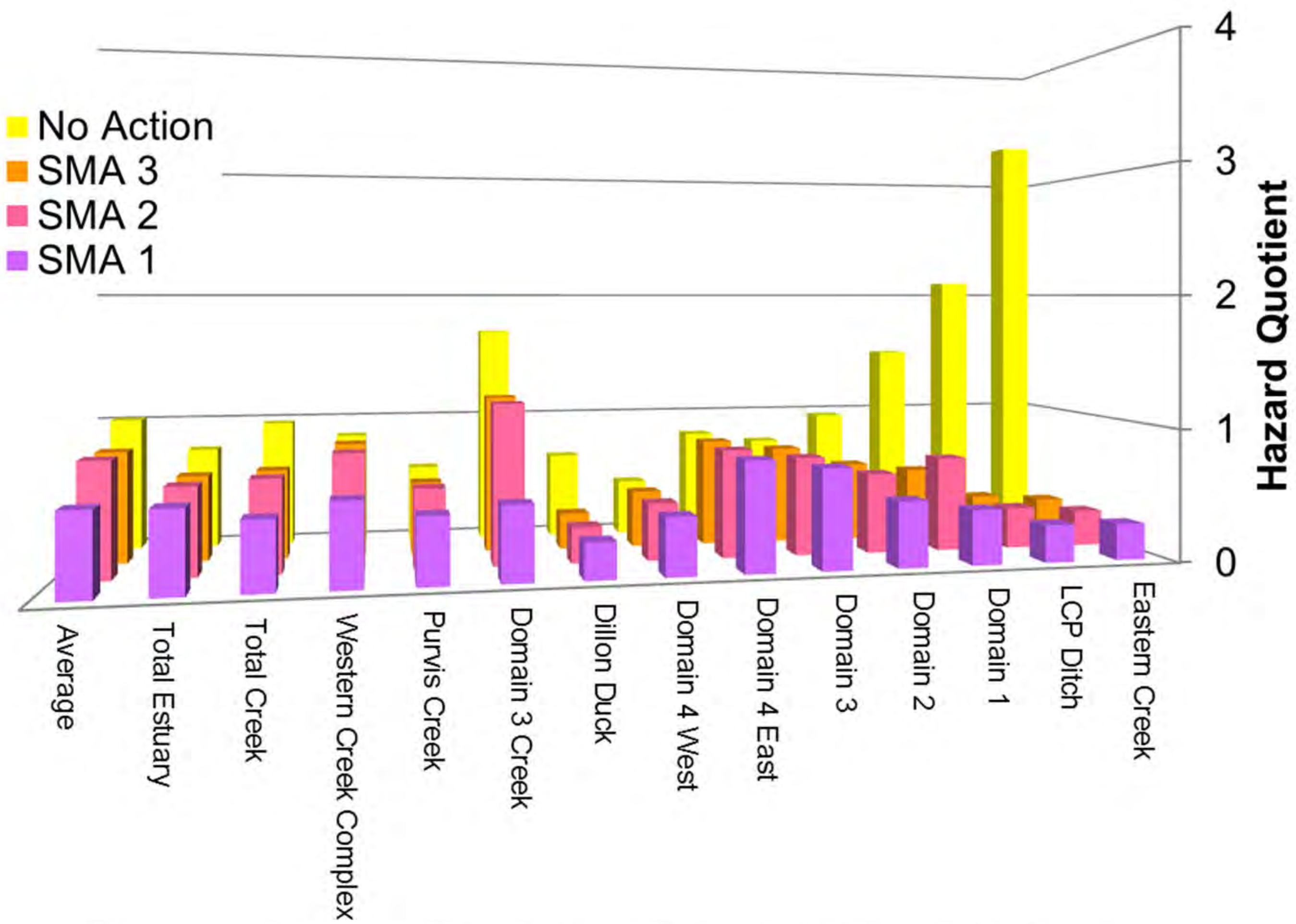
Current Conditions and Baseline Ecological Risk Assessment Findings for Mammals and Birds for Aroclor 1268

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

6-1B



Average = Average of Purvis Creek/ Domain 3/ Domain 3 Creek

Remedy Alternatives 2 through 6 each provide overall protection for green heron populations.

- The evaluation shows that for the majority of areas, the starting point for the green heron is below the threshold HQ value of 1.
- Each of the areas with a HQ exceeding the threshold value of 1 are evaluated further on Figure 6-2B.

HQ	Hazard quotient.
No Action	Remedy Alternative 1
SMA	Sediment Management Area
SMA 1	Remedy Alternatives 2 and 3
SMA 2	Remedy Alternatives 4 and 5
SMA 3	Remedy Alternative 6

Appendix L provides the technical supporting information for this figure.

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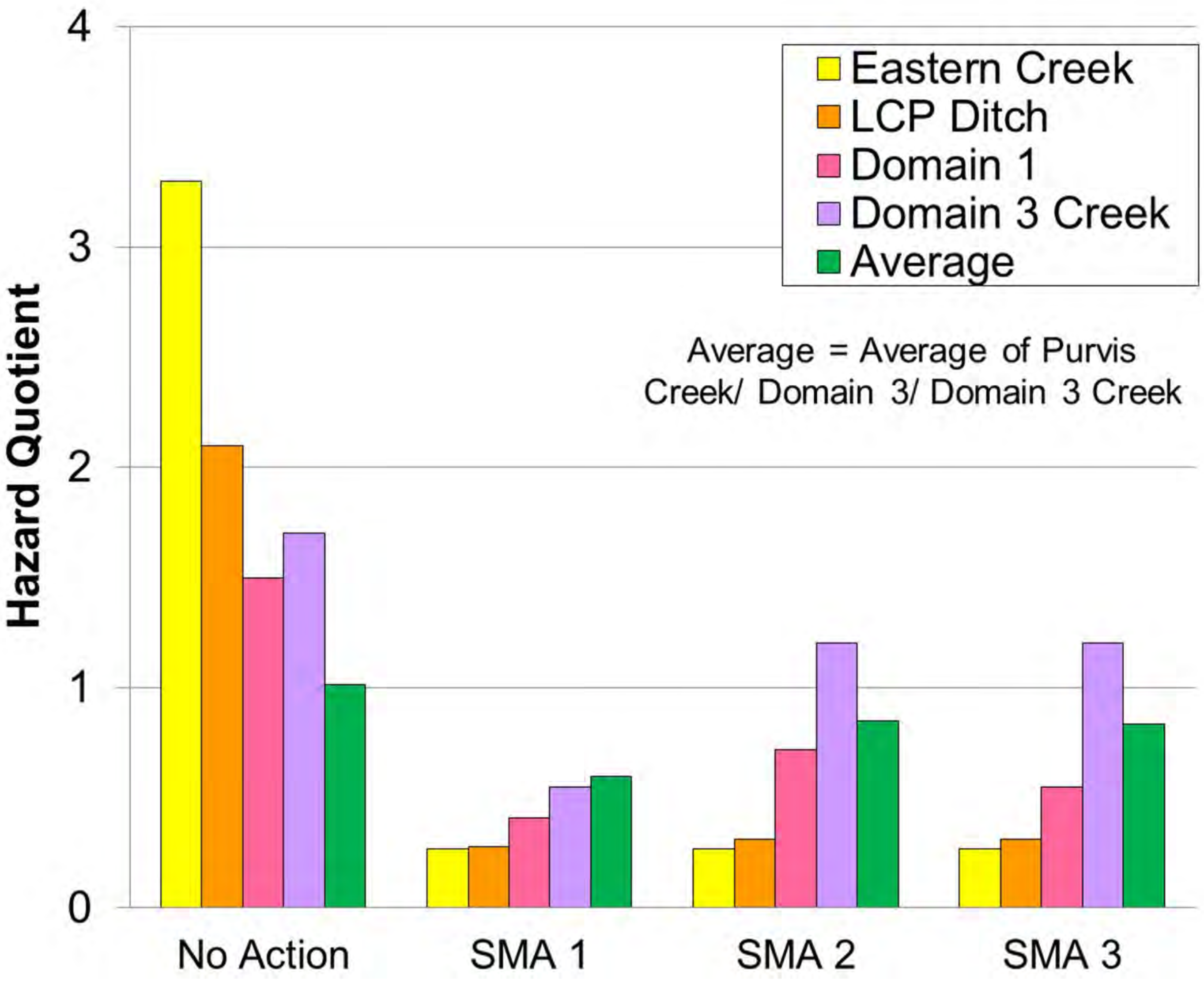
Remedy Effectiveness Evaluation for the Mercury Exposures and Green Heron Exposed to All Areas

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

6-2A



Average = Average of Purvis Creek/ Domain 3/ Domain 3 Creek

Remedy Alternatives 2 through 6 each provide overall protection for green heron populations.

Results for this sensitive species indicates Alternatives are protective for all mammal and bird populations.

Appendix L provides the technical supporting information for this figure.

No Action	Remedy Alternative 1
SMA	Sediment Management Area
SMA 1	Remedy Alternatives 2 and 3
SMA 2	Remedy Alternatives 4 and 5
SMA 3	Remedy Alternative 6

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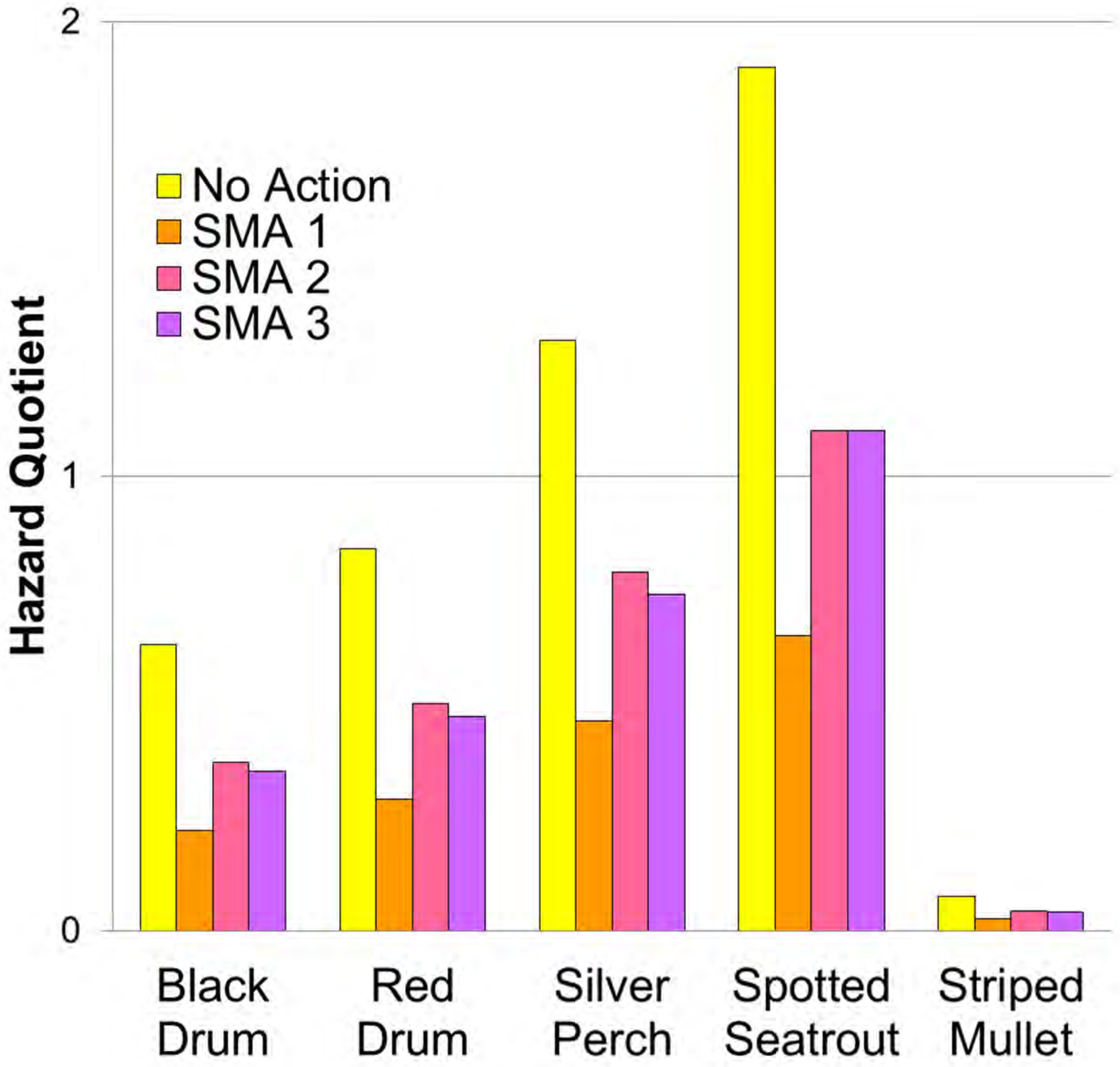
Remedy Effectiveness Evaluation for Mercury and Green Heron In Areas with HQs Exceeding a Threshold Value of 1

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

6-2B



Remedy Alternatives 2 through 6 each provide overall protection for Finfish populations.

HQ	Hazard quotient.
No Action	Remedy Alternative 1
SMA	Sediment Management Area
SMA 1	Remedy Alternatives 2 and 3
SMA 2	Remedy Alternatives 4 and 5
SMA 3	Remedy Alternative 6

Appendix L provides the technical supporting information for this figure.

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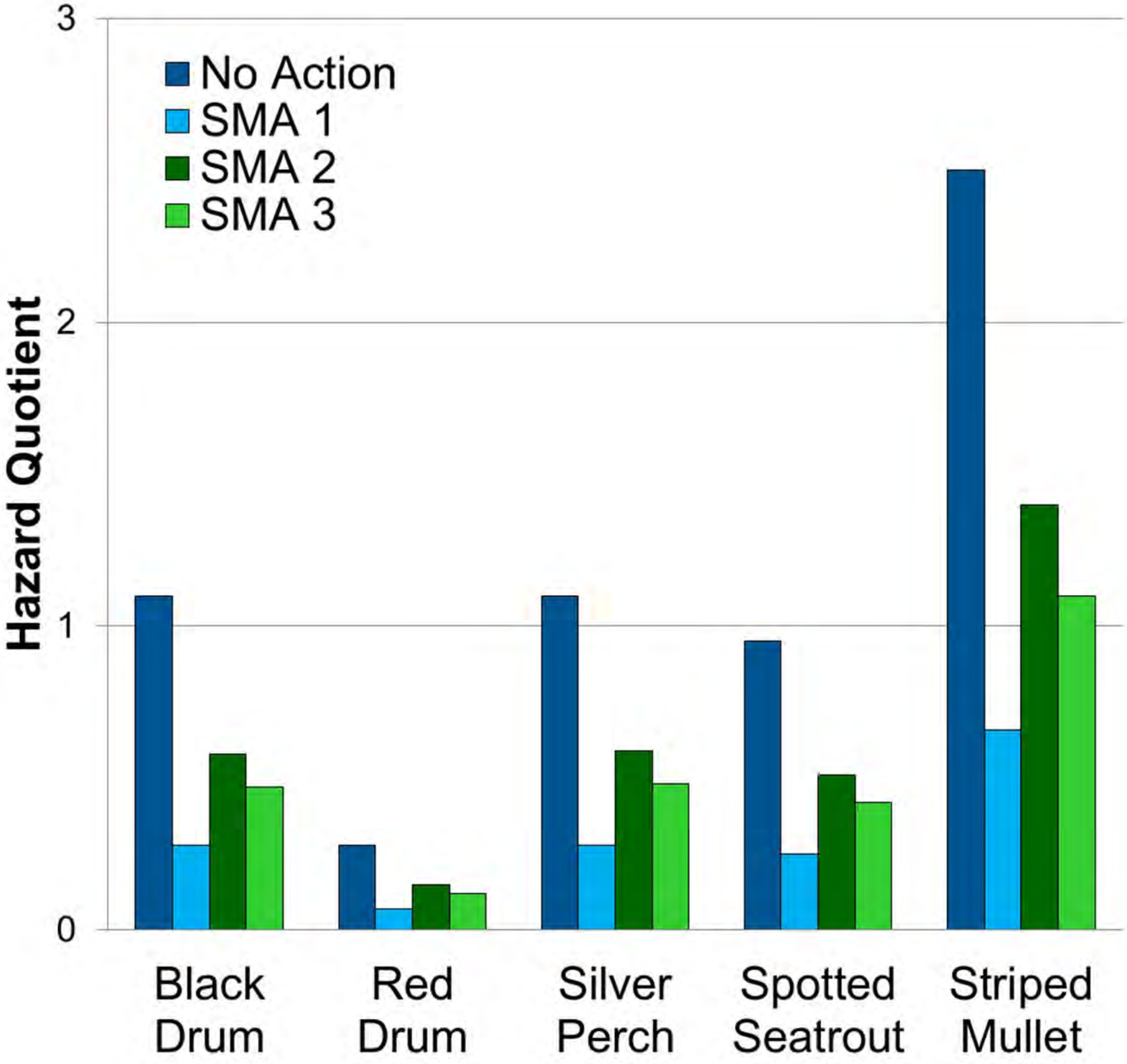
Remedy Effectiveness Evaluation for Mercury and Finfish

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

6-3



Remedy Alternatives 2 through 6 each provide overall protection for Finfish populations.

HQ	Hazard quotient.
No Action	Remedy Alternative 1
SMA	Sediment Management Area
SMA 1	Remedy Alternatives 2 and 3
SMA 2	Remedy Alternatives 4 and 5
SMA 3	Remedy Alternative 6

- Figure 6-4B shows that striped mullet concentrations from 2011 are even lower than those used in this evaluation, which relied on 2005-2007 data.

Appendix L provides the technical supporting information for this figure.

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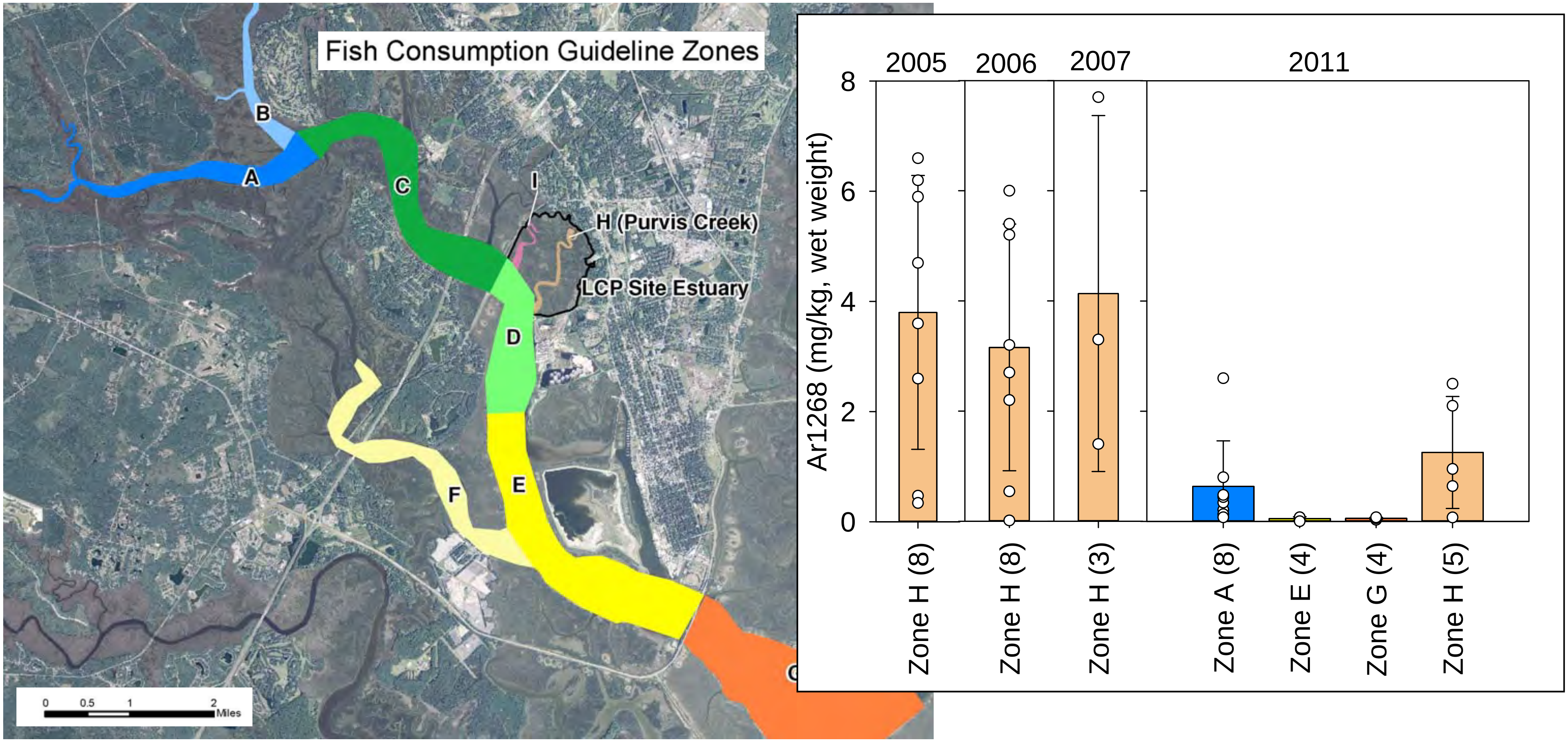
Remedy Effectiveness Evaluation for Aroclor 1268 and Finfish

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

6-4A



- Risk estimates were overestimated because pre-remedy conditions assumes 2005-2007 concentrations and did not include the 2011 fish tissue data set for mullet from Zone H (the LCP Site estuary)
- A full set of fish and crab tissue analytical results is provided graphically in Appendix F

	Bar	Mean concentration
	o	Individual sample point.
🟦	Zone A	Turtle River from Hwy 303 to Buffalo River
🟨	Zone E	Turtle River from Channel Marker 9 to Hwy 17
🟧	Zone G	Brunswick River
▨	Zone H	Purvis Creek

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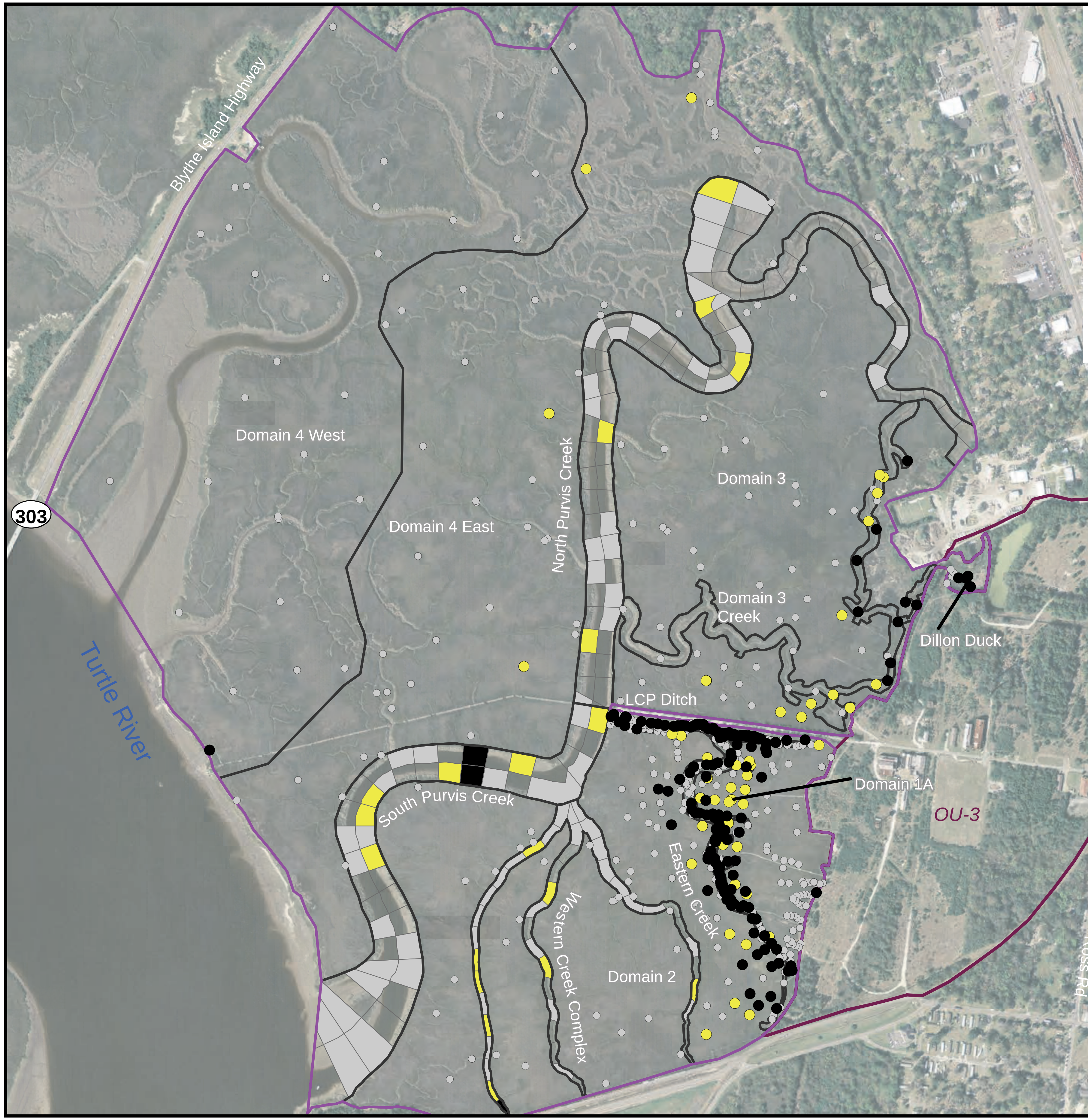
Striped Mullet Aroclor 1268 Fish Tissue Concentrations over Time

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

6-4B



Legend

- ● No Exceedance of Either Lower or Upper End Benthic RGOs
- ● Within the Range of Benthic Community RGOs
- ● Exceeds Range of Benthic Community RGOs
- ☐ No Sample Location in 50-Meter Averaging Polygon
- ▨ Does not Exceed the Range of the Benthic Community RGOs Shown Below
- ▨ Within the Range of the Benthic Community RGOs Shown Below
- ■ Exceeds the Range of the Benthic Community RGOs Shown Below
- ☐ OU1 Boundary
- ☐ Creek/Domain Boundary
- ☐ OU3 Boundary

Constituent	SWAC RGOs	Benthic Community RGOs
Hg	1-2	4-11
Ar1268	2-4	6-16
Pb	--	90-177
TPAHs	--	4

Notes:
-Colored boxes in Purvis Creek and Western Creek Complex reflect locations where averaging along approximately 50-meter polygons was conducted when more than one sample was collected within the approximate 50-meter interval.
-Units for all RGOs is mg/kg.

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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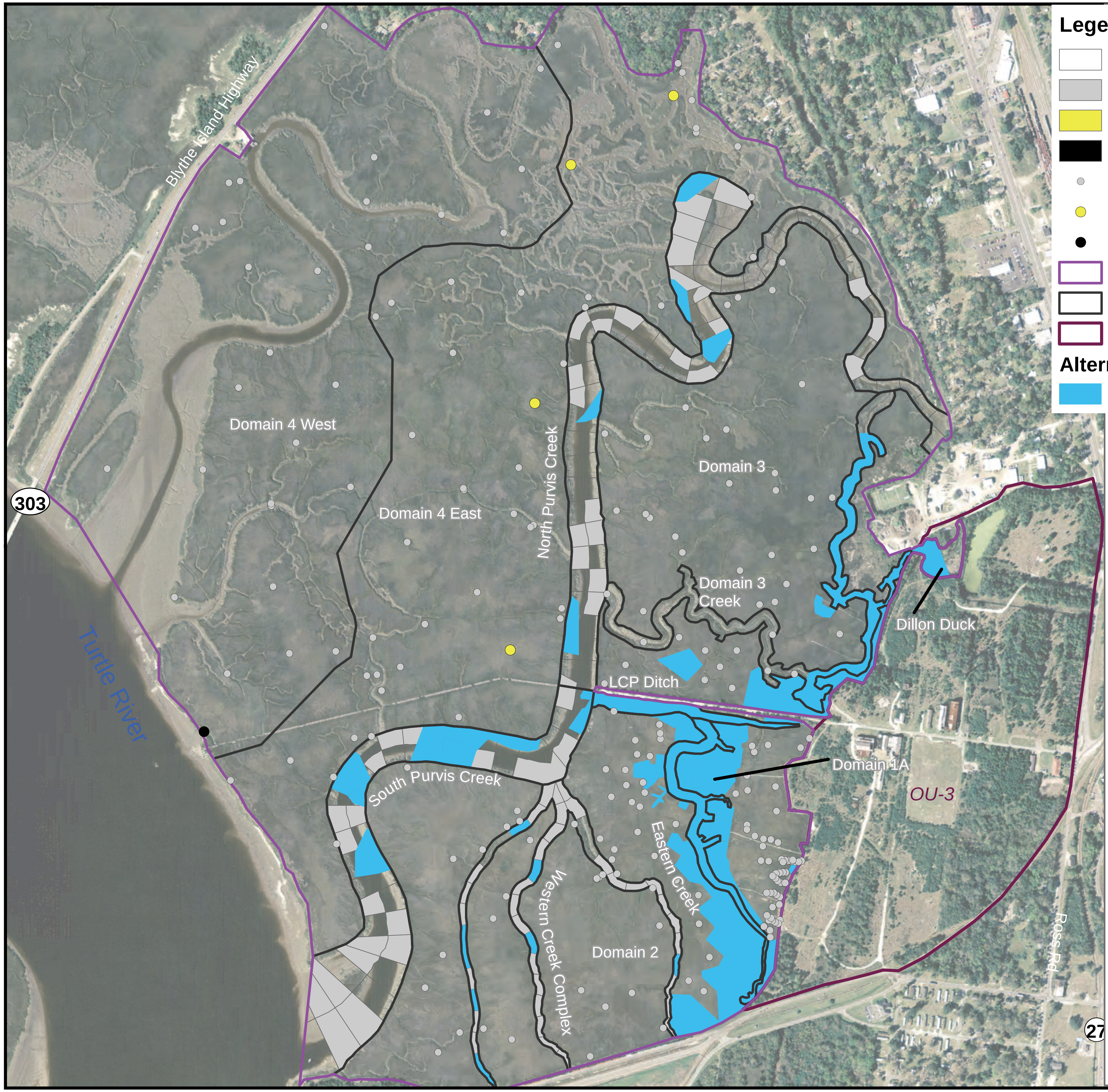
Remedy Effectiveness Consideration for Alternative 1

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 6-5



Legend

☐ No Sample Location in 50-Meter Averaging Polygon
▒ Does not Exceed the Range of the Benthic Community RGOs Shown Below
🟨 Within the Range of the Benthic Community RGOs Shown Below
⬛ Exceeds the Range of the Benthic Community RGOs Shown Below
○ No Exceedance of Either Lower or Upper End Benthic RGOs
🟡 Within the Range of Benthic Community RGOs
● Exceeds Range of Benthic Community RGOs
☐ OU1 Boundary
☐ Creek/Domain Boundary
☐ OU3 Boundary

Alternative 2: 48 Acres

🟦 Dredge All (48 acres)

Constituent	SWAC RGOs	Benthic Community RGOs
Hg	1-2	4-11
Ar1268	2-4	6-16
Pb	--	90-177
TPAHs	--	4

Notes:
-Colored boxes in Purvis Creek and Western Creek Complex reflect locations where averaging along approximately 50-meter polygons was conducted when more than one sample was collected within the approximate 50-meter interval.
-Units for all RGOs is mg/kg.

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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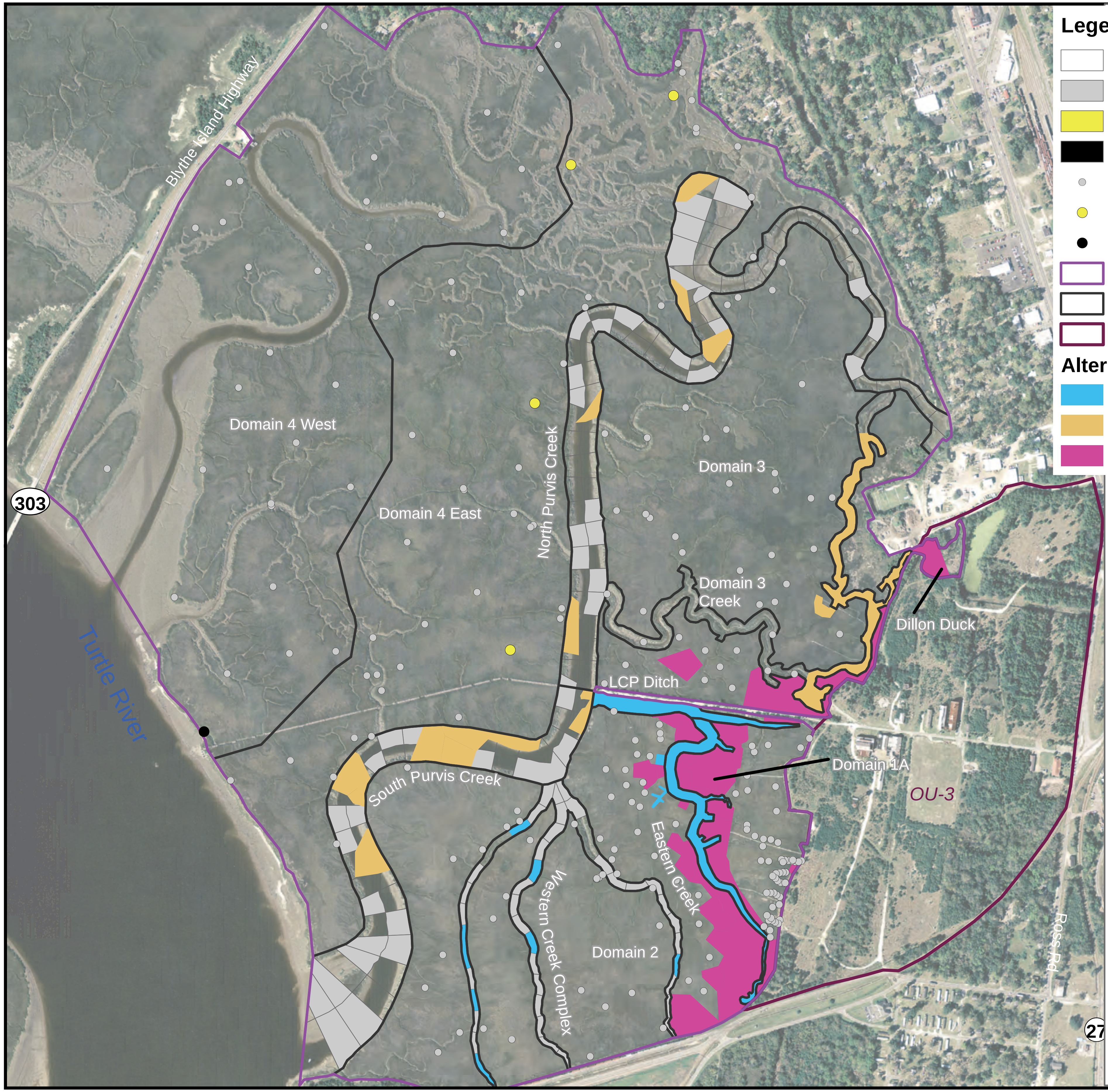
Remedy Effectiveness Consideration for Alternative 2 (SMA-1)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 6-6A



Legend

- ⬜ No Sample Location in 50-Meter Averaging Polygon
- ▨ Does not Exceed the Range of the Benthic Community RGOs Shown Below
- 🟨 Within the Range of the Benthic Community RGOs Shown Below
- ⬛ Exceeds the Range of the Benthic Community RGOs Shown Below
- ● No Exceedance of Either Lower or Upper End Benthic RGOs
- ● Within the Range of Benthic Community RGOs
- ● Exceeds Range of Benthic Community RGOs
- ☐ OU1 Boundary
- ☐ Creek/Domain Boundary
- ☐ OU3 Boundary

Alternative 3: 48 Acres

- 🟦 Dredge (9 acres)
- 🟧 Cap (16 acres)
- 🟪 Thin Cover - 6 in (23 acres)

Constituent	SWAC RGOs	Benthic Community RGOs
Hg	1-2	4-11
Ar1268	2-4	6-16
Pb	--	90-177
TPAHs	--	4

Notes:
-Colored boxes in Purvis Creek and Western Creek Complex reflect locations where averaging along approximately 50-meter polygons was conducted when more than one sample was collected within the approximate 50-meter interval.
-Units for all RGOs is mg/kg.

0 800 1,600
Feet

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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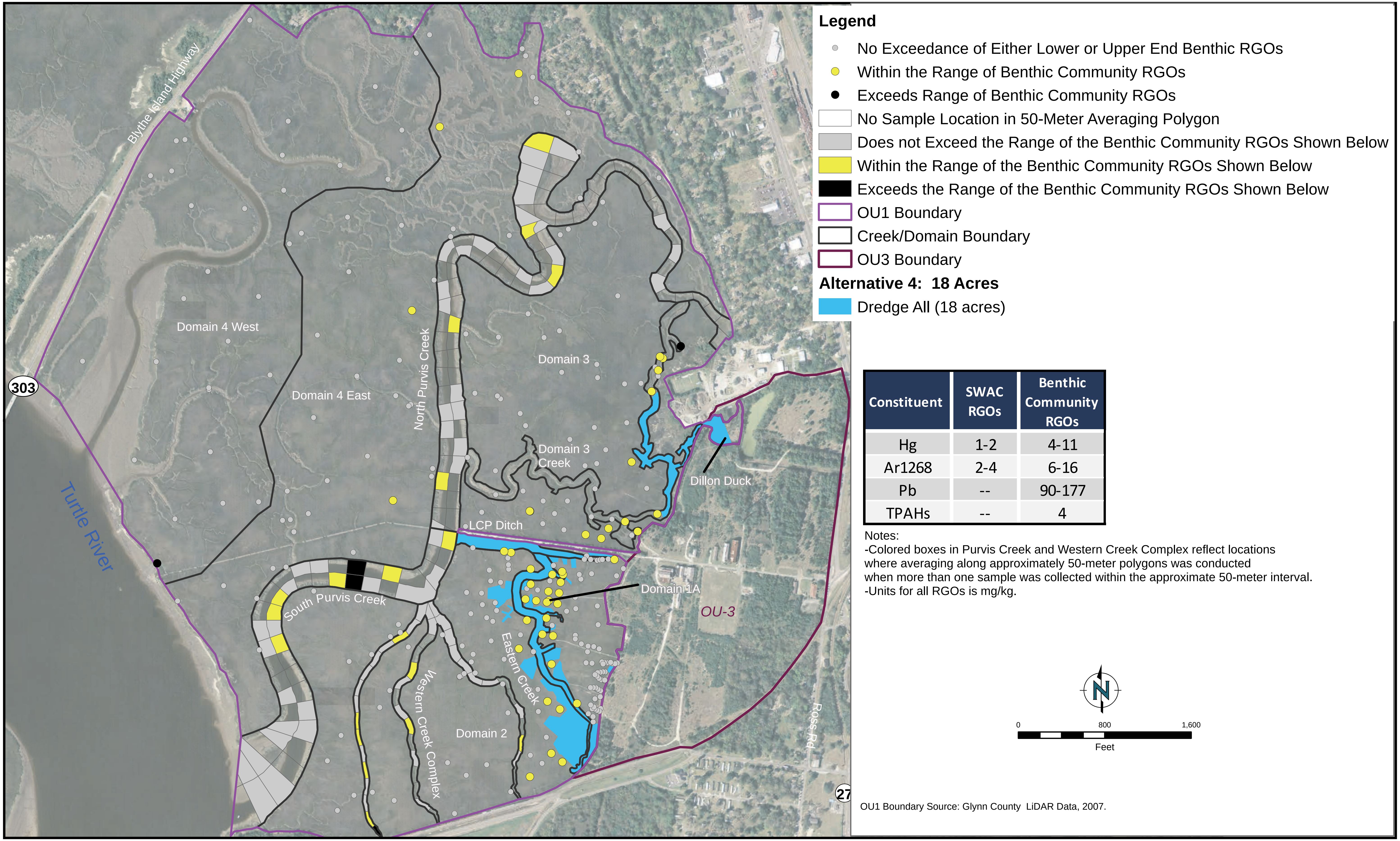
Remedy Effectiveness Consideration for Alternative 3 (SMA-1)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 6-6B



Legend

- ● No Exceedance of Either Lower or Upper End Benthic RGOs
- ● Within the Range of Benthic Community RGOs
- ● Exceeds Range of Benthic Community RGOs
- ☐ No Sample Location in 50-Meter Averaging Polygon
- ▨ Does not Exceed the Range of the Benthic Community RGOs Shown Below
- ▨ Within the Range of the Benthic Community RGOs Shown Below
- ■ Exceeds the Range of the Benthic Community RGOs Shown Below
- ☐ OU1 Boundary
- ☐ Creek/Domain Boundary
- ☐ OU3 Boundary

Alternative 4: 18 Acres

- ■ Dredge All (18 acres)

Constituent	SWAC RGOs	Benthic Community RGOs
Hg	1-2	4-11
Ar1268	2-4	6-16
Pb	--	90-177
TPAHs	--	4

Notes:
-Colored boxes in Purvis Creek and Western Creek Complex reflect locations where averaging along approximately 50-meter polygons was conducted when more than one sample was collected within the approximate 50-meter interval.
-Units for all RGOs is mg/kg.

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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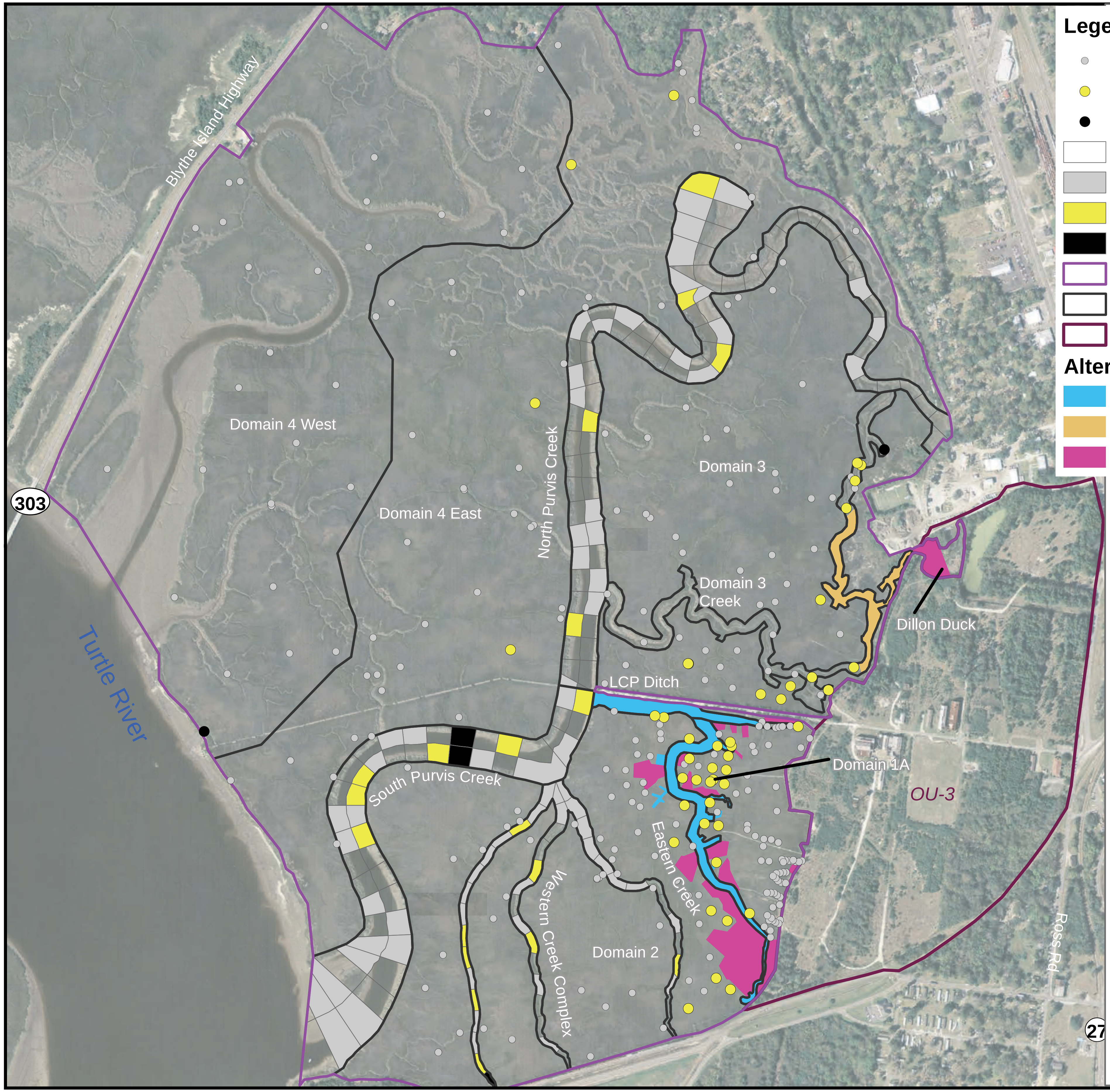
Remedy Effectiveness Consideration for Alternative 4 (SMA-2)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 6-7A



Legend

- ● No Exceedance of Either Lower or Upper End Benthic RGOs
- ● Within the Range of Benthic Community RGOs
- ● Exceeds Range of Benthic Community RGOs
- ☐ No Sample Location in 50-Meter Averaging Polygon
- ▨ Does not Exceed the Range of the Benthic Community RGOs Shown Below
- 🟨 Within the Range of the Benthic Community RGOs Shown Below
- ⬛ Exceeds the Range of the Benthic Community RGOs Shown Below
- ☐ OU1 Boundary
- ☐ Creek/Domain Boundary
- ☐ OU3 Boundary

Alternative 5: 18 Acres

- 🟦 Dredge (7 acres)
- 🟧 Cap (3 acres)
- 🟪 Thin Cover - 6 in (8 acres)

Constituent	SWAC RGOs	Benthic Community RGOs
Hg	1-2	4-11
Ar1268	2-4	6-16
Pb	--	90-177
TPAHs	--	4

Notes:
-Colored boxes in Purvis Creek and Western Creek Complex reflect locations where averaging along approximately 50-meter polygons was conducted when more than one sample was collected within the approximate 50-meter interval.
-Units for all RGOs is mg/kg.

N

0 800 1,600
Feet

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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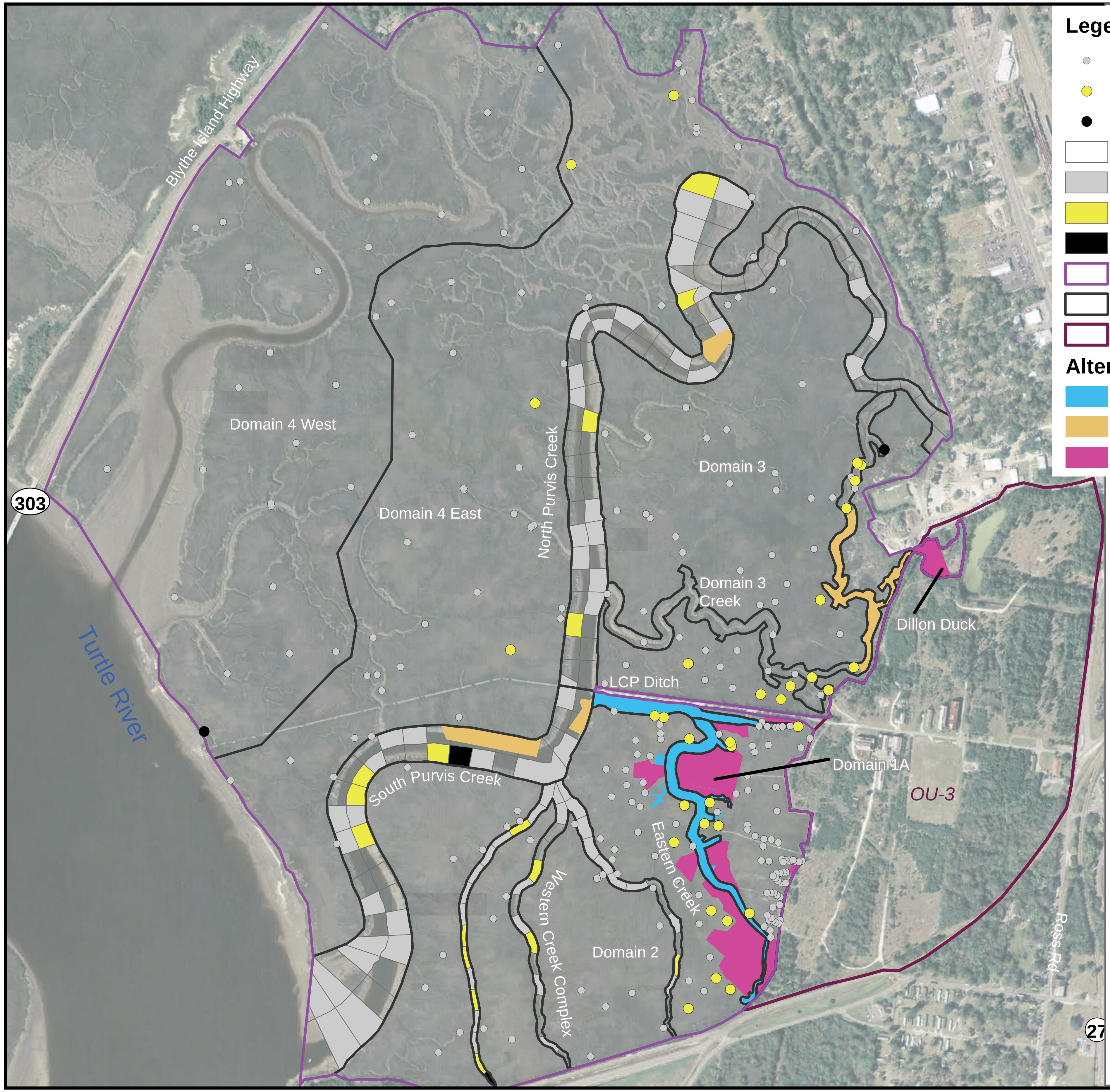
Remedy Effectiveness Consideration for Alternative 5 (SMA-2)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 6-7B



Legend

- ● No Exceedance of Either Lower or Upper End Benthic RGOs
- ● Within the Range of Benthic Community RGOs
- ● Exceeds Range of Benthic Community RGOs
- ☐ No Sample Location in 50-Meter Averaging Polygon
- ▨ Does not Exceed the Range of the Benthic Community RGOs Shown Below
- 🟨 Within the Range of the Benthic Community RGOs Shown Below
- ⬛ Exceeds the Range of the Benthic Community RGOs Shown Below
- ☐ OU1 Boundary
- ☐ Creek/Domain Boundary
- ☐ OU3 Boundary

Alternative 6: 24 Acres

- 🟦 Dredge (7 acres)
- 🟧 Cap (6 acres)
- 🟪 Thin Cover - 6 in (11 acres)

Constituent	SWAC RGOs	Benthic Community RGOs
Hg	1-2	4-11
Ar1268	2-4	6-16
Pb	--	90-177
TPAHs	--	4

Notes:
-Colored boxes in Purvis Creek and Western Creek Complex reflect locations where averaging along approximately 50-meter polygons was conducted when more than one sample was collected within the approximate 50-meter interval.
-Units for all RGOs is mg/kg.

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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Remedy Effectiveness Consideration for Alternative 6 (SMA-3)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure 6-8

A. Southeastern most portion of Eastern Creek

Low Tide

B. Southeastern most portion of Eastern Creek

High Tide

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Remedy Implementability Challenges

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

FIGURE

6-9

C. Domain 3 Marsh

Low Tide

D. Domain 3 Marsh

High Tide

E. Confluence of Eastern Creek and LCP ditch

High Tide

F. Confluence of Eastern Creek and LCP ditch

Low Tide

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Remedy Implementability Challenges

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

FIGURE
6-9

G. General Marsh at High Tide

High Tide

H. Purvis Creek at High Tide

High Tide

I. Domain 3 Creek

Narrow and shallow Creeks prevalent at LCP Chemical Site

J. Eastern Creek

Marsh sloughing

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Remedy Implementability Challenges

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

FIGURE **6-9**

K. Eastern Creek Near High Tide

Soft Sediments

L. Eastern Creek 4 hours after High Tide

Soft Sediments

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Remedy Implementability Challenges

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

FIGURE
6-9

M. Domain 3

Debris littering the area

N. Domain 3 Creek

Debris littering the area

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Remedy Implementability Challenges

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

FIGURE
6-9

O. LCP Ditch

Debris

P. LCP Ditch

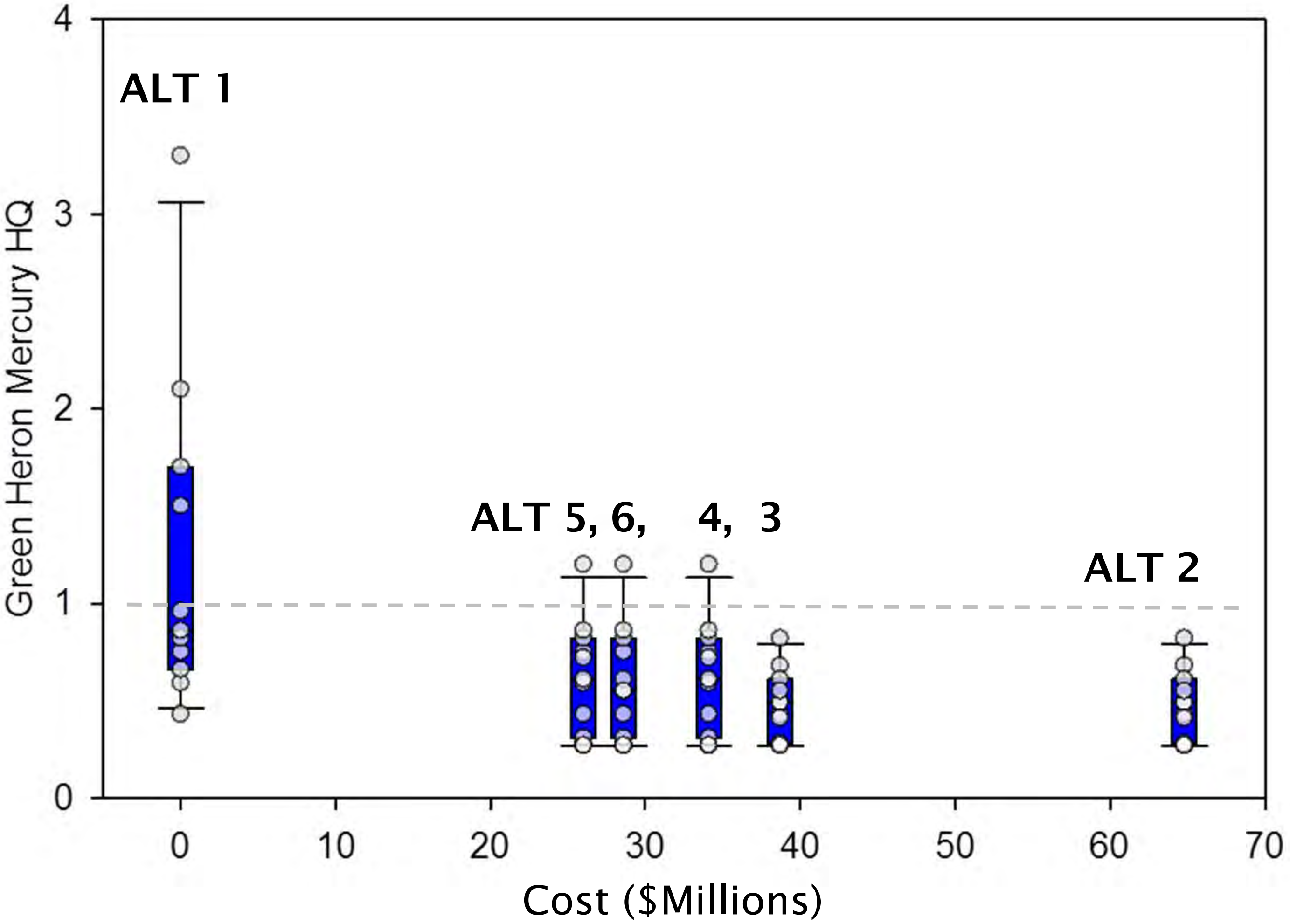
Debris

Q. Purvis Creek

Remnants of the causeway across Purvis Creek

R. Die-back Area

This picture is oriented west from the eastern portion of Domain 1, and is representative of a dieback area at the site.



- Box indicates 25th and 75th percentiles.
- Middle of box is the median.
- Whiskers indicate 10th and 90th percentiles.
- Points indicate green heron HQs from the exposure areas on-site, as summarized in Section 6 (Figures 6-2A and 6-2B).

ALT Alternative

HQ Hazard quotient

Alternative	Cost in $Mil
ALT 1	$0
ALT 2	$65
ALT 3	$39
ALT 4	$34
ALT 5	$26
ALT 6	$29

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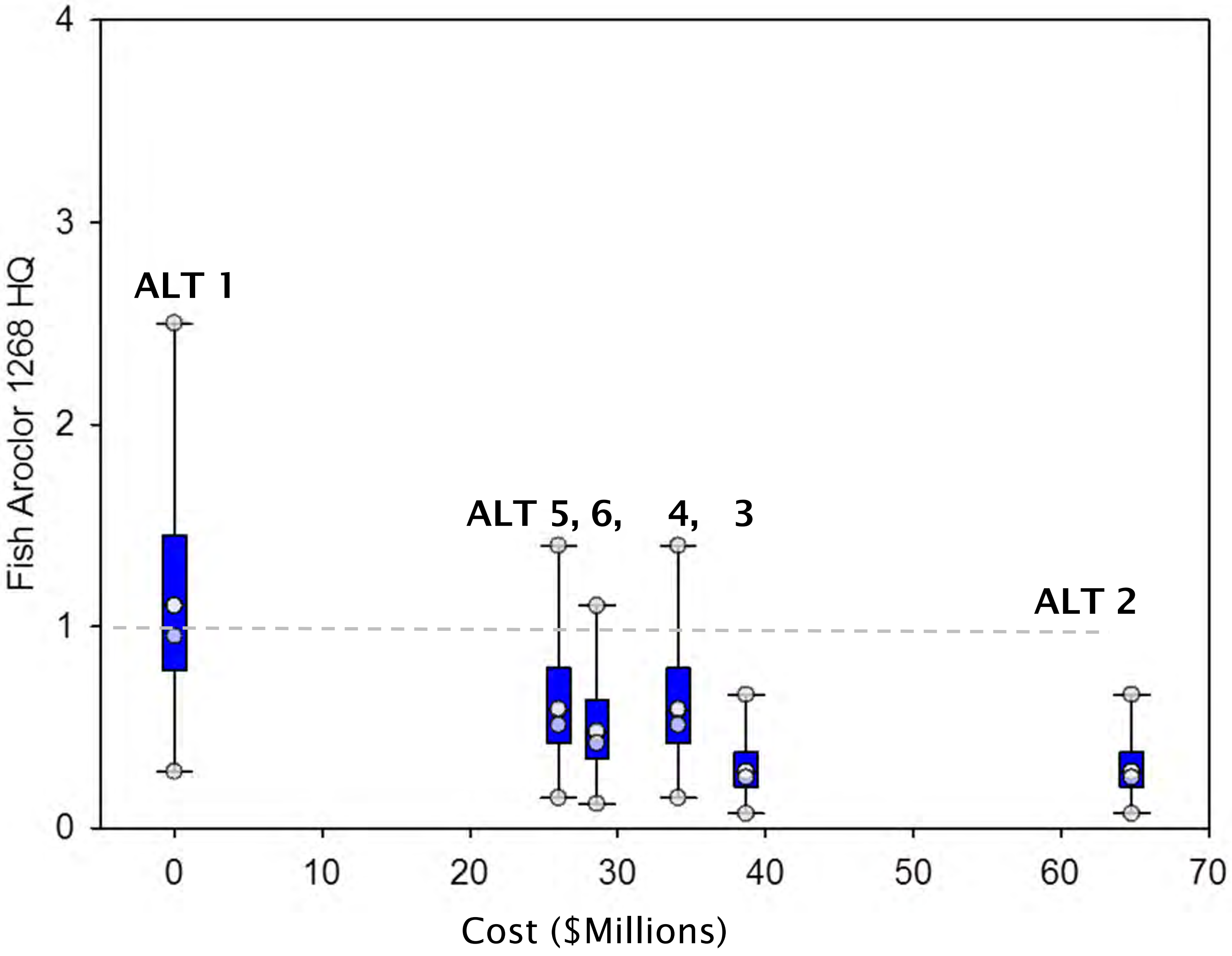
Remedy Alternative Comparison for Green Heron Mercury Risk Reduction by Cost

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

7-1A



- Box indicates 25th and 75th percentiles.
- Middle of box is the median.
- Whiskers indicate 10th and 90th percentiles.
- Points indicate finfish HQs from Section 6 of the FS (Section 6-3).

ALT	Alternative
HQ	Hazard quotient

Alternative	Cost in $Mil
ALT 1	$0
ALT 2	$65
ALT 3	$39
ALT 4	$34
ALT 5	$26
ALT 6	$29

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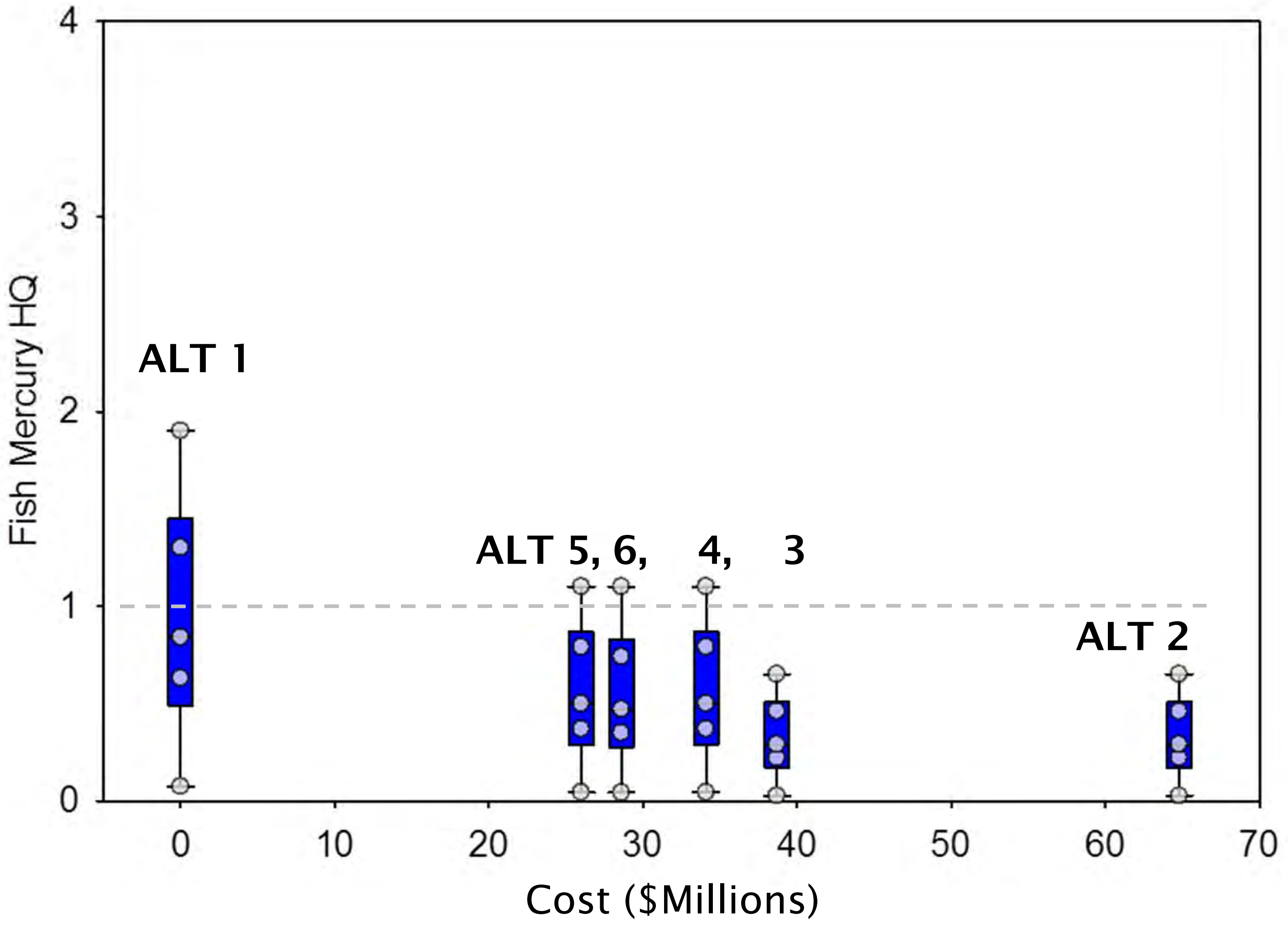
Remedy Alternative Comparison for Finfish Aroclor 1268 Risk Reduction HQs by Cost

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

7-1B



- Box indicates 25th and 75th percentiles.
- Middle of box is the median.
- Whiskers indicate 10th and 90th percentiles.
- Points indicate finfish HQs from Section 6 (Figure 6-4A).

ALT	Alternative
HQ	Hazard quotient

Alternative	Cost in $Mil
ALT 1	$0
ALT 2	$65
ALT 3	$39
ALT 4	$34
ALT 5	$26
ALT 6	$29

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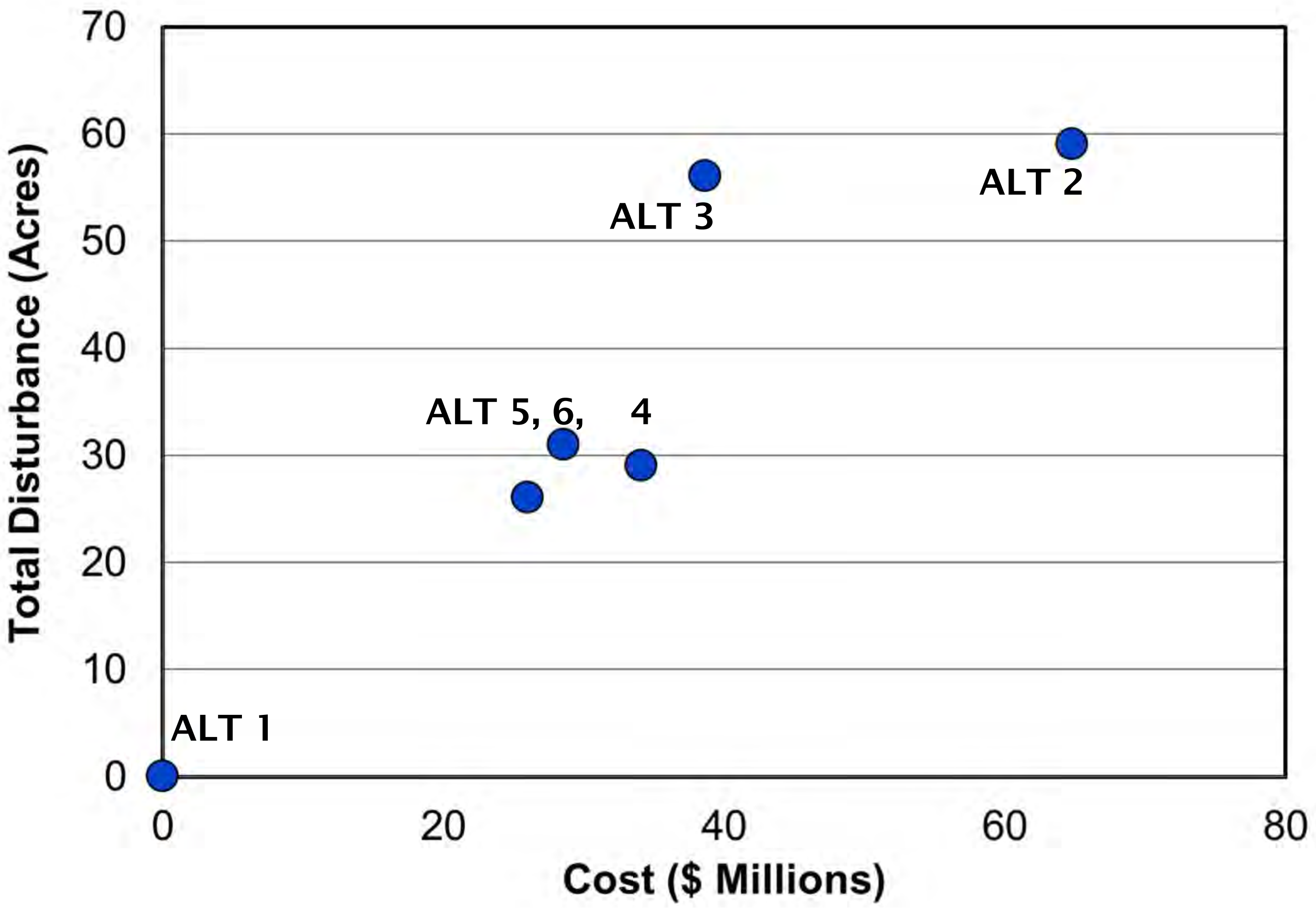
Remedy Alternative Comparison for Finfish Mercury Risk Reduction by Cost

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

7-1C



- Capital Costs were summarized in Table 6-5.

ALT Alternative

Alternative	Cost in $Mil	Remedy Footprint (Acres)	Marsh Disturbance beyond Footprint (Acres)	Total Acres of Disturbance
ALT 1	$0	0	-	0
ALT 2	$65	48	11	59
ALT 3	$39	48	8	56
ALT 4	$34	18	11	29
ALT 5	$26	18	8	26
ALT 6	$29	24	7	31

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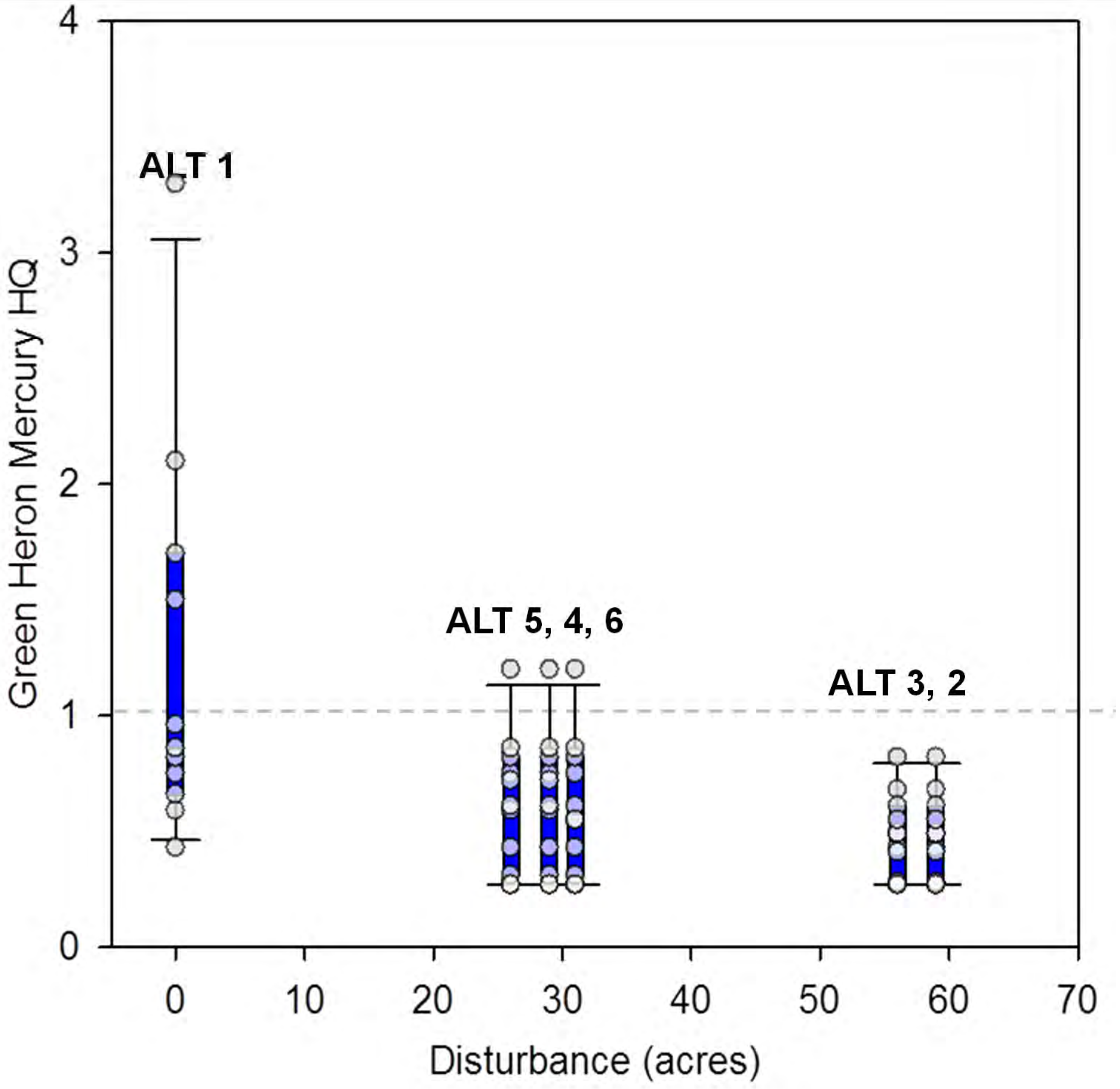
Remedy Alternative Comparison of Cost vs Disturbance

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

7-2



- Box indicates 25th and 75th percentiles.
- Middle of box is the median.
- Whiskers indicate 10th and 90th percentiles.
- Points indicate green heron HQs from the exposure areas on-site, as summarized in Section 6 (Figures 6-2A and 6-2B).

ALT Alternative

HQ Hazard quotient

Alternative	Disturbance in acres
ALT 1	0
ALT 2	59
ALT 3	56
ALT 4	29
ALT 5	26
ALT 6	31

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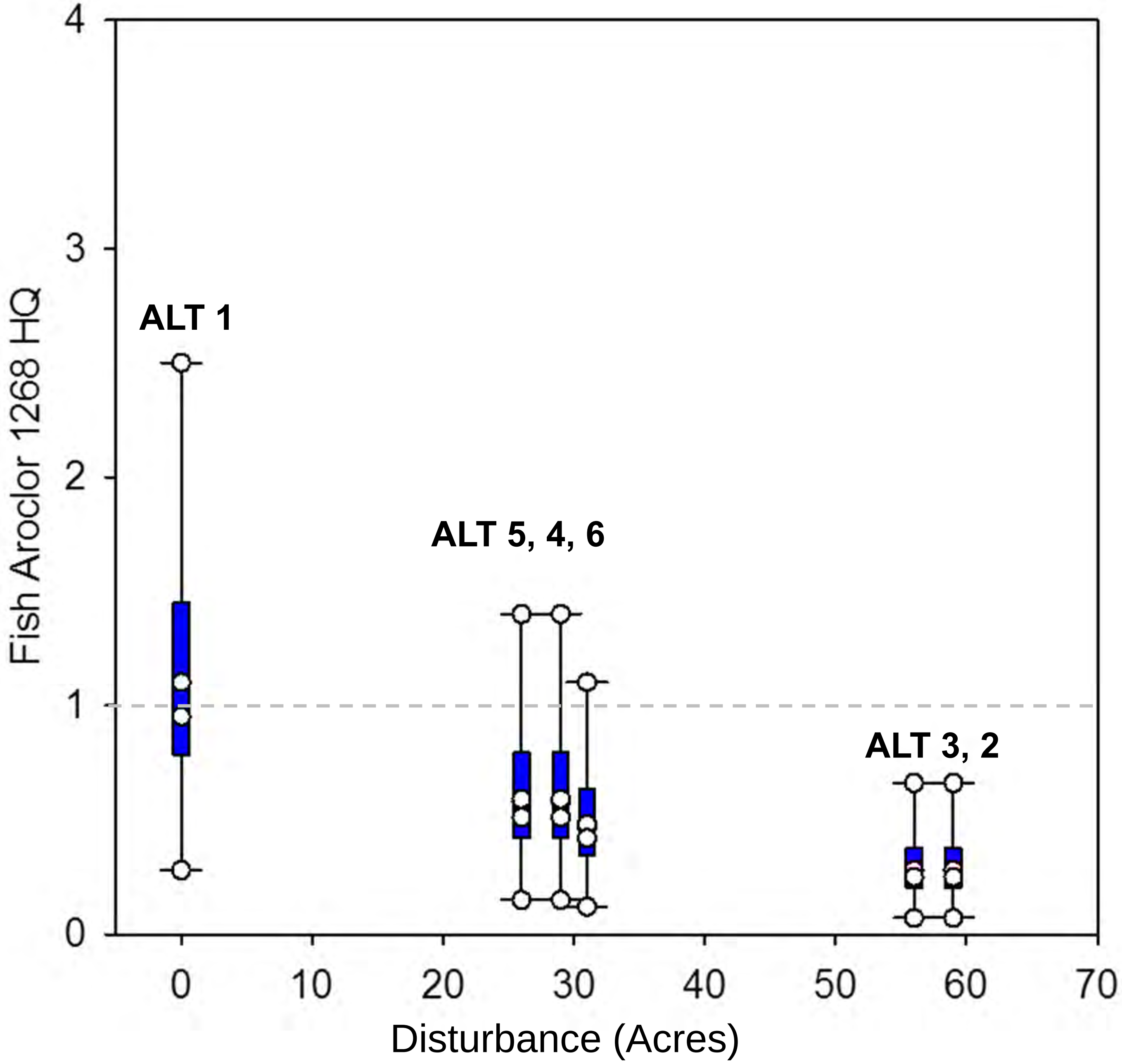
Remedy Alternative Comparison for Green Heron Mercury Risk Reduction by Disturbance (Acres)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

7-3A



- Box indicates 25th and 75th percentiles.
- Middle of box is the median.
- Whiskers indicate 10th and 90th percentiles.
- Points indicate finfish HQs from Section 6 of the FS (Section 6-3).

ALT	Alternative
HQ	Hazard quotient

Alternative	Disturbance in acres
ALT 1	0
ALT 2	59
ALT 3	56
ALT 4	29
ALT 5	26
ALT 6	31

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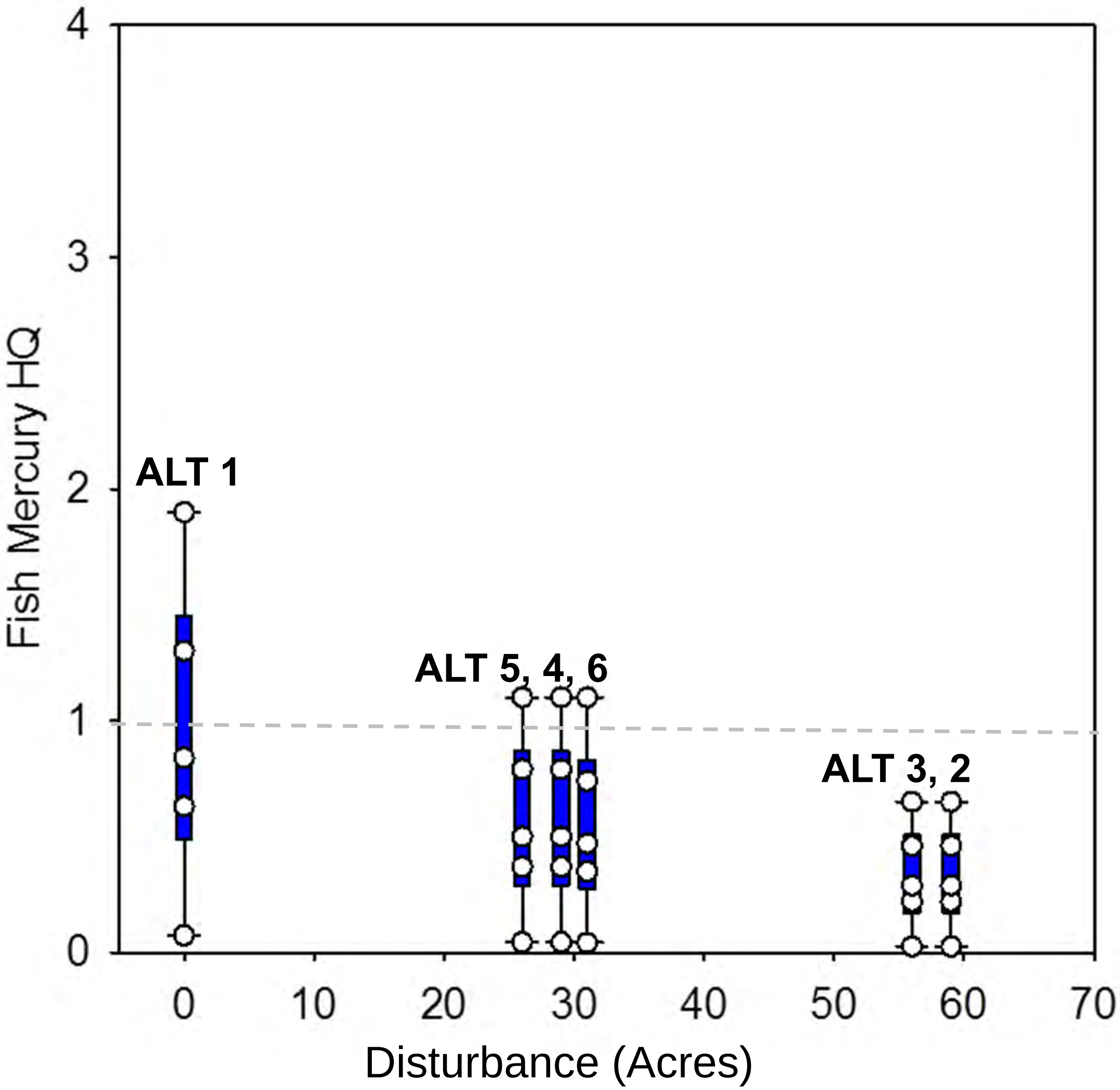
Remedy Alternative Comparison for Finfish Aroclor 1268 Risk Reduction HQs by Disturbance (Acres)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

7-3B



- Box indicates 25th and 75th percentiles.
- Middle of box is the median.
- Whiskers indicate 10th and 90th percentiles.
- Points indicate finfish HQs from Section 6 (Figure 6-4A).

ALT	Alternative
HQ	Hazard quotient

Alternative	Disturbance in acres
ALT 1	0
ALT 2	59
ALT 3	56
ALT 4	29
ALT 5	26
ALT 6	31

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Remedy Alternative Comparison for Finfish Mercury Risk Reduction and Disturbance (Acres)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

7-3C

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Appendix A
Groundwater Evaluation

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:
Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:
ENVIRON International Corporation

Anchor QEA, LLC

Date:
June 2, 2014

Deleted: October 18, 2013

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Contents

List of Tables

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List of Figures

Attachment A1

Boring Logs (EPS 2012)

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Acronyms and Abbreviations

%	percent
bgs	below ground surface
cfs	cubic feet per second
COC	chemicals of concern
CSM	conceptual site model
cm/sec	centimeters per second
USEPA	US Environmental Protection Agency
ft	feet
GAEPD	Georgia Environmental Protection Division
g/d	grams per day
IR	thermal infrared
ITRC	Interstate Technology and Regulatory Commission
kg/yr	kilograms per year
mg/kg	milligram(s) per kilogram
MW	monitoring well
µg/L	microgram(s) per liter
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
ppb	parts per billion
TAL	target analyte list
VOC	volatile organic compound

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Executive Summary

Appendix A of the OU1 FS presents the concepts and methods used to calculate mass discharges of mercury, lead, and total polycyclic aromatic hydrocarbon (PAH) towards the marsh sediments through upland groundwater at the LCP Brunswick Site (Site). Appendix A provides a brief description of the Site hydrogeologic setting followed by the conceptual model of groundwater flow at the Site. A discussion of the computational framework and software used in the analysis is also provided.

Groundwater seepage to the surface water may occur as diffuse flow through the marsh sediments or as focused flow through seeps. Local groundwater flows from the uplands toward the marsh within the Satilla sand aquifer beneath the marsh.

The presence of seeps raised the concern that the groundwater transport pathway into the marsh, via the seeps, may be significant. To address this concern, a sampling program was conducted to determine whether seeps in the marsh flats represent preferential flow paths for elevated concentrations of chemicals of concern (COCs). Seep locations were chosen for the deployment of porewater samplers (also called peepers). Peepers were placed at two depths within each of the identified seep areas to examine the COC porewater concentrations in the marsh at each location. The peeper investigation targeted locations where thermal infrared imagery results showed the greatest potential for groundwater seepage into the marsh. Thus, the approach targeted the greatest potential for contaminant migration into the marsh. The remedial investigation for OU1 presents that data acquired by the peeper investigation. The peeper results suggest that transport of mercury, Aroclor 1268, lead, and total PAHs via focused groundwater pathways in the marsh result in nominal concentrations at the point of discharge.

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Approach

In order to evaluate the COC mass being transported by these groundwater pathways, a transect-based mass flux calculation known as the transect method and outlined by the Interstate Technology and Regulatory Commission (ITRC 2010) was employed. Application of this method used Site-specific data and well-specific data along a transect running approximately north-south at the edge of the uplands. All of the wells along the transect were resampled and 11 new wells were installed to obtain a concentration data set (locations of the new wells were selected approximately mid-distance between existing monitoring well cluster locations bordering the marsh, to address potential gaps in the COC concentrations used in the flux analysis). The transect included 16 wells with hydraulic conductivity measurements.

Three different analyses were conducted:

- The first analysis compared the potential increase in mercury concentrations in surface sediment due to groundwater sources from the uplands to measured values representing the same period. A 14-acre portion of the marsh was excavated, backfilled with clean soil, and revegetated with marsh grasses in 1999. Surface sediment sampling was conducted across this area approximately four years after the remediation. The average mercury concentration found in the remediated portion of the marsh after this 4-year period was

0.54 milligrams per kilogram (mg/kg). At issue is whether the 0.54 mg/kg concentration of mercury in the remediated sediments could be attributed to groundwater transport of mercury. Mass flux analysis estimates that the maximum groundwater contribution to the average surface sediment bed mercury concentration would be 0.02 mg/kg. This estimate is made using conservative assumptions and is over an order of magnitude less than the measured sediment bed mercury concentration of 0.54 mg/kg, demonstrating that the groundwater pathway is an insignificant contributor to mass accumulation within the sediments. The actual mass transported to the sediments over this time period via groundwater is expected to have been much less than 0.02 mg/kg because conservative assumptions were applied in the flux calculation.

- The second analysis computes the groundwater-surface water dilution that occurs within the marsh based on surface water hydrodynamic modeling results and the mass flux analysis. Groundwater flow south of the causeway is diluted into the surface water flow of 130 cubic feet per second (cfs) (obtained from the hydrodynamic modeling calibration) resulting in approximately 1,800:1 dilution (similar dilution is expected north of the causeway). This analysis shows that the low porewater concentrations of COCs measured in marsh sediments, when further diluted by surface water mixing, will result in no change to instream water quality. Groundwater is therefore not a significant contributor to the COC concentrations in surface water.
- The third analysis compares the magnitude of the computed mass discharge to published values to assess whether those discharges pose concern. The plume classification system of Newell et al. (2011) provides a sense of the magnitude of the mass fluxes calculated in Appendix A. Newell et al. (2001) classifies the magnitudes of mass discharges and aligns the magnitudes with a surface water (stream flow) or groundwater receptor (pumping rate) size that might be of concern. Both mercury and lead plumes at the Site, based on their total mass discharges, are classified as magnitude 5 plumes (the other COCs would fall into a lower class). Based on the published classification system, a magnitude 5 plume would not be a threat to a stream flowing at 1 cfs or greater. Based on the hydrodynamic modeling at OU1, the comparable stream size for the marsh system at OU1 is approximately 500 cfs.

Based on the three analysis conducted, the groundwater pathway is not a significant issue for sediment or water quality in the marsh.

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1 Introduction

This appendix details the concepts and methods used to calculate mass discharges of mercury, lead, and total polycyclic aromatic hydrocarbon (PAH) towards the marsh sediments through upland groundwater at the LCP Brunswick Site (Site). A brief description of the Site hydrogeologic setting is followed by the conceptual model of groundwater flow at the Site. A discussion of the computational framework and software used in the analysis is provided. Details and results of May 2012 fieldwork conducted at the Site are followed by a discussion of calculated groundwater and mass fluxes at the Site.

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2 Background

The Site is underlain by the Satilla Formation, which is Holocene to Pleistocene in age and about 55 feet (ft) thick in the vicinity of the Site and divided into two general layers. The Upper Satilla sand is the local aquifer and extends to a depth of about 45 ft below ground surface (bgs) and is composed of uniform very fine to medium sand with thin, discontinuous clay layers. The thin clay layers result in an anisotropic hydraulic conductivity for the formation, in which the vertical hydraulic conductivity of the unit is significantly lower than the horizontal hydraulic conductivity (Geosyntec 2002). The Lower Satilla is about 10 ft thick and, in the vicinity of the marsh and uplands at the Site, is variable in texture ranging from clean sand to dense clayey sand. Slug tests conducted in the Upper and Lower Satilla sand indicate a horizontal hydraulic conductivity on the order of 10^{-2} centimeters per second (cm/sec). Beneath the Satilla formation is the partially cemented sandstone of the Coosawhatchie Formation (approximate hydraulic conductivity of 10^{-5} cm/sec [Geosyntec 2002]), which forms a semi-confining layer between the Satilla sands and underlying aquifers within the Coosawhatchie Formation. Figure A1 shows a conceptual cross- section of the site layering for the local flow system.

Groundwater and surface water interactions at the Site are partially attenuated by the marsh sediments that overlie the Satilla formation and locally provide semi-confined conditions for groundwater flow. Measured hydraulic conductivities of the marsh clay are consistently low (1.3×10^{-7} to 1.8×10^{-8} cm/sec) (GeoSyntec 1997) and texture is consistently fine-grained as well. The marsh sediments are typically 7–8 ft thick; locally, marsh sediment may be thicker, and near the uplands, it may be thinner. In isolated locations, the potential for localized groundwater seepage to the surface water exists, as indicated by a thermal infrared (IR) study conducted in 2009 (Stockton Infrared Thermographic Services 2009; EPS 2012).

The groundwater in the Satilla formation at the Site is nonpotable due to naturally occurring high dissolved mineral content. Groundwater within the surficial water bearing zone (upper 50 ft) underlying the Site uplands contains inorganic and organic chemicals associated with past upland disposal practices. Locally, groundwater flows from east to west (Figure A2) and, based on groundwater level measurements taken during low-tide events, there is an upward gradient through the sediments during low tide. During flood tide, this gradient is reversed, based on measured groundwater head elevations and known tide elevations. Such gradient reversals create a hyporheic zone by introducing surface water into the marsh sediment porewater and potentially beyond the interface with the groundwater aquifer.

Flow from the uplands toward the marsh occurs within the Satilla sand aquifer beneath the marsh and results in discharge to the marsh sediments via seepage and to Purvis Creek, which ultimately discharge to the Turtle River. Groundwater seepage to the surface water may occur as diffuse flow through the marsh sediments or as focused flow through seeps. It should be noted that, while groundwater seepage is a potential pathway into the upland fringe marsh areas, any transport is likely partially attenuated by the dense organic rich clay sediments along the marsh.

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Groundwater seeps were first noted (during the initial Site characterization studies in 1995) as occurring along the marsh edge, where the marsh clay was absent and the underlying sand was exposed. Depending upon the intensity and duration of the rainfall event, the seepage occurs mostly at isolated locations. Nearshore groundwater seeps have been sampled by lysimeters in 2001 and 2003, and groundwater from the seeps is characterized by mercury concentrations of less than 10 micrograms per liter (µg/L; EPS 2009).

Deleted: Seepage events are typically brief (on the scale of a few days) and are observed to occur during high water table conditions following extended or intense rainfall events.

In order to determine whether preferential groundwater pathways exist that could result in focused groundwater discharge in the marsh, a thermal IR study was conducted on June 15, 2009 (Stockton Infrared Thermographic Services 2009). This study identified 14 areas of focused groundwater discharge or seeps at the marsh surface, near the marsh shoreline, and along the channel edges. Seeps identified in the thermal IR study show a low intensity of groundwater discharge.

Deleted: The seeps in locations adjacent to contaminated upland wells are isolated and do not form a thermal trace that impacts the temperature in a marsh surface channel.

The presence of seeps raised the concern that the groundwater transport pathway into the marsh, via the seeps, may be significant. To address this concern, a sampling program was conducted to determine whether seeps in the marsh flats represent preferential flow paths for elevated concentrations of chemicals of concern (COCs). Seep locations were chosen for the deployment of porewater samplers (peepers). Peepers were placed at two depths within each of the identified seep areas to examine the COC porewater concentrations in the marsh at each location. The peeper investigation targeted locations where the IR imagery results showed the greatest potential for groundwater seepage into the marsh. Thus, the approach targeted the greatest potential for contaminant migration into the marsh. The remedial investigation for OU1 presents that data acquired by the peeper investigation. The peeper results suggest that transport of mercury, Aroclor 1268, lead, and total PAHs via focused groundwater pathways in the marsh result in nominal concentrations at the point of discharge.[1]

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[1] Peeper Aroclor 1268 concentrations were non-detect (<0.005 µg/L) in 16 of 18 samples representing 8 seep stations in the marsh; the two detections occurred in nearshore peepers, including the peepers at Seep 10D (0.0092 µg/L) and Seep 11S (0.012 µg/L). These results, combined with the observation that Aroclor1268 concentrations in all groundwater samples supporting this analysis were non-detect, eliminated concern for Aroclor 1268 transport to the marsh via groundwater.

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3 Conceptual Site Model of Local Groundwater Flow to the Estuary

The groundwater conceptual site model (CSM) includes local groundwater flow from the uplands into the salt marsh crossing a vertical plane parallel to the marsh boundary along four flow paths, among which the groundwater COC contribution is divided as illustrated in Figure A3. Shallow groundwater in the Satilla aquifer, down to the cemented sandstone, migrates towards the marsh, approximately perpendicular to the marsh boundary. COCs that are transported along each flow path encounter a sequence of geochemical conditions that affect the fate of the COCs as they are transported. Each groundwater flow path is discussed next from longest to shortest:

- Flow Path to Purvis Creek and Beyond: The longest flow path is from the uplands to Purvis Creek and beyond. This path is dominated by water that begins near the bottom of the Satilla sand aquifer at the marsh boundary and is transported more than 1,000 ft within the Satilla sand. The groundwater enters the marsh sediments from below. Discharge may occur as diffuse flow through the marsh sediments or through focused seeps that emanate in Purvis Creek.
- Flow Path to Marsh Flats and Intertidal Channels: This flow path begins with groundwater at depth along the marsh boundary. The groundwater is transported within the aquifer and enters the marsh sediments from below. Discharge through the marsh sediments may occur as diffuse discharge through the marsh sediments or through focused seeps.
- Flow Path to Restored Marsh Area: This flow path begins at shallow depths along the marsh boundary; groundwater is transported less than 500 ft from the upland within the aquifer. The groundwater then enters the marsh sediments from below. Discharge through the marsh sediments may occur as diffuse discharge through the marsh sediments or through focused seeps.
- Flow Path to Nearshore Seeps: The shortest flow path between the upland groundwater and the marsh leads to nearshore seeps, such as those that have been identified and sampled by lysimeters. This transport flow path is dominated by the shallowest groundwater in the aquifer along the marsh boundary. The groundwater may be expressed at the surface after intense rainfall events. The distance of transport within the aquifer is short, and the discharge to the surface may be in an area where marsh sediments are thinner than out on the marsh flats.

Each of these flow paths encounters lithologic and biogeochemical zones that affect the fate of the COCs being transported. The major differences between the flow paths are related to the residence time of the groundwater in the various lithologic and biogeochemical zones. Along each flow path, the zones encountered are as follows:

- The aquifer
- The marsh sediments below the root zone
- The marsh sediments within the root zone

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Upon discharge to the surface, direct mixing with tidal surface water occurs. The more focused the discharge (i.e., as a seep), the higher the potential COC concentration, but also the greater the influence of surface water dilution at the point of discharge to the surface water. Conversely, diffuse discharges upwelling through the sediment bed will be subject to more attenuation within the sediments, and they are also subject to dilution at the point of discharge to the surface water.

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4 Computational Framework

In order to evaluate the COC mass being transported by these groundwater pathways, a transect-based mass flux calculation known as the transect method and outlined by the Interstate Technology and Regulatory Commission (ITRC 2010) was employed. ITRC is a state-led coalition of regulators, industry experts, citizen stakeholders, academia, and federal partners that work to achieve regulatory acceptance of environmental technologies and innovative approaches. The transect method relies on groundwater samples collected along a transect perpendicular to and intersecting a groundwater plume (Figure A4a). The transect is divided into any number of subareas, each representing a discrete area of uniform concentration and groundwater flow such that the full width and thickness of the plume is defined. Groundwater data are interpolated across the transect to map COC concentrations; the resulting interpolation map represents the COC concentration distribution in the transect at the time of sampling (Figure A4b-c).

The mass discharge (mass per unit time) through each subarea is calculated as follows:

$$M_i = K_i \times h_i \times C_i \times A_i$$

Where,

M_i is the mass discharge

K_i is the hydraulic conductivity

h_i is the hydraulic gradient

C_i is the concentration

A_i is the area of subarea i

The groundwater flow direction and hydraulic gradient for each segment of the transect can be determined from potentiometric surface contour maps. Representative measurements of hydraulic conductivity can be obtained from field tests (e.g., slug or pumping tests). An interpolation is used to fill gaps of concentration and flow data.

The total mass discharge M through the transect then becomes the sum of all individual mass discharges:

$$M = \sum_{i=1}^{n} M_i$$

where n represents the number of all subareas on the transect cross section.

Application of this method uses the following:

- Site-specific data and well-specific data along the transect

- 16 wells along the transect have hydraulic conductivity measurements
- All wells along the transect have concentration measurements
- The area is determined by the geometry between surveyed well locations

This amount of data and spatial distribution of the data provides a very robust and complete dataset on which to base the mass flux analysis. Water level maps were used to develop hydraulic gradient. May 2012 field sampling and drilling was conducted in consultation with the United States Environmental Protection Agency (USEPA) and Georgia Environmental Protection Division (GAEPD) to gather a current and consistent measure of COC concentrations along the transect.

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5 Field Work

5.1 Field Work

To support the groundwater flux analysis, 11 additional monitoring wells (6 locations) were installed between May 14 and May 16, 2012. Locations were selected approximately mid-distance between existing monitoring well cluster locations bordering the marsh to address potential gaps in the COC concentrations used in the flux analysis. At 5 of the new well locations (DP-1, DP-2, DP-3, DP-5, DP-6), paired wells were completed, with 1 set at approximately 14 ft bgs, the “A” well, and 1 set at approximately 28 ft bgs, the “B” well. Location DP-4 was set with a single shallow “A” well at approximately 14 ft bgs to complement the existing monitoring well cluster MW-104B/C. Figure A5 shows the sampling transect to which the flux analysis was applied and the monitoring well locations sampled for the purpose of the flux analysis.

5.2 Field and Laboratory Parameters

Following DP well installation and well development, all transect wells and supplemental temporary groundwater sampling points shown on Figure A5 were sampled for the following constituents of interest to support the flux analysis:

Potential COCs	Geochemical/Indicator Parameters
target analyte list metals (TAL metals)	silica
mercury	sulfate/sulfide
volatile organic compounds (VOC)	chloride
polycyclic aromatic hydrocarbons (PAH)	total organic carbon
polychlorinated biphenyls (PCB)	pH

The selection of upland wells, sampling methods, and analytical constituents and methods were reviewed with USEPA and GAEPD. The consensus of the review meeting was incorporated into a groundwater monitoring work plan (EPS 2012). The newly installed DP wells exhibited high turbidity during sampling; therefore an additional set of samples to be analyzed for metals were collected for filtered sample testing.

5.3 Results of Field Work

Tables A1 to A6 provide the groundwater analysis results for all transect wells grouped by parameter type:

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- volatile organic compound (VOC)
- PAH
- polychlorinated biphenyls (PCBs)
- metals
- geochemical indicators
- field parameters

5.3.1 Potentiometric Surface Map

On the day prior to initiating the groundwater sampling, depth-to-water measurements were conducted during low tide in all of the monitoring wells on the Site. Due to the high dissolved solids content of the groundwater, the field water level measurements are subsequently adjusted to an equivalent freshwater head value (based on water temperature and total dissolved solids). Field water levels and corrected water levels are provided in Table A7. Corrected groundwater levels were used to construct a site potentiometric surface, as shown on Figure A6. This potentiometric surface is consistent with past derivations and shows a westerly groundwater flow direction (from high ground uplands across the marsh).

5.3.2 DP Boring Logs

Boring logs for the DP series wells are included in Attachment A1. In general, all borings exhibited sand, fine to coarse grade, with some silt at all levels, with the exception of DP-5. DP-5 also exhibits several feet of clay interbedded with sand.

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6 Site Specific Computations of Groundwater Flux and Mass Discharges

The transect method was applied to the LCP estuary using the most recent groundwater samples from wells located along the upland boundary of the marsh (Figure A5) and hydraulic conductivities at 16 locations along the transect. This method allows the mass of COCs migrating in the groundwater at the marsh boundary to be quantified. The groundwater flow pathways describing the flow towards the marsh are discussed in the Section 3, groundwater CSM. Initial application of this method for mercury was completed using the available chemistry data from upland wells located at the marsh boundary (based on concentrations from 2010 and earlier). That analysis indicates that the mass of mercury transported by the groundwater flow paths toward the restored marsh area was insufficient to account for the measured mercury in the restored marsh. This preliminary finding was consistent with the hypothesis of tidal redistribution of in-channel sediment into the restored marsh.

The 2012 groundwater data (Tables A1-A7) are used to calculate the mass of COCs being transported by groundwater toward the marsh. The locations of the wells at the Site that are used to form transects are shown in Figure A7. To facilitate interpretation of results, a total of five transects are formed north of the causeway (Transects 4 and 5) and south of the causeway (Transects 1, 2, and 3) along the boundary between the restored marsh area and uplands. Table A8 lists the transects by number and provides the associated individual wells, well clusters, and temporary points that make up each transect.

In order to calculate better estimates of the mass flux from the uplands, temporary DP series monitoring wells were installed along the upland transect. These sampling points and their chemistry data were collected during the May 2012 field event.

6.1 Data Used in the Computation

Hydraulic conductivity values (Table A9) at different depths and locations along the transect were used in the mass discharge calculations and were determined from slug tests (Geosyntec 1997). A biased value for hydraulic gradient from the uplands towards the marsh is taken to provide a conservative assumption. Available measurements are taken at low tide when the gradient between the uplands and the marsh is a maximum. Tides will result in fluctuating gradients, and the actual average groundwater flow gradient is expected to be considerably lower. Maximum hydraulic gradient from the uplands towards the marsh is taken from potentiomentric surface maps from the October 2006 and October 2005 sampling events. The most recent potentiometric surface map from the May 2012 water level event (Figure A6) is consistent with these previous measurement events. From these measurements, and as a simplifying and conservative assumption, a value of $3.0\text{x}10^{-3}$ ft/ft is used across the entire transect to represent the gradient at low tide. Concentration values used in the calculation for mercury, lead, and total PAH at each well location are listed in Table A10.

The following conservative assumptions and approaches were used to establish a conservatively biased flux analysis that is considered highly protective of the marsh.

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- For the cases where both filtered and unfiltered sample analyses were available, the concentration for the unfiltered sample was used in the calculation.
- Depth to the water table is used in the transect method calculation to provide an upper boundary for the concentration interpolation. The water level depths used in these calculations are provided in Table A11 and are taken from the sampling conducted in May 2010, which are consistent with the data from the May 2012 water level event.
- A positive gradient was assumed for 100 percent (%) of the calculation (i.e., the flux analysis assumed low tide conditions exist at all times).
- The transect method calculation assumes that the transects cover the full width and thickness of the plume. As a conservative assumption, the plume is assumed to start at the water table, and the concentration value measured in the uppermost well in the cluster is applied uniformly to the area between the water table and the top of the screen.
- At temporary well locations DP-1, DP-2, DP-3, DP-5 and DP-6, there are only two vertical points for the calculation; none of the DP series temporary wells penetrated to the full depth of the aquifer. At each of these temporary wells, an aquifer bottom depth is estimated by interpolating the elevation of the top of sandstone layer from two adjacent wells. The relatively conservative concentration value at the deeper temporary well is applied uniformly down to the estimated aquifer bottom.

6.2 Computation Results

The computations were conducted using the Mass Flux Toolkit developed for the Environmental Security Technology Certification Program by GSI Environmental (Farhat and Newell 2011). The computed estimates of mass discharge (kilograms per year [kg/yr]) towards the marsh through the groundwater pathway are shown in Table A12. Vertically, the total mass discharge along each transect is divided among the four groundwater pathways identified in the groundwater CSM, and attenuation will occur along each pathway.

The highest mass flux for mercury and lead is found in Transect 1, which contains the wells with the highest concentrations of those substances in shallow groundwater. The flux computed for Transect 1 is 0.35 kg/yr mercury and 0.73 kg/yr lead. Transect 5 shows the largest total PAH flux of 0.72 kg/yr; the Transect 5 lead flux was 0.62 kg/yr.

6.3 Analysis of Results

Transport of the COCs towards the marsh along a groundwater pathway may have two potential impacts: surface water quality could be impacted or contaminants could adsorb onto sediments and thus sediment concentrations could be impacted. In order to assess the potential impact on these media, three analyses were performed.

- The first analysis compared the potential increase of mercury concentrations in surface sediment south of the causeway to measured values over the same period.
- The second analysis computed the groundwater-surface water dilution that occurs within the marsh south of the causeway based on surface water hydrodynamic modeling results and the mass flux analysis.

- The third analysis simply compared the magnitude of the mass discharge based on the mass flux analysis to published values to evaluate the magnitude of mercury, lead, and total PAH discharges and whether those discharges pose concern.

Analysis 1. In 1999, a 14-acre portion of the marsh was excavated, backfilled with clean soil, and revegetated with marsh grasses. Sampling of the surface sediment was conducted across this area approximately four years after the remediation. The average mercury concentration found in the remediated portion of the marsh after this 4-year period was 0.54 milligrams per kilogram (mg/kg). At issue is whether the 0.54 mg/kg concentration of mercury in the remediated sediments could be attributed to groundwater transport of mercury.

Mercury transport to the remediated marsh sediments, along the groundwater pathway, can be calculated based on the flux analysis. The maximum possible amount of mercury that could have been transported via the groundwater pathway was computed using the following conservative assumptions:

1) No chemical processes attenuate mercury along the groundwater pathway.
2) Transport of mercury accumulates only in the top 1 ft of sediments (i.e., not in deeper sediments).
3) 20% of the mercury mass discharged along Transects 1, 2, and 3 south of the causeway is partitioned into the 1 ft of remediated marsh surface sediments. Assumption 3 accounts for the existence of the other transport pathways to portions of the marsh further away from the shoreline.

Based on these assumptions the maximum sediment concentration that could be attributed to a groundwater pathway over the 4-year accumulation period is calculated as follows:

$$Mass\ Accumulation = \frac{Mass\ Flux\ x\ 4\ years}{Sediment\ Mass\ (i.e., surface\ area\ x\ thickness\ of\ 1\ ft/bulk\ density)}$$

Based on the mass discharge results shown in Table A12, an assumed sediment thickness of 1 ft, a remediated surface area of 11 acres, a sediment bulk density of 1.2 grams per cubic centimeter, and 4 years of mercury accumulation, the estimated maximum groundwater contribution of mercury to the average surface sediment bed concentration would be 0.02 mg/kg. This estimate is made using conservative assumptions and is over an order of magnitude less than the measured sediment bed concentration of 0.54 mg/kg, demonstrating that the groundwater pathway is an insignificant contributor to mass accumulation within the sediments. The actual mass transported to the sediments over this time period via groundwater is expected to have been much less than 0.02 mg/kg because conservative assumptions were applied in the flux calculation, attenuation of mercury by chemical processes within the marsh along the groundwater pathway does occur, and the marsh sediment thickness is known to be 7–8 ft in this area.

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Analysis 2. The second analysis is based on the dilution that takes place upon groundwater discharge to surface water. Dilution of the groundwater results in attenuation of the groundwater concentrations and should be considered for evaluating the impact on receptors in the surface water due to instream water quality. An estuary system with tidal flushing can be evaluated by the equivalent flow out of the domain (Mitsch and Gosselink 2000). Using the methods reported by Mitsch and Gosselink (2000), the hydrodynamic model was employed to estimate the flow of water through the marsh, south of the causeway, due to tidally influenced flows. These tides equate to an effective flow of 130 cubic feet per second (cfs).

Due to the geometry of the marsh, it is convenient to calculate the tidal dilution for the surface water area south of the causeway, since it compares directly with values from the groundwater transect locations south of the causeway. Comparable dilution north of the causeway occurs as well but is not quantified here. Of the five groundwater transects in Table A8, the first three are located south of the causeway and were used to compare to the estimated estuarine stream flow south of the causeway (i.e. 130 cfs). The groundwater flows through Transects 1, 2, and 3 are 0.033, 0.018, and 0.022 cfs, respectively. The sum of these groundwater flows into the surface water flow of 130 cfs results in approximately 1,800:1 dilution of the flow of groundwater into surface water for the marsh south of the causeway.

Measured or estimated porewater concentrations will experience significant dilution upon discharge to the surface water. Peeper studies that evaluated marsh porewater concentrations exhibited very low concentrations of COCs. For example, the mercury median (0.0036 parts per billion [ppb]) result and the lead median (<4 ppb) result for the peeper study would be diluted to significantly below non-detect concentrations in the surface water. Even a point computation of the highest mercury concentration from the peeper study (6 ppb mercury measured in the peeper at seep 11-D), when diluted 1800:1 in the surface water, represents a concentration of only 0.003 ppb in surface water. This analysis shows that the low porewater concentrations of COCs measured in marsh sediments, when further diluted by surface water mixing, will result in no change to instream water quality. Groundwater is therefore not a significant contributor to COCs in surface water.

Analysis 3. The third analysis uses the plume classification system of Newell et al. (2011) to provide a sense of the magnitude of the mass fluxes calculated in this appendix. That work classifies the magnitudes of mass discharges and aligns the magnitudes with a surface water (stream flows) or groundwater receptor (pumping rates) size that might be of concern. The classification system is developed from a 40-site database of mass discharge measurements, which span 8 orders of magnitude (from 0.00078 grams per day [g/d] to 56,000 g/d).

Both mercury and lead plumes at the Site, based on their estimated total mass discharges of 1.21 g/d and 4.11 g/d through all five transects, are classified as magnitude 5 plumes (the other COCs would fall into a lower class). Based on the classification system, a magnitude 5 plume would not be a threat to a 1-cfs stream. Based on the hydrodynamic modeling, the comparable stream size for the entire marsh system being evaluated here is approximately 500 cfs.

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Based on the mass flux analysis conducted, the size of the marsh system, and dilution from the surface water, the groundwater pathway is not a significant issue for sediment or water quality in the marsh. From the analysis presented, as a transport pathway, groundwater is not a significant contributor to sediment concentrations. In addition, this evaluation shows that groundwater is not a significant contributor to COCs in surface water. Based on plume magnitude, the size of this groundwater plume is very small compared to the flux necessary to result in a potential threat to general surface water quality at the Site.

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Appendix A
Groundwater Evaluation

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Tables

Table A1
Results of 2012 Transect Monitoring Program - Wells Analyzed for Volatile Organic Compounds
LCP Chemical, Brunswick, GA

Location	1,1,1-Trichloroethane	1,1,2,2-Tetrachloroethane	1,1,2-Trichloroethane	1,1-Dichloroethane	1,1-Dichloroethene	1,2-Dichloroethane	1,2-Dichloropropane	2-Butanone (MEK)
DP-1A	<0.075	<0.16	<0.14	0.090	<0.08	<0.08	<0.095	<1.9
DP-1B	<0.38	<0.8	<0.7	<0.39	<0.4	<0.4	<0.48	<9.5
DP-2A	<0.75	<1.6	<1.4	<0.77	<0.8	<0.8	<0.95	<19
DP-2B	<0.38	<0.8	<0.7	<0.39	<0.4	<0.4	<0.48	<9.5
DP-3A	<0.075	<0.16	<0.14	<0.077	<0.08	<0.08	<0.095	<1.9
DP-3B	<0.75	<1.6	<1.4	<0.77	<0.8	<0.8	<0.95	<19
DP-4A	<0.075	<0.16	<0.14	<0.077	<0.08	<0.08	<0.095	<1.9
DP-5A	<0.075	<0.16	<0.14	0.43	<0.08	<0.08	<0.095	<1.9
DP-5B	<0.075	<0.16	<0.14	0.16	<0.08	<0.08	<0.095	<1.9
DP-6A	<0.075	<0.16	<2.8	<0.077	<0.08	<0.08	<0.095	5.2
DP-6B	<0.38	<0.8	<0.7	<0.39	<0.4	<0.4	<0.48	<9.5
MW-104B	<0.075	<0.16	<0.14	0.51	0.090	<0.08	<0.095	<1.9
MW-104C	<0.75	<1.6	<1.4	1.7	<0.8	<0.8	<0.95	<19
MW-110A	<0.15	<0.32	<3.5	<0.16	<0.16	<0.16	<0.19	10
MW-110B	<0.075	<0.16	<0.14	<0.077	<0.08	<0.08	<0.095	<1.9
MW-110C	<0.075	<0.16	<0.14	0.18	<0.08	<0.08	0.10	<1.9
MW-111A	<0.75	<1.6	<1.4	3.2	1.4	<0.8	<1.1	120
MW-111B	<0.75	<1.6	<1.4	1.0	<0.8	<0.8	<0.95	<19
MW-111C	<0.075	<0.16	<0.14	0.27	<0.08	<0.08	0.27	<1.9
MW-112A	<0.38	<0.8	<0.7	<0.39	<0.4	<0.4	<0.48	<9.5
MW-112B	<0.38	<0.8	<0.7	<0.39	<0.4	<0.4	<0.48	<9.5
MW-112C	<0.38	<0.8	<0.7	<0.39	<0.4	<0.4	<0.48	<9.5
MW-113A	<0.19	<0.4	<0.35	<0.2	<0.2	<0.2	<0.24	<4.8
MW-113B	<0.075	<0.16	<0.14	<0.077	<0.08	<0.08	<0.095	<1.9
MW-113C	<0.075	<0.16	<0.14	<0.077	<0.08	<0.08	<0.095	12
MW-114A	<0.075	<0.16	<1.4	<0.077	<0.08	<0.08	<0.095	<1.9
MW-114B	<0.075	<0.16	<0.14	<0.077	<0.08	<0.08	<0.095	<1.9
MW-114C	<0.075	<0.16	<0.14	<0.077	<0.08	<0.08	0.80	<1.9
MW-354A	<0.075	<0.16	<0.14	0.23	<0.08	<0.08	<0.095	<1.9
MW-354B	<0.38	<0.8	<0.7	4.8	<0.4	<0.4	<0.48	<9.5
MW-358A	<0.075	<0.16	<0.14	<0.077	<0.08	<0.08	<0.095	<1.9
MW-358B	<0.38	<0.8	<0.7	1.3	<0.4	<0.4	<0.48	18

Table A1
Results of 2012 Transect Monitoring Program - Wells Analyzed for Volatile Organic Compounds
LCP Chemical, Brunswick, GA

Location	2-Hexanone	4-Methyl-2-pentanone	Acetone	Benzene	Bromodichloro-methane	Bromoform	Bromomethane
DP-1A	<2.7	<2.6	<3.3	0.20	<0.091	<0.16	<0.1
DP-1B	<14	<13	<17	<0.31	<0.46	<0.8	<0.5
DP-2A	<27	<26	<33	6.4	<0.91	<1.6	<1
DP-2B	<14	<13	<17	4.4	<0.46	<0.8	<0.5
DP-3A	<2.7	<2.6	17	0.080	<0.091	<0.16	<0.1
DP-3B	<27	<26	<33	4.6	<0.91	<1.6	<1
DP-4A	<2.7	<2.6	6.5	1.5	<0.091	<0.16	<0.1
DP-5A	<2.7	<2.6	<3.3	0.070	<0.091	<0.16	<0.1
DP-5B	<2.7	<2.6	<3.3	0.090	<0.091	<0.16	<0.1
DP-6A	<54	<2.6	19	68	<0.091	<3.2	<0.1
DP-6B	<14	<13	18	13	<0.46	<0.8	<0.5
MW-104B	<2.7	<2.6	<3.3	0.29	<0.091	<0.16	<0.1
MW-104C	<27	<26	<33	1.3	<0.91	<1.6	<1
MW-110A	<68	<5.2	41	100	<0.19	<4	<0.2
MW-110B	<2.7	<2.6	<3.3	0.97	<0.091	<0.16	<0.1
MW-110C	<2.7	<2.6	3.5	1.0	<0.091	<0.16	<0.1
MW-111A	<27	<26	460	14	<0.91	<1.6	<1
MW-111B	<27	<26	<33	5.1	<0.91	<1.6	<1
MW-111C	<2.7	<2.6	<3.3	0.57	<0.091	<0.16	<0.1
MW-112A	<14	<13	<19	0.95	<0.46	<0.8	<0.5
MW-112B	<14	<13	<17	1.9	<0.46	<0.8	<0.5
MW-112C	<14	<13	110	4.8	<0.46	<0.8	<0.5
MW-113A	<6.8	<6.5	<12	1.3	<0.23	<0.4	<0.25
MW-113B	<2.7	<2.6	<12	1.2	<0.091	<0.16	<0.1
MW-113C	<2.7	<2.6	120	0.36	<0.091	<0.16	<0.1
MW-114A	<2.7	<2.6	<31	0.15	<0.091	<0.16	<0.1
MW-114B	<2.7	<2.6	<11	<0.062	<0.091	<0.16	<0.1
MW-114C	<2.7	<2.6	<3.3	1.3	<0.091	<0.16	<0.1
MW-354A	<2.7	<2.6	<3.3	1.4	<0.091	<0.16	<0.1
MW-354B	<14	<13	<18	3.8	<0.46	<0.8	<0.5
MW-358A	<2.7	<2.6	<3.3	0.30	<0.091	<0.16	<0.1
MW-358B	<14	<13	190	3.9	<0.46	<0.8	<0.5

Table A1
Results of 2012 Transect Monitoring Program - Wells Analyzed for Volatile Organic Compounds
LCP Chemical, Brunswick, GA

Location	Carbon disulfide	Carbon tetrachloride	Chlorobenzene	Chloroethane	Chloroform	Chloromethane	cis-1,2-Dichloroethene
DP-1A	1.1	<0.096	<0.11	<0.16	<0.072	<0.068	0.090
DP-1B	3.8	<0.48	<0.55	<0.8	<0.36	<0.34	<0.34
DP-2A	0.90	<0.96	<1.1	<1.6	<0.72	<0.68	<0.67
DP-2B	<0.35	<0.48	81	<0.8	<0.36	<0.34	<0.34
DP-3A	0.92	<0.096	<0.11	<0.16	<0.072	<0.068	<0.067
DP-3B	0.70	<0.96	2.7	<1.6	<0.72	<0.68	<0.67
DP-4A	0.36	<0.096	170	<0.16	<0.072	<0.068	<0.067
DP-5A	0.33	<0.096	0.14	<0.16	<0.072	<0.068	0.14
DP-5B	0.29	<0.096	0.30	<0.16	<0.072	<0.068	<0.067
DP-6A	1.8	<0.096	<2.2	<0.16	<0.072	<0.068	<0.067
DP-6B	1.1	<0.48	<0.55	<0.8	<0.36	<0.34	<0.34
MW-104B	0.080	<0.096	0.26	<0.16	<0.072	<0.068	0.53
MW-104C	<0.69	<0.96	2.3	<1.6	<0.72	<0.68	1.4
MW-110A	1.2	<0.2	<2.8	<0.32	<0.15	<0.14	<0.14
MW-110B	<0.069	<0.096	<0.11	<0.16	<0.072	<0.068	<0.067
MW-110C	<0.069	<0.096	<0.11	<0.16	<0.072	<0.068	<0.067
MW-111A	2.1	<0.96	<1.1	<1.6	<0.72	<0.68	<0.67
MW-111B	0.80	<0.96	<1.1	<1.6	<0.72	<0.68	<0.67
MW-111C	<0.069	<0.096	<0.11	<0.16	<0.072	<0.068	0.27
MW-112A	<0.35	<0.48	2.3	<0.8	<0.36	<0.34	<0.34
MW-112B	0.70	<0.48	2.1	<0.8	<0.36	<0.34	0.85
MW-112C	0.75	<0.48	8.1	<0.8	<0.36	<0.34	<0.34
MW-113A	0.45	<0.24	<0.28	<0.4	<0.18	<0.17	1.2
MW-113B	0.39	<0.096	2.4	<0.16	<0.072	<0.068	0.99
MW-113C	<0.069	<0.096	0.14	<0.16	<0.072	<0.068	0.28
MW-114A	<0.069	<0.096	<0.11	<0.16	<0.072	<0.068	<0.067
MW-114B	<0.069	<0.096	<0.11	<0.16	<0.072	<0.068	<0.067
MW-114C	0.21	<0.096	<0.11	<0.16	<0.072	<0.068	0.73
MW-354A	<0.069	<0.096	38	<0.16	<0.072	<0.068	0.24
MW-354B	0.90	<0.48	42	<0.8	<0.36	<0.34	3.2
MW-358A	0.17	<0.096	9.7	<0.16	<0.072	<0.068	0.16
MW-358B	0.80	<0.48	31	<0.8	<0.36	<0.34	0.40

Table A1
Results of 2012 Transect Monitoring Program - Wells Analyzed for Volatile Organic Compounds
LCP Chemical, Brunswick, GA

Location	cis-1,3-Dichloropropene	Dibromochloro-methane	Dichloromethane (Methylene chloride)	Ethyl benzene	m&p-Xylene	o-Xylene	Styrene
DP-1A	<0.18	<0.14	<0.1	0.82	1.0	0.29	<0.089
DP-1B	<0.9	<0.7	1.3	<0.25	<0.55	<0.37	<0.45
DP-2A	<1.8	<1.4	2.3	1.2	1.4	1.0	<0.89
DP-2B	<0.9	<0.7	1.3	1.1	0.90	0.60	<0.45
DP-3A	<0.18	<0.14	<0.1	0.090	0.13	<0.074	<0.089
DP-3B	<1.8	<1.4	2.2	1.4	3.4	1.6	<0.89
DP-4A	<0.18	<0.14	<0.1	0.11	0.40	0.21	<0.089
DP-5A	<0.18	<0.14	<0.13	0.060	0.17	0.24	<0.089
DP-5B	<0.18	<0.14	<0.1	0.43	<0.12	0.12	<0.089
DP-6A	<0.18	<2.8	<14	290	290	41	<1.8
DP-6B	<0.9	<0.7	<11	9.2	31	6.6	<0.45
MW-104B	<0.18	<0.14	<0.1	<0.05	<0.11	<0.074	<0.089
MW-104C	<1.8	<1.4	2.0	0.50	<1.1	<0.74	<0.89
MW-110A	<0.36	<3.5	<28	550	390	330	<2.3
MW-110B	<0.18	<0.14	<0.1	1.4	<0.11	<0.074	<0.089
MW-110C	<0.18	<0.14	<0.1	0.23	0.74	0.21	<0.089
MW-111A	<1.8	<1.4	5.4	100.0	90	100	<0.89
MW-111B	<1.8	<1.4	2.7	23	40	30	<0.89
MW-111C	<0.18	<0.14	<0.1	<0.05	<0.11	<0.074	<0.089
MW-112A	<0.9	<0.7	1.9	1.4	2.0	1.2	<0.45
MW-112B	<0.9	<0.7	1.8	2.7	1.8	1.3	<0.45
MW-112C	<0.9	<0.7	1.9	8.4	4.4	1.9	<0.45
MW-113A	<0.45	<0.35	0.93	0.83	0.60	<0.19	<0.23
MW-113B	<0.18	<0.14	<0.16	0.47	0.66	0.59	<0.089
MW-113C	<0.18	<0.14	0.10	0.70	1.2	0.28	<0.089
MW-114A	<0.18	<0.14	<0.14	<0.22	1.0	0.31	<0.089
MW-114B	<0.18	<0.14	<0.12	<0.05	<0.11	<0.074	<0.089
MW-114C	<0.18	<0.14	<0.1	6.1	15	3.4	<0.089
MW-354A	<0.18	<0.14	0.12	0.13	0.17	0.13	<0.089
MW-354B	<0.9	<0.7	2.0	10	5.2	3.3	<0.45
MW-358A	<0.18	<0.14	0.11	<0.05	<0.11	0.080	<0.089
MW-358B	<0.9	<0.7	1.7	12	74	19	<0.45

Table A1
Results of 2012 Transect Monitoring Program - Wells Analyzed for Volatile Organic Compounds
LCP Chemical, Brunswick, GA

Location	Tetrachloroethene	Toluene	trans-1,2-Dichloroethene	trans-1,3-Dichloropropene	Trichloroethene	Vinyl chloride
DP-1A	<0.099	0.16	<0.072	<0.068	<0.1	<0.075
DP-1B	<0.5	<0.27	<0.36	<0.34	<0.5	<0.38
DP-2A	<0.99	3.2	<0.72	<0.68	<1	<0.75
DP-2B	<0.5	1.2	<0.36	<0.34	<0.5	<0.38
DP-3A	<0.099	0.12	<0.072	<0.068	<0.1	<0.075
DP-3B	<0.99	<0.54	<0.72	<0.68	<1	<0.75
DP-4A	<0.099	0.30	<0.072	<0.068	<0.1	<0.075
DP-5A	<0.099	0.14	<0.072	<0.068	<0.1	<0.075
DP-5B	<0.099	0.25	<0.072	<0.068	<0.1	<0.075
DP-6A	<2	63	<0.072	<1.4	<0.1	<0.075
DP-6B	<0.5	15	<0.36	<0.34	<0.5	<0.38
MW-104B	<0.099	<0.054	2.1	<0.068	1.3	0.24
MW-104C	<0.99	<0.54	3.0	<0.68	1.4	<0.75
MW-110A	<2.5	540	<0.15	<1.7	<0.2	<0.15
MW-110B	<0.099	0.30	<0.072	<0.068	<0.1	<0.075
MW-110C	<0.099	0.22	<0.072	<0.068	<0.1	<0.075
MW-111A	1.7	29	<0.72	<0.68	1.1	<0.75
MW-111B	<0.99	15	<0.72	<0.68	<1	<0.75
MW-111C	<0.099	<0.054	<0.072	<0.068	<0.1	<0.075
MW-112A	<0.5	1.1	<0.36	<0.34	<0.5	<0.38
MW-112B	<0.5	0.40	<0.36	<0.34	<0.5	<0.38
MW-112C	<0.5	1.3	<0.36	<0.34	<0.5	<0.38
MW-113A	<0.25	0.25	3.6	<0.17	0.33	2.3
MW-113B	<0.099	0.54	<0.072	<0.068	<0.1	<0.075
MW-113C	<0.099	0.37	0.14	<0.068	<0.1	0.18
MW-114A	<0.099	0.45	<0.072	<0.068	<0.1	<0.075
MW-114B	<0.099	<0.054	<0.072	<0.068	<0.1	<0.075
MW-114C	<0.099	3.1	<0.072	<0.068	<0.1	<0.075
MW-354A	<0.099	0.12	0.19	<0.068	<0.1	<0.075
MW-354B	<0.5	0.35	<0.36	<0.34	<0.5	<0.38
MW-358A	<0.099	0.23	<0.072	<0.068	<0.1	<0.075
MW-358B	<0.5	1.9	<0.36	<0.34	<0.5	<0.38

Concentrations expressed in microgram(s) per liter (μg/L)
< denotes non-detect result

Table A2
Results of 2012 Transect Monitoring Program - Analyzed for Polycylclic Aromatic Hydrocarbons
LCP Chemical, Brunswick, GA

Location	1,2,4-Trichlorobenzene	1,2-Dichlorobenzene	1,3-Dichlorobenzene	1,4-Dichlorobenzene	2-Methyl-naphthalene	Acenaphthene	Acenaphthylene	Anthracene
DP-1A	<0.096	<0.12	<0.1	<0.12	0.11	0.0084	<0.0034	0.016
DP-1B	<0.48	<0.6	<0.5	<0.6	2.6	0.77	<0.059	0.10
DP-2A	<0.96	<1.2	<1	<1.2	0.18	0.017	<0.007	0.072
DP-2B	<0.48	13	800	390	0.82	0.37	<0.048	0.091
DP-3A	<0.096	<0.12	0.14	<0.12	0.012	0.0078	<0.0034	<0.0036
DP-3B	<0.96	<1.2	<1	<1.2	0.088	<0.044	<0.034	<0.052
DP-4A	<0.096	0.23	1.7	3.5	0.011	0.14	0.019	0.013
DP-5A	<0.096	<0.12	0.78	2.7	0.74	0.14	<0.016	<0.012
DP-5B	410	1.1	21	34	0.039	0.35	<0.12	0.032
DP-6A	<0.096	<0.12	<0.1	<0.12	72	0.63	<0.18	0.052
DP-6B	<0.48	<0.6	1.1	<0.6	0.67	0.77	<0.085	<0.049
MW-104B	200	1.7	16	15	0.031	0.27	<0.03	0.024
MW-104C	150	1.4	76	68	0.033	0.40	<0.067	0.076
MW-110A	<0.2	<0.24	0.34	<0.24	6.5	0.87	<0.44	0.065
MW-110B	<0.096	<0.12	<0.1	<0.12	2.9	0.36	<0.049	0.027
MW-110C	0.32	<0.12	<0.1	<0.12	0.18	0.0089	<0.0037	<0.0039
MW-111A	<1.5	<1.2	<1	<1.2	200	3.0	<0.24	<1.7
MW-111B	<0.96	<1.2	<1	<1.2	62	1.0	<0.23	<0.17
MW-111C	<0.096	<0.12	<0.1	<0.12	0.011	<0.0088	<0.0068	<0.0072
MW-112A	<0.48	2.2	1.2	0.85	1.1	0.38	<0.11	1.3
MW-112B	<0.48	4.1	<0.5	<0.6	0.26	<0.044	<0.034	0.086
MW-112C	<0.48	31	<0.5	1.4	0.081	<0.044	<0.034	0.10
MW-113A	<0.24	<0.3	<0.25	<0.3	0.37	1.3	<0.11	0.63
MW-113B	<0.096	4.3	<0.1	<0.12	0.99	0.29	<0.037	0.025
MW-113C	<0.096	<0.12	<0.1	<0.12	0.29	<0.043	<0.0034	<0.0036
MW-114A	<0.096	<0.12	<0.1	<0.12	0.91	0.42	<0.07	0.036
MW-114B	<0.096	<0.12	<0.1	<0.12	0.017	0.16	<0.0052	0.021
MW-114C	<0.096	<0.12	<0.1	<0.12	0.011	<0.0093	<0.0035	0.0094
MW-354A	<0.096	20	0.59	9.4	0.015	0.24	<0.17	0.040
MW-354B	<0.48	85	0.55	12	0.47	0.25	<0.055	<0.15
MW-358A	<0.096	0.47	<0.1	0.34	0.018	<0.0063	<0.0093	<0.013
MW-358B	<0.48	280	1.6	38	1.8	0.13	<0.034	0.20

Table A2

Results of 2012 Transect Monitoring Program - Analyzed for Polycylclic Aromatic Hydrocarbons

LCP Chemical, Brunswick, GA

Location	Benzo(a)-anthracene	Benzo(a)-pyrene	Benzo(b)-fluoranthene	Benzo(g,h,i)-perylene	Benzo(k)-fluoranthene	Chrysene	Dibenzo(a,h)-anthracene	Dibenzofuran
DP-1A	<0.0026	<0.0043	<0.0023	<0.0029	<0.0025	<0.0034	<0.0025	0.0065
DP-1B	<0.013	<0.022	<0.012	<0.015	<0.013	<0.017	<0.013	0.23
DP-2A	<0.0054	0.016	<0.0047	0.0065	<0.0052	<0.007	0.010	0.016
DP-2B	0.11	0.036	0.036	0.015	<0.013	0.14	<0.013	0.21
DP-3A	<0.0026	<0.0043	<0.0023	<0.0029	<0.0025	<0.0034	<0.0025	<0.0046
DP-3B	<0.026	<0.043	<0.023	<0.029	<0.025	<0.034	<0.025	<0.046
DP-4A	<0.0052	<0.0086	<0.0046	<0.0058	<0.005	<0.0068	<0.005	<0.0092
DP-5A	<0.0052	<0.0086	<0.0046	<0.0058	<0.005	<0.0068	<0.005	0.047
DP-5B	<0.013	<0.022	<0.012	<0.015	<0.013	<0.017	<0.013	0.38
DP-6A	<0.026	<0.043	<0.023	<0.029	<0.025	<0.034	<0.025	0.66
DP-6B	<0.013	<0.022	<0.012	<0.015	<0.013	<0.017	<0.013	<0.13
MW-104B	<0.0056	<0.0093	<0.005	<0.0063	<0.0054	<0.0074	<0.0054	0.042
MW-104C	<0.006	<0.0098	0.013	<0.0066	<0.0057	<0.0078	<0.0057	0.15
MW-110A	<0.014	<0.023	<0.013	<0.016	<0.014	<0.019	<0.014	0.52
MW-110B	<0.015	<0.024	<0.013	<0.016	<0.014	<0.019	<0.014	0.11
MW-110C	<0.0028	<0.0046	<0.0025	<0.0031	<0.0027	<0.0037	<0.0027	0.0055
MW-111A	<0.052	<0.086	<0.046	<0.058	<0.05	<0.068	<0.05	<1.1
MW-111B	<0.026	<0.022	0.042	<0.015	<0.013	<0.017	<0.013	1.2
MW-111C	<0.0052	<0.0086	<0.0046	<0.0058	<0.005	<0.0068	<0.005	<0.0092
MW-112A	1.4	0.58	0.39	0.22	0.085	1.4	0.063	0.17
MW-112B	<0.026	0.066	0.090	0.029	<0.025	<0.034	<0.025	<0.046
MW-112C	0.59	0.34	0.34	0.16	<0.025	0.69	0.049	<0.046
MW-113A	0.045	0.0065	0.012	0.0074	<0.0025	0.033	<0.0025	1.0
MW-113B	<0.0026	<0.0043	<0.0023	<0.0029	<0.0025	<0.0034	<0.0025	0.099
MW-113C	<0.0026	<0.0043	<0.0023	<0.0029	<0.0025	<0.0034	<0.0025	<0.0046
MW-114A	<0.0026	<0.0043	<0.0023	<0.0029	<0.0025	<0.0034	<0.0025	0.19
MW-114B	<0.0026	<0.0043	<0.0023	<0.0029	<0.0025	<0.0034	<0.0025	0.050
MW-114C	<0.0027	<0.0044	<0.0024	<0.003	<0.0026	<0.0035	<0.0026	<0.0047
MW-354A	<0.0026	<0.0043	<0.0023	<0.0029	<0.0025	<0.0034	<0.0025	0.039
MW-354B	<0.0054	0.017	0.018	0.016	0.017	<0.007	<0.0052	<0.056
MW-358A	<0.0026	<0.0043	<0.0023	<0.0029	<0.0025	<0.0034	<0.0025	0.010
MW-358B	<0.026	<0.043	0.072	<0.029	<0.025	<0.034	<0.025	<0.046

Table A2
Results of 2012 Transect Monitoring Program - Analyzed for Polycylclic Aromatic Hydrocarbons
LCP Chemical, Brunswick, GA

Location	Fluoranthene	Fluorene	Hexachloro-butadiene	Indeno(1,2,3-cd) pyrene	Naphthalene	Phenanthrene	Pyrene
DP-1A	<0.0056	0.013	<0.11	<0.0026	0.21	0.028	0.012
DP-1B	0.030	0.51	<0.55	<0.013	1.2	0.67	0.042
DP-2A	0.058	0.043	<1.1	<0.0054	0.86	0.11	0.093
DP-2B	0.069	0.33	<0.55	<0.013	1.2	0.31	0.34
DP-3A	<0.0044	0.0059	<0.11	<0.0026	0.034	0.0052	<0.0035
DP-3B	<0.044	<0.038	<1.1	<0.026	0.53	<0.2	<0.035
DP-4A	<0.0088	0.027	<0.11	<0.0052	0.095	<0.01	0.030
DP-5A	0.022	0.091	<0.11	<0.0052	1.2	<0.029	0.10
DP-5B	<0.022	0.53	<0.11	<0.013	0.51	0.036	0.026
DP-6A	<0.044	0.75	<0.11	<0.026	260	0.72	0.077
DP-6B	<0.022	0.15	<0.55	<0.013	5.6	<0.076	0.024
MW-104B	<0.0095	0.087	<0.11	<0.0056	0.33	0.015	<0.0076
MW-104C	<0.01	0.17	<1.1	<0.006	0.22	<0.025	0.028
MW-110A	<0.024	0.68	<0.22	<0.014	110	0.78	0.038
MW-110B	<0.024	0.23	<0.11	<0.015	26	0.12	<0.02
MW-110C	<0.0047	<0.0041	<0.11	<0.0028	0.55	<0.0054	<0.0038
MW-111A	<0.088	0.35	<1.1	<0.052	150	<2.2	<0.07
MW-111B	<0.022	1.7	<1.1	<0.013	47	<0.13	0.028
MW-111C	<0.0088	<0.0076	<0.11	<0.0052	0.053	<0.01	<0.007
MW-112A	1.1	0.15	<0.55	0.11	0.49	0.86	5.0
MW-112B	<0.044	0.078	<0.55	0.038	2.3	0.12	0.063
MW-112C	0.17	<0.038	<0.55	0.090	6.4	0.12	1.1
MW-113A	0.15	1.3	<0.28	0.0055	0.90	1.1	0.42
MW-113B	<0.0044	0.24	<0.11	<0.0026	0.43	0.15	0.0052
MW-113C	<0.0044	<0.0038	<0.11	<0.0026	0.68	<0.34	<0.0035
MW-114A	0.0048	0.44	<0.11	<0.0026	0.55	0.029	0.0095
MW-114B	<0.0044	0.12	<0.11	<0.0026	0.20	0.013	0.0046
MW-114C	0.0068	<0.0091	<0.11	<0.0027	0.065	0.010	0.012
MW-354A	<0.0044	0.070	<0.11	<0.0026	0.099	0.010	<0.0035
MW-354B	<0.009	<0.094	<0.55	0.017	7.0	<0.11	0.073
MW-358A	<0.0044	<0.011	<0.11	<0.0026	0.033	<0.012	<0.0035
MW-358B	<0.044	0.10	<0.55	<0.026	19	0.057	0.045

Concentrations expressed in microgram(s) per liter (µg/L)
< denotes non-detect result

Table A3
Results of 2012 Transect Monitoring Program - Wells Analyzed for Target Analyte List Metals
LCP Chemicals, Brunswick, GA

Location	Aluminum	Aluminum, dissolved	Antimony	Antimony, dissolved	Arsenic	Arsenic, dissolved	Barium	Barium, dissolved	Beryllium	Beryllium, dissolved
DP-1A	4,750	353	0.480	0.510	3.74	2.73	586	621	0.110	<0.08
DP-1B	59,400	2,110	0.180	0.240	40.1	12.5	112	6.22	1.88	0.230
DP-2A	3,930	582	1.01	1.78	18.6	15.7	34.0	19.4	0.340	0.270
DP-2B	150,000	14,500	0.780	1.48	49.2	21.9	494	103	4.96	1.40
DP-3A	7,340	75.5	0.580	0.150	4.39	0.830	137	120	0.450	<0.04
DP-3B	3,260	2,310	0.180	0.710	16.9	14.3	131	128	8.02	7.01
DP-4A	2,310	296	0.140	0.400	4.86	3.98	282	272	0.0900	<0.04
DP-5A	14.4	4.20	0.880	0.140	2.61	1.99	177	170	<0.16	<0.16
DP-5B	176	52.2	0.0500	0.0300	0.350	0.280	6.05	5.65	0.0100	0.0100
DP-6A	179	67.4	0.0700	0.100	1.61	1.79	233	211	0.0100	0.0100
DP-6B	7,830	598	0.0700	0.420	28.7	7.64	240	40.3	0.160	0.0300
MW-104B	733	-	0.0500	-	1.34	-	23.5	-	1.15	-
MW-104C	22,200	-	0.490	-	15.9	-	411	-	24.0	-
MW-110A	45.4	-	0.0400	-	5.17	-	6.72	-	0	-
MW-110B	118	-	<0.003	-	0.120	-	17.0	-	0.130	-
MW-110C	10.2	-	0.580	-	0.610	-	529	-	<0.08	-
MW-111A	159,000	-	1.52	-	129	-	3,910	-	12.9	-
MW-111B	46,200	-	0.650	-	46.5	-	1,170	-	10.1	-
MW-111C	2.00	-	0.0900	-	0.390	-	94.5	-	<0.04	-
MW-112A	23,500	-	0.660	-	9.83	-	191	-	1.13	-
MW-112B	4,610	-	0.360	-	35.4	-	282	-	17.7	-
MW-112C	1,710	-	1.37	-	66.8	-	137	-	12.3	-
MW-113A	80,700	-	0.860	-	27.1	-	145	-	1.85	-
MW-113B	20,400	-	0.0700	-	6.77	-	99.1	-	1.55	-
MW-113C	105	-	1.81	-	2.03	-	7,160	-	<0.16	-
MW-114A	1,340	-	0.0700	-	1.54	-	9.31	-	0.0900	-
MW-114B	12,400	-	0.0500	-	5.09	-	67.0	-	1.58	-
MW-114C	221	-	<0.15	-	3.09	-	96.8	-	1.95	-
MW-354A	847	-	0.100	-	1.84	-	9.77	-	0.400	-
MW-354B	18,000	-	1.69	-	29.0	-	712	-	15.7	-
MW-358A	233	-	0.0600	-	0.510	-	5.76	-	0.790	-
MW-358B	7,540	-	0.360	-	46.6	-	59.8	-	36.2	-

Table A3
Results of 2012 Transect Monitoring Program - Wells Analyzed for Target Analyte List Metals
LCP Chemicals, Brunswick, GA

Location	Cadmium	Cadmium, dissolved	Calcium	Calcium, dissolved	Chromium	Chromium, dissolved	Chromium, hexavalent	Cobalt	Cobalt, dissolved	Copper
DP-1A	<0.14	<0.14	602,000	578,000	19.0	8.53	-	1.27	0.670	1.26
DP-1B	0.950	0.0700	2,360	1,050	56.7	13.6	-	29.7	4.81	6.82
DP-2A	<0.07	<0.07	96,800	79,800	38.7	30.0	-	2.40	3.43	9.41
DP-2B	1.29	0.120	25,500	14,800	243	87.7	-	25.0	10.1	24.9
DP-3A	0.120	0.0700	166,000	247,000	26.8	1.24	-	2.62	2.07	5.59
DP-3B	<0.14	<0.14	77,000	71,300	393	371	-	1.77	2.62	13.3
DP-4A	0.110	<0.07	211,000	206,000	5.91	2.87	-	0.510	0.290	0.820
DP-5A	<0.28	<0.28	333,000	342,000	<1.2	<1.2	-	<0.36	<0.36	0.930
DP-5B	<0.007	<0.007	24,800	24,600	2.45	2.01	-	0.0800	0.0300	0.180
DP-6A	0.0100	<0.007	60,800	61,300	1.75	1.55	-	0.260	0.260	0.290
DP-6B	4.99	0.200	18,300	12,700	34.7	10.4	-	33.2	2.91	61.8
MW-104B	<0.007	-	5,250	-	6.88	-	-	0.130	-	0.180
MW-104C	0.0800	-	31,500	-	137	-	-	1.63	-	5.46
MW-110A	<0.007	-	83,800	-	1.74	-	<40	0.0400	-	9.21
MW-110B	<0.007	-	2,620	-	0.570	-	-	<0.009	-	0.0900
MW-110C	<0.14	-	625,000	-	5.96	-	-	<0.18	-	<0.4
MW-111A	2.80	-	8,540	-	1,420	-	<40	24.8	-	43.0
MW-111B	0.830	-	5,160	-	438	-	-	9.31	-	15.7
MW-111C	<0.07	-	273,000	-	0.350	-	-	<0.09	-	<0.2
MW-112A	0.220	-	144,000	-	72.1	-	-	1.15	-	12.7
MW-112B	0.430	-	50,200	-	1,350	-	-	5.21	-	56.9
MW-112C	1.08	-	48,400	-	2,660	-	<40	9.24	-	231
MW-113A	0.290	-	21,500	-	138	-	-	4.54	-	19.7
MW-113B	0.410	-	1,110	-	26.2	-	-	1.98	-	1.77
MW-113C	<0.28	-	4,430,000	-	8.84	-	-	<0.36	-	4.98
MW-114A	0.0300	-	3,060	-	6.69	-	-	0.140	-	0.350
MW-114B	0.130	-	2,710	-	40.1	-	-	0.510	-	0.390
MW-114C	<0.35	-	84,900	-	65.9	-	-	<0.45	-	9.29
MW-354A	<0.07	-	3,640	-	11.1	-	-	0.350	-	0.830
MW-354B	<0.28	-	13,600	-	717	-	-	4.20	-	40.1
MW-358A	<0.07	-	29,200	-	8.79	-	-	0.200	-	2.39
MW-358B	0.280	-	9,740	-	1,220	-	<40	3.08	-	31.0

Table A3
Results of 2012 Transect Monitoring Program - Wells Analyzed for Target Analyte List Metals
LCP Chemicals, Brunswick, GA

Location	Copper, dissolved	Iron	Iron, dissolved	lead	Lead, dissolved	Magnesium	Magnesium, dissolved	Manganese	Manganese, dissolved	Mercury
DP-1A	<0.4	1,500	710	4.82	0.110	446,000	432,000	474	469	0.880
DP-1B	1.29	32,200	1,880	10.6	1.05	3,560	69.5	181	7.60	20.2
DP-2A	8.02	1,590	839	11.7	6.15	18,800	16,300	132	89.1	8.56
DP-2B	14.0	33,000	5,460	51.7	8.78	8,040	2,180	176	44.1	7.08
DP-3A	0.280	15,900	6,270	5.91	<0.02	103,000	68,400	907	1,110	0.0100
DP-3B	13.4	2,390	363	3.58	3.35	61,500	56,100	188	166	0.760
DP-4A	0.240	13,000	11,000	0.560	0.110	76,200	75,700	609	615	0.0600
DP-5A	<0.8	928	32.9	<0.08	<0.08	793,000	787,000	212	210	0
DP-5B	0.110	5,730	5,140	0.130	0.0500	7,330	7,030	238	230	0
DP-6A	0.190	2,510	2,260	0.450	0.0200	8,310	8,500	307	321	0
DP-6B	4.66	9,750	752	51.0	4.02	4,740	3,140	106	42.9	0.0200
MW-104B	-	274	-	0.100	-	1,340	-	15.0	-	0.0400
MW-104C	-	6,290	-	6.78	-	4,810	-	182	-	2.54
MW-110A	-	282	-	0.280	-	6,150	-	126	-	0.0100
MW-110B	-	1,940	-	<0.002	-	848	-	25.4	-	0
MW-110C	-	64,500	-	<0.04	-	59,100	-	1,900	-	0.0400
MW-111A	-	3,360	-	165	-	989	-	16.9	-	6.36
MW-111B	-	6,900	-	26.0	-	1,400	-	24.6	-	3.72
MW-111C	-	9,720	-	<0.02	-	51,800	-	556	-	0
MW-112A	-	2,710	-	20.6	-	127,000	-	645	-	4.96
MW-112B	-	1,160	-	9.05	-	4,760	-	153	-	7.72
MW-112C	-	7,430	-	7.63	-	172	-	110	-	15.0
MW-113A	-	11,800	-	66.8	-	68,100	-	48.8	-	27.6
MW-113B	-	6,830	-	3.47	-	1,180	-	25.8	-	3.44
MW-113C	-	17.4	-	0.320	-	18.7	-	0.400	-	69.1
MW-114A	-	5,110	-	1.42	-	399	-	28.2	-	0.100
MW-114B	-	8,470	-	5.58	-	785	-	46.0	-	0.280
MW-114C	-	336	-	<0.1	-	3,280	-	18.8	-	0.480
MW-354A	-	13.8	-	0.150	-	346	-	11.6	-	0.0300
MW-354B	-	593	-	5.33	-	1,820	-	30.7	-	0.530
MW-358A	-	18.0	-	0.140	-	54,500	-	25.9	-	0
MW-358B	-	1,050	-	3.22	-	348	-	48.4	-	12.5

Table A3
Results of 2012 Transect Monitoring Program - Wells Analyzed for Target Analyte List Metals
LCP Chemicals, Brunswick, GA

Location	Mercury, dissolved	Nickel	Nickel, dissolved	Potassium	Potassium, dissolved	Selenium	Selenium, dissolved	Silver	Silver, dissolved	Sodium
DP-1A	0.0900	6.06	3.33	72,500	70,700	<5	<5	0.330	0.220	4,500,000
DP-1B	3.27	33.2	13.3	4,060	949	<5	6.50	0.130	0.0400	160,000
DP-2A	4.96	41.7	27.5	15,300	14,200	7.60	5.70	0.220	0.120	2,340,000
DP-2B	2.21	45.2	15.5	7,740	3,780	12.9	12.1	0.170	0.0800	477,000
DP-3A	<0.02	17.2	14.2	53,400	37,600	<5	<5	0.100	<0.05	1,280,000
DP-3B	0.720	33.2	30.7	24,900	22,700	<5	6.30	0.130	0.150	5,010,000
DP-4A	<0.02	4.02	2.87	30,900	30,800	<5	<5	0.0500	<0.05	857,000
DP-5A	<0.02	<0.4	<0.4	241,000	243,000	<5	<5	<0.2	<0.2	6,610,000
DP-5B	<0.02	0.230	0.230	3,000	2,930	<5	<5	0	<0.005	46,900
DP-6A	<0.02	0.970	0.890	2,620	2,630	<5	<5	0.0100	<0.005	17,800
DP-6B	<0.02	17.2	2.55	3,110	1,890	7.10	<5	0.0400	0.0100	92,500
MW-104B	-	0.530	-	1,320	-	5.60	-	<0.005	-	112,000
MW-104C	-	13.6	-	3,110	-	5.80	-	<0.05	-	839,000
MW-110A	-	0.450	-	5,480	-	<5	-	<0.005	-	119,000
MW-110B	-	0.0400	-	2,250	-	<5	-	<0.005	-	94,500
MW-110C	-	0.470	-	9,990	-	<5	-	0.560	-	3,980,000
MW-111A	-	128	-	1,340	-	16.7	-	0.420	-	1,810,000
MW-111B	-	45.7	-	969	-	10.5	-	0.300	-	1,210,000
MW-111C	-	<0.1	-	2,960	-	<5	-	0.150	-	850,000
MW-112A	-	13.9	-	21,000	-	11.9	-	<0.05	-	2,360,000
MW-112B	-	145	-	12,200	-	13.1	-	<0.1	-	63,100,000
MW-112C	-	339	-	19,900	-	23.2	-	<0.2	-	10,900,000
MW-113A	-	41.0	-	18,000	-	12.2	-	0.0800	-	2,290,000
MW-113B	-	4.12	-	2,040	-	<5	-	<0.005	-	236,000
MW-113C	-	16.3	-	15,800	-	10.3	-	<0.2	-	1,750,000
MW-114A	-	0.440	-	577	-	<5	-	<0.005	-	67,100
MW-114B	-	1.03	-	1,690	-	6.60	-	<0.005	-	184,000
MW-114C	-	8.02	-	55,900	-	<5	-	<0.25	-	17,500,000
MW-354A	-	1.50	-	4,440	-	5.20	-	<0.05	-	383,000
MW-354B	-	94.4	-	8,510	-	11.6	-	<0.2	-	9,680,000
MW-358A	-	0.760	-	29,300	-	<5	-	<0.05	-	846,000
MW-358B	-	112	-	3,510	-	10.4	-	<0.2	-	8,770,000

Table A3
Results of 2012 Transect Monitoring Program - Wells Analyzed for Target Analyte List Metals
LCP Chemicals, Brunswick, GA

Location	Sodium, dissolved	Thallium	Thallium, dissolved	Vanadium	Vanadium, dissolved	Zinc	Zinc, dissolved
DP-1A	4,360,000	<0.008	<0.008	12.0	9.00	5.60	15.9
DP-1B	149,000	0.470	<0.0008	64.3	7.40	170	1.70
DP-2A	2,260,000	<0.004	<0.004	357	302	6.40	6.30
DP-2B	425,000	0.440	<0.004	360	252	167	11.9
DP-3A	1,000,000	0.0500	<0.004	16.2	2.80	20.8	10.1
DP-3B	4,260,000	<0.008	<0.008	734	688	10.4	6.70
DP-4A	848,000	<0.004	<0.004	9.60	6.10	2.90	2.00
DP-5A	6,450,000	<0.016	<0.016	4.70	4.60	<0.7	<0.7
DP-5B	45,800	<0.0004	<0.0004	2.10	2.60	4.80	<0.7
DP-6A	17,600	<0.0004	<0.0004	2.90	2.00	0.900	<0.7
DP-6B	83,900	1.25	0.0400	24.2	9.50	180	6.90
MW-104B	-	0	-	19.0	-	0.700	-
MW-104C	-	<0.02	-	295	-	6.20	-
MW-110A	-	<0.0004	-	3.00	-	4.20	-
MW-110B	-	<0.0004	-	9.80	-	<0.7	-
MW-110C	-	<0.008	-	7.30	-	1.30	-
MW-111A	-	0.540	-	2,010	-	66.1	-
MW-111B	-	0.210	-	654	-	39.0	-
MW-111C	-	<0.004	-	1.10	-	1.20	-
MW-112A	-	0.0200	-	140	-	21.7	-
MW-112B	-	<0.008	-	2,790	-	33.6	-
MW-112C	-	<0.016	-	6,680	-	62.0	-
MW-113A	-	0.120	-	155	-	49.0	-
MW-113B	-	0.0400	-	82.2	-	35.2	-
MW-113C	-	<0.016	-	16.6	-	13.1	-
MW-114A	-	0	-	10.9	-	4.90	-
MW-114B	-	0	-	117	-	9.50	-
MW-114C	-	<0.02	-	240	-	7.70	-
MW-354A	-	<0.004	-	34.8	-	4.10	-
MW-354B	-	<0.016	-	1,350	-	24.7	-
MW-358A	-	<0.004	-	25.1	-	9.30	-
MW-358B	-	<0.016	-	2,310	-	30.0	-

Concentrations are expressed in milligram(s) per lliter (mg/L)

< denotes non-detect result

- denotes parameter not sampled

Table A4
Results of 2012 Transect Monitoring Program - Wells Analyzed for Polychlorinated Biphenyls
LCP Chemical, Brunswick, GA

Location	Aroclor-1016	Aroclor-1221	Aroclor-1232	Aroclor-1242	Aroclor-1248	Aroclor-1254	Aroclor-1260	Aroclor-1268
DP-1A	<0.049	<0.057	<0.049	<0.049	<0.11	<0.049	<0.049	<0.049
DP-1B	<0.049	<0.3	<0.049	<0.049	<0.049	<0.067	<0.049	<0.049
DP-2A	<0.051	<0.051	<0.051	<0.051	<0.051	<0.051	<0.051	<0.051
DP-2B	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049
DP-3A	<0.049	<0.064	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049
DP-3B	<0.49	<0.49	<0.49	<0.49	<0.49	<0.49	<0.49	<0.49
DP-4A	<0.049	<0.089	<0.23	<0.049	<0.049	<0.049	<0.049	<0.049
DP-5A	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049
DP-5B	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049
DP-6A	<0.049	<0.47	<0.08	<0.049	<0.049	<0.049	<0.049	<0.049
DP-6B	<0.062	<0.2	<0.11	<0.059	<0.049	<0.049	<0.049	<0.049
MW-104B	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049
MW-104C	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
MW-110A	<0.49	<9.8	<0.49	<0.49	<0.49	<0.49	<0.49	<0.49
MW-110B	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049
MW-110C	<0.049	<0.096	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049
MW-111B	<0.049	<0.16	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049
MW-111C	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049
MW-112A	<0.055	<0.055	<0.055	<0.055	<0.055	<0.055	<0.055	<0.055
MW-112B	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049
MW-112C	<0.057	<0.057	<0.057	<0.057	<0.057	<0.057	<0.057	<0.057
MW-113A	<0.056	<0.056	<0.056	<0.056	<0.056	<0.056	<0.056	<0.056
MW-113B	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049
MW-113C	<0.13	<1.5	<0.9	<0.15	<0.093	<0.049	<0.049	<0.049
MW-114A	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049
MW-114B	<0.053	<0.053	<0.053	<0.053	<0.053	<0.053	<0.053	<0.053
MW-114C	<0.057	<0.057	<0.057	<0.057	<0.057	<0.057	<0.057	<0.057
MW-354A	<0.054	<0.2	<0.054	<0.054	<0.054	<0.054	<0.054	<0.054
MW-354B	<0.056	<0.056	<0.056	<0.056	<0.056	<0.056	<0.056	<0.056
MW-358A	<0.051	<0.051	<0.051	<0.051	<0.051	<0.051	<0.051	<0.051
MW-358B	<0.54	<0.54	<0.54	<0.54	<0.54	<0.54	<0.54	<0.54

Concentrations expressed in microgram(s) per liter (µg/L)
< denotes non-detect result

Table A5

Results of 2012 Transect Monitoring Program - General Geochemical Indicator Parameters (Laboratory Measurements)

LCP Chemical, Brunswick, GA

Location	Chloride	pH	Silica, as SiO2	Sulfate	Sulfide	Total Dissolved Solids (TDS)	Total Organic Carbon (TOC)
DP-1A	8,300	6.49	11.9	1,780	2.80	16,100	96.2
DP-1B	20.7	9.35	22.3	13.0	1.40	821	39.9
DP-2A	2,800	9.14	65.6	229	9.40	6,610	390
DP-2B	331	8.54	9.7	2.90	0.850	2,110	249
DP-3A	1,880	6.27	17.1	551	<0.03	4,690	26.1
DP-3B	6,890	7.53	19.0	3.10	50.2	13,700	635
DP-4A	1,950	6.34	8.30	248	2.26	4,050	60.6
DP-5A	13,500	7.18	14.8	1,720	1.79	24,500	9.10
DP-5B	21.0	6.37	18.4	37.8	1.95	276	13.8
DP-6A	57.5	6.16	37.7	4.45	7.82	458	46.0
DP-6B	37.0	6.64	96.2	2.39	4.10	925	18.2
MW-104B	-	6.19	-	-	-	423	-
MW-104C	-	6.5	-	-	-	2,170	-
MW-110A	-	6.4	-	-	-	610	-
MW-110B	-	5.09	-	-	-	303	-
MW-110C	-	6.08	-	-	-	15,400	-
MW-111A	-	6.63	-	-	-	10,100	-
MW-111B	-	9.74	-	-	-	5,000	-
MW-111C	-	6.85	-	-	-	3,900	-
MW-112A	-	7.52	-	-	-	6,180	-
MW-112B	-	8.8	-	-	-	18,900	-
MW-112C	-	10.2	-	-	-	30,900	-
MW-113A	-	8.14	-	-	-	8,350	-
MW-113B	-	9.69	-	-	-	1000	-
MW-113C	-	11.9	-	-	-	25,200	-
MW-114A	-	6.83	-	-	-	278	-
MW-114B	-	7.1	-	-	-	868	-
MW-114C	-	8.56	-	-	-	45,800	-
MW-354A	-	6.77	-	-	-	918	-
MW-354B	-	7.52	-	-	-	28,000	-
MW-358A	-	6.86	-	-	-	2,520	-
MW-358B	-	10.7	-	-	-	25,000	-

Concentrations are expressed in milligram(s) per lliter (mg/L)

< denotes non-detect result

- denotes parameter not sampled

Table A6

Results of 2012 Transect Monitoring Program - General Geochemical Indicator Parameters (Field Measurements)

LCP Chemical, Brunswick, GA

Location	Conductivity (mS/cm)	Dissolved Oxygen (µg/L)	Eh, field (mv)	pH, field	Salinity %	Temperature, field (°C)	Turbidity, field (NTU)
DP-1A	26.2	1.31	-110	6.41	---	20.91	72.2
DP-1B	0.559	0.2	-313	9.27	0.01	21.4	774
DP-2A	11	1.56	-331	9.21		22.57	181
DP-2B	1.94	0.21	-356	8.49	0.07	21.93	71,000
DP-3A	5.27	4.09	-94	5.72	0.28	22.19	377
DP-3B	22.5	0.05	-384	7.24	---	20.81	35.5
DP-4A	6.45	0.03	-221	6.17	---	21.41	80
DP-5A	36.9	0.21	-304	7.24	2.25	24.76	0
DP-5B	0.437	2.73	-184	6.29	---	22.24	0
DP-6A	0.506	1	-244	5.49	0.02	21.74	0
DP-6B	0.477	0.04	-255	6.44	---	21.26	776
MW-104B	0.491	1.42	-176	5.86	0.01	21.83	1.52
MW-104C	3.39	0.5	-184	6.24	0.16	21.83	1.4
MW-110A	1.08	0.13	-305	6.17	---	20.99	8.89
MW-110B	0.573	1.41	75	4.81	---	20.73	0
MW-110C	22.6	0.61	-5	5.82	---	20.78	19
MW-111A	6.07	4.52	-328	6.49	0.27	21.19	48
MW-111B	5.24	0.87	-420	9.64	---	20.71	50.2
MW-111C	6.36	0.52	-56	6.7	---	21	2.64
MW-112A	10.4	0	-309	6.89	---	21.14	69.4
MW-112B	24.9	0.24	-420	8.94	1.46	22.91	10.1
MW-112C	38.7	0.75	-589	9.29	2.39	23.35	16.4
MW-113A	12.2	0.44	-391	7.88	---	23.87	119
MW-113B	1.04	0.39	-310	8.74	0.05	24.23	132
MW-113C	31	0.94	-97	11.94	---	25.42	4.75
MW-114A	0.253	0.93	-150	6.38	0.01	21.03	3.1
MW-114B	0.764	0	-50	6.17	---	20.7	9.1
MW-114C	66.9	0.88	-299	7.9	4.54	21.9	0.43
MW-354A	1.77	0.53	-265	5.71	0.09	22.02	0.01
MW-354B	5	0.03	-386	7.27	---	21.51	9.74
MW-358A	4.45	1.59	-289	6.14	0.24	22.44	0
MW-358B	32	0.14	-573	10.9	2.03	22.04	3.98

--- denotes parameter not sampled
°C: degrees Celsius
mS/cm: millisieman(s) per centimeter
µg/L: microgram(s) per liter
mv: millivolts
NTU: Nephelometric Turbidity Units

Table A7
Measured Groundwater Elevation and Density Correction
LCP Chemical, Brunswick, GA

Location	Top of Casing Elevation (ft MSL)	Depth to Water from Top of Casing (ft)	Total Dissolved Solids (mg/L)	Groundwater Density (g/cm^3)	Corrected Groundwater Elevation (ft MSL)
MW-514B	12.52	7.39	9,660	1.005	5.32
MW-515A	12.73	7.77	5,020	1.002	5.01
MW-515B	12.64	8.14	14,300	1.008	4.85
MW-516A	10.96	6.50	7,210	1.003	4.56
MW-516B	10.85	6.98	29,800	1.019	4.71
MW-517A	12.79	7.90	4,850	1.002	4.94
MW-517B	12.89	8.53	17,600	1.011	4.80
MW-518A	11.54	7.14	8,160	1.004	4.52
MW-518B	11.63	7.82	14,700	1.009	4.16
MW-519A	12.87	7.99	4,920	1.002	4.93
MW-519B	12.90	8.27	42,900	1.028	5.81

ft MSL: feet above mean sea level
mg/L: milligram(s) per liter
g/cm^3: gram(s) per cubic centimeter

Table A8
Definition of the Individual Transects
LCP Chemical, Brunswick, GA

Transect	Monitoring Locations Making up the Transect
1	MW-114, DP-1, MW-113, DP-2, MW-112
2	MW-112, DP-3, MW-358
3	MW-358, MW-354, MW-104, DP-4
4	DP-4, DP-5, MW-110
5	MW-110, DP-6, MW-111

Table A9
Hydraulic Conductivity from Slug Tests at Transect Wells
(Geosyntec 1997)
LCP Chemical, Brunswick, GA

Well	Hydraulic Conductivity (cm/sec)
MW-104A	1.18E-02
MW-104B	2.90E-02
MW-104C	1.60E-02
MW-112A	1.90E-02
MW-112B	1.19E-02
MW-112C	2.05E-03
MW-113A	1.30E-02
MW-113B	7.37E-03
MW-113C	9.85E-04
MW-114A	4.30E-03
MW-114B	1.52E-02
MW-114C	1.00E-03
MW-354A	1.42E-02
MW-354B	2.97E-03
MW-358A	1.05E-02
MW-358B	2.19E-02

cm/sec: centimeter(s) per second

Table A10
Concentrations of Mercury, Lead, and Total Polycyclic Aromatic Hydrocarbon, in Each Well Used in the Transect Calculation
LCP Chemical, Brunswick, GA

Well	Mercury (µg/L)	Lead (µg/L)	Total PAH (µg/L)
DP-1A	8.80E-01	4.80E+00	2.10E-01
DP-1B	2.02E+01	1.06E+01	5.04E+00
DP-2A	8.56E+00	1.17E+01	6.39E-01
DP-2B	7.08E+00	5.17E+01	2.92E+00
DP-3A	1.08E-02	5.91E+00	5.22E-02
DP-3B	7.60E-01	3.58E+00	4.50E-01
DP-4A	6.47E-02	5.64E-01	2.77E-01
DP-4C	2.54E+00	6.78E+00	9.45E-01
DP-5A	6.90E-04	0.00E+00	1.19E+00
DP-5B	1.13E-04	1.31E-01	1.52E+00
DP-6A	1.74E-03	4.53E-01	7.51E+01
DP-6B	2.40E-02	5.10E+01	1.85E+00
MW-104B	3.73E-02	1.00E-01	5.18E-01
MW-104C	2.54E+00	6.78E+00	9.45E-01
MW-110A	8.19E-03	2.75E-01	9.75E+00
MW-110B	2.60E-04	0.00E+00	3.86E+00
MW-110C	3.89E-02	0.00E+00	2.20E-01
MW-111A	6.36E+00	1.65E+02	2.06E+02
MW-111B	3.72E+00	2.60E+01	6.63E+01
MW-111C	1.80E-03	0.00E+00	6.68E-02
MW-112A	8.00E-02	2.06E+01	2.85E+01
MW-112B	7.72E+00	9.05E+00	9.69E-01
MW-112C	1.50E+01	7.63E+00	3.92E+00
MW-113A	2.76E+01	6.68E+01	6.44E+00
MW-113B	3.44E+00	3.47E+00	1.83E+00
MW-113C	6.91E+01	3.18E-01	5.05E-01
MW-114A	1.03E-01	1.42E+00	2.09E+00
MW-114B	2.78E-01	5.58E+00	4.02E-01
MW-114C	4.80E-01	0.00E+00	7.45E-02
MW-354A	2.50E-02	1.54E-01	5.15E-01
MW-354B	5.30E-01	5.33E+00	1.12E+00
MW-358A	3.43E-03	1.36E-01	6.93E-02
MW-358B	1.25E+01	3.22E+00	2.57E+00

µg/L: microgram(s) per liter
PAH: polycyclic aromatic hydrocarbon

Table A11
Depth to Water Table Used for Calculating Mass Discharge
LCP Chemical, Brunswick, GA

Well	Depth to Water Table (ft)
DP-1	2.76
DP-2	3.39
DP-3	4.63
DP-4	3.39
DP-5	4.26
DP-6	3.10
MW-104	3.48
MW-110	4.32
MW-111	2.35
MW-112	3.14
MW-113	3.24
MW-114	5.49
MW-354	3.59
MW-358	3.24

ft: feet

Table A12
Computed Mass Discharge Towards the Marsh
LCP Chemical, Brunswick, GA

Transect	Mercury (kg/yr)	Lead (kg/yr)	Total PAH (kg/yr)
1	0.35	0.73	0.15
2	0.051	0.13	0.11
3	0.022	0.018	0.012
4	0.002	0.007	0.030
5	0.022	0.62	0.72

kg/yr: kilogram(s) per year
PAH: polycyclic aromatic hydrocarbon

Appendix A
Groundwater Evaluation

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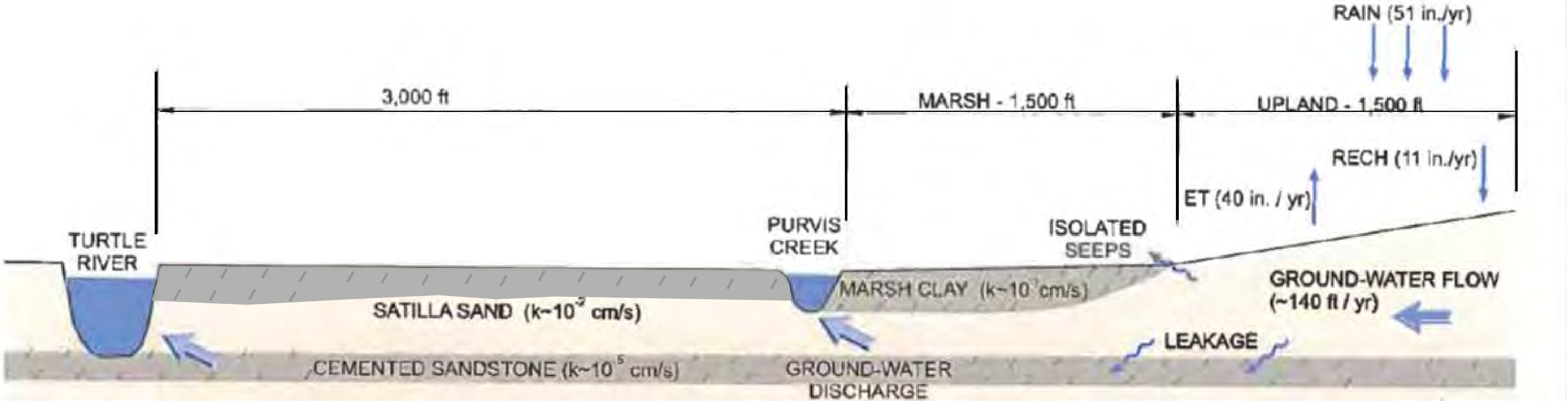
Figures

DRAFT



Source: Adapted from Figure 2.1-1 1997 RI Report (GeoSyntec Consultants, 1997)

ENVIRON ANCHOR QEA

Shallow Groundwater Flow System

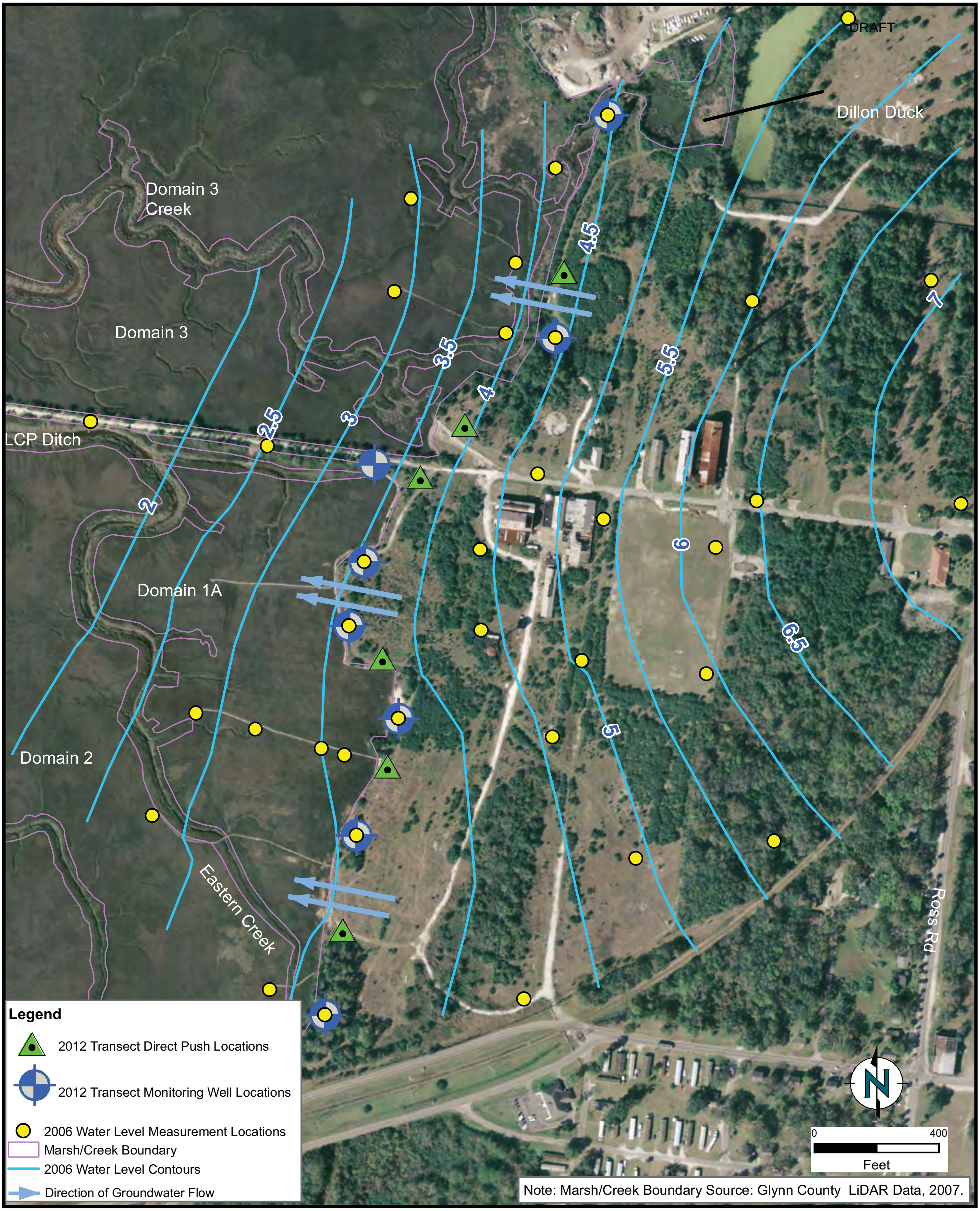
LCP CHEMICAL SITE
BRUNSWICK, GA

Figure
A1

DRAFTED BY:

DATE: 9/12/2012

0227105C



Note: Marsh/Creek Boundary Source: Glynn County LiDAR Data, 2007.

ENVIRON
ANCHOR QEA

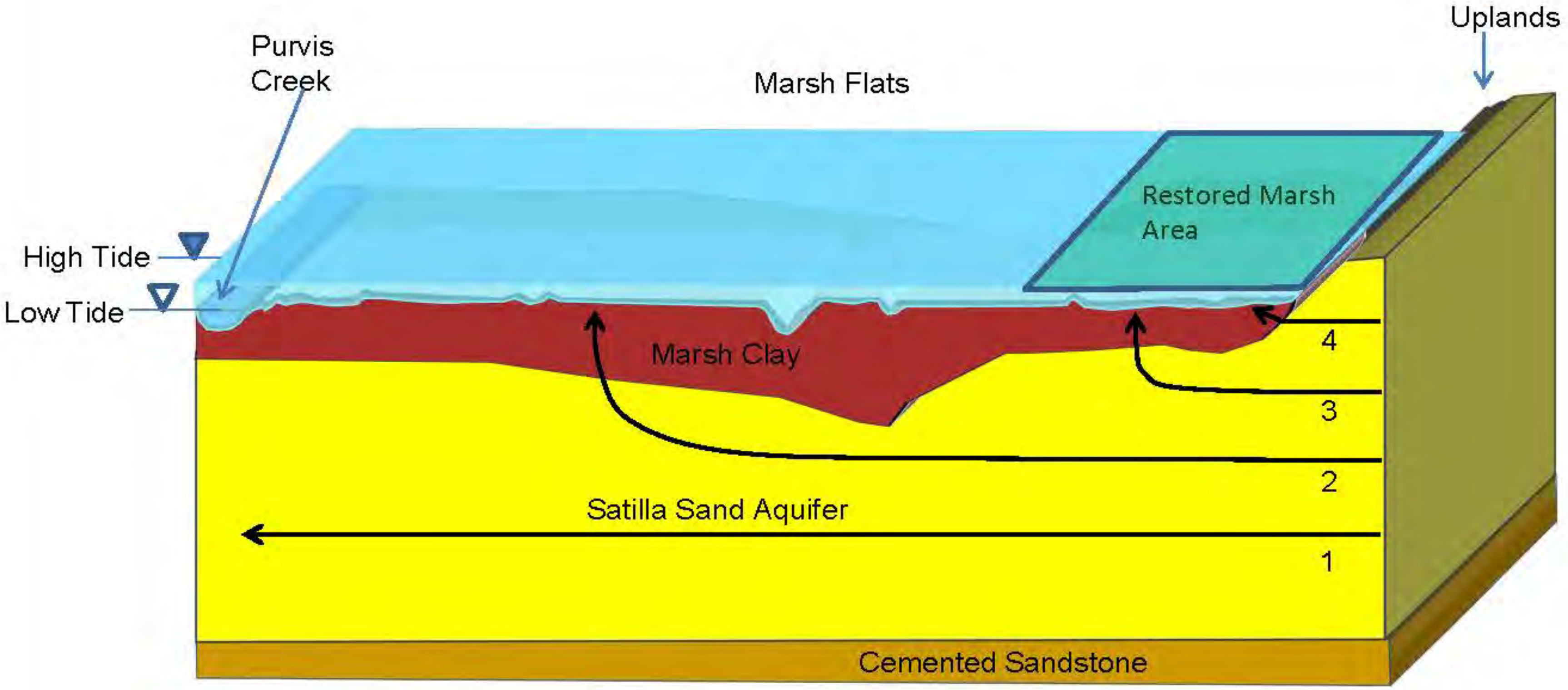
DRAFTED BY: MRJ
DATE: 09/12/2012

Groundwater Flow Direction and Gradients

LCP CHEMICAL SITE
BRUNSWICK, GA

Figure
A2

PROJECT: 02-27105C



1 Net Flow Path to Purvis Creek and Beyond
2 Net Flow Path to Marsh Flats and Intertidal Channels
3 Net Flow Path to Restored Marsh Area
4 Net Flow Path to Nearshore Seeps

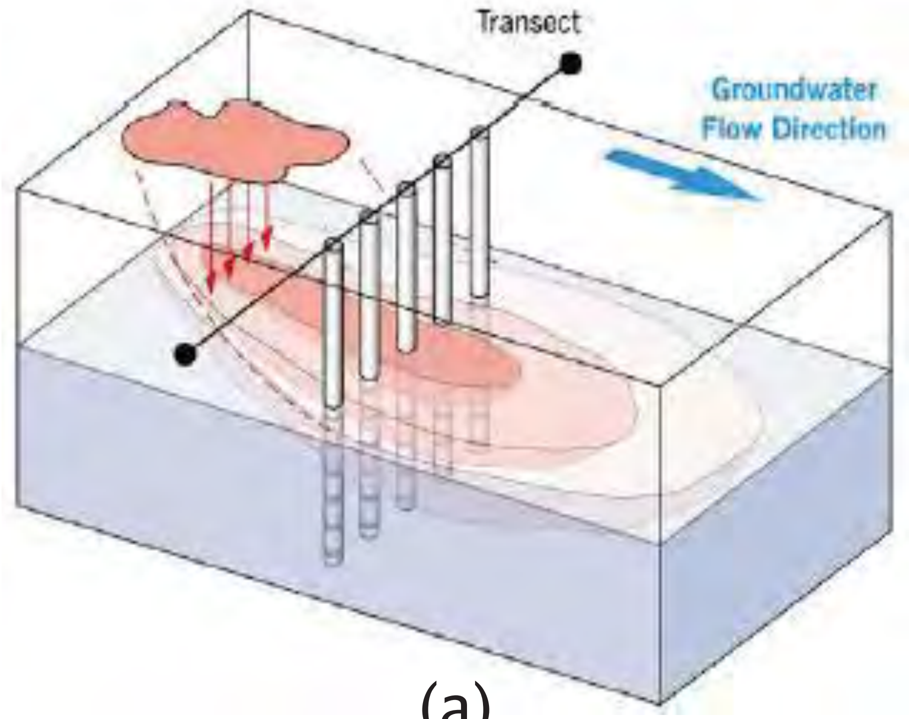
Note: Tidal forces can reverse groundwater flows beneath the marsh

ENVIRON
ANCHOR QEA

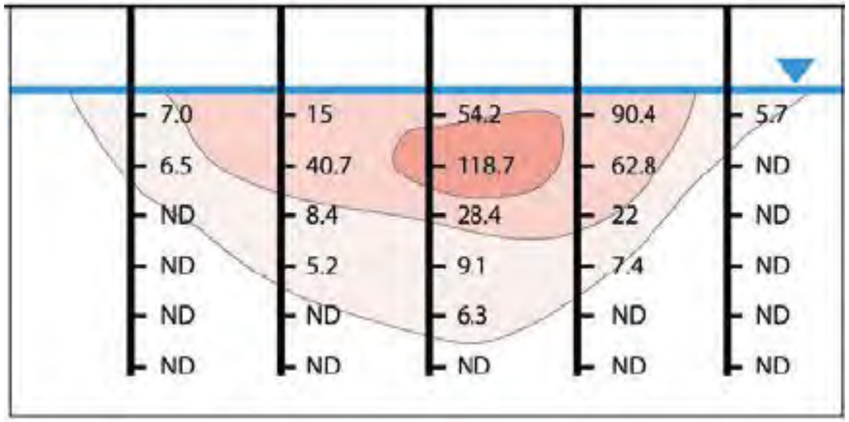
Groundwater Conceptual Site Model

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

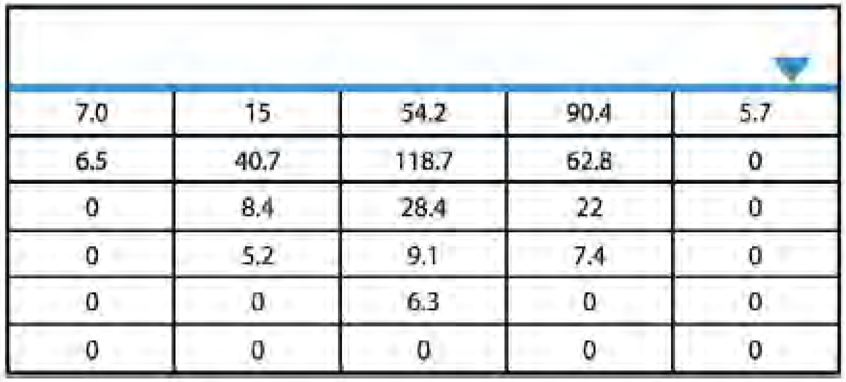
Figure
A3



(a)



(b)



7.0	15	54.2	90.4	5.7
6.5	40.7	118.7	62.8	0
0	8.4	28.4	22	0
0	5.2	9.1	7.4	0
0	0	6.3	0	0
0	0	0	0	0

(c)

Note: Adapted from ITRC 2010 Figure 4-1

ENVIRON ANCHOR QEA

DRAFTED BY:

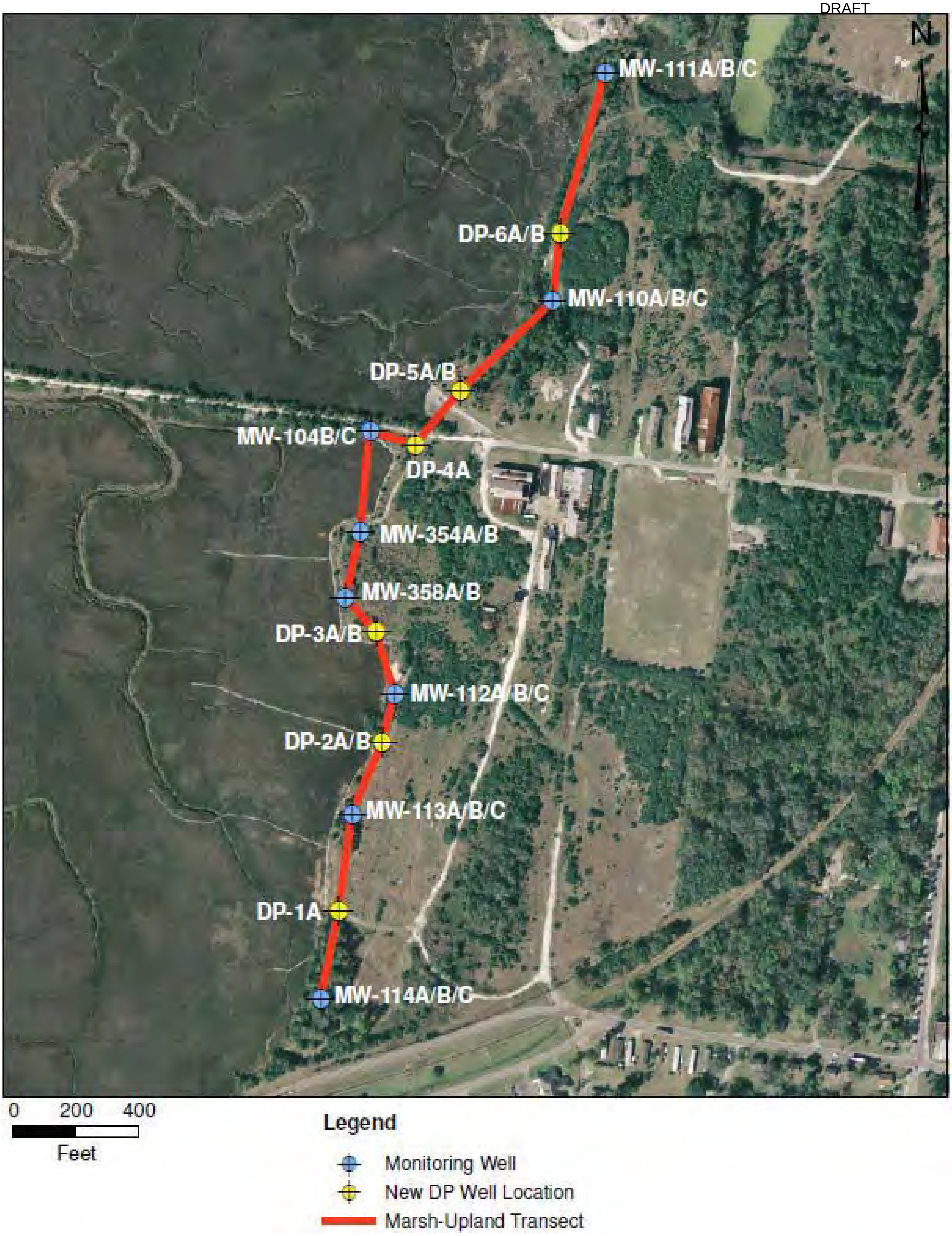
DATE: 9/12/2012

The Transect Method

LCP CHEMICAL SITE
BRUNSWICK, GA

Figure
A4

0227105C



Note: Figure content prepared by Environmental Planning Specialists, Inc.

ENVIRON ANCHOR QEA

Marsh-Upland Transect Monitoring Wells

LCP CHEMICAL SITE
BRUNSWICK, GA

Figure
A5

DRAFTED BY:

DATE: 3/11/2013

0227105C

DRAFT

Note: Figure content prepared by Environmental Planning Specialists, Inc.

ENVIRON ANCHOR QEA

DRAFTED BY:

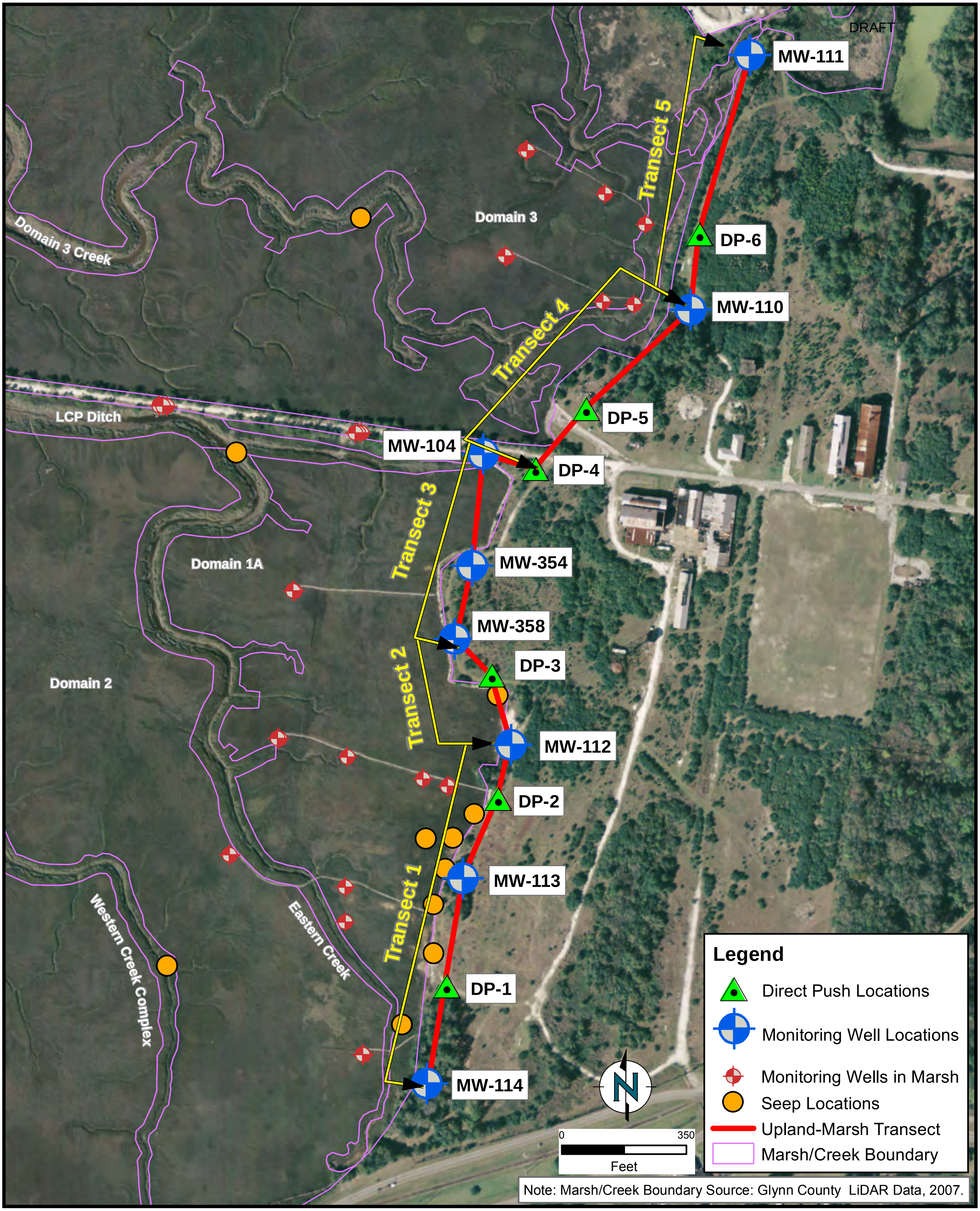
DATE: 3/11/2013

Potentiometric Surface Map April 2012
Upper Satilla Aquifer

LCP CHEMICAL SITE
BRUNSWICK, GA

Figure
A6

0227105C



Note: Marsh/Creek Boundary Source: Glynn County LiDAR Data, 2007.

ENVIRON ANCHOR QEA

DRAFTED BY: MRJ

DATE: 3/28/2012

Well Locations Included in the Site Transect Calculation

LCP CHEMICAL SITE
BRUNSWICK, GA

Figure
A7

PROJECT: 0227105C

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Attachment A1

Boring logs (EPS 2012)

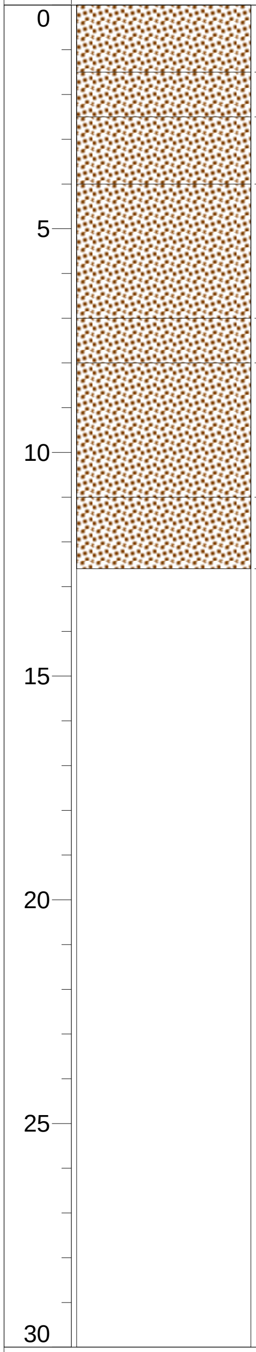
PROJECT: **LCP, Brunswick GA**		**Log of Boring No. DP-1A**	
SITE LOCATION:	4125 Ross Road	TOP OF CASING ELEVATION (ft): 8.42	
DRILLING CONTRACTOR:	Atlas Geo-Sampling	DATE STARTED: 5/14/2012	DATE FINISHED: 5/14/2012
DRILLING METHOD:	Direct Push	TOTAL DEPTH (ft.): 12.61	SCREEN INTERVAL (ft.): 2.61-12.61
DRILLING EQUIPMENT:	T190 on 9635 Skid	DEPTH TO WATER AT TIME OF BORING (ft.):	CASING (ft.): 0-2.61
SAMPLING METHOD:	DP Technology w/ Acetate Liner	LOGGED BY: K. Kessler	

DEPTH (feet)

DESCRIPTION

Stick-Up Value (ft): 0.42

WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS



brown med. SAND (potential backfill)

gray fine-med. SAND; slight staining

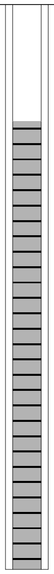
gray fine-med. SAND; no staining

brown fine-med. SAND; sand saturated at 4.5ft

brown med. SAND

dark brown med. SAND

brown med-coarse SAND

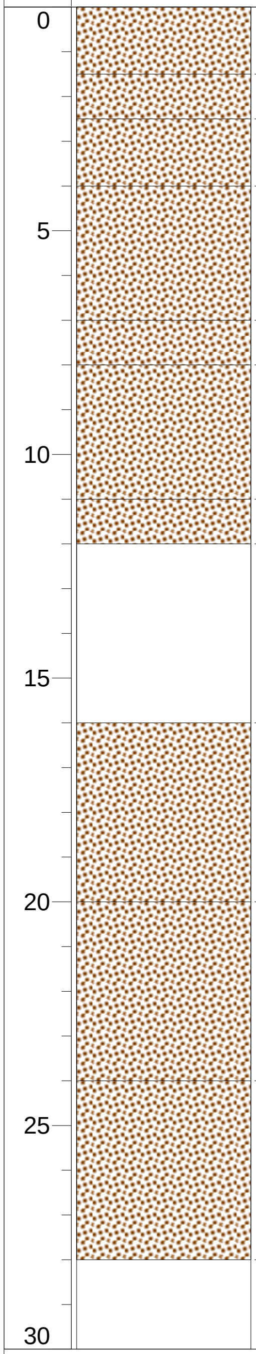


Well constructed using 2 inch schedule 40 PVC with a prepacked screen.

EPS

PROJECT: **LCP, Brunswick GA**	**Log of Boring No. DP-1B**		
SITE LOCATION: 4125 Ross Road	TOP OF CASING ELEVATION (ft): 8.87		
DRILLING CONTRACTOR: Atlas Geo-Sampling	DATE STARTED: 5/14/2012	DATE FINISHED: 5/14/2012	
DRILLING METHOD: Direct Push	TOTAL DEPTH (ft.): 29.18	SCREEN INTERVAL (ft.): 24.18-29..18	
DRILLING EQUIPMENT: T190 on 9635 Skid	DEPTH TO WATER AT TIME OF BORING (ft.):	CASING (ft.): 0-24.18	
SAMPLING METHOD: DP Technology w/ Acetate Liner	LOGGED BY: K. Kessler		

DEPTH (feet)	DESCRIPTION	WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS
	Stick-Up Value (ft): 0.87	



brown med. SAND (potential backfill)

gray fine-med. SAND; slight staining

gray fine-med. SAND; no staining

brown fine-med. SAND; sand saturated at 4.5ft

brown med. SAND

dark brown med. SAND

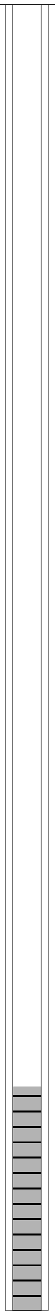
brown med-coarse SAND

no recovery

dark gray well sorted med. SAND

gray fine-med. SAND (slightly finer grained than previous run)

gray fine-med. SAND

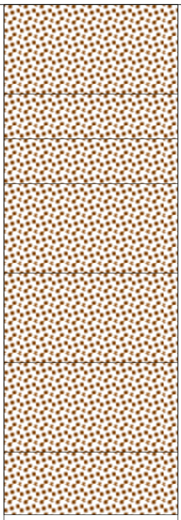


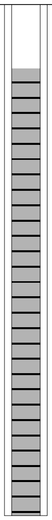
Well constructed using 2 inch schedule 40 PVC with a prepacked screen.

EPS

PROJECT: **LCP, Brunswick GA**		**Log of Boring No.**	**DP-2A**
SITE LOCATION:	4125 Ross Road	TOP OF CASING ELEVATION (ft):	8.11
DRILLING CONTRACTOR:	Atlas Geo-Sampling	DATE STARTED: 5/15/2012	DATE FINISHED: 5/15/2012
DRILLING METHOD:	Direct Push	TOTAL DEPTH (ft.): 11.43	SCREEN INTERVAL (ft.): 1.43-11.13
DRILLING EQUIPMENT:	T190 on 9635 Skid	DEPTH TO WATER AT TIME OF BORING (ft.):	CASING (ft.): 0-1.43
SAMPLING METHOD:	DP Technology w/ Acetate Liner	LOGGED BY:	J. Vickery

Stick-Up Value (ft): 0.7





DEPTH (feet)	DESCRIPTION	WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS
0	fine SAND, light brown, no odor	
	fine SAND "beach", light tan, no odor	
	fine SAND, gray	
5	fine SAND, med. gray, wet with sulfur odor	Well constructed using 2 inch schedule 40 PVC with a prepacked screen.
	fine SAND, dark brown, wet with sulfur odor	
	fine SAND, dark brown, sulfur odor	
10	fine to med SAND, med tan color	
15		
20		
25		
30		

PROJECT: **LCP, Brunswick GA**		**Log of Boring No.**	**DP-2B**
SITE LOCATION:	4125 Ross Road	TOP OF CASING ELEVATION (ft):	8.53
DRILLING CONTRACTOR:	Atlas Geo-Sampling	DATE STARTED: 5/15/2012	DATE FINISHED: 5/15/2012
DRILLING METHOD:	Direct Push	TOTAL DEPTH (ft.): 28.68	SCREEN INTERVAL (ft.): 23.68-28.68
DRILLING EQUIPMENT:	T190 on 9635 Skid	DEPTH TO WATER AT TIME OF BORING (ft.):	CASING (ft.): 0-23.68
SAMPLING METHOD:	DP Technology w/ Acetate Liner	LOGGED BY:	J. Vickery

DEPTH (feet)

DESCRIPTION

Stick-Up Value (ft): 1.12

WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS

0

5

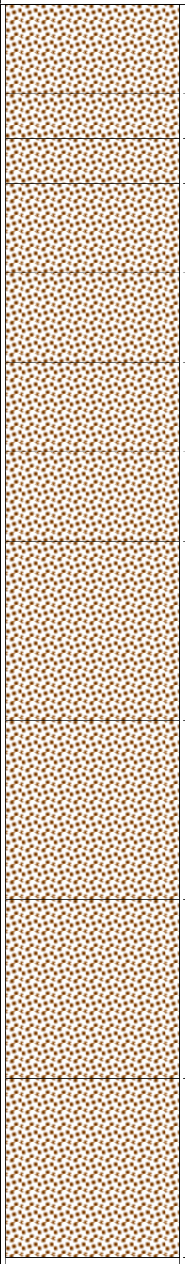
10

15

20

25

30



fine SAND, light brown, no odor

fine SAND "beach", light tan, no odor

fine SAND, gray

fine SAND, med. gray, wet with sulfur odor

fine SAND, dark brown, wet with sulfur odor

fine SAND, dark brown, sulfur odor

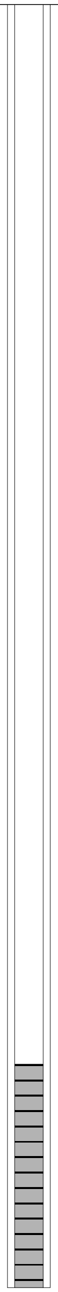
fine to med SAND, med tan color

fine to med SAND, med tan color

fine to med SAND, med tan color, petroleum odor

Fine to med. SAND, dark gray

Fine to med. SAND, dark gray

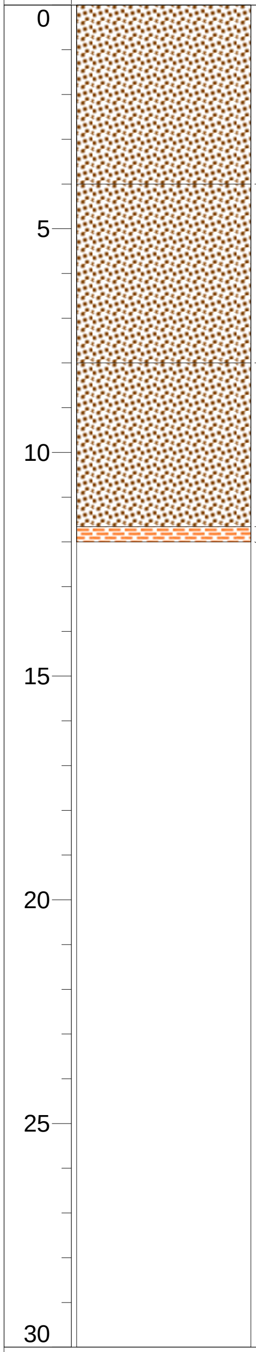


Well constructed using 2 inch schedule 40 PVC with a prepacked screen.

EPS

PROJECT: **LCP, Brunswick GA**		**Log of Boring No. DP-3A**	
SITE LOCATION:	4125 Ross Road	TOP OF CASING ELEVATION (ft): 8.84	
DRILLING CONTRACTOR:	Atlas Geo-Sampling	DATE STARTED: 5/15/2012	DATE FINISHED: 5/15/2012
DRILLING METHOD:	Direct Push	TOTAL DEPTH (ft.): 12.18	SCREEN INTERVAL (ft.): 2.18-12.18
DRILLING EQUIPMENT:	T190 on 9635 Skid	DEPTH TO WATER AT TIME OF BORING (ft.):	CASING (ft.): 0-2.18
SAMPLING METHOD:	DP Technology w/ Acetate Liner	LOGGED BY: J. Vickery	

DEPTH (feet)	DESCRIPTION	WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS
	Stick-Up Value (ft): 0.74	

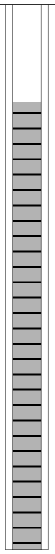


4" of "beach" SAND. Bottom of core is fine, dark brown SAND.

Bottom of core is fine, dark brown SAND.

fine, dark brown SAND

Gray, sticky CLAY



Well constructed using 2 inch schedule 40 PVC with a prepacked screen.

EPS

PROJECT:

LCP, Brunswick GA

Log of Boring No. DP-3B

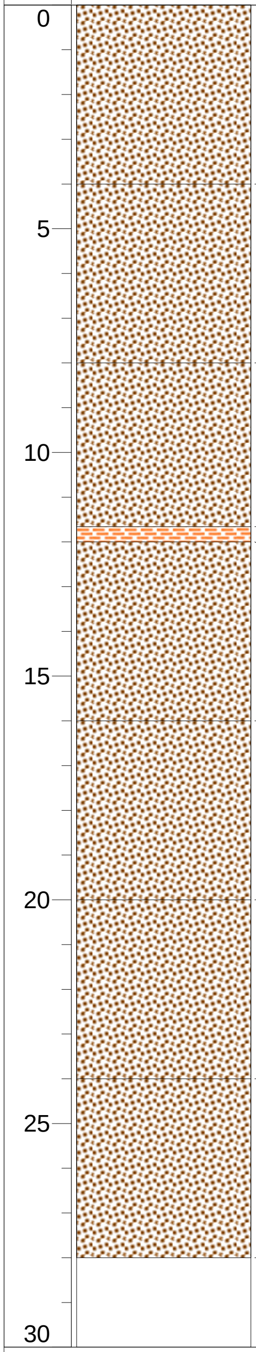
SITE LOCATION:	4125 Ross Road	TOP OF CASING ELEVATION (ft):	9.3
DRILLING CONTRACTOR:	Atlas Geo-Sampling	DATE STARTED: 5/15/2012	DATE FINISHED: 5/15/2012
DRILLING METHOD:	Direct Push	TOTAL DEPTH (ft.): 28.37	SCREEN INTERVAL (ft.): 23.37-28.37
DRILLING EQUIPMENT:	T190 on 9635 Skid	DEPTH TO WATER AT TIME OF BORING (ft.):	CASING (ft.): 0-23.37
SAMPLING METHOD:	DP Technology w/ Acetate Liner	LOGGED BY:	J. Vickery

DEPTH (feet)

DESCRIPTION

Stick-Up Value (ft): 1.2

WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS



4" of "beach" SAND. Bottom of core is fine, dark brown SAND.

Bottom of core is fine, dark brown SAND.

fine, dark brown SAND

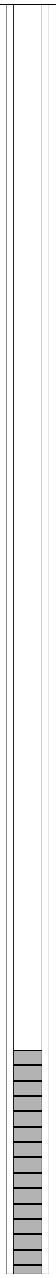
Gray, sticky CLAY

Fine to med. SAND; dark gray at 16'

Fine to med. SAND; dark gray

Fine to med. SAND at 24' dark gray, slightly finer than previous

Fine to med. SAND at 28' dark gray

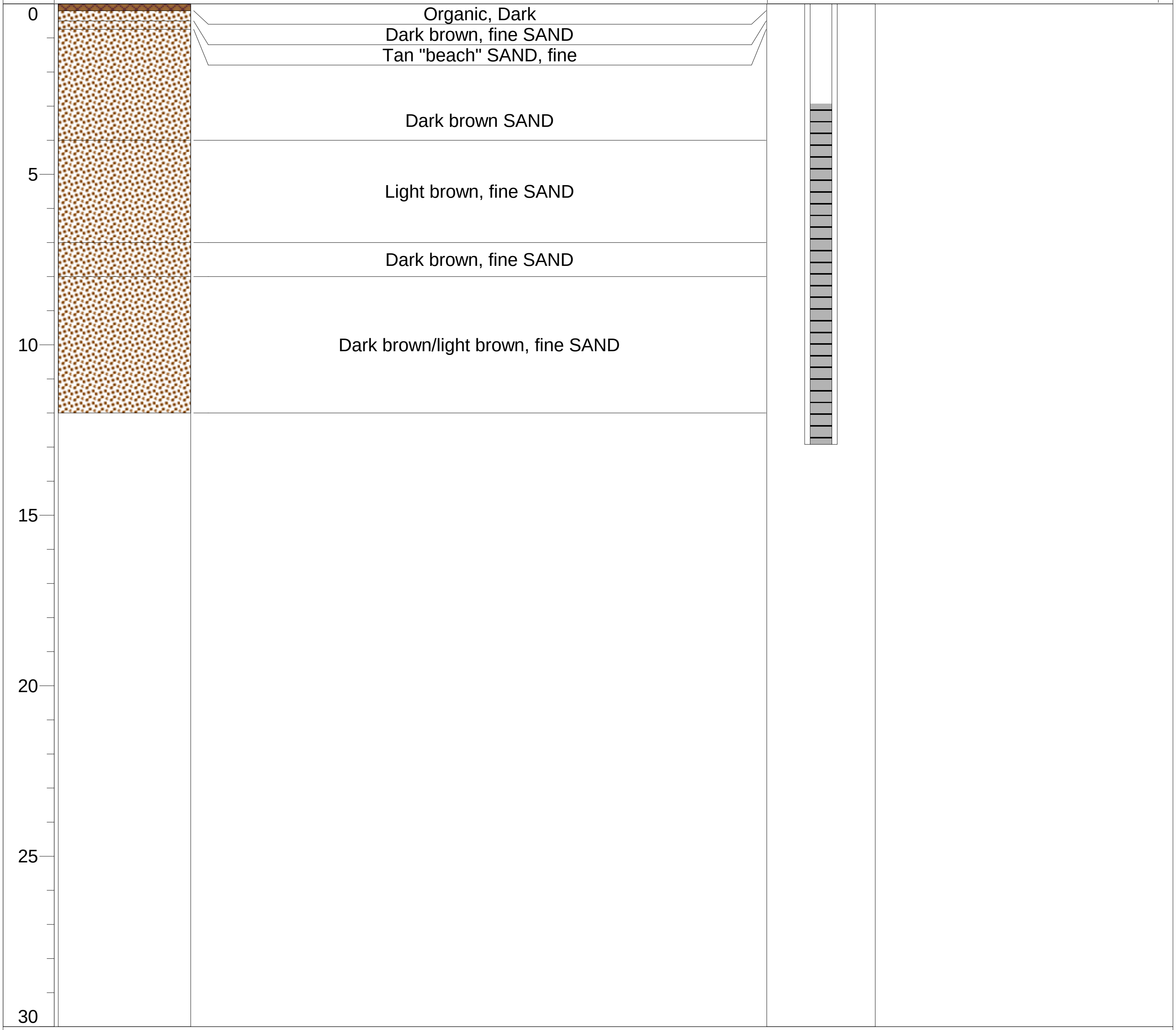


Well constructed using 2 inch schedule 40 PVC with a prepacked screen.

PROJECT: **LCP, Brunswick GA**		**Log of Boring No. DP-4A**	
SITE LOCATION:	4125 Ross Road	TOP OF CASING ELEVATION (ft): 9.11	
DRILLING CONTRACTOR:	Atlas Geo-Sampling	DATE STARTED: 5/15/2012	DATE FINISHED: 5/15/2012
DRILLING METHOD:	Direct Push	TOTAL DEPTH (ft.): 12.93	SCREEN INTERVAL (ft.): 2.93-12.93
DRILLING EQUIPMENT:	T190 on 9635 Skid	DEPTH TO WATER AT TIME OF BORING (ft.):	CASING (ft.): 0-2.93
SAMPLING METHOD:	DP Technology w/ Acetate Liner	LOGGED BY: J. Vickery	

DEPTH (feet)	DESCRIPTION	WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS

Stick-Up Value (ft): 1.43



Organic, Dark

Dark brown, fine SAND

Tan "beach" SAND, fine

Dark brown SAND

Light brown, fine SAND

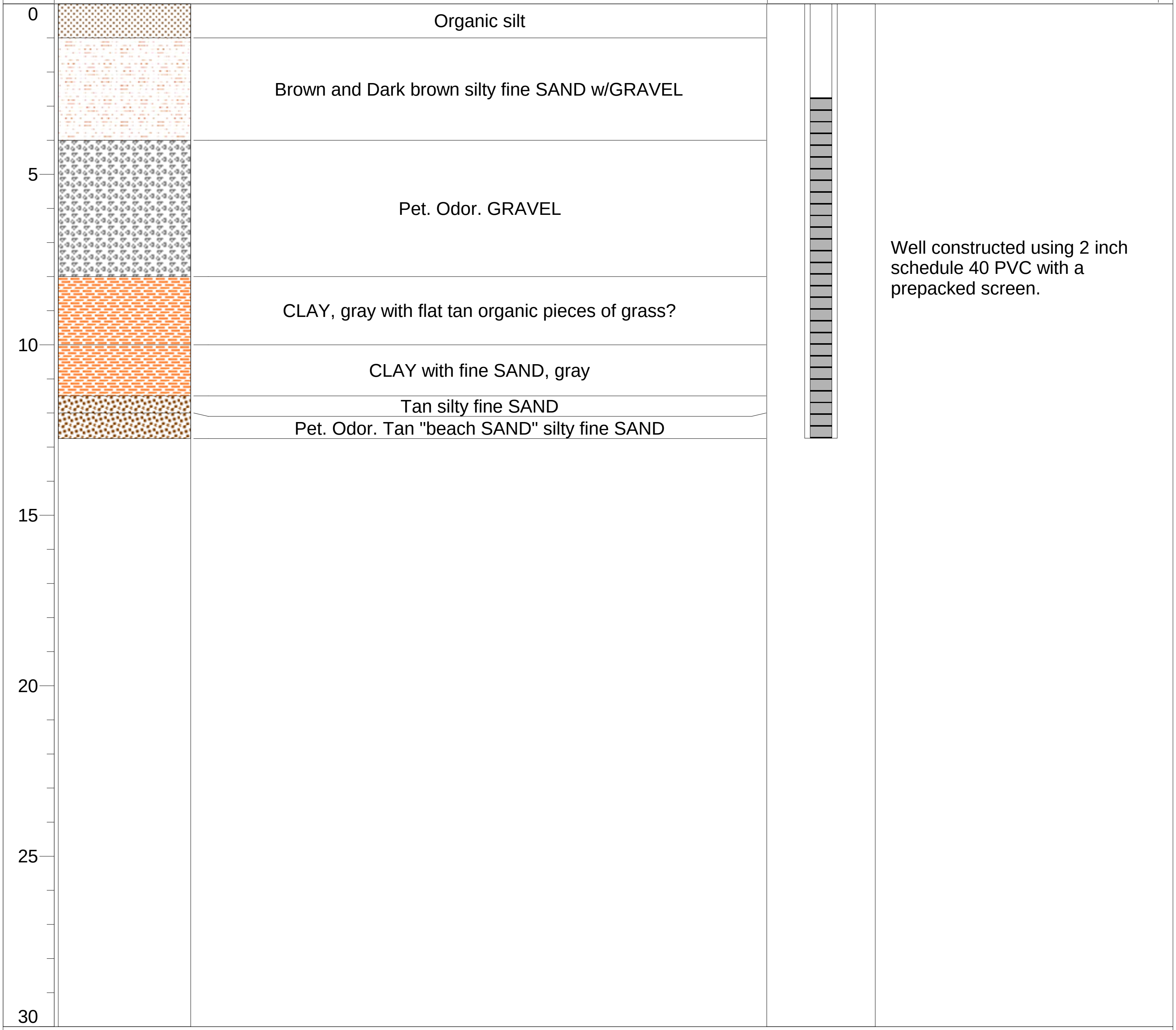
Dark brown, fine SAND

Dark brown/light brown, fine SAND

EPS

PROJECT: **LCP, Brunswick GA**		**Log of Boring No. DP-5A**	
SITE LOCATION:	4125 Ross Road	TOP OF CASING ELEVATION (ft): 9.49	
DRILLING CONTRACTOR:	Atlas Geo-Sampling	DATE STARTED: 5/16/2012	DATE FINISHED: 5/16/2012
DRILLING METHOD:	Direct Push	TOTAL DEPTH (ft.): 12.74	SCREEN INTERVAL (ft.): 2.74-12.74
DRILLING EQUIPMENT:	T190 on 9635 Skid	DEPTH TO WATER AT TIME OF BORING (ft.):	CASING (ft.): 0-2.74
SAMPLING METHOD:	DP Technology w/ Acetate Liner	LOGGED BY: J. Vickery	

DEPTH (feet)	DESCRIPTION	WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS
	Stick-Up Value (ft): 1.07	



Organic silt

Brown and Dark brown silty fine SAND w/GRAVEL

Pet. Odor. GRAVEL

CLAY, gray with flat tan organic pieces of grass?

CLAY with fine SAND, gray

Tan silty fine SAND

Pet. Odor. Tan "beach SAND" silty fine SAND

Well constructed using 2 inch schedule 40 PVC with a prepacked screen.

EPS

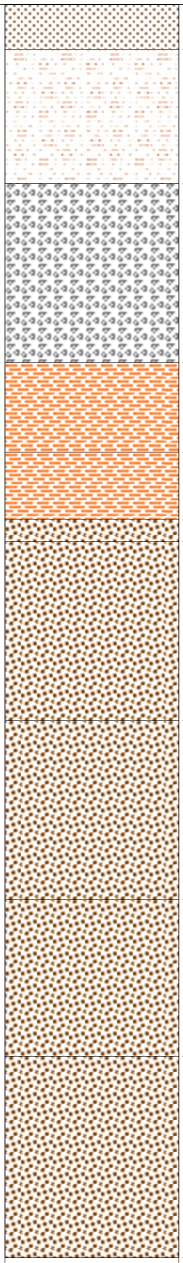
PROJECT:

LCP, Brunswick GA

Log of Boring No. DP-5B

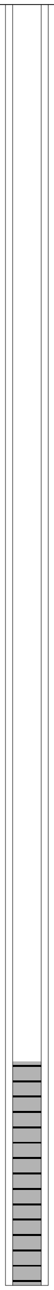
SITE LOCATION:	4125 Ross Road	TOP OF CASING ELEVATION (ft):	9.4
DRILLING CONTRACTOR:	Atlas Geo-Sampling	DATE STARTED: 5/16/2012	DATE FINISHED: 5/16/2012
DRILLING METHOD:	Direct Push	TOTAL DEPTH (ft.): 28.61	SCREEN INTERVAL (ft.): 23.61-28.61
DRILLING EQUIPMENT:	T190 on 9635 Skid	DEPTH TO WATER AT TIME OF BORING (ft.):	CASING (ft.): 0-23.61
SAMPLING METHOD:	DP Technology w/ Acetate Liner	LOGGED BY:	J. Vickery

DEPTH (feet)	DESCRIPTION	WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS
	Stick-Up Value (ft): 0.98	



DEPTH (feet): 0, 5, 10, 15, 20, 25, 30

- Organic silt
- Brown and Dark brown silty fine SAND w/GRAVEL
- Pet. Odor. GRAVEL
- CLAY, gray with flat tan organic pieces of grass?
- CLAY with fine SAND, gray
- Tan silty fine SAND
- Pet. Odor. Tan "beach SAND" silty fine SAND
- Pet. Odor. Tan silty fine SAND
- Pet. Odor. Tan silty fine SAND
- pet. Odor. Gray silty fine SAND



Well constructed using 2 inch schedule 40 PVC with a prepacked screen.

EPS

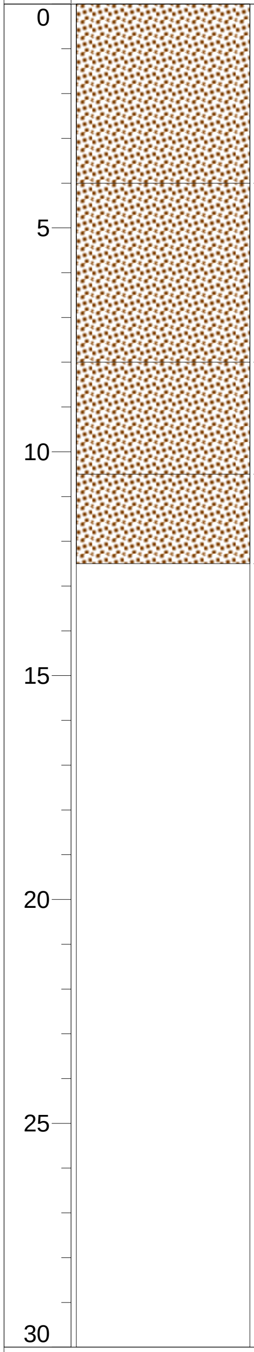
PROJECT: **LCP, Brunswick GA**	**Log of Boring No. DP-6A**
SITE LOCATION: 4125 Ross Road	TOP OF CASING ELEVATION (ft): 10.28
DRILLING CONTRACTOR: Atlas Geo-Sampling	DATE STARTED: 5/16/2012 / DATE FINISHED: 5/16/2012
DRILLING METHOD: Direct Push	TOTAL DEPTH (ft.): 12.5 / SCREEN INTERVAL (ft.): 2.50-12.50
DRILLING EQUIPMENT: T190 on 9635 Skid	DEPTH TO WATER AT TIME OF BORING (ft.): / CASING (ft.): 0-2.50
SAMPLING METHOD: DP Technology w/ Acetate Liner	LOGGED BY: J. Vickery

DEPTH (feet)

DESCRIPTION

Stick-Up Value (ft): 2

WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS

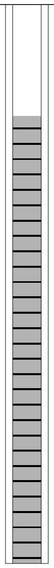


Brown, silty fine SAND to dark brown, silty fine SAND

Gray and dark gray, silty fine SAND. Sheen at 4'. Strong pet. Odor

Dark brown, tan, dark gray, silty fine SAND. Strong pet. Odor

Light gray silty fine SAND. Strong pet. Odor. 100% rec.



Well constructed using 2 inch schedule 40 PVC with a prepacked screen.

EPS

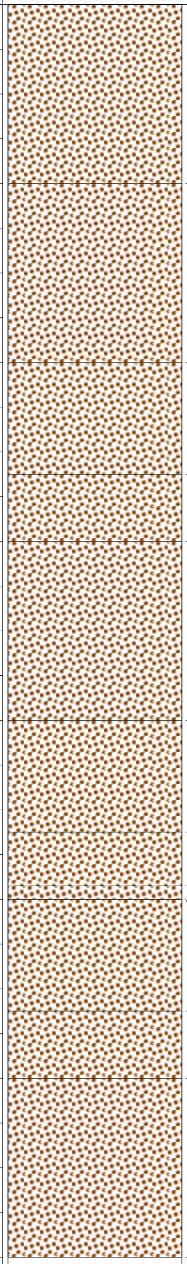
PROJECT:

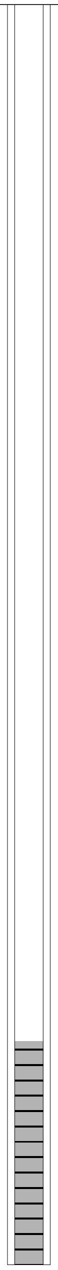
LCP, Brunswick GA

Log of Boring No. DP-6B

SITE LOCATION: 4125 Ross Road		TOP OF CASING ELEVATION (ft): 9.71	
DRILLING CONTRACTOR: Atlas Geo-Sampling		DATE STARTED: 5/16/2012	DATE FINISHED: 5/16/2012
DRILLING METHOD: Direct Push		TOTAL DEPTH (ft.): 28.17	SCREEN INTERVAL (ft.): 23.17-28.17
DRILLING EQUIPMENT: T190 on 9635 Skid		DEPTH TO WATER AT TIME OF BORING (ft.):	CASING (ft.): 0-23.17
SAMPLING METHOD: DP Technology w/ Acetate Liner		LOGGED BY: J. Vickery	

DEPTH (feet)	DESCRIPTION Stick-Up Value (ft): 1.43	WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS
0	Brown, silty fine SAND to dark brown, silty fine SAND	
5	Gray and dark gray, silty fine SAND. Sheen at 4'. Strong pet. Odor	
	Dark brown, tan, dark gray, silty fine SAND. Strong pet. Odor	
10	Light gray silty fine SAND. Strong pet. Odor. 100% rec.	
15	Dark tan silty fine SAND. Strong pet. odor	
	Dark tan silty fine SAND	
	Tan silty fine SAND	
20	Dark gray silty fine SAND with 5-6 thin (2 1/2 cm) layers of dark gray fine SAND	
	Tan silty fine SAND	
	Gray silty fine SAND	
25	Stron pet. Odor. Tan to gray silty fine SAND	Well constructed using 2 inch schedule 40 PVC with a prepacked screen.
30		





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Appendix B
Hydrodynamic Modeling

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:
Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:
Anchor QEA, LLC

ENVIRON International Corporation

Date:
June 2, 2014

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Acronyms and Abbreviations

%	percent
ADCP	acoustic Doppler current profiler
cfs	cubic foot per second
cfs/mi^2	cubic foot per second per square mile
CSM	conceptual site model
FS	feasibility study
ft/s	foot per second
LiDAR	Light Detection and Ranging
mi^2	square mile
mm/yr	millimeters per year
NAVD88	North American Vertical Datum 1988
NOAA	National Oceanic and Atmospheric Administration
OU1	operable unit 1
RMSE	root mean square error
Site	Brunswick LCP OU1 Site
TRBE	Turtle River/ Brunswick Estuary
USGS	United States Geological Survey
WSE	water surface elevation

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Executive Summary

This hydrodynamic modeling study was performed to evaluate the characteristics and system responses to various remedial alternatives at the LCP Chemical Superfund Site (the Site) Operable Unit 1 (OU1). The primary objectives of the modeling study were to develop a conceptual site model (CSM) and to evaluate the potential effects of various remedial alternatives on hydrodynamics and circulation within the Site. Modeling of sediment transport was not the objective of this investigation. However, sediment transport patterns can be generically inferred based on the results of the hydrodynamic model. The model was used to simulate the movement of water in the estuarine system and accounts for the effects of tides, tributary inflow, bathymetry, and flooding and drying of intertidal marsh areas.

The RMA-2 hydrodynamic model was used to simulate changes in water depth, current velocity, and bed shear stress over space and time. The hydrodynamic model was developed and calibrated using Site-specific data to the extent feasible. A boundary-fitted numerical grid with relatively high resolution in the Site was used to represent spatial variations in geometry and bathymetry throughout the estuary. The model reproduced four key characteristics of hydrodynamics within the Site:

1. Amplitude and phase of water surface elevation
2. Qualitative differences in the symmetry (asymmetry) of tidal currents during ebb and flood tide between Turtle River and Purvis Creek
3. Changes in the magnitude of along-channel velocity during the neap-spring tidal cycle
4. Flooding and drying of secondary channels and intertidal marsh areas

Successful calibration of the model indicated that it can be used as a management tool to develop a CSM and to reliably evaluate remedial alternatives for a range of flow and tidal conditions.

To quantify the effects of the remedial alternatives on hydrodynamics, the model was used to predict changes in the inundated intertidal areas and maximum current velocity due to remediated bed conditions. The hydrodynamic model was used to simulate the potential effects of two remedial scenarios on hydrodynamics and circulation within the Site:

1. Sediment remedy Alternative 2 consists of dredging and backfill (with a net change of minus 0.5 feet in all remediation areas).

2. Sediment remedy Alternative 3 specifies a combination of remedial action with dredging and backfill (net change of minus 0.5 feet), capping (net increase in bed elevation of 1 foot), and thin cover (net increase in bed elevation of 0.5 feet).

These two alternatives were chosen for hydrodynamic evaluation during the feasibility study (FS) since between these two remedial scenarios, a wide range of potential variations in sediment remedy assumptions can be bracketed.

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Existing conditions and the two remedial scenarios discussed above were simulated for the following three hydrodynamic conditions:

1. typical tidal conditions over a spring-neap tidal cycle
2. 100-year flood
3. hurricane storm surge

The latter two events were modeled to simulate the expected behavior of the Site under extreme events. Note that the 100-year flood and the 100-year storm surge were used for this study as it is a consistent standard practice at Superfund sites to evaluate extreme event influence. Additional simulations for storm surges with rarer recurrence intervals (e.g., 500-year event) may be considered during the design phase of the project to test sensitivities. Based on experience from other sites of similar characteristics, the incremental effects of higher-frequency storm surges on marsh sites such as the Brunswick LCP Site is not expected to be considerable. In general, the change in the areal extent of intertidal inundation due to either remedial scenario was less than 4 percent (%), which indicated that the remedial scenarios would not have a significant effect on the circulation and marsh inundation within the Site. Overall, only relatively minor increases in maximum current velocities (relative to existing conditions) were predicted to occur for the two remedial scenarios, indicating that implementation of the remedies will not influence the general hydrodynamic characteristics of the marsh and tidal creeks.

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1 Introduction

This hydrodynamic modeling study was performed to evaluate the characteristics and system responses to the various remedial alternatives in support of the feasibility study for Operable Unit 1 (OU1) at the LCP site in Brunswick, Georgia (the Site). The Site is located in the upper portions of an estuary that is composed of the South Brunswick and Turtle rivers (Figure B1-1). The Site, which is approximately 662 acres of flat, vegetated tidal marsh and approximately 98 acres of tidal creeks within the Turtle River/Brunswick Estuary (TRBE) (Figure B1-2). The marsh elevation is low (approximately 2 to 3 feet above mean sea level), and the numerous channels and creeks traversing the marsh are under tidal influence from the nearby Turtle River (Optimal Geomatics, Inc. 2008). The marsh is bounded by the LCP property and uplands to the east, Purvis Creek to the north, uplands to the northwest, uplands that are not part of the LCP property to the south, and Turtle River to the west.

The primary objectives of the modeling study were to develop a conceptual site model (CSM) and to evaluate the potential effects of various remedial alternatives on hydrodynamics and circulation within the Site. Modeling of sediment transport was not the objective of this investigation. However, sediment transport patterns can be generically inferred based on the results of the hydrodynamic model.

The technical approach focused on developing, calibrating, and applying a hydrodynamic model of the Site. Site-specific data were collected during field studies conducted during January and February 2012 in order to use local data to set up and calibrate the model. The calibrated model was used to evaluate hydrodynamics and circulation within the Site for the following conditions:

- typical tidal conditions over a spring-neap tidal cycle
- 100-year flood
- hurricane storm surge

The potential effects of two remedial alternatives on current velocities and circulation patterns (i.e., extent and frequency of marsh inundation) were compared to current conditions.

1.1 Overview of Sediment Transport Processes

Various terms related to sediment transport processes are used throughout this appendix. The following list provides definitions of the primary terms discussed:

- *Annual time scales*: Refers to time periods of 1 to 10 years, with average or typical conditions being the focus of the sediment transport processes that are examined or discussed in this appendix. Variability in the processes exists over time but conclusions or observations generally relate to long-term average conditions.
- *Depositional environment*: An area in which the elevation of the sediment bed is increasing over annual time scales. In a depositional environment, it is possible for the sediment bed

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to experience occasional erosion as a result of high-flow events or storm surges, but more sediment is depositing than eroding over annual time scales.

- *Erosional environment*: An area in which the elevation of the sediment bed is decreasing over annual time scales. The sediment bed may experience some deposition over time scales of less than a year, but more sediment is eroding than depositing over annual time scales.
- *Dynamic equilibrium*: The condition in which there is no observable net increase or decrease in the sediment bed elevation over annual time scales, although the sediment bed experiences episodic erosion and deposition over short time scales.
- *Episodic erosion*: Occasional scour from the sediment bed that occurs during a high-flow event or storm surge. During these events, high current velocities erode the sediment bed at some locations. A depositional or dynamic equilibrium environment (as defined above) can experience episodic erosion, which generally occurs over periods of hours to days.

A study of a coastal Georgia marsh located approximately 25 miles northeast of the Site found that net sedimentation rates varied within the marsh (Letzsch and Frey 1980). Additionally, seasonal variations were observed in which maximum sedimentation occurred in the summer months, whereas the minimum occurred during the fall. The study found that sedimentation rates varied from 2 to 6 millimeters per year (mm/yr) within the marsh; this range is consistent with similar marsh systems on the East Coast (Stumph 1983. Christiansen 1998). During the last century, sea level rise has consistently averaged approximately 3 mm/yr. Sea level rise is predicted to continue at a rate of 2 to 7 mm/yr, which in turn will create conditions that are favorable for continued sediment deposition. Overall, sediment deposition is anticipated to continue in response to ongoing sea level rise over the next century, consistent with the typical response of estuaries to sea level rise. The marshes within the Site are expected to continue growing at a sufficient rate to keep up with sea level rise, due to additional biological growth and sediment trapping.

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2 Hydrodynamic Model Development and Calibration

As discussed above, the objective of the modeling in the FS was to infer general trends in hydrodynamic characteristics in the system under existing conditions, as well as postremedy conditions. Sediment depositional and transport processes were not modeled in the FS; however, the results of the hydrodynamic model can be used to infer general sediment deposition and transport patterns in the system. The hydrodynamic model simulates the movement of water in the estuarine system that is composed of the South Brunswick and Turtle rivers. The model accounts for the effects of the following factors on water movement:

- Tides
- Inflow from tributaries
- Variability in sediment bed elevation and channel geometry across the entire Site
- Flooding and drying of intertidal and marsh areas

The hydrodynamic model is used to simulate changes in water depth, current velocity, and bed shear stress over space and time.

2.1 Description of Hydrodynamic Model Structure

The hydrodynamic model used for this study is RMA-2, which is a component of the Surface Modeling System developed by the United States Army Corps of Engineers (USACE 2011) that has been used to simulate hydrodynamics in many estuaries. RMA-2 is a two-dimensional, depth-averaged model that uses an unstructured numerical grid, which makes it possible to accurately represent complex system geometry and bathymetry over a wide range of spatial scales. This capability is useful for incorporating the secondary and tertiary creek channels within the Site into the model. In addition, RMA-2 is able to simulate flooding and drying of intertidal channels and marsh areas. A two-dimensional, depth-averaged model provides realistic simulation of hydrodynamics at the Site because significant density-driven circulation due to vertical stratification of salinity does not occur within the Site.

Development and calibration of the hydrodynamic model required the following types of data:

- Bathymetry and geometry
- Freshwater inflows
- Water surface (tidal) elevation
- Current velocity

The model predicts variation in time and space in water surface elevation, water depth, current velocity, and bed shear stress.

2.2 Numerical Grid and Bathymetry

Realistic simulation of tidal hydrodynamics within the Site necessitated using a numerical grid that extended outside the Site (Figure B2-1). In addition to the Site, the numerical grid

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incorporates channel and intertidal areas of the Turtle and South Brunswick rivers so that the estuary is accurately simulated by the model. On Figure 2-5 of the FS, the yellow line represents the extent of the "approximate Turtle River Estuary," which includes intertidal and floodplain areas that are infrequently inundated and have minimal effect on large-scale tidal circulation within the estuary. The numerical grid shown on Figure B2-1 was designed so that the geometry and bathymetry of the estuary were adequately incorporated into the hydrodynamic model.

The numerical grid of the model is boundary-fitted and contains approximately 5,000 grid cells with a wide range of spatial resolution. Grid cells in the Turtle and South Brunswick rivers have a relatively coarse resolution (over 700 feet in the across- and along-channel directions). The numerical grid within the Site has a relatively fine resolution (i.e., the size of an individual grid cell within the Site is considerably smaller than a grid cell outside the Site). Grid cell size varies across the Site in order to capture differences in geometry between primary, secondary, and tertiary creek channels (Figure B2-2). Grid cells within Purvis Creek, which is a primary channel, range in size from 100 to 250 feet and 30 to 50 feet along and across the channel directions, respectively. Grid cells used to resolve secondary and tertiary channels (e.g., Eastern Creek) are typically 25 to 50 feet and 5 to 15 feet along and across the channel directions, respectively.

The bathymetry and topography inputs for the hydrodynamic model were specified using data and information from four sources. The Glynn County (Georgia) Light Detection and Ranging (LiDAR) survey conducted in 2008 provided topography data for the intertidal marsh areas throughout the model domain (Optimal Geomatics, Inc. 2008). Within the Site, creek channel inputs were specified using data collected during a single-beam bathymetry conducted in January 2012. For the region outside of the Site, in-channel bathymetry inputs were specified using data from the National Oceanic and Atmospheric Administration's (NOAA's) National Geophysical Data Center Coastal Relief Model (2012). The topography for areas outside the coverage of the Glynn County LiDAR dataset was specified by the United States Geological Survey (USGS) National Elevation Dataset (2009).

As described above, data from these four sources were combined to generate the spatial distribution of bed elevation (i.e., bathymetry and topography) throughout the model domain (Figures B2-3 and B2-4). Bed elevation inputs to RMA-2 model are specified at grid nodes, which are located at the corners of a grid cell. To ensure realistic representation of bathymetry and topography within the model, spatial averages of bed elevation data within the vicinity of each node were calculated and used as input to the model.

2.3 Boundary Conditions

The model required specification of water surface elevation (WSE) at the downstream boundary of the model, which is located near the Sidney Lanier Bridge (Figure B2-5). Three tidal gauging stations are located in the vicinity of the downstream boundary (Figure B2-6):

- USGS station at Brunswick River

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- USGS station at Saint Simons Island
- NOAA station at Saint Simons Island

WSEs measured at these three gauging stations are similar, with minimal differences in amplitude and phase. Thus, data collected at any of these three stations could be used to specify WSE input at the downstream boundary. Data collected at the USGS Saint Simons Island station were used to specify model inputs because this station has the longest historical data record. Figure B2-7 shows WSE specified at the downstream boundary during the model calibration period (January 18 to February 7, 2012), which is discussed in Sections 2.4 and 2.5. During this 21-day period, the WSE ranged between minus 6 and plus 4 feet North American Vertical Datum 1988 (NAVD88) and included a spring-neap tidal cycle.

No USGS flow gauging stations are located on freshwater tributaries to the Turtle and South Brunswick rivers (Figure B2-5 shows freshwater tributary locations). Thus, flow rates for those freshwater tributaries were estimated using data collected at USGS gauging stations on a stream within a watershed that is located in the vicinity of the Turtle and South Brunswick rivers. Specifically, flow rate data collected at the USGS gauging station on the Little Satilla River near Offerman Dam were used to estimate tributary inflows to the model. The average flow rate of the Little Satilla River is 500 cubic feet per second (cfs), with a drainage area of 645 square miles (mi^2) at the USGS gauging station. The average flow rate was normalized by the drainage area to compute a runoff rate of approximately 0.8 cubic feet per second per square mile (cfs/mi^2) for the Little Satilla River. The combined drainage area of the Turtle and South Brunswick rivers is 232 mi^2. Multiplying the average runoff rate for the Little Satilla River by this drainage area produced an estimated average flow rate for the Turtle and South Brunswick rivers of 190 cfs. The average flow rate for the Turtle and South Brunswick rivers (190 cfs) corresponds to the tributary inflow to the estuary from the surrounding watershed. This flow rate was used as a boundary condition for inflow to the hydrodynamic model.

The groundwater analysis in Appendix A used surface water model outputs to estimate a groundwater flow rate into the estuary. The purpose of the groundwater flow rate was to estimate a conservative surface water-to-groundwater dilution ratio to understand whether groundwater flows have the potential to impact surface water COC concentrations. The goal of the groundwater analysis was not to establish a groundwater boundary condition for the hydrodynamic model and was not used in the model. The Appendix A groundwater analysis estimated a peak surface water flow rate of 130 cfs entering the estuary. Use of the 130 cfs value conservatively produced estimates of maximum groundwater flows toward the estuary.

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United States Environmental Protection Agency (USEPA) guidance documents recommend evaluating bed stability during episodic storm events with return periods of 100 years (i.e., 1% probability of the event occurring in any particular year), which is standard practice at Superfund sites. A standard statistical approach (i.e., Log-Pearson Type 3) was used to analyze the 60-year period (1951 through 2010) of USGS flow rate data collected for the Little Satilla River. That analysis yielded a flow rate of 20,700 cfs for the 100-year flood. Although there were two events with flow rates higher than this 100-year flow rate (namely, the 1930 and 1948 floods,

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with flow rates of 38,000 and 27,000 cfs, respectively), they are not appropriate for use in the bed stability analysis because of the following:

- The flow rates for the 1930 and 1948 floods were estimated; therefore their accuracies are uncertain.
- Return periods of the 1948 and 1930 floods are 300 years, and greater than 500 years, respectively.
- 100-year flood analysis is standard practice at Superfund sites across the US and widely accepted by USEPA.

Therefore, the model used the 100-year flow rate assumption of 20,700 cfs for the Little Satilla River, which corresponds to a runoff rate of 32 cfs/mi^2. This runoff rate was used to estimate the 100-year flood discharge for the Turtle and South Brunswick rivers, which was 7,400 cfs.

The combined inflow rate for the Turtle and South Brunswick rivers was divided between three inflow locations, based on the approximate subwatershed drainage area (Figure B2-5). Average inflow conditions were assumed during the calibration simulation discussed below. The 100-year flood was simulated during the evaluation of remedial alternatives, which is discussed in more detail in Section 3.

2.4 Model Calibration

The hydrodynamic model was calibrated using water level sensor data and acoustic Doppler current profiler (ADCP) data collected between January 18 and February 7, 2012. WSE data were obtained from the two water level sensors deployed in Turtle River and Purvis Creek (i.e., Stations WL1 and WL2 in Figure B2-8). Four ADCPs were deployed during this field study:

- One in Turtle River (Station T1),
- Two at locations in Purvis Creek (Stations P1 and P2)
- One within Eastern Creek (Station E1)

These ADCPs provided WSE and along-channel current velocity data, which were used to evaluate model performance during the calibration process (RPS Evans-Hamilton 2012).

The ADCP data indicates that qualitative differences exist between tidal currents in the Turtle River and Purvis Creek. At Station T1 in the Turtle River, current velocities during ebb and flood tides are approximately symmetrical for both spring and neap conditions (Figures B2-9 and B2-10). Within Purvis Creek, at Station P1, asymmetric patterns are observed in tidal currents during ebb and flood tides, with a higher degree of asymmetry occurring during spring tide (Figure B2-11) than during neap tide conditions (Figure B2-12). These observations were used to evaluate the ability of the model to simulate differences in tidal hydrodynamics between Turtle River and Purvis Creek.

Two model inputs were refined during the calibration process:

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1. Manning's *n* coefficient, which is a parameter that describes the surface roughness of the river bottom
2. The effective bed elevation of intertidal marsh areas within the Site

The Manning's *n* coefficient was set to a relatively high value of 0.3 in the intertidal marsh areas in order to incorporate the effects of dense vegetation on hydrodynamic drag forces (Chow 1959). A Manning's *n* value of 0.02 was specified in the creek channels, with a value of 0.01 in Eastern Creek. The difference in Manning's *n* values between Eastern Creek and other creek channels reflects localized variations in channel geometry and resolution of the numerical grid, which are incorporated into the model via this lumped input parameter.

Bed elevation values within intertidal, vegetated marshes of the Site were originally approximated using LiDAR data collected by Glynn County. During the calibration process, it was determined that decreasing the marsh bed elevation by an average of 1 foot resulted in considerable improvements in the model's simulation of existing conditions. This refinement in model marsh bed elevation was considered valid due to the inherent inaccuracies with LiDAR measurements that are typically observed over marsh vegetation. To this effect, a NOAA (2010) study on LiDAR data collected within a South Carolina marsh notes:

> When testing the marsh category separately, it becomes clear the marsh land cover is a unique category that may have significantly higher errors and biases than the 'upland' (i.e., traditional) land covers. This suggests that LiDAR data are highly positively biased in marsh land cover.

The root mean square error (RMSE) for LiDAR data collected from the South Carolina marsh in the NOAA study was 0.76 feet, which is very close to the marsh bed elevation refinement of 1 foot used for this study.

As discussed in Section 2.2, the LiDAR data used to specify bed elevation in the intertidal marsh areas were collected during 2008 as part of a larger survey that encompassed all of Glynn County, Georgia. Optimal Geomatics (2008) performed a quality control analysis of the LiDAR data, which were collected from a wide range of land use categories (including marshes), and concluded:

> Glynn County, GA contains areas of thick marsh grass vegetation, which is very difficult to fully penetrate with LiDAR. Additional ground validation was taken in order to establish the accuracy associated with the [digital elevation model] for this particular vegetation class. …The testing of these points revealed an RMSE of 0.86 feet.

Optimal Geomatics (2008) collected validation data from three general types of land surfaces during the quality control study:

1. Hard surfaces (e.g., bare earth, road)
2. Upland vegetation (e.g., grass, brush, trees)

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3. High marsh grass areas (i.e., vegetated marshes)

The validation data were collected at locations throughout Glynn County (Figure B2-13), with a cluster of validation measurements obtained at each sampling location (Figure B2-14). Reported errors in the LiDAR data (i.e., difference between LiDAR and validation measurement) (Optimal Geomatics 2008) were used to generate cumulative frequency distributions of the LiDAR errors for hard surfaces, upland vegetation, and high marsh grass areas (refer to Figures B2-15, B2-16, and B2-17, respectively). These results produced these conclusions about the Glynn County LiDAR data:

- Errors for all surfaces may be represented by a normal (Gaussian) distribution, which means that relative comparisons of errors for different surfaces are reliable.
- The median error (i.e., 50th percentile) for hard surfaces (Figure B2-15) and upland vegetation (Figure B2-16) ranged between approximately plus or minus 0.25 feet, with no significant bias for nearly all of the surfaces shown on these two figures.
- The distribution of errors for high marsh grass, or vegetated marshes (Figure B2-17), is positively biased, with a median value of approximately plus 0.8 feet. This type of land surface is most predominant in the Site.

One measurement of bed elevation was available to validate the LiDAR data collected from marsh areas within the Site. The LiDAR error for this measurement is consistent with the Glynn County error distribution (Figure B2-17). The results of the quality control analysis provide significant support for lowering the LiDAR-derived average elevation of vegetated marshes within the Site by 1 foot during model calibration.

2.5 Calibration Results

Model performance was evaluated using qualitative and quantitative methods. Qualitative evaluation was primarily focused on visual inspection of graphical comparisons of predicted and measured values. Two metrics were used to quantitatively evaluate the performance of the hydrodynamic model (i.e., predictive skill assessment). The first metric defines model skill as follows (Wilmott 1981; Warner et al. 2005):

$$Skill = 1 - \frac{\sum |X_{model} - X_{obs}|^2}{\sum \left(|X_{model} - \overline{X_{obs}}| + |X_{obs} - \overline{X_{obs}}| \right)^2} \qquad \text{(B-1)}$$

where:

X_{model} = predicted value at time n
X_{obs} = measured value at time n
$\overline{X_{obs}}$ = average measured value over time period

Perfect agreement between predicted and observed values corresponds to a skill of one, and complete disagreement produces a skill of zero.

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The second metric used to evaluate model performance is root mean square error (RMSE), which was calculated using the following equation (Sokal and Rohlf 2012):

$$RMSE = [1/N \sum(X_{model} - X_{obs})^2]^{1/2} \tag{B-2}$$

Where:N = number of model-data comparisons

Note that relatively small phase differences between predicted and measured WSE and current velocity in a tidal system, such as in Turtle River and Purvis Creek, can produce a relatively large RMSE, whereas the skill level using Equation B-1 will be relatively high (i.e., greater than 0.9). Thus, for the tidally-influenced Brunswick Site, more emphasis should be focused on the skill metric than on RMSE when evaluating model performance.

Comparisons of predicted and measured WSE at the water level sensor locations (WL1 and WL2) during the 21-day calibration period are presented in Figure B2-18. During the calibration period, WSE at both locations ranged between approximately minus 6 and plus 4 feet NAVD88. Results of the quantitative evaluation of WSE at Stations WL1 and WL2 are presented in Table B2-1. These results indicate the following:

- High tide is predicted accurately.
- The model tended to slightly under predict WSE during low tide.
- Predicted WSE was in phase with measure values.
- Changes in tidal range throughout the spring-neap cycle were reproduced by the model. Overall, predicted WSE at both locations was in satisfactory agreement with measured values.

- WSE skill level was 0.99 at both locations.

Model predictions of WSE and along-channel velocity at Stations T1, P1, P2, and E1 during the calibration period in 2012 are compared to measured values in Figures B2-19 to B2-22. The quantitative evaluation of WSE at these four stations produced a skill level of 0.98 or greater and RMSE of about 0.4 to 0.5 feet (Table B2-2). The along-channel velocity at Station T1 fluctuated between approximately plus 2 feet per second (ft/s; flood tide) and minus 2.5 ft/s (ebb tide). The predicted along-channel velocity at Station T1 was slightly underpredicted during ebb tide. Results of the skill assessment for current velocity at Stations T1, P1, P2, and E1 are presented in Table B2-2. Current velocities at the three stations within Purvis Creek had a skill level of 0.98 or greater (RMSE of about 0.1 to 0.3 feet/second), with the Turtle River location having a skill level of 0.82 (RMSE of 0.4 feet/second). Overall, the comparisons of velocity and WSE are acceptable for the objectives of this study.

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Peak current velocities during ebb and flood tides within Purvis Creek tended to be slightly lower than peak velocities in Turtle River. Generally, the predicted current velocities at Stations P1 and P2 reproduced the shape, magnitude, and phase of the measured velocities with good

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accuracy (Figures B2-20 and B2-21). WSEs at Stations P1 and P2 were slightly underpredicted during low tide, but this result is consistent with model performance at Station WL1.

In the Eastern Creek, the predicted WSE reproduced the magnitude and phase of measured values at Station E1 (Figure B2-22). The model also realistically simulated flooding and drying at this location. During flood tide, the maximum along-channel velocity within the Eastern Creek was underpredicted. The underprediction during flood tide was primarily caused by uncertainty in geometry and bathymetry of the tidal channel and marsh area in the vicinity of Station E1 and limitations of numerical grid resolution in the area surrounding Station E1. However, the model adequately predicted maximum velocity during ebb tide, which is similar in magnitude to peak values during flood tide. Peak current velocities during ebb and flood tides are approximately equal at Station E1. Thus, model reliability for evaluating bed stability is not affected by underprediction of peak current velocity during flood tide.

The calibration results for the hydrodynamic model show that the WSE and current velocity is predicted with adequate accuracy within the Site. In addition to satisfactorily predicting the magnitude of WSE and current velocity, the model was able to reproduce the shape of the tidal signal within the Site, including realistic simulation of asymmetrical characteristics of the tidal signal. Model results for the 21-day calibration period demonstrate that the model captured these key characteristics of hydrodynamics within the Site:

- Amplitude and phase of WSE
- Qualitative differences in the symmetry (asymmetry) of tidal currents during ebb and flood tide between Turtle River and Purvis Creek
- Changes in the magnitude of along-channel velocity during the neap-spring tidal cycle
- Flooding and drying of secondary channels and inter-tidal marsh areas

Successful calibration of the model indicates that the model can be used as a management tool during this FS level study to reliably evaluate remedial alternatives for a range of flow and tidal conditions (i.e., typical tidal conditions over a spring-neap tidal cycle, 100-year flood, and hurricane storm surge).

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3 Evaluation of Sediment Remedy Alternatives

Successful calibration of the model produced a quantitative tool that was used to evaluate the potential effects of two sediment remedy alternatives on hydrodynamics and circulation within the Site. This model was used to predict changes in inundated intertidal area and maximum current velocity due to remediated bed conditions in order to quantify the effects of the two remedial alternatives on hydrodynamics in the marsh.

The remedial alternatives evaluated consisted of two sediment-management-area footprints that cover 48 acres of the Site. Sediment remedy Alternative 2 (Figure B3-1) consists of dredging and backfill with a net removal of up to 0.5 feet in all remediation areas. Sediment remedy Alternative 3 (Figure B3-2) specifies a combination of remedial action with dredging and backfill (net removal of up to 0.5 feet), capping (net increase in bed elevation of 1 foot), and thin-cover placement (net increase in bed elevation of 0.5 feet). These two alternatives were selected for hydrodynamic evaluation because they bracket a wide range of potential variations in sediment remedy assumptions. Thus, existing conditions and the two remedial alternatives were simulated for three hydrodynamic conditions:

1. Typical tidal conditions over a spring-neap tidal cycle
2. 100-year flood
3. Hurricane storm surge

3.1 Sediment Remedy Alternatives: Typical Tidal Conditions

The remedial alternatives were evaluated for typical tidal conditions over a spring-neap cycle (i.e., 21-day calibration period in 2012). The spatial distribution of maximum predicted current velocity for existing conditions and for Alternatives 2 and 3 are presented in Figures B3-3, B3-4, and B3-5, respectively. Spatial patterns of maximum velocity are similar for all three conditions. As expected, higher velocities occur within the main channel of Purvis Creek, with velocities greater than 2 ft/s near the mouth of Purvis Creek. The intertidal marsh areas experience lower current velocities, with peak values that were less than 0.25 ft/s. Maximum velocities in the secondary channels were typically between 0.25 and 1.5 ft/s, with higher velocities occurring in a few isolated areas.

To evaluate the effect of remediated bed elevations on the Site hydrodynamics, maximum increases in current velocity between the remedial scenarios and existing conditions were determined.

The spatial distribution of differences in maximum predicted velocity between Alternative 2 and existing conditions is shown in Figure B3-6 and can be summarized as follows:

- The predicted maximum velocity in Purvis Creek did not experience a significant change (i.e., less than plus or minus 0.1 ft/s) following remediation.
- The predicted maximum velocity in Eastern Creek decreased by 0.1 to 0.5 ft/s, which is consistent with lowering the sediment bed following remediation.

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- Overall, implementation of Alternative 2 has a minor effect on velocity, with the maximum increase in velocity being 0.21 ft/s within the Site.

The spatial distribution of differences in maximum predicted velocity between Alternative 3 and existing conditions is shown in Figure B3-7. As shown on this figure and presented in Table B3-1, the maximum increase in predicted velocity in the Site is 0.44 ft/s following remediation. Generally, increases in predicted velocity due to Alternative 3 occur within the remediation footprint, with typical increases being less than 0.5 ft/s.

To further investigate the effects of both remedial scenarios on circulation and marsh inundation (i.e., spatial extent and frequency) within the Site, the areal extent of inundation within intertidal marsh areas was compared between remediated conditions and existing conditions. The areal extent of inundation was compared at high and low water levels (i.e., maximum WSE during flood tide and minimum WSE during ebb tide) during neap and spring tidal conditions. For spring tide conditions, high and low water levels were plus 3.9 and minus 4.7 feet NAVD88, respectively, which corresponded to conditions on January 23, 2011. For neap tide conditions, high and low water levels were plus 1.4 and minus 4.1 feet NAVD88, respectively, which occurred on January 28, 2011. During spring tide, the entire Site was predicted to be inundated during high water, with less than 10% of the Site inundated during low water. During neap tide conditions, approximately 60% of the Site was inundated during high water.

Total inundated areas for Alternatives 2 and 3 are compared to existing conditions in Figures B3-8 and B3-9, respectively. The change in the areal extent of inundation due to either remedial scenario was less than 4%, which indicates that the remedial scenarios would not have a significant effect on circulation and marsh inundation (i.e., spatial extent and frequency) within the Site. The inundation results are summarized in Table B3-2.

3.2 Sediment Remedy Alternatives: 100-Year Flood Conditions

A 100-year flood on tributaries to the estuary was simulated assuming that typical tidal conditions (i.e., 21-day calibration period) existed at the downstream boundary. Maximum predicted current velocities for existing conditions and Alternatives 2 and 3 for the 100-year flood are presented in Figures B3-10, B3-11, and B3-12, respectively. The differences in predicted velocity relative to existing conditions for Alternatives 2 and 3 are shown in Figures B3-13 and B3-14, respectively.

Results of the 100-year flood simulation are similar to the results for typical tidal conditions with average tributary flow (Figures B3-3 through B3-7), which is due to the relatively low freshwater inflow to the Turtle and South Brunswick rivers, even during a rare flood. As presented in Table B3-1, during the 100-year flood event, maximum increases in velocity are 0.20 and 0.43 ft/s for Alternatives 2 and 3, respectively. These results indicate that the remediated bed conditions do not have a significant impact on hydrodynamics within the Site, even during a 100-year flood event.

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3.3 Sediment Remedy Alternatives: Hurricane Storm Surge

Consistent with standard practice at other Superfund sites across the US, as well as an industry practice widely accepted by USEPA and USACE, the hurricane storm surge simulation considered a 100-year storm surge occurring during a spring tidal cycle as the worst-case condition. A representative spring tidal cycle, which spanned nine days, was selected from the historical record at the USGS Saint Simons Island gauging station. The increase in WSE corresponding to the 100-year storm surge event was estimated from the NOAA gauging station at Fort Pulaski, Georgia, which was the closest gauging station to the Site with storm exceedance data. At the Fort Pulaski station, a 100-year return period event (i.e., 1% probability of occurring in a particular year) corresponds to a WSE of plus 6.8 feet NAVD88.

To simulate conservative storm surge conditions (i.e., accounting for the combined effects of spring tides and the 100-year storm surge), WSE values during the spring tidal cycle were adjusted such that the maximum WSE reached the estimated 100-year storm surge elevation (Figure B3-15). Maximum increases in predicted current velocity for all remedial scenarios and hydrodynamic conditions are summarized in Table B3-1.

When compared to the typical tidal condition and 100-year flood simulations, larger areas within Purvis Creek and the secondary channels were predicted to have maximum velocities greater than 2 ft/s during the hurricane storm surge following remedy implementation (Figures B3-16 through B3-18). As presented in Table B3-1, maximum increases in velocity relative to existing conditions due to implementation of Alternatives 2 and 3 were 0.20 and 0.55 ft/s, respectively. In general, predicted increases in maximum velocity are larger for Alternative 3 than Alternative 2 (Figures B3-19 and B3-20). However, the increase in maximum velocity is typically less than 0.5 ft/s for both remedial scenarios, with only isolated areas experiencing larger changes (i.e., greater than 0.5 ft/s).

Although the velocity changes associated with the 100-year flood and hurricane storm surges were relatively minor, primarily impacting the remediation areas and not the remaining marsh, they may influence various remedy design parameters such as armoring requirements and construction/material placement methods.

Additional simulations for storm surges with rarer recurrence intervals (e.g., 500-year event) may be considered during the design phase of the study to evaluate model sensitivities. However, based on experience from other sites of similar characteristics, the incremental effects of higher frequency storm surges on marsh sites such as the Brunswick LCP Site is not expected to be considerable. The *2010 Georgia Hurricane Readiness Plan* (GEMA 2010) establishes procedures for state employees to follow in the event of a hurricane. The document presents a range of wind speeds and storm surges for Category 1 to 5 hurricanes, as well as typical effects of each category. It also provides a brief, though unsubstantiated, anecdote from 1898 in which a Category 4 hurricane caused a 16-foot storm surge in the city of Brunswick and surrounding communities.

A 2009 USACE document titled *Chatham County Emergency Operations Plan, Incident Annex A, Appendix 5, Historic Storm Tide Elevations* (USACE 2012), catalogues historic surge

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elevations based on observer accounts and maximum tide gauge records. The storm surges from the historical observer accounts range from 10 to 13 feet, NAVD 88, and the maximum surge from the tide gauge records ranges from 6 to 7 feet, NAVD 88. Computer model predictions of storm surges for Category 1 to 5 hurricanes were presented in the 2012 Operations Plan (USACE 2012), but the recurrence intervals for these storm surge predictions were not discussed, which is a key drawback of the report.

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4 Summary

The hydrodynamic model was developed and calibrated using Site-specific data to the extent feasible. A boundary-fitted numerical grid, with relatively high resolution in the Site, was used to represent spatial variations in geometry and bathymetry throughout this estuary. The model was calibrated using WSE and current velocity data collected during a 21-day period (January 18 to February 7, 2012), which included a spring-neap tidal cycle. The model reproduced four key characteristics of hydrodynamics within the Site:

- Amplitude and phase of WSE
- Qualitative differences in the symmetry (asymmetry) of tidal currents during ebb and flood tide between Turtle River and Purvis Creek
- Changes in the magnitude of along-channel velocity during the neap-spring tidal cycle
- Flooding and drying of secondary channels and inter-tidal marsh areas

Successful calibration of the model indicated that it can be used as a management tool to develop a CSM and to reliably evaluate remedial alternatives for a range of flow and tidal conditions.

The hydrodynamic model was used as a tool to evaluate the potential effects of two remedial alternatives on hydrodynamics and circulation within the Site. To quantify the effects of the remedial alternatives on hydrodynamics, the model was used to predict changes in inundated intertidal area and maximum current velocity due to remediated bed conditions. The hydrodynamic model was used to simulate two remedial scenarios:

1. Alternative 2 consists of dredging and backfill with a net change of minus 0.5 feet in all remediation areas.
2. Alternative 3 specifies a combination of remedial action with dredging and backfill (net change of minus 0.5 feet), capping (net increase in bed elevation of 1 foot), and thin cover (net increase in bed elevation of 0.5 feet).

Existing conditions and the two remedial scenarios were simulated for three hydrodynamic conditions:

1. typical tidal conditions over a spring-neap tidal cycle
2. 100-year flood
3. hurricane storm surge

In general, the change in the areal extent of intertidal inundation due to either remedial scenario was less than 4%, which indicated that the remedial scenarios would not have a significant effect on the circulation and marsh inundation within the Site. Overall, only relatively minor increases in maximum current velocities (relative to existing conditions) were predicted to occur for the two remedial scenarios.

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Appendix B
Hydrodynamic Modeling

Tables

Table B2-1: Skill Assessment for WSE during Model Calibration Period

Water Level Sensor Location	Skill	RMSE (feet)
WL1	0.99	0.43
WL2	0.99	0.52
E1	0.99	0.37
P1	0.99	0.51
P2	0.99	0.44
T1	0.99	0.49

Note:
RMSE = root mean square error
WSE = water surface elevation

Table B2-2: Skill Assessment for Current Velocity During Model Calibration Period

Current Meter Location	Skill	RMSE (feet/second)
E1	0.82	0.41
P1	0.98	0.18
P2	0.99	0.12
T1	0.98	0.28

Note:
RMSE = root mean square error

Table B3-1: Maximum Increases in Predicted Current Velocity for Sediment Remedy Alternatives 2 and 3

Sediment Remedial Alternatives	Maximum Increase: Typical Tidal Conditions (ft/s)	Maximum Increase: 100-year Flood (ft/s)	Maximum Increase: Hurricane Storm Surge (ft/s)
2	0.21	0.20	0.20
3	0.44	0.43	0.55

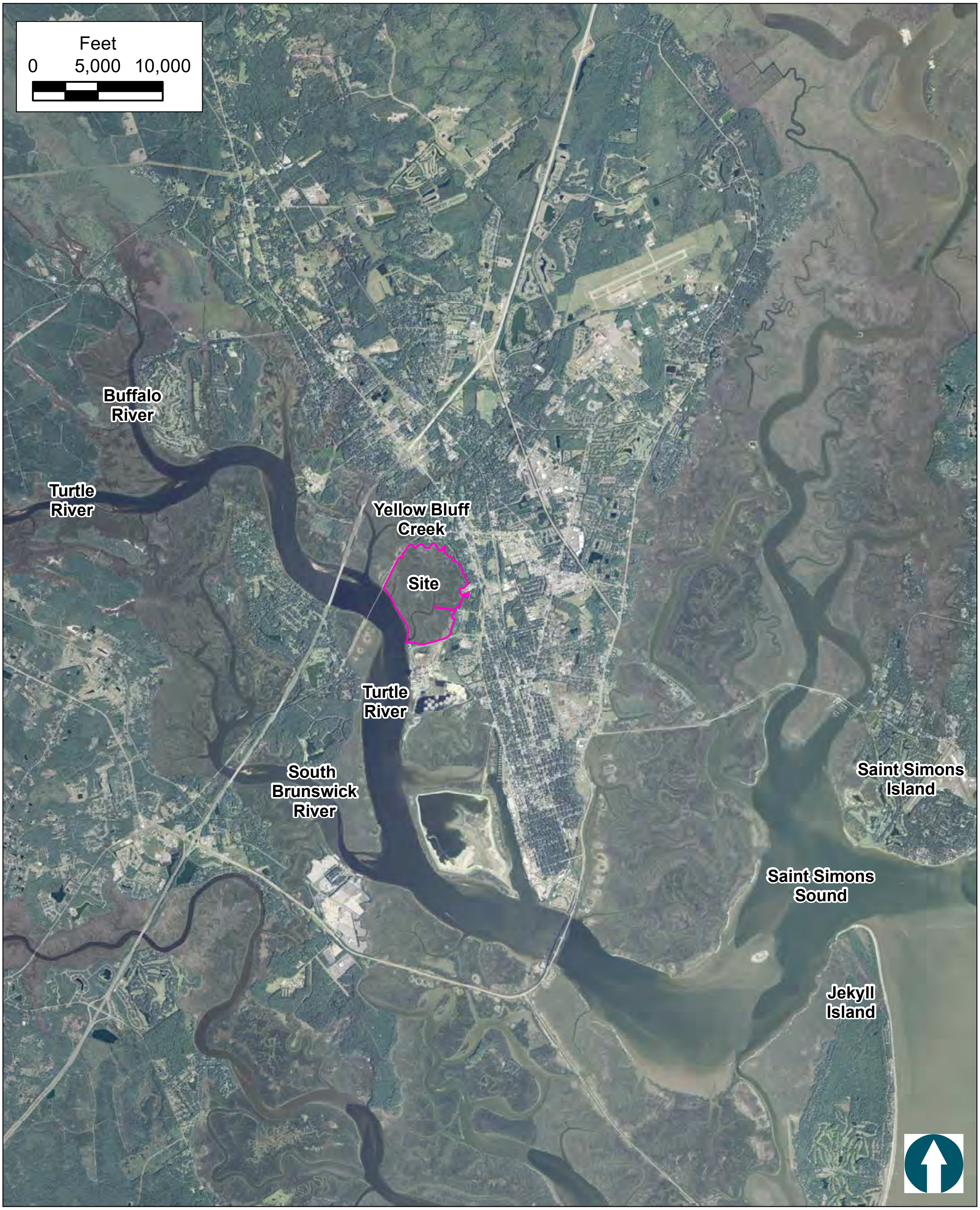
Note:
Maximum increase denotes values when compared with existing conditions.
ft/s – feet per second

Table B3-2: Relative Difference in Inundation Area With Respect to Existing Conditions

Tidal Conditions	Sediment Remedial Alternative 2	Sediment Remedial Alternative 3
Neap tide, low water	0.9%	-0.7%
Neap tide, high water	3.5%	-1.3%
Spring tide, low water	0.9%	-0.7%
Spring tide, high water	0.0%	0.0%

Appendix B
Hydrodynamic Modeling

Figures



Overview of Brunswick River Estuary

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B1-1

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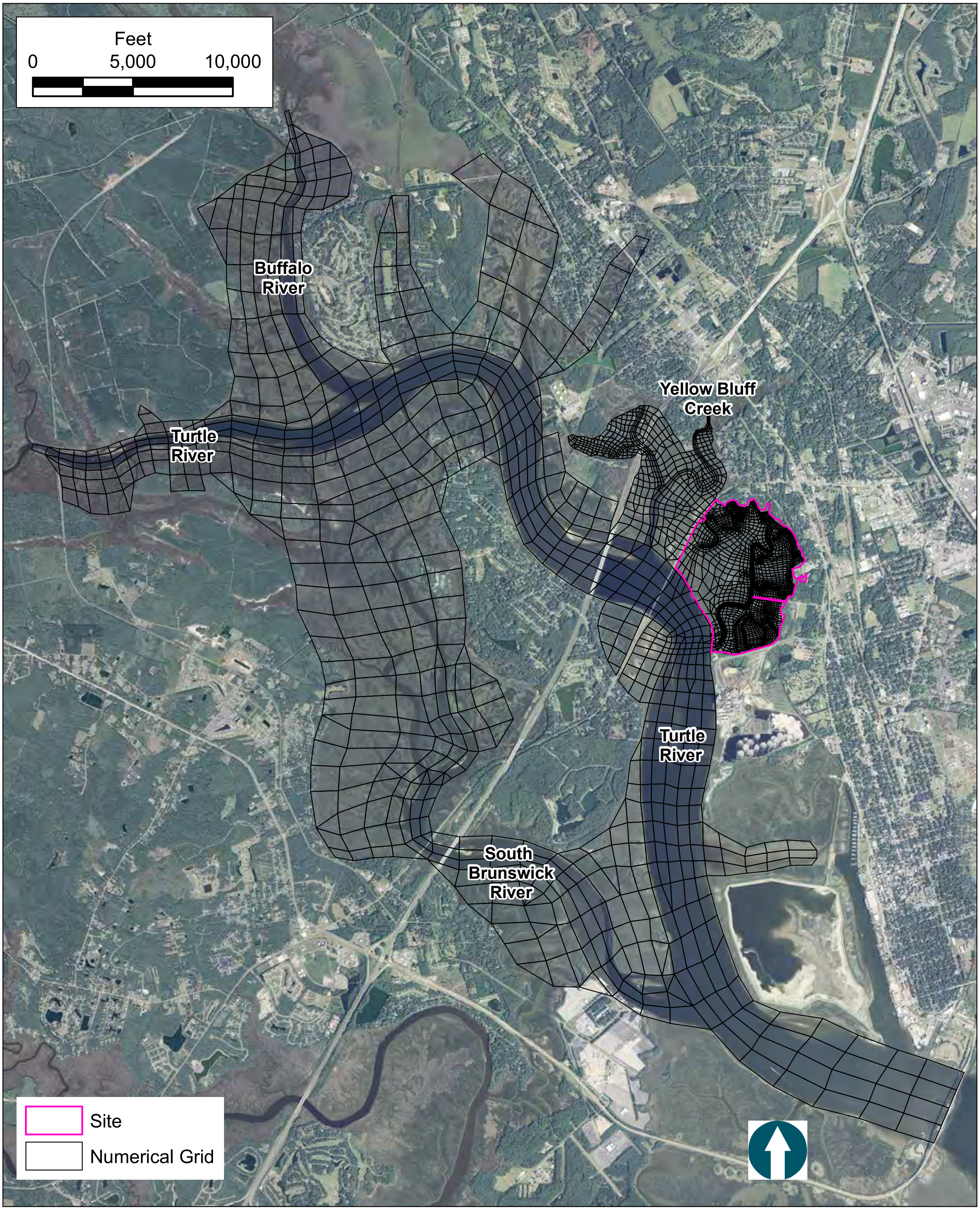
Intertidal Marsh and Creek Area Adjacent to Brunswick LCP Site

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B1-2



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Numerical Grid for Model Domain

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-1

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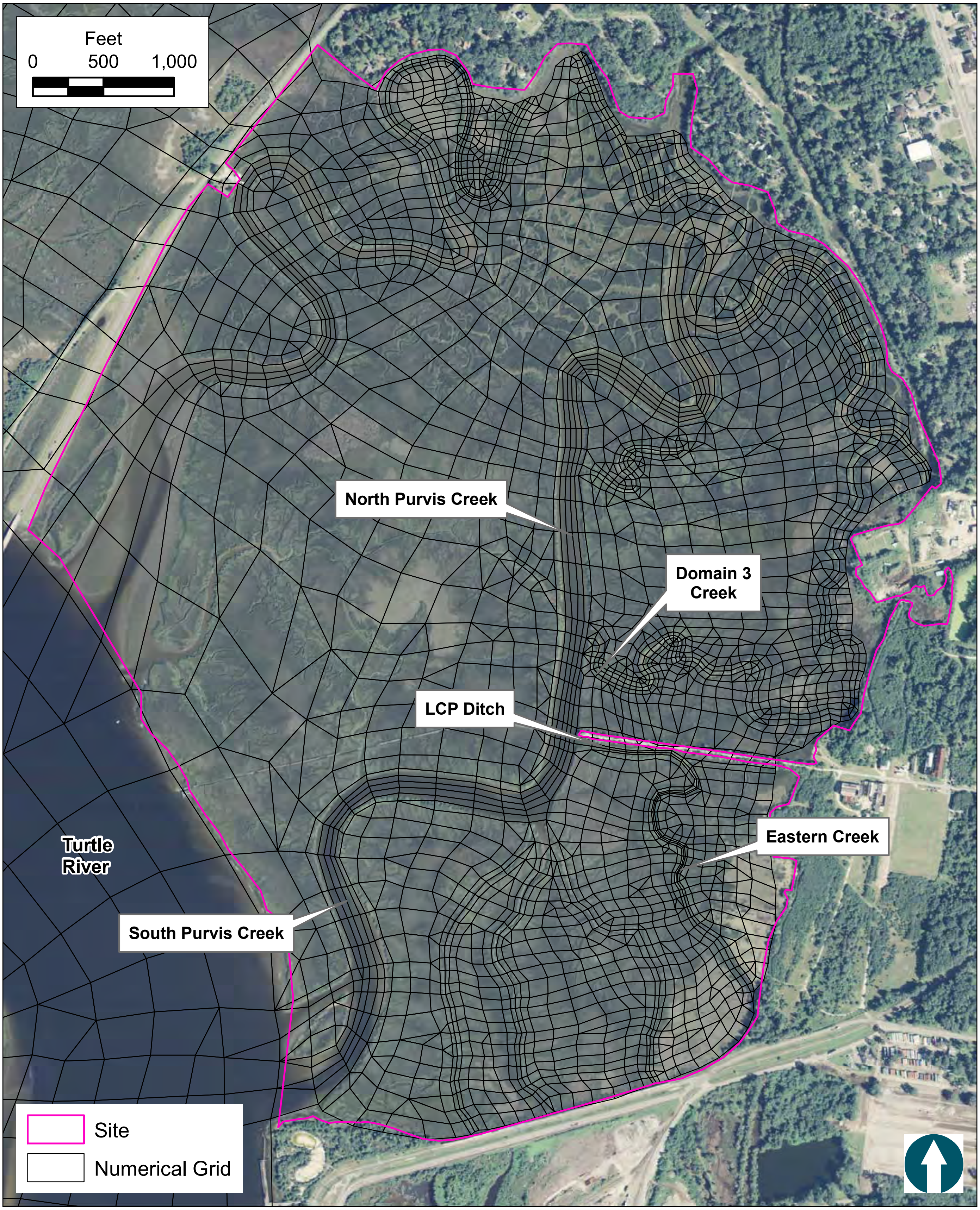

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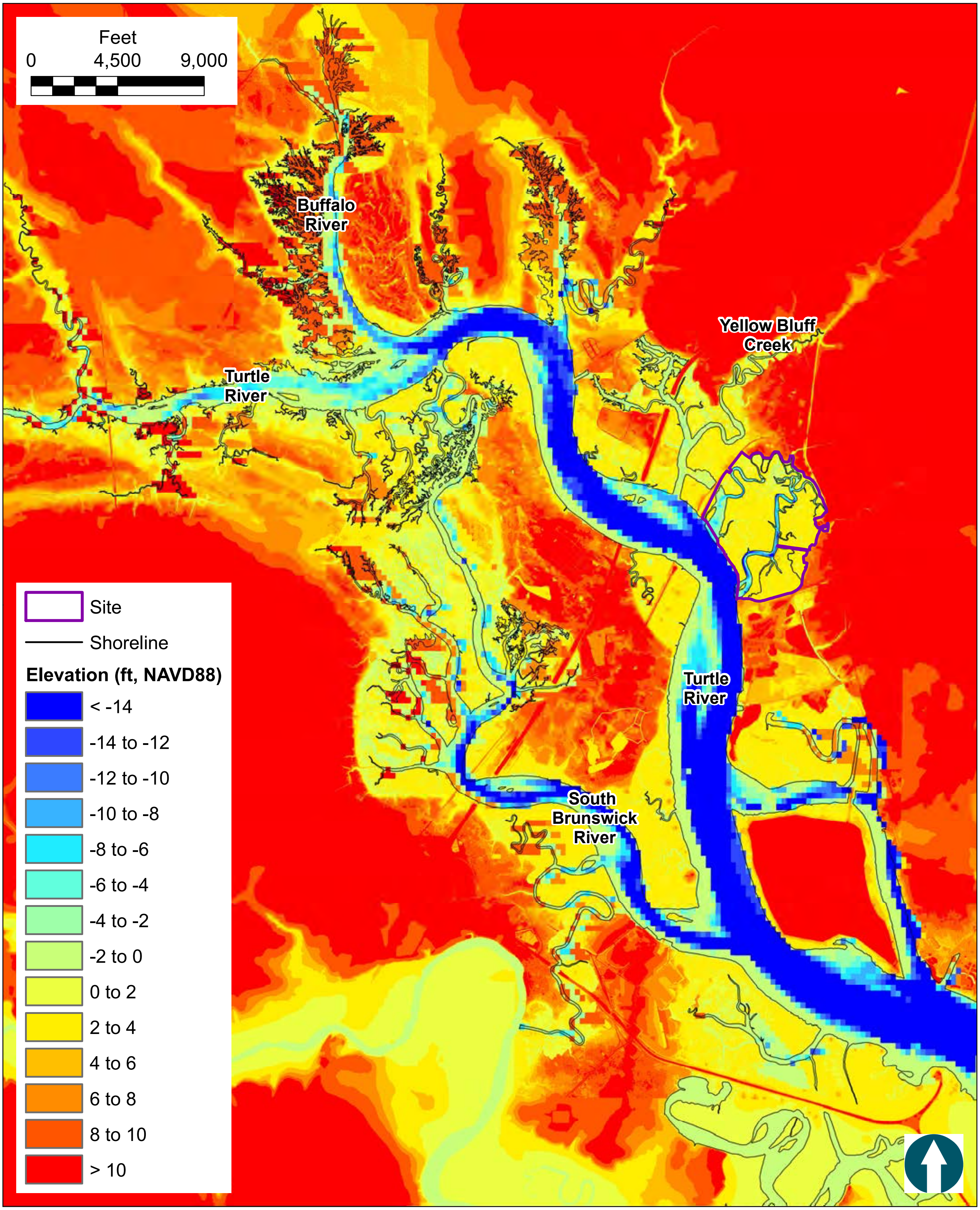
Numerical Grid within the Site

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-2



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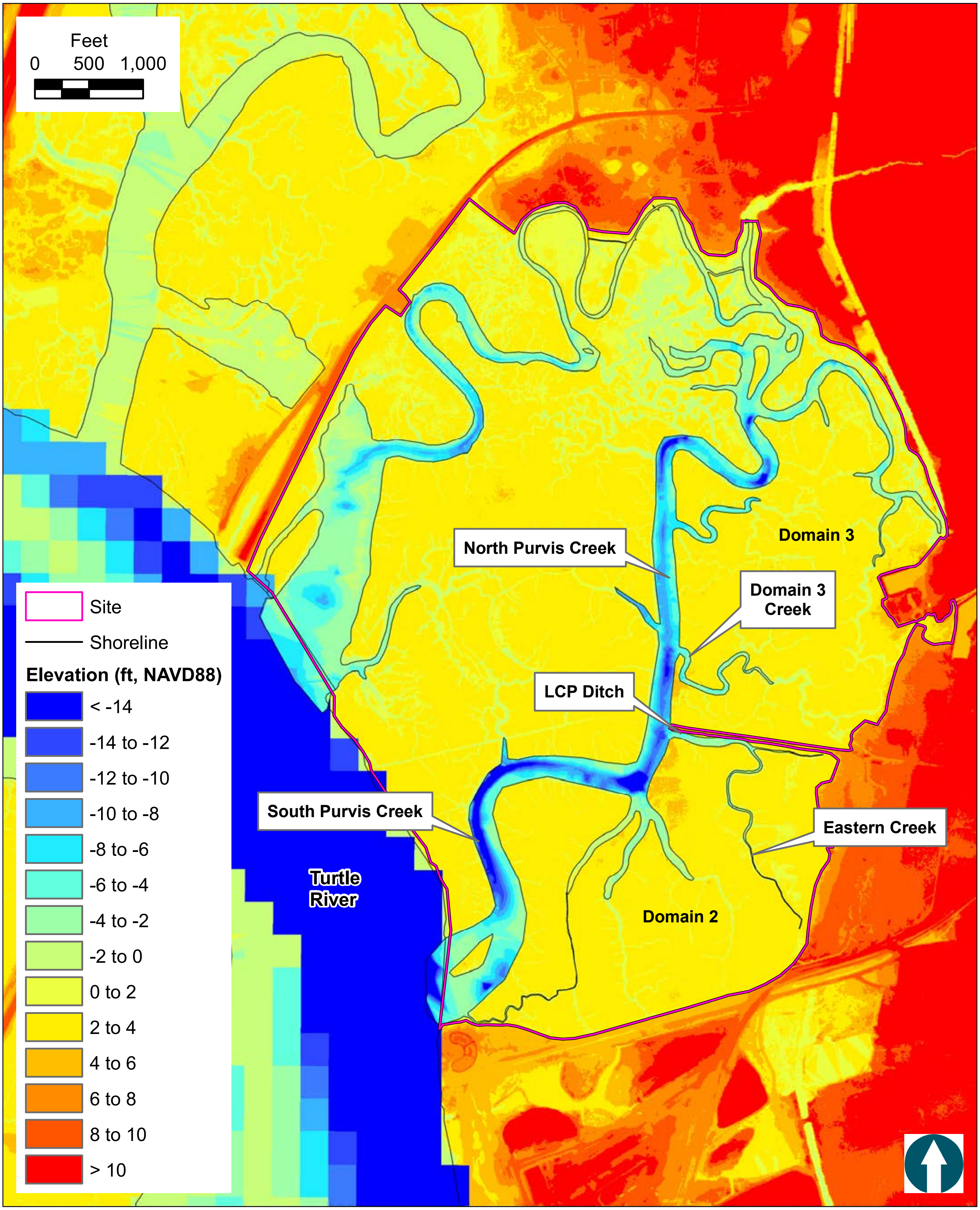
Bed Elevation for Model Domain

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-3



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Surface Elevation within the Site based on LiDAR Data in Marshes and Single-beam Bathymetry in Channels

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-4

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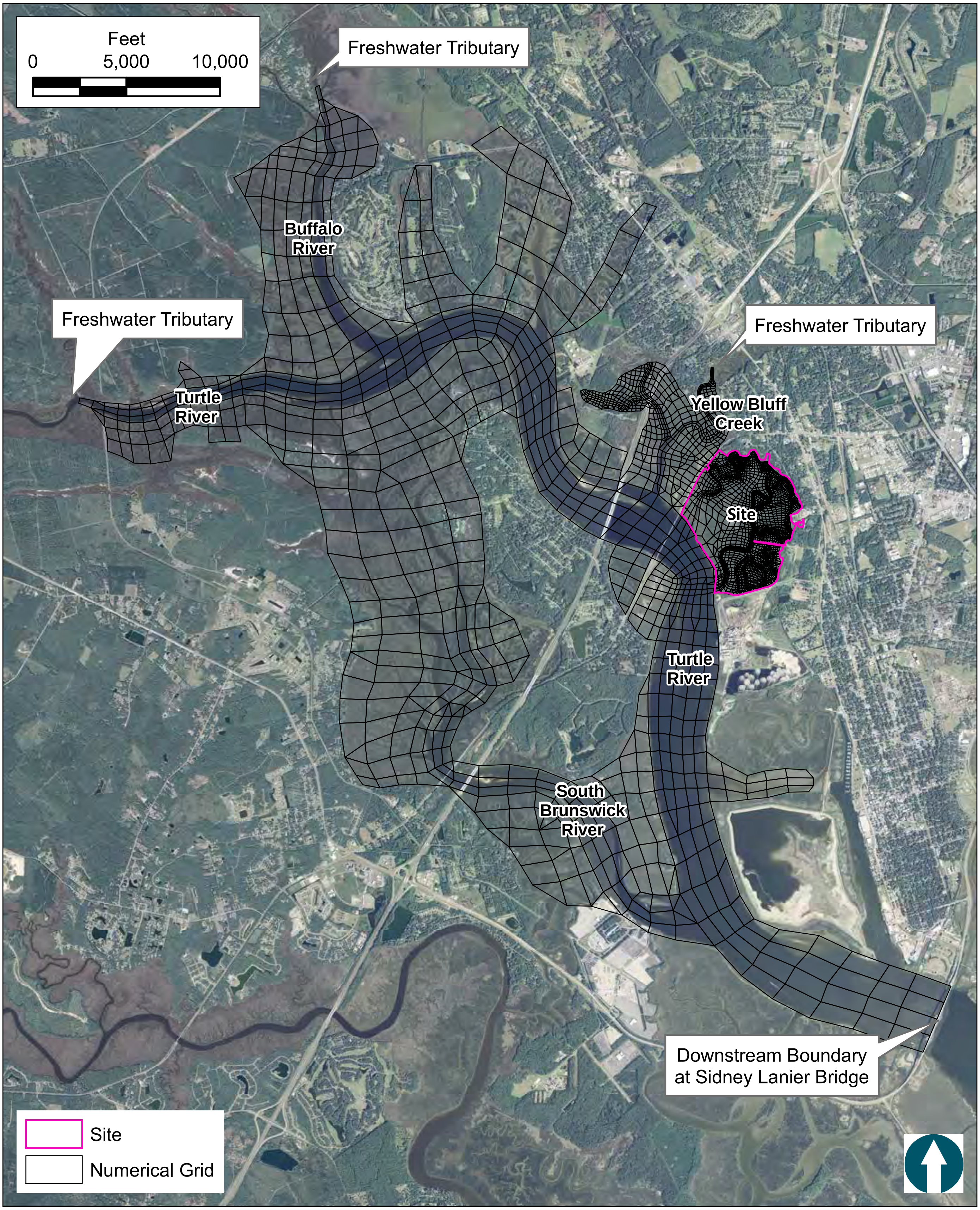

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Locations of Downstream Boundary and Tributaries

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Figure B2-5

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Locations of Tidal Gauging Stations

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-6

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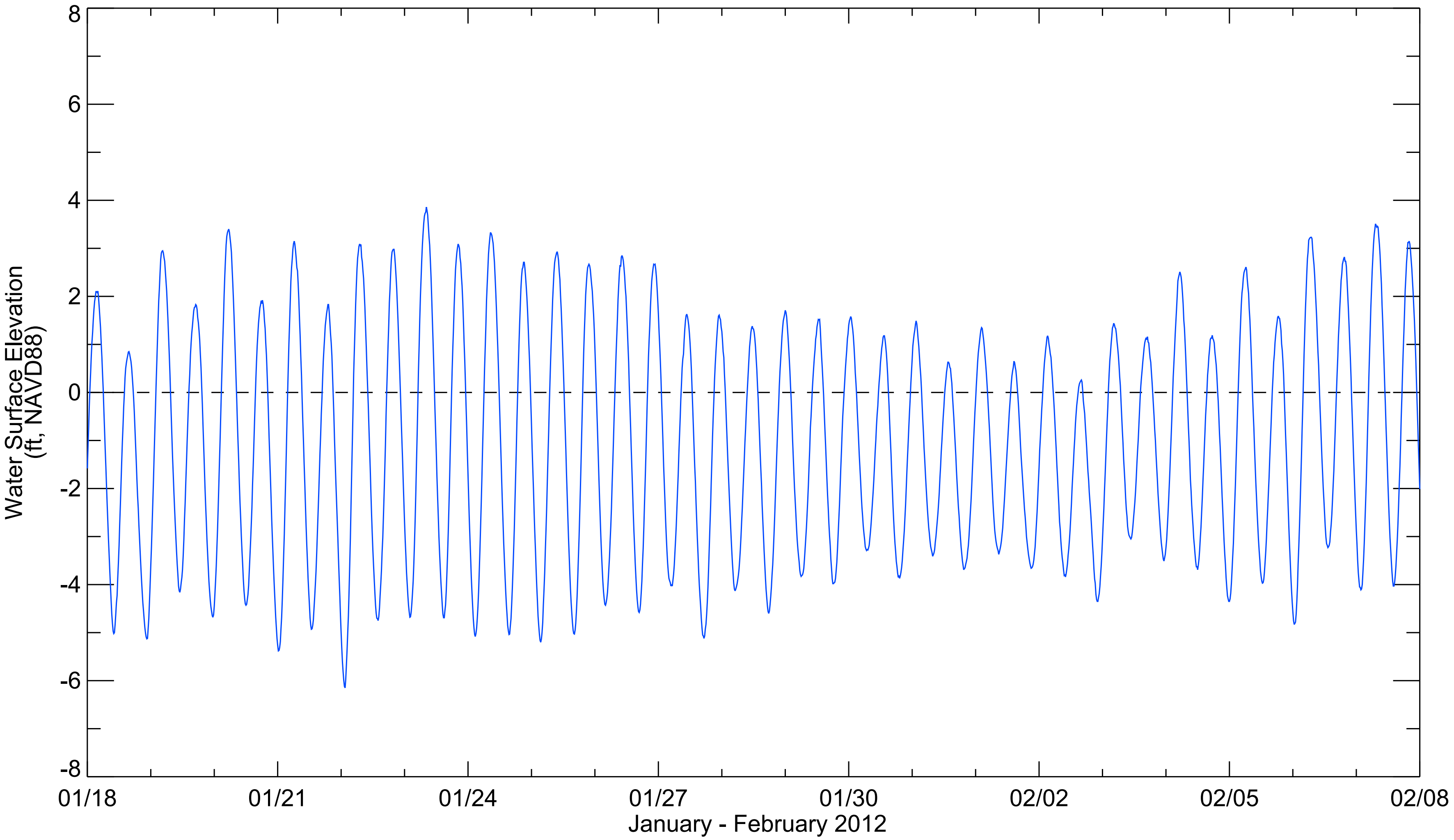
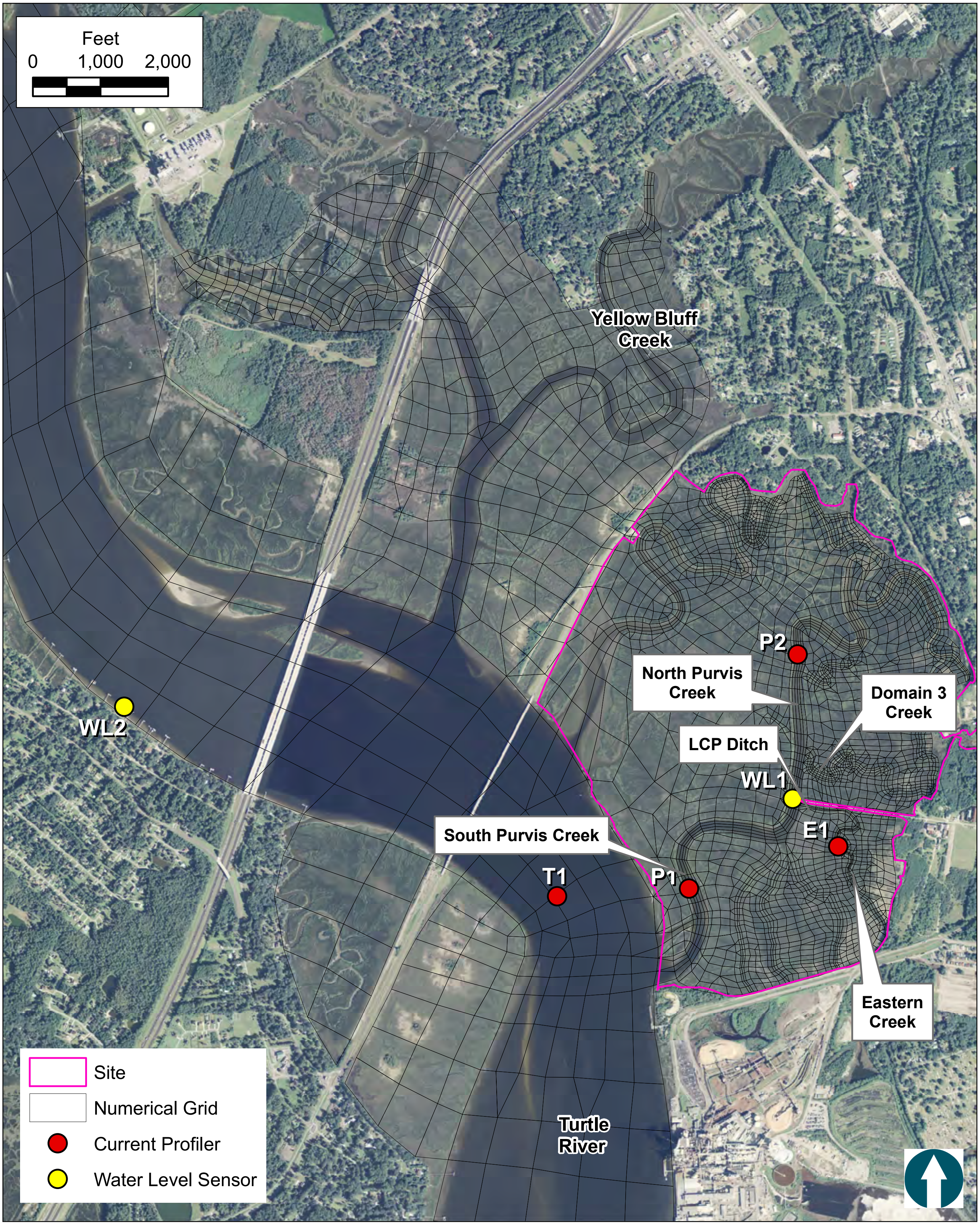


Water Surface Elevation at Downstream Boundary during Calibration Period

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-7



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Locations of Water Level Sensors and ADCPs near Site

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-8

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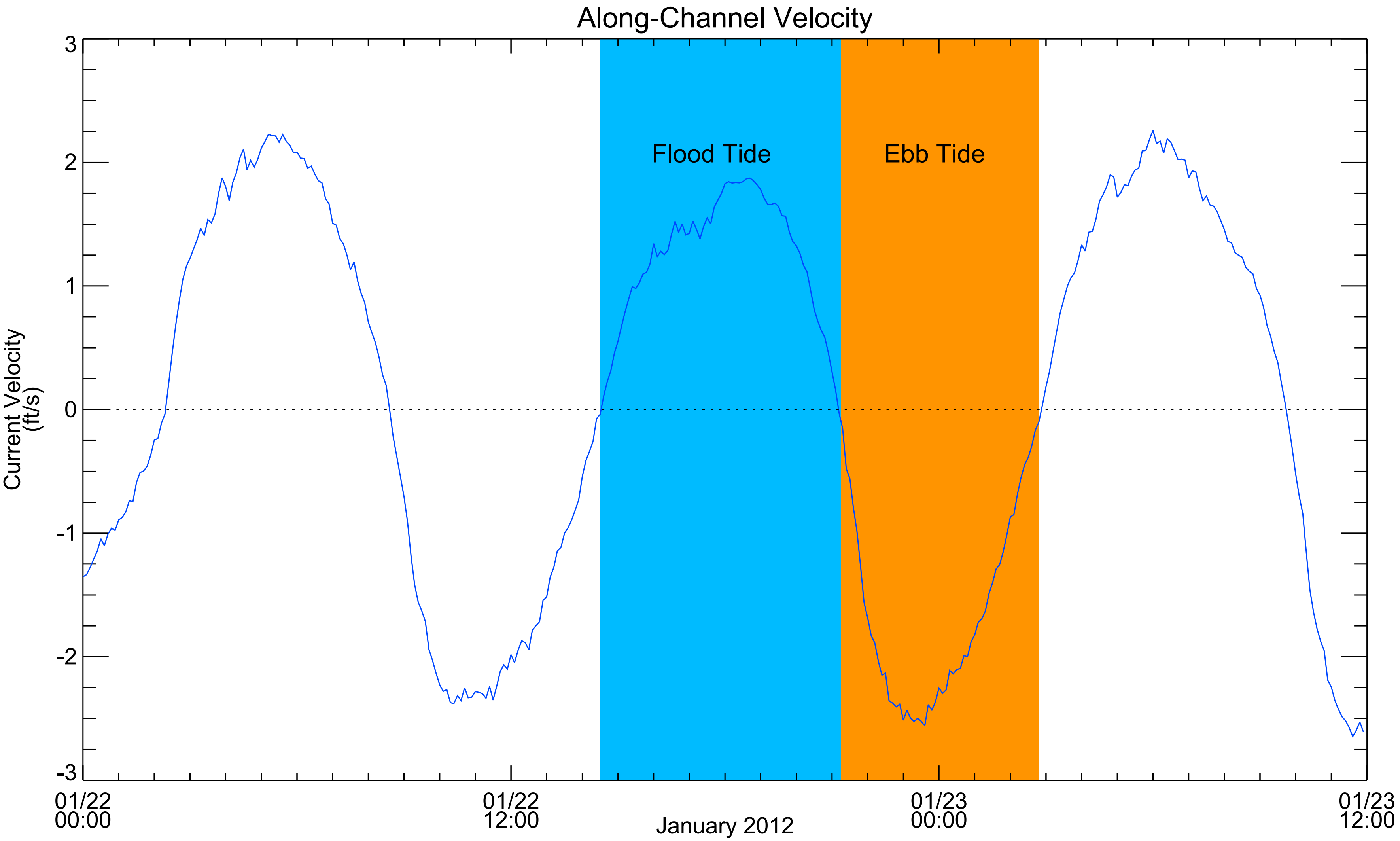

Behavior of Tidal Currents in Turtle River (Station T1) during Spring Tide

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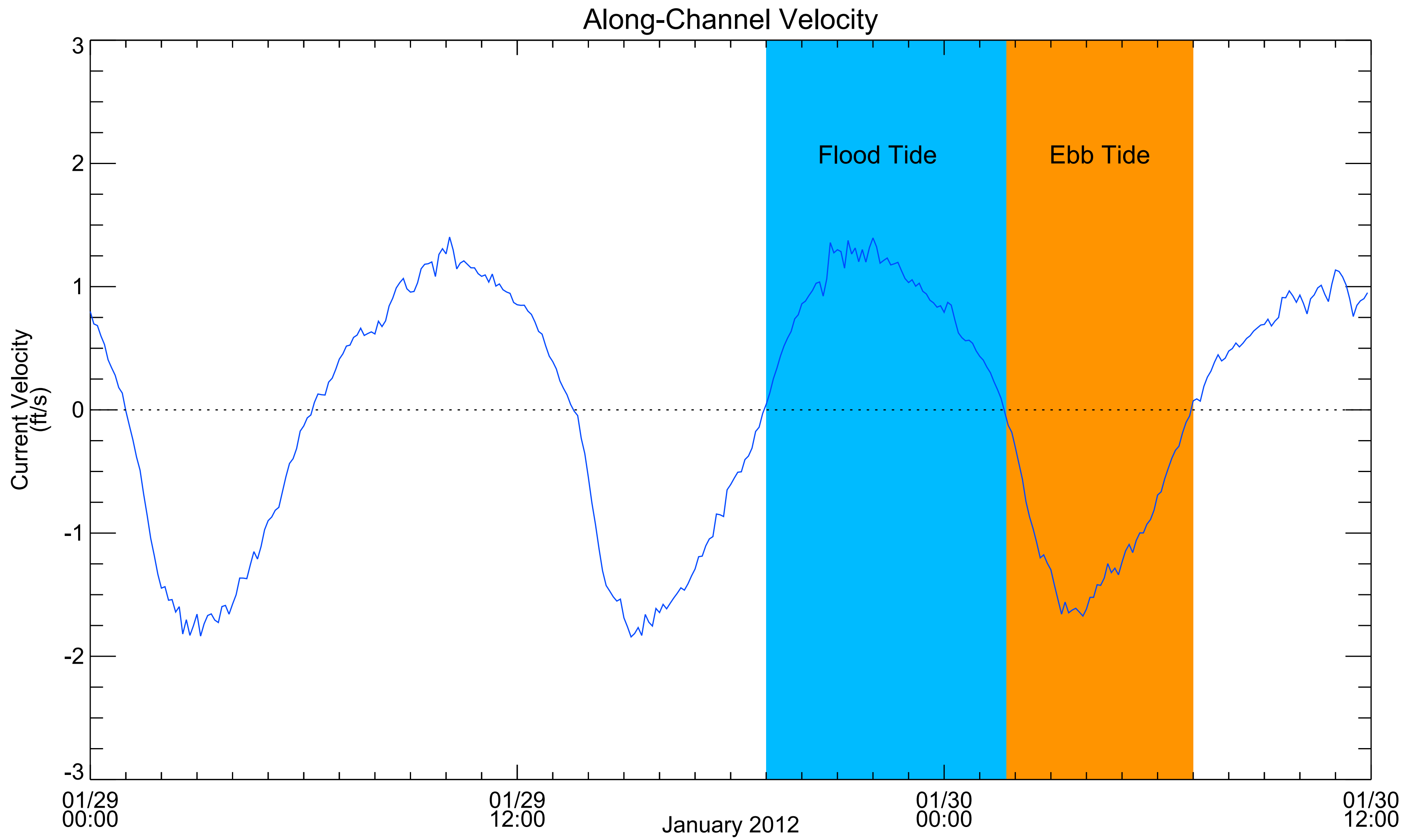
LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-9



Behavior of Tidal Currents in Turtle River (Station T1) during Neap Tide

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Figure B2-10

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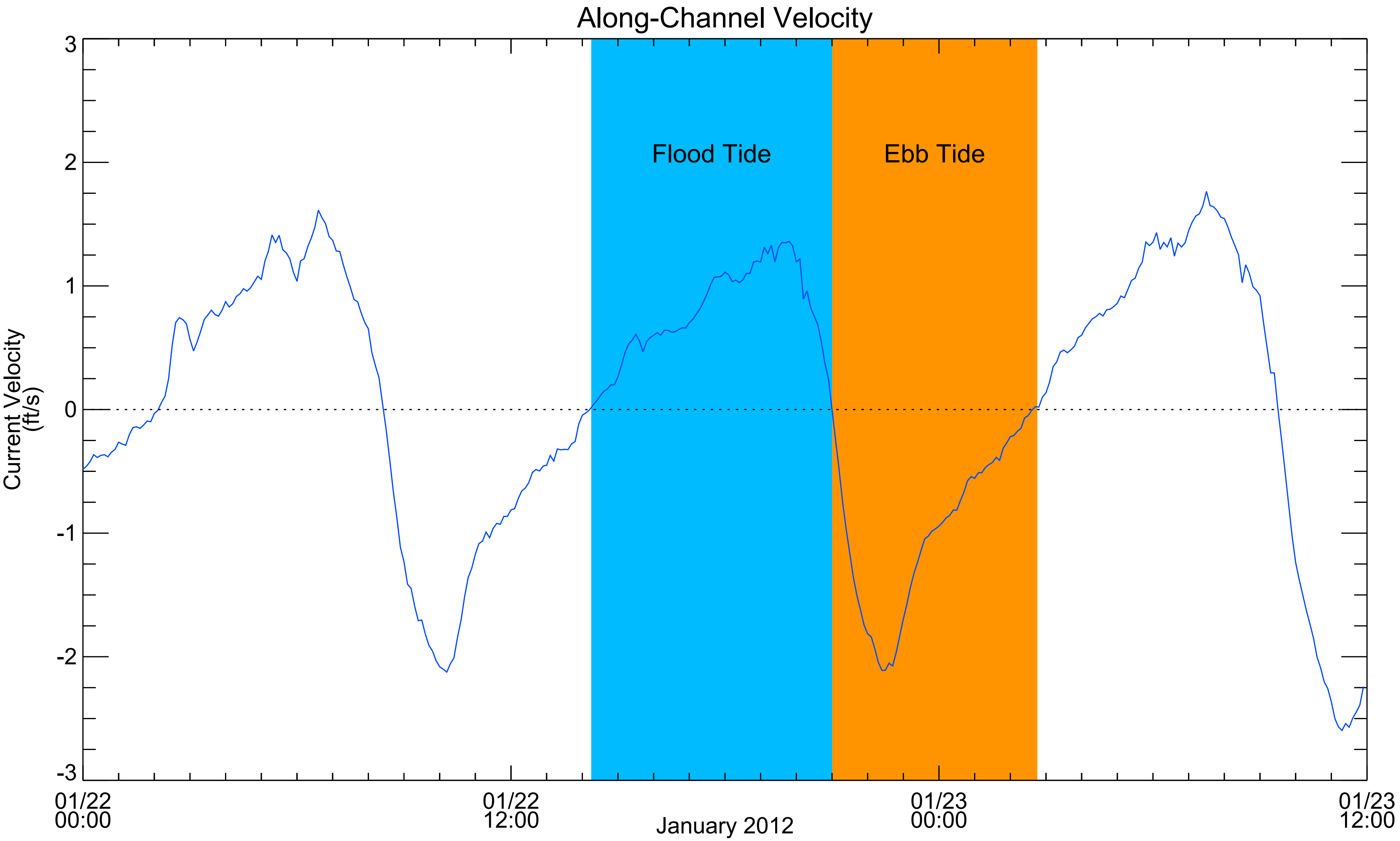

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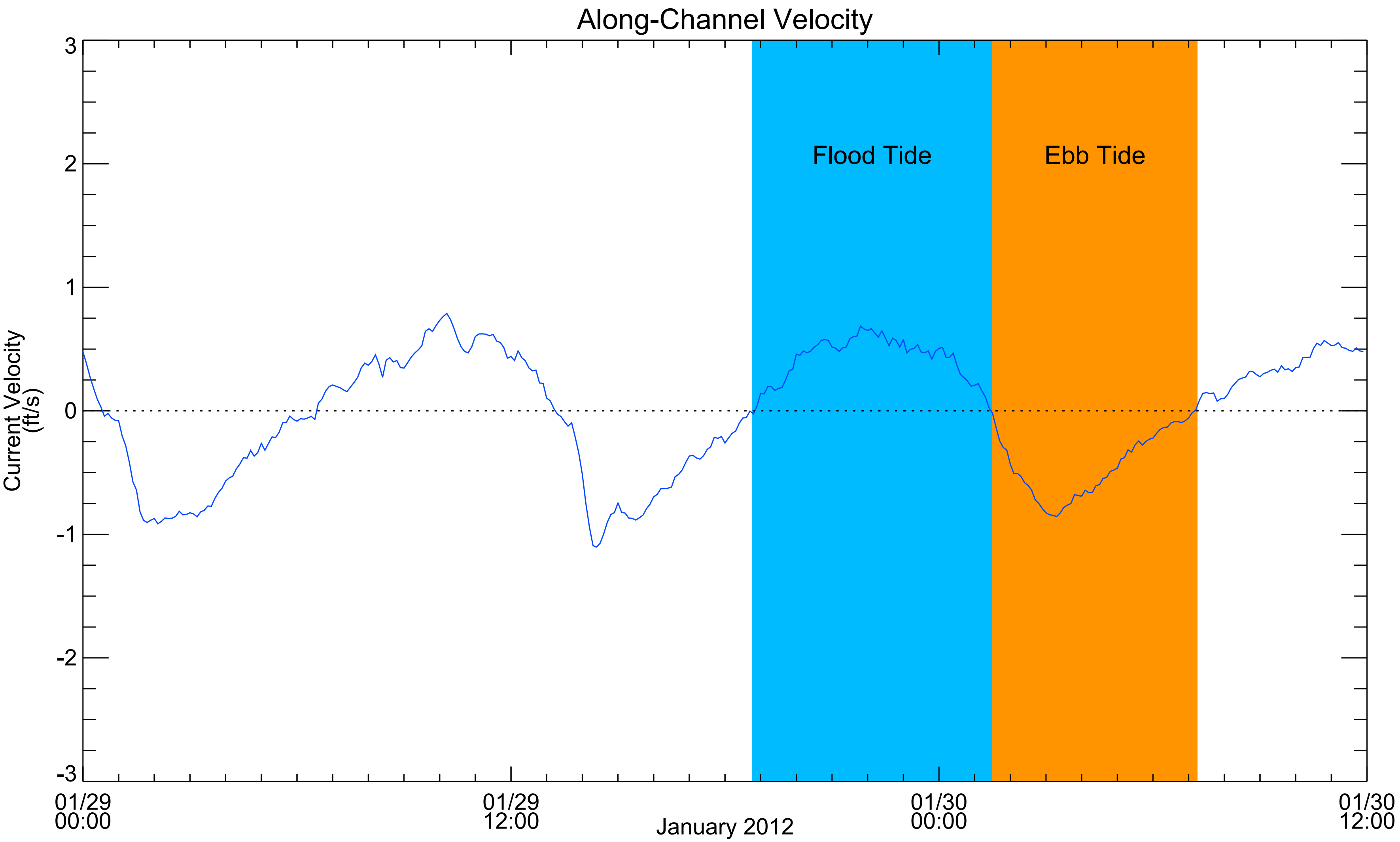
Behavior of Tidal Currents in Purvis Creek (Station P1) during Spring Tide

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-11



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Behavior of Tidal Currents in Purvis Creek (Station P1) during Neap Tide

Figure B2-12

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

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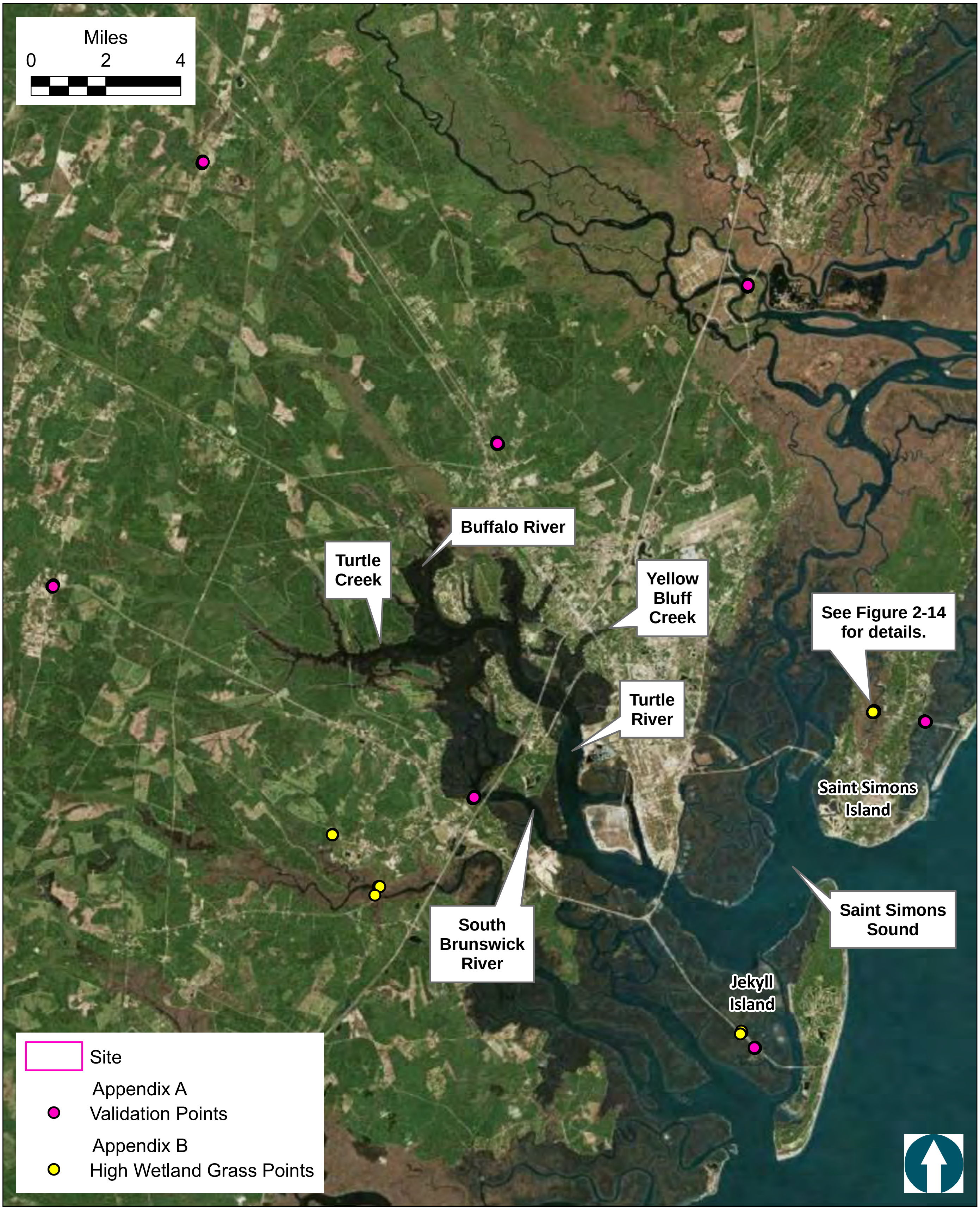

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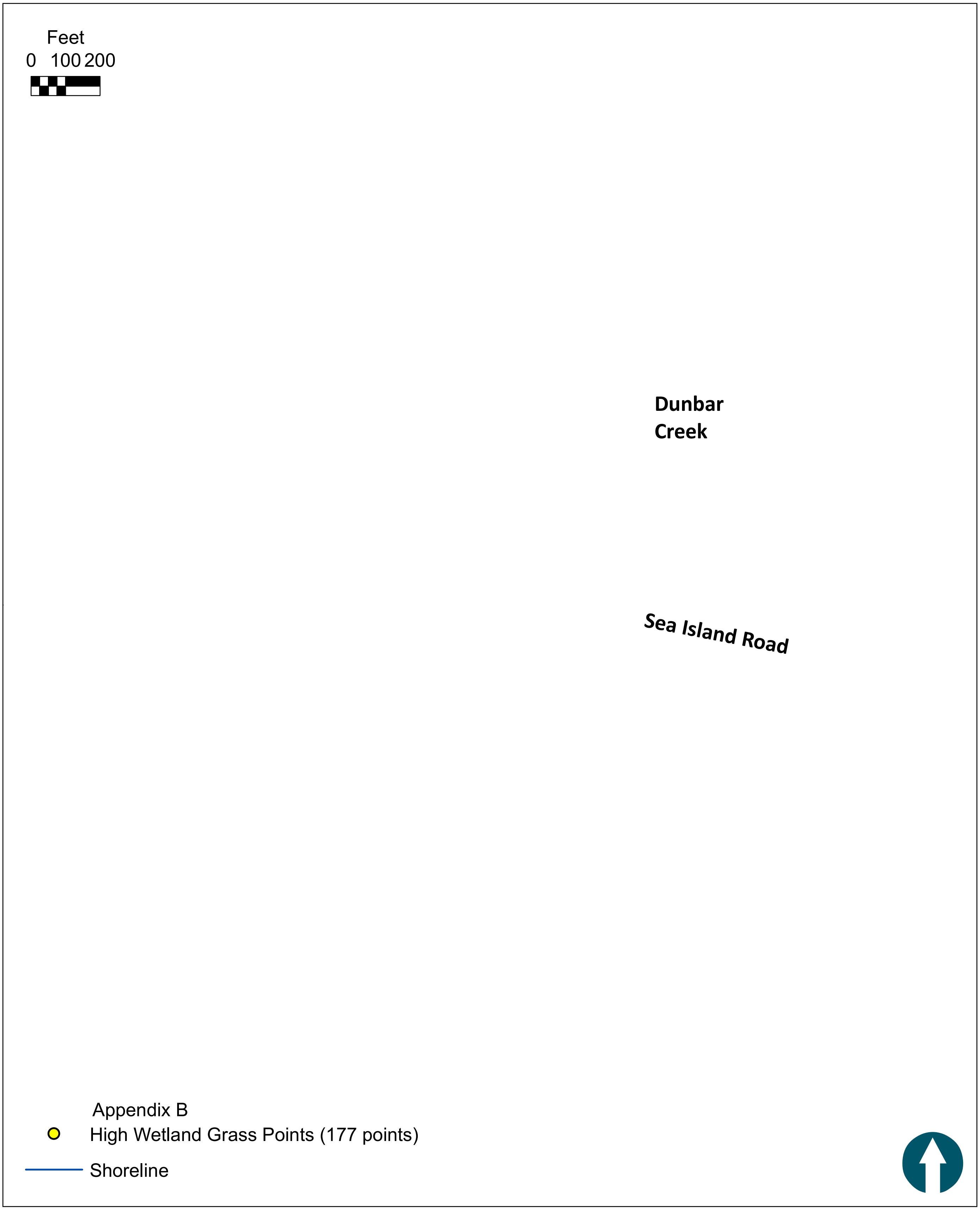
LiDAR DEM Quality Control Survey Locations
in Glynn County, Georgia

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-13



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Cluster of LiDAR Validation Measurements
at a Quality Control Survey Location

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-14

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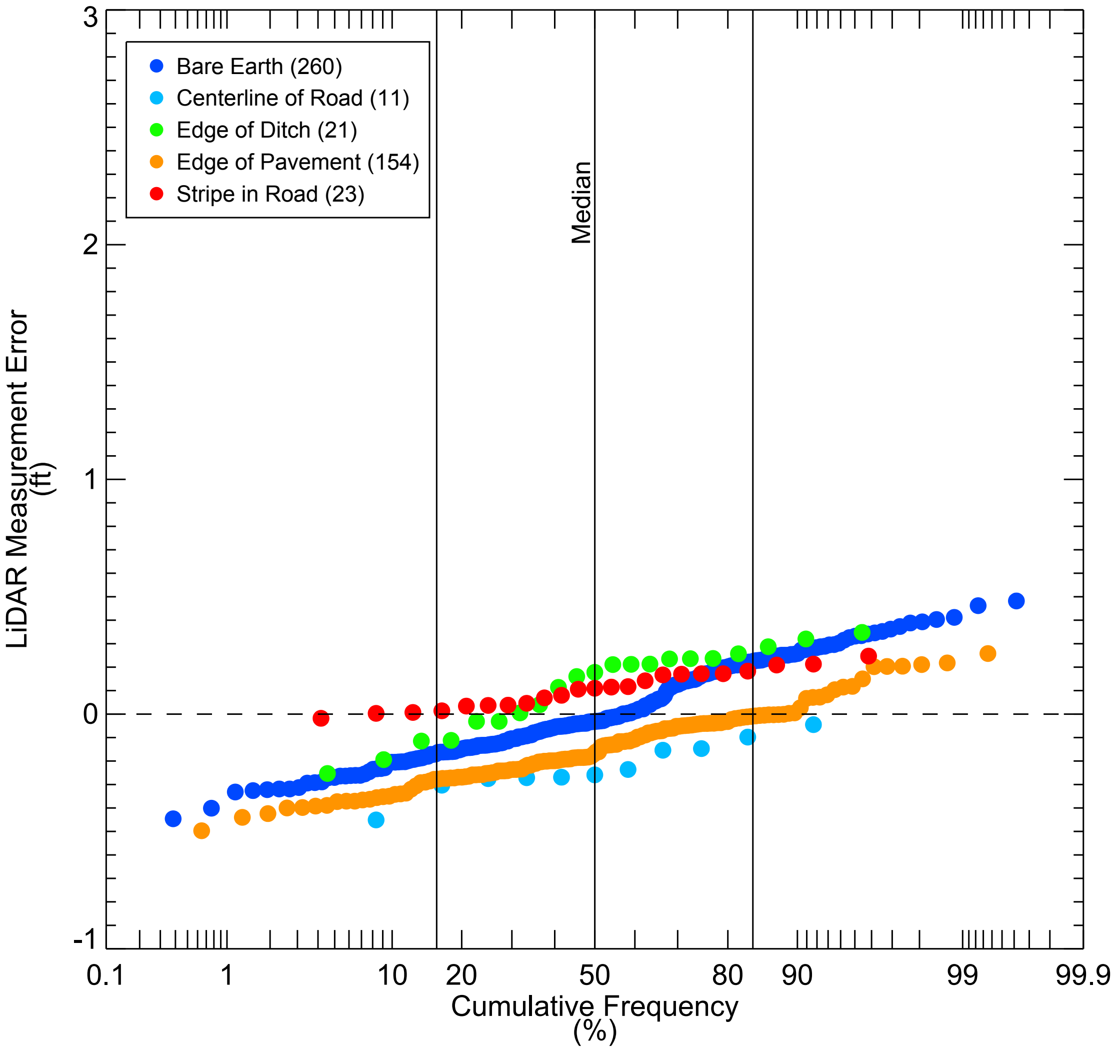

Cumulative Frequency Distributions of LiDAR Measurement Errors at Validation Points for Hard Surfaces

Note: Number of measurements for each surface noted in parentheses in legend.

Figure B2-15

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

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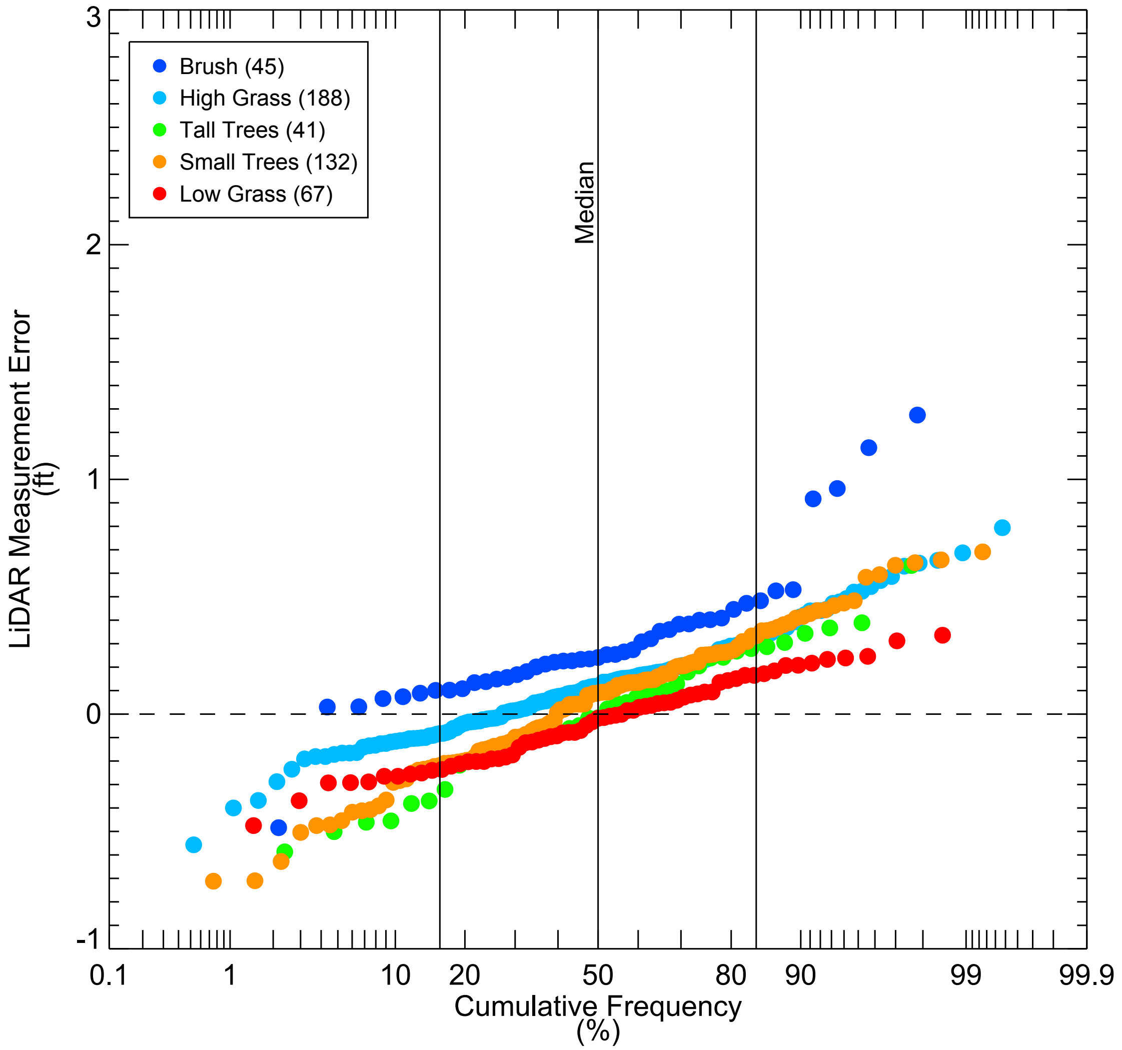

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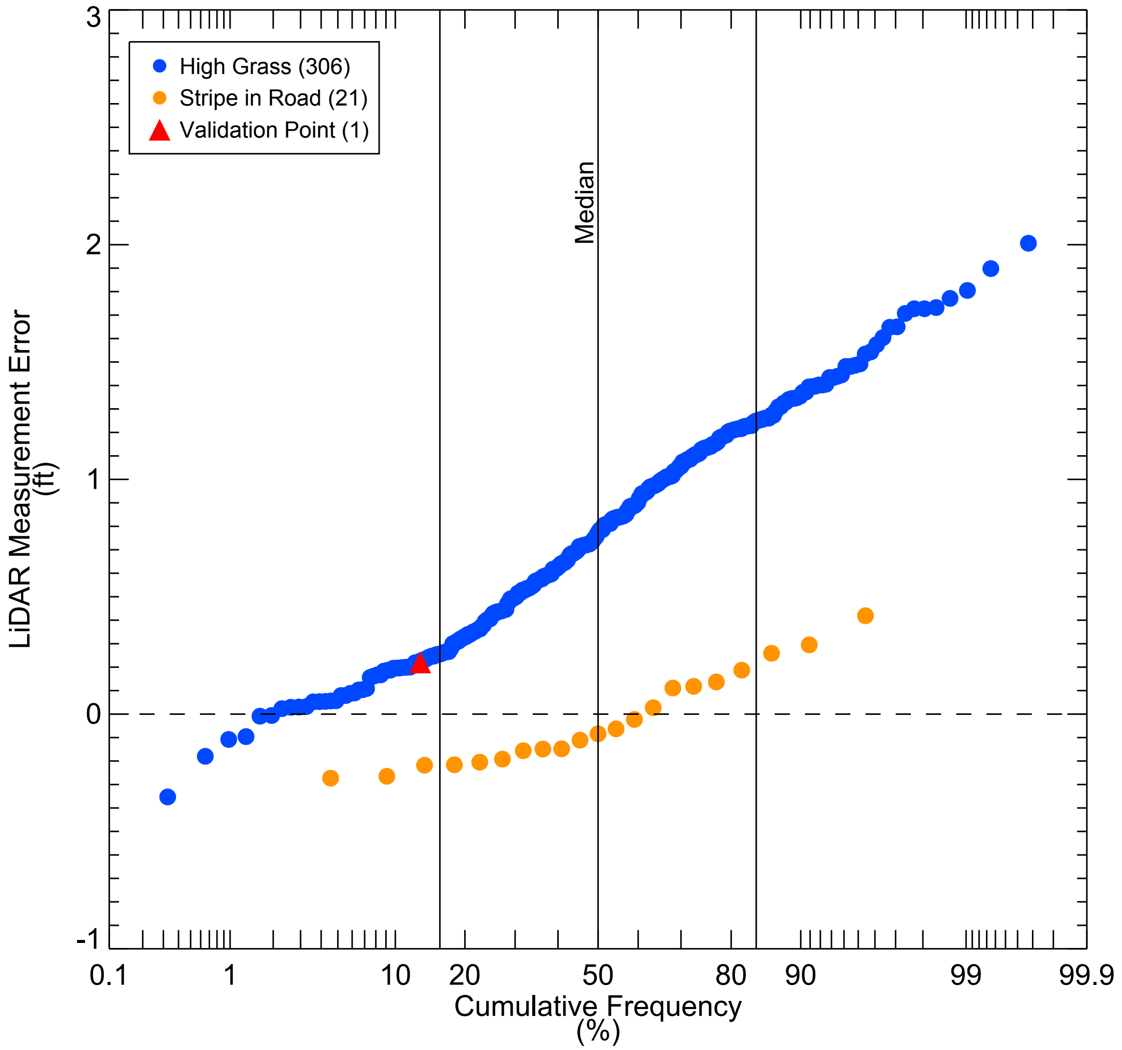
Cumulative Frequency Distributions of LiDAR Measurement
Errors at Validation Points for Upland Vegetation

Note: Number of measurements for each surface noted in parentheses in legend.

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-16



Cumulative Frequency Distributions of LiDAR
Measurement Errors in Marsh High Grass Areas

Note: Number of measurements for each surface noted in parentheses in legend.

Figure B2-17

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

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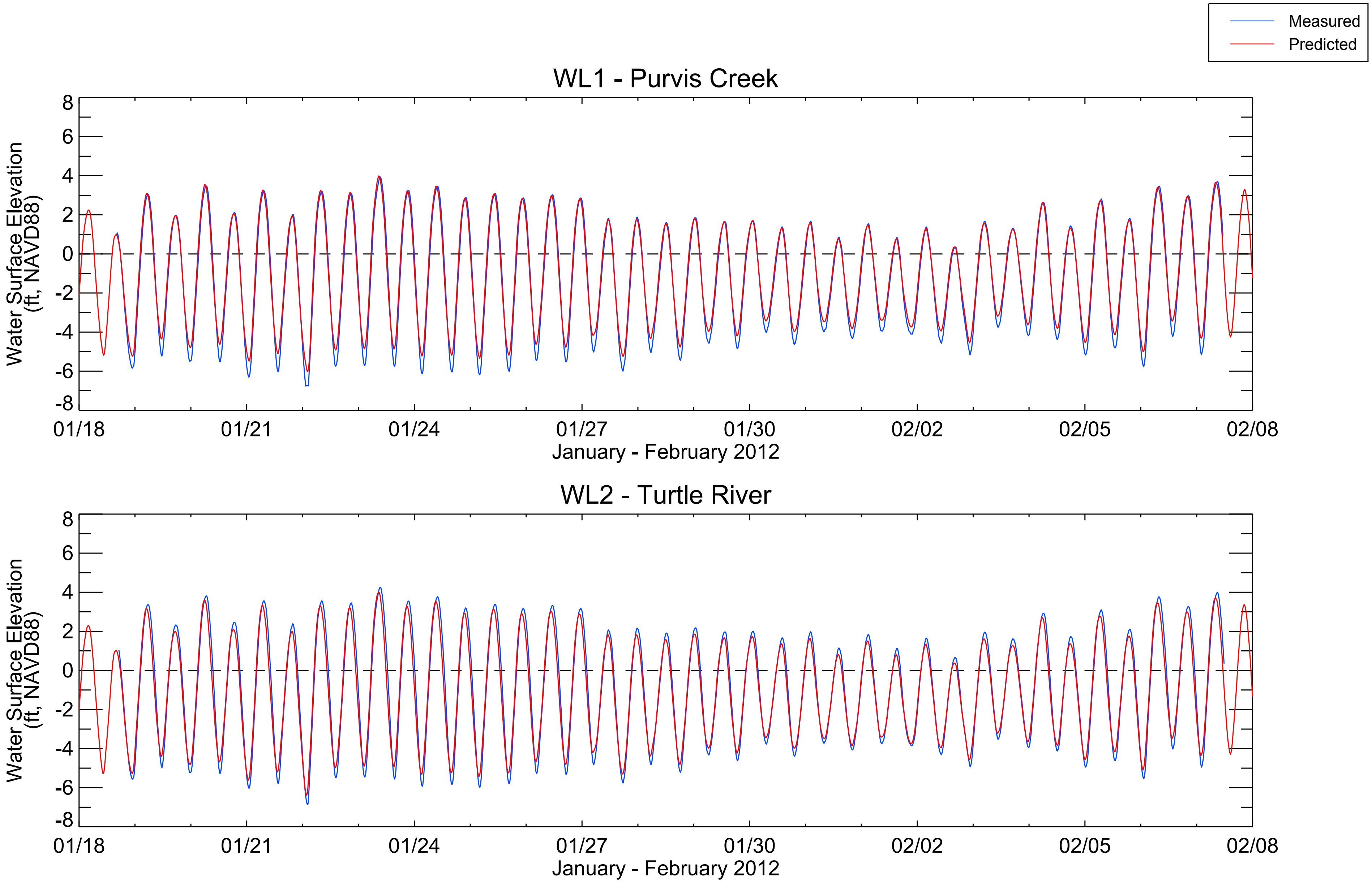

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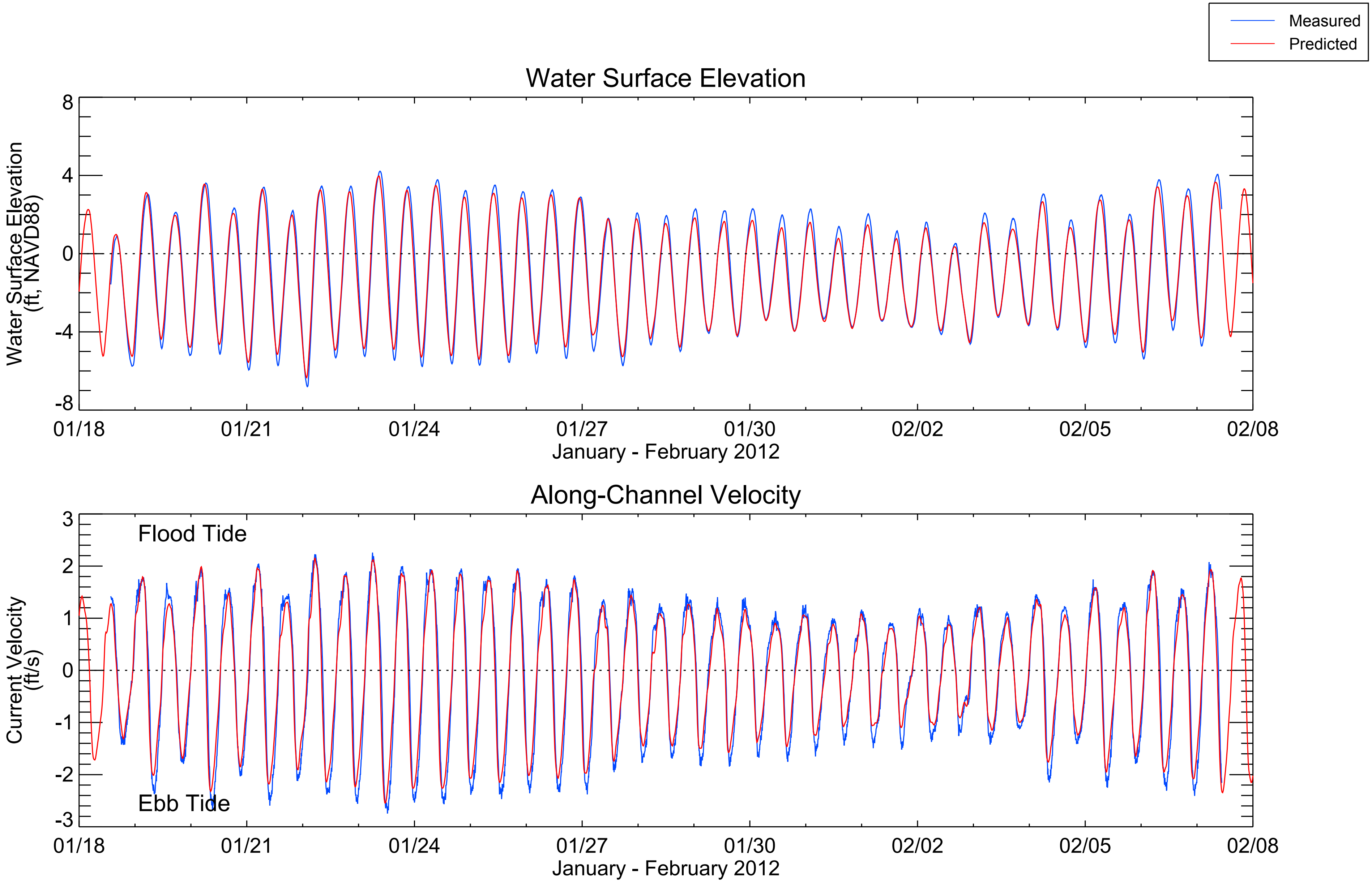
Comparison of Predicted and Measured Water Surface
Elevation at Stations WL1 and WL2

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-18



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Comparison of Predicted and Measured Water Surface Elevation and
Along-Channel Current Velocity at Station T1 during Calibration Period

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-19

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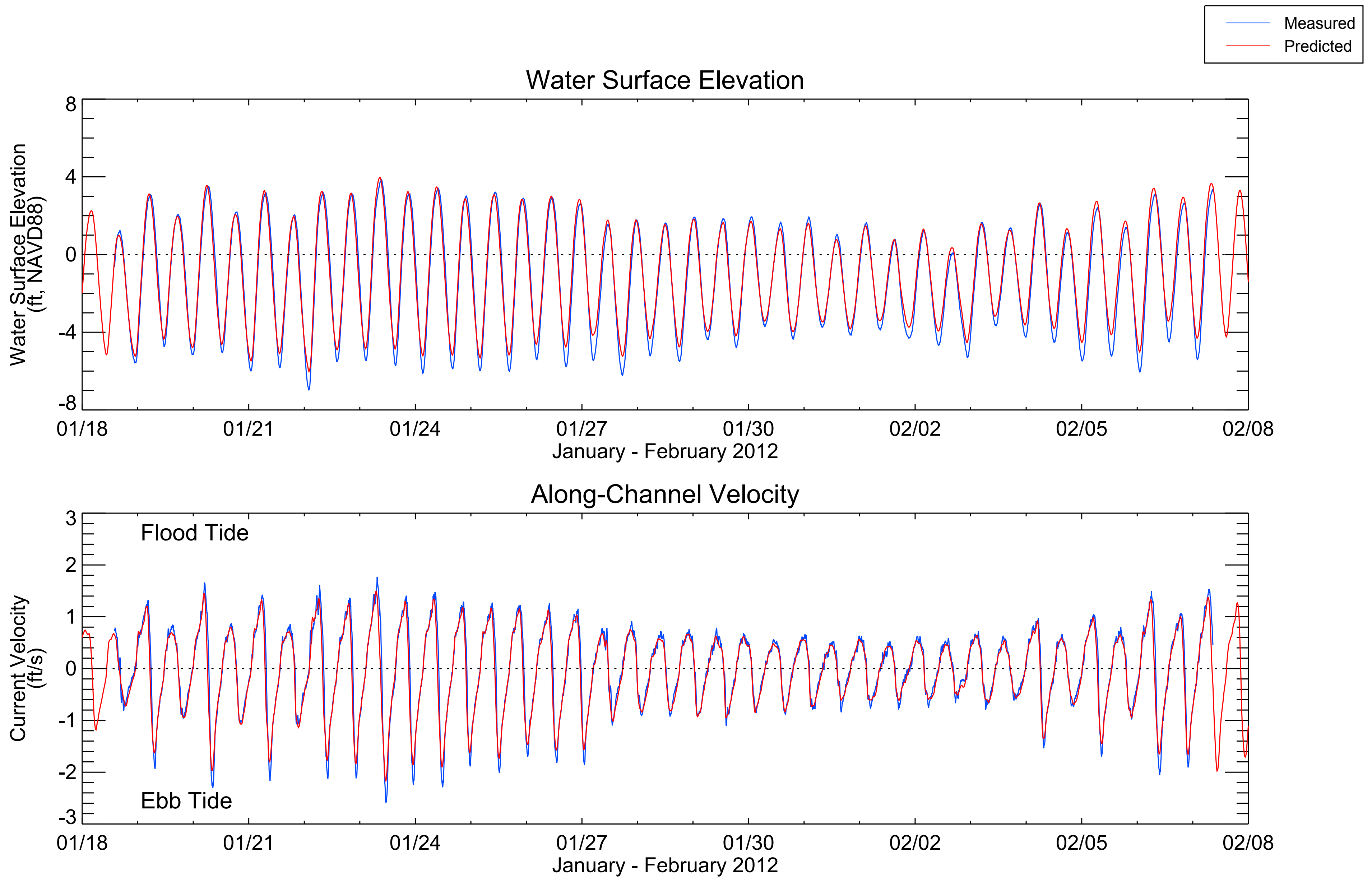
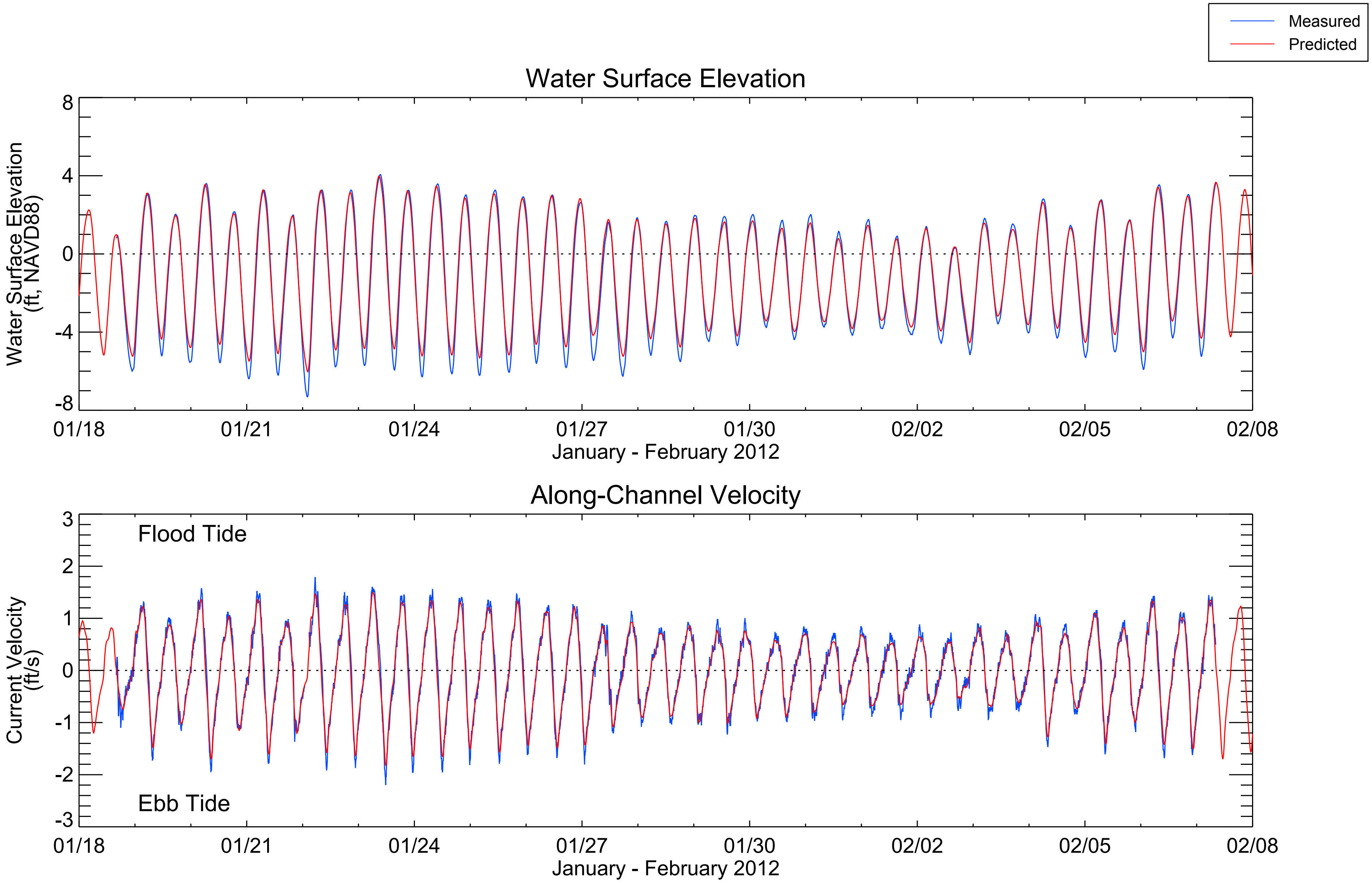


Comparison of Predicted and Measured Water Surface Elevation and
Along-Channel Current Velocity at Station P1 during Calibration Period

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-20



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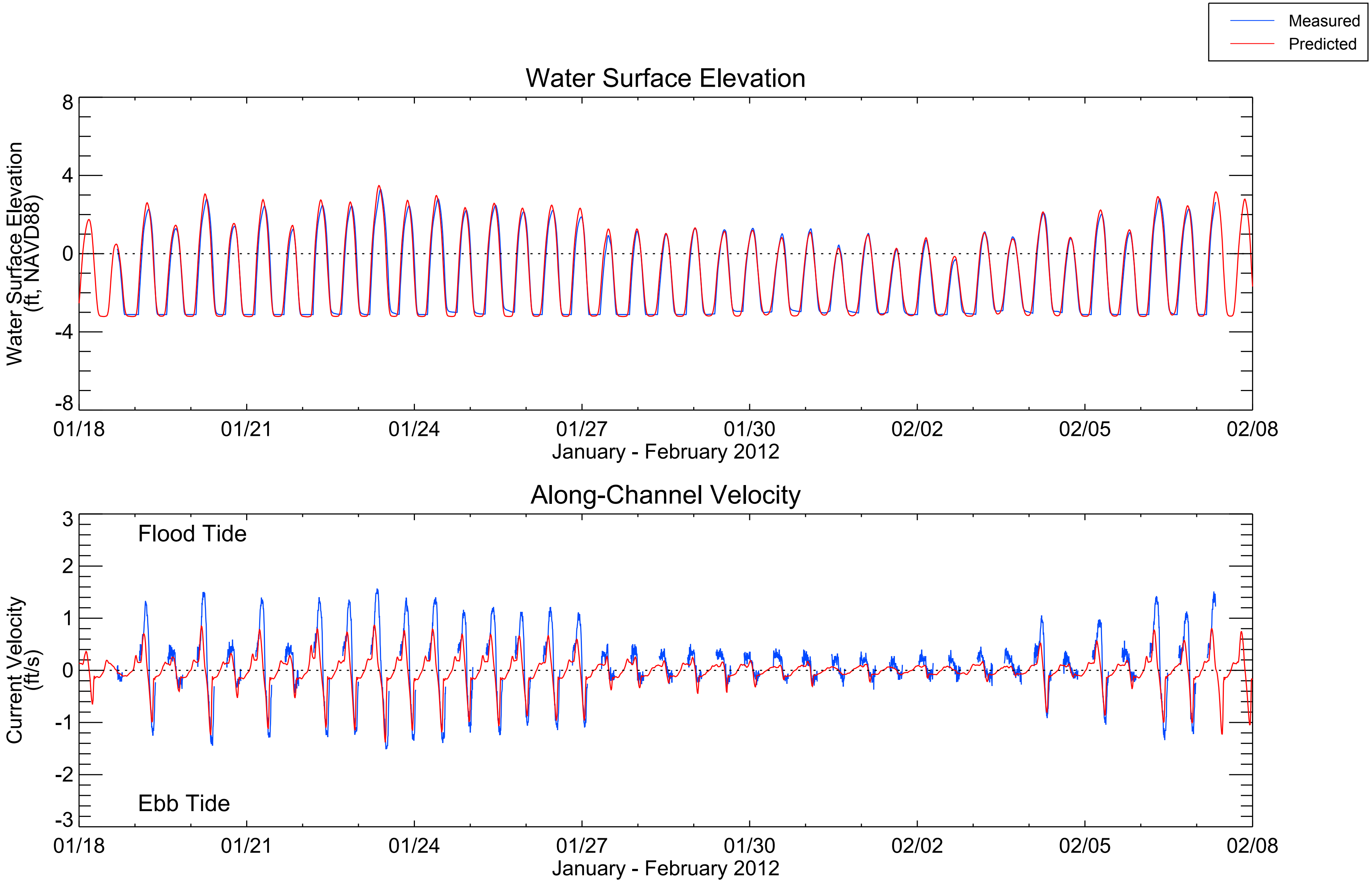
Comparison of Predicted and Measured Water Surface Elevation and
Along-Channel Current Velocity at Station P2 during Calibration Period

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-21



ENVIRON

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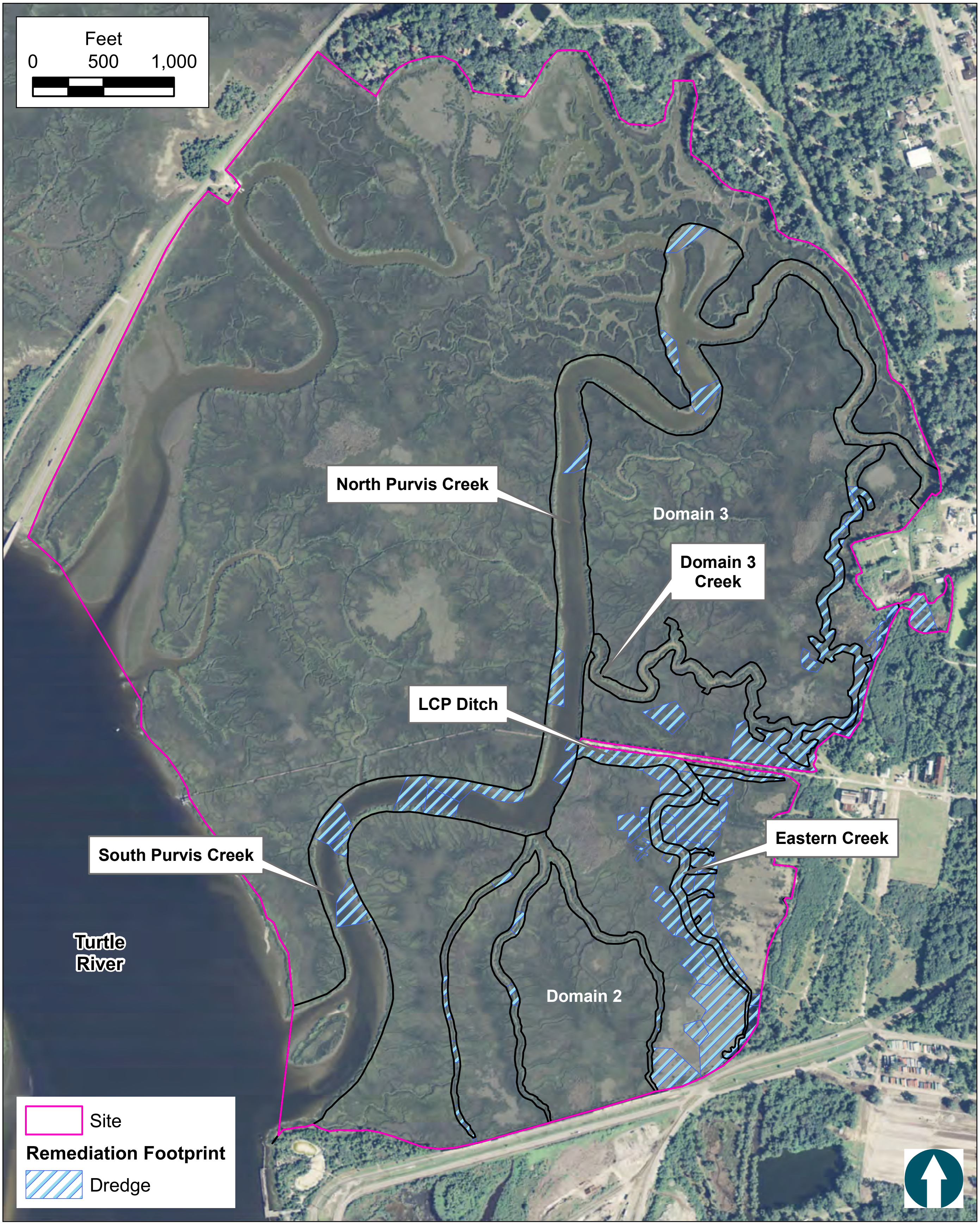
Comparison of Predicted and Measured Water Surface Elevation and Along-Channel Current Velocity at Station E1 during Calibration Period

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B2-22



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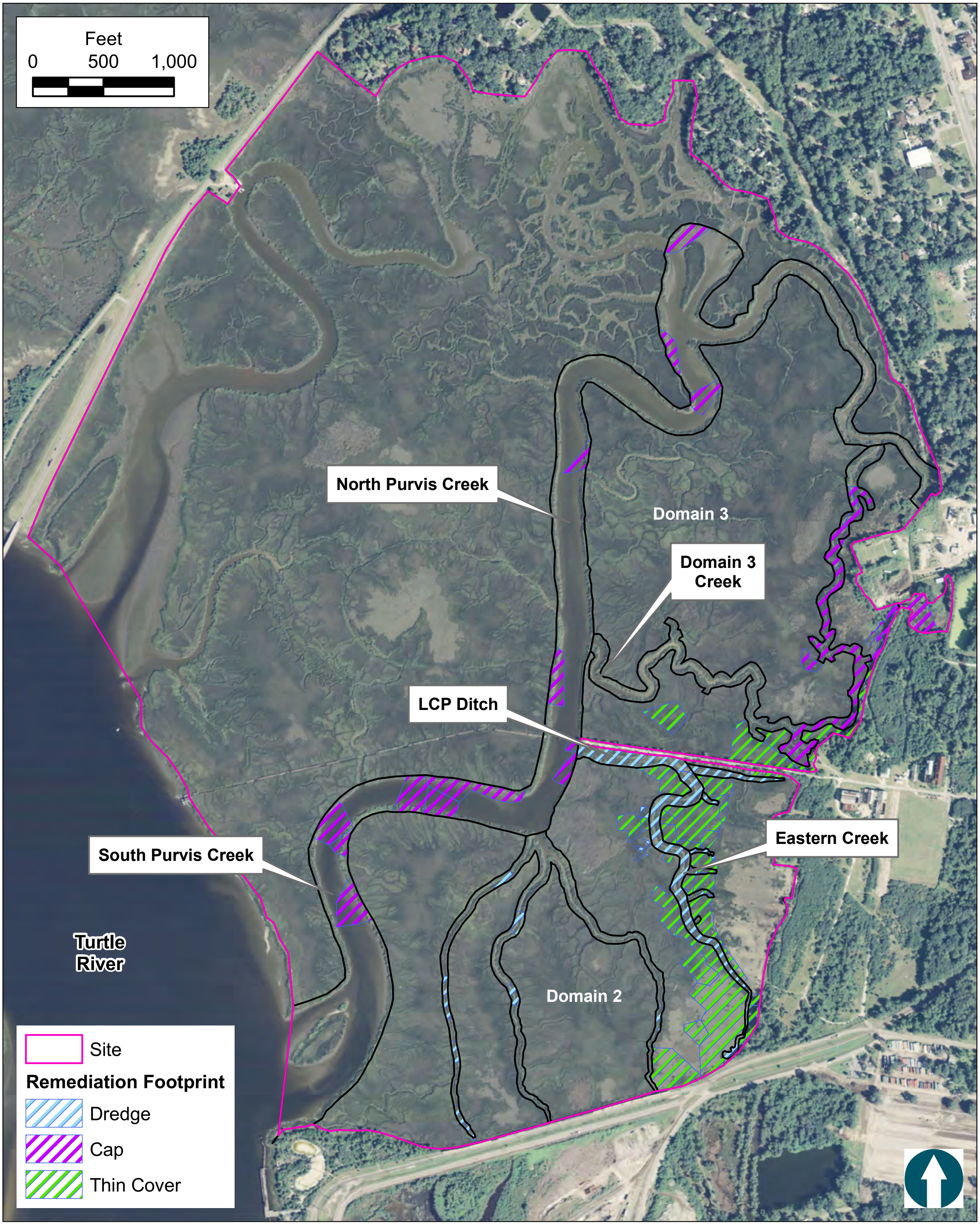
Remedial Alternative Footprint for Alternative 2

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-1



Remedial Alternative Footprint for Alternative 3

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-2

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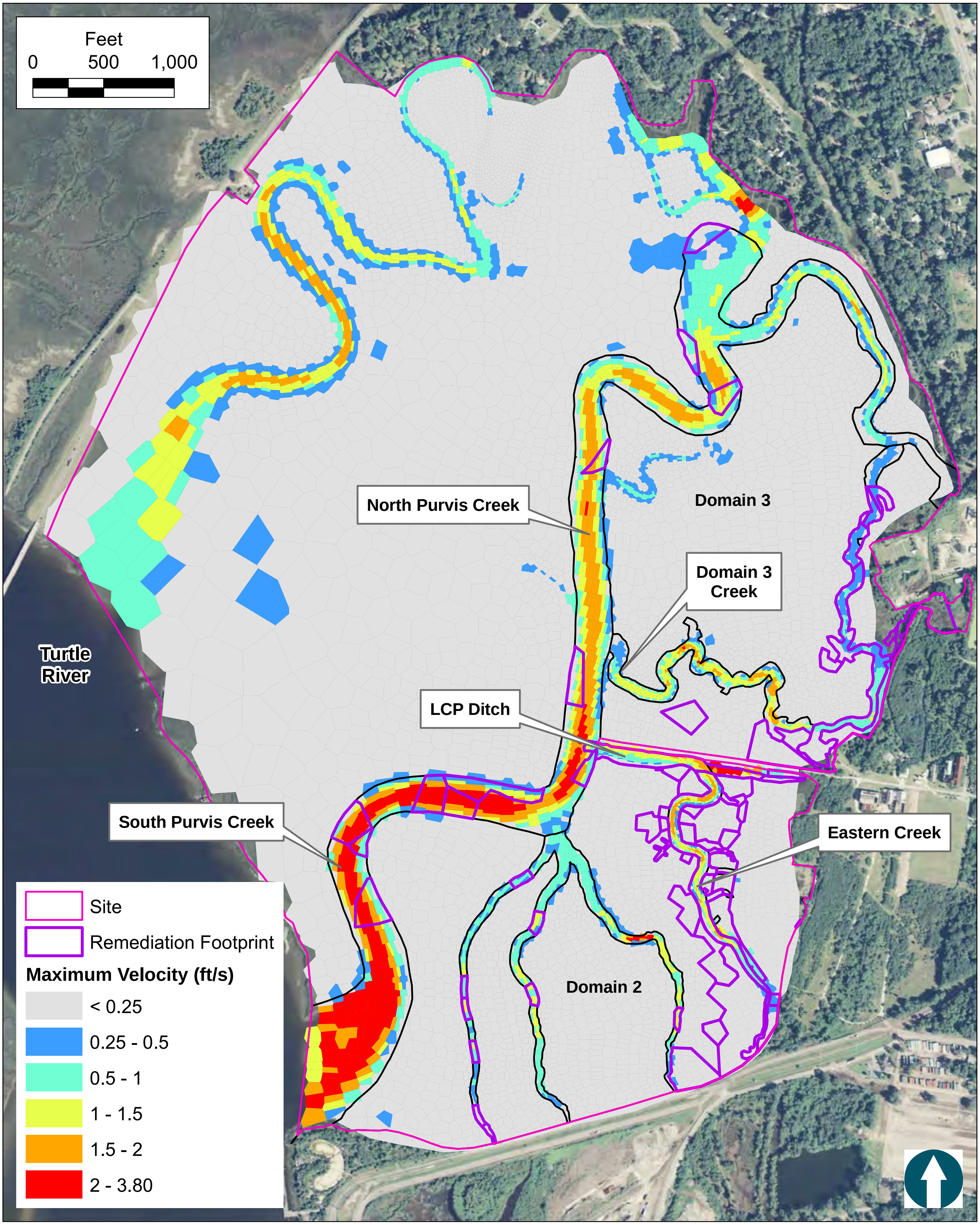

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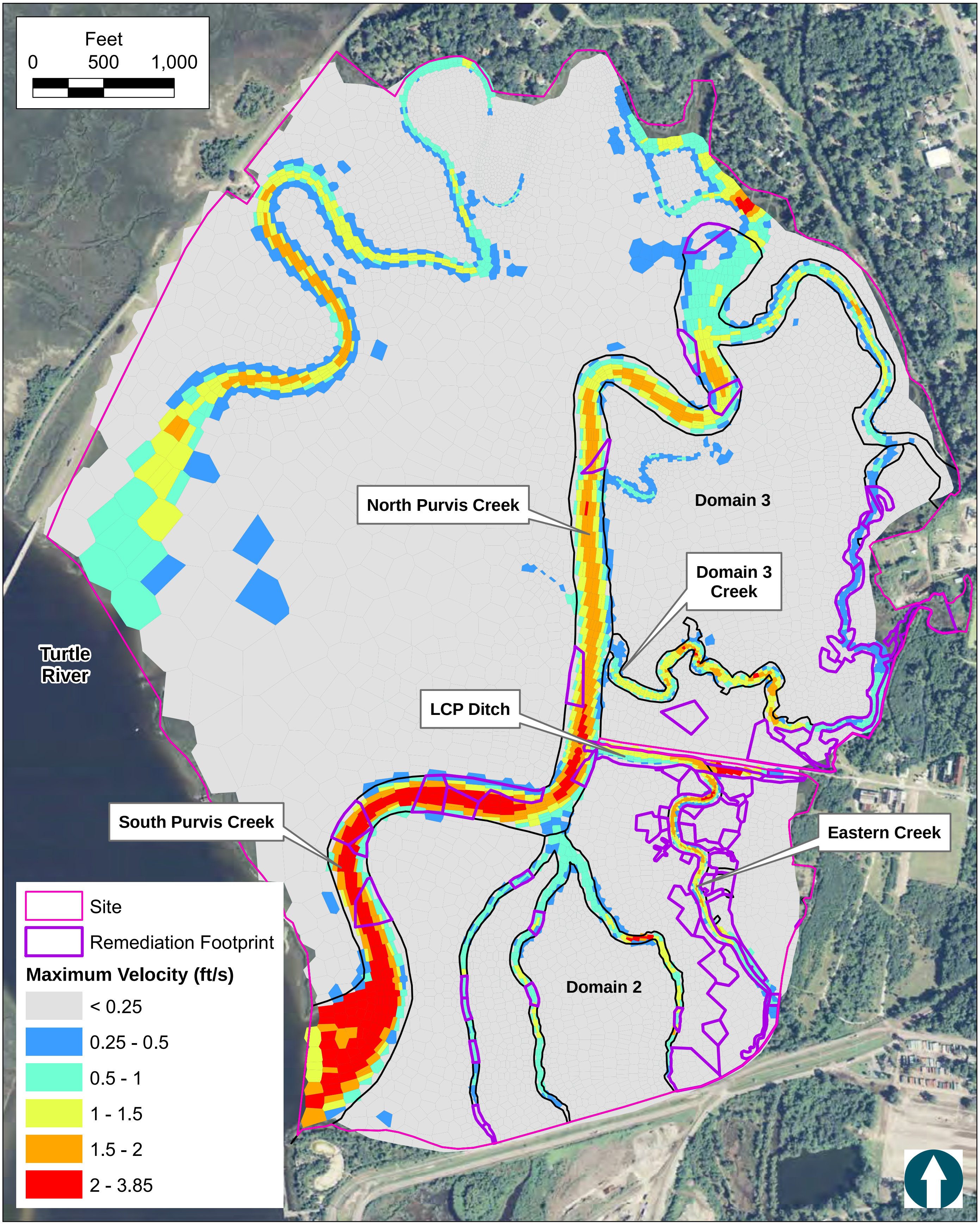
Maximum Predicted Current Velocity for
Existing Conditions: Typical Tidal Conditions

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-3



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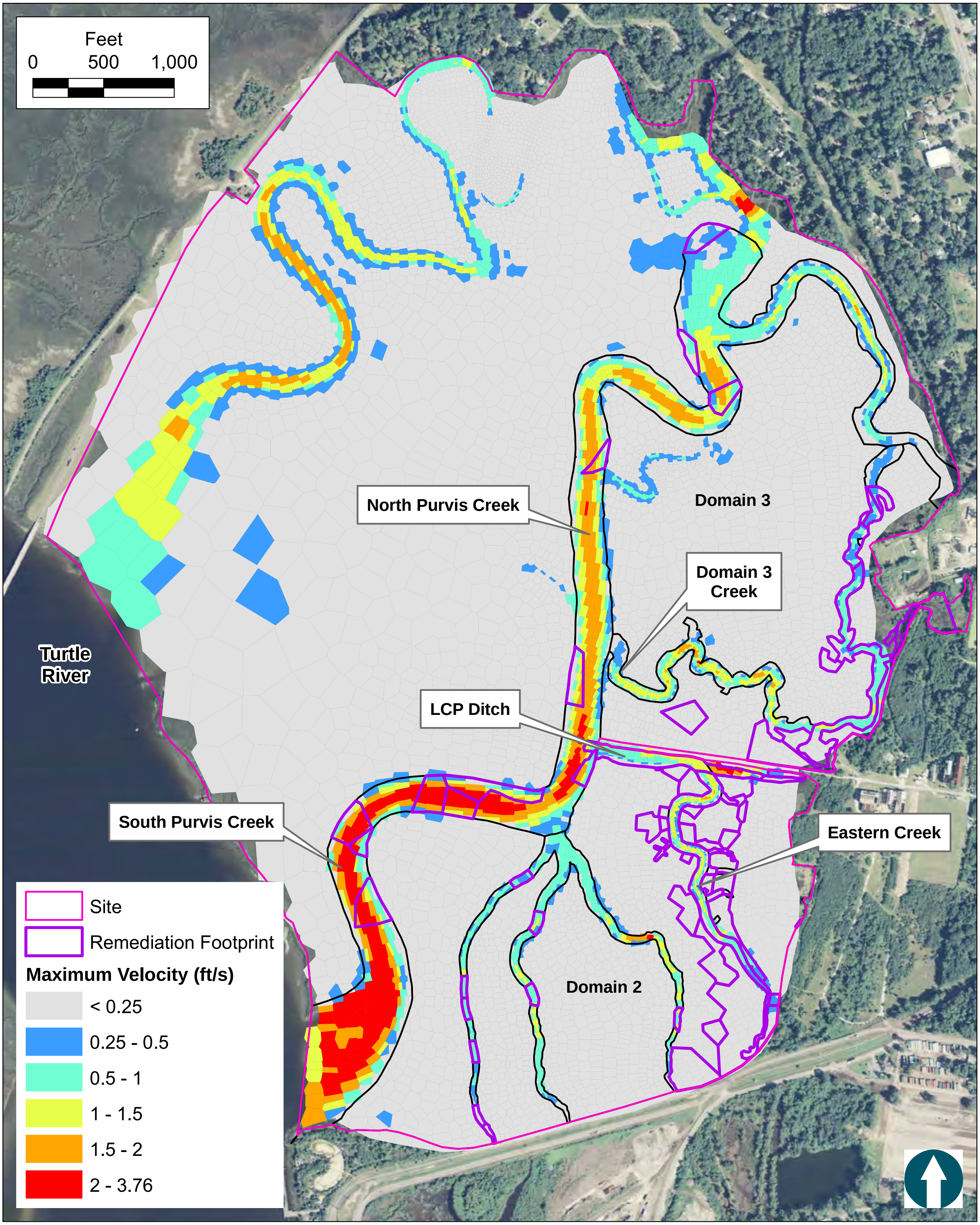
Maximum Predicted Current Velocity for
Alternative 2: Typical Tidal Conditions

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-4



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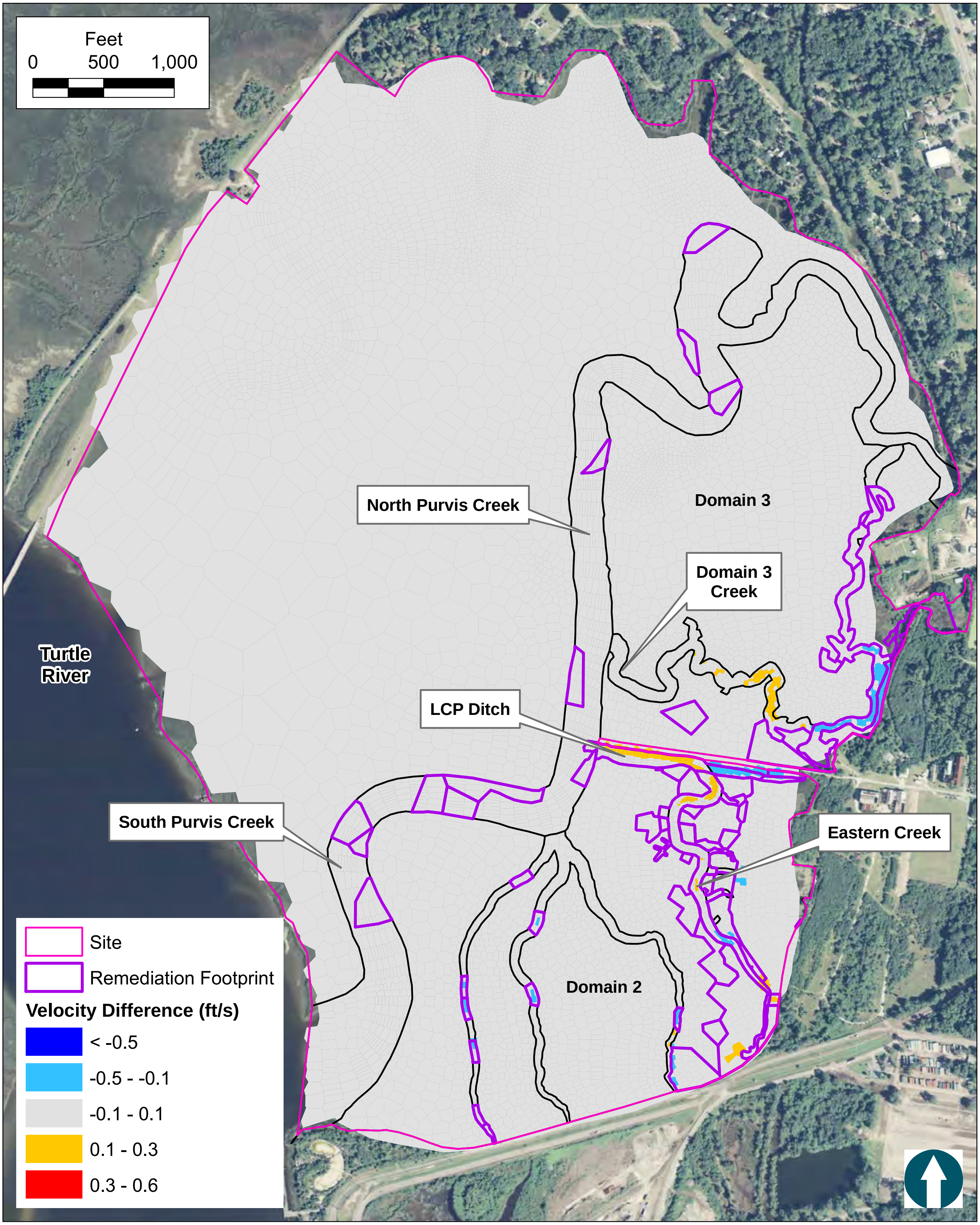
ENVIRON
ANCHOR QEA

Maximum Predicted Current Velocity for
Alternative 3: Typical Tidal Conditions

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure
B3-5



ENVIRON
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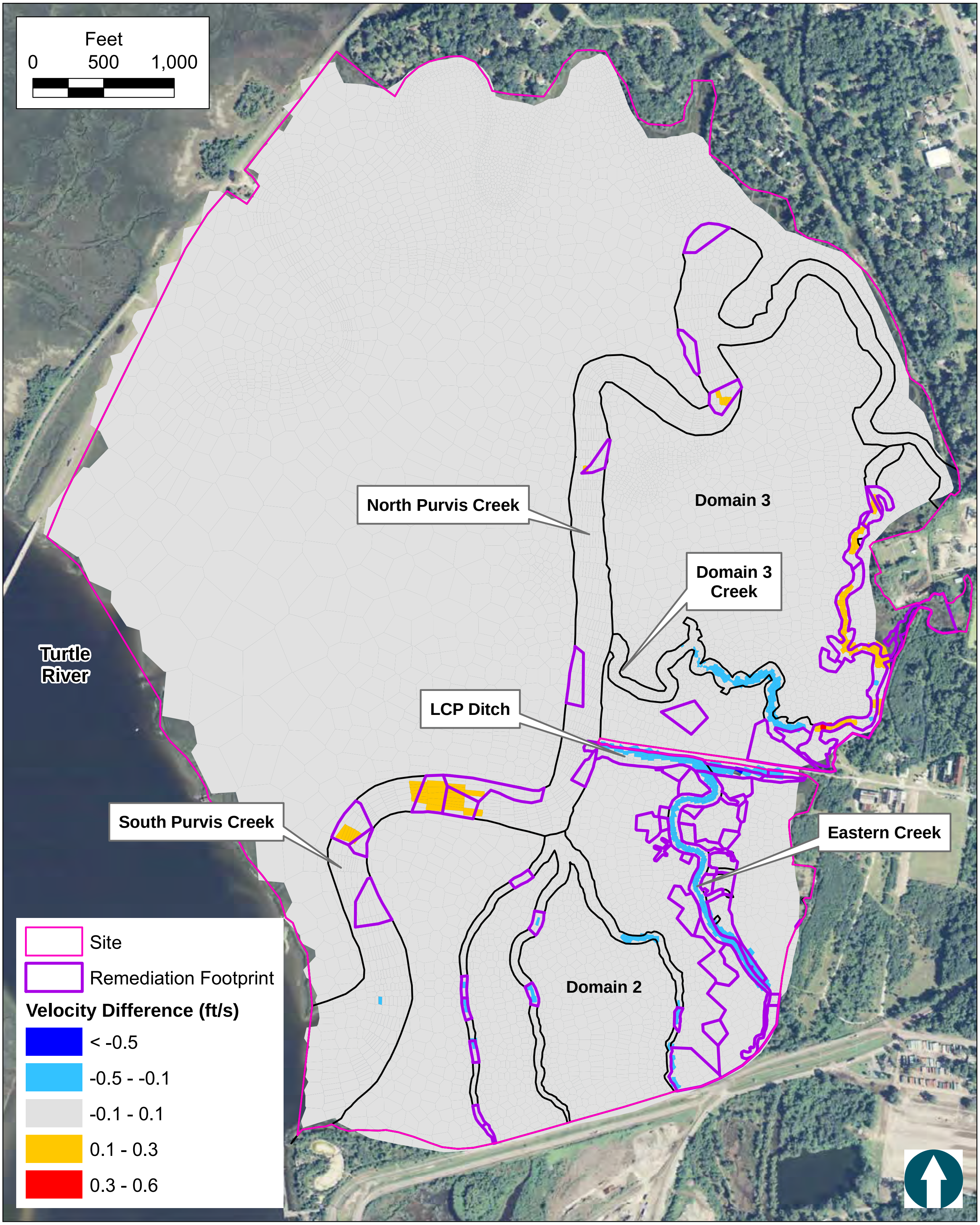
Difference in Maximum Predicted Current Velocity between Alternative 2 and Existing Conditions: Typical Tidal Conditions

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-6



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Difference in Maximum Predicted Current Velocity between Alternative 3 and Existing Conditions: Typical Tidal Conditions

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-7

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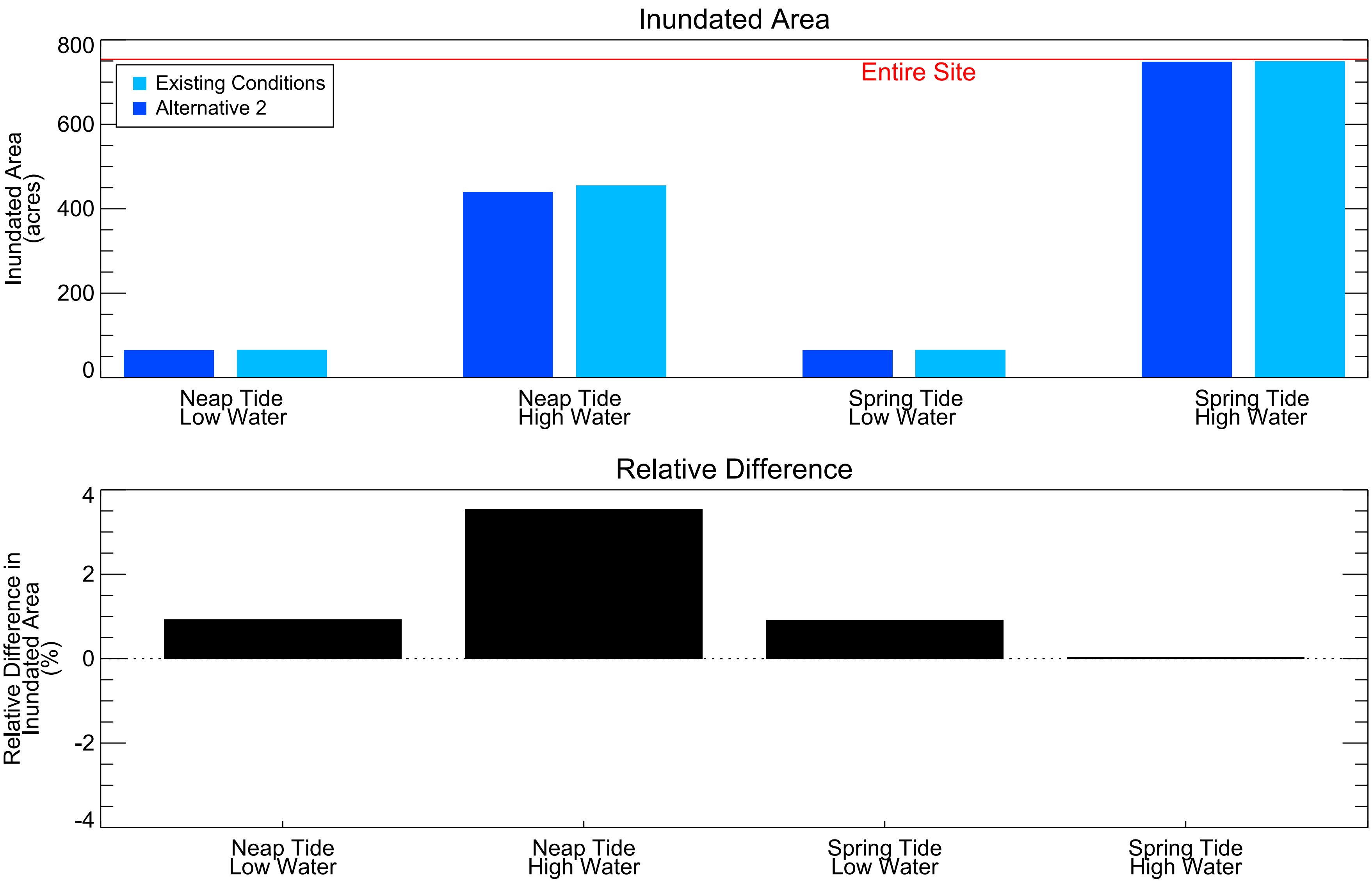

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Comparison of Inundated Area at Low and High Tides between
Alternative 2 and Existing Conditions: Typical Tidal Conditions

Note: Relative difference is computed as the Alternative 2 inundated area minus the existing conditions inundated area, divided by the total site area.

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-8

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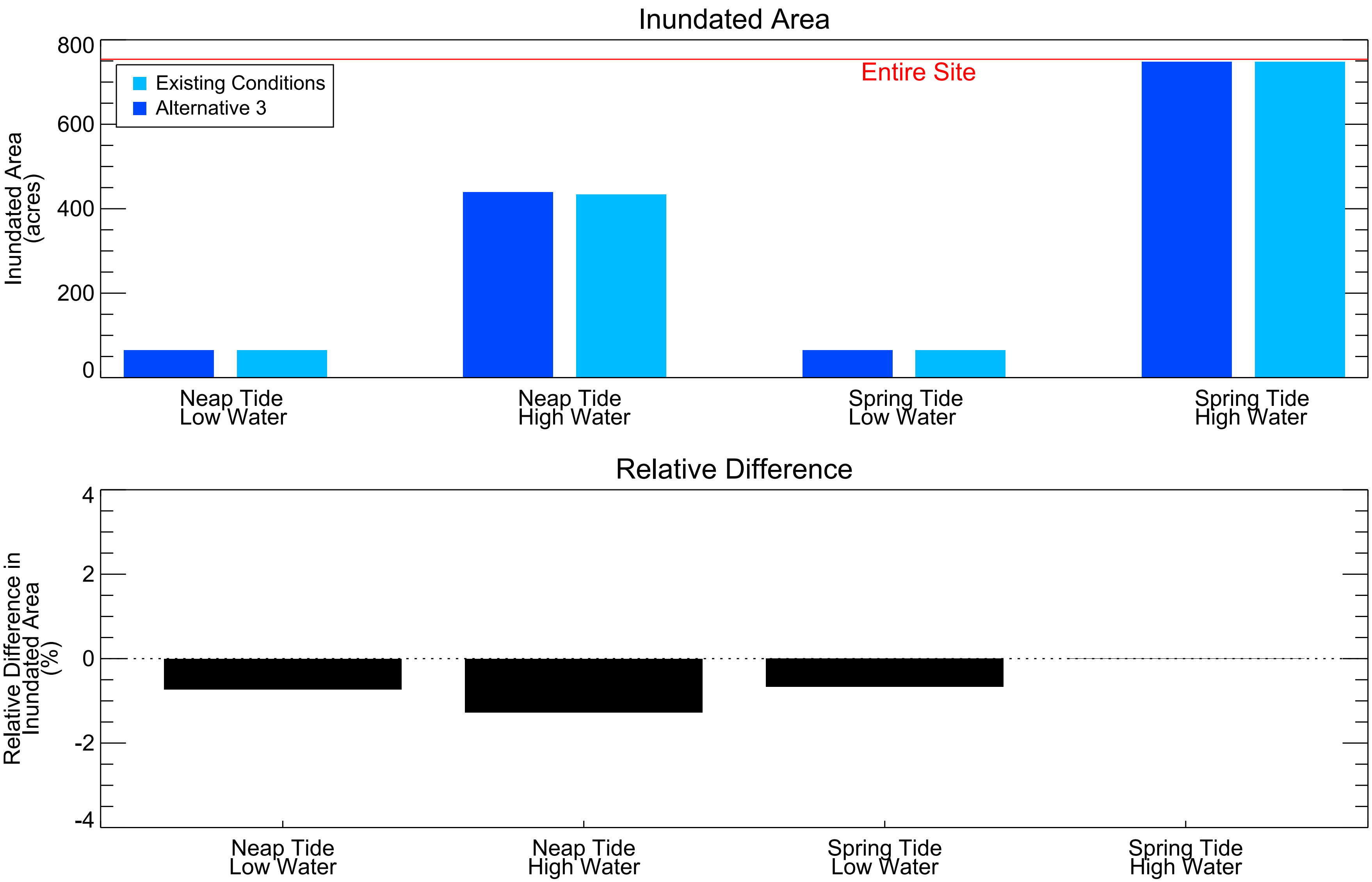


ENVIRON

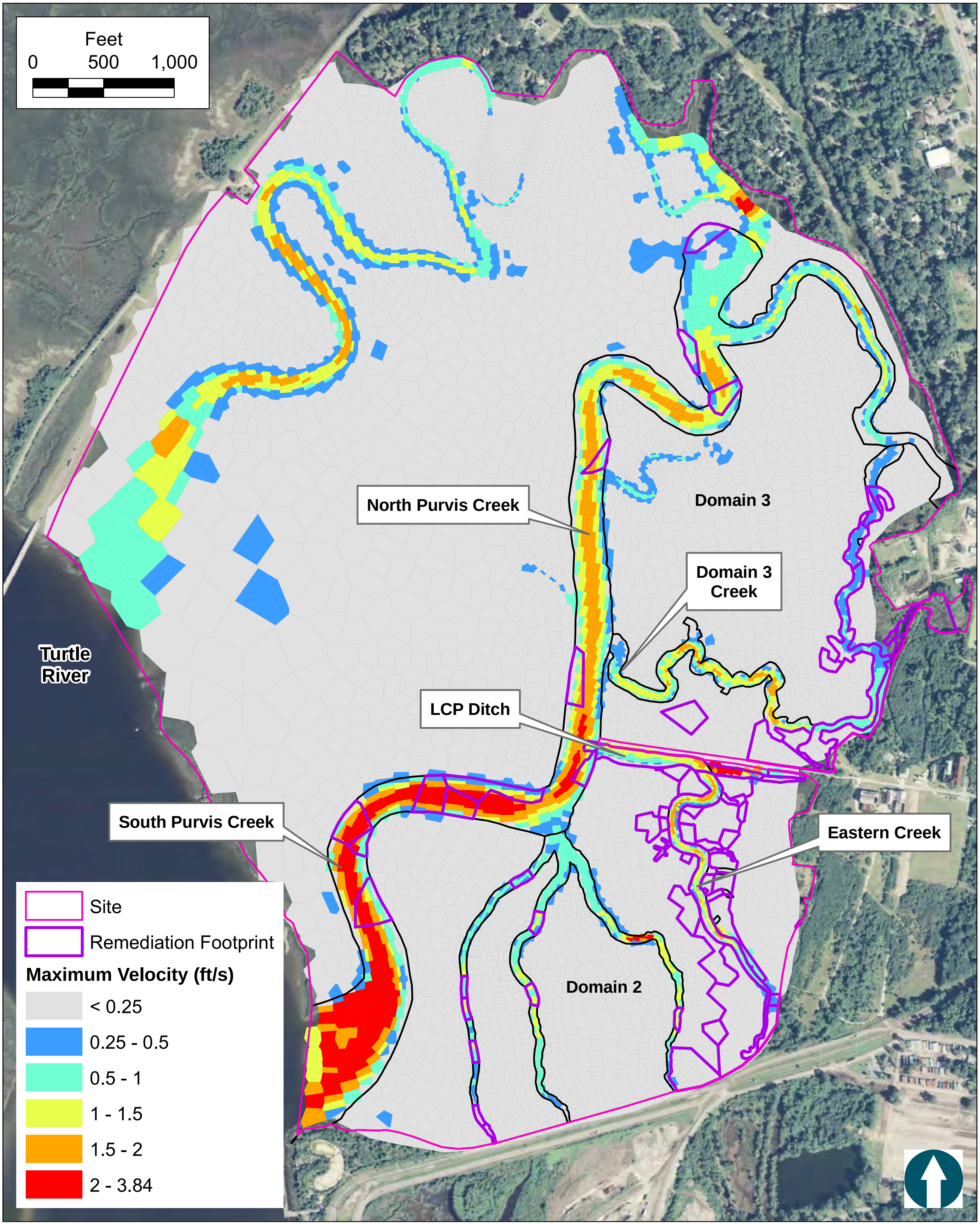
ANCHOR QEA

Comparison of Inundated Area at Low and High Tides between
Alternative 3 and Existing Conditions: Typical Tidal Conditions

Note: Relative difference is computed as the Alternative 3 inundated area minus the existing conditions inundated area, divided by the total site area.

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-9



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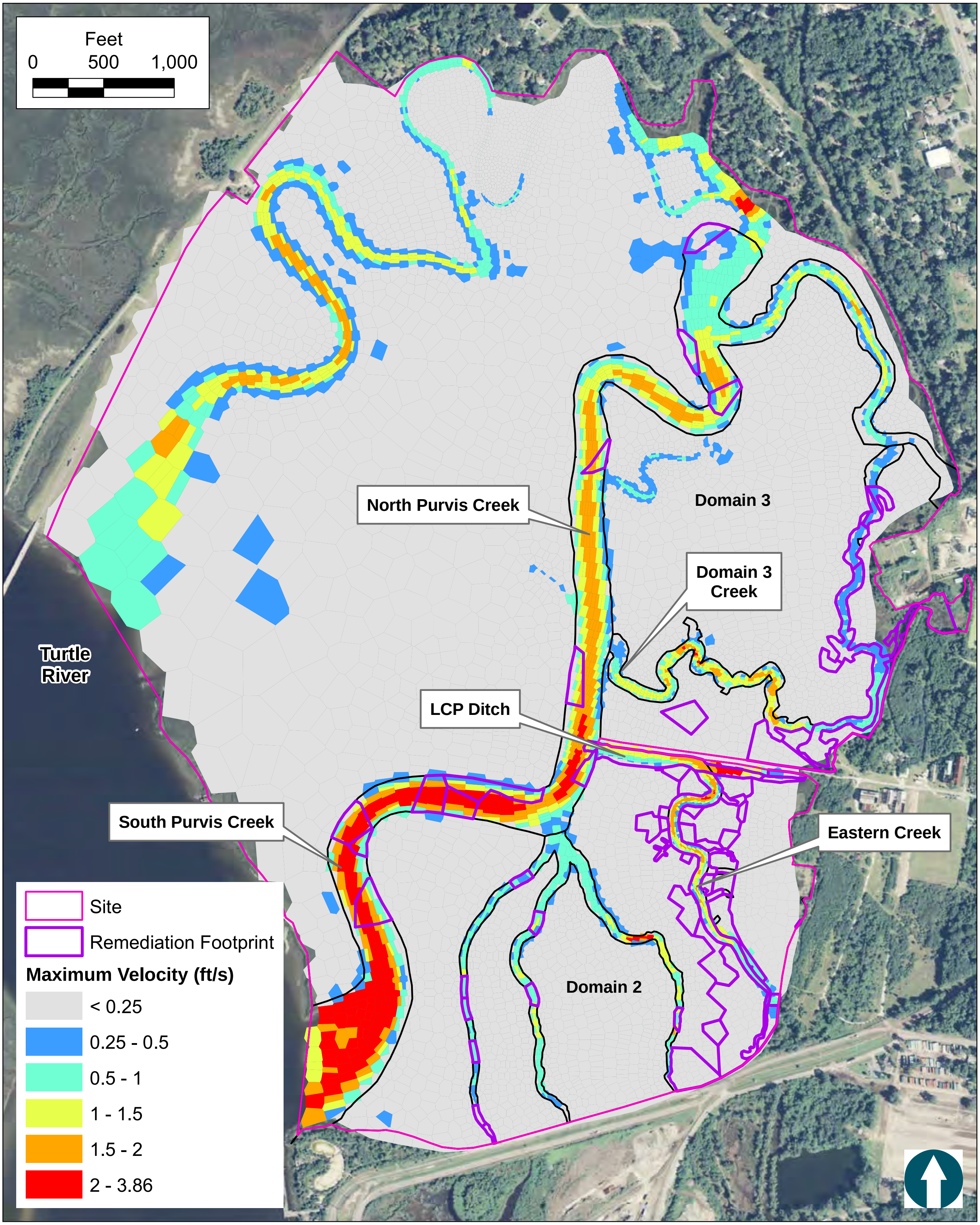
Maximum Predicted Current Velocity for
Existing Conditions: 100-Year Flood

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-10



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ENVIRON

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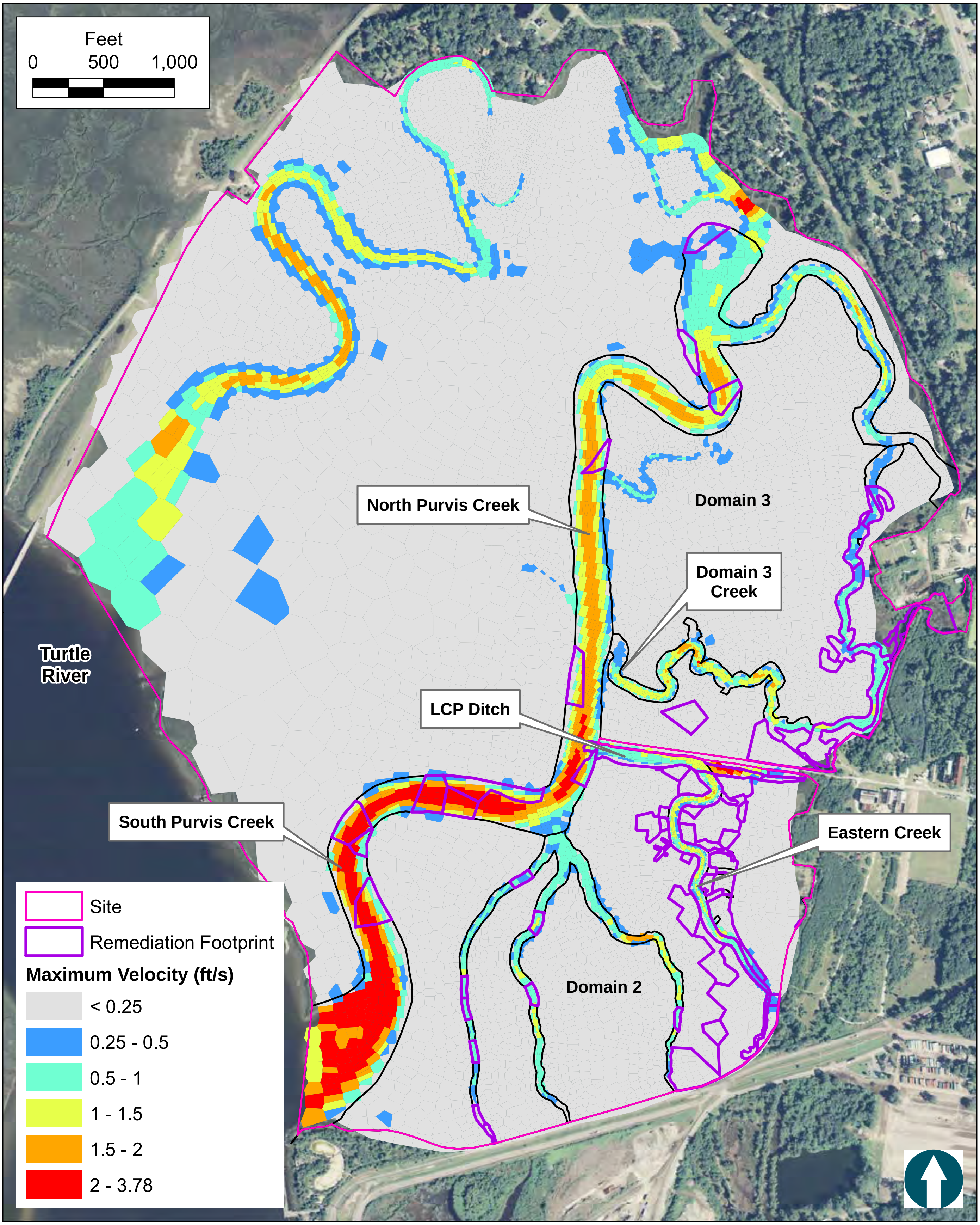
Maximum Predicted Current Velocity for
Alternative 2: 100-Year Flood

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-11



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ENVIRON

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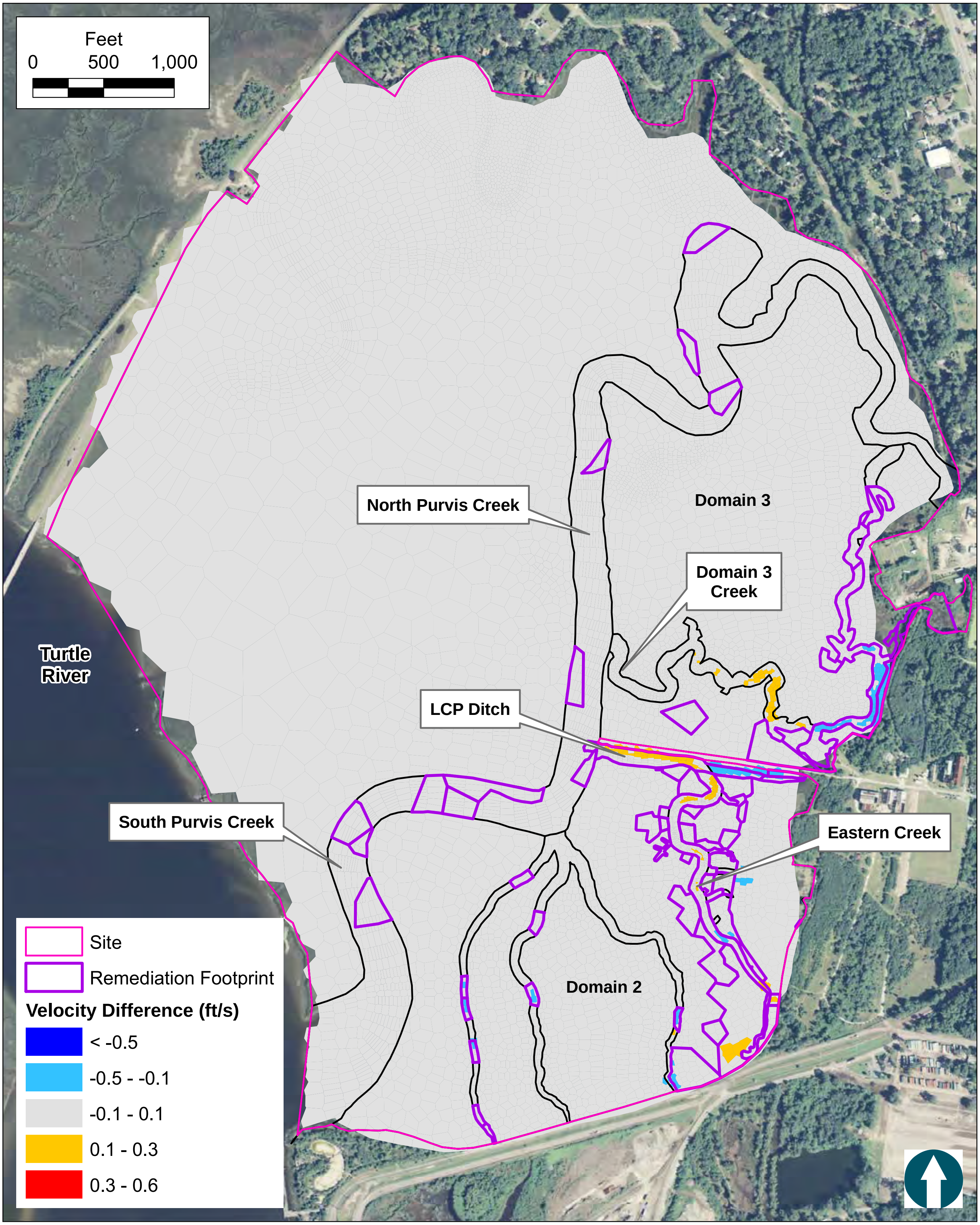
Maximum Predicted Current Velocity for
Alternative 3: 100-Year Flood

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-12



Difference in Maximum Predicted Current Velocity between Alternative 2 and Existing Conditions: 100-Year Flood

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-13

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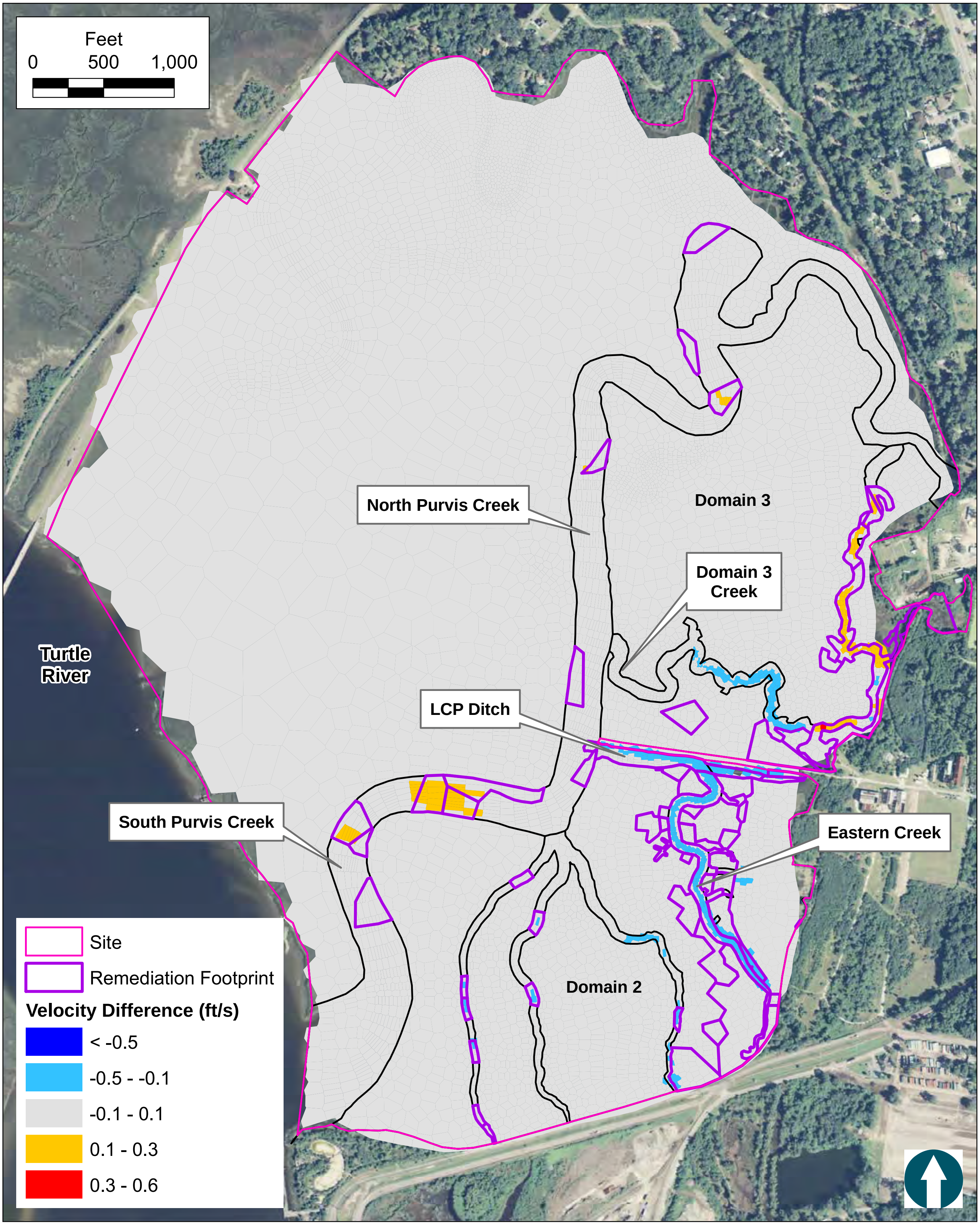

Difference in Maximum Predicted Current Velocity between Alternative 3 and Existing Conditions: 100-Year Flood

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-14

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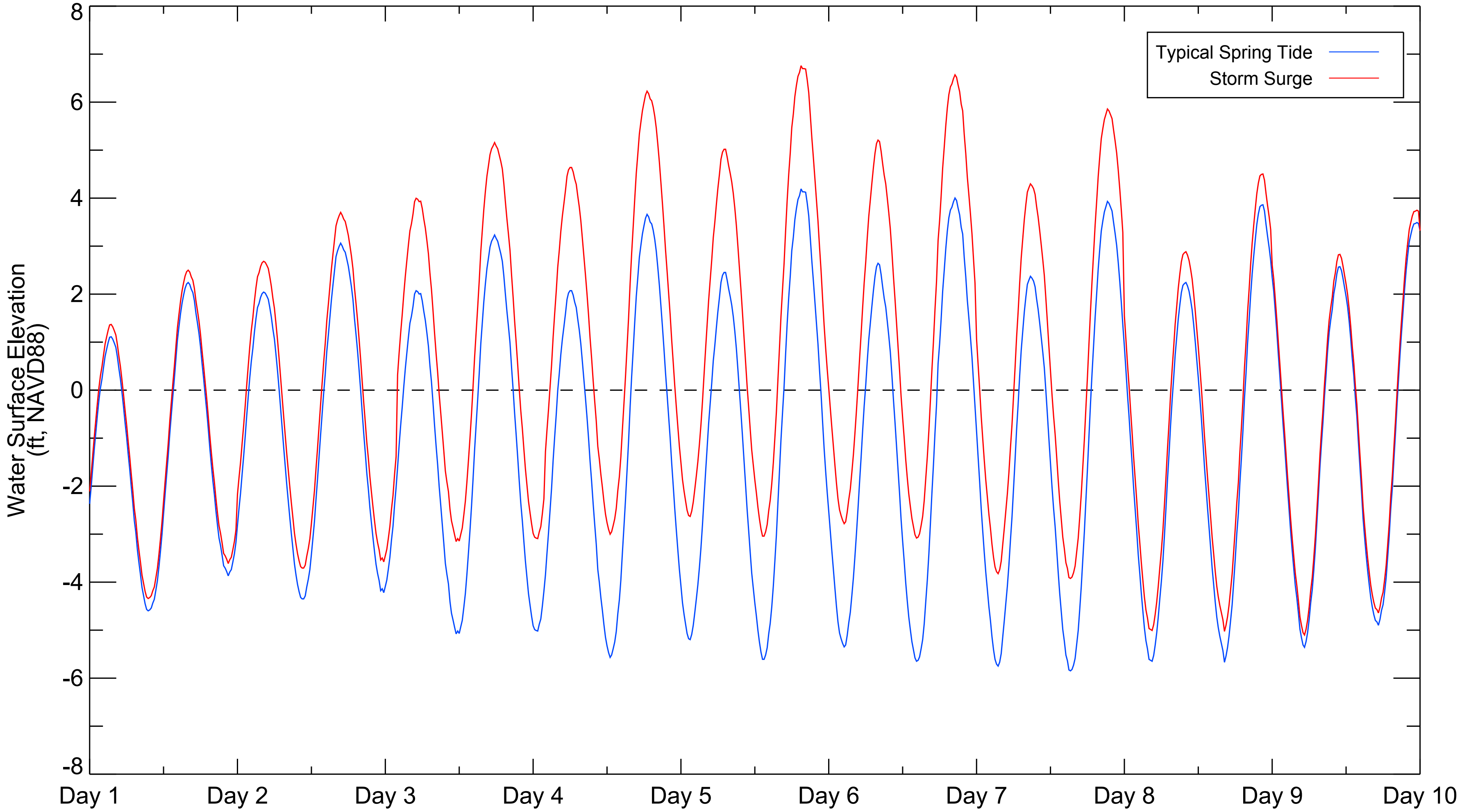

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Water Surface Elevation at Downstream Boundary
during Hurricane Storm Surge Simulation

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-15

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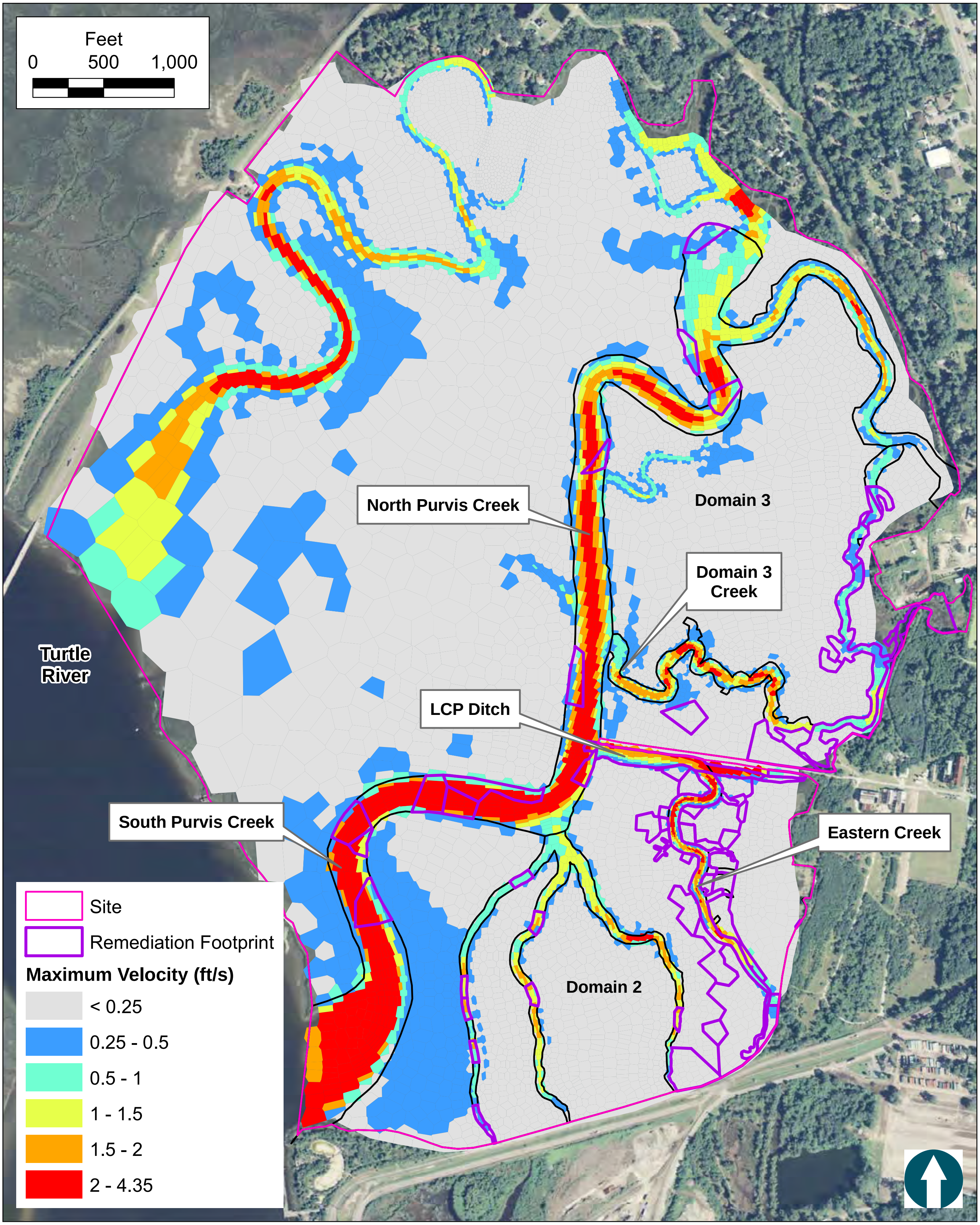

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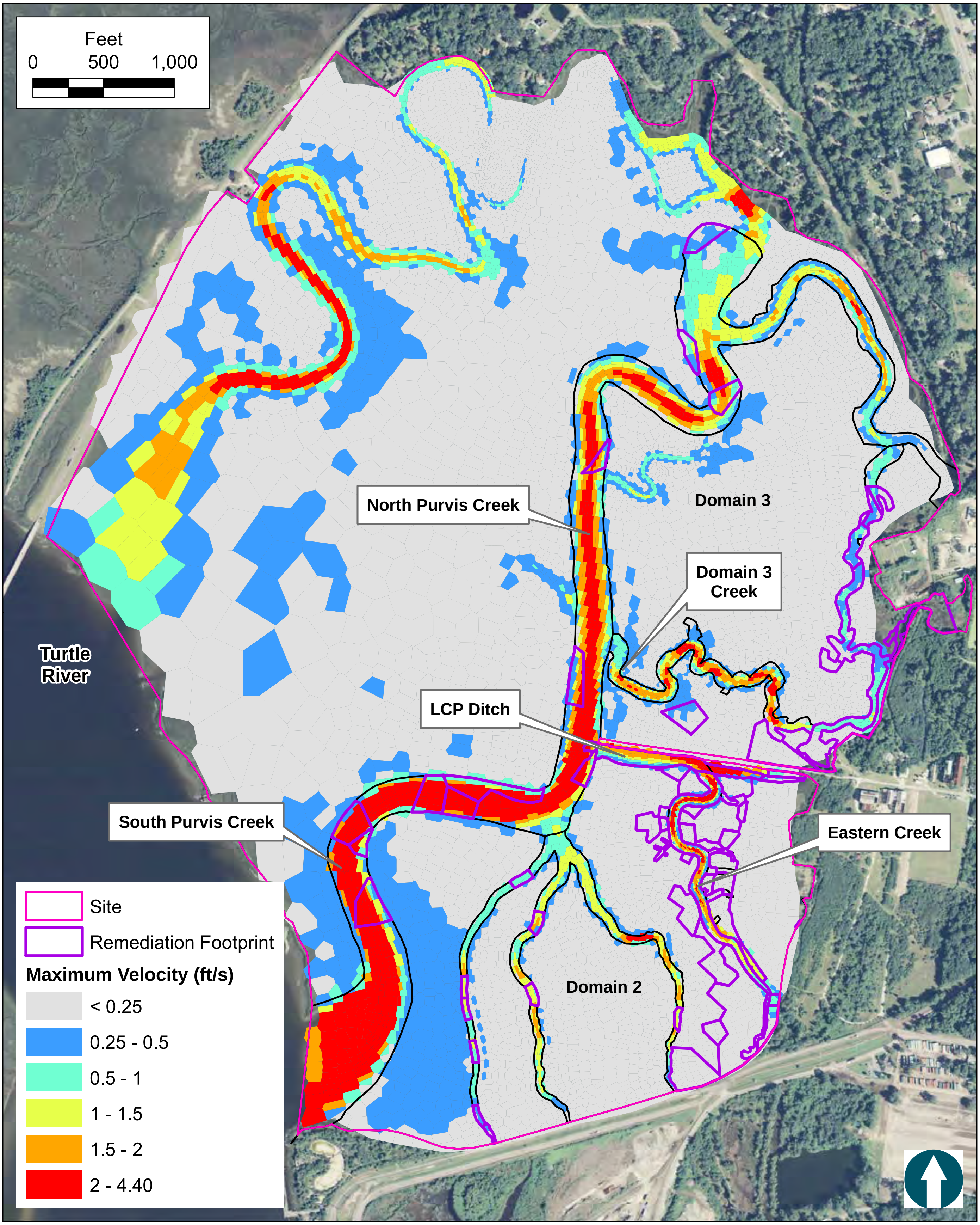
Maximum Predicted Current Velocity for
Existing Conditions: Hurricane Storm Surge

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-16



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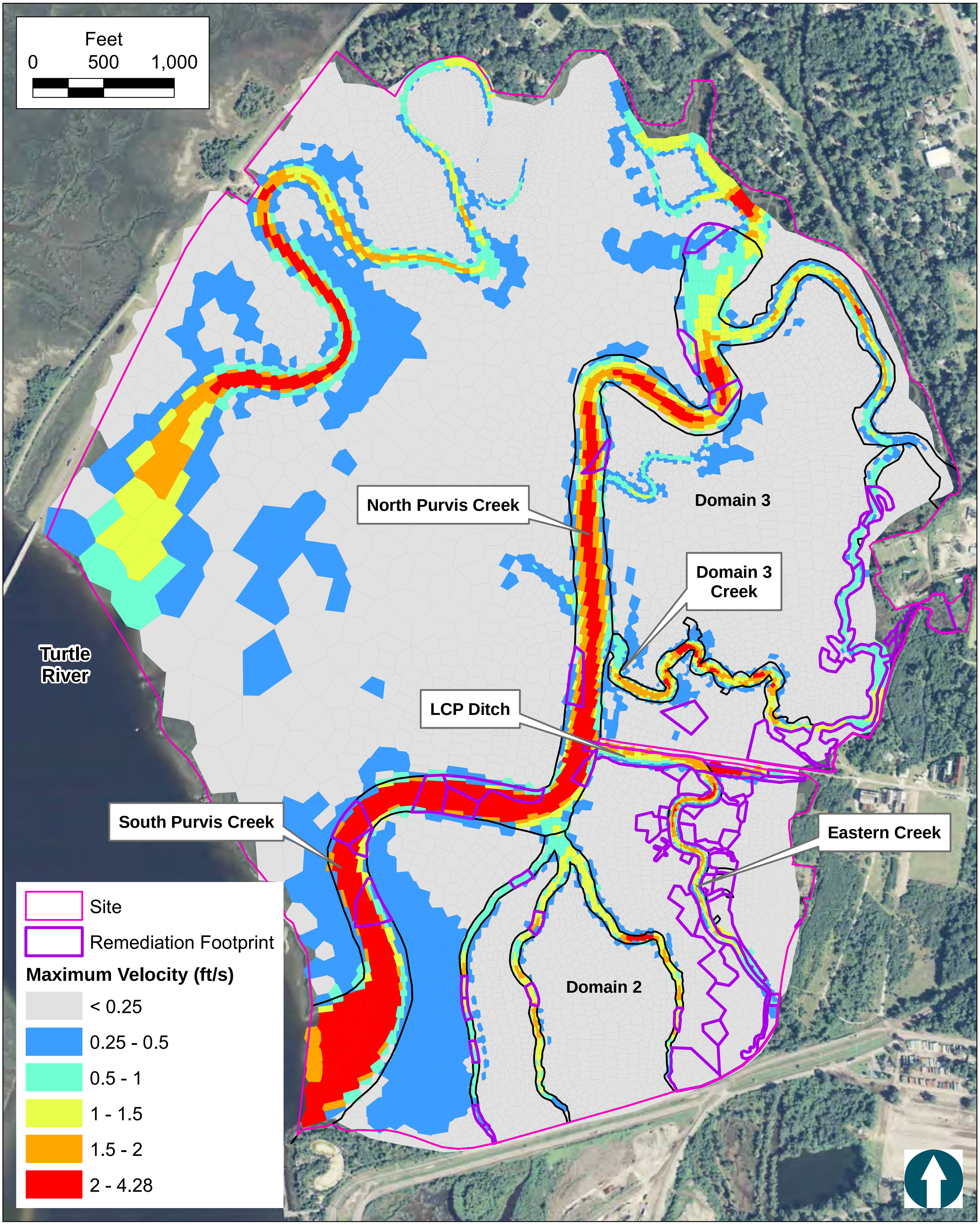
Maximum Predicted Current Velocity for
Alternative 2: Hurricane Storm Surge

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-17



Maximum Predicted Current Velocity for Alternative 3: Hurricane Storm Surge

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-18

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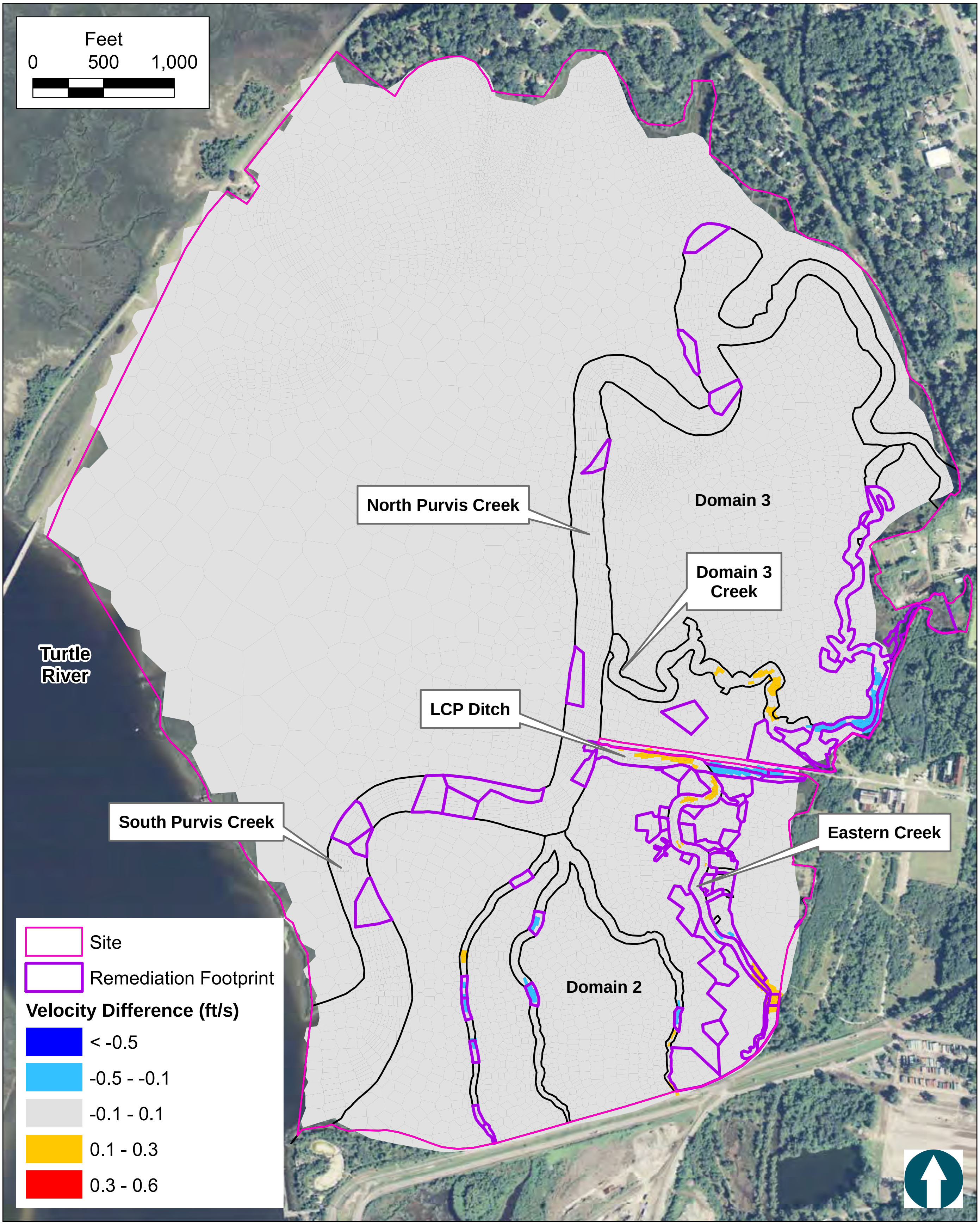

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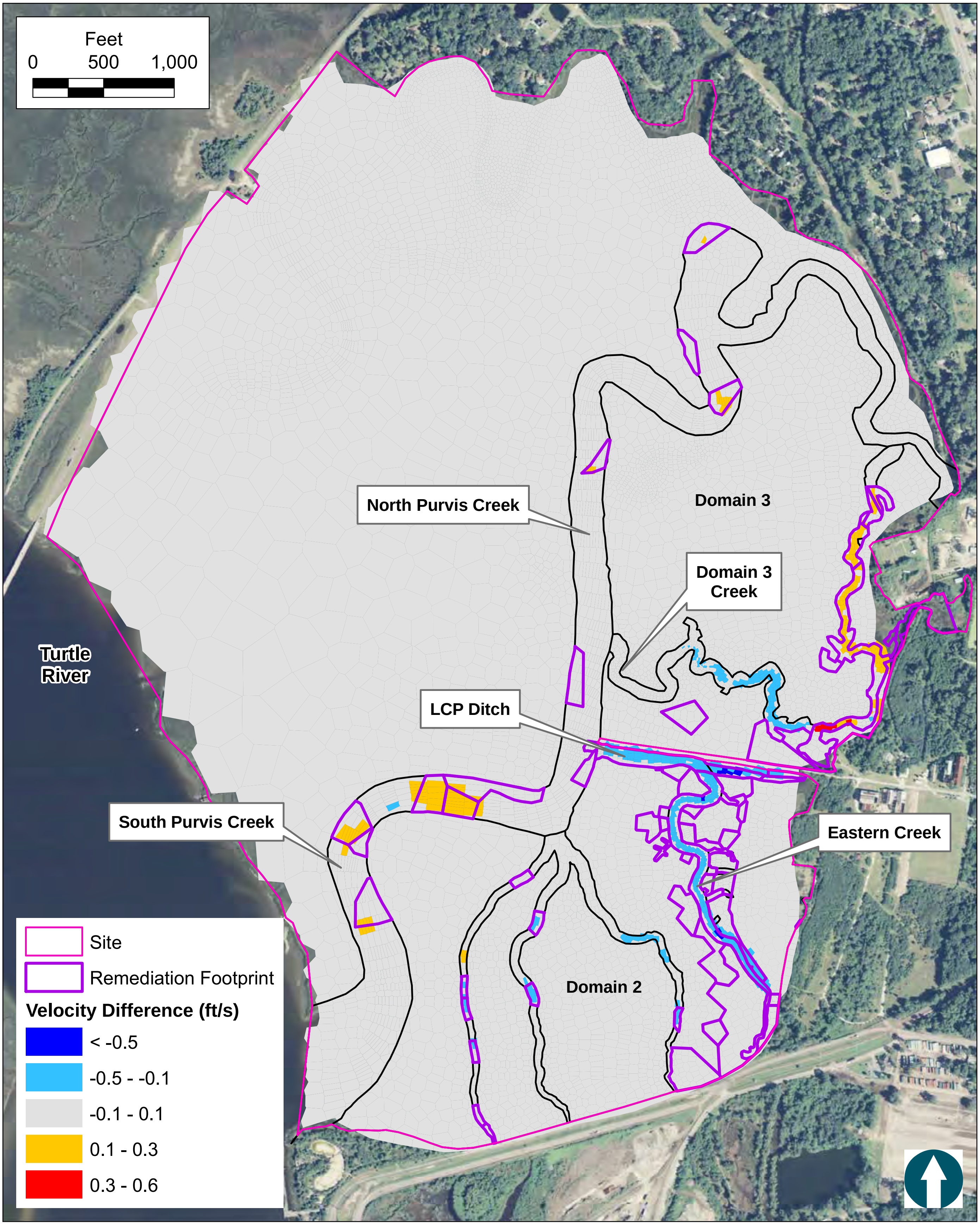
Difference in Maximum Predicted Current Velocity between Alternative 2 and Existing Conditions: Hurricane Storm Surge

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-19



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Difference in Maximum Predicted Current Velocity between Alternative 3 and Existing Conditions: Hurricane Storm Surge

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure B3-20

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Appendix C
Aquatic Organism Life History Information

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:
Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:
ENVIRON International Corporation

Anchor QEA, LLC

Date:
June 2, 2014

Deleted: October 18, 2013

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Appendix C: Aquatic Organism Life History Information

The information in this appendix is provided in support of the feasibility study (FS) of OU1. This appendix provides a tabular summary of life history characteristics for sediment-dwelling organisms and fish found in the OU1 estuary.

List of Tables

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Tables

Table C-1
Life History Characteristics for Sediment-Dwelling Organisms in the OU1 Estuary
LCP Chemical, Brunswick, GA

Common Name	Lifespan (years)	Habitat	Movement and Burrowing Patterns	Diet and Forage Pattern	Predators
Polychaetes Class Polychaeta	1-10+ (Depends on species)	Commonly found burrowing in sediments, or live in tubes. Some species are free-swimming, and some live as commensals or parasites. Polychaetes are the most abundant macrofauna of the ocean at different depths and water temperatures (EOL 2013a). There are more than 10,000 species of polychaetes (EOL 2013a).	Polychaetes can be divided into three categories: sessile, burrowing, or free-moving (EOL 2013a, PZNOW 2013). They use appendages called parapodia for movement (for those species that move) (PZNOW 2013). Sessile polychaetes live in permanent tubes or burrows and use their parapodia to circulate water in the tube so as to feed (EOL 2013a). Burrowing depth of common polychaete species found within OU1 (as determined by Horne et al. [1999]) is within 6 inches (EOL 2013a, Gamenick et al. 1998, Nelson and Capone 1990).	Organic matter such as detritus or other smaller organisms such as phytoplankton, benthic invertebrates, bacteria, and meiofauna (EOL 2013a).	Polychaetes are the prey of a large suite of predators which include shrimp, crabs, fish, and birds (NHM 2013).
Oligochaetes Class Oligochaeta	Several weeks to years (Depends on species) (NYDEC 2013)	Oligochaetes can live in a variety of habits from terrestrial to aquatic (UMich 2013). There are over 3,100 known species of oligochaetes with aquatic oligochaetes often associated with sediment (Wade et al. 2004).	Generally found in soft bottom sediments. Juveniles often enter estuaries as pelagic (free floating) larvae (ASMFC 2012, GDNR 2013c). Larvae enter estuaries on tidal currents and post larvae prefer nutrient-rich and muddy waters of tidal creeks and channels. Juveniles are more often found over muddy bottoms in estuaries. Adults sometimes move into near-shelf waters but are primarily estuary-dwelling and show little migratory behavior once larva settlement occurs (Hill 2005; SCDNR 2013). Based on various studies of oligochaete bioturbation, burrowing depth is within the upper 15 cm of the sediment column and predominantly in the upper 3 to 10 cm (Francois et al. 2002, Shull 2001).	Organic matter such as detritus and other smaller organisms such as microphytobenthos, and sediment-bound bacteria (Gillet et al. 2007). Some species can be considered direct deposit feeders (Brusca and Brusca 1990).	Oligochaetes are the prey of a large suite of predators which include shrimp, crabs, fish, and birds (NHM 2013).
Amphipods Order Amphipoda	1-3 (Wade et al. 2004)	Amphipods can be found in still or flowing water, in the sediment, or on the sediment and among aquatic vegetation and organic debris (Wade et al. 2004).	Amphipods are mobile (swim or crawl) and/or burrow depending on the species (Wade et al. 2004). Amphipods can be found throughout the tidal column but distribution patterns vary among species (Ingolfsson and Agnarsson 2003). Some amphipods burrow but many others do not. Based on Limia and Raffaelli (1997), amphipod bioturbation relative to other species is considered minor. Some amphipods stay near the interstices created by outer leaves, stems and root masses of smooth cordgrass (Parker et al. 2008). Ingolfsson and Agnarsson (2003) note that amphipod distribution be underrepresented when typical sediment grab sample techniques are used.	Macro- and epiphytic algae (Parker et al. 2008); detritivores or predators on small insects and crustaceans (Wade et al. 2004).	Fish, crabs, birds, and grass shrimp (Nelson 1979).
Grass Shrimp *Palaemonetes* spp.	~ 6-8 (GDNR 2007)	Inhabit water near underwater structures such as oyster shells, docks, or Spartina stands (Coen and Wenner 2013a; Anderson 1985). Indigenous grass shrimp studies of OU1 showed grass shrimp use both creek and marsh habitats.	Grass shrimp are aquatic organisms with gills, so they move in and out of estuaries with the tide. They tend to drift with the tidal cycle migrating seaward (or downstream) on an ebbing tide, and landward (upstream) on an incoming tide (Anderson 1985). They do not burrow and spend time moving among marsh grasses.	Zooplankton, algae, detritus, mysids, and microorganisms (Coen and Wenner 2013a, Anderson 1985).	Important source of food to crabs, fish, and birds (Coen and Wenner 1985a).
Marsh Periwinkles *Littorina irrorata*	Unknown - varies with food availability and environmental factors (Sweat 2009a)	Salt marsh resident and can be found in high-marsh areas around freshwater seeps and low-marsh areas that are submerged in salt water (greater than 25 parts per thousand). Commonly found on marsh grass at or above the water level (Walters and Coen 2013, Munoz 2005).	Marsh periwinkles tend to withdraw into its shell at low tide (Munoz 2005). In addition, marsh periwinkles tend to climb on marsh plants in response to predation and tidal inundation in warmer months (Vaughn and Fisher 2009; Walters and Coen 2013; Munoz 2005). A mark-recapture study indicated that marsh periwinkles rarely move more than 2 meters from their release point over a four month period with adults more likely to forage away from base of Spartina at low tide than juvenile snails (Vaughn and Fisher 1992).	Forage on substratum at low tide (Vaughn and Fisher 1992). Herbivore: Microalgae and detritus (Walters and Coen 2013, Munoz 2005).	Fish, blue crabs, birds, small mammals, sea urchins (Munoz 2005, Walters and Coen 2013).
Mud Snails *Ilynassa obsoleta*	5 (GISD 2008)	Mud snails occur in estuarine habitats. They can be found in the benthic zone of intertidal flats and estuaries (GISD 2008).	In two mark-recapture studies over 5 to 6 months, mud snails moved a mean daily net distance of 1.7 meters and 2.2 meters but snails often moved 10-20 meters per day. In both studies, snails achieved net dispersal within 20 days and had moved up to 100 m from release site. Snails were not found crossing sandbars and most moved away from shore into a tidal gully (Curtis 2004).	Mud snails are facultative scavengers and deposit feeders and will consume food items such as diatoms, minute worms, algae, fish and crustacean remains, and other organic matter, including faeces found on underwater surfaces (GISD 2008).	Crabs, other snails, and birds (Brenchley 1982).
Ribbed Mussels *Geukensia demissa*	15 (Nestlerode 2009)	Ribbed mussels are usually lodged within stems and roots of smooth cordgrass in estuaries and salt marshes (URI 1998, Coen and Walters 2013b) as well as intertidal oyster reefs (Coen and Walters 2013b).	Ribbed mussels are predominantly sedentary. They anchor themselves with byssal threads to the substrate (URI 1998) but have the ability to reattach themselves if dislodged (Coen and Walters 2013b). They can move slowly but only if forced to by changes in their environment (Nestlerode 2009).	Filter feeders: Plankton and organic matter (URI 1998); bacteria-plankton (Coen and Walters 2013b). Ribbed mussels only feed when they are submerged (Coen and Walters 2013b).	Blue crabs, mud crabs, and shore birds like clapper rails (Nestlerode 2009).

Table C-1
Life History Characteristics for Sediment-Dwelling Organisms in the OU1 Estuary
LCP Chemical, Brunswick, GA

Common Name	Lifespan (years)	Habitat	Movement and Burrowing Patterns	Diet and Forage Pattern	Predators
Oysters *Crassostrea virginica*	20 (Puglisi 2008)	Oysters are found in predominantly intertidal along the coast forming dense fringing or patch reefs (Manley et al. 2010). They live on firm, stable bottoms in brackish waters of sheltered bays and estuaries, usually at depths of 2 to 3 meters.	Oyster distribution is dependent on where larvae settle as adult oysters are sessile (Stanley and Sellers 1986).	Filter feeders: Plankton (Stanley and Sellers 1986).	Oyster drill, lightning whelk, blue crab, and the stone crab (Stanley and Sellers 1986).
Fiddler Crab *Uca* spp.	1-1.5 (Grimes et al. 1989)	Fiddler crabs prefer to burrow in areas of intermediate root mat density and close to hard structural elements. There is limited burrowing in lower intertidal areas where soft, fluid substratum will not support burrows (Bertness and Miller 1984, Grimes et al. 1989).	Exhibits site fidelity (Teal 1958) but can forage in marsh and creek areas up to 50 meters from burrow (Montague 1980, Sweat 2009b). Fiddler crabs tend to have two types of burrows: temporary burrows for refuge by non-breeding crabs and breeding burrows (Christy 1982). Burrows used for breeding tend to be longer and deeper than those used for temporary refuge (Christy 1983, Christy 1987). Results from a study by Christy (1987), indicated that females tended to choose burrows with a minimum depth of 5 inches for breeding, with burrows often deeper. Fiddler crabs tend to plug their burrows during high tide (Grimes et al. 1984). A recent study suggests that the presence of biological organisms that burrow may increase methylation due to their influence on aerobic condition of sediments, the presence of sulfide-reducing bacteria, and the aerobic condition of the sediments (Sizmur et al. 2013).	Fiddler crabs feed and are primarily the most active at low tide (GCRL 2013). Their diet consists of algae, bacteria, fungus, detritus, diatoms, fungi, and vascular plants (Grimes et al. 1989, Teal 1958)	Part of the green heron, clapper rail, and red-winged blackbird diet as well as several other birds. In addition, they are prey to numerous fish species (Grimes et al. 1989) as well as turtles and mammals such as otters and raccoons (Sweat 2009b).
Blue Crab *Callinectes sapidus*	~ 3 (Churchill 1919)	Upper, middle, and lower estuary as well as the adjacent marine water depending on their life stage. Early larval stages can be found in the lower estuary and adjacent marine waters and enter the estuaries as megalopae, where they adapt to a more benthic lifestyle (Hill et al. 1989, Perry and McIlwain 1986, Van Den Avyle 1984). Mature males tend to prefer creeks, rivers, and upper estuaries while non-mating females are usually in the lower estuaries and surrounding waters (Hill et al. 1989). Blue crabs are abundant in shallow water during warm weather; however, they tend to migrate to deeper water during winter (Churchill 1919, Hill et al. 1989).	Excellent swimmers but rarely move from one estuarine system to another with the exception of adjacent coastal areas (Hill et al. 1989). Most spawning females seasonally migrate from low-salinity mating ground to high salinity spawning grounds (Van Engel 1958, Tankersley et al. 1998). Spawning females often migrate many miles from estuaries to the higher salinity waters of the ocean. After spawning, females tend to stay in the high salinity waters of the lower estuary and coastal ocean (Van Engel 1958).	They are opportunistic feeders and their diet consists of bivalves, crustaceans, carrion, worms, plant and animal detritus (Hill et al. 1989, Perry and McIlwain 1986, Van Den Avyle 1984). They are considered to be important detritivores and scavengers (Hill et al. 1989).	Comprise some portion of the diet for many bird and mammal species including humans (Hill et al. 1989, Perry and McIlwain 1986, Van Den Avyle 1984).

Table C-2
Life History Characteristics for Fish in the OU1 Estuary
LCP Chemical, Brunswick, GA

Common Name	Approximate Lifespan (years)	Approximate Size at Maturity (inches)	Habitat	Approximate Water Depth (meters)	Movement Patterns	Diet and Forage Areas	Fisheries	Minimum Catch Size [(a)]	Distribution and Abundance in Georgia
Mummichog *Fundulus heteroclitus*	5 (Abraham 1985)	Females: 1.5; Males: 1.2 (Abraham 1985)	Always found in calm and protected waters (bays, estuaries, coastal creeks, and into fresh water) (GDNR 2013a).	0-3.7 m (Abraham 1985)	Relatively stationary fish with high site fidelity and relatively small home ranges in protected, calm waters (Lotrich 1975, Abraham 1985) but subject to movement consistent with the tidal cycles in an estuary like OU1. Primarily utilizes marsh habitats on flooding tides (Teo and Able 2003). Mummichogs are especially abundant in salt marshes and tidal creeks (Abraham 1985, Nelson et al 1991).	Omnivorous feeder, food includes small crustaceans, polychaetes, insect larvae and vegetable matter (Froese and Pauly 2013). Mummichogs feed throughout the water column (Katz 1975), and primarily in daylight at high tide (Abraham 1985). Foraging occurs in creek and marsh habitats (Pirri et al. 2001).	Although not valued as commercial or sport fish, mummichogs are important because of their role in the marsh food web (Abraham 1985).	No minimum length	In Georgia, they occur predominantly in the St. Marys, Satilla, Ogeechee, and Savannah River basins (GMNH 2009). Highly abundant at all life stages in the mixing and salt water zones of the Savannah River, Ossabow Sound, Sapelo Sound, Altamaha River, and St Andrew/St Simon Sound (Nelson et al. 1991).
Silver Perch *Bairdiella chrysoura*	6 (Perlmutter 1961)	6 (GDNR 2013b)	Prefers protected waters of bays, estuaries, and coastal streams. Abundant in coastal rivers and streams during the winter (GDNR 2013b).	Common found at depths of 3 - 10 m (Sprague and Luczkovich 2011).	Adults are shore fishes that migrate offshore during colder months. Generally spawn in shallow estuarine areas and young recruits settle and stay in nursery habitats (Breder 1928, Rooker et al. 1997). When larvae are capable of swimming, they settle in shallow tidal creeks. As they get bigger, they move into deeper creeks and estuaries and only return to tidal creeks at high tide (NERRS 2013).	Finfish, detritus, benthic invertebrates and crustaceans (Froese and Pauly 2013). Foraging occurs in creek and marsh habitats depending on the life stage of the fish.	Not valued as a commercial fish but important ecologically in terms of abundance, trophic interactions, and residence (Grammer et al. 2009).	No minimum length	Abundant in estuaries along the Gulf of Mexico and the Atlantic coast of United States (Grammer et al. 2009).
Black Drum *Pogonias cromis*	43-58 (Hill 2005)	11-13 (Sutter et al. 1986)	Generally found in areas with soft bottoms. Found usually over sand and sandy mud bottoms in coastal waters, especially in areas with large river runoffs. Juveniles often enter estuaries (ASMFC 2012, GDNR 2013c).	Found in shallow waters along coast and have been collected in water less than a meter (Silverman 1979). Adult: 5-27 m with majority found at 20-27 m (Sutter et al. 1986)	Larvae enter estuaries on tidal currents and post larvae prefer nutrient-rich and muddy waters of tidal creeks and channels. Juveniles are more often found over muddy bottoms in estuary creeks. Adults sometimes move into continental shelf waters but are primarily estuary-dwelling and show little migratory behavior (Hill 2005, SCDNR 2013a). Although black drum show little migratory behavior, movement within the larger TRBE is likely as studies of tagged black drum show movement patterns within a bay system with adults leaving the bay system for deeper waters at age 4 (Hill 2005).	Primarily bottom feeders that feed on invertebrates and fishes (Sutter et al. 1986, Hill 2005). Foraging occurs in creek and marsh habitats. In shallow water, black drums sometimes feed in the vertical position so that their tails stick out of the water (Sutter et al. 1986).	Black drum are more important recreationally than commercially in Georgia (ASMFC 2012).	10 inches	Adults, juveniles, and larvae are common in the estuarine and marine areas of Savannah River, Ossabow Sound, Sapelo Sound, Altamaha river, St. Andrew/St. Simon Sound while spawning adults and eggs are rare. Although rare, juveniles can sometimes be found in tidally fresh areas of these sounds. Adults are abundant in the marine areas of St. Andrew/St. Simon Sound (Nelson et al. 1991). In Georgia, they are common around oysters and usually found over sand or sandy mud bottoms in coastal waters, especially in areas with large river runoffs (GDNR 2013c).
Red Drum *Sciaenops ocellatus*	~38 (SCNDR 2013b)	Females: 33; Males: 28 (SCDNR 2013)	Adults use nearshore and inshore bottom habitats such as tidal creeks, oyster reefs, and beaches, typically over sand and sandy mud bottoms. (SCDNR 2013b). Juveniles use estuaries near shallow tidal creeks and salt marshes, commonly at marsh grass edges or in the vicinity of oyster reefs. Juveniles reside in deeper river channels during winter. Subadults inhabit larger tidal creeks, rivers, and front beaches of barrier islands (SCDNR 2013).	Adults have been observed feeding along the shoreline at depths >1.2 m from low tide through flood tide to 70 meters offshore (Mercer 1984)	Spawning aggregations occur near estuary inlets and passes along barrier island beaches. Larval red drum use vertical migrations to ride tidal currents into tidal creeks and shallow salt marsh nursery habitats (SCDNR 2013b, ASMFC 2002). Diel vertical migration was observed in larvae with larvae found at depth at night and higher in the water column during the day (ASMFC 2002). Studies conducted in Georgia have revealed the importance of Altamaha River estuary to adult red drum for spawning activity (ASMFC 2002).	All sizes forage on or near the bottom while inshore juvenile foraging typically occurs at marsh grass edges in creeks. Adults feed on fish and crustaceans and juveniles feed on grass shrimp, small fish, and fiddler crabs (SCDNR 2013b). Foraging occurs in creek and marsh habitats.	Important recreationally and is of minor importance commercially. No direct commercial fishery currently exists for red drum and commercial landings reported have primarily been the result of bycatch. Commercial landings in Georgia are limited to hook and line captured fish and typically do not exceed 3,000 pounds since the late 1970s. Red drum is a prized sport fish. Recreational landings (in pounds) of red drum in Georgia have fluctuated between 10,000 to 1 million since 1980 (ASMFC 2002).	14 inches	In Sapelo Sound, Altamaha River, and St Andrew/St Simon Sound, adults, juveniles, and larvae are common to highly abundant in estuarine and marine waters while subadults and eggs are rare (Nelson et al. 1991). A telemetry study on subadult and young adult red drum in Georgia found that subadults co-occurred with adult fish in schools along beaches and shoals during fall months, and at natural and artificial reefs in offshore waters during the water (ASMFC 2002).

Table C-2
Life History Characteristics for Fish in the OU1 Estuary
LCP Chemical, Brunswick, GA

Common Name	Approximate Lifespan (years)	Approximate Size at Maturity (inches)	Habitat	Approximate Water Depth (meters)	Movement Patterns	Diet and Forage Areas	Fisheries	Minimum Catch Size [(a)]	Distribution and Abundance in Georgia
Spotted Seatrout *Cynoscion nebulosus*	8 (GDNR 2007)	10-12 (Blanchet et al. 2001)	All ages use inshore live bottom habitats. Although seatrout primarily use estuaries and rivers, they also have been known to use shallow coastal bays, sounds, beaches of barrier islands. The adults tend to be common near salt marsh edges and over grass beds, in the vicinity of tidal creek mouths and channels, and over oyster reefs. The juveniles tend to prefer shallow tidal creeks and salt marsh as nursery habitats, often over submerged vegetation. Subadults inhabit larger tidal creeks and main portions of estuaries (SCDNR 2013c).	0 -10 m (FMNH 2013)	Seasonal movements within the estuarine and coastal zones. (GDNR 2007)	Forage finfish species and crustaceans (GDNR 2007). Juveniles forage in tidal creeks and marsh areas while adults forage in tidal creeks at salt marsh edge and in the vicinity of tidal creek mouths, channels, and over oyster reefs (SCDNR 2013c).	Although spotted seatrout is the most important recreational sport fish species in Georgia (GDNR 2007), there have been no commercial landings of spotted seatrout in Georgia since 2000 (NMFS 2013).	13 inches	All life stages are abundant or highly abundant in the mixing zone and seawater in the estuaries of Sapelo Sound, Altamaha River, and St. Andrew/St. Simon Sound. Juveniles are also common in the tidal fresh zone of these estuaries (Nelson et al. 1991).
Striped Mullet *Mugil cephalus*	4-6; maximum 13 (Leard et al. 1995)	Females: 9-10; Males: 8-9 (Leard et al. 1995)	Striped mullet can be found in rivers, lakes, bays, and canals and on barrier islands in fresh, brackish, or marine waters. Habitat vary greatly and may change with their life stage (Leard et al. 1995).	Striped mullet occupy different depths from 0-125 m (EOL 2013b). Striped mullet may stratify by depth according to size with the larger individuals moving into deeper water habitats, particularly in winter (SCDNR 2013d)	Estuarine habitat is primarily used by juveniles and adults. They spawn offshore or near passes, and larvae move inshore and into estuaries (Nelson et al. 1991). Mullet form large schools for spawning (hundreds of thousands of individuals) and smaller schools for feeding (Leard et al. 1995).	Larval mullet eat planktonic crustaceans. Adult mullet eat microalgae, macrophyte detritus, and sediment. They suck up the uppermost layer of sediment, consume the organics, and excrete the sediment (Leard et al. 1995). Foraging occurs in creek and marsh habitats.	While striped mullet is important recreationally, there has been no commercial landings of mullet in Georgia since 2000 (NMFS 2013).	No minimum length	Adults and juveniles are abundant to highly abundant in estuarine and marine waters in Sapelo Sound, Altamaha River, and St. Andrew/St. Simon Sound while larvae are rare. Adults and juveniles are common to abundant, respectively in tidal freshwater areas (Nelson et al. 1991)

(a) Information on minimum catch size taken from GDNR Coastal Division website. http://www.marinefishesofgeorgia.org/

TRBE Turtle River/Brunswick Estuary

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Appendix D
2012 Analytical Data Summary

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:
Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:
ENVIRON International Corporation

Anchor QEA, LLC

Date:
June 2, 2014

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Appendix D: 2012 Analytical Data Summary

Analytical data is provided electronically in the Feasibility Study Database.

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Appendix E
Data Handling and Data Issues Resolution

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:
Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:
ENVIRON International Corporation

Anchor QEA, LLC

Date:
June 2, 2014

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Contents

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Acronyms and Abbreviations

BERA	baseline ecological risk assessment
ENVIRON	ENVIRON International Corporation
FS	feasibility study
ft	foot
LCP	LCP Chemicals of Georgia, Inc.
LiDAR	light detection and ranging
µg/kg	microgram(s) per kilogram
NOAA	National Oceanic and Atmospheric Administration
PAH	polycyclic aromatic hydrocarbon
RI	remedial investigation
USEPA	United States Environmental Protection Agency

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Executive Summary

This appendix supports the *Feasibility Study Report for OU1 (Estuary) – LCP Chemicals Site, Brunswick, Georgia* (the FS) and it summarizes the data handling approaches and resolution of data questions from the United States Environmental Protection Agency (USEPA) about data used in the FS. This appendix identifies the samples included and excluded from the FS. This appendix also identifies final changes made to the LCP project database. All planning and execution of work associated with the resampling effort was conducted as part of OU1 field efforts (MWH and GeoSyntec 2005).

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1 Introduction

This appendix supports the *Feasibility Study Report for OU1 (Estuary) – LCP Chemicals Site, Brunswick, Georgia* (the FS). The focus of this appendix is to provide clarity regarding decisions regarding data usage. Section 2 of this appendix discusses data handling approaches and issues and the rationale behind those approaches. Section 2 also addresses questions about specific sample locations that were identified by the United States Environmental Protection Agency (USEPA) in emails dated April 12, 2013, and July 12, 2013 (USEPA 2013). Section 3 identifies final actions performed in the FS, the rationale behind those actions, and corresponding edits made to the project database.

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2 Data Handling Approaches

The datasets used in the FS were from data collected from 1995 to 2012. These are identified in detail in Section 2 of the FS. This section discusses the general data processing decisions applied to the entire FS dataset and specific data decisions used to address anomalous or questionable sample results encountered by ENVIRON and questioned by USEPA (USEPA, 2013):

2.1 Depth Intervals

The FS considered surface sediment samples using an approach consistent with the baseline ecological risk assessment (BERA; Black and Veatch 2011). This surface interval reflects the biologically active zone and is the primary focus for remedial decision-making in the FS. Specifically, the FS focuses on the surface interval, defined as follows:

- For locations where the 0 to 0.5 foot (ft) interval was sampled, the surface sediment interval is defined as 0 to 0.5 ft below the sediment surface.
- For locations where the 0 to 1 ft interval was sampled, but the 0 to 0.5 ft interval was not, the surface sediment interval is defined as 0 to 1 ft below the sediment surface.

2.2 Management of Multiple Data Sets over Space and Time

Many locations were sampled on more than one occasion and some sample locations were sampled at multiple depths within the upper 0 to 0.5 foot interval or 0 to 1 foot interval. The X and Y coordinates, not the location name, associated with each sample result were used to determine if sample results were collected from the same location. The following management decisions were made for these sample locations:

- Data management for multiple sample depth intervals at a single location

  Except as noted below, data were averaged over the surface sediment interval when multiple samples were collected, as was the case in 1995 and 1996 when, for example, samples were collected over 2-inch intervals at several locations.

  There were only eight locations sampled in 1995 and 1996 where samples were collected between the intervals of 0.5 to 1 ft. This interval was not included because at each of these locations, the interval above it was also sampled (i.e., the upper 0 to 0.5 ft interval was available and was preferentially selected in accordance with the BERA 2003 to 2007 monitoring interval). The specific locations were: PURVIS CREEK 110, SCC-01, SCC-03, SCCD-06, SCCD-08, SCCD-09, SCM-01, and SCM-03.

- Data management for multiple sampling events at a single location over time

  For locations with multiple sampling events over time, data were averaged and this average value is the value provided in the FS dataset.

2.3 Handling of Duplicates

Duplicates were included in the FS dataset and were averaged following the rules for multiple sampling events at a single location over time as described in Section 2.2 (i.e., all samples from each location in the surface sediment interval were averaged). There were some duplicates that were not flagged consistently with the primary samples in a duplicate set (Table E-1). For example, for some samples flagged as having been “1=Removed” or “5=Believed Removed,” the duplicate sample was not flagged accordingly—these duplicates were managed consistently with their respective primary samples and were not included in the FS.

2.4 Total Polycyclic Aromatic Hydrocarbons (PAHs)

Total PAH sediment concentrations were determined by summing the concentrations of the 18 individual PAHs analyzed during the remedial investigation (RI) sediment sampling. The individual PAH compounds include: acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, 1-methynaphthalene, 2-methynaphthalene, naphthalene, phenanthrene, and pyrene.

2.5 Handling of Non-detects

Non-detected sample results were included in the FS dataset and given a value of half the stated detection limit for mercury, Aroclor 1268 and lead results. For total PAH results, the handling of non-detects was modified to account for elevated detection limits for individual PAH results reported during the 1995-1999 sampling events. An elevated detection limit was defined as greater than 400 micrograms per kilogram (µg/kg), as this is the level where using half the detection limit would lead to an exceedance of the total PAH remedial goal. For non-detect PAH results, half the detection limit was used if the detection limit was less than 400 µg/kg and no value was assigned if the detection limit was greater than 400 µg/kg.

The approach for summing total PAH concentrations with non-detect results was reviewed with the Agencies during a conference call on August 2, 2012. Locations where PAH detection limits were elevated are shown in Figure E-1. Among the approximately 450 samples where PAHs were analyzed, approximately 5 percent (%) had elevated detection limits where at least one individual PAH compound had a detection limit greater than 400 µg/kg. The uncertainty associated with this data processing approach had no significant impact on the characterization of PAHs, decisions about remedy alternatives, or an understanding of remedy effectiveness because locations with elevated PAHs were sampled in subsequent events at the same or nearby locations and with lower detection limits.

2.6 Specific Data Processing Decisions

Table E-1 provides a summary of locations identified as having data questions by the USEPA in the emails dated April 12 and July 12, 2013, and the final handling of the data in the FS. Additional detail is provided below to explain the rationale for the final data handling decision:

- Samples 1011, 75, 77, 82, and PTI-E9 are shown in Figure E-2. These locations from the 1995 USEPA Phase I, II, and III and 1996 PTI sampling events were excluded from the FS because they were flagged “5” (Believed removed) in the RI database. These locations were questioned during the BERA sampling due to their location just outside of the 1998-1999 removal action limits and the poor quality of GIS coordinates in 1995 and 1996. Subsequently, these locations were resampled and analyzed for mercury during the 2002 BERA sampling event (MWH and GeoSyntec 2005; Section 4.2 and Figure 4-1a). The results of the resampling were significantly different from the 1995 sample results; the 2002 mercury concentrations were up to two orders of magnitude different from the concentrations reported in 1995. Aroclor 1268 data was not collected in 2002 however the

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significant difference in the mercury data suggests that all results from these 1995 locations are questionable. Due to the questionable accuracy of the data collected in 1995 and 1996, only the 2002 resampling results were included in the FS. This is consistent with the use of the data in the RI (EPS and ENVIRON 2012). This is consistent with previous discussions with USEPA about the use of resample data (MWH and GeoSyntec 2005).

- Sample 98106-RW-03 was collected during the Marsh Confirmation Sampling Event in 1998. Results from this sample were not included in the RI database, but were included in the USEPA database. Sample 98106-RW-03 is identified in the USEPA database as a post-excavation bottom sample and was likely capped as a part of the 1998-1999 remedial action (EPS and ENVIRON 2012). This location was resampled during the 2002 BERA sampling event. The 2002 resampling results were significantly lower than the original 98106-RW-03 results; therefore, only the resampling result was included in the FS.
- Location 45A (B04439) from the 1995 USEPA Phase II sampling event was resampled in 2012. The goal of this resampling effort was to refine the remedial alternatives being developed in the FS. The resampling effort involved the collection of three adjacent samples, all within a 5-ft distance (Figure E-3). The three 2012 samples were averaged and the average value is used in the FS.
- Initially sampled as part of the 1995 Phase II sampling effort, Purvis Creek Location 54 (B4441) was resampled over multiple sampling events (Figure E-4). A value of 76 mg/kg Aroclor 1268 was reported during the 1995 sampling event, but could not be repeated by subsequent sampling. The post-1995 resampling values collected at or near the former Location 54 are used in the FS.
- The location of 5-NOAA sampled during the National Oceanic and Atmospheric Administration (NOAA) 1997 sampling event has been inconsistently documented in the database historically. After a review of Figure 2-1 of the NOAA 1997 report (Figure E-5) and consultation with the people who conducted the sampling, it was confirmed that this location is in the LCP ditch and not in the Domain 3 Marsh. Thus, the FS database and the mapping in the FS are correct and do not need to be changed. Sampling locations that were confounded by unresolved uncertainties were retained in the database.
- A set of sample locations were identified as upland samples as part of the more current light detection and ranging (LiDAR) mapping. These are illustrated on Figure E-6. These locations will be addressed as part of OU3. The database was updated to reflect these locations as soil samples.

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3 Final Actions Performed to Database

The following actions were employed to resolve the questions related to data handling, as indicated in the final column of Table E-1 (with notations in blue text):

- The database was updated to change the Removed flag for duplicate locations in 1998-1999 removal action from 0 (not removed) to 1 (removed).
- The sampling locations from 1998 GeoSyntec Eastern Marsh Delineation Sampling event are placed in the upland area to be addressed under OU3, not in OU1.
- Notes were added to samples 1011, 75, 77, 82, PTI-E9, 54, and 45A to indicate that these results were replaced by more recently collected sample results.

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4 References Cited

Black and Veatch. 2011. Baseline Ecological Risk Assessment for the Estuary at the LCP Chemical Site in Brunswick, GA – Site Investigation and Risk Characterization (Revision 4). Prepared for EPA Region 4 by Black & Veatch Special Projects Corp, April.

EPS and ENVIRON. 2012. Remedial Investigation Report Operable Unit 1 – Estuary LCP Chemical Site, Brunswick, Georgia. Prepared for the Site Steering Committee, May.

MWH and GeoSyntec. 2005. Comprehensive Report of Estuarine Ecological Monitoring at the LCP Chemicals Site, 2000-2003. Brunswick, GA. April.

USEPA. 2013. Email Communications between Galo Jackson (USEPA) and Mary Sorensen (ENVIRON) dated April 12 and July 12, 2013.

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Tables

Table E-1. Resolution of Feasibility Study Data Questions Posed By the USEPA in Email Dated April 12, 2013
LCP Chemicals, Brunswick, GA

Location	Domain	Easting	Northing	Initial Sample Concentrations, mg/kg		Comments from the USEPA and Resample Information (As Applicable) Based on April 2013 Communications	Data Source	Additional Explanation (As Applicable)	Additional EPA Comments from July 12, 2013	Final Actions
				Mercury	Aroclor-1268					
1011	1	860257.1	432038	34	–	Included in Appendix D, but labeled as K24160. In Appendix D Hg = 0.78 mg/kg	1995 EPA Phase I,II,III Sampling	All of these locations were excluded from the FS because these samples are flagged "5" in the database. This flag was applied since these locations were re-characterized in a subsequent sampling effort (MWH & GeoSyntec, 2005; Section 4.2 and Figure 4-1a).	The 2005 report mentioned above present the re-sampling of all six of these samples. The report mentions that prior to May 2000, the GPS signal was intentionally degraded and that error was in the range of tens of meters or more. Does this mean that all the pre-May 2000 locations are in doubt? If so, why exclude only the high concentrations, such as these six samples?	The sample results from locations 1011, 75, 77, 82 and PTI-E9 were not included in the FS dataset due to the questions surrounding the coordinate data and the availability of results from subsequent resampling that demonstrated the location plotted from 1995 and 1996 coordinates is not correct. The exclusion of these data from the FS is consistent with decisions made in the OU1 Remedial Investigation (EPS and ENVIRON 2012). This does not mean that all locations from the pre-May 2000 are in doubt. The locatons excluded are only those identified for resampling as part of the MWH & GeoSyntec efforts of 2005. Those resampling decisions were made in coordination with the USEPA and all results were reported to the USEPA.
75	1	860560.1	431723	29	5.2	Included in Appendix D, but labeled as B04354. In Appendix D Hg = 1.1 mg/kg and no data for Ar1268				
82	1	860251.1	431507	39	5.9	Included in Appendix D, but labeled as B04347. In Appendix D Hg = 9.2 mg/kg and no data for Ar1268				
PTI-E9	1	860327.13	432062.97	43.3	52	Inlcuded in Appendix D, labeled E9. In Appendix D Hg = 0.76 mg/kg and no data for Ar1268.	1996 PTI Sampling			
77	1	860636.1	431297	55	27	Added to Appendix D, labeled B04352. In Appendix D Hg = 10 mg/kg and no data for Ar1268.	1995 EPA Phase I,II,III Sampling			
98106-RW-03	1	860896.1	430909	39.3	33		1998 Geosyntec	Post-excavation bottom sample from Domain 1 in the EPA database. Resampling in 2002 verified that concentration of surface soils are significantly lower.		Sample 98106-RW-03 was excluded from the FS dataset.
97269-21	Main Canal	860380.4	432395.9	11.6	31	Sample included in Marsh Area close-Out Report Removed Characterization table.	1997 Geosyntec LCP Ditch Sampling Event	These samples were not included in the FS because they are duplicates of samples that were removed as part of the 1998-99 removal action, and thus are not included in the FS evaluation (database flag of "1= Removed"). • 97269-21 was a duplicate of 97269-20 • 97269-43 was a duplicate of 97269-42 • 97270-02 was a duplicate of 97270-01	Close-Out Report (COR) does not present the duplicate sample results. Samples 21, 43 and 02 are located in the Main Canal, which is proposed for removal, so it's not worth spending too much time on these samples. Further, in the EPA copy of the database, these samples are flagged as not removed ("0"). Need to confirm.	BOTH EPA and PRP DATABASES are now corrected to change codes from 0 to 1.
97269-43	Main Canal	860776.3	432364.5	36.1	230	Sample included in Marsh Area close-Out Report Removed Characterization table.				
97270-02	Main Canal	860724.8	432358.6	43.5	68	Sample included in Marsh Area close-Out Report Removed Characterization table.				
97269-47	2A	860156.5	432414.4	10.6	11	Sample included in Marsh Area close-Out Report Removed Characterization table.		This sample was included in the FS. 97269-47 is a duplicate of 97269-49 and was averaged with 97269-49. The averaged value was presented as 97269-49.	97269-~~49~~ 47?. Averaging was done correctly.	Averaged value was included in the FS dataset.

Table E-1. Resolution of Feasibility Study Data Questions Posed By the USEPA in Email Dated April 12, 2013
LCP Chemicals, Brunswick, GA

Location	Domain	Easting	Northing	Initial Sample Concentrations, mg/kg		Comments from the USEPA and Resample Information (As Applicable) Based on April 2013 Communications	Data Source	Additional Explanation (As Applicable)	Additional EPA Comments from July 12, 2013	Final Actions
				Mercury	Aroclor-1268					
94207-01	3 NS Ditch	861654.1	433097.9	15.3	–		1994 Geosyntec	Samples were collected in 1994 as part of the GeoSyntec Removal Action Sampling. Pre-1995 samples were not used in the FS evaluation. The use of data for the RI and the FS was consistent with the data used in the BERA except that some data prior to 2000 were added to the RI and the FS only if they increased spatial coverage where not otherwise available from 2000 and later.	Agree. 1994 data are not to be included. All these samples are mentioned in COR characterization table but not in Removed Characterization table. Implies these samples have not been removed.	1994 data are not included in FS dataset. No change to the database is needed.
94207-02	3 NS Ditch	861460.1	432744.9	6.4	–					
94207-03	3	861116.1	432724.9	4.23	–					
94207-04	3 NS Ditch	861737.1	433251.9	1.57	–					
94207-05	3 NS Ditch	861790.1	433348.9	3.38	–					
94207-08	Main Canal	860086.1	432454	6.27	–					
98142-MED-16	1	860776.31	432364.5	8.64	1.2		1998 Geosyntec Eastern Marsh Delineation Sampling	These samples were from the GeoSyntec Eastern Marsh Delineation Sampling. The LiDAR-based boundaries for OU1 places these samples in the upland area, not in OU1. These samples, their locations, and chemical concentrations have been communicated to EPS so they can evaluate their impact on risk-management considerations for OU3 soils.	This needs to be checked. I have no way of verifying	The locations of these samples are discussed in Appendix E of the FS and illustrated on Figure E-6. BOTH EPA and PRP DATABASES are now corrected change these samples from sediment to upland soil.
98142-MED-20	1	861240.06	431557.94	2.5	2.43 U					
98153-MED-24	1	861203.56	431481.44	8.67	9.5					
98153-MED-27	1	861235.06	431557.94	2.55	2.1					
98153-MED-29	1	861241.06	431575.94	18.3	5.72					
98153-MED-31	1	861247.06	431596.94	0.56 U	2.26 U					
98156-MED-47	1	861259.06	431638.94	0.56 U	2.24 U					
BM038	2A	860087.06	432105.19	14	4.2		Brunswick Initiative Sampling	These samples are not included in the FS database nor in Appendix D of the FS. The samples were not collected as part of CERCLA efforts , they were not collected using a site-specific work plan; there is little information on how the samples were collected, processed, and analyzed; and there is little confidence in the precise positioning of the samples. Furthermore, data prior to 2000 were added to the FS only if they increased spatial coverage where not otherwise available from 2000 and later and this dataset only provided 3 samples in OU1.	Tend to agree.	1994 data are not included in FS dataset. No change to the database is needed.
BR069	Purvis Creek	858198.44	430846.19	1.8	5.2					

Table E-1. Resolution of Feasibility Study Data Questions Posed By the USEPA in Email Dated April 12, 2013
LCP Chemicals, Brunswick, GA

Location	Domain	Easting	Northing	Initial Sample Concentrations, mg/kg		Comments from the USEPA and Resample Information (As Applicable) Based on April 2013 Communications	Data Source	Additional Explanation (As Applicable)	Additional EPA Comments from July 12, 2013	Final Actions
				Mercury	Aroclor-1268					
FS-AREA1	3	861513.75	434105.69	0.68-1.1	0.63-1.3		2000-2007 BERA Sampling	The data for FS-AREA 1 is included in the FS but the label for FS-AREA 1 is not provided in Appendix D, as it was averaged with sample C-200, and the average concentration is represented by sample C-200.	Low	Data provided in Appendix D, average was checked and confirmed correct based on averaging rules outlined in Section 2 of this Appendix. No change to the database is needed.
M-38	3	860957.44	432984.44	1.89-3.58	0.62-1.2			The data for M-38 is included in the FS but the label for M-38 is not provided in Appendix D, as it was averaged with sample C-31, and the average concentration is represented by sample C-31.	Low	
M-D3-6A	3	860352.88	432776.41	–	13	Coordinates are incorrect in Appendix D.	2012 ENVIRON Sampling	The sample is located in Domain 3, north of LCP Ditch; the sample coordinates in Appendix D are correct. Only a single set of coordinates identified as M-D3-A are shown for the average of M-D3-6A, -6B, and -6C.	Agree.	Averaged value was included in the FS dataset. No change to the database is needed.
M-D3-6B	3	860343.13	432777.5	–	8.1					
M-D3-6C	3	860362.31	432775.47	–	6.6					
5-NOAA	3					Coordinates differ in LCP database and Appendix D. LCP database places this sample in Domain 3 marsh, but Appendix D places it in LCP Ditch.	1997 NOAA Sampling	It was confirmed that this location is in the LCP ditch and not in the Domain 3 Marsh. Thus, the FS database and the mapping in the FS is correct and does not need to be changed.		5-NOAA will remain in the LCP Ditch at the coordinates specified in Appendix D. No change to the database is needed. However, this appendix now documents the uncertainty associated with this location.
54	Purvis Creek	858056.86	430621.91	3.48	76		EPA 1995 Phase II Sediment Sampling	Location was resampled among several sampling efforts as illustrated in Figure E-4 of this appendix. Location 54 was not included in Appendix D of the FS because it was resampled.	Coordinates differ in LCP database and Appendix D. LCP database places this sample in Domain 4 marsh, but Appendix D places it in Purvis Creek.	The actual placement of Location 54 has always been in question, which is why it was resampled. Location 54 was excluded from the FS dataset. This appendix now documents the uncertainty associated with the placement of Location 54. Location 54 is now excluded from Appendix D. BOTH EPA and PRP DATABASES should have a new flag added to document the location is suspect.

MWH and GeoSyntec, 2005. Comprehensive Report of Estuarine Ecological Monitoring at the LCP Chemicals Site, 2000-2003. Brunswick, GA. April.
EPS and ENVIRON. 2012. Remedial Investigation Report Operable Unit 1 – Estuary LCP Chemical Site, Brunswick, Georgia. May.

Blue Text	Indicates final edits to the LCP database in accordance with resolution of these issues.
Red Text	Indicates comments from the USEPA regarding a preliminary version of this data table provided to the USEPA in April of 2013 (following the submittal of the Draft FS).

BERA	baseline ecological risk assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
FS	feasibility study
GPS	geographic information system
LiDAR	light detection and ranging
mg/kg	milligram(s) per kilogram
NOAA	National Oceanic and Atmospheric Administration
PRP	potentially responsible parties
U	Compound was analyzed for but not detected.
USEPA	United States Environmental Protection Agency

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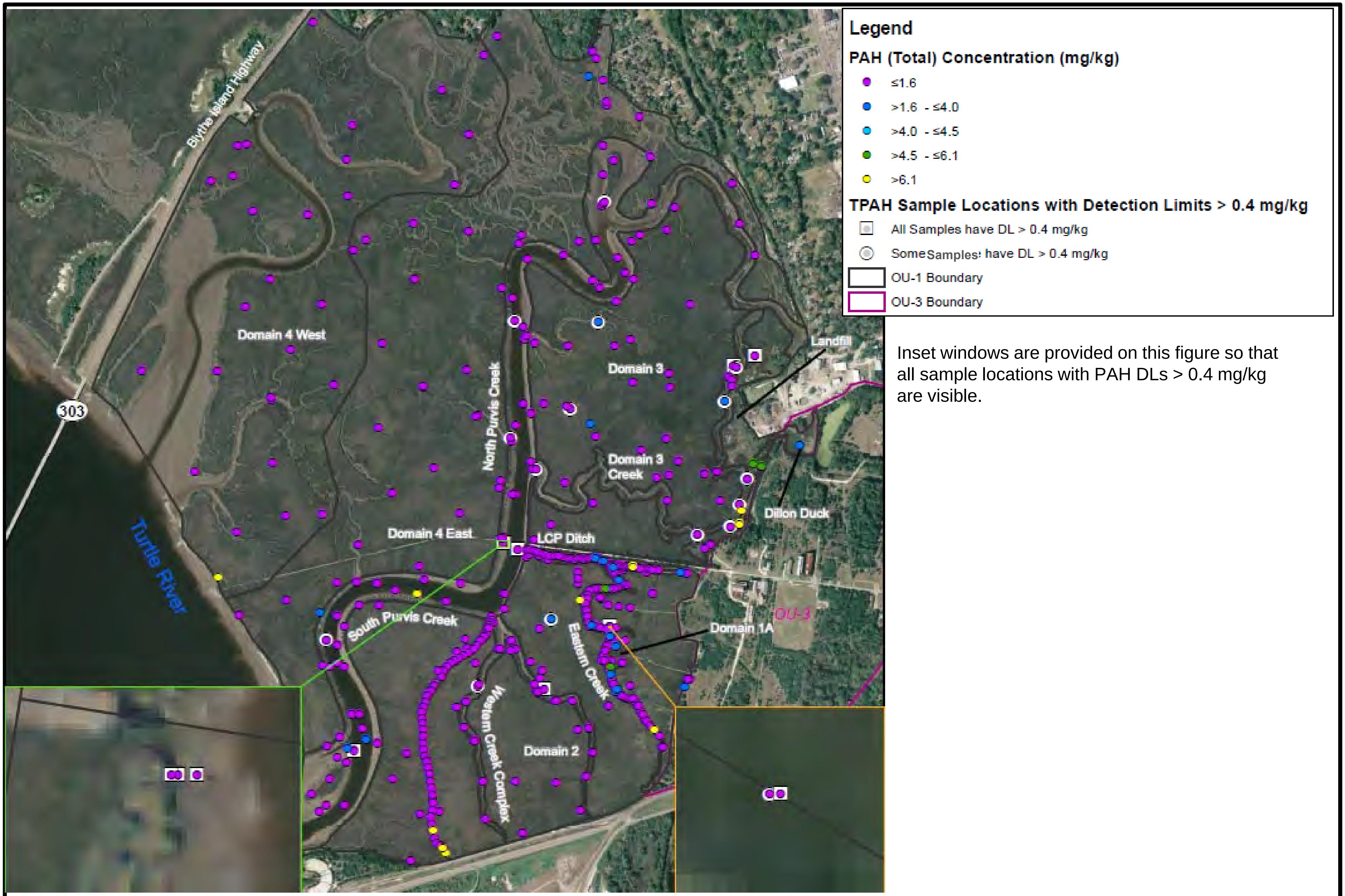
Figures



Inset windows are provided on this figure so that all sample locations with PAH DLs > 0.4 mg/kg are visible.

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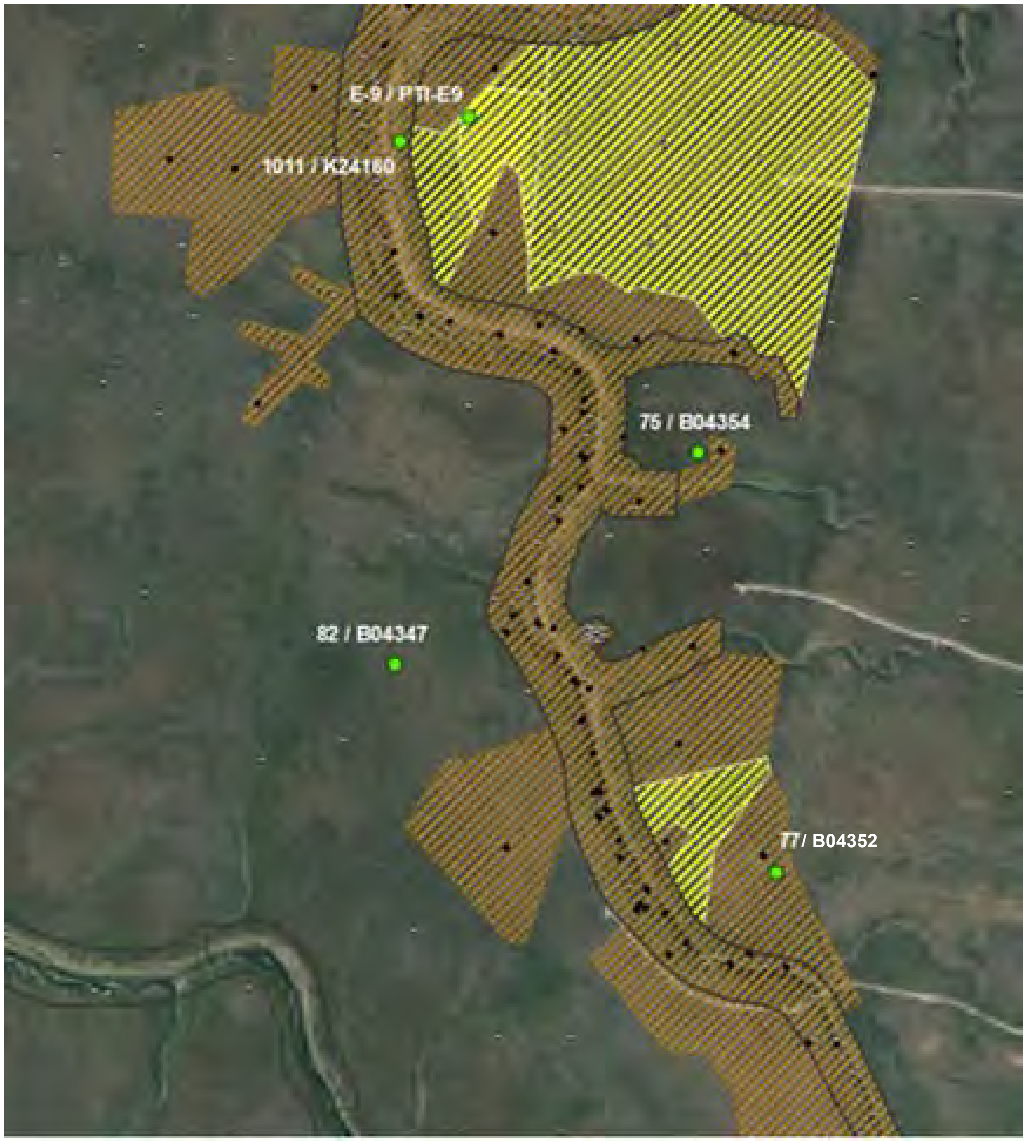
Total PAH Sample Locations with Elevated Detection Limits

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

E-1



Location	Concentration, mg/kg		Resample Location Name	Resample Concentration, mg/kg		Data Source
	Mercury	Aroclor-1268		Mercury	Aroclor-1268	
1011	34	–	K02416	0.78	-	1995 EPA Phase I,II,III Sampling
75	29	5.2	B04354	1.1	-	
77	55	27	B04352	10	-	
82	39	5.9	B04347	9.2	-	
PTI-E9	43.3	52	E-9	0.76	-	1996 PTI Sampling

- Brown and yellow hatching reflects the Sediment Management Area 3 footprint.
- The 1995 and 1996 data from the locations identified in the table above were not included in the FS because these locations were recharacterized in a subsequent sampling effort (MWH & GeoSyntec, 2005; Section 4.2 and Figure 4-1a). Recharacterization results were included in the FS.

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Domain 1 and 2 Resampled Locations

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

E-2

- Location 45A (B04439) from the EPA 1995 Phase I, II, III sampling event was resampled with three new samples in 2012. This 2012 sample was labeled M-D3 6A, 6B, and 6C.
- Data from M-D3-6A/B/C were averaged in the FS.
- Because data were averaged, a single set of GIS coordinates is provided.
- Coordinates relied on M-D3-6A location.

Domain 3 Resample Location

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

E-3

Location	Aroclor 1268 Concentration (in mg/kg)
54	76
10-NOAA	7.0
C-16	4.335
M-28	1.38
PURVIS CREEK 110	0.825
SD-LPC-C20	1.3
SD-LPC-C21	0.64
C-PC-02B	0.15
C-PC-02A	0.195
C-PC-02C	0.54

- Location 54 (B4441) was sampled in the 1995 Phase II sampling effort. The GIS coordinates were suspect.
- Multiple sampling efforts at and around Location 54 did not indicate similar results.
- The value of 76 mg/kg was not included in the FS.

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Aroclor 1268 Location 54 and Surrounding Sampling Locations

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

E-4

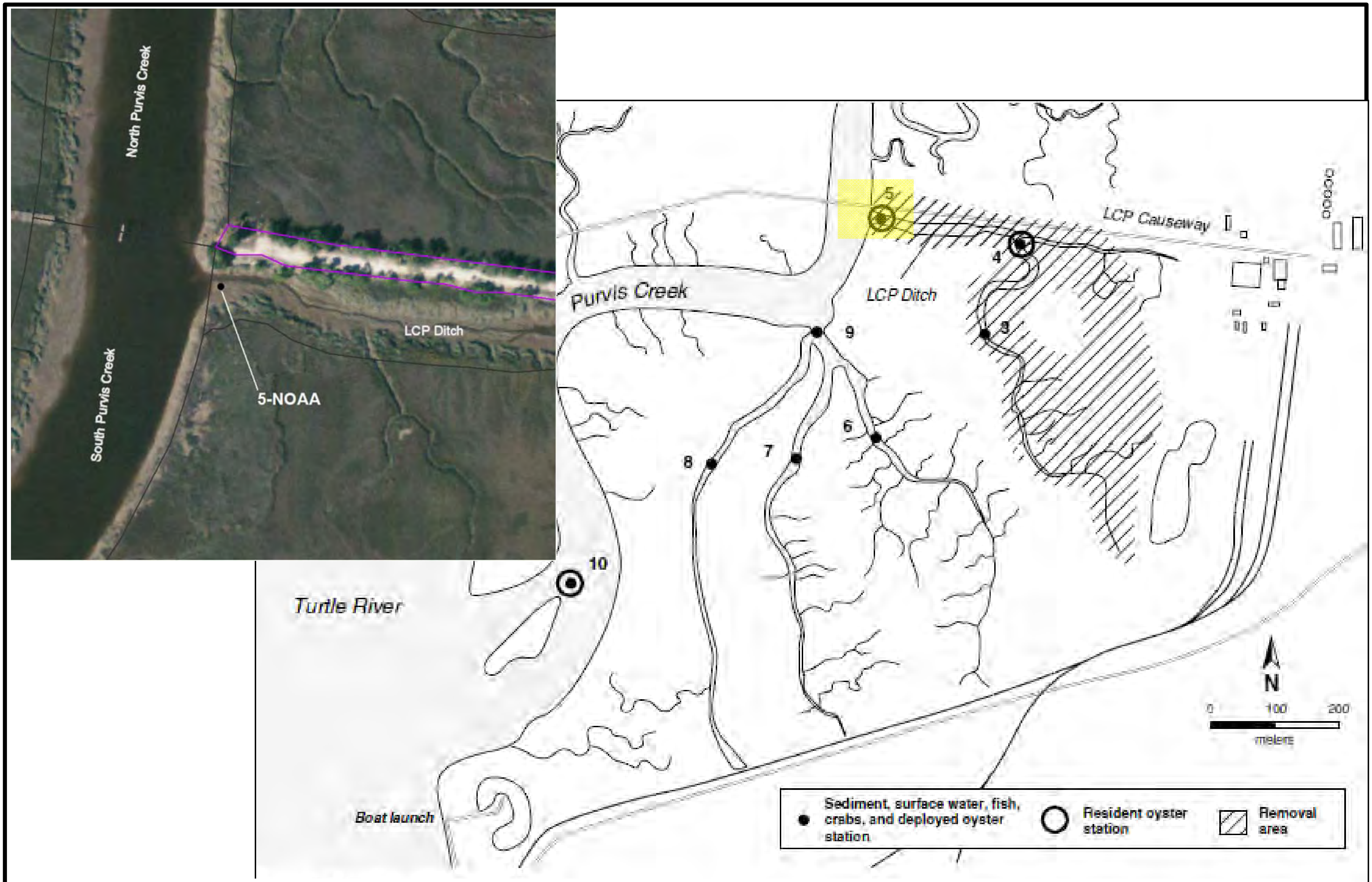

Figure sourced from the NOAA 1997 sampling report.

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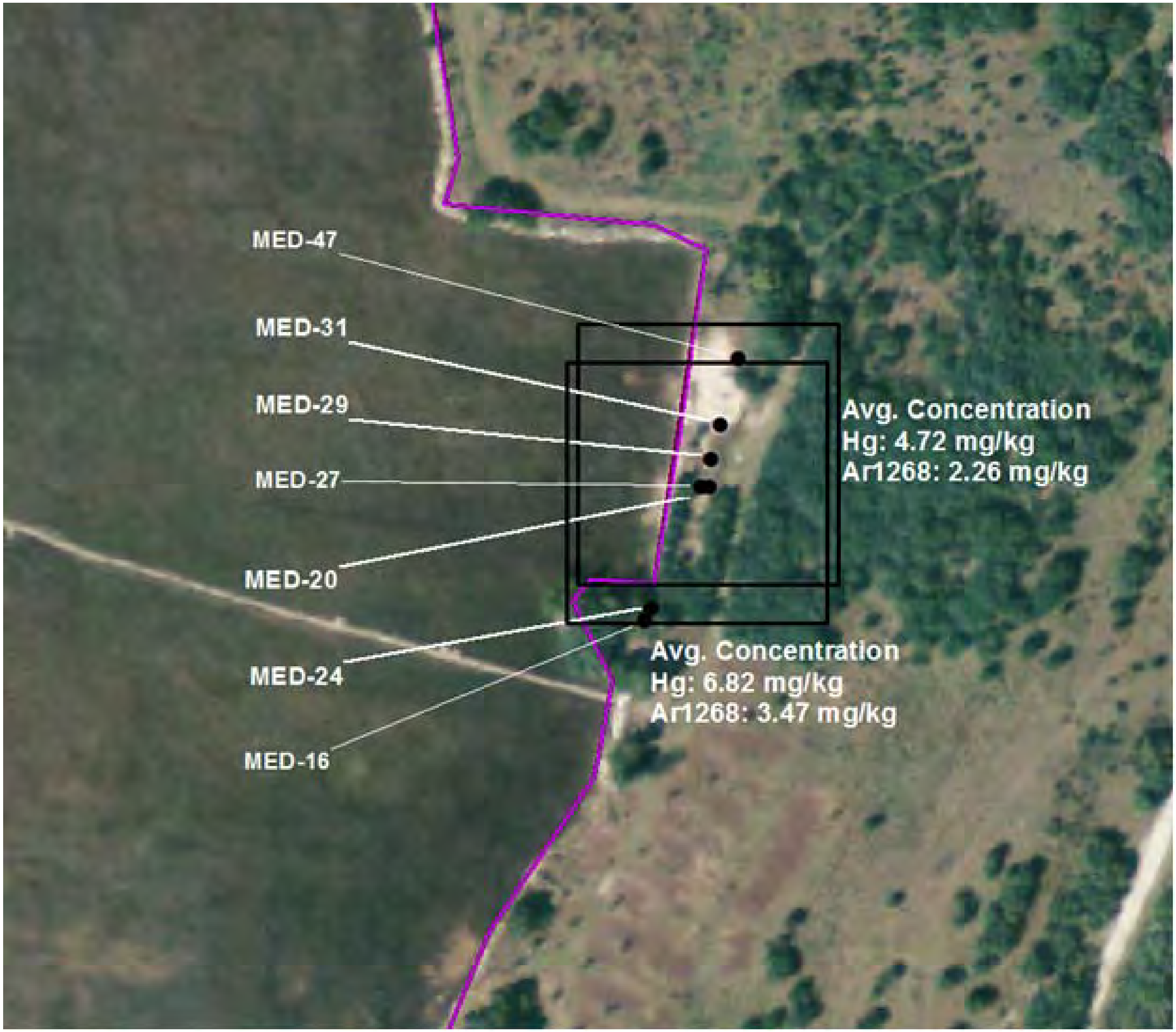
Location NOAA-5

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

E-5



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Samples Identified as Upland Soil Samples

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

E-6

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Appendix F
Fish and Shellfish Tissue Concentration Supporting Graphics

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:
Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:
ENVIRON International Corporation

Anchor QEA, LLC

Date:
June 2, 2014

Deleted: October 18, 2013

Deleted: DRAFT

Appendix F: Fish and Shellfish Tissue Concentration Supporting Graphics

The information in this appendix is provided in support of the feasibility study (FS) of OU1. The information is used to inform remedy alternative decisions, and to evaluate long-term monitoring trends for the LCP Site estuary. This appendix provides a graphical summary of the 2011 fish tissue data collection effort. These data already have been reported to the United States Environmental Protection Agency (USEPA), the Georgia Environmental Protection Division, and the Georgia Department of Natural Resources (GADNR) in tabular form by Environmental Planning Specialists, Inc. in 2011. These data were used by GADNR to set fish consumption advisories for Turtle River/Brunswick Estuary (TRBE) in 2012.

This appendix is includes the following sections:

Section F-1:	Excerpt from GADNR Fish Consumption Advisory Threshold Memorandum Describes dietary thresholds used by the GADNR to set fish consumption advisories
Section F-2:	Collection Locations for Fish and Shellfish within the Turtle River/Brunswick Estuary Presents a map of fish and shellfish sample locations, or zones, in the TRBE
Section F-3:	Available Fish and Shellfish Data (Fillet Tissues, Wet Weight) Presents a tabular and graphical depiction of available edible tissue data of fish and shellfish collected in the TRBE
Section F-4:	Available Fish and Shellfish Data (Whole-Body Fish Tissues, Wet Weight) Presents a tabular and graphical depiction of available whole-body data of fish and shellfish collected in the TRBE

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Section F-1 Contents: Excerpt from GADNR Fish Consumption Advisory Threshold Memorandum

This section is an excerpt from the GADNR technical memorandum identifying the dietary thresholds used by GADNR to establish fish consumption advisories for the TRBE. The edible fish and shellfish tissue data provided in Section F-3 are compared to these thresholds. These thresholds are not appropriate for comparing to the whole-body fish tissue data provided in Section F-4 because anglers do not consume the whole-body fish samples, only the edible tissues.

Georgia Department of Natural Resources (GA DNR). 2004. “Data Summary for the Turtle River.” Technical Memorandum from R.O. Manning, Environmental Toxicology Coordinator, Georgia Department of Natural Resources, Atlanta, Georgia, to J. McNamara, Georgia Environmental Protection Division, Atlanta, Georgia. February 9.

Georgia Department of Natural Resources
2 Martin Luther King, Jr. Drive, Suite 1152 East Tower, Atlanta, Georgia 30334-4100
Lonice C. Barrett, Commissioner
Carol A. Couch, Ph.D., Director
Environmental Protection Division
404/656-4713

MEMORANDUM

TO: Jim McNamara

FROM: Randall O. Manning, Ph.D., DABT
Environmental Toxicology Coordinator

DATE: February 9, 2004

RE: Data summary for the Turtle River

Samples of shellfish and/or finfish have been collected in the Turtle River near LCP in 1991, 1992, 1993, 1995, 1997, and 2002. While most of the samples have been analyzed for a large number of chemicals (> 40), my summary will deal only with total mercury and total PCBs (in this area almost exclusively Arochlor 1268) because those two chemicals have been found in sufficient quantity to contribute to fish consumption restrictions. In all instances, samples are edible composites, and numbers of composites (not individuals) are referred to as N. Composites of fish are created using fillet tissue from five individuals of the same species and size class. In rare instances composites may be created using less than five fish, but the majority of data summarized herein are for 5 fish composites. For shellfish, compositing is not based on specific numbers of organisms, but composites are created based on tissue volume (or amount) needed for laboratory analysis. All results are in mg/kg or ppm.

Since 1991, more than 700 composites of fish and shellfish have been collected in the Turtle River near LCP. About 75% of those composites (535) represent tissues from 5 individual fish. More that 2600 individual fish have been collected from the area.

The data is evaluated on a yearly basis for development of fish consumption guidelines. Those guidelines are developed using U.S. EPA's potency factors for carcinogenicity and reference doses for non-cancer toxicity, whichever is most restrictive. Inputs used in the risk calculation include a risk level of 1 X 10^{-4} for cancer, a 30-year exposure duration for both carcinogens and toxics, 70 kg as the body weight for an adult, and 70 years as the lifetime duration. A U.S. EPA algorithm is used, and solved for intake (gm/day). By making intake the dependant variable, the difficult issue of determining what are appropriate intake values for different subpopulations is avoided.

The intake value (which is really how much one can eat to keep theoretical lifetime cancer risk less than 1 X 10^{-4}, or to keep the daily intake below the RfD for non-cancer toxicity) is then compared to a scale equating to meals per week or month.

The scale is:

Calculated intake (gm/day)	equates to	guidance
≤ 3		do not eat
> 3 - 10		limit consumption to 1 meal/month
> 10 - 30		limit consumption to 1 meal/week
> 30		no restrictions

The scale is based on a range of meal sizes from ¼ to ½ lb. For practical purposes, the tissue concentrations for total PCBs and total mercury that bound the different consumption recommendations are shown below.

Chemical	No Restriction	One Meal/ Week	One Meal/ Month	Do Not Eat	FDA Action Level
PCBs (mg/kg)	≤ 0.10	> 0.10	> 0.30	> 1.0	2.0
mercury (mg/kg)	≤ 0.23	> 0.23	> 0.71	> 2.0	1.0

1991

In 1991 five composites of oysters and five composites of crab were collected in Purvis Creek and the Turtle River. Ranges and averages are shown below.

Sample	Contaminant	Conc. Range (ppm)	Mean Conc. (ppm)
Oysters, N=5	Mercury	0.1 to 1.2	0.4
	PCBs	0.1 to 0.4	0.2
Crab, N=5	Mercury	0.1 to 0.5	0.5
	PCBs	0.1 to 9.9	3.1

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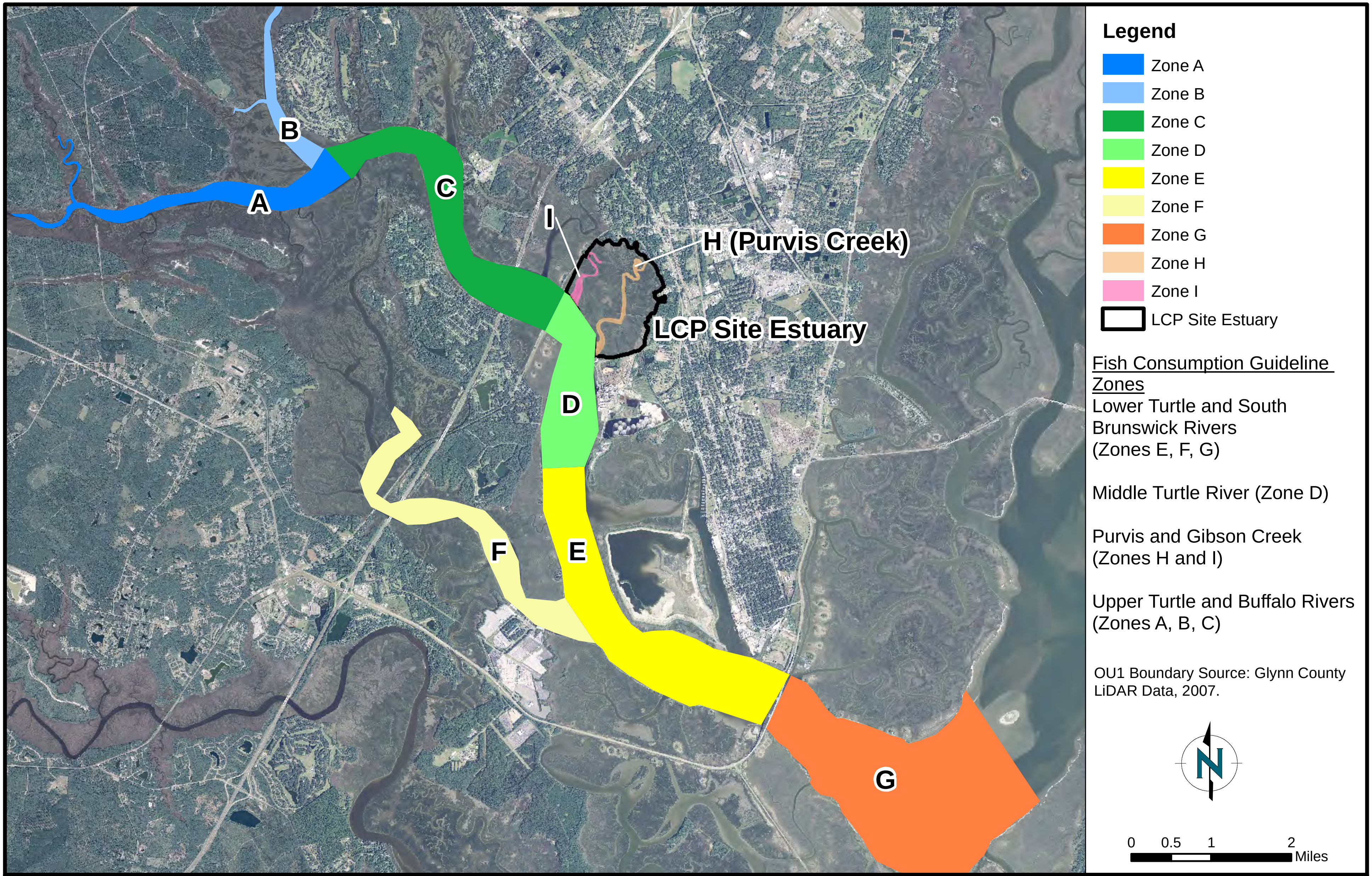
Section F-2 Contents: Collection Locations for Fish and Shellfish within the Turtle River/Brunswick Estuary

This section includes a map of fish and shellfish sample locations in the Turtle River/Brunswick Estuary. Data groupings in Sections F-3 and F-4 of this memorandum provided time trends for Zone H, with is the LCP Site estuary. In addition, Sections F-3 and F-4 provides a graphical summary of all locations sampled in the 2011 fish collection effort.



<u>Fish Consumption Guideline Zones</u>

Lower Turtle and South Brunswick Rivers (Zones E, F, G)

Middle Turtle River (Zone D)

Purvis and Gibson Creek (Zones H and I)

Upper Turtle and Buffalo Rivers (Zones A, B, C)

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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Collection Locations for Fish and Shellfish within the Turtle River / Brunswick Estuary

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure F-2

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Section F-3 Contents: Available Fish and Shellfish Data (Edible Tissues, Wet Weight)

This section presents a tabular and graphical presentation of available edible tissue data from fish and shellfish collected in the TRBE from 1995 to 2011. In addition, this section provides a graphical summary of all locations sampled in the 2011 fish collection effort. These edible fish and shellfish tissue data are compared to dietary thresholds used by the GADNR to set fish consumption advisories, as was described in Section F-1 for the locations identified in Section F-2.

The graphics in this portion of Appendix F show that the concentrations of mercury and Aroclor 1268 have decreased over time. Table 3-4 of the FS summarizes the changes in fish consumption advisories over time; consumption advisories have been lifted for some species due to low concentrations and have been reduced for many other species due to lowering concentrations. However, there are still fish with some degree of exceedances of the threshold levels, which is a basis of discussion in Section 6 of the FS.

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Figures include the following:

Figure F-3A: Tabular Summary of Shrimp and Crab Edible Tissues, and Fish Fillet Sample Counts by Year for All Zones

Each of the figures listed below provides the comparison of fish and crab tissue data for multiple fish species for the two years with the most data for Zone H, the LCP Site estuary, as follows:

- Figure F-3B: Mercury
- Figure F-3C: Aroclor 1268

Each of the figures below provides the comparison of fish and crab tissue data for all years by location, focused on Zone H (with all locations illustrated for the 2011 sampling event) as follows:

- Figure F-3D: Mercury in Blue Crab
- Figure F-3E: Aroclor 1268 in Blue Crab
- Figure F-3F: Mercury in Atlantic Croaker
- Figure F-3G: Aroclor 1268 in Atlantic Croaker
- Figure F-3H: Mercury in Black Drum
- Figure F-3I: Aroclor 1268 in Black Drum
- Figure F-3J: Mercury in Red Drum
- Figure F-3K: Aroclor 1268 in Red Drum
- Figure F-3L: Mercury in Sheepshead
- Figure F-3M: Aroclor 1268 in Sheepshead

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- Figure F-3N: Mercury in Southern Flounder
- Figure F-3O: Aroclor 1268 in Southern Flounder
- Figure F-3P: Mercury in Southern Kingfish
- Figure F-3Q: Aroclor 1268 in Southern Kingfish
- Figure F-3R: Mercury in Spot
- Figure F-3S: Aroclor 1268 in Spot
- Figure F-3T: Mercury in Spotted Seatrout
- Figure F-3U: Aroclor 1268 in Spotted Seatrout
- Figure F-3V: Mercury in Striped Mullet
- Figure F-3W: Aroclor 1268 in Striped Mullet

Species Collected	Fillet Count Per Year						Grand Total
	1995	2002	2004	2005	2006	2011	
Atlantic Croaker	0	19	0	1	3	1	24
Black Drum	0	29	10	9	0	24	72
Blue Crab	14	27	14	9	0	27	91
Brown Shrimp	17	0	0	0	0	0	17
Flounder	0	0	0	2	0	0	2
Red Drum	0	15	8	1	0	23	47
Sheepshead	0	25	0	1	0	13	39
Silver Perch	0	0	14	0	0	0	14
Southern Flounder	0	27	0	0	0	12	39
Southern Kingfish	0	25	0	3	1	28	57
Spot	14	27	0	0	0	17	58
Spotted Seatrout	0	28	12	9	0	32	81
Striped Mullet	0	28	8	9	0	27	72
White Shrimp	0	27	0	0	0	27	54

Notes:
(a) Fish counts are for all zones (Zone A to Zone I).
(b) 2002 and 2011 (highlighted in yellow) have the largest sample counts and allow the most robust comparison over time.

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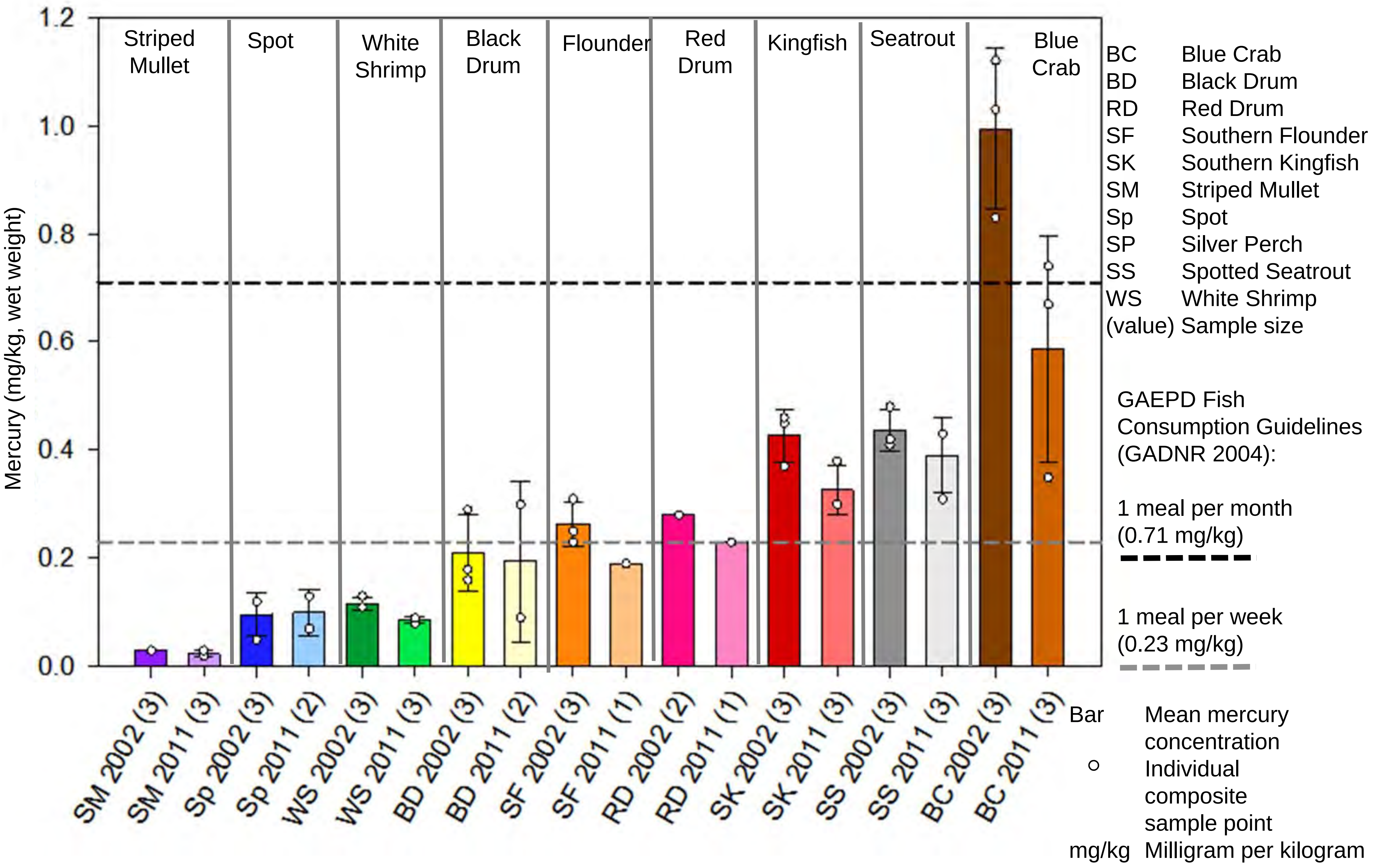
Tabular Summary of Shrimp and Crab Edible Tissues and Fish Fillet Sample Counts by Year For All Zones

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure
F-3A



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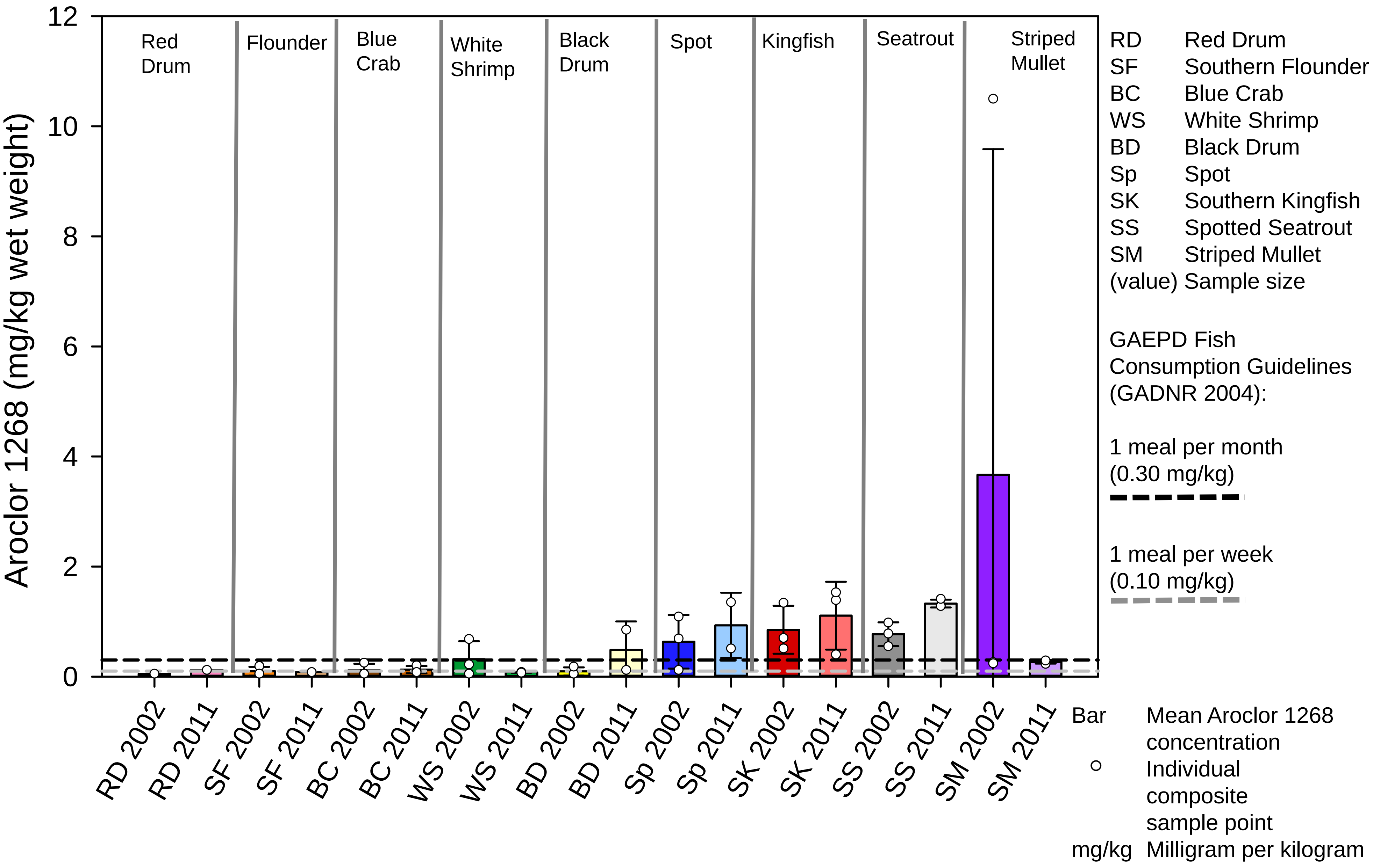
Comparison of Mercury in Shrimp, Crab, and Fish Fillet Tissue for the Two Years with the Most Data for Zone H (2002 vs. 2011, wet weight)

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure F-3B



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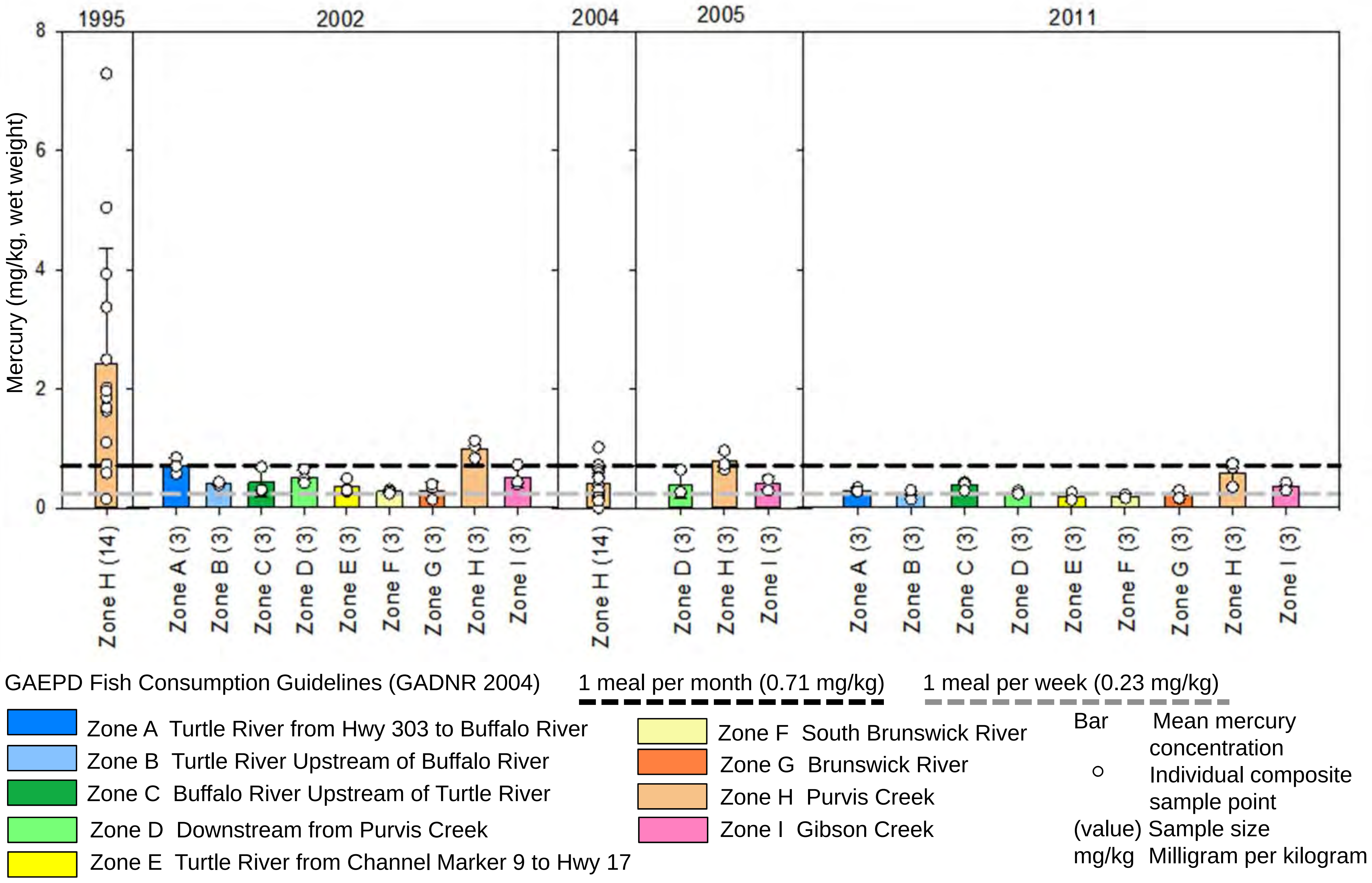
Comparison of Aroclor 1268 in Fillet Tissue for the Two Years with the Most Data for Zone H (2002 vs. 2011, wet weight)

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3C



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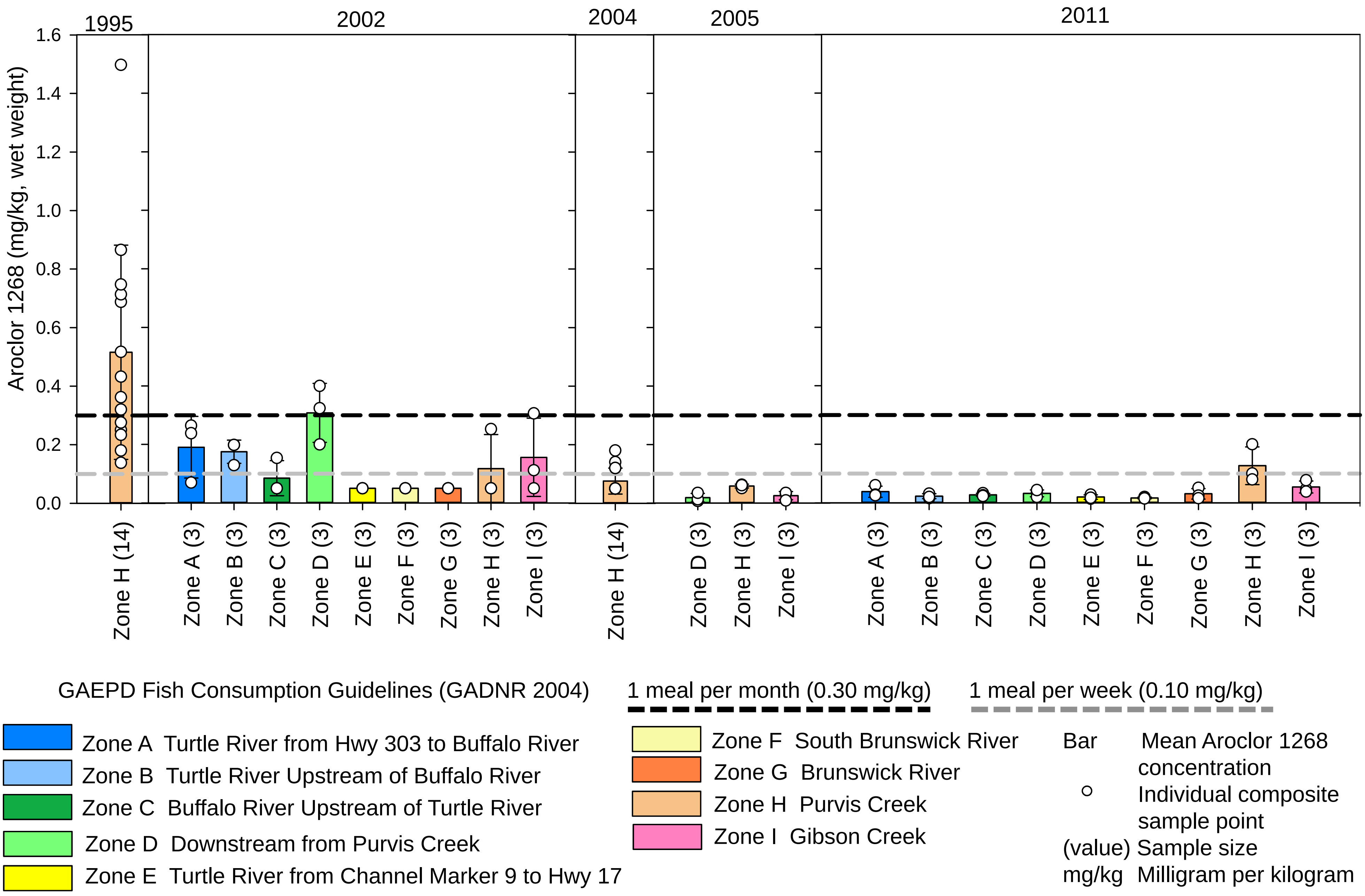
Comparison of Mercury Fillet Tissue Data for All Years By Location (Wet Weight) for Blue Crab

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3D



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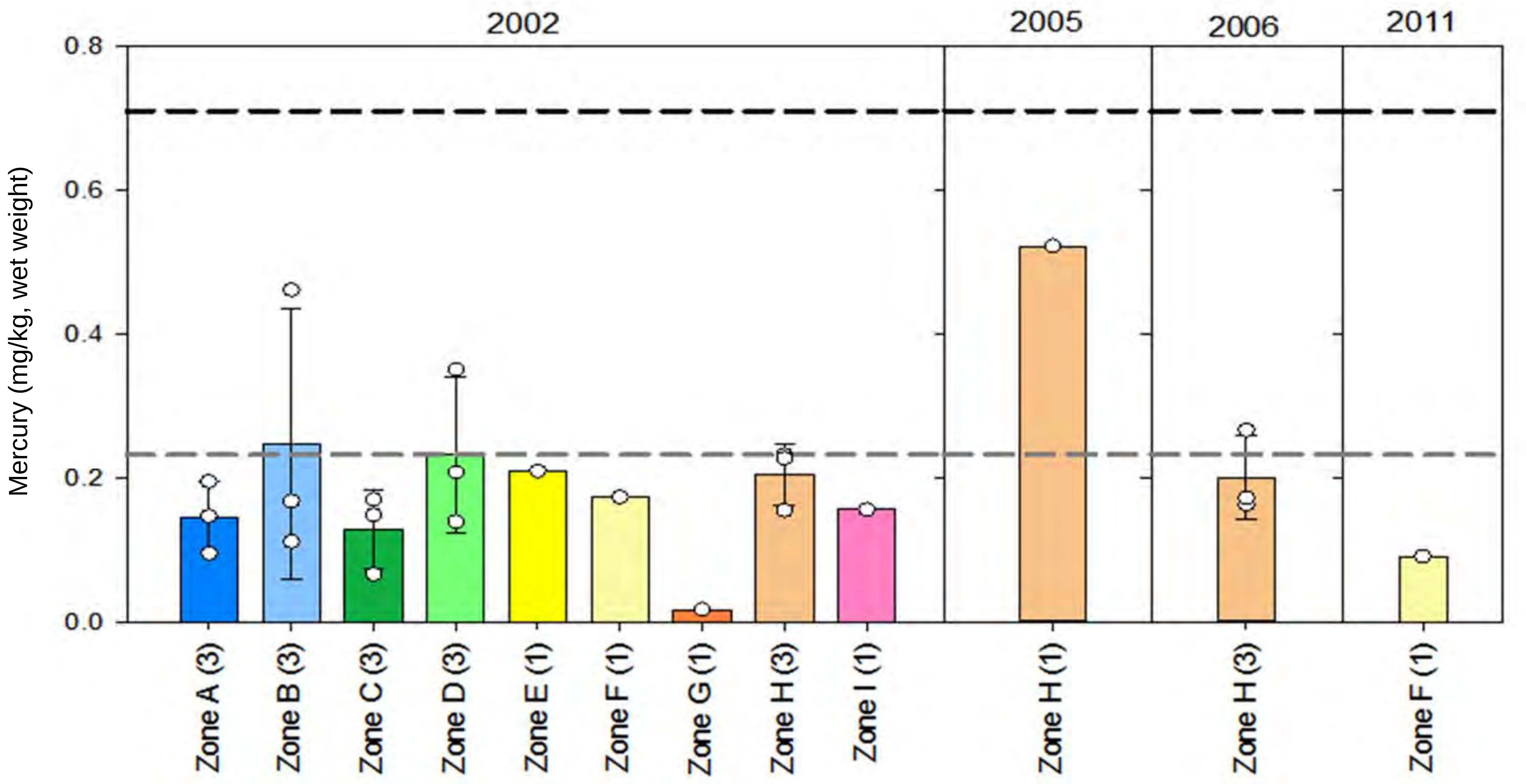
Blue Crab Aroclor 1268 (Edible Tissue, Wet Weight)
All Zones Over Time

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3E



GAEPD Fish Consumption Guidelines (GADNR 2004)

1 meal per month (0.71 mg/kg) ▬ ▬ ▬

1 meal per week (0.23 mg/kg) ▬ ▬ ▬

🟦 Zone A Turtle River from Hwy 303 to Buffalo River
🟦 Zone B Turtle River Upstream of Buffalo River
🟩 Zone C Buffalo River Upstream of Turtle River
🟩 Zone D Downstream from Purvis Creek
🟨 Zone E Turtle River from Channel Marker 9 to Hwy 17
🟨 Zone F South Brunswick River
🟧 Zone G Brunswick River
🟧 Zone H Purvis Creek
🟥 Zone I Gibson Creek

Bar	Mean mercury concentration
○	Individual composite sample point
(value)	Sample size
mg/kg	Milligram per kilogram

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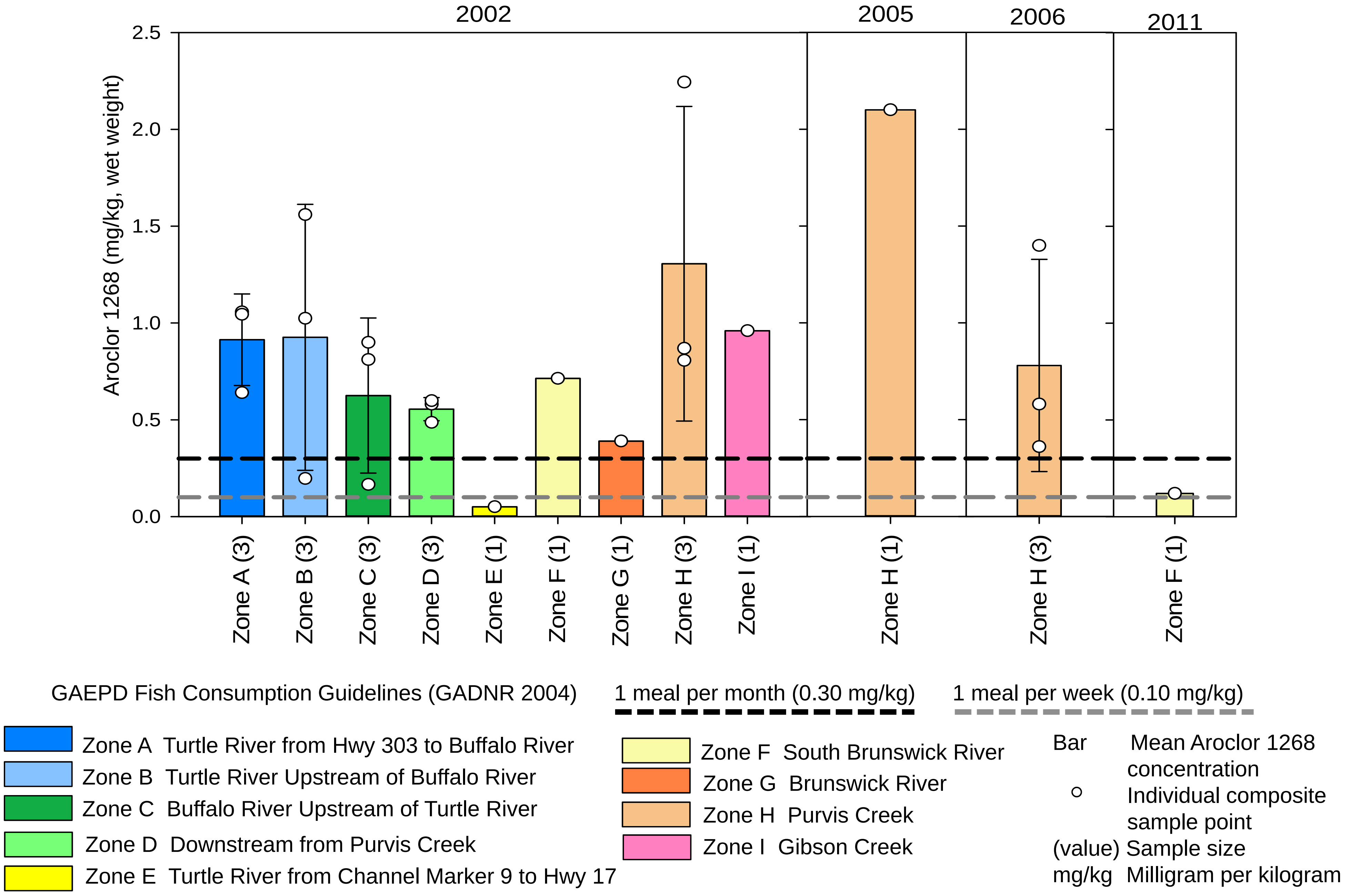
Comparison of Mercury Fillet Tissue Data for All Years by Location (Wet Weight) for Atlantic Croaker

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3F



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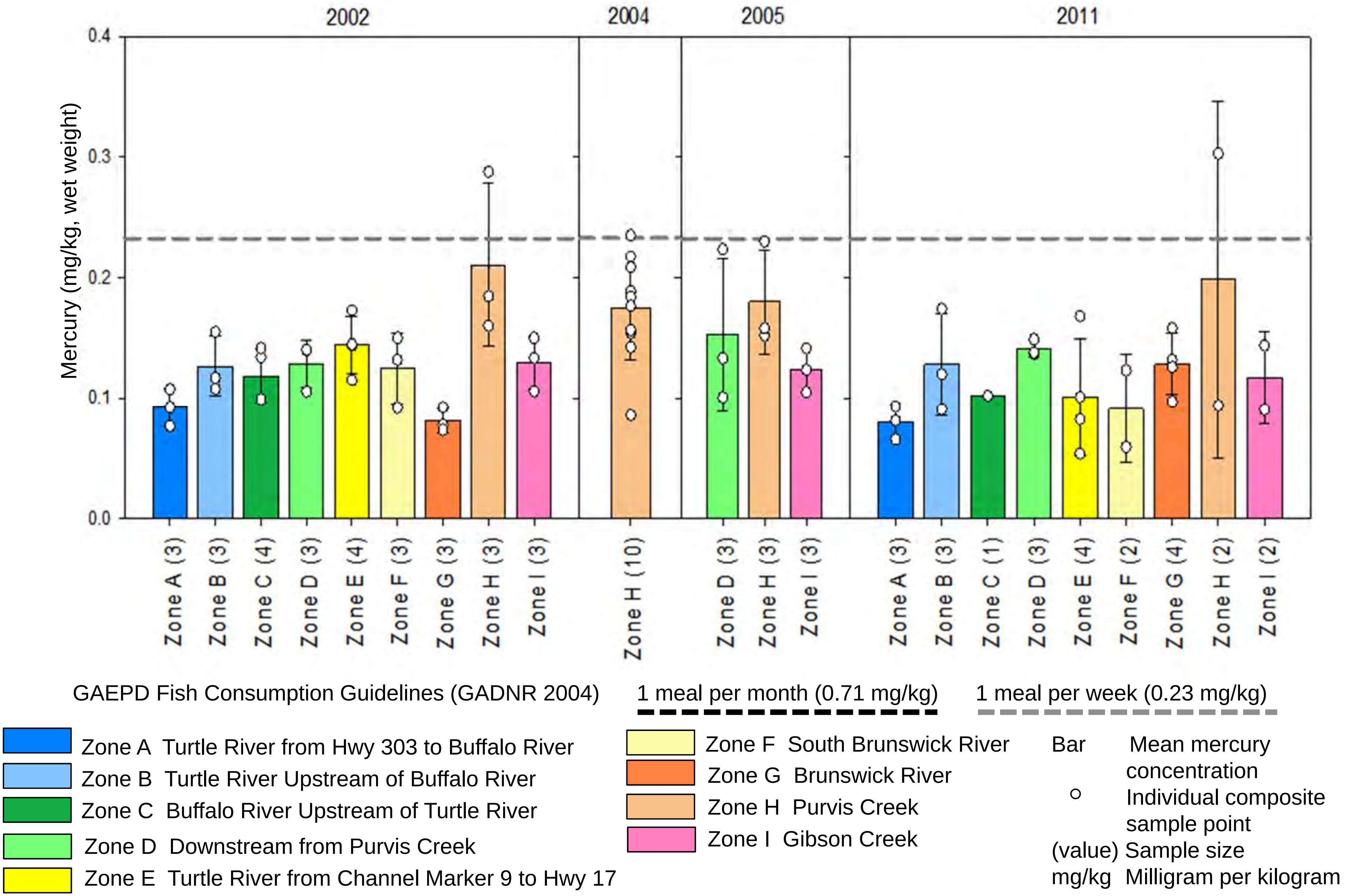
Comparison of Aroclor 1268 Fillet Tissue Data for All Years by Location (Wet Weight) for Atlantic Croaker

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3G



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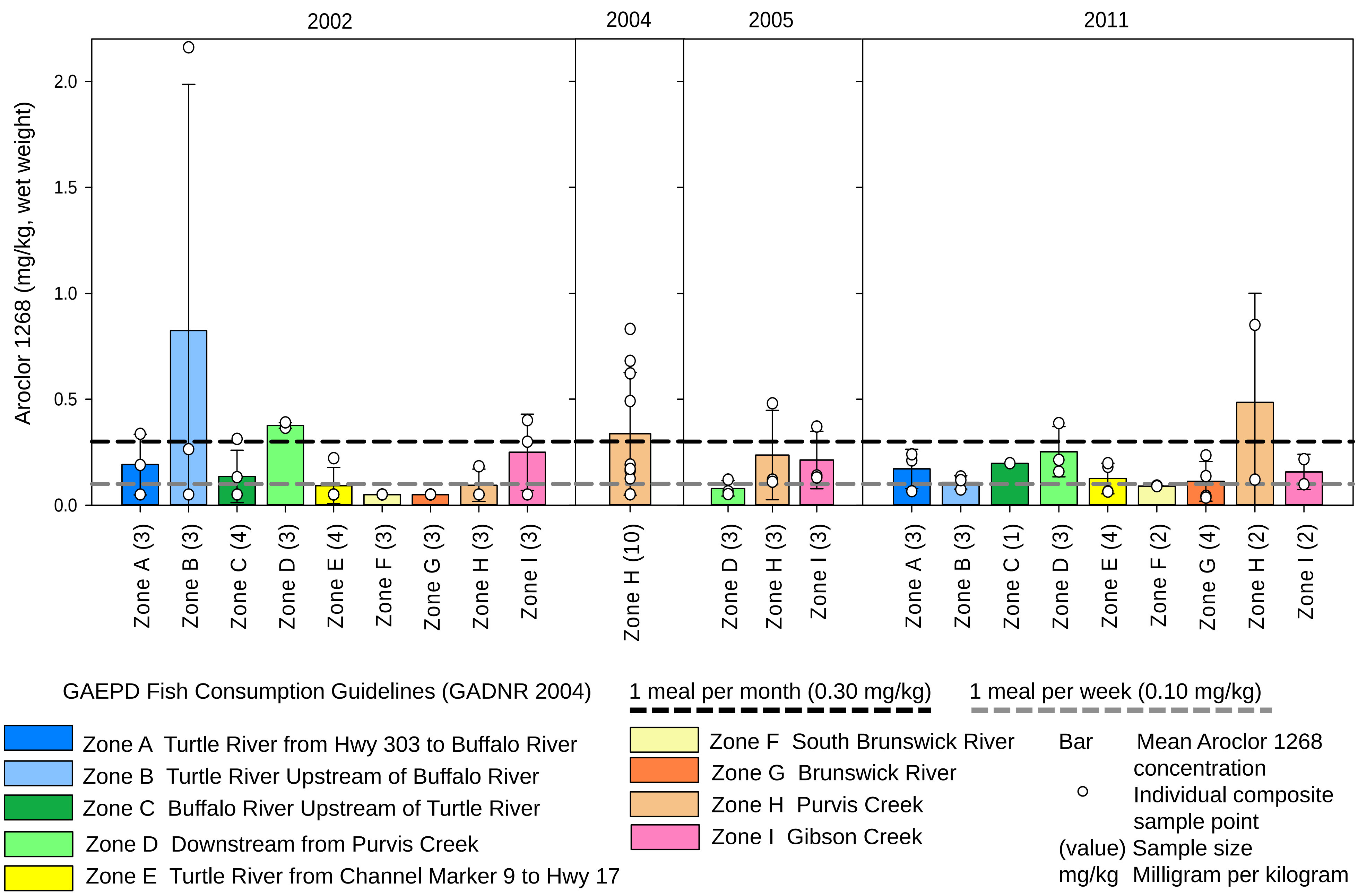
Comparison of Mercury Fillet Tissue Data for All Years by Location (Wet Weight) for Black Drum

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3H



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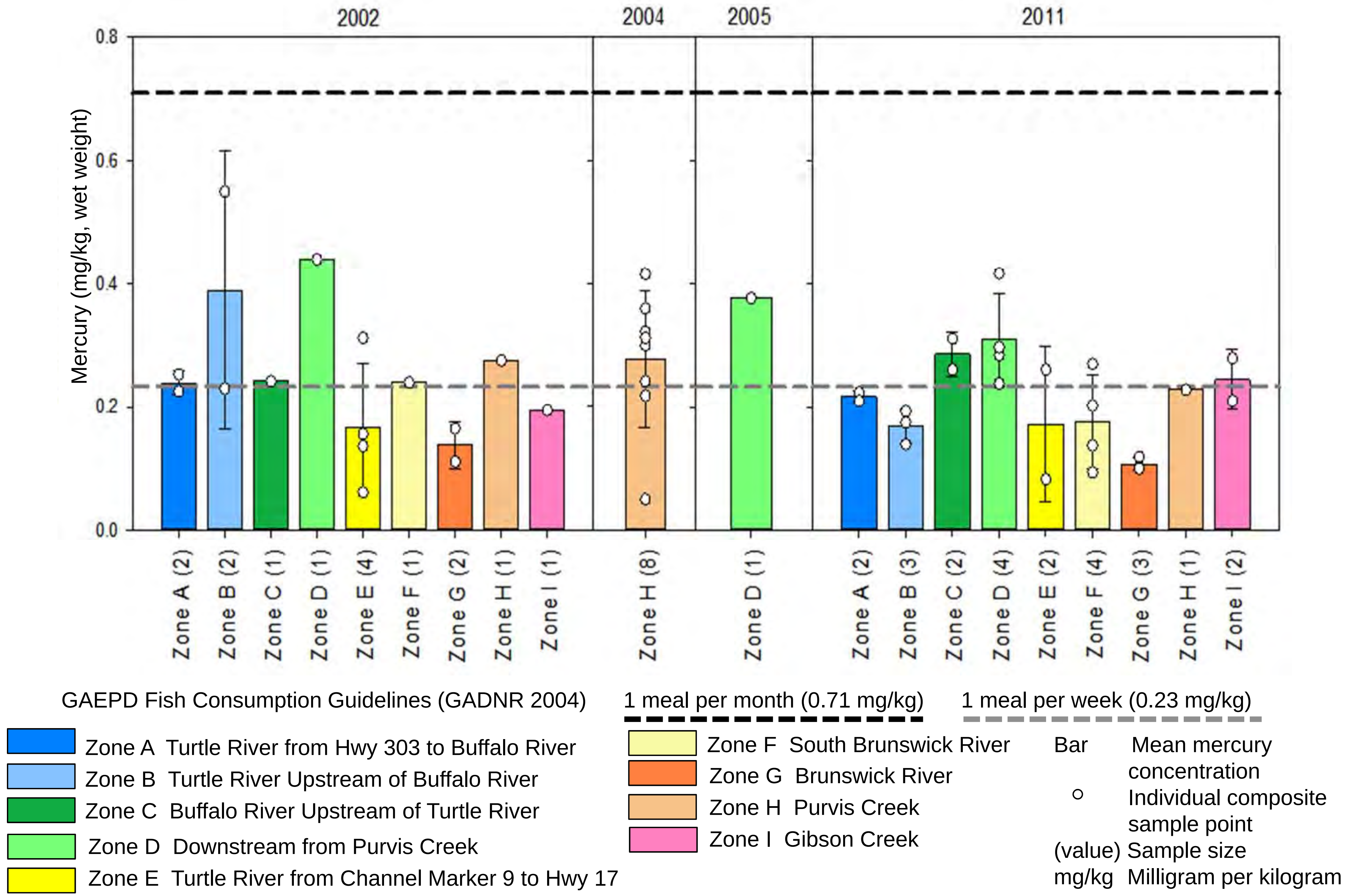
Comparison of Aroclor 1268 Fillet Tissue Data for All Years by Location (Wet Weight) for Black Drum

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3I



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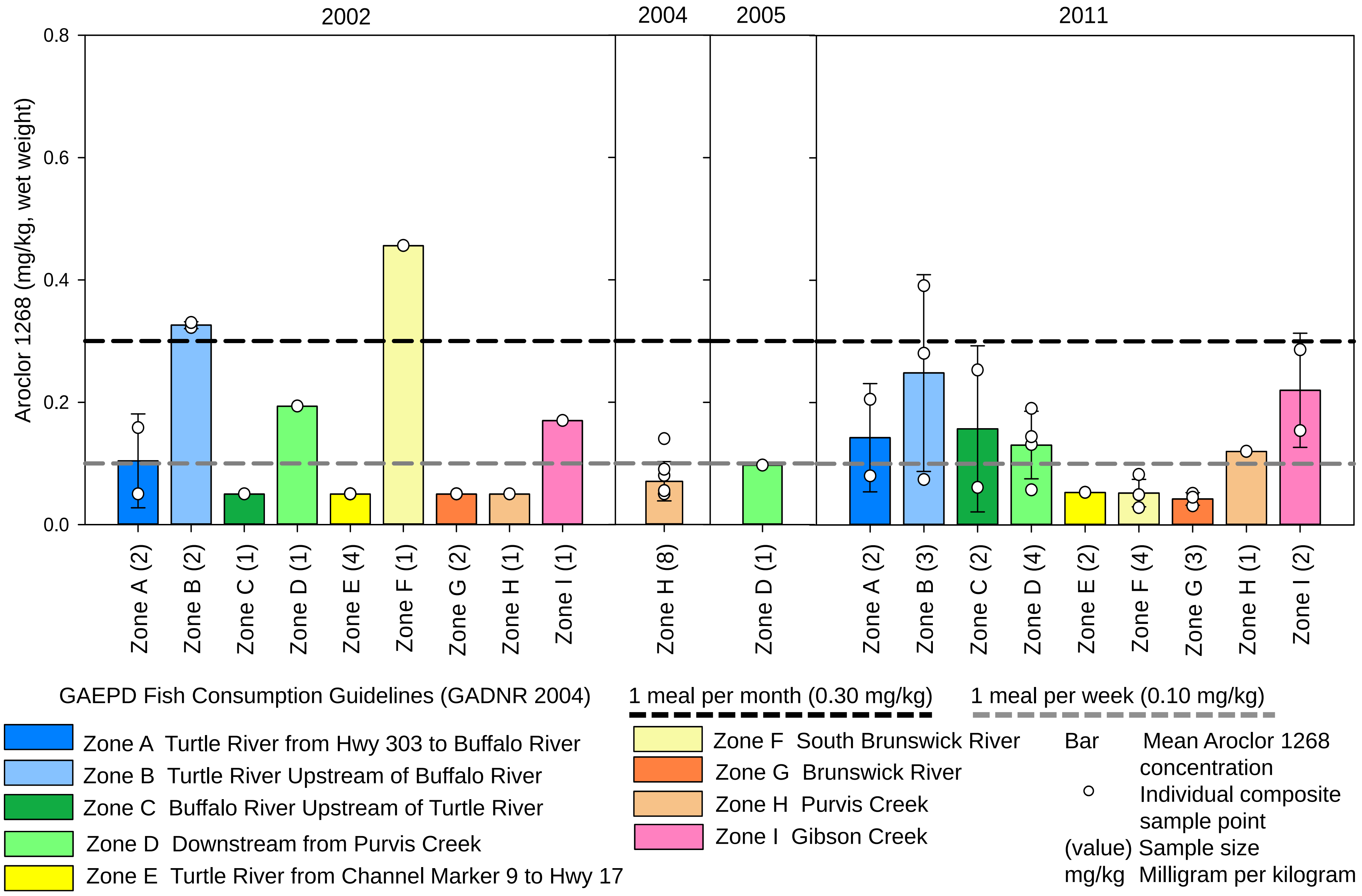
Comparison of Mercury Fillet Tissue Data for All Years by Location (Wet Weight) for Red Drum

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3J

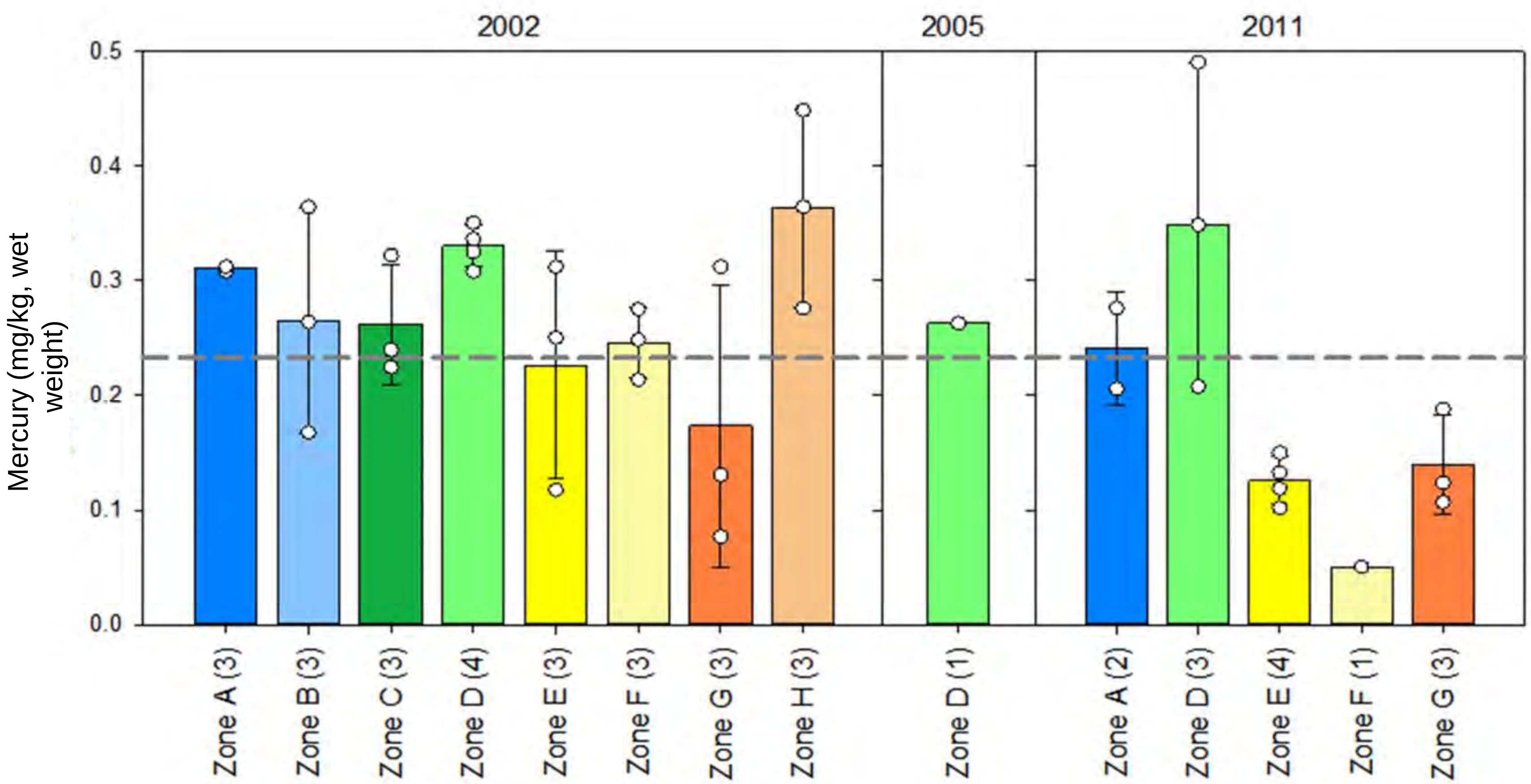


Comparison of Aroclor 1268 Fillet Tissue Data for All Years by Location (Wet Weight) for Red Drum

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3K



GAEPD Fish Consumption Guidelines (GADNR 2004)

1 meal per month (0.71 mg/kg) ▬ ▬ ▬ ▬ ▬

1 meal per week (0.23 mg/kg) ▬ ▬ ▬ ▬ ▬

- 🟦 Zone A Turtle River from Hwy 303 to Buffalo River
- 🟦 Zone B Turtle River Upstream of Buffalo River
- 🟩 Zone C Buffalo River Upstream of Turtle River
- 🟩 Zone D Downstream from Purvis Creek
- 🟨 Zone E Turtle River from Channel Marker 9 to Hwy 17
- 🟨 Zone F South Brunswick River
- 🟧 Zone G Brunswick River
- 🟧 Zone H Purvis Creek

Bar	Mean mercury concentration
○	Individual composite sample point
(value)	Sample size
mg/kg	Milligram per kilogram

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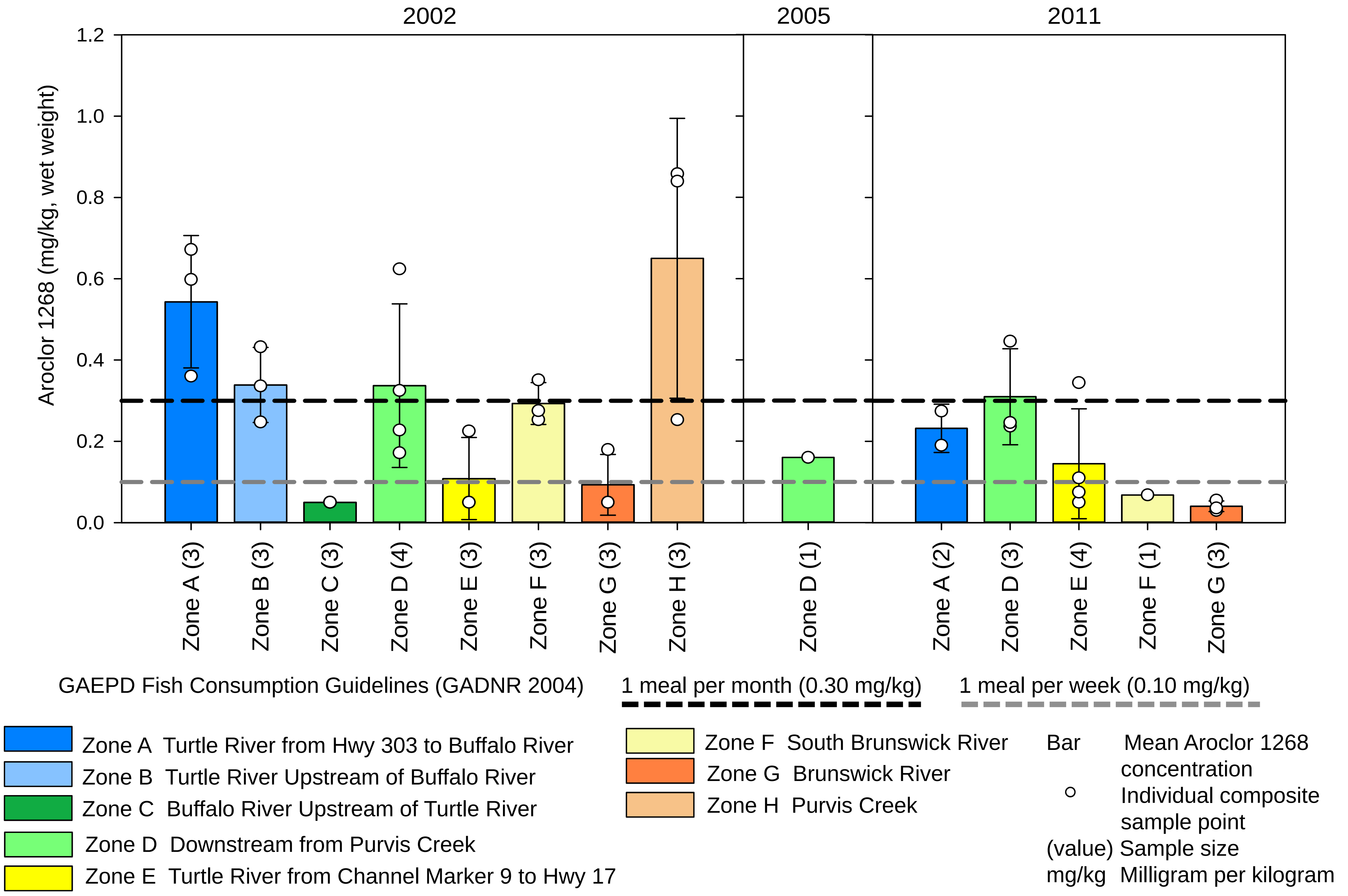
Comparison of Mercury Fillet Tissue Data for All Years by Location (Wet Weight) for Sheepshead

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3L



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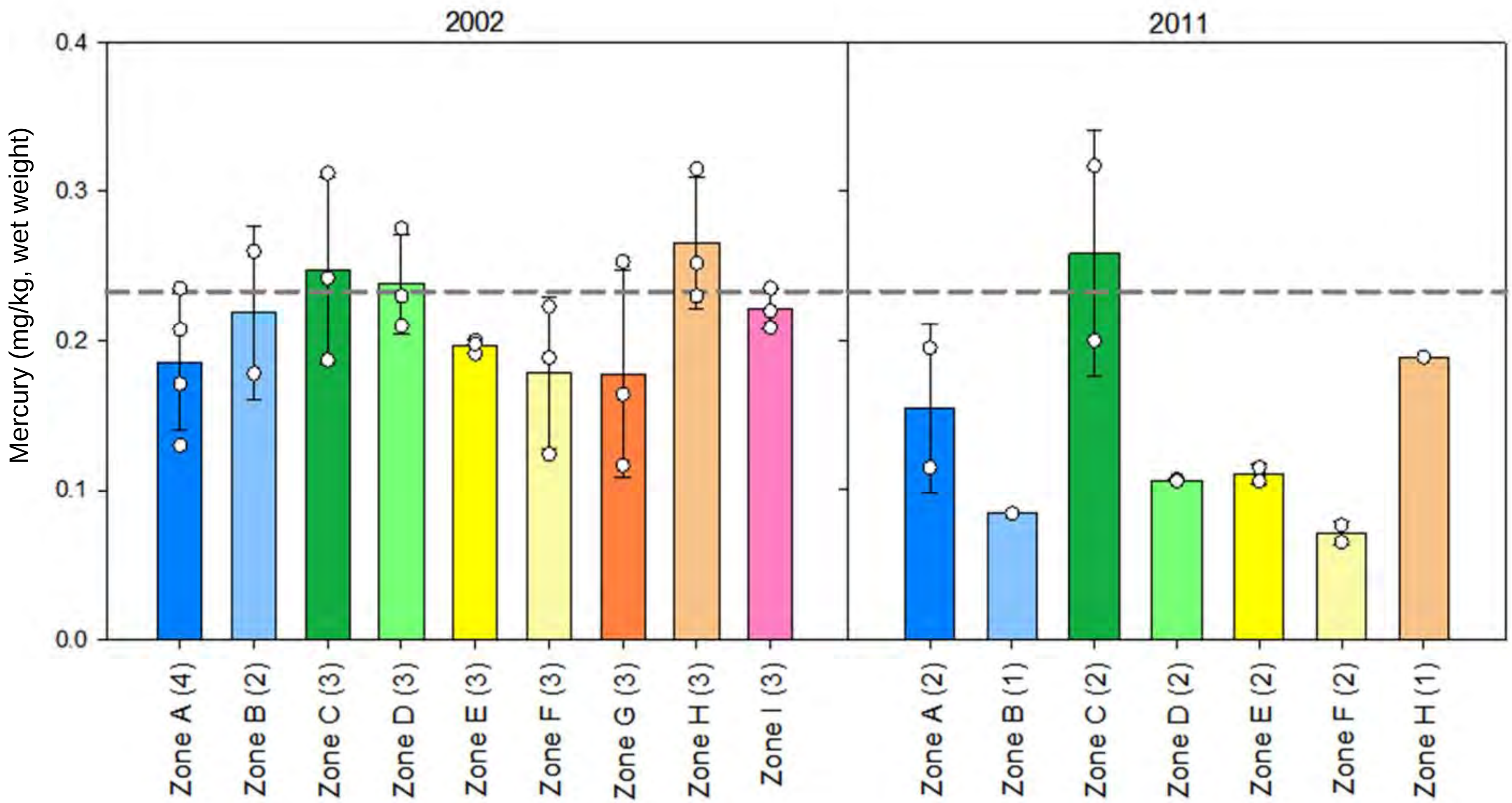
Comparison of Aroclor 1268 Fillet Tissue Data for All Years by Location (Wet Weight) for Sheepshead

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3M



GAEPD Fish Consumption Guidelines (GADNR 2004) 1 meal per month (0.71 mg/kg) 1 meal per week (0.23 mg/kg)

🟦 Zone A Turtle River from Hwy 303 to Buffalo River
🟦 Zone B Turtle River Upstream of Buffalo River
🟩 Zone C Buffalo River Upstream of Turtle River
🟩 Zone D Downstream from Purvis Creek
🟨 Zone E Turtle River from Channel Marker 9 to Hwy 17
🟨 Zone F South Brunswick River
🟧 Zone G Brunswick River
🟧 Zone H Purvis Creek
🟪 Zone I Gibson Creek

Bar Mean mercury concentration
○ Individual composite sample point
(value) Sample size
mg/kg Milligram per kilogram

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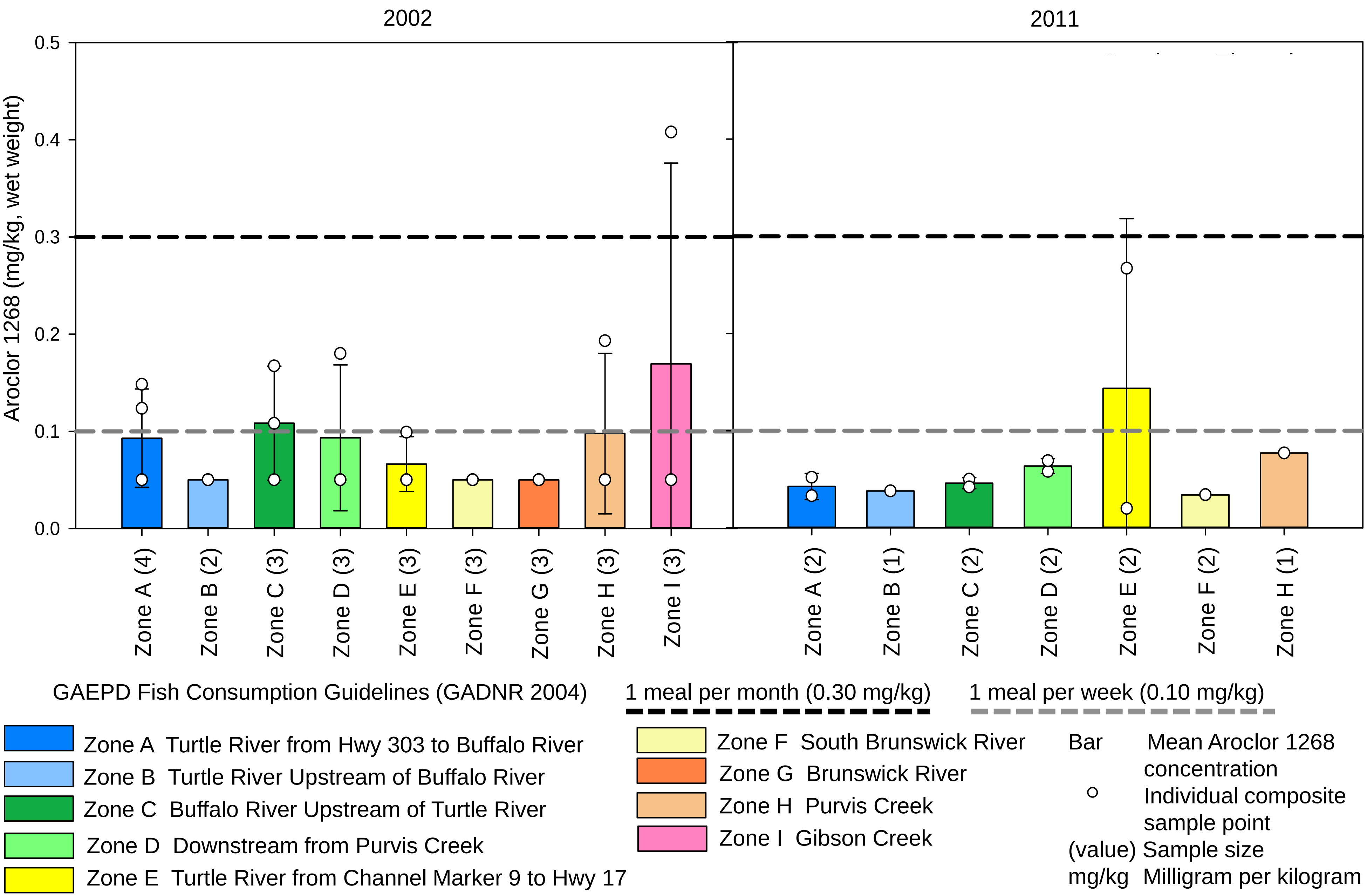
Comparison of Mercury Fillet Tissue Data for All Years by Location (Wet Weight) for Southern Flounder

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3N

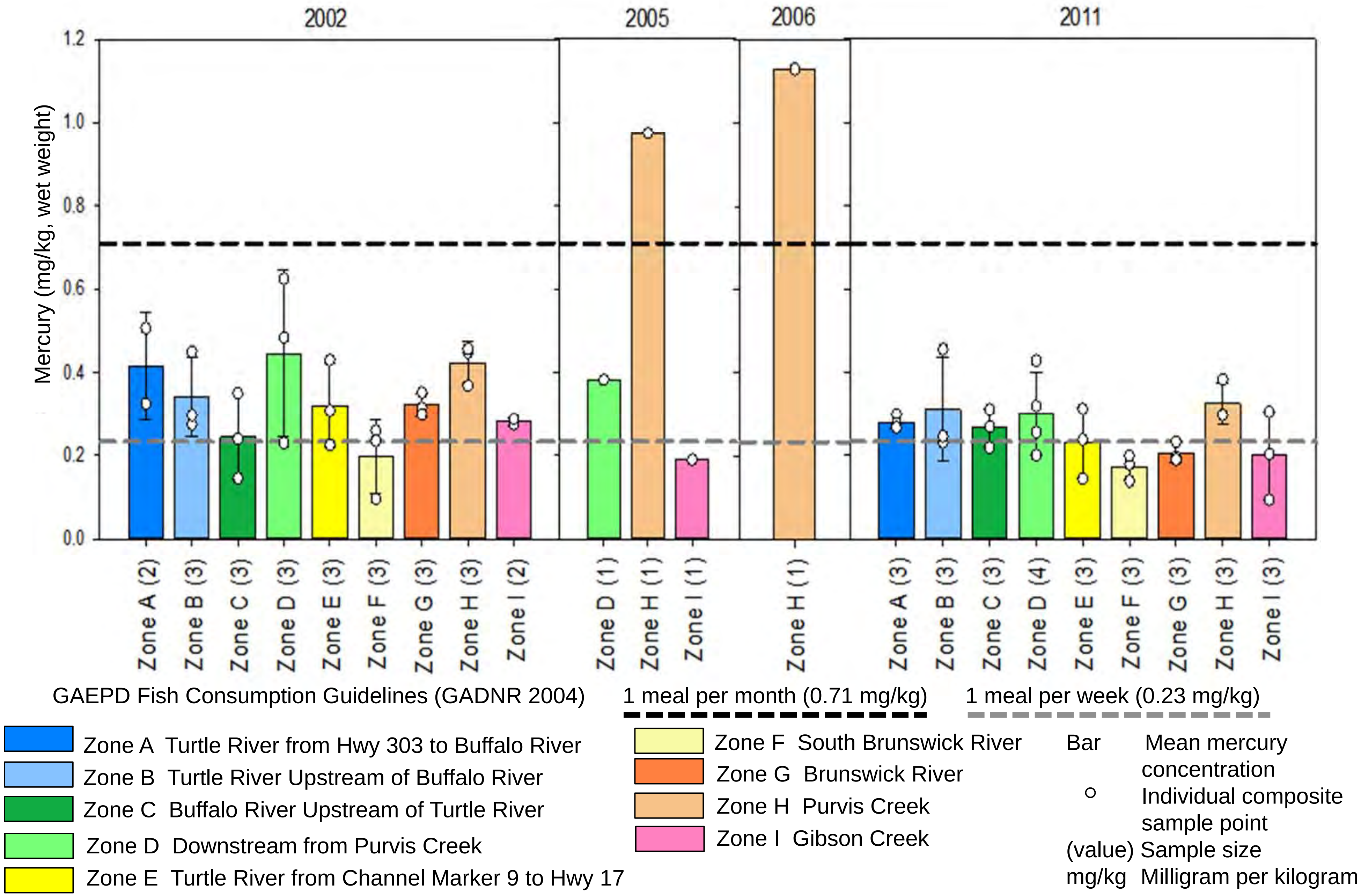


Comparison of Aroclor 1268 Fillet Tissue Data for All Years by Location (Wet Weight) for Southern Flounder

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3O



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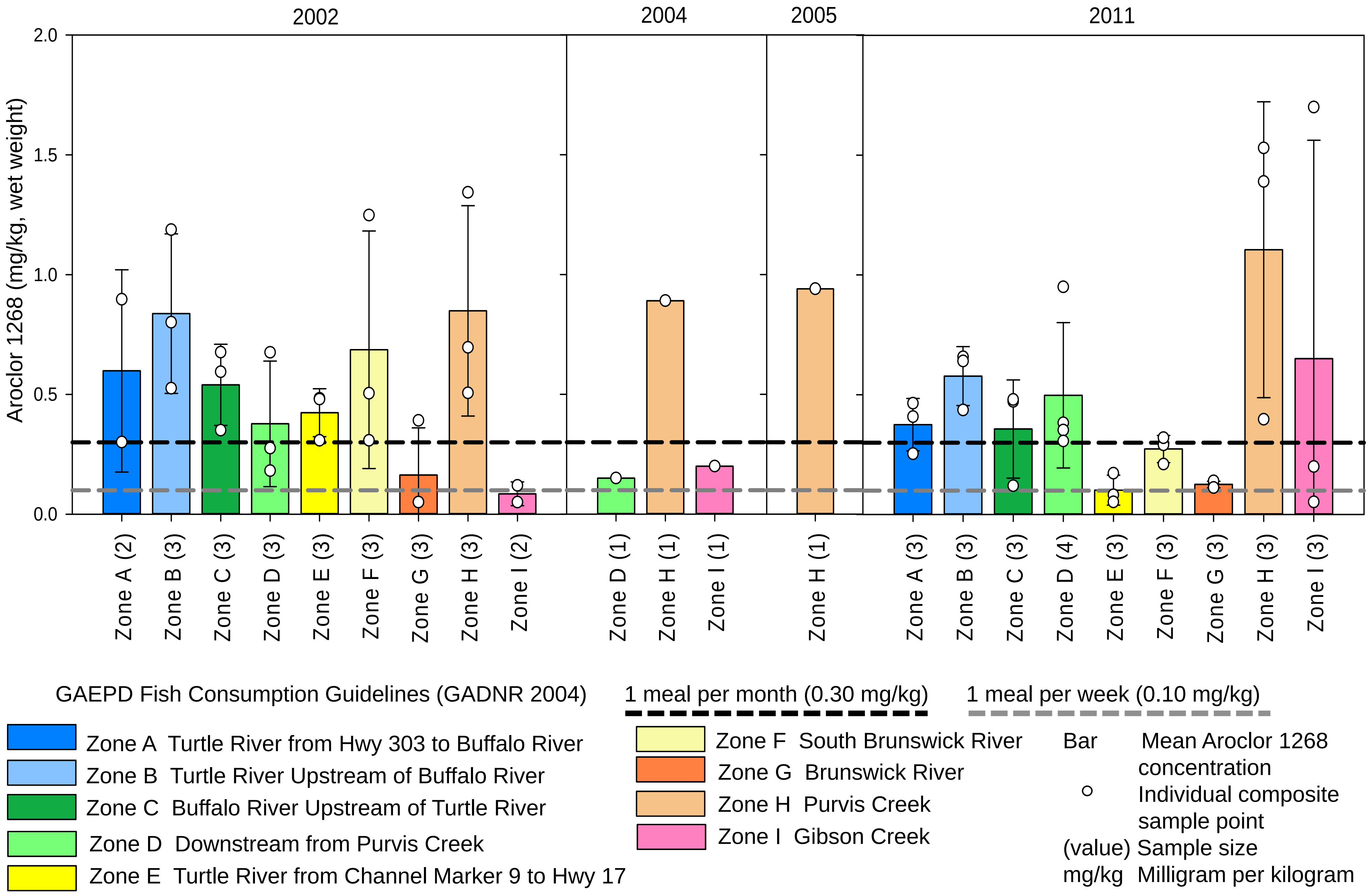
Comparison of Mercury Fillet Tissue Data for All Years by Location (Wet Weight) for Southern Kingfish

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3P



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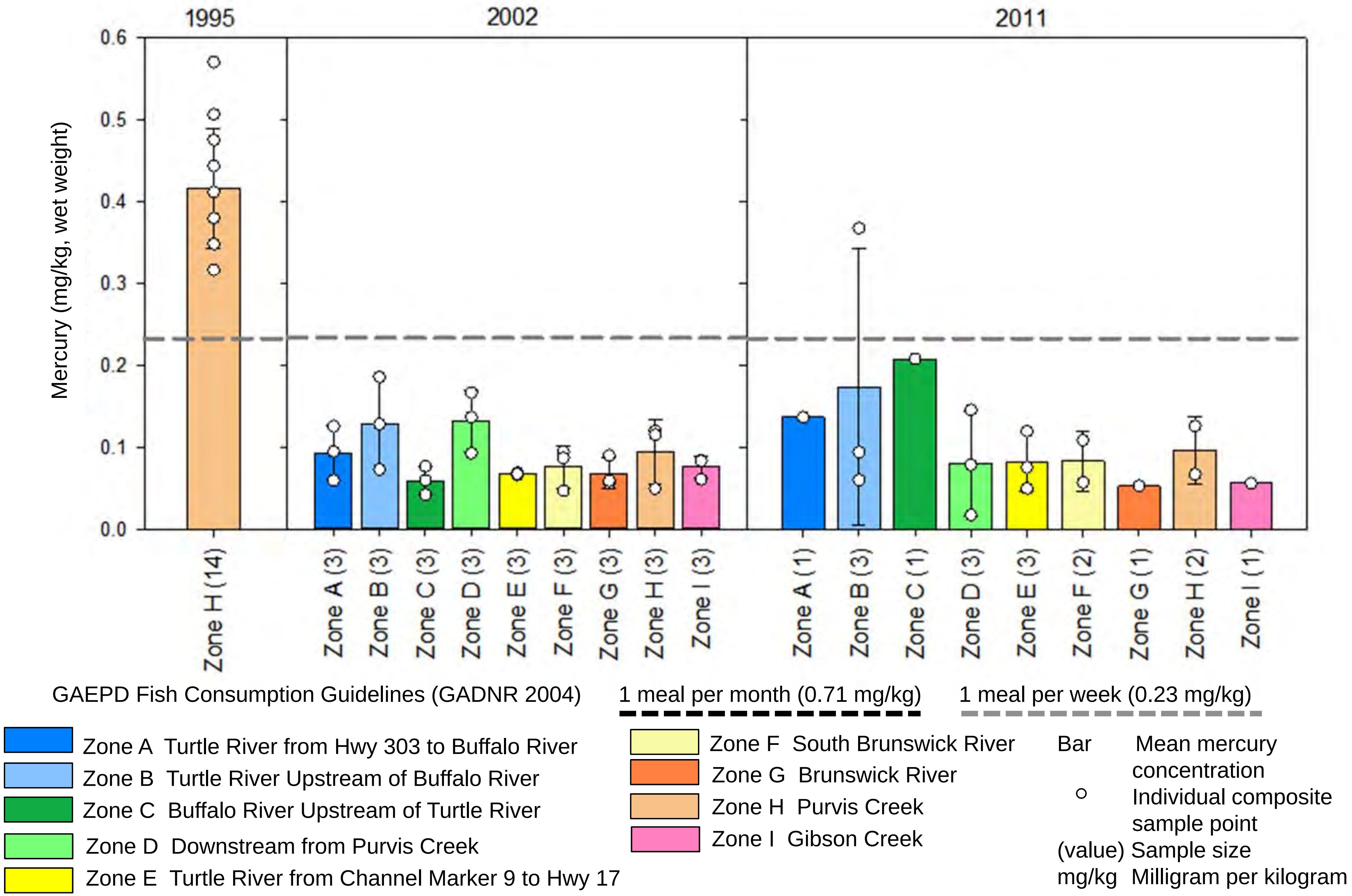
Comparison of Aroclor 1268 Fillet Tissue Data for All Years by Location (Wet Weight) for Southern Kingfish

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3Q



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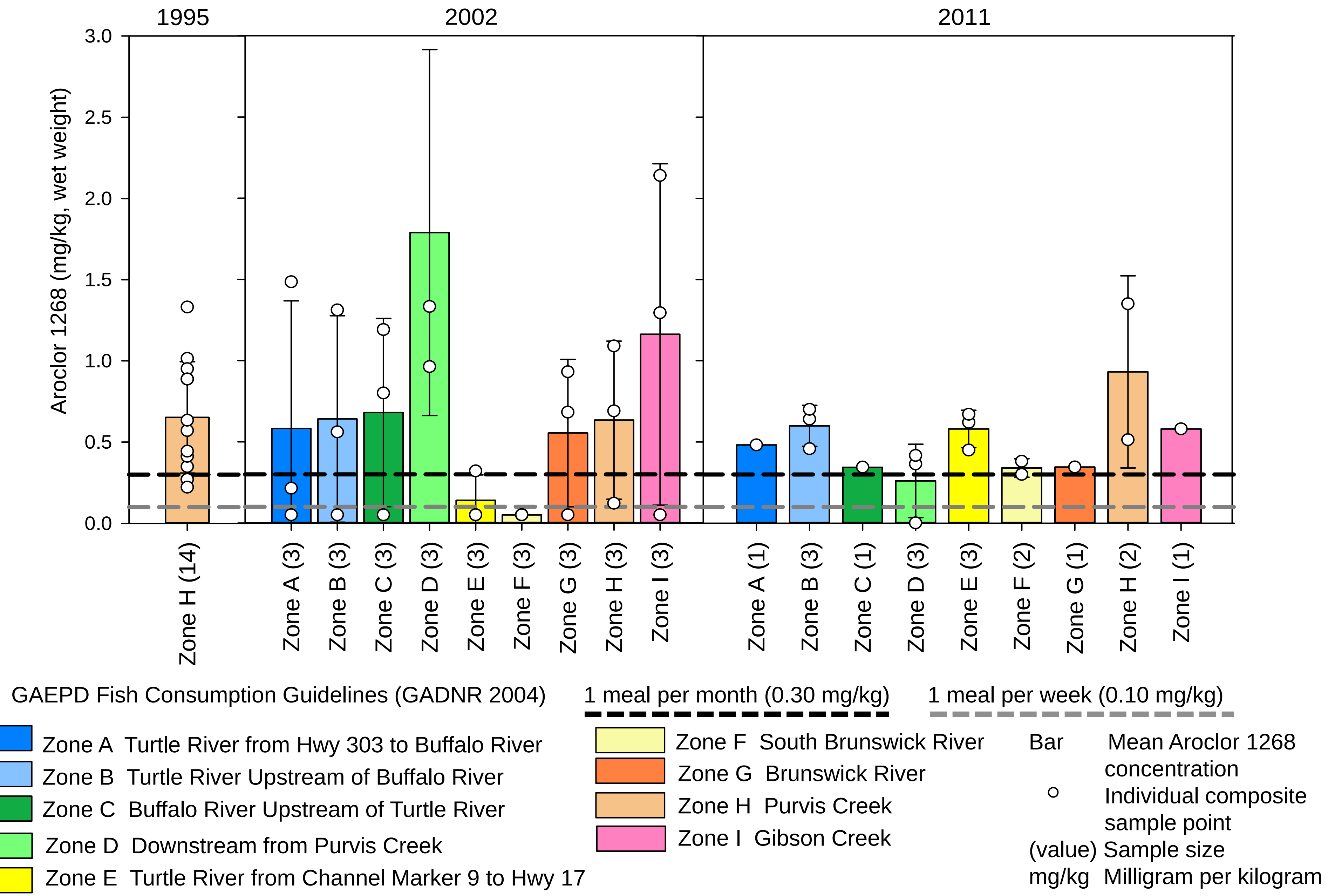
Comparison of Mercury Fillet Tissue Data for All Years by Location (Wet Weight) for Spot

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3R



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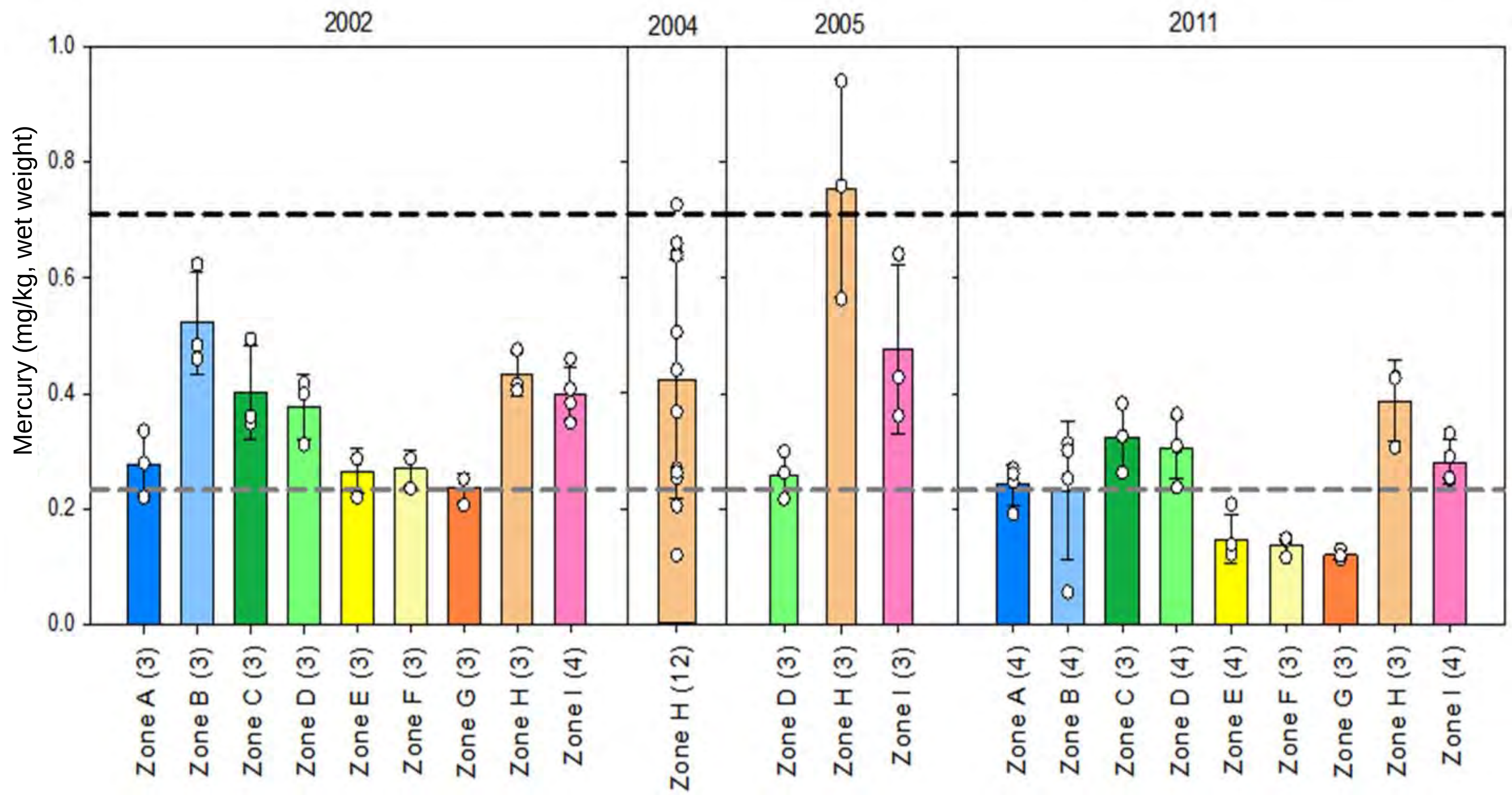
Comparison of Aroclor 1268 Fillet Tissue Data for All Years by Location (Wet Weight) for Spot

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3S



GAEPD Fish Consumption Guidelines (GADNR 2004)

1 meal per month (0.71 mg/kg)

1 meal per week (0.23 mg/kg)

- 🟦 Zone A Turtle River from Hwy 303 to Buffalo River
- 🟦 Zone B Turtle River Upstream of Buffalo River
- 🟩 Zone C Buffalo River Upstream of Turtle River
- 🟩 Zone D Downstream from Purvis Creek
- 🟨 Zone E Turtle River from Channel Marker 9 to Hwy 17
- 🟨 Zone F South Brunswick River
- 🟧 Zone G Brunswick River
- 🟧 Zone H Purvis Creek
- 🟪 Zone I Gibson Creek

Bar	Mean mercury concentration
○	Individual composite sample point
(value)	Sample size
mg/kg	Milligram per kilogram

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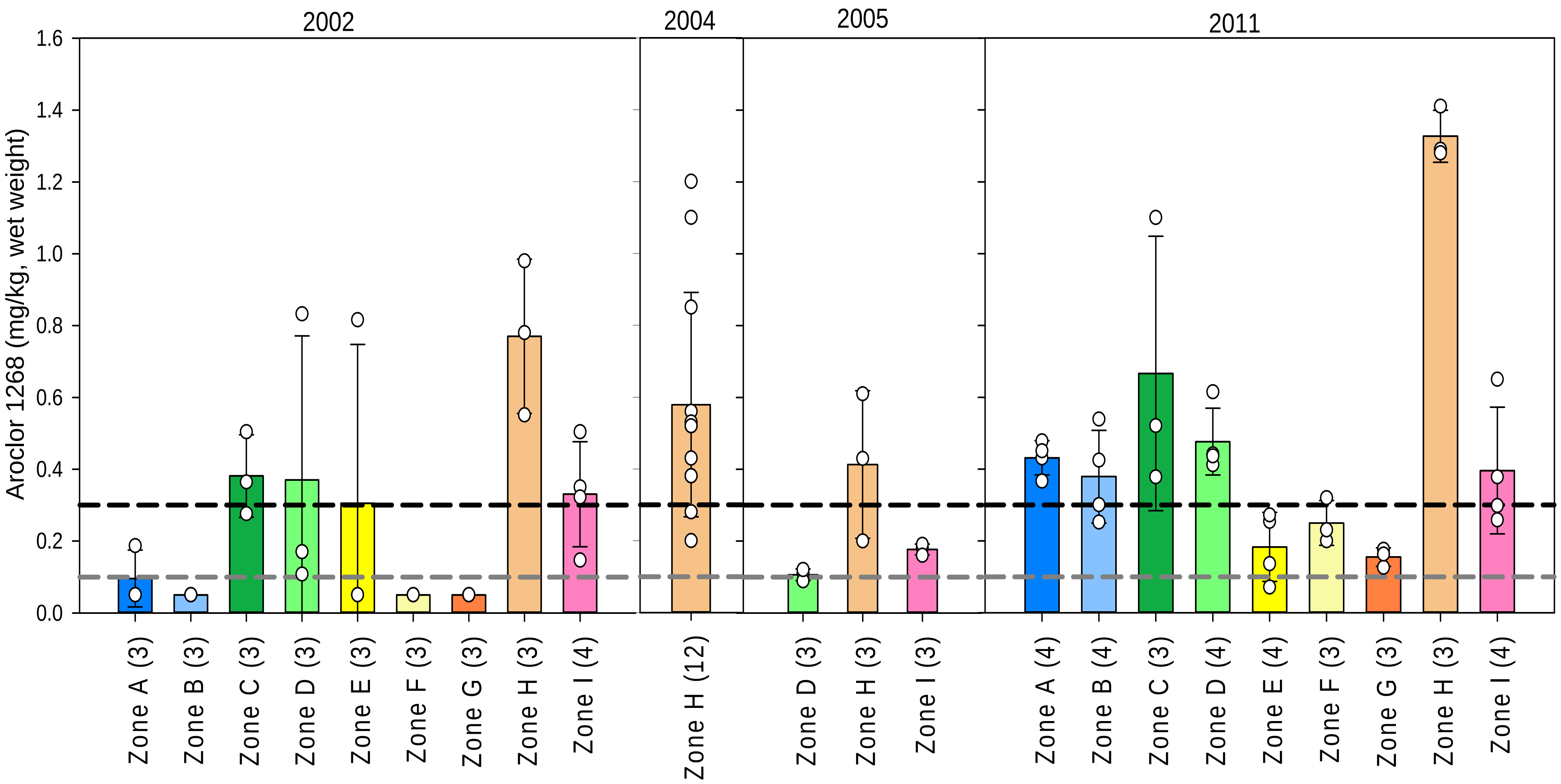
Comparison of Mercury Fillet Tissue Data for All Years by Location (Wet Weight) for Spotted Seatrout

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3T



GAEPD Fish Consumption Guidelines (GADNR 2004)   1 meal per month (0.30 mg/kg)   1 meal per week (0.10 mg/kg)

■ Zone A Turtle River from Hwy 303 to Buffalo River
■ Zone B Turtle River Upstream of Buffalo River
■ Zone C Buffalo River Upstream of Turtle River
■ Zone D Downstream from Purvis Creek
■ Zone E Turtle River from Channel Marker 9 to Hwy 17
■ Zone F South Brunswick River
■ Zone G Brunswick River
■ Zone H Purvis Creek
■ Zone I Gibson Creek

Bar	Mean Aroclor 1268 concentration
○	Individual composite sample point
(value)	Sample size
mg/kg	Milligram per kilogram

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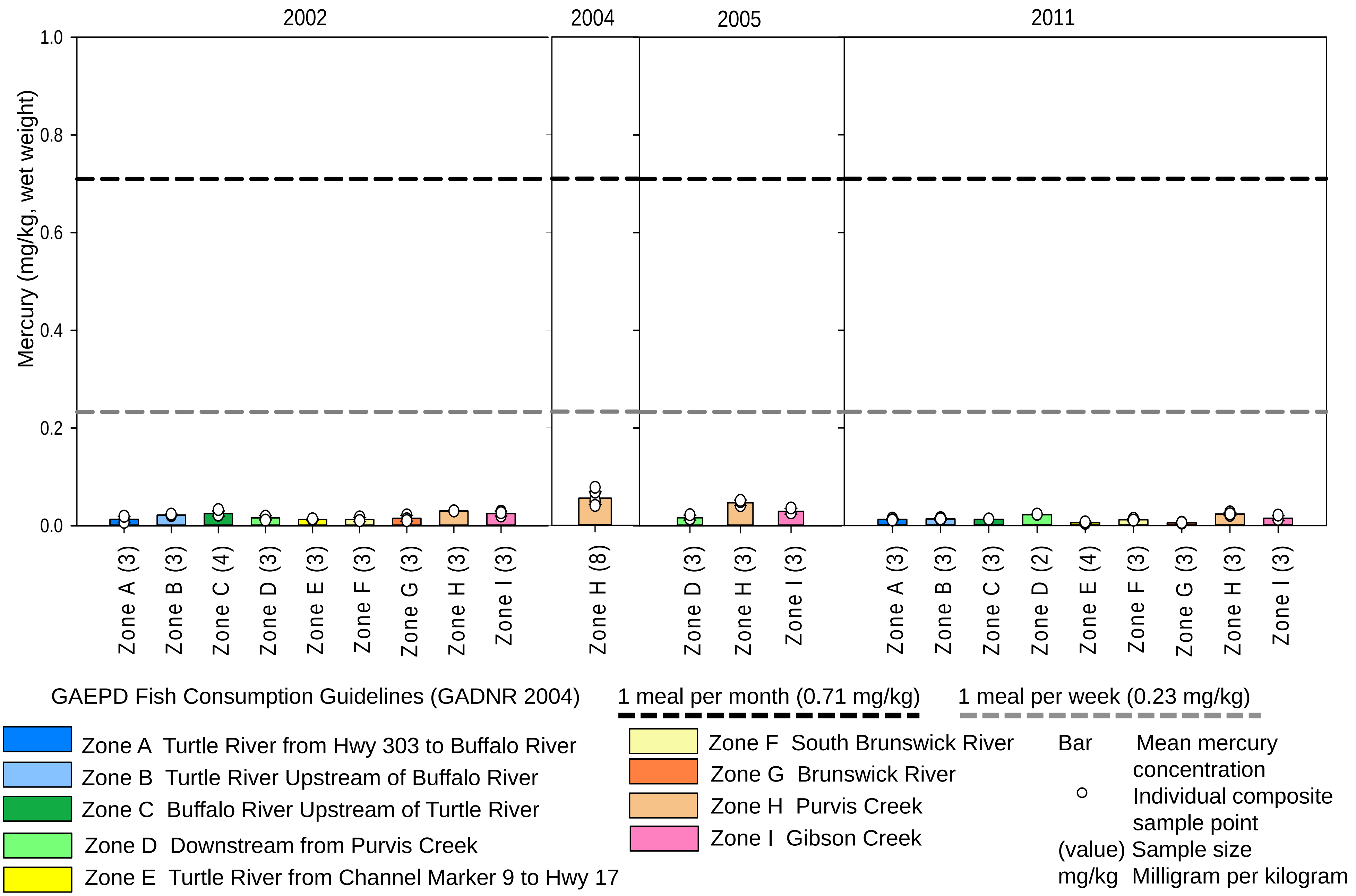
Comparison of Aroclor 1268 Fillet Tissue Data for All Years by Location (Wet Weight) for Spotted Seatrout

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3U



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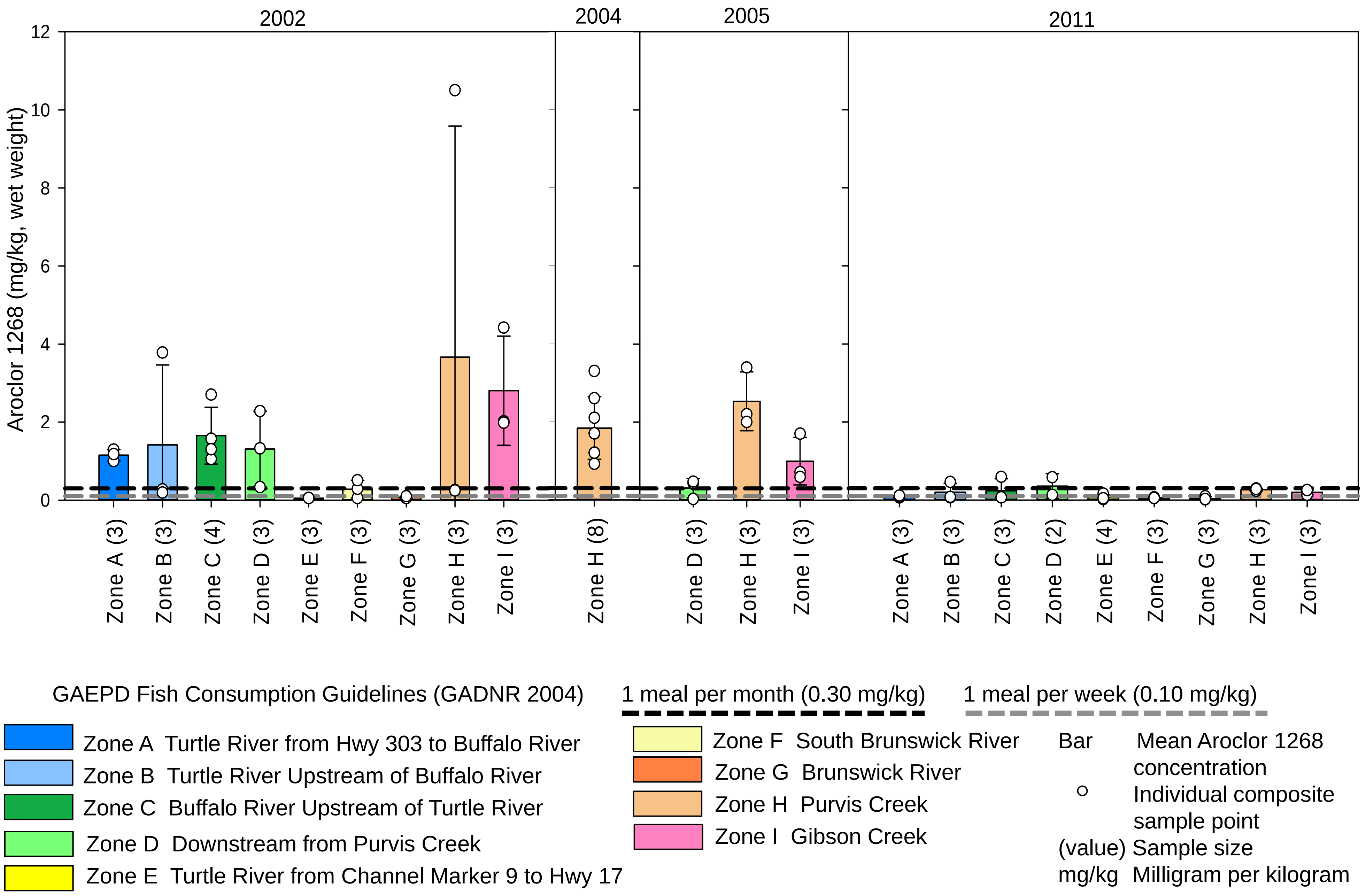
Comparison of Mercury Fillet Tissue Data for All Years by Location (Wet Weight) for Striped Mullet

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3V



Comparison of Aroclor 1268 Fillet Tissue Data for All Years by Location (Wet Weight) for Striped Mullet

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-3W

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Section F-4 Contents: Available Fish and Shellfish Data (Whole-Body Tissues, Wet Weight)

This section presents a tabular and graphical presentation of available whole-body tissue data from fish and shellfish collected in the TRBE from 1995 to 2011. In addition, this section provides a graphical summary of all locations sampled in the 2011 fish collection effort. Note that Section 6 and Appendix M of the FS provide additional considerations related to whole-body fish tissues and the anticipated remedial effectiveness anticipated for whole-body fish tissues.

Figures include the following:

Figure F-4A: Tabular Summary of Whole-Body Shrimp, Crab, and Fish Sample Counts by Year for All Zones

Each of the figures below provides the comparison of fish and crab tissue data for multiple fish species for the two years with the most data, as follows:

- Figure F-4B: Mercury
- Figure F-4C: Aroclor 1268

Each of the figures below provides the comparison of fish and crab tissue data for all years by location, as follows:

- Figure F-4D: Mercury in Blue Crab
- Figure F-4E: Aroclor 1268 in Blue Crab
- Figure F-4F: Mercury in Black Drum
- Figure F-4G: Aroclor 1268 in Black Drum
- Figure F-4H: Mercury in Red Drum
- Figure F-4I: Aroclor 1268 in Red Drum
- Figure F-4J: Mercury in Spotted Seatrout
- Figure F-4K: Aroclor 1268 in Spotted Seatrout
- Figure F-4L: Mercury in Silver Perch
- Figure F-4M: Aroclor 1268 in Silver Perch
- Figure F-4N: Mercury in Striped Mullet
- Figure F-4O: Aroclor 1268 in Striped Mullet

Species Collected	Fish Count Per Year										Grand Total
	1995	1997	2000	2002	2003	2004	2005	2006	2007	2011	
Black Drum	0	0	2	8	8	0	8	8	8	10	52
Blue Crab	0	0	14	14	14	0	14	14	7	33	110
Brown Shrimp	7	0	0	0	0	0	0	0	0	0	7
Flounder	0	0	0	0	0	0	5	0	0	0	5
Red Drum	0	0	0	1	8	0	14	3	4	11	41
Sheepshead	0	0	0	0	0	0	6	0	0	0	6
Silver Perch	0	0	8	8	8	0	8	8	8	32	80
Southern Kingfish	0	0	0	0	0	0	4	0	0	0	4
Spot	0	0	1	0	0	0	2	0	0	0	3
Spotted Seatrout	0	0	1	8	8	0	8	8	8	32	73
Striped Mullet	0	0	0	0	0	0	8	8	3	21	40
White Shrimp	0	0	0	0	0	0	9	0	0	0	9

Notes:

(a) Fish counts are for all zones (Zone A to Zone I).

(b) 2005 and 2011 (highlighted in yellow) have the largest sample counts and allow the most robust comparison over time.

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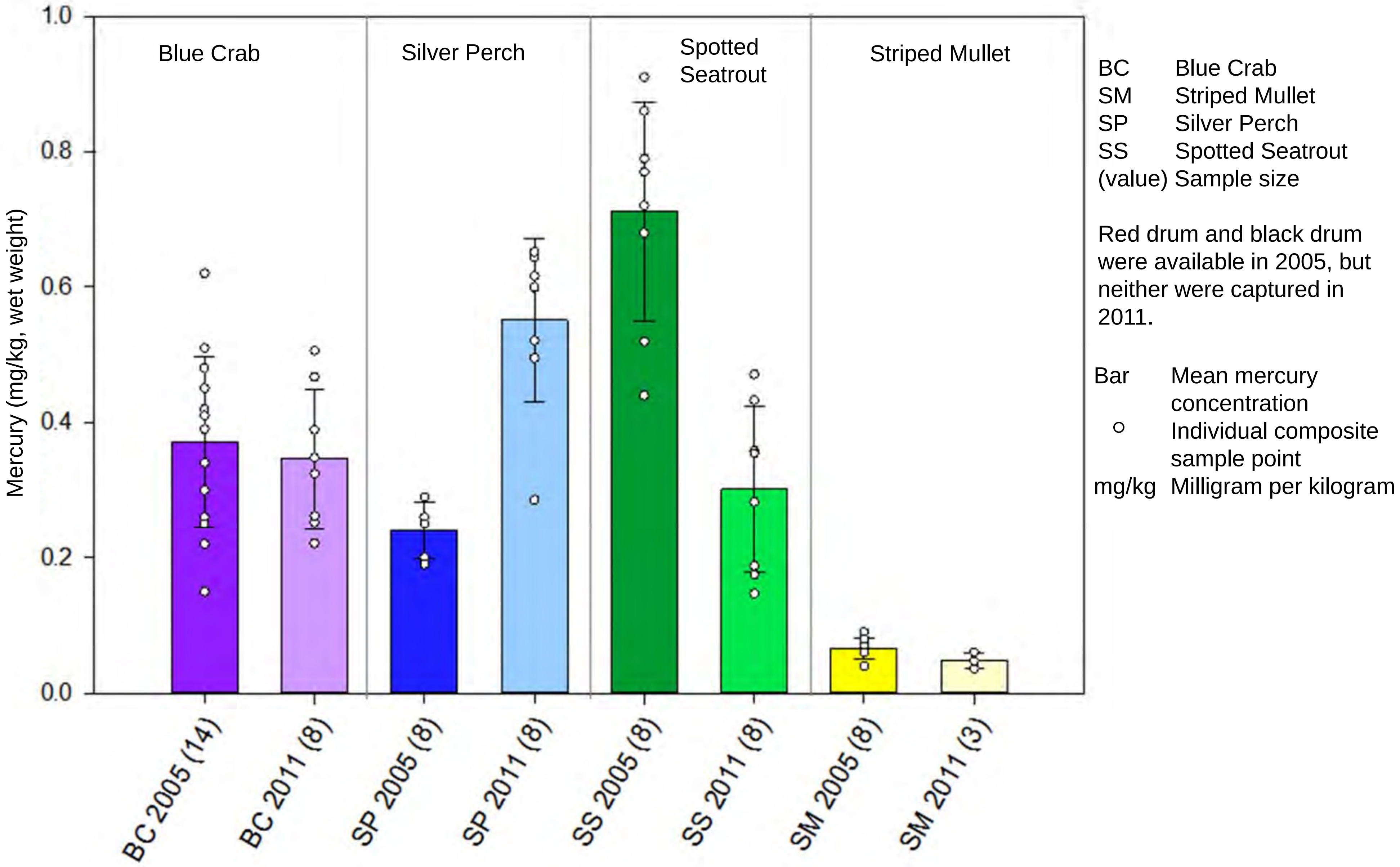
Tabular Summary Of Whole Body Shrimp, Crab, and Fish Sample Counts by Year For All Zones

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-4A



Red drum and black drum were available in 2005, but neither were captured in 2011.

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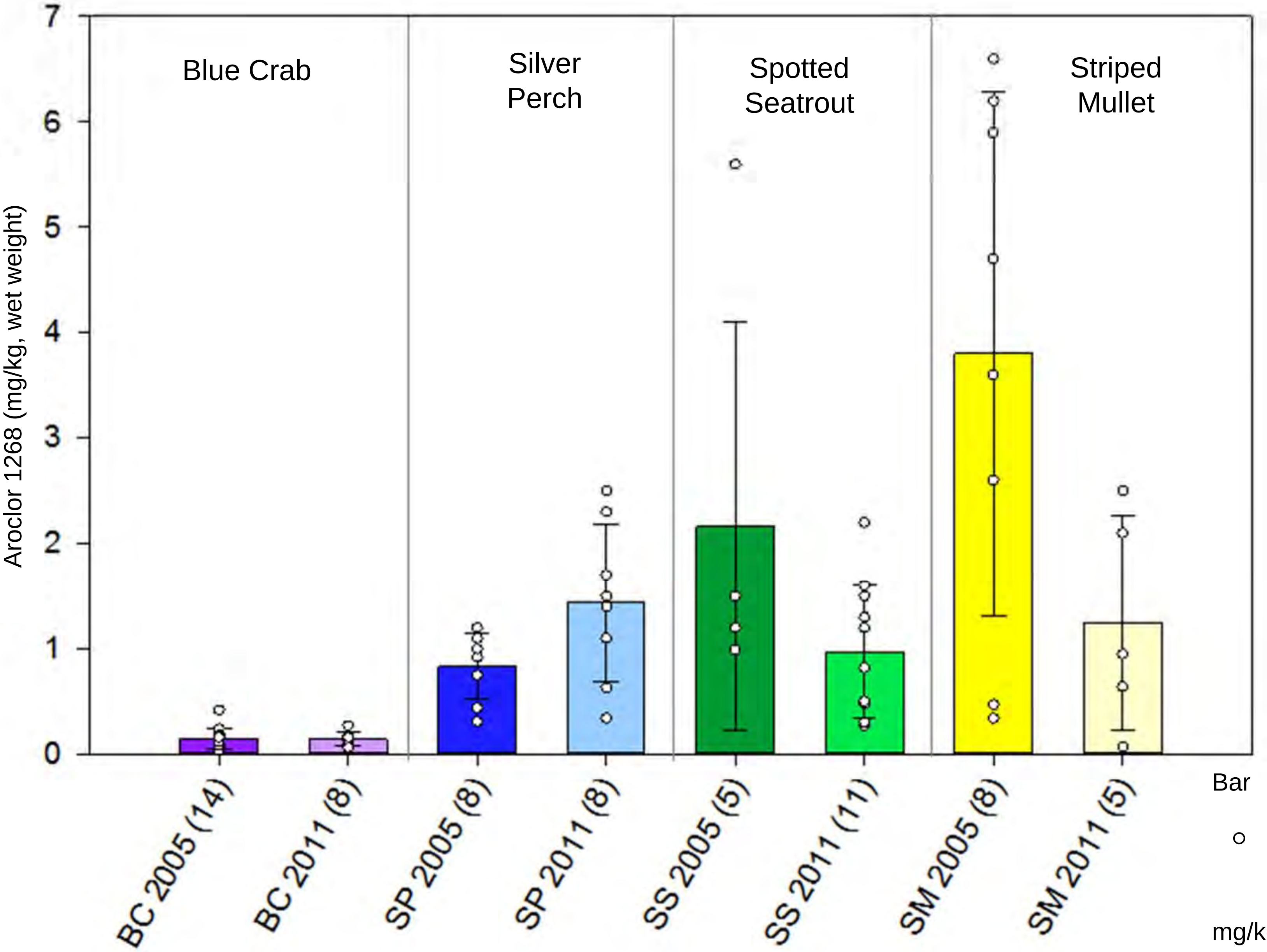
Comparison of Mercury for Multiple Fish Species in Whole-Body Crab and Fish Tissues for the Two Years with the Most Data for Zone H (2005 vs. 2011, wet weight)

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-4B



BC	Blue Crab
SM	Striped Mullet
SP	Silver Perch
SS	Spotted Seatrout
(value)	Sample size

Red drum and black drum were available in 2005, but neither were captured in 2011.

Bar	Mean Arcoclor 1268 concentration
○	Individual composite sample point
mg/kg	Milligram per kilogram

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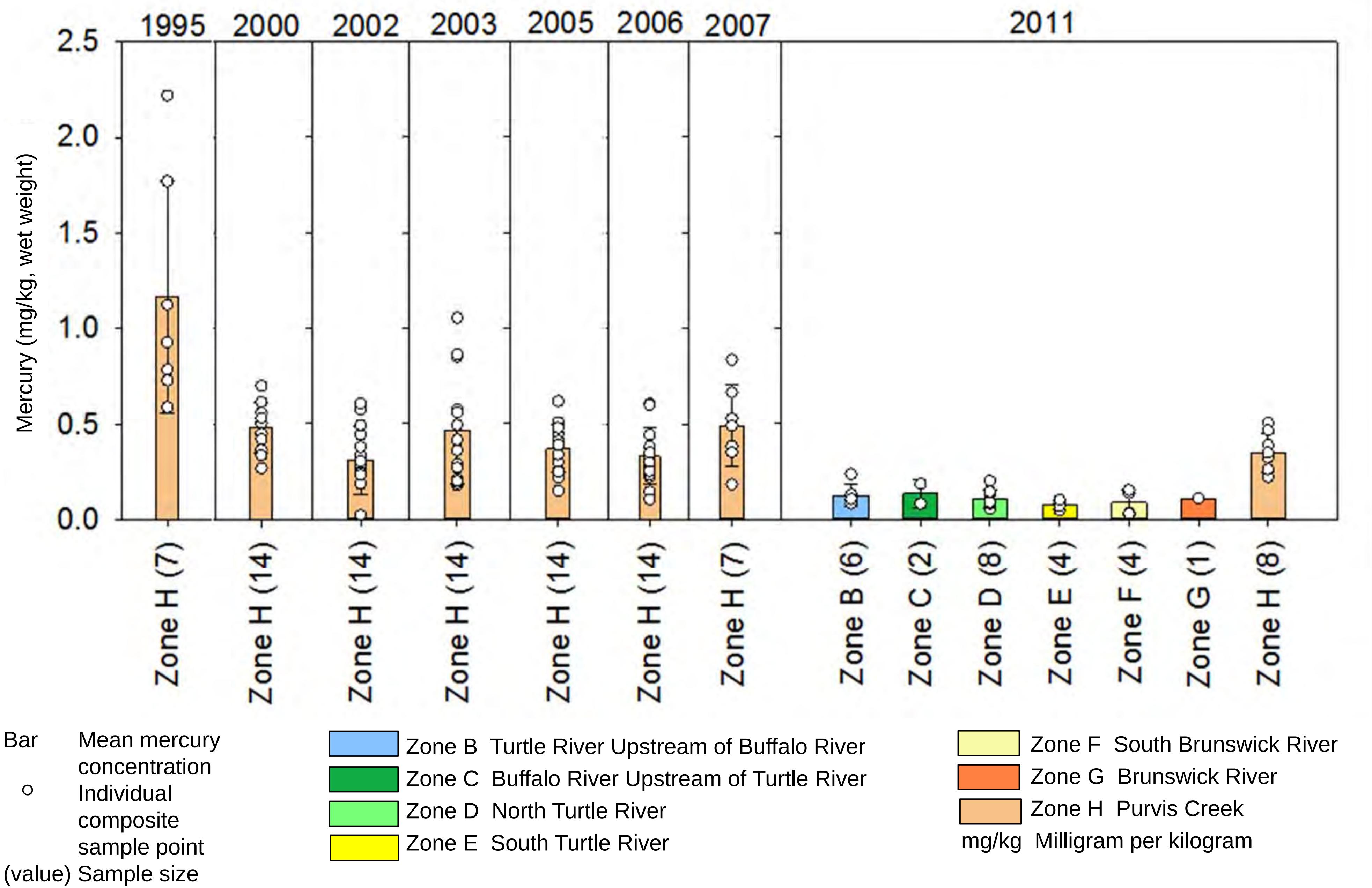
Comparison of Aroclor 1268 in Whole-Body Crab and Fish Tissues for the Two Years with the Most Data for Zone H (2005 vs. 2011, wet weight)

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-4C

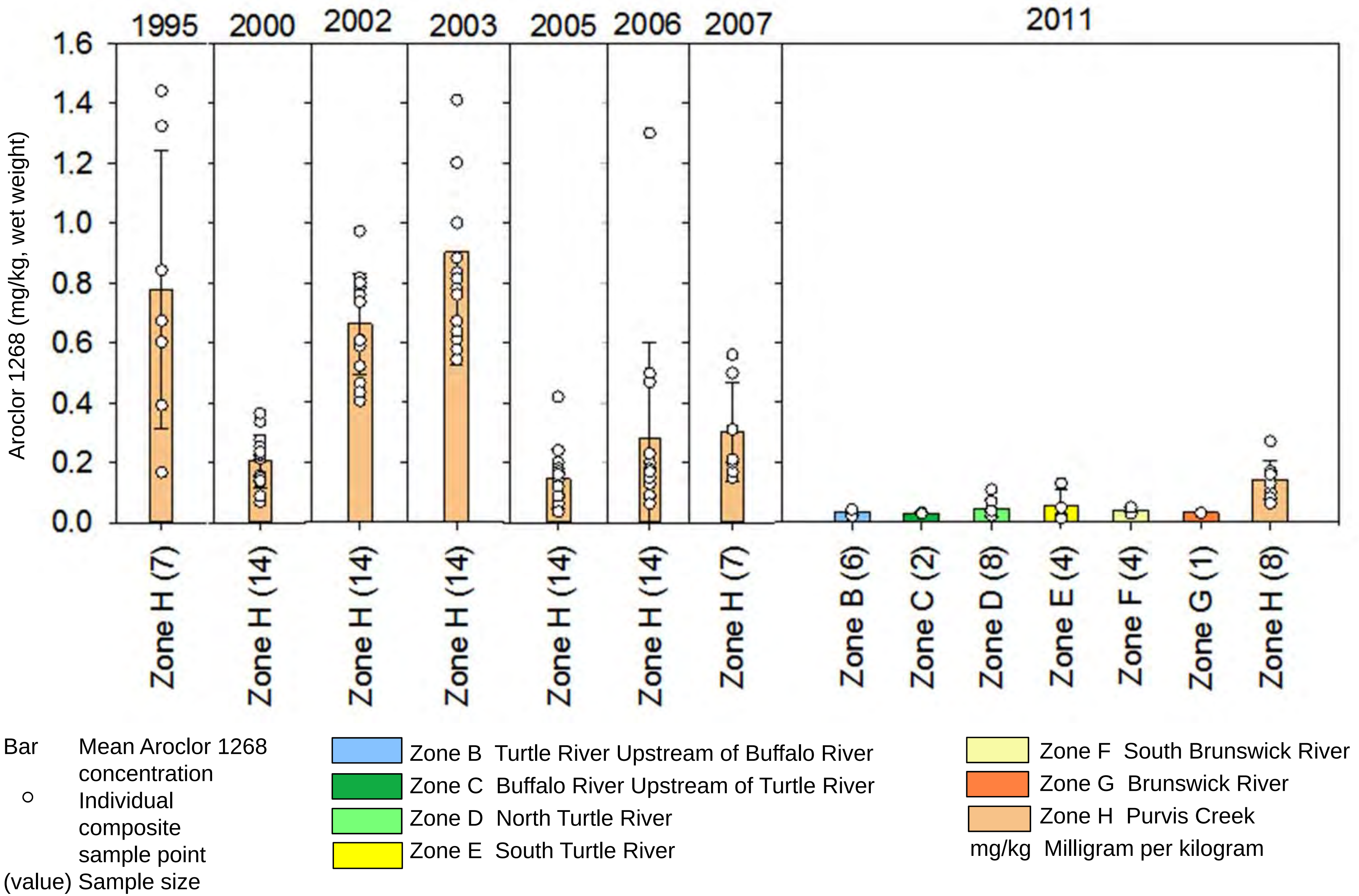


Comparison of Whole-Body Mercury Crab Tissue Data for All Years by Location (Wet Weight) for Blue Crab

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-4D



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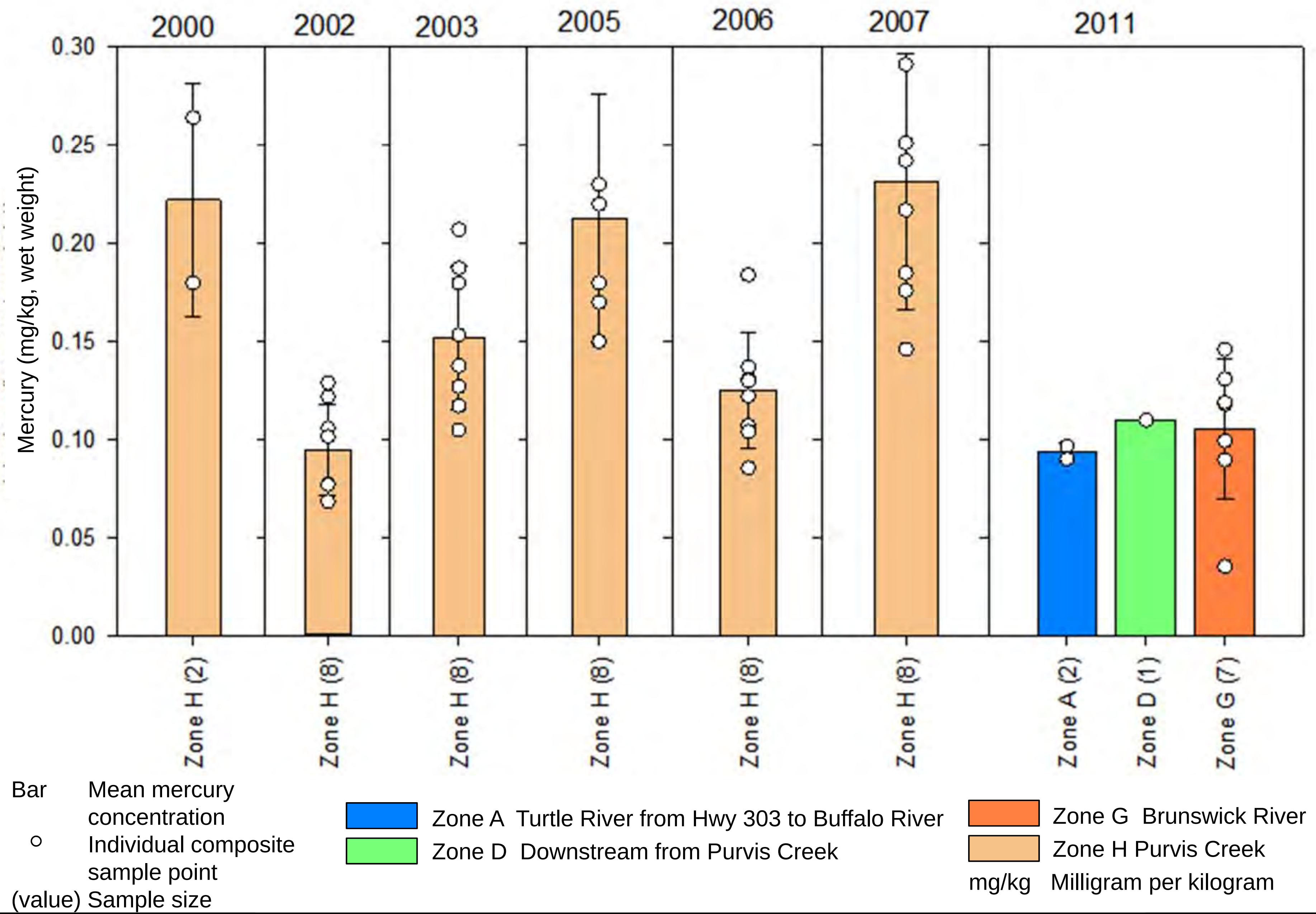
Comparison of Whole-Body Aroclor 1268 Crab Tissue Data for All Years by Location (Wet Weight) for Blue Crab

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-4E



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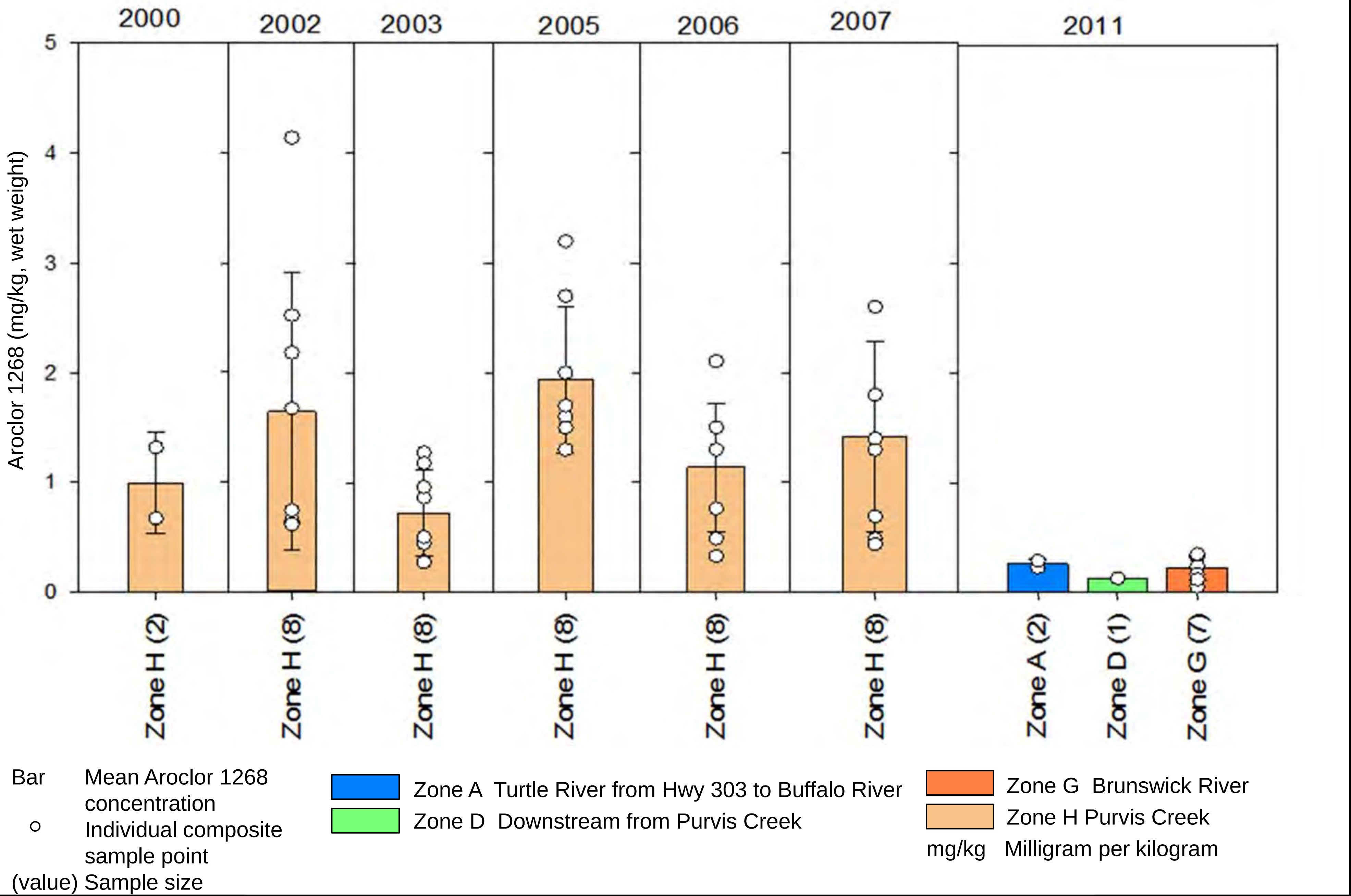
Comparison of Whole-Body Mercury Fish Tissue Data for All Years by Location (Wet Weight) for Black Drum

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-4F



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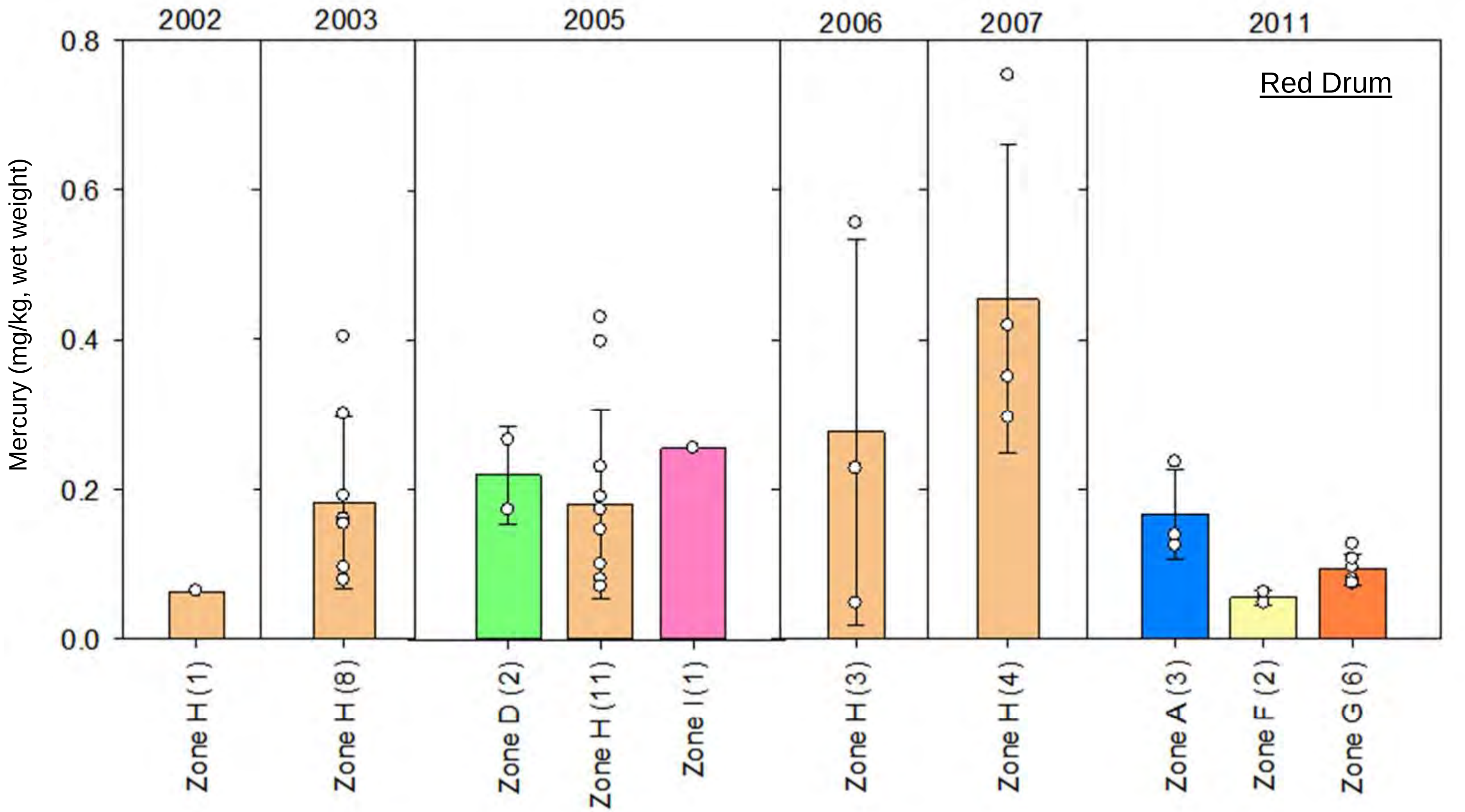
Comparison of Whole-Body Aroclor 1268 Fish Tissue Data for All Years by Location (Wet Weight) for Black Drum

Figure

F-4G

LCP CHEMICAL SITE, BRUNSWICK GEORGIA



Bar Mean mercury concentration

○ Individual composite sample point

(value) Sample size

🟦 Zone A Turtle River from Hwy 303 to Buffalo River

🟩 Zone D Downstream from Purvis Creek

🟨 Zone F South Brunswick River

🟧 Zone G Brunswick River

🟫 Zone H Purvis Creek

🟪 Zone I Gibson Creek

mg/kg Milligram per kilogram

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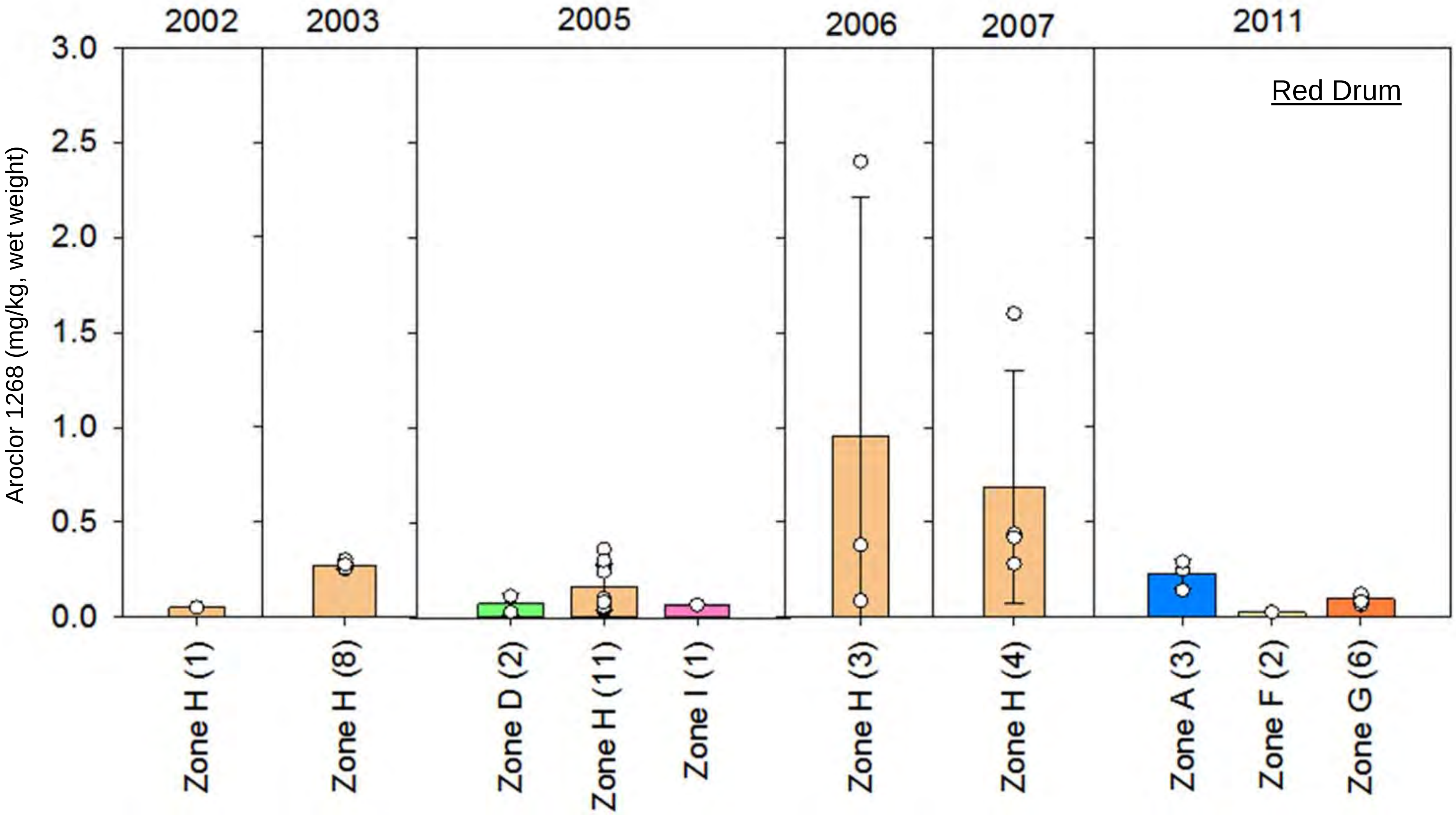
Comparison of Whole-Body Mercury Fish Tissue Data for All Years by Location (Wet Weight) for Red Drum

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-4H



Bar	Mean Aroclor 1268 concentration
○	Individual composite sample point
(value)	Sample size

🟦	Zone A Turtle River from Hwy 303 to Buffalo River
🟩	Zone D Downstream from Purvis Creek
🟨	Zone F South Brunswick River
🟧	Zone G Brunswick River
🟫	Zone H Purvis Creek
🟪	Zone I Gibson Creek
mg/kg	Milligram per kilogram

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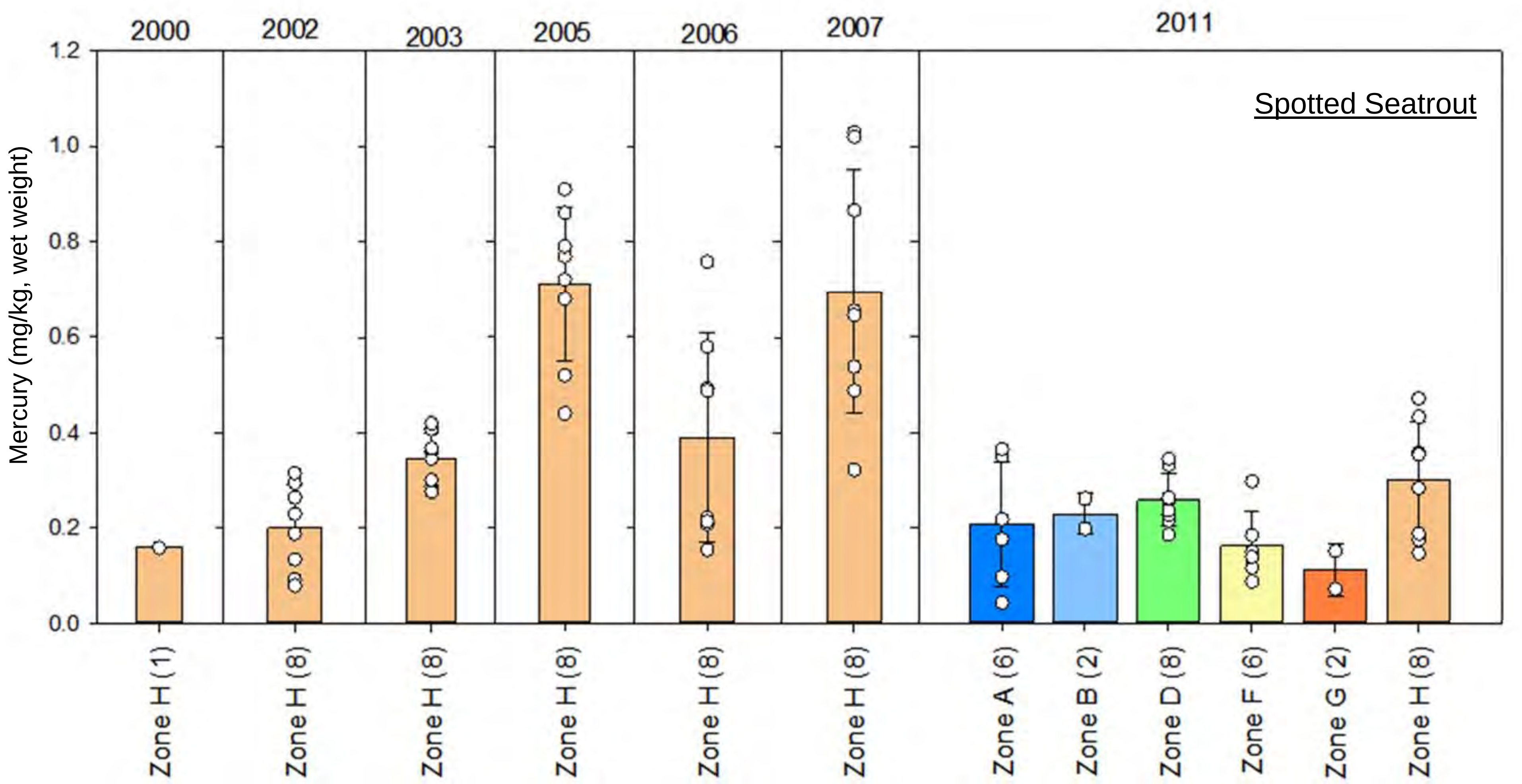
Comparison of Whole-Body Aroclor 1268 Fish Tissue Data for All Years by Location (Wet Weight) for Red Drum

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-4I



Bar Mean mercury concentration
○ Individual composite sample point
(value) Sample size

🟦 Zone A Turtle River from Hwy 303 to Buffalo River
🟦 Zone B Turtle River Upstream of Buffalo River
🟩 Zone D Downstream from Purvis Creek
🟨 Zone F South Brunswick River
🟧 Zone G Brunswick River
🟫 Zone H Purvis Creek
mg/kg Milligram per kilogram

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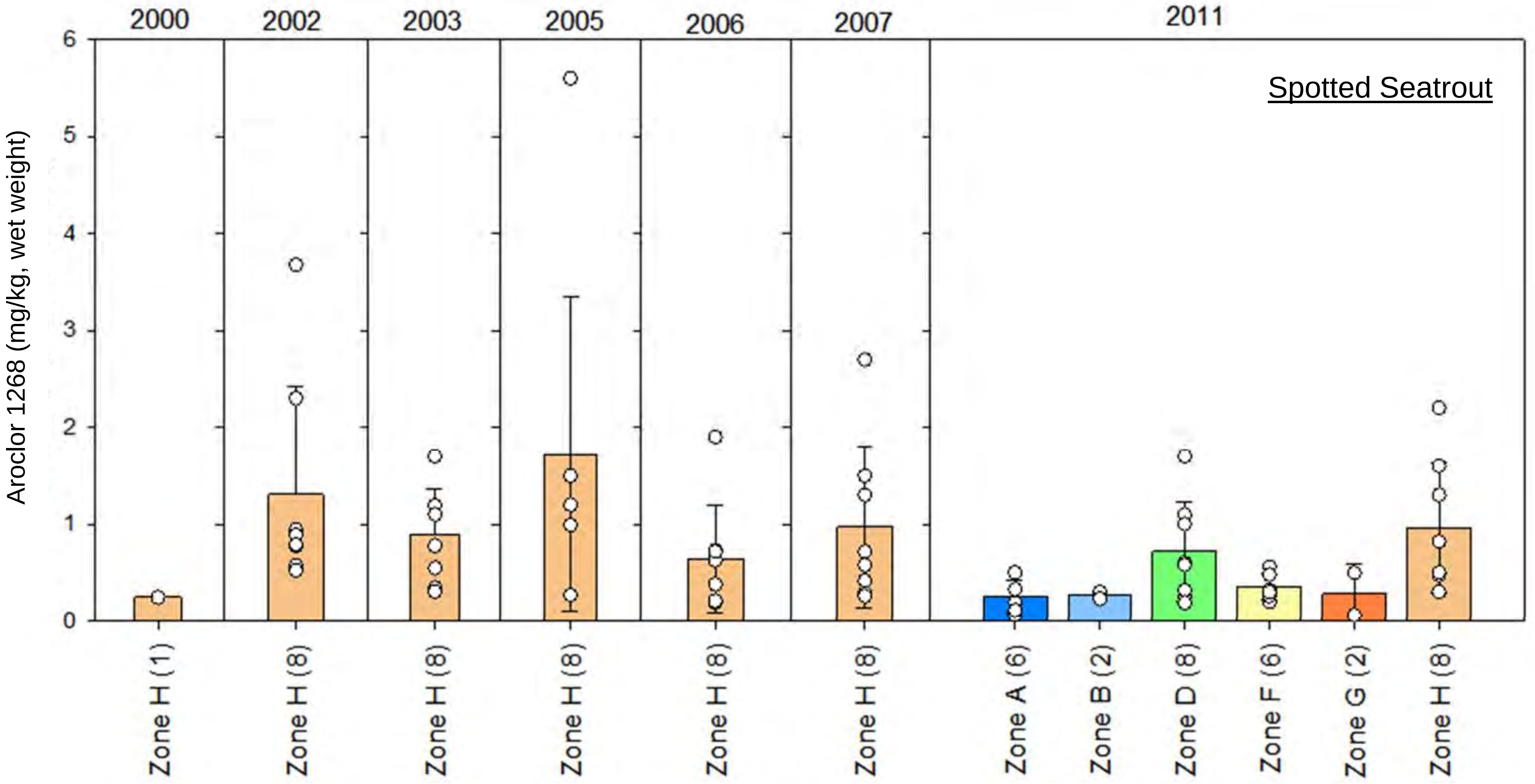
Comparison of Whole-Body Mercury Fish Tissue Data
for All Years by Location (Wet Weight) for Spotted Seatrout

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-4J



Bar	Mean Aroclor 1268 concentration
○	Individual composite sample point
(value)	Sample size

🟦	Zone A	Turtle River from Hwy 303 to Buffalo River
🟦	Zone B	Turtle River Upstream of Buffalo River
🟩	Zone D	Downstream from Purvis Creek
🟨	Zone F	South Brunswick River
🟧	Zone G	Brunswick River
🟫	Zone H	Purvis Creek
mg/kg		Milligram per kilogram

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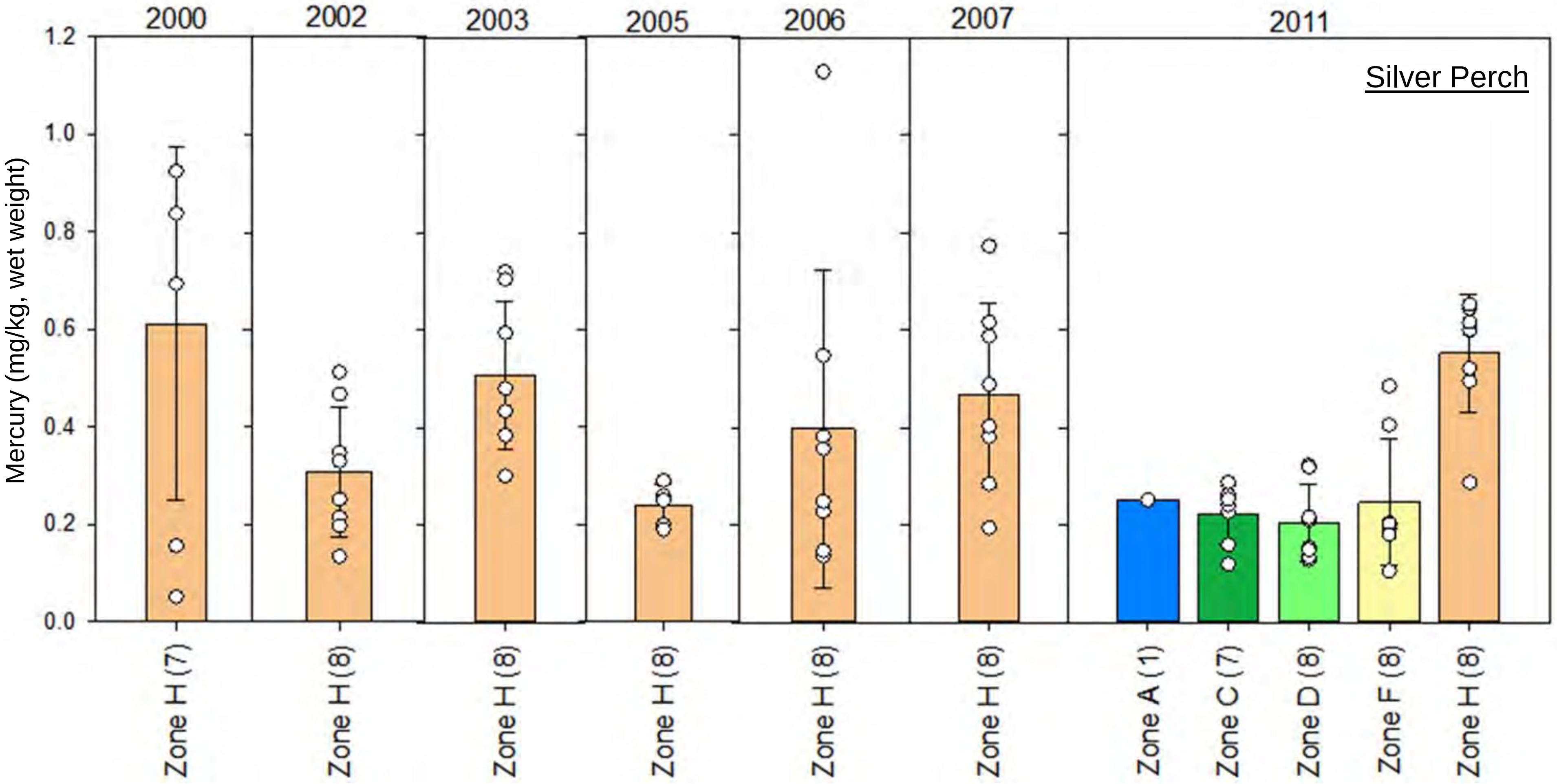
Comparison of Whole-Body Aroclor 1268 Fish Tissue Data for All Years by Location (Wet Weight) for Spotted Seatrout

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-4K



Bar Mean mercury concentration
○ Individual composite sample point
(value) Sample size

🟦 Zone A Turtle River from Hwy 303 to Buffalo River
🟩 Zone C Buffalo River Upstream of Turtle River
🟩 Zone D Downstream from Purvis Creek
🟨 Zone F South Brunswick River
🟧 Zone H Purvis Creek
mg/kg Milligram per kilogram

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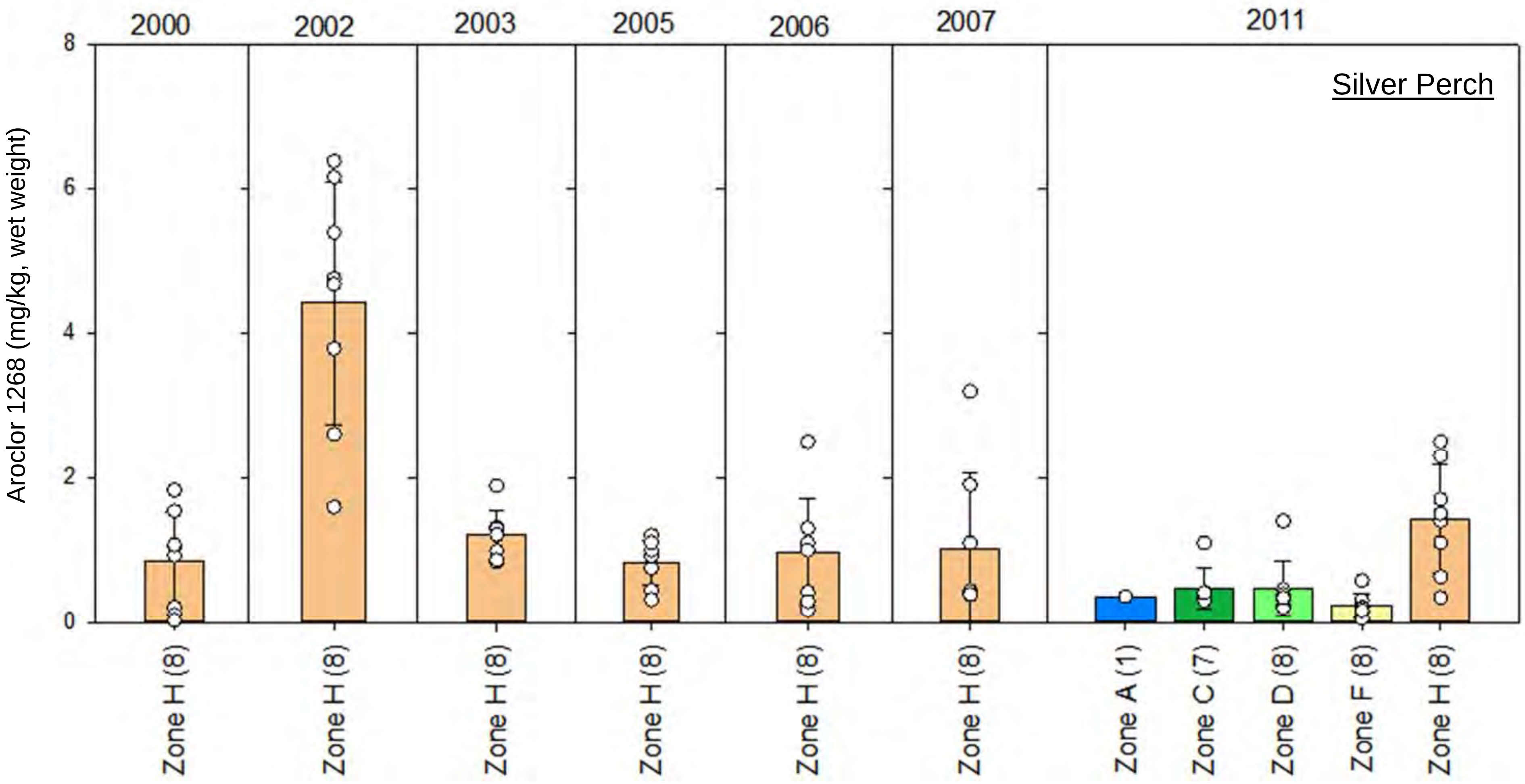
Comparison of Whole-Body Mercury Fish Tissue Data for All Years by Location (Wet Weight) for Silver Perch

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-4L



Bar Mean Aroclor 1268 concentration

○ Individual composite sample point

(value) Sample size

🟦 Zone A Turtle River from Hwy 303 to Buffalo River

🟩 Zone C Buffalo River Upstream of Turtle River

🟩 Zone D Downstream from Purvis Creek

🟨 Zone F South Brunswick River

🟧 Zone H Purvis Creek

mg/kg Milligram per kilogram

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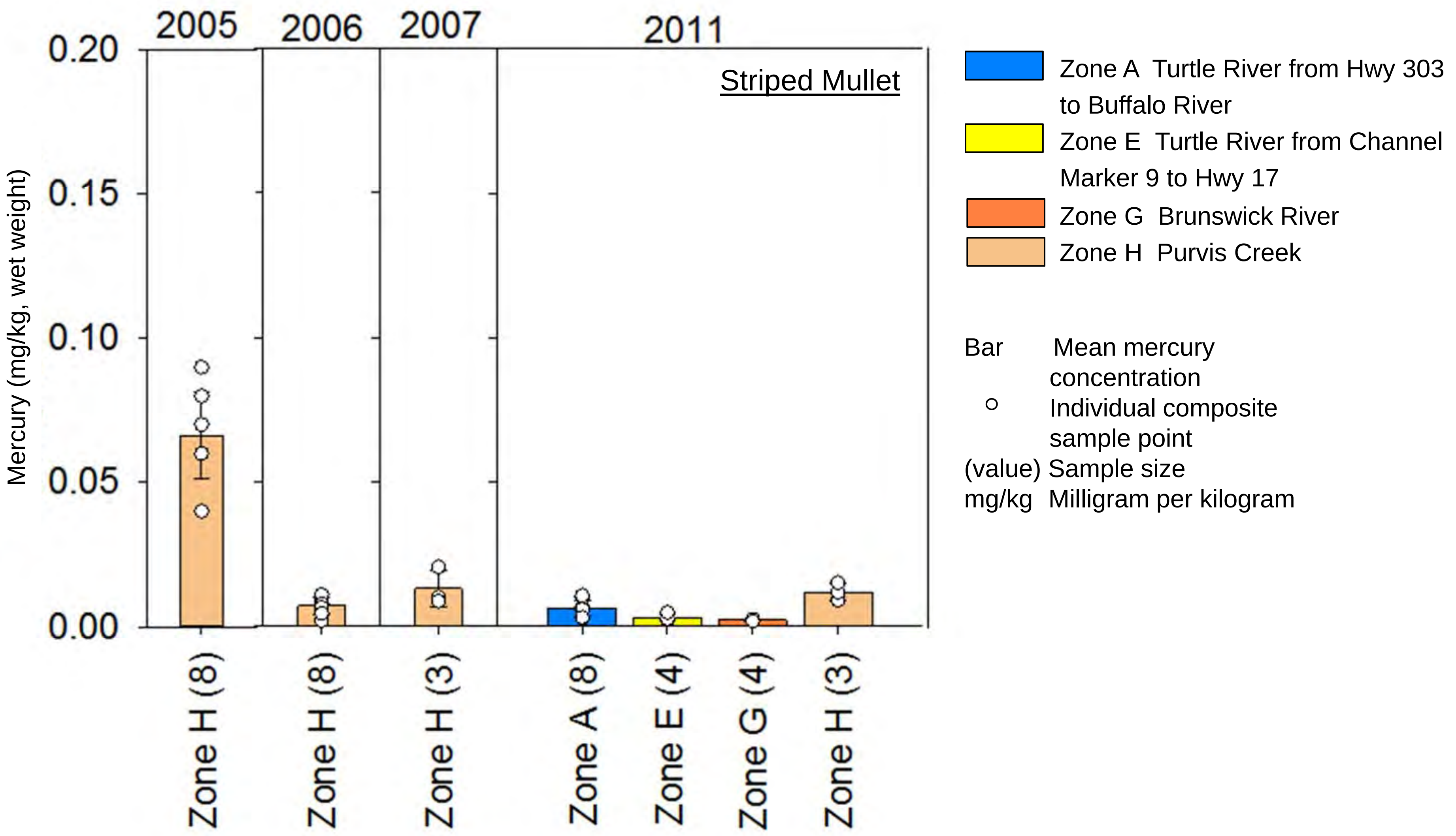
Comparison of Whole-Body Aroclor 1268 Fish Tissue Data for All Years by Location (Wet Weight) for Silver Perch

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-4M



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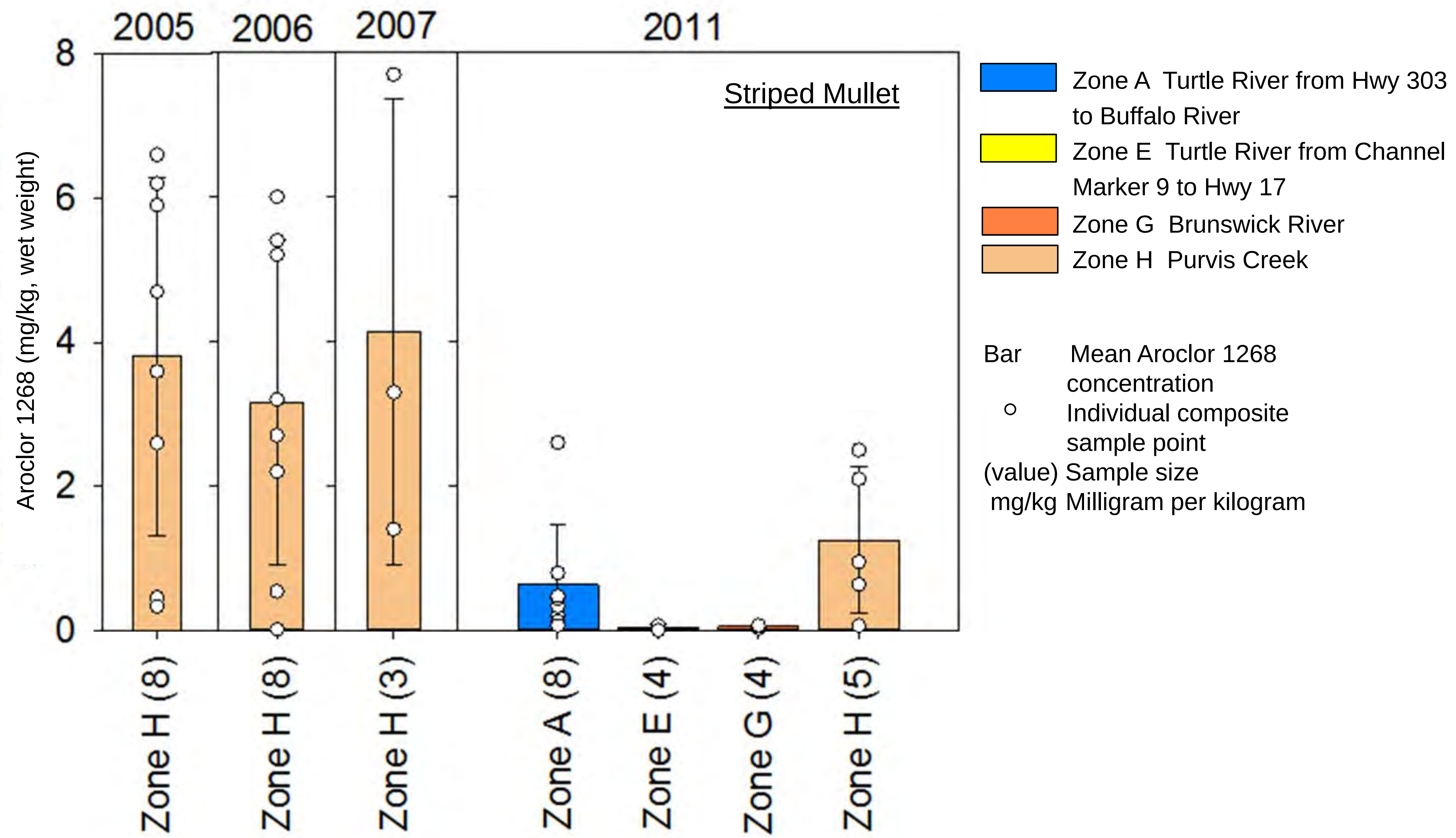
Comparison of Whole-Body Mercury Fish Tissue Data for All Years by Location (Wet Weight) for Striped Mullet

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-4N



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Comparison of Whole Body Aroclor 1268 Fish Tissue Data for All Years by Location (Wet Weight) for Striped Mullet

LCP CHEMICAL SITE, BRUNSWICK GEORGIA

Figure

F-4O

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Appendix G
Remedial Goal Option Correspondence

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:
Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:
ENVIRON International Corporation

Anchor QEA, LLC

Date:
June 2, 2014

Deleted: October 18, 2013¶

ENVIRON
ANCHOR QEA

Deleted: DRAFT¶

Contents

- Letter: “Human Health Risk Assessment for the Estuary, OU1 (Estuary): LCP Chemicals Superfund Site, Brunswick, Glynn County, GA” (USEPA, November 30, 2011).
- Letter and memorandum: “*Response to EPA’s November 2011 Letter regarding Remedial Goal Option (RGO) Ranges for the Remedial Action Alternatives for OU1 (Estuary) – LCP Chemicals Site, Brunswick, GA*” (Honeywell, November 2, 2012).
- Agency Reply Letter: “*Remedial Goal Option (RGO) Ranges for the Remedial Action Alternatives for OU1 (Estuary): LCP Chemicals Superfund Site (Site), Brunswick, Glynn County, Georgia*” (USEPA, November 20, 2012).
- Letter: “*Remedial Goal Option (RGO) Ranges for the Remedial Action Alternatives of OU1 (Estuary): LCP Chemicals Superfund Site, Brunswick, Glynn County, GA*” (USEPA, February 20, 2013b).
- Letter: “*Remedial Goal Option (RGO) Ranges for Remedial Action Alternatives for OU1 (Estuary): LCP Chemicals Superfund Site, Brunswick, Glynn County, GA*” (USEPA, March 8, 2013c).

Appendix G
Remedial Goal Option Correspondence

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Human Health Risk Assessment for the Estuary, OU1 (Estuary): LCP Chemicals Superfund Site

Letter

Brunswick, Glynn County, Georgia

USEPA November 30, 2011

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

NOV 3 0 2011

Ref: 4WD-SRB

Via Delivery as Email-attachment to (Prashant.gupta@honeywell.com) and Certified Mail

Mr. Prashant K. Gupta
Honeywell, Inc.
4101 Bermuda Hundred Road
Chester, Virginia 23836

Re: Human Health Risk Assessment for the Estuary, Operable Unit One (OU 1):
LCP Chemicals Superfund Site, Brunswick, Glynn County, Georgia

Dear Mr. Gupta:

The purpose of this letter is to notify Honeywell International, Inc. (Honeywell) that the U.S. Environmental Protection Agency is approving its August 2011 draft of the Human Health Risk Assessment for the Estuary, Operable Unit One (OU 1), of the LCP Chemicals Site Superfund (Site). In addition, the EPA is now directing Honeywell to submit the draft remedial investigation report, described in detail in the Scope of Work (SOW) incorporated into the Administrative Order by Consent for Remedial Investigation/Feasibility Study, EPA Docket No. 95-17-C (AOC). Acknowledging Honeywell's November 3, 2011 proposal for the development of the feasibility study, the following are remedial goal option (RGO) ranges EPA has developed. In the meantime, EPA is discussing internally the process outlined by Honeywell.

In developing and screening the remedial action alternatives, Honeywell is directed to use the RGO ranges set out below, which have been selected as explained in detail in the enclosed paper. These RGO ranges for mercury, Aroclor 1268, lead and total polynuclear aromatic hydrocarbons (PAHs) integrate the RGOs developed in the April 2011 Baseline Ecological Risk Assessment for the LCP Estuary and the conclusions of the now-approved August 2011 Human Health Risk Assessment for the LCP Estuary. This integration is necessary in order to identify and evaluate potential cleanup alternatives which are protective of both human health and the environment. Based on information provided in the two tables in the enclosed paper, the EPA and the Georgia Environmental Protection Division have selected the following sediment RGOs for the LCP Estuary (OU 1) Feasibility Study:

• Aroclor 1268 -	2, 4 and 6 milligram per kilogram (mg/kg);
• Mercury -	1, 2, and 4 mg/kg;
• Lead-	40, 60 and 90 mg/kg; and
• Total PAHs-	1.5, 2.5 and 4.0 mg/kg

In addition to using the RGOs listed above, Honeywell may also utilize other RGO ranges for each of these hazardous substances, as long as it provides the justification for using such ranges in its development and screening of remedial action alternatives.

The EPA's instructions for evaluating the RGOs for protection of both human health and ecological receptors are contained at the end of the enclosed paper.

Please submit the draft remedial investigation report for OU1 to the EPA for review and approval within 15 calendar days of receipt of this letter.

If you have any questions regarding the approval of the Human Health Risk Assessment for OU1 of the LCP Chemicals Site or the instructions for next steps in this letter, please contact me at (404) 562-8937.

Sincerely,

Galo Jackson

Galo Jackson, P.G.
Remedial Project Manager
Superfund Remedial Branch

Enclosures

cc: J. McNamara, EPD

LCP Estuary Sediment Remedial Goal Options

The purpose of this paper is to determine the appropriate ranges of sediment remedial goal options (RGOs) to choose in order to adequately protect both human and ecological receptors. At this Site, human health is at risk due to consumption of contaminated fish from the LCP Estuary. Ecological receptors are also at risk. The selected RGO ranges can then be used in the Feasibility Study (FS) to evaluate cleanup alternatives.

Sediment RGOs for Protection of Human Health

The human health risk assessment (HHRA) for OU1 identified non-cancer hazards and cancer risks from consumption of clapper rail, shellfish (blue crabs and white shrimp) and a variety of finfish taken from the LCP Estuary. The development of RGOs for the LCP Estuary is based on the premise that the source of contamination in the Estuary is the contaminated sediments, regardless of how the fish, shellfish or clapper rail acquired the chemical through the local food web. This means that the tissue concentrations measured in the consumed food items are ultimately related to the levels of contamination in the sediment sources.

For finfish, blue crab and white shrimp, the average area-weighted Estuary creek sediment concentrations were used to represent the exposure source. These sediments represent permanently inundated habitat areas for fish, shrimp, and blue crabs. Marsh sediments were not included because they are tidally influenced and subject to periodic wet-dry cycles. Based on numerous sediment samples collected in the LCP Estuary, the calculated area-weighted average Aroclor 1268 sediment concentration is 7.44 mg/kg. The area-weighted mercury concentration is calculated to be 2.74 mg/kg. Attachment A shows how the averages were calculated.

For the clapper rail exposed to tidal marsh sediment instead of creek sediment, the average marsh sediment concentrations were used to represent the exposure source. The average marsh sediment concentrations of Aroclor 1268 and mercury were calculated to be 3.41 mg/kg and 2.17 mg/kg, respectively (derived from Table 1 in the HHRA).

The LCP sediment concentrations were compared to the tissue concentrations at the levels that resulted in a non-cancer hazard index (HI) of ≥ 1 or in cancer risk of $\geq 10^{-6}$. This relationship was then used to predict sediment and/or tissue concentrations that would result a HI=1.0 or cancer risk $=10^{-4}$. The HHRA sediment RGO calculations are presented in Attachment A. The following table summarizes the sediment RGOs based on the various reasonable maximum exposure (RME) consumption scenarios.

Sediment RGOs for Human Health *			
RME Consumption Scenario	Adult	Child	Cancer
Aroclor-1268			
Clapper rail	2.4	0.9-2.7[1]	2.3
Shellfish	8.5	3.6-10.8[1]	8.7
Finfish – Recreational	4.4	2.9-8.7[1]	4.6
Finfish – High Consumption	2.5	1.5-4.5[1]	2.7
Mercury			
Clapper rail	10.8	3.1	NA
Shellfish	3.9	1.7	NA
Finfish – Recreational	2.7	1.4	NA
Finfish – High Consumption	1.4	0.9	NA
* - All concentrations in mg/kg			

Sediment RGOs for Protection of Ecological Receptors

The Baseline Ecological Risk Assessment (BERA) developed a range of sediment RGOs that would be protective for various receptors, as summarized in the following table. This range is based on the no-observed-adverse-effect-level (NOAEL) and lowest-observed-adverse-effect-level (LOAEL).

Sediment RGOs for Ecological Receptors *	
Aroclor-1268	
Mammals	5 – 10
Finfish	3 – 6
Benthic Invertebrates	3 – 13
Mercury	
Birds	1 – 3
Mammals	2 – 4
Finfish	1 – 3
Benthic Invertebrates	1.4 – 3.2
Lead	
Benthic Invertebrates	41 – 60[2]
Total PAHs	
Benthic Invertebrates	0.8 – 1.5
* - All concentrations in mg/kg	

---

[1] The ranges shown represent a HI range of 1 to 3.

[2] The grass shrimp sediment effect concentration (SEC) for lead was not used because a very low number of effect data were used to calculate it.

Selection of RGO Range for the Feasibility Study

An integration of the human health and ecological sediment RGOs is needed to address potential cleanup alternatives protective of human health and the environment. Based on the above two tables, the following sediment RGOs have been selected for the FS:

Aroclor 1268 -	2, 4, and 6 mg/kg;
Mercury -	1, 2 and 4 mg/kg;
Lead-	40, 60 and 90 mg/kg; and
Total PAHs-	1.5, 2.5 and 4.0 mg/kg

Methods for Evaluating RGOs for Ecological Receptors and Human Health

The following table summarizes the method that should be used for the evaluation of the RGOs.

	Methods for Evaluating RGOs for Ecological Receptors and Human Health		
Contaminant	Concentrations, mg/kg		
Aroclor 1268	2	4	6
Method of Evaluation	Area Average	Area Average	NTE[3]
Mercury	1	2	4
Method of Evaluation	Area Average	NTE	NTE
Lead	40	60	90
Method of Evaluation	NTE	NTE	NTE
PAHs	1.5	2.5	4.0
Method of Evaluation	NTE	NTE	NTE

To protect ecological receptors and human health, the feasibility study should evaluate the average concentrations of the above sediment contaminants. Those contaminant concentration RGOs designated as "NTE" are based on the sediment toxicity to benthic organisms. RGOs designated as "NTE" should be evaluated as the average measured or estimated concentrations within grids of creeks and marsh measuring 50 by 50 meters. Those contaminant concentrations

---

[3] Not to Exceed

designated as "Area Average" are based on risks to human health from consumption of waterfowl in the case of the 3.0 mg/kg of Aroclor 1268 or risk to humans and ecological receptors that consume fish in the case of the 3.0 mg/kg for Aroclor 1268 and the 1.0 mg/kg for mercury. Since the clapper rail is exposed to contamination in the marsh, the RGO of 3.0 mg/kg for Aroclor 1268 should be based on the area average of concentrations in the creeks and marsh. The contaminant concentration RGOs of 3.0 for Aroclor and 1.0 for mercury are based on consumption of fish. They should be evaluated as the average of the concentrations in all four creeks (Main Canal, Eastern Creek, Western Creek Complex, and Purvis Creek) combined.

Attachment A

Calculation of Human Health Sediment RGOs

If assume that the source of all mercury and A-1268 in finfish is from the LCP estuary creek sediment (regardless of how the fish acquired the chemical through the food web), then fish body burden is ultimately related to the sediment source.

For finfish, blue crab and white shrimp the average area-weighted estuary stream sediment concentrations are used to represent the exposure source.

Area	*% Total Area*	*Avg A-1268 Sed. Conc.*	*Sed. Aroclor-1268 Contribution*	*Average Hg Sed.Conc.*	*Sed. Mercury Contribution*
Main Canal	2	27.64	0.553	7.4	0.148
Eastern Creek	7	49.57	3.470	20.28	1.420
Western Creek Complex	4	3.18	0.127	2.75	0.110
Purvis Creek	87	3.78	3.289	1.22	1.061
Area Weighted Creeks Sediment Concentration			**7.44** mg/kg dw		**2.74** mg/kg dw

However, for Clapper rail exposure, the average marsh sediment concentrations are used and derived from Table 1 in the HHRA.

	Aroclor-1268	*Mercury*
Average Marsh Sediment Concentration	**3.408** mg/kg dw	**2.167** mg/kg dw

Four human health exposure scenarios resulted in RME and/or CTE risks and hazards.

Given the above assumptions, the risk or hazard index for each COC is related to the sediment source via the fish consumption pathway.

Therefore, the sediment remedial goal is the average sediment concentration divided by the hazard index of each COC.

To calculate the sediment RGO for cancer risk, the following relationship is used: (EPC/sediment concentration) = target tissue concentration / X

The following RGOs are based on the RME hazards and risks.

Clapper rail (data from Table 19).	*Aroclor 1268 HI*	***RGO Marsh Sed.***	mg/kg	*Mercury HI*	***Hg RGO Marsh Sed.***
Adult consumption	1.4	**2.4**		0.2	**10.8**
Child consumption	4.0	**0.9**		0.7	**3.1**
Cancer Risk	10-4	**2.3**			

Target tissue at 10-4 Risk: 19.42/1.5E-04 = x/1.0E-04 = 12.95

Sed RGO: 19.42/3.408 = 12.95/x = 2.3

Shellfish (data from Table 16).

	A-1268 HI	***RGO Creek Sed.***	*Mercury HI*	***Hg RGO Creek Sed.***
Adult consumption	0.88	**8.5**	0.7	**3.9**
Child consumption	2.08	**3.6**	1.6	**1.7**
Cancer Risk	10-4	**8.7**		

Combined EPCs of crab and shrimp: (0.195*0.50)+(0.533*0.50) = 0.364
Combined target tissue at 10-4 Risk: 0.364/8.5E-05 = x/1.0E-04 = 0.428
Sed RGO: 0.364/7.44 = 0.428/x = 8.7

Finfish - recreationally caught (data from Tables 12a and 12c).

Adult consumption	1.7	**4.4**	1.0	**2.7**
Child consumption	2.6	**2.9**	2.0	**1.4**
Cancer Risk	10-4	**4.6**		

Combined EPCs for all finfish: see below = 0.525
Combined target tissue at 10-4 Risk: 0.525/1.6E-04 = x/1.0E-04 = 0.328
Sed RGO: 0.525/7.44 = 0.328/x = 4.6

Finfish - high quantity consumers (data from Tables 14a and 14c).

Adult consumption	3.0	**2.5**	2.0	**1.4**
Child consumption	5.0	**1.5**	3.0	**0.9**
Cancer Risk	10-4	**2.7**		

Combined EPCs for all finfish: see below = 0.525
Combined target tissue at 10-4 Risk: 0.525/2.8E-04 = x/1.0E-04 = 0.188
Sed RGO: 0.525/7.44 = 0.188/x = 2.7

Finfish	*A-1268 EPC*	*FI*	*adjusted EPC*
Atlantic Croaker	1.427	0.011	0.016
Black Drum	0.343	0.039	0.013
Red Drum	0.148	0.207	0.031
Sheepshead	0.724	0.099	0.072
Southern Flounder	0.249	0.044	0.011
Southern Kingfish	0.716	0.197	0.141
Spot	1.785	0.0004	0.001
Spotted Seatrout	0.556	0.394	0.219
Striped Mullet	2.704	0.008	0.022
∑ EPC			**0.525**

This ∑EPC results in recreational risk of 1.6E-04 and high quantity consumer risk of 2.8E-04.

Another way to calculate the sediment RGOs (via the fish consumption pathway) is to use the area-weighted sediment concentration and the fish EPC to calculate the fish bioaccumulation factor (BAF). Then use the BAF for each fish and the target tissue concentration (that is normalized to the chemical HI) to calculate the sediment RGO.

BAF = EPC/sediment conc.

An example using the recreational fish consumer scenarios for adult and child:

	EPC		*EPC*	
Finfish	*A-1268*	*A-1268 BAF*	*Mercury*	*Hg BAF*
Atlantic Croaker	1.427	**0.192**	0.302	**0.110**
Black Drum	0.343	**0.046**	0.177	**0.065**
Red Drum	0.148	**0.020**	0.343	**0.125**
Sheepshead	0.724	**0.097**	0.372	**0.136**
Southern Flounder	0.249	**0.033**	0.257	**0.094**
Southern Kingfish	0.716	**0.096**	0.663	**0.242**
Spot	1.785	**0.240**	0.124	**0.045**
Spotted Seatrout	0.556	**0.075**	0.495	**0.181**
Striped Mullet	2.704	**0.364**	0.042	**0.015**

To check the BAF, we notice that the striped mullet has the highest BAF for Aroclor 1268 and indeed has the highest target tissue concentration.

Adult recreational consumers		Child recreational consumers	
Target Tissue Conc.		*Target Tissue Conc.*	
A-1268 (HI=1.7)	*Mercury (HI=1)*	*A-1268 (HI=1.7)*	*Mercury (HI=1)*
0.839	0.302	0.5488	0.151
0.202	0.177	0.1319	0.089
0.087	0.343	0.0569	0.172
0.426	0.372	0.2785	0.186
0.146	0.257	0.0958	0.129
0.421	0.663	0.2754	0.332
1.050	0.124	0.6865	0.062
0.327	0.495	0.2138	0.248
1.591	0.042	1.0400	0.021
1.7	**1.0**	**2.6**	**2.0**

Sediment RGOs (these match RGOs calculated above)

4.4	2.7	2.9	1.4
4.4	2.7	2.9	1.4
4.4	2.7	2.9	1.4
4.4	2.7	2.9	1.4
4.4	2.7	2.9	1.4
4.4	2.7	2.9	1.4
4.4	2.7	2.9	1.4
4.4	2.7	2.9	1.4
4.4	2.7	2.9	1.4

Appendix G
Remedial Goal Option Correspondence

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Response to USEPA's November 2011 Letter Regarding Remedial Goal Option (RGO) Ranges for the Remedial Action Alternatives for OU1 (Estuary): LCP Chemicals Superfund Site

Letter and Memorandum

Brunswick, Glynn County, Georgia

Honeywell November 2, 2012

Honeywell

Honeywell
P.O. Box 1057
Morristown, NJ 07962-1057

November 2, 2012

VIA EMAIL AND REGULAR MAIL

Mr. Galo Jackson
US EPA Region IV
Waste Management Division
Superfund Program
61 Forsyth Street, SW
Atlanta, Georgia 30303

Re: Response to EPA's November 2011 Letter regarding the Remedial Goal Option (RGO) Ranges for the Remedial Action Alternatives for OU1 (Estuary) – LCP Chemicals Site, Brunswick, Georgia

Dear Mr. Jackson,

On November 30, 2011, the United States Environmental Protection Agency (EPA) issued a letter approving the August 2011 draft of the Human Health Risk Assessment for the Estuary, Operable Unit One (OU1) for the LCP Chemicals Site, Brunswick, Georgia. In that letter, EPA provided RGO values and supplied the RGO calculations in an attachment. EPA also offered Honeywell an opportunity to propose alternative RGO values, "Honeywell may also utilize other RGO ranges for each of [the] hazardous substances, as long as it provides the justification for using such ranges in the development and screening of remedial action alternatives."

In response to EPA's invitation to use alternative RGO ranges, and consistent with our previous discussions, Honeywell is submitting additional RGOs for use in the feasibility study (FS) process. These additional RGOs establish a broader range of values to manage risks at the Site, and we believe better balance the damage/benefit ratio that arises from the inherent uncertainty in the science. Honeywell's experts prepared the attached memorandum outlining alternative RGO values as well as the technical basis for those values. With your concurrence, we intend to use these RGO values in conjunction with the range of RGO values in the EPA letter. This broader range of values will be used to screen and compare sediment remedial action alternatives in the OU1 FS. The FS will explain and justify RGOs applied to the various alternatives. This explanation will include a discussion of the risk basis for remediation, the relative risk reduction achieved by the remedy, and the balance achieved between short and long-term ecological harm.

Thank you for your consideration of these additional alternative RGO ranges and we look forward to receiving your concurrence so that we can move the process forward without delay. Please feel free to call me at 973-722-1656 if you have any questions.

Sincerely,

Prash K.

Prashant K. Gupta
Remediation Manager

Enclosure

cc: Jim Brown, GAEPD
Jim McNamara, GAEPD
Brett Mitchell, Georgia Power
Paul Taylor, Atlantic Richfield Company
Victor Magar, ENVIRON

ENVIRON

MEMORANDUM

Date:	November 2, 2012
To:	John Morris, Honeywell Prashant Gupta, Honeywell
From:	Victor Magar, ENVIRON Mary Sorensen, ENVIRON
Cc:	Tim Iannuzzi, ARCADIS, Inc. Paul Taylor, ARCO Brett Mitchell, Georgia Power Darahyl Dennis, Georgia Power
Re:	LCP Chemicals Site, Brunswick, GA – Remedial Goal Options

This memorandum proposes Remedial Goal Options (RGOs) for use at the LCP Chemicals Site, Brunswick, Georgia (the “Site”). RGOs establish a range of acceptable risk-based media concentrations to be employed by risk managers in a Feasibility Study (FS). RGOs are derived from site-specific risk assessment results and EPA Region 4 supports using multiple lines of evidence to develop RGOs, including toxicity testing, benthic community evaluations, and site-specific biota-to-sediment accumulation relationships. The risk manager uses RGOs to establish remediation action levels (RALs) for Chemicals of Concern (COCs).[1] The RALs, derived from the risk-assessment RGOs, will be considered in the FS and included in the Proposed Plan and the Record of Decision (ROD).

In a letter dated November 30, 2011, EPA Region 4 and the Georgia Environmental Protection Division (GAEPD) proposed sediment RGOs for the estuary (OU1) at the Site for the FS for the following for COCs:

- Aroclor 1268 (Ar1268)
- Mercury (Hg)
- Lead (Pb)
- Total polynuclear aromatic hydrocarbons (TPAH)

RGOs were designated by EPA as either “Area Average” or not-to-exceed (NTE) values. Area averages reflect RGOs for human health and ecological receptors that consume

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[1] RALs also are referred to as Cleanup Levels (CL) that eventually become Remediation Goals (RGs). Generally, RG refers to levels promulgated in the ROD and reflect final goals established in the FS risk-management process.

waterfowl and fish and they were derived using risk-based calculations presented in the EPA's RGO letter and the baseline ecological risk assessment (BERA). RGOs designated as NTE are based on results of sediment toxicity tests for benthic organisms. The EPA RGO Memo identifies area average values for Ar1268 and Hg, and NTE values for all four constituents, as follows:

Area Average Values

Ar1268	2-4 mg/kg in the creeks and marsh areas
Hg	1 mg/kg in all four creeks (Main Canal, Eastern Creek, Western Creek Complex, and Purvis Creek) combined

NTE Values

Ar1268	6 mg/kg
Hg	2 or 4 mg/kg
Pb	40, 60, or 90 mg/kg
TPAH	1.5, 2.5, or 4.0 mg/kg

The EPA's RGO letter provides that in addition to using the RGOs proposed by EPA and GAEPD, "Honeywell may also utilize other RGO ranges for each of these hazardous substances, as long as it provides the justification for using such ranges in its development and screening of remedial action alternatives." As provided for in the letter, this memorandum proposes other RGO ranges for the four COCs for consideration in the FS, and provides justification for using these proposed ranges. We propose alternative Ar1268 and Hg RGOs for area averaging and alternative NTE values for all four constituents (Ar1268, Hg, TPAH, and Pb). The RGOs proposed in this letter are derived from the EPA-approved BERA and human health risk assessment (HHRA) documents. In the interest of brevity, we do not redefine those values, but instead reference respective BERA and HHRA tables.

We believe that the proposed RGOs described herein support protective management decisions that are consistent with the EPA's *Ecological Risk Assessments and Risk Management Principles for Superfund Sites*[2] directive (Superfund Sites Directive). The primary principle of this directive states that "Superfund's goal is to reduce ecological risks to levels that will result in the recovery and maintenance of *healthy local populations and communities of biota*." EPA advocates a multiple-lines-of-evidence approach to assess risks and make risk-management decisions. "Through the use of field studies and/or toxicity tests,

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[2] OSWER Directive 9285.7-28P. 1999. *Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites*. http://www.epa.gov/oswer/riskassessment/ecorisk/pdf/final99.pdf

several types of data may be developed to provide supporting information for a *lines-of-evidence* approach to characterizing site risks. *This approach is far superior to using single studies or tests or measurements* to determine whether or not the observed or predicted risk is unacceptable." For this reason, we think it is important to consider a broader range of RGOs beyond those developed by EPA Region 4, given the substantial ecological and toxicological data and information that exist for this Site, which we believe collectively suggest that ecological risks at the site are more limited than the application of EPA Region 4's RGOs would suggest.

The Superfund Sites Directive also recommends that the risk manager ask the following question: *Will the cleanup cause more ecological harm than the current site contamination?* Removal or in-situ treatment of the contamination may cause more long-term ecological harm (often due to wide spread physical destruction of habitat) than leaving it in place. The likelihood of the response alternatives to achieve success and the time frame for a biological community to fully recover should be considered in remedy selection. The evaluation of ecological effects resulting from implementing various alternatives should be discussed in the FS and should include input from the ecological risk assessor and the federal and/or state trustees responsible for the resources that may be impacted by the response.

NTE RGO VALUES FOR CONSIDERATION

Table 1 shows Sediment Effects Concentration (SEC) values for amphipod survival, as reported in the OU1 BERA. Highlighted cells identify nearest RGO values; for example, the EPA-recommended RGO values for Ar1268 (6 mg/kg) and Hg (4 mg/kg) correspond to Threshold Effects Levels (TEL) for both chemicals, respectively. The range of EPA-recommended RGOs for TPAH align with Effects Range-Low (ER-L), probable effects levels (PEL), and Effects Range-Mean (ER-M) values, and the range of EPA-recommended RGOs for Pb align with TEL, ER-L, and PEL values. The results in Table 1 suggest that ER-L, PEL, and ER-M values for amphipod survival may be used to establish acceptable RGOs for site-specific COCs.

Table 1. Amphipod Survival SECs Compared to NTE-Values Proposed by EPA[1]

	TEL	*ER-L*	*PEL*	*ER-M*	*AET*
Hg	4.2	11.3	15.4	21.7	62
Ar1268	6.2	16	20.3	32	64
TPAH	0.8	1.5	2.1	4.4	6
Pb	40.8	60	88.4	196	177

[1] BERA Table 4-20

Highlighting indicates proximity of EPA-recommended RGO values to Amphipod SECs

Table 2 shows SEC values for grass shrimp as reported in the OU1 BERA. According to Table 2, for grass shrimp, the Hg NTE RGO value falls between the ER-L and PEL, Ar1268 and TPAH NTE RGOs fall between their respective TEL and ER-L values, and the highest Pb NTE RGO is less than the TEL value.

Table 2. Grass Shrimp SECs Compared to NTE-Values Proposed by EPA[1]

		TEL		*ER-L*		*PEL*	*ER-M*	*AET*
Hg		1.4		3.2	RGO	4.8	10.5	11
Ar1268		3.2	RGO	12		10.7	20	41
TPAH		1.6	RGO	4		4.5	6.1	11.5
Pb	RGO	139		1190		198	1190	419

[1] BERA Table 4-22

Highlighting indicates proximity of EPA-recommended RGO values to grass shrimp SECs

The EPA's proposed RGOs are among the lowest of the derived SECs and were derived using organisms known to be among the most sensitive that can be used in toxicity testing. While these SECs can be used to help guide a remedy decision, they should not define the decision. Instead, we believe that decisions regarding the application of all RGOs should consider the following factors.

- The protectiveness of the RGO must be balanced against remedial decisions that are destructive to the marsh.
- SECs are not a threshold above which adverse effects are guaranteed. For example, a TEL reflects a concentration that is the geometric mean of the 15th percentile of data showing “no effects.” That means 85 percentiles of data had higher concentrations and showed “no effect.” Therefore, one could expect to exceed the TEL in numerous places and show no adverse impacts, even to the most sensitive organisms. This is particularly important to consider, given the fact that actual statistical relationships between sediment chemistry of the COCs and toxicity have not been found at the Site, and that toxicity is also pervasive in sediment from the reference/background locations for the Site.
- *In situ* studies of the benthic community composition also showed that many organisms were present at locations that had elevated levels of the various COCs above their respective ER-M and AET levels. These studies were not as comprehensive as the sediment toxicity testing studies and in no way negate the value of the toxicity testing studies or the SECs to guide the remedy decisions, but they do provide a line of evidence to balance those risk management decisions.
- Amphipods are well established as being among the most sensitive of laboratory testing organisms. However, they also are a very small part of any natural benthic community (the BERA describes that less than 5 percent of the taxa at reference/background locations were amphipods).

- Even the AET, which by definition is the highest concentration where no toxicity was observed, is not a threshold above which adverse effects are guaranteed. This is particularly true for the grass shrimp AET, as the proposed alternative RGO for Hg exceeds the grass shrimp AET and therefore, the remedy will still be protective of the benthic community, including grass shrimp. When considering grass shrimp studies, the RGO should consider the multiple lines of evidence available for grass shrimp and should not focus on a single study or measurement end point to determine whether or not the observed or predicted risk is unacceptable.
  - *In situ* studies showed that grass shrimp embryos hatched with the same success from the LCP Estuary as from reference areas, even when collected from locations that had elevated levels of Hg, Ar1268, or both constituents above their respective ER-M and AET levels.
  - A TEL based on embryo development is more sensitive than embryo hatching. However, embryo development was not an endpoint studied in the *in situ* studies. Nonetheless, we can still learn from this to reasonably apply RGOs for grass shrimp. For example, according to the BERA,[3] the TEL for grass shrimp for embryo hatching endpoint is 3.9 mg/kg. Accordingly, the hatching success observed in situ would appear to confound the TEL results, if the TEL were a threshold above which effects should be seen.
  - Most of the toxicity testing studies relied on naïve shrimp (shrimp cultivated for this study and previously unexposed to sediment from the Site) which would be more sensitive than shrimp from the site.
  - RGOs should consider how organisms use the estuary. Grass shrimp are very mobile and are unlikely to be exposed to any single location for long periods of time. As tides ebb, grass shrimp follow the tides and will move from their locations. Thus, NTE RGOs are not readily applicable to grass shrimp.
  - Grass shrimp prefer to live atop submerged grasses and carry their broods against their bodies, which limits their potential exposures to sediment contaminants (Figure 1). The grass shrimp in the laboratory toxicity studies were confined to a very small space for 56 days and were directly exposed to sediment (i.e., the sediment microcosms did not have grass, which grass shrimp prefer), which results in a conservative estimate of toxicity. Within the LCP Estuary, grass shrimp are not confined to any location for 56 days. Rather, they move about the estuary over large areas, more likely measured by many acres as they are nektonic and move with the tide. Thus, the studies substantially and artificially increased

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[3] BERA Table 4-22.

chemical exposures, rendering the studies highly conservative. Knowing that grass shrimp at the site are unimpaired, based on the in situ studies, reinforces this understanding.

Figure 1. Grass shrimp photos.

The conservative nature of the BERA suggests that a broader range of NTE values, employing a full range of amphipod and grass shrimp SEC values, is appropriate for the Site. Table 3 shows the range of surface sediment target values that we propose. Although the ER-L, PEL, and ER-M values all would be appropriate for Hg and Ar1268, we propose using the more conservative ER-L and PEL values for the Hg and Ar1268 target sediment concentrations. For Pb and TPAH, we extend the range to include ER-M and AET values. Further, we are not referring to these values as “NTE,” because of the constraints that NTE establishes on risk-management decisions. Instead, we refer to the proposed RGOs as target sediment concentrations.

Table 3. Amphipod and Grass Shrimp SECs Compared to Proposed Sediment Target Concentrations

	Amphipod SEC Values[1]				
	TEL	*ER-L*	*PEL*	*ER-M*	*AET*
Hg	4.2	11.3	15.4	21.7	62
Ar1268	6.2	16	20.3	32	64
TPAH	0.8	1.5	2.1	4.4	6
Pb	40.8	60	88.4	196	177
	Grass Shrimp SEC Values[2]				
	TEL	*ER-L*	*PEL*	*ER-M*	*AET*
Hg	1.4	3.2	4.8	10.5	11
Ar1268	3.2	12	10.7	20	41
TPAH	1.6	4	4.5	6.1	11.5
Pb	139	1190	198	1190	419

[1] BERA Table 4-20

[2] BERA Table 4-22

Highlighting indicates proximity of RGO values to SECs

AREA AVERAGE RGO VALUES FOR CONSIDERATION

For Ar1268, we recommend employing an Area Average value of 4 mg/kg, consistent with the EPA’s November 2011 letter. For the Hg Area Average, we recommend a value of 2 mg/kg. Because the risk-driver for mercury is based on consumption of fish, the Hg Area Average should focus on creeks, not marsh areas, consistent with the approach recommended in the EPA's RGO letter. The FS will show Area Averages for all areas (e.g., Domain 1 and 2, particularly with regard to the green heron) and will demonstrate risk reduction from the proposed remedy alternative.

SUMMARY OF PROPOSED RGO VALUES AND FS LINES OF EVIDENCE

Table 4 summarizes our proposed RGO values for the Site. Combined with the RGOs proposed by EPA, we believe that these RGOs provide a range of sediment COC concentrations that, when employed, are conservatively protective of human health, fish/wildlife receptors, and of the benthic community.

Table 4. Summary of Proposed RGO Values in Addition to the EPA RGOs

Constituent	*SWAC*	*SEC-Based Target Sediment Concentrations*			
		ER-L	PEL	ER-M	AET
Ar1268	4	16	20	—	—
Hg	2	11	15	—	—
TPAHs	—	—	—	—	6
Pb	—	—	—	200	—

We believe that the development of a range of RGOs is appropriate for consideration in the FS. The additional RGOs presented in this memorandum establish a broader range of values to manage risks at the Site, and we believe better balances the damage/benefit ratio that arises from the inherent uncertainty in the science. The application of RGOs in the FS and remedy selection process will be considered in conjunction with, and as part of, the nine National Contingency Plan (NCP) criteria pursuant to the Superfund regulations. This explanation will include a discussion of the risk basis for remediation, the relative risk reduction achieved by the remedy, and the balance achieved between short and long-term ecological harm.

Appendix G
Remedial Goal Option Correspondence

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Remedial Goal Options (RGO) Ranges for the Remedial Action Alternatives for OU1 (Estuary): LCP Chemicals Superfund Site

Agency Reply Letter

Brunswick, Glynn County, Georgia

USEPA November 20, 2012

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

NOV 2 0 2012

Ref: 4WD-SRB

Via Delivery as Email-attachment to (Prashant.gupta@honeywell.com) and U.S. Mail

Mr. Prashant K. Gupta
Honeywell, Inc.
4101 Bermuda Hundred Road
Chester, Virginia 23836

Re: Remedial Goal Option (RGO) Ranges for the Remedial Action Alternatives for OU1 (Estuary): LCP Chemicals Superfund Site (Site), Brunswick, Glynn County, Georgia

Dear Mr. Gupta:

Thank you for your letter dated November 2, 2012, in which Honeywell, Inc. proposes to use additional RGO ranges for the contaminants of concern (COCs) in the development and screening of remedial action alternatives for OU1. You confirmed that the company will also utilize all the RGOs the U.S. Environmental Protection Agency provided in its November 30, 2011 letter as well.

While the EPA does not agree with some of the technical points in the memorandum about the selection of RGO ranges attached to your letter, it acknowledges that the memorandum does provide useful information which the EPA and the Georgia Environmental Protection Division will consider during their review of the remedial alternatives developed for OU1 in the Feasibility Study.

If you have any questions regarding the preceding, please contact me at (404) 562-8937.

Sincerely,

Galo Jackson

Galo Jackson, P.G.
Remedial Project Manager
Superfund Remedial Branch

cc: J. McNamara, EPD

Appendix G
Remedial Goal Option Correspondence

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Remedial Goal Options (RGO) Ranges for the Remedial Action Alternatives for OU1 (Estuary): LCP Chemicals Superfund Site

Letter

Brunswick, Glynn County, Georgia

USEPA February 20, 2013b

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

FEB 2 0 2013

Ref: 4WD-SRB

Via Delivery as Email-attachment to Prashant.gupta@honeywell.com and U.S.Mail

Mr. Prashant K. Gupta
Honeywell, Inc.
4101 Bermuda Hundred Road
Chester, VA 23836
Dear Mr. Gupta

Re: Remedial Goal Option (RGO) Ranges for the Remedial Action Alternatives of OU1 (Estuary): LCP Chemicals Superfund (Site), Brunswick, Glynn County, GA

Dear Mr. Gupta:

On November 30, 2011, the Environmental Protection Agency (EPA) sent Honeywell International, Inc. (Honeywell) a letter, concurrently approving the August 2011 draft of the Operable Unit 1 (the Estuary) Human Health Risk Assessment and directing the company to use a range of remedial goal options (RGOs) for the Site's four contaminants of concern (COCs), in developing and screening the remedial action alternatives in the draft feasibility study (FS). The November 2011 letter provided Honeywell the opportunity to utilize other RGO ranges for the COCs, as long as justification was provided, to develop alternatives for consideration.

Following a series of facilitated meetings attended by representatives of the EPA, the State of Georgia Environmental Protection Division (GaEPD) and the responsible parties, on November 2, 2012, Honeywell responded to EPA's November 2011 RGO letter, providing additional RGOs for use in the draft FS.

This is to confirm that during the November 29, 2012 meeting, the EPA and the GaEPD did agree to accept the following RGO values as an upper boundary for use in developing and screening the remedial action alternatives is the draft FS:

- Aroclor-1268: 16 parts per million (ppm);
- Mercury: 11 ppm;
- Lead: 177 ppm; and
- Total polynuclear aromatic hydrocarbons: 4 ppm.

If you have questions regarding the preceding, please contact me at (404) 562-8937.

Sincerely,

Galo Jackson

Galo Jackson, P.G.
Remedial Project Manager
Superfund Remedial Branch

cc: J. McNamara, GaEPD

Appendix G
Remedial Goal Option Correspondence

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Remedial Goal Options (RGO) Ranges for Remedial Action Alternatives for OU1 (Estuary): LCP Chemicals Superfund Site

Letter

Brunswick, Glynn County, Georgia

USEPA March 8, 2013c

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

Ref: 4WD-SRB

MAR [illegible] 2013

Via Delivery as Email-attachment to Prashant.gupta@honeywell.com and U.S.Mail

Mr. Prashant K. Gupta
Honeywell, Inc.
4101 Bermuda Hundred Road
Chester, VA 23836
Dear Mr. Gupta

Re: Remedial Goal Option (RGO) Ranges for Remedial Action Alternatives for OU1 (Estuary): LCP Chemicals Superfund (Site), Brunswick, Glynn County, GA

Dear Mr. Gupta:

The purpose of this letter is to further clarify previous correspondence dated November 30, 2011 and February 20, 2013 on the above-referenced subject.

On November 30, 2011, the U.S. Environmental Protection Agency sent Honeywell International, Inc. (Honeywell) a letter, concurrently approving the August 2011 draft of the Operable Unit 1 (the Estuary) Human Health Risk Assessment and directing the company to use a range of remedial goal options (RGOs) for the Site's four contaminants of concern (COCs) in developing and screening the remedial action alternatives in the draft feasibility study (FS). The November 2011 letter provided Honeywell the opportunity to utilize other RGO ranges for the COCs, as long as justification was provided, to develop alternatives for consideration.

Following a series of facilitated meetings attended by representatives of the EPA, the State of Georgia Environmental Protection Division (GaEPD) and the responsible parties, on November 2, 2012, Honeywell responded to EPA's November 2011 RGO letter, proposing additional RGOs for use in the draft FS. In my recent correspondence dated February 20, 2013, specifying the upper-bound RGO values for use in developing and screening the remedial action alternatives in the draft FS, I neglected to address the proposed area average value for mercury of 2 parts per million (ppm). To eliminate any confusion, I am providing below a summary of the RGO ranges that the EPA and GaEPD agreed Honeywell could use to develop and screen the remedial action alternatives in the draft FS. Note that the RGOs presented in the EPA's November 30, 2011 letter should be presented as a starting point in the draft FS, with risk management and feasibility and/or implementability factors used to justify any departure from these RGOs.

Contaminant of Concern	SWAC[1] RGO Range	Benthic Community RGO
Aroclor 1268	2-to- 4 ppm	6-to-16 ppm
Mercury	1-to-2 ppm	4-to-11 ppm
Total PAHs	--	4 ppm
Lead	--	90- to-177 ppm

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[1] Surface weighted area average

If you have questions regarding the preceding, please contact me at (404) 562-8937.

Sincerely,

Galo Jackson, P.G.
Remedial Project Manager
Superfund Remedial Branch

cc: J. McNamara, GaEPD

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Appendix H
Cost Estimates

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:
Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:
ENVIRON International Corporation

Anchor QEA, LLC

Date:
June 2, 2014

Deleted: October 18, 2013¶

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Contents

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Acronyms and Abbreviations

CM	construction management
CY	cubic yard
FS	feasibility study
gpm	gallons per minute
LTM	long-term monitoring
TSCA	Toxic Substances Control Act

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1 Introduction

This appendix provides the basis for the cost estimate presented in Section 6 of the *Feasibility Study - LCP Chemical Superfund Site, Operable Unit No. 1 (Estuary), Brunswick, GA* (FS) Report. Six sediment remedial alternatives were evaluated, including:

- Alternative 1: No action
- Alternative 2: Sediment Removal in SMA-1
- Alternative 3: Sediment Removal, Capping, and Thin Cover in SMA-1
- Alternative 4: Sediment Removal in SMA-2
- Alternative 5: Sediment Removal, Capping, and Thin Cover in SMA-2
- Alternative 6: Sediment Removal, Capping and Thin Cover in SMA-3

The six alternatives include, in some combination, the following items:

- Removal of 1.5 feet of sediment with placement of 1 foot of clean backfill material
- Placement of cap material consisting of a 6-inch sand isolation layer and a 6-inch erosion protection layer
- Thin-cover placement involving application of a thin layer of 6 inches of clean material over existing vegetated marsh areas

Table H-1 summarizes dredge volumes and remediation areas associated with each of the remedy components included in each alternative. Some of the key factors incorporated in the development of estimated cost for each alternative include the following items:

- Large tidal variations, ranging from 7 to 9 feet
- Narrow creeks (less than 10 ft wide) with shallow draft (less than 2 ft) restrictions
- Daily inundation of offshore work areas
- Limited land access to offshore remediation areas
- Low strength marsh environment, limiting equipment productivity/effectiveness

The cost estimate includes indirect (nonconstruction and overhead) costs, direct (construction) costs and reoccurring costs (annual operation and maintenance). All estimated costs are provided in 2013 dollars.

The following sections describe the basis of the cost estimate. Section 2 summarizes the indirect costs associated with each of the alternatives. Section 3 describes the direct construction costs associated with each of the remedial technologies that make up the sediment remedial alternatives. Section 4 outlines reoccurring costs associated with the remedy, and Section 5 provides a summary overview of the estimated costs by remedy alternative.

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In order to arrive at a reasonable, FS-level cost estimate, various assumptions were made regarding the predicted means and methods of construction. Many of these assumptions may change during the design and contractor bidding processes. Thus, they are intended only to establish a basis for costs and are not intended to direct the means and methods of construction.

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2 Indirect Costs

Indirect costs include nonconstruction and overhead-related costs. For the FS, indirect costs include costs associated with the implementation of institutional controls, studies, design (engineering, plans and specifications), project management, and construction management (CM).

2.1 Institutional Control

Institutional control costs are included as a single lump-sum cost item for each alternative; costs are assumed to be consistent between alternatives and are not expected to vary significantly based on remedy footprint or construction methodology.

2.2 Predesign investigation and Reporting

The predesign investigations and reporting are included in all alternatives as a single lump-sum cost item; costs are assumed to be consistent between alternatives and are not expected to vary significantly based on remedy footprint or construction methodology. This cost is representative of the anticipated costs to collect and analyze pertinent information (e.g., bench scale sediment dewatering, stabilization, debris and topographic surveys) prior to final design of the selected alternative.

2.3 Remedial Design

The remedial design costs are estimated as 8% of the total direct construction costs of each alternative. This determination was based on past experience with design effort and agency interaction on projects of similar scope.

2.4 Construction Management

The CM costs have been estimated in this analysis as 8% of the total direct construction costs of each alternative. This determination was based on past experience with CM and construction quality assurance efforts on projects of similar site conditions.

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3 Direct Construction Costs

Direct construction costs were developed using estimated material quantities and anticipated labor crew, construction equipment, and production rate estimates. Direct construction tasks include mobilization and site preparation, dredging operations, capping operations, thin cover placement operations, marsh restoration, and demobilization and staging-area restoration.

The construction schedule varies for each sediment remedial alternative based on dredging quantity, capping area, and expected production rates throughout the various conditions of the LCP Site, Operable Unit 1 (OU1). The construction season is not restricted, and remedial activities are expected to occur year round. Costs assume a 12 hours per day, 5 days per week schedule.

3.1 Mobilization and Site Preparation

Mobilization and site preparation cost elements include the following costs associated with materials, equipment, and labor:

- Mobilization of general construction support material and equipment to the site
- Establishing necessary temporary facilities at the site
- Construction of the staging areas (for regulated and nonregulated material)
- Installation of soil erosion and sediment controls
- Construction of access roads to the remediation areas

The majority of the cost elements in this section are presented on a lump-sum basis to represent the cost of completing each element, and it is assumed that minimal additional costs for maintenance/repair during construction are required. Mobilization of equipment, access roads and associated costs are proportional to the scope and extent of each remedial footprint of each alternative (Table H-2).

3.2 Dredging

Sediment removal cost elements include bathymetric and topographic surveys, debris removal, sediment removal, turbidity controls and water quality monitoring, sediment dewatering/stabilization, transport and disposal of removed sediments, shoreline stabilization along creek boundaries, and backfill testing and placement operations.

Sediment removal costs were developed separately for different areas of OU1 to differentiate costs associated with deep-water removal (North and South Purvis Creek), shallow-water/marsh removal (LCP Ditch, Eastern Creek, Western Creek Complex, Domain 3 Creek, Dillon Duck, Domain 1A Marsh, Domain 2 Marsh & Domain 3 Marsh), and removal of regulated or nonregulated material.

Equipment and labor assumed for deep-water removal includes excavators operating on flexi-float platforms and performing sediment removal using a hydraulically operated environmental

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bucket. Sediment would be removed and placed into small scows and transported to a temporary mooring facility. Material would be offloaded mechanically and transported by truck to the on-site staging area for dewatering/stabilization.

The anticipated equipment and labor assumed for shallow water/marsh removal includes excavators operating from landside using mats and/or the constructed access road for access to the remedy areas. Removal would be performed using a hydraulically operated environmental bucket. Sediment would be removed and placed into trucks and transported to the on-site staging area for dewatering and/or stabilization.

Approximately 1 foot of clean material will be backfilled over the areas where sediment was removed utilizing the same equipment used for sediment removal operations. Material is expected to be placed in a manner to minimize compaction and to promote reestablishment of benthic or marsh habitat.

Excavated material is expected to dewater on a constructed slack drying pad prior to stabilization. Material transported via truck will be end dumped onto the pad and managed to promote drying of the sediments. Once free water has been removed, material will be stabilized for transportation and disposal using Portland cement or other pozzolanic materials, assumed for this estimate to be blended in at a 15% by weight ratio. Blending is assumed to be accomplished using a hydraulic excavator used to turn over sediment and mix in reagent prior to load out. Water generated during the dewatering and handling process will be managed through an on-site water treatment plant.

Once the material is sufficiently dewatered and stabilized, it will be transported to an approved disposal facility. Costs currently assume regulated material will be transported to and disposed at a Toxic Substances Control Act (TSCA) facility—assumed to be the facility in Emmelle, Alabama for the purpose of this cost estimate. Nonregulated materials are assumed to be disposed at the Camden County, Georgia landfill facility. Debris removed from within the allowable dredging limits will also be transported to the Camden County, Georgia landfill for disposal.

Costs associated with the health and safety program at the site vary throughout construction based on the duration and number of concurrent operations. Costs include time and materials for a certified industrial hygienist to be present on-site.

3.2.1 Quantities

Sediment removal volumes have been calculated using a 1.5-foot removal depth over the entire remedial footprint designated for sediment removal for each alternative. A 0.5-foot overdredging allowance was added to the proposed removal depth to account for removal inefficiencies. The total removal volumes represent the combination of the deep water, shallow water, and marsh removal volumes.

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Dewatering operations costs assume that the full volume of sediment removed from the site will be processed at an on-site dewatering and stabilization area. Costs assume the use of a stabilization agent at a rate of 15% by weight, to aid dewatering.

Disposal volumes are calculated assuming a density of dewatered sediment at 1.35 tons per cubic yard (CY). Debris volume is calculated as 15% of the total removal.

Backfill placement volumes assume a 1.0-foot sand backfill layer will be placed over the entire dredging area following removal operations. A 0.25-foot over-placement tolerance is added to the proposed placement thickness, which adjusts the total estimated backfill placement volume to represent a 1.25-foot layer over the entire dredging footprint.

3.2.2 Unit Costs

Dredging unit rates consider labor, equipment, and materials necessary to complete operations and integrate a projected production rate to determine a cost per CY of removal. These costs include costs associated with sediment removal, dewatering/stabilization, transportation and disposal, and backfilling of dredge areas. Production rates are calculated assuming equipment capacities and cycle times (Table H-3). Production rates consider operational downtime due to typical maintenance, repairs, and tidal cycle impacts. Costs for removal of regulated material include decontamination at the end of operations.

Dewatering costs assume passive dewatering of the mechanically-dredged sediment and operation of an on-site water treatment system. For water treatment, a 300-gallon-per-minute (gpm) system with granular activated carbon, organoclay, and metals media was assumed. It was also assumed that treatment media is replaced every three months during dewatering operations. The costs for dewatering and water treatment vary depending on the estimated dredging duration that is controlled by the dredging volume.

Transportation costs have been developed for transport and disposal of both regulated and nonregulated material. Regulated material is transported to a disposal facility located in Emmelle, Alabama, and nonregulated material and project debris are transported to the Camden County, Georgia, landfill.

The backfill placement costs were calculated by considering labor and equipment necessary to complete operations and integrating a calculated production rate to determine a cost per CY. Costs for purchase and delivery of the backfill material are included in this line item.

3.3 Capping

Capping includes all cost associated with the purchase, transport and placement of an engineered cap in OU1. Cost elements developed in this section include purchase and placement of the isolation cap layer and the erosion protection layer.

The equipment and labor for deep-water and shallow-water/marsh capping operations are similar to the equipment assumed for sediment removal operations. Placement uses hydraulic excavators operating from flexi-float platforms, or from constructed haul roads to remedial

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areas. Material is placed using hydraulic environmental clamshell buckets. Production rates are comparable to backfilling operations for dredging.

Health and safety costs depend on the remedy duration and types of equipment associated with the remediation. Costs include time and materials for a certified industrial hygienist based on the duration of capping operations.

3.3.1 Quantities

The proposed cap includes both an isolation layer and erosion protection layer, consisting of sand placed directly over the existing sediments for isolation followed by an armor stone layer for erosion protection. The sand layer is 0.5 feet thick plus 0.25-foot over-placement tolerance for a total layer thickness of up to 0.75 feet. Similarly, the armor stone layer is 0.5 feet thick plus 0.25-foot over-placement tolerance for a total layer thickness of up to 0.75 feet.

3.3.2 Unit Costs

Capping unit rates consider labor and equipment necessary to complete operations and integrate a calculated production rate to determine a cost per CY. Production rates are calculated assuming equipment capacities and cycle times (Table H-4). When calculating production rates, consideration is given to operational downtime due to typical maintenance, repairs, and tidal cycle impacts.

3.4 Thin-Layer Cover Placement

The thin-layer cover placement includes costs associated with the purchase, transport, and placement of a thin-layer cover at designated areas of the marsh. Locations receiving thin-layer cover vary depending on the proposed alternative. This cost estimate assumes that thin-layer covers will be placed hydraulically, with sand materials slurried for transport and placement in designated areas.

Health and safety costs depend on the duration and types of equipment associated with remediation. Costs include time and materials for a certified industrial hygienist based on the duration of thin-layer cover operations.

3.4.1 Quantities

The proposed thin-layer cover consists of a sand layer placed directly over the existing sediments. For estimating cost purposes, the thin-layer cover was assumed to be 0.5 feet thick plus 0.25-foot over-placement tolerance for a total layer thickness of up to 0.75 feet.

3.4.2 Unit Costs

Thin-layer cover unit rates considered labor and equipment required to operate the pipeline transport and placement system. Costs are integrated into an estimated production rate. The estimated production rate considers the distance of the proposed thin-layer cover areas from the assumed material loading area, percent solids, and equipment capacities (Table H-5). When calculating production rates, consideration is given to operational downtime due to typical maintenance, repairs, and tidal cycle impacts.

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3.5 Marsh Restoration

The marsh restoration includes repairs to areas of the marsh impacted by construction, including access roads. Marsh restoration includes restoring impacted areas with appropriate plantings on 2-foot centers, except for the thin-cover placement areas which do not require plantings to promote recovery. The footprint for marsh restoration varies for each alternative depending on the access road layout necessary to reach the proposed remedial areas.

3.6 Demobilization/Site Restoration

Demobilization and Site restoration costs include operations required to restore OU1 to conditions similar to those prior to the start of construction. This includes labor, equipment, and disposal costs to dismantle and dispose of the gravel and asphalt paving used to construct the on-site regulated material staging area, nonregulated material staging area, and Site access roads. Costs to breakdown and remove temporary facilities are based on previous project experience.

3.7 Construction Cost Contingency

The costs presented in this appendix are developed at the FS level and are provided for the purposes of comparison of the level of effort, schedule, and technical elements among the proposed sediment remedial alternatives. Actual costs may be higher or lower than the costs presented in the report—within a range typical of an FS level alternatives analysis (e.g., +50%/ -30%)—due to varying preremedy, remedy-implementation, and postremedy activities, subcontractor costs, and equipment for each alternative (USEPA 2000).

A construction cost contingency of 15% of the sum of direct construction costs is employed. This contingency is lower than the upper end of the recommended contingency by USEPA (2000), due to the fact that two independent construction estimates from reputable national contractors were used to validate and confirm cost assumptions and estimates. The two contractors conducted independent Site visits, met with the FS team, and relied on their experience on similar site environments, prior to developing their own independent estimates.

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4 Recurring Costs

Recurring costs include operations and maintenance and monitoring costs, applied after remedy implementation. Depending on the alternative, long-term monitoring (LTM) of cap areas, LTM of thin-layer cover areas, and of marsh restoration components of the remedy may be specified.

The cost for the LTM program has been estimated in this analysis as 15% of the total direct cost of each of the operations (cap, thin-layer cover and/or marsh restoration) of the alternative.

Conceptually, the LTM program would consist of the following:

- Physical monitoring of the capped, which would include periodic geophysical surveys and sampling.
- Physical monitoring of the thin layer cover areas, which would include periodic geophysical surveys and sampling.
- Biological monitoring of the marsh restoration areas, focusing on biological community metric.
- Physical monitoring following major storm events of a predetermined return interval, to characterize remedy stability.
- Chemistry monitoring, including sediment chemistry, water chemistry, and chemistry in fish, to measure remedy performance against RAOs

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5 Summary of Cost Estimates

A summary of total costs associated with each alternative is presented in Table H-6. The detailed FS cost sheets for Alternative 2 through Alternative 6 are presented in Tables H-7 through H-11.

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6 References

USEPA (U. S. Environmental Protection Agency). 2000. A Guidance to Developing and Documenting Cost Estimates during the Feasibility Study. Office of Emergency and Remedial Response. Washington DC. EPA 540-R-00-002/OSWER 9355.0-75.

Appendix H
Cost Estimates

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Tables

Table H-1
Summary of Remedy Alternatives
LCP Chemical, Brunswick, GA

Alternative		Remediation Area (Acres)	Dredge Volume (CY)
No Action			
ALT 1	No action	N/A	N/A
SMA-1 (48 Acres)			
ALT 2	Dredge & Backfill: all areas	47.5	142,800
ALT 3	Dredge & Backfill: LCP Ditch, Eastern Creek, and Western Creek Complex	8.2	26,800
	Cap: Domain 3 Creek, Purvis Creek North, and Purvis Creek South	16	
	Thin cover: Dillon Duck, Domain 1A, Domain 2, and Domain 3	23.3	
SMA-2 (18 Acres)			
ALT 4	Dredge & Backfill: all areas	17.6	56,690
ALT 5	Dredge & Backfill: LCP Ditch and Eastern Creek	6.5	21,620
	Cap: Domain 3 Creek	3	
	Thin cover: Dillon Duck, Domain 1A, and Domain 2	8.1	
SMA-3 (24 Acres)			
ALT 6	Dredge & Backfill: LCP Ditch and Eastern Creek	6.5	21,620
	Cap: Domain 3 Creek and Purvis Creek South	6	
	Thin cover: Domain 1A, Domain 2, and Dillon Duck	11.1	

ALT: alternative
N/A: not applicable
CY: cubic yard

Table H-2
Access Road and Dewatering/Staging Area Footprint
LCP Chemical, Brunswick, GA

Alternative	Access Road and Dewatering/Staging Area Footprint (Acres)
ALT 2	21.6
ALT 3	15.6
ALT 4	13.9
ALT 5	11.3
ALT 6	12.5

Table H-3
Production Rates for Mechanical Dredging
LCP Chemical, Brunswick, GA

Task	Production Rate	Units
Mechanical dredge – deep water	430	CY/day
Mechanical dredge – shallow water/marsh	350	CY/day
Mechanical placement of backfill	430	CY/day

CY/day: cubic yards per day

Table H-4
Cap Production Rates
LCP Chemical, Brunswick, GA

Task	Production Rate	Units
Mechanical placement of sand cap – deep water	350	CY/day
Mechanical placement of sand cap – shallow water/marsh	230	CY/day
Mechanical placement of armor stone cap – deep water	280	CY/day
Mechanical placement of armor stone cap – shallow water/marsh	190	CY/day

CY/day: cubic yards per day

Table H-5
Thin-Layer Cover Production Rate
LCP Chemical, Brunswick, GA

Task	Production Rate	Units
Thin-Layer Cover	170	CY/day

CY/day: cubic yards per day

Table H-6
Summary FS Costs for Remedial Alternatives
LCP Chemical, Brunswick, GA

Alternative		Area (Acres)	Total Estimated Cost (Present Day $M)	Estimated Cost per Acre (Present Day $M/Acre)
No Action				
ALT 1	No action	N/A	N/A	N/A
SMA-1 (48 Acres)				
ALT 2	Dredge: all areas	47.5	$64.80	1.37
ALT 3	Dredge: LCP Ditch, Eastern Creek, and Western Creek Complex	8.2	$38.70	0.82
	Cap: Domain 3 Creek, Purvis Creek North, and Purvis Creek South	16		
	Thin Cover: Domain 1A, Domain 2, Domain 3, and Dillon Duck	23.3		
SMA-2 (18 Acres)				
ALT 4	Dredge: all areas	17.6	$34.10	1.94
ALT 5	Dredge: LCP Ditch and Eastern Creek	6.5	$26.00	1.48
	Cap: Domain 3 Creek	3		
	Thin Cover: Dillon Duck, Domain 1A, and Domain 2	8.1		
SMA-3 (24 Acres)				
ALT 6	Dredge: LCP Ditch and Eastern Creek	6.5	$28.60	1.21
	Cap: Domain 3 Creek & Purvis Creek South	6		
	Thin Cover: Dillon Duck, Domain 1A, and Domain 2	11.1		

$M: million of dollars
$M/acre: million of dollars per acre
N/A: not applicable

Table H-7
Alternative 2 – Feasibility Study Cost Estimate
LCP Chemical, Brunswick, GA

Task		Quantity	Unit	Unit Cost	Total Cost
Indirect Costs					
1.01	Institutional Controls	1	LS	$250,000	$250,000
1.02	Predesign Investigations and Reporting	1	LS	$600,000	$600,000
1.03	Remedial Design		8%	$0	$3,884,320
1.04	Construction Management		8%	$0	$3,884,320
Direct Construction Costs					
2.0	Mobilization and Site Preparation	1	LS	$10,957,000	$10,957,000
3.0	Dredging	153,200	CY	$220	$34,215,000
4.0	Capping	0	CY	$0	$0
5.0	Thin-Layer Cover	0	CY	$0	$0
6.0	Marsh Restoration	1	LS	$2,564,000	$2,564,000
7.0	Demobilization and Site Restoration	1	LS	$818,000	$818,000
Recurring Costs					
8.0	Long-term Monitoring of Capping Areas	1	LS	$0	$0
9.0	Long-term Monitoring of Thin-Layer Cover Area	1	LS	$0	$0
10.0	Long-term Monitoring of Marsh Restoration Are	1	LS	$385,000	$385,000
				Contingency (15% of TDCC)	$7,283,100
				Total Alternative Cost	**$64,840,740**

CY: cubic yard
LS: lump sum
SF: square foot
TDCC: Total Direct Construction Cost

General notes and assumptions follow Table H-11

Table H-8
Alternative 3 – Feasibility Study Cost Estimate
LCP Chemical, Brunswick, GA

Task		Quantity	Unit	Unit Cost	Total Cost
Indirect Costs					
1.01	Institutional Controls	1	LS	$250,000	$250,000
1.02	Predesign Investigations and Reporting	1	LS	$600,000	$600,000
1.03	Remedial Design		8%	$0	$2,229,760
1.04	Construction Management		8%	$0	$2,229,760
Direct Construction Costs					
2.0	Mobilization and Site Preparation	1	LS	$8,318,000	$8,318,000
3.0	Dredging	26,800	CY	$360	$9,660,000
4.0	Capping	34,850	CY	$120	$4,193,000
5.0	Thin-Layer Cover	28,040	CY	$120	$3,233,000
6.0	Marsh Restoration	1	LS	$174,000	$1,734,000
7.0	Demobilization and Site Restoration	1	LS	$734,000	$734,000
Recurring Costs					
8.0	Long-term Monitoring of Capping Areas	1	LS	$629,000	$629,000
9.0	Long-term Monitoring of Thin-Layer Cover Area	1	LS	$485,000	$485,000
10.0	Long-term Monitoring of Marsh Restoration Are	1	LS	$260,000	$260,000
			Contingency (15% of TDCC)		$4,180,800
			Total Alternative Cost		**$38,736,320**

CY: cubic yard
LS: lump sum
SF: square foot
TDCC: Total Direct Construction Cost

General notes and assumptions follow Table H-11

Table H-9
Alternative 4 – Feasibility Study Cost Estimate
LCP Chemical, Brunswick, GA

Task		Quantity	Unit	Unit Cost	Total Cost
Indirect Costs					
1.01	Institutional Controls	1	LS	$250,000	$250,000
1.02	Predesign Investigations and Reporting	1	LS	$600,000	$600,000
1.03	Remedial Design		8%	$0	$2,014,800
1.04	Construction Management		8%	$0	$2,014,800
Direct Construction Costs					
2.0	Mobilization and Site Preparation	1	LS	$7,233,000	$7,233,000
3.0	Dredging	56,700	CY	$270	$15,527,000
4.0	Capping	0	CY	$0	$0
5.0	Thin Layer Cover	0	CY	$0	$0
6.0	Marsh Restoration	1	LS	$1,713,000	$1,713,000
7.0	Demobilization and Site Restoration	1	LS	$712,000	$712,000
Recurring Costs					
8.0	Long-term Monitoring of Capping Areas	1	LS	$0	$0
9.0	Long-term Monitoring of Thin-Layer Cover Area	1	LS	$0	$0
10.0	Long-term Monitoring of Marsh Restoration Are	1	LS	$257,000	$257,000
				Contingency (15% of TDCC)	$3,777,750
				Total Alternative Cost	**$34,099,350**

CY: cubic yard
LS: lump sum
SF: square foot
TDCC: Total Direct Construction Cost

General notes and assumptions follow Table H-11

Table H-10
Alternative 5 – Feasibility Study Cost Estimate
LCP Chemical, Brunswick, GA

Task		**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Indirect Costs					
1.01	Institutional Controls	1	LS	$250,000	$250,000
1.02	Predesign Investigations and Reporting	1	LS	$600,000	$600,000
1.03	Remedial Design		8%	$0	$1,508,640
1.04	Construction Management		8%	$0	$1,508,640
Direct Construction Costs					
2.0	Mobilization and Site Preparation	1	LS	$6,345,000	$6,345,000
3.0	Dredging	21,600	CY	$400	$8,670,000
4.0	Capping				
4.1	Sand	3,630	CY	$81	$293,500
4.2	Armor Stone	3,630	CY	$132	$478,500
5.0	Thin-Layer Cover	9,520	CY	$118	$1,128,000
6.0	Marsh Restoration	1	LS	$1,264,000	$1,264,000
7.0	Demobilization and Site Restoration	1	LS	$679,000	$679,000
Recurring Costs					
8.0	Long-term Monitoring of Capping Areas	1	LS	$116,000	$116,000
9.0	Long-term Monitoring of Thin-Layer Cover Areas	1	LS	$169,000	$169,000
10.0	Long-term Monitoring of Marsh Restoration Areas	1	LS	$190,000	$190,000
			Contingency (15% of TDCC)		$2,828,700
			Total Alternative Cost		**$26,028,980**

CY: cubic yard
LS: lump sum
SF: square foot
TDCC: Total Direct Construction Cost

General notes and assumptions follow Table H-11

Table H-11
Alternative 6 – Feasibility Study Cost Estimate
LCP Chemical, Brunswick, GA

Task	Quantity	Unit	Unit Cost	Total Cost
Indirect Costs				
1.01 Institutional Controls	1	LS	$250,000	$250,000
1.02 Predesign Investigations and Reporting	1	LS	$600,000	$600,000
1.03 Remedial Design		8%	$0	$1,653,280
1.04 Construction Management		8%	$0	$1,653,280
Direct Construction Costs				
2.0 Mobilization and Site Preparation	1	LS	$6,888,000	$6,888,000
3.0 Dredging	21,600	CY	$400	$8,604,000
4.0 Capping				
4.1 Sand	7,260	CY	$82	$598,500
4.2 Armor Stone	7,260	CY	$134	$971,500
5.0 Thin-Layer Cover	13,190	CY	$114	$1,505,000
6.0 Marsh Restoration	1	LS	$1,408,000	$1,408,000
7.0 Demobilization and Site Restoration	1	LS	$691,000	$691,000
Recurring Costs				
8.0 Long-term Monitoring of Capping Areas	1	LS	$236,000	$236,000
9.0 Long-term Monitoring of Thin-Layer Cover Areas	1	LS	$226,000	$226,000
10.0 Long-term Monitoring of Marsh Restoration Area	1	LS	$211,000	$211,000
			Contingency (15% of TDCC)	$3,099,900
			Total Alternative Cost	**$28,595,460**

CY: cubic yard
LS: lump sum
SF: square foot
TDCC: Total Direct Construction Cost

General notes and assumptions follow Table H-11

Feasibility Study Cost Estimate Assumptions
LCP Chemical, Brunswick, GA

General Notes

- All costs are provided in present day dollars and all cost expenditures are assumed to occur at the start of construction.
- Work is to be conducted 5 days per week, 12 hours per day. Work is to be conducted year round with no planned interruptions in operations.
- Costs do not include property costs (where applicable), access costs, legal fees, Agency oversight, or public relations efforts.
- These costs have been developed using currently available information regarding site characteristics, such as site bathymetry, potential debris, and physical properties of the existing sediment at the site. As information regarding these site characteristics changes or new information becomes available, these costs will be subject to change.
- These estimates are developed using current and generally accepted engineering cost estimation methods. Note that these estimates are based on assumptions concerning future events and actual costs may be affected by known and unknown risks including, but not limited to, changes in general economic and business conditions, site conditions that were unknown to Anchor QEA, LLC at the time the estimates were performed, future changes in site conditions, regulatory or enforcement policy changes, and delays in performance. Actual costs may vary from these estimates and such variations may be material. Anchor QEA, LLC is not licensed as accountants, or securities attorneys, and, therefore, make no representations that these costs form an appropriate basis for complying with financial reporting requirements for such costs.

Assumptions:

1.01 Institutional controls include deed restrictions, navigational controls and signage installation as deemed necessary.

1.02 Pre-design investigation includes all sampling, analysis and design work to be conducted prior to construction.

1.03 Remedial design work includes all plans, specifications and reporting necessary for construction to be implemented at the site. This has been preliminarily estimated as 8% of the direct construction costs based on best engineering judgment and previous experience at similar sites.

1.04 Construction management costs include necessary monitoring and oversight throughout construction. This includes only elevation verification after excavation, surface WQ measurement during dredging, and post backfill verification that the surface layer is clean. This cost has been preliminarily estimated as 8% of the direct construction costs based on best engineering judgment and previous experience at similar sites.

2.0 Mobilization and site preparation includes all pre-construction submittals and bonds. Also includes construction of temporary facilities, access roads, staging areas, mooring facilities and installation of soil erosion and sediment controls. Includes all costs necessary to mobilize construction equipment and general construction support materials necessary to complete the work.

3.0 Dredging costs include all equipment, labor, and materials necessary to perform the sediment removal operations at the site. Variations in dredging costs have been developed to account for adjustments in sediment disposal characterization, removal methodology due to site conditions and limited working times due to tidal cycles. Costs for sediment dewatering and disposal are also included in this task and vary depending on material characterization. This task also includes costs associated with turbidity controls, turbidity monitoring, health and safety oversight, and site surveying.

4.0 Capping costs include all equipment, labor, and materials necessary to perform the capping operations. Costs for delivery and placement of the cap components are included and placement cost variations have been developed to account for variable site conditions which impact production of this task. Also includes costs associated with turbidity monitoring and health and safety oversight.

5.0 Thin layer cover costs include all equipment, labor and materials necessary to perform the thin cover placement operations. Costs for delivery and placement of the cover material is included. It is assumed that thin cover placement will be conducted utilizing a pipeline transport system to delivery the slurried cover materials. Also includes costs associated with turbidity monitoring and health and safety oversight.

6.0 Marsh restoration costs include all equipment, labor and materials necessary to perform the restoration activities over the area impacted by the construction of access roads. Assumes that general plantings will be spaced on 2-foot centers over the restoration area.

7.0 Demobilization and site restoration involves removing equipment, materials, and labor from the site and restoring all disturbed areas to conditions similar to those existing prior to the start of construction. Disturbed areas include, at a minimum the two constructed staging areas, access roads, temporary site facilities, and temporary mooring facilities. It is assumed that only the top 2 inches of gravel on the access roads will be transported off site for disposal and that all remaining road fill material will be utilized in the remedy to the extent possible.

8.0 The cost for cap monitoringhas been estimated in this analysis as 15% of the total direct capping cost of the alternative.

9.0 The cost for thin layer cover monitoring has been estimated in this analysis as 15% of the total direct thin layer cover cost of the alternative.

10.0 The cost for marsh restoration monitoring has been estimated in this analysis as 15% of the total direct marsh restoration cost of the alternative.

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Appendix I
Review of Technical Issues: Thin-Cover Placement in *Spartina* Marsh and Potential Bioturbation Effects

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:
Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:
ENVIRON International Corporation

Anchor QEA, LLC

Date:
June 2, 2014

Deleted: October 18, 2013
Section Break (Continuous)

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Contents

List of Attachments

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Acronyms and Abbreviations

µg/g	microgram(s) per gram
cm	centimeter(s)
COC	chemical of concern
EMNR	enhanced monitored natural recovery
ft	foot/feet
g/cm^3	gram(s) per cubic centimeter
$g/m^2/yr$	gram(s) per meter(s) squared per year
m	meter(s)
m^2	meter(s) squared
MHW	mean high water
MLW	mean low water
MNR	monitored natural recovery
OU1	Operable Unit 1 (Estuary)
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
psu	practical salinity unit
USACE RDC	USACE Research and Development Center
SWAC	surface- weighted average concentration
USACE	United States Army Corp of Engineers
USEPA	United States Environmental Protection Agency

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Executive Summary

This appendix presents the results of a literature review regarding the effectiveness of using thin-cover placement as a remediation technique to accelerate natural recovery of contaminated sediments, and the feasibility of a smooth cordgrass (*Spartina alterniflora* or *Spartina*) salt marsh to naturally recover once the marsh has been remediated through the placement of a thin cover as a restoration layer. The effectiveness of placing a thin layer of sediment to restore natural marshes and the subsequent marsh recovery patterns has been closely monitored by the United States Army Corps of Engineers Research and Development Center (USACE RDC) since the 1990s. Case studies found in peer-reviewed literature were summarized for the following topics:

1. Methods for the placement of a thin-cover of clean sediment material on a salt marsh

   Case studies indicate several methods can be used to apply clean sediment material to a salt marsh. The most common for larger scale applications are direct application of clean material onto the marsh as a slurry through a hydraulic pipeline or high-pressure spray equipment. In recent times, manual application using flexible pipelines as well as sprays from barges (where navigational drafts permit this) also have been used.

2. Effectiveness of use as a remediation technique

   Thin covers have been demonstrated as effective remediation techniques at a number of sites. Thin covers enhance natural recovery processes and minimize impacts to the aquatic environment by effectively reducing the mobility, toxicity, and potential exposure to chemicals of concern (COCs).

3. Natural habitat recovery time of smooth cordgrass through varying depths of sediment

   Recovery times once a thin cover of sediment has been applied to a salt marsh varied depending on thickness of the layer and other site-specific factors, including hydrologic regime.

   - Marshes that received up to 23 centimeters (cm) (9 inches) of cover material reached stem densities comparable to reference areas within one to two growing seasons. It is conceivable that marshes where thinner layers are applied would recover even faster.
   - Sediment layers up to 38 cm (15 inches) of cover material had longer recovery times when compared to reference areas. This is because of the longer times required for the rhizomes to grow through a thicker layer.

4. *Spartina* tolerance characteristics

   Spartina tolerance characteristics are discussed, as this information is directly linked to the local hydrologic regime, and can inform the successful placement of thin-cover material in the marsh. Site-specific data show that the placement of a thin cover within the marsh is within limits of vegetation tolerance for OU1. Matching the characteristics of the cover material to existing conditions (e.g., total organic carbon or percent organic matter, particle size distribution such as percent fines, bulk density, and nutrient levels) may help accelerate *Spartina* regeneration and marsh recovery.

5. Potential issues related to bioturbation from fiddler crabs (*Uca spp*.) and other sediment dwelling organisms

   Bioturbation can potentially influence the effectiveness of capping and thin-cover to the extent that the process allows mixing of contamination at depth with the cleaner material at the surface.

   - The burrowing activity of fiddler crabs is a type of bioturbation, and burrowing can occur up to depths exceeding 30 cm (12 inches). However, the majority of fiddler crab burrows have been reported to be within 15 cm (6 inches). The deeper burrows are breeding burrows that are maintained and defended, so once established, there is little additional movement of sediment. In addition, the crabs forage and feed at the sediment surface not at depth, so they do not cycle sediment from depth to the surface as part of feeding activities.
   - Oligochaetes and polychaetes are sediment-dwelling worms that are often considered significant with regard to bioturbation, as these organisms consume sediment at depth and release material at the surface. These organisms are predominantly within the upper 15 cm of the sediment column, often in the uppermost 3-10 cm. There are papers showing that some burrowing may occur to depths beyond 15 cm, but the vast majority of burrowing is not to those depths.
   - In relatively low-risk areas, thin-cover restoration may be designed to allow for some mixing with underlying sediment; under this condition, the goal of thin-cover placement would be to substantially reduce or dilute surface sediment chemical concentrations, not to prevent contact with underlying sediment. For low-risk areas, such a dilution approach would reduce chemical concentrations to protective levels.

This review supports the use of a thin-cover restoration layer in the LCP marsh of 15 cm (6 inches) as a protective remedy alternative. Based upon the literature reviewed, thin-cover placement of clean material over the LCP marsh is expected to be an effective remediation technique that will achieve Site-specific remedial goals while minimizing disturbance to the aquatic environment. Regeneration of the *Spartina* marsh is expected to occur within approximately one to two years following application of the target thicknesses for the LCP Site. Furthermore, the proposed elevation changes resulting from thin-cover placement are well within *Spartina* tolerance limits. Recovery within one to two years is likely less than it would take for the more intrusive remediation of excavation of contaminated sediments and replanting. Bioturbation will not diminish the effectiveness of thin-cover in the marsh, as the majority of bioturbation will not extend below the thin cover. However, it is noted that bioturbation to depths below 15 cm cannot be prevented 100% of the time in 100% of the remediated area. The thin-cover is not intended as an uninterrupted chemical barrier, but as a layer to substantively

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reduce surface sediment chemical concentrations; therefore, some bioturbation beyond the cover depth does not diminish the effectiveness of this remedy and thus does not preclude its beneficial use as a protective remedy.

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1 Introduction

This appendix provides a summary of case studies on the effectiveness of using thin-cover placement as a remediation technique and the ability of a *Spartina alterniflora* (smooth cordgrass or *Spartina*) salt marsh to respond and recover following placement of thin layers of clean sediment material using different placement techniques.

Available information from published literature pertaining to thin-cover sediment placement on a salt marsh are compiled and reviewed here so as to evaluate its appropriate use as a remediation technique at the LCP Site, Brunswick, Georgia. The information summarized herein also will be used to recommend a thin cover that is suitable for the receiving marsh. To ensure that the information is applicable to the Site, the review focused on case studies from Georgia and the Southeast United States (i.e., USEPA Region 4) when available. This appendix is organized as follows:

This introduction (Section 1) is followed by a discussion of case studies where thin-cover placement was used as a remediation technique at a chemically impacted site and its reported effectiveness (Section 2). Section 3 discusses case studies where thin-cover was placed on *Spartina* and the reported marsh recovery rates. Section 4 discusses methods for thin-cover placement and associated limitations, and Section 5 lists smooth cordgrass tolerances and characteristics. Research on the composition of thin-cover materials to stimulate marsh recovery is summarized in Section 6 and tidal channel influences on marsh recovery are discussed in Section 7. Section 8 describes the impacts of bioturbation on thin-cover effectiveness. References are provided in Section 9. The document also includes the following attachments:

- Attachment I-1 presents case studies for thin-cover.
- Attachment I-2 provides additional citations for *Spartina* restoration.
- Attachment I-3 provides an overview of bioturbation data.

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2 Case Studies of Thin-Cover Placement of Sediment for Remediation of Chemically Impacted Sites

Remediation success is determined by the ability of a remedy to achieve remedial action goals within an acceptable time, and by the long-term permanence of the remedy. The case studies reviewed in this section are studies where thin-cover placement of clean material over impacted sediment was used as a remediation alternative. This technique is sometimes referred to as enhanced monitored natural recovery (EMNR) when the goal is to accelerate monitored natural recovery (MNR) processes, such as the acceleration of natural deposition. There are several case studies where thin-cover placement has been used effectively as a remediation technique to reduce the mobility, toxicity, and exposure to COCs, including estuarine, river, tidal flats and marsh settings. The following are key highlights of the case studies reviewed for this appendix:

- Thin covers or thin caps have been successfully applied at numerous sediment sites as part of remedial measures (Attachment I-1). Ongoing monitoring confirms the protectiveness of thin covers as a remedial measure that also accelerates ongoing natural recovery at many sediment sites.
- At the East 11th Street tideflats restoration project in Washingon, over 10 years of monitoring has shown successful performance of clean sand placement; low fines and reduction of COC levels below project thresholds have been documented at this site.
- At the Bremerton Naval Complex in Bremerton, Washington, the investigation of physical isolation processes supported the selection of thin-cover placement to address polychlorinated biphenyl (PCB)- and mercury-contaminated sediments. Postconstruction monitoring results over subsequent years (2003 to 2007) indicate minimal changes to bathymetry and reduced concentrations in mercury over time. However, incomplete source control near the thin-cover has resulted in minimal net change in sediment PCB concentrations over time (Magar et al. 2009, Merritt et al. 2010).
- Several remedy options (source control, institutional controls, dredging, isolation capping, thin-layer cover, and MNR) were used in Commencement Bay (Tacoma, Washington), in the nearshore tide flats (Magar et al. 2009)—sediments were impacted with PCBs, polycyclic aromatic hydrocarbons (PAHs), 4-methylphenol, and volatile organic compounds. Thin-cover placement was used in areas of moderate concern. Results indicate that remedial goals in areas where thin cover was used have been achieved. Long-term monitoring was considered complete in 2004.
- At the nearshore tidal flats in Middle Harbor, Washington, long-term monitoring demonstrated that silt and/or wood debris has naturally accumulated over the cover and the cover was found to be stable.
- At the Grasse River site in New York, postconstruction monitoring showed that average PCB concentration in the surface of the thin-layer cover was 99% lower than the preremediation value. Further, there appeared to be little mixing of the cover with underlying sediments.

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- A 15-cm cap was placed over mercury- and PAH-impacted sediment in Wyckoff/Eagle Harbor, Puget Sound, Washington in areas of moderate concern (Merritt et al. 2010). Postremediation monitoring events occurred between 1999 and 2007. Results indicate that the cap has remained stable. In addition, results indicate that chemicals of concern (COCs) are remaining below criteria for most of the area except for a small area which has shown an increase in mercury concentrations in 2005 which is believed to be from lateral transport of chemicals in the absence of wider harbor source control.
- Thin-cover placement of clean material (sand) was placed over a 4-acre PCB-impacted area in the Lower Duwamish Waterway, Seattle, Washington (Stern et al. 2009). The thickness of the layer was between 9 and12 inches. Monitoring results over subsequent years indicate that the thin-cover placement achieved its remedial goals and suggests that underlying sediments have not mixed in with surface sediments. Results of the thin-cover placement were compared with the monitoring results from an adjacent site which was remediated with MNR. Results from both techniques indicated that the final surface concentration is dominated by the waterway loading rather than be the initial treatment (MNR or EMNR); however, thin-cover placement is reported as having increased the recovery rate so that cleanup goals will be achieved earlier than anticipated.
- Herrenkohl et al. (2006) reported on the long-term success of using thin-cover placement at a site in Ward Cover, Alaska, in 2001 that was impacted with ammonia, sulfide, and 4-methylphenol. Approximately 6 inches of clean sand was applied over 27 acres of sediment in Ward Cove, Alaska in 2001. The effectiveness of the remedial technique was monitored 3 years after initial placement of the thin-cover. Results indicate that areas subjected to EMR had reduced toxicity and increased abundance and diversity of benthic communities.
- During construction of an approximately 40 acre sediment cap remedy in the Lower Hackenack River, the work area was hit by superstorm Sandy in 2012. The sediment cap and thin-cover areas, with design thicknesses of 6 to 12 inches and consisting of sand and armoring, was in various stages of completion (i.e., the uppermost exposed layer in the cap areas at the time of superstorm Sandy was sand, filter material or armoring). To assess the integrity of the partially constructed caps, thickness verification measurements were performed following the storm at locations that corresponded to locations previously assessed for cap thickness quality control verification. Based on a comparison of cap layer thickness measurements made prior to and following superstorm Sandy, it was demonstrated that the storm event did not result in substantive loss of the exposed sand layer, filter or armor layers in the cap areas.

A common theme among the case studies reviewed was that thin-cover placement performed effectively in various river, estuary, and marsh settings; however, results were sometimes confounded by recontamination by background or site contaminant sources. Recontamination, when it occurred, occurred through surface water transport and deposition onto the sediment cap. Recontamination of this type is not unique to thin-cover placement and would occur at comparable levels for dredging and capping remedies.

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3 Thin-Cover Placement of Sediment on *Spartina* and Marsh Recovery Rates

The case studies reviewed here are primarily from the 2007 United States Army Corps of Engineers (USACE) technical summary document, *Thin Layer Placement of Dredged Material on Coastal Wetlands: A Review of Technical and Scientific Literature* (Ray 2007). Methods for applying thin layers of clean sediment varied between studies and are discussed in the section below on placement techniques. A summary of these studies is provided in Attachment I-1. In general, thin-cover placement techniques emulate natural deposition events that occur in marsh systems. The technique was originally developed in Louisiana to mitigate losses of coastal wetlands due to natural causes such as alteration of natural sediment deposition patterns, marsh subsidence, and sea level rise. Key highlights of the case studies we reviewed are presented below:

- In Glynn County, Georgia, *Spartina* regrowth was monitored after placement of three types of sediment material (coarse sand, mixed sand and clay, or clay) at six thicknesses (8, 15, 23, 61, 91 cm) on undisturbed salt marsh plots. Reimold et al. (1978) applied sediment at different stages of plant growth (February, July, and November). Results indicate that *Spartina* was able to regrow and penetrate though 23 cm (9 inches) of sediment regardless of the sediment layer composition, whereas plots covered with ≥ 60 cm of sediment did not recover at all. The authors found that the *Spartina* regrowth in the less-than-60-cm plots was comparable to undisturbed reference marshes within one to two growing seasons.

- Two studies examined the effects of manually applied clean dredged materials (primarily medium sand) of varying thickness (0 to 10 cm, 4 inches) to sparsely vegetated *Spartina* and reference plots in Masonboro Island, North Carolina (Leonard et al. 2002, Croft et al. 2006). Both studies found that the placement of dredged material on sparsely vegetated plots stimulated plant growth. Before the placement of dredged material on the plots, *Spartina* densities were highest in reference plots (256 stems per square meter [m^{-2}]) when compared to the sparsely vegetative experimental plots (149 stems m^{-2}). Average stem density increased in all plots after the application of dredged material. By the end of the second summer, there was no statistically significant difference in stem density between the reference plots (336 stems m^{-2}) and experimental plots (308 stems m^{-2}). In addition to stimulating growth, placement of dredged material stimulated benthic algal biomass.

- Cahoon and Cowan (1987, 1988) investigated the response of salt marsh wetlands to the application of thin layers of dredged material using high-pressure spraying at Lake Coquille and Dog Lake, Louisiana. Sediment layers of 10-15 cm (4-6 inches) and 18-38 cm (7-15 inches) were applied to salt marshes at Dog Lake and Lake Coquille, respectively, and growth of vegetation was monitored. The authors found that although vegetation on the plots was still buried after 14 months, recolonization of representative marsh species was apparent. It was speculated that complete revegetation would likely occur within 3 years.

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- LaSalle (1992) revisited the Lake Coquille and Dog Lake thin-cover placement sites originally sampled by Cahoon and Cowan. After five years, the salt marsh at Dog Lake was no longer distinguishable from nearby references sites with regard to percent coverage of *Spartina.* American glasswort (*Salicornia virginica*), a subdominant plant, was most abundant at the experimental sites whereas saltgrass (*Distichlis spicata)* and needlerush grass (*Juncus roemerianus)* were more abundant at the reference sites.

- DeLaune et al. (1990) looked at the effect of adding dredged material onto salt marsh plots in Barataria Bay, Louisiana. Dredged material was manually placed onto deteriorated salt marsh plots in two applications. In the first application, sediment was placed on the experimental plots to a thickness of 2-3 cm (0.8-1.2 inches) to 4-5 cm (1.5-2 inches). In the second application, sediment thickness ranged from 4-6 cm (1.5-2.4 in.) to 8-10 cm (3.1-3.9 in.). The authors reported that the addition of thin layers of sediment increased aboveground biomass and density of *Spartina* shoots when compared to control areas.

- Ford et al. (1999) examined the effects of spraying sediment material onto a salt marsh in Venice, Louisiana, as a method of disposal for dredged material. Sediment was applied to a 0.5-hectare salt marsh using a high-pressure spray to a thickness of 2.3 cm (approximately 1 inch). Although the high-pressure spray initially flattened vegetation, plants quickly recovered with the percent coverage of *Spartina* increasing to above preapplication coverage values. Results indicated that the treated marsh was indistinguishable from control areas with respect to sediment and vegetation properties.

- In Venice, Louisiana, sediment was hydraulically dredged from the Gulf of Mexico and applied to a 43-hectare (106-acre) salt marsh to a thickness of approximately 60 cm (24 inches) (Mendelssohn and Kuhn 2003). Results indicated that the marsh recovered in two years after sediment application; that is, within two years total plant coverage, height, and biomass were comparable to reference areas. The magnitude of recovery was greater for areas that received more than 30 cm (15 inches). Based on the results, the authors postulated that the added material acted as a fertilizer to the salt marsh. Although plant diversity was similar between the experimental and reference marsh, soil elevation and bulk density was higher in the experimental areas. Based on the study, it is uncertain if plants recolonized areas that received more than 30 cm (15 inches) of sediment or regenerated through it. Given the results of other case studies, the latter is more likely.

- Slocum et al. (2005) studied the effects of sediment enrichment over a seven-year period on the same marsh from the Mendelssohn and Kuhn (2003) study. This study was initiated to close information gaps by providing a larger-scale and longer-term sediment enrichment experiment. The authors found that sediment values reported by Mendelsohhn and Kuhn (2003) consolidated over time and ranged from 0 to 22 cm (0 to 9 inches). While the benefits of sediment addition included increased bulk density, nutrient availability, aeration, and reduced hydrogen sulfide, the authors reported that this fertilization effect of the added sediment was a relatively short-term benefit. In

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> addition, a minor disadvantage of the sediment application was the creation of areas with a high sand content and increased elevation. These areas, however, were small when compared to areas that received moderate amounts of sediment. The authors concluded that sediment enrichment was an effective method for restoring degraded marshes that are affected by sea-level rise and subsidence.

Based on the literature reviewed, recovery of marshes after the addition of sediment layers varied depending on the thickness of the layers and the condition of the marsh at the time of application. Marshes generally recovered within 1 to 2 growing seasons (i.e., 1 to 2 years) following placement of dredge material layers up to 23 cm (9 inches); marshes that received layers of sediment between 23 cm (9 inches) and 38 cm (15 inches) took longer to recover, but still recovered within 2 to 5 years.

Case studies indicate that the placement of sediment on top of marsh vegetation may stimulate primary production depending on the physical characteristics and nutrient content of the added material, both of which can be engineered to required specifications, if needed. Although this “fertilizer effect” was found to be relatively short-lived (effects appeared to dissipate after approximately three years), the effect helped stimulate the rapid recovery of salt marsh vegetation after placement. Other benefits of sediment application to a marsh include positive impacts on wetland biogeochemistry as well as increased elevation, accretion rates, and sediment bulk density. In addition, mineral sediment enrichment precipitates hydrogen sulfide, a phytotoxin, by providing iron and manganese, which improves plant growth and organic matter production (King et al. 1982).

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4 Methods for Placement and Limitations for Placement of Thin Cover

There are several methods to place sediment onto a marsh; each of which have their own advantages and drawbacks. Historically, methods such as bucket dredging and low pressure spray techniques had limited physical ranges and tended to result in uneven layers of poorly mixed sediments (Ray 2007). Placement distances also were limited because the material source (barge) had to be located near a water body. Cahoon and Cowan (1987) report that the maximum distance that materials could be placed onto a salt marsh from the water's edge using bucket dredge or low-pressure spray techniques was 61 meters (m) (200 feet [ft]) and that deposited materials were often poorly mixed and of uneven thickness. On the other hand, these authors report a maximum application distance of 91 m (298 ft) using high-pressure spray equipment and deposited materials were more uniform when compared to the conventional bucket dredge and low-pressure spray techniques.

The USACE Environmental Research and Development Center (ERDC) evaluated placement techniques and concluded that the optimal technique for thin-layer placement was to spray a slurry of clean sediment onto a salt marsh using a modified hydraulic dredge with a high-pressure nozzle (see photo at left) (Ray 2007). A cutter head suction dredge (a type of hydraulic dredge) is typically used. In almost all cases, the cutter head, pump, and spray devices are located on the same vessel. However, sometimes the pump and spray devices may be connected by a few hundred meters of piping to maximize their reach (see photo above which shows a marsh reconstruction

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project in Louisiana that was implemented recently) (Wilber 1993). In order to use thin-layer placement successfully, the nature of the existing marsh bottom must be well understood, including sediment characteristics and potential for settlement.

In considering placement methods, desired final sediment surface elevations should be taken into account as well as the drainage pattern of the receiving marsh as these are important components for natural regeneration and recovery of salt marsh vegetation after sediment application. Ray (2007) states that receiving marshes must have adequate drainage to ensure that water does not pond and drown salt marsh vegetation. In areas of low tidal range, care must be taken to ensure that sediment addition does raise the sediment bed above tidal elevations required by salt marsh plants. Addition of too much sediment can convert intertidal wetland habitat into upland habitat (Leonard et al. 2002). Other important considerations include physical and chemical characteristics of the new material (in comparison to existing marsh sediments), as well as the distance from the source of material to the receiving marsh as submerged aquatic habitats may be sensitive to elevated turbidities and increased sedimentation. An understanding of site morphology and the existing ecosystem combined with best management practices should be used to minimize the potential for adverse impacts to sensitive receptors.

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5 *Spartina* Tolerances and Characteristics

Below is a list of *Spartina* tolerances and characteristics summarized from McKee and Patrick (1988), White (2004), Bush and Houck (2008) and Mullens (2007).

- *Spartina* is a colonial, intertidal salt marsh plant that tends to grow parallel and continuous along coastal shorelines.
- The width and thickness of plant colonies is controlled by site-specific factors, including elevation and slope as well as the frequency, depth, and duration of tidal inundation.
- *Spartina* grows in sandy aerobic or anaerobic soils with pH ranging from 3.7 to 7.9.
- *Spartina* can tolerate salinities ranging from 0 to 35 parts per thousand (0 to 35 psu). White (2004) reported *S. alterniflora* was the dominant grass in the Altamaha River estuary at salinities above 15 practical salinity units (psu), codominant with *S. cynosuroides* at salinities between 0.5 and 15 psu, and subdominant in oligohaline conditions (<0.5 psu).

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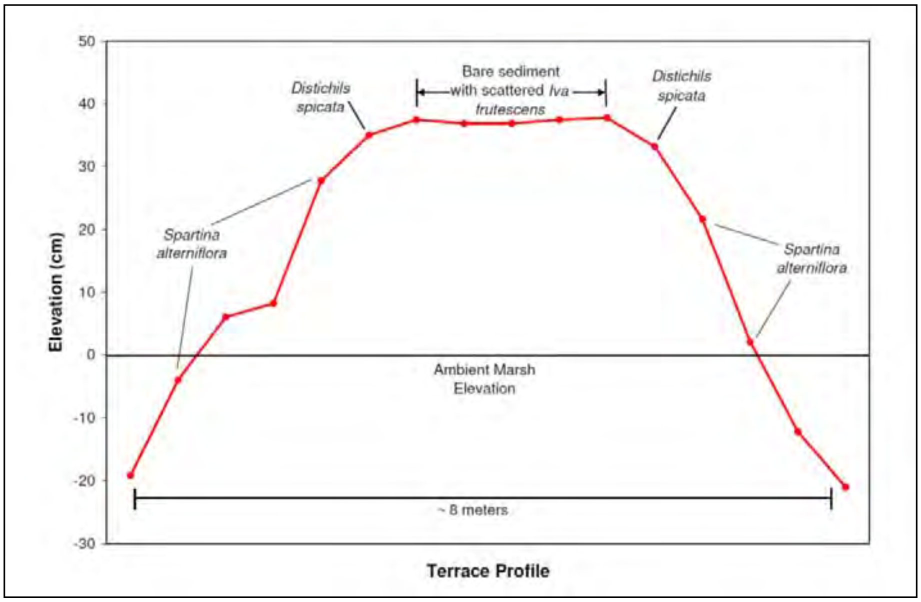
- The optimum water depth for establishing plantings is approximately 3 to 46 cm (1 to 18 inches).
- In newly constructed salt marsh terraces composed of dredge materials in Louisiana, Mullens (2007) showed that *Spartina* flourished when the percent of time flooded was 50% to 60%.
- Tidal elevation range varies regionally based on mean tidal amplitude or range (McKee and Patrick 1988) and in relation to biotic and abiotic factors. *Spartina* reportedly occurs at elevations ranging from just above mean low water (MLW) to just above mean high water (MHW). According to the National Oceanic and Atmospheric Administration National Ocean Service datum for Howe Street Pier in Brunswick (Station 8677406), the corresponding elevation for MLW is 20.23 ft and for MHW is 27.36 ft.
- Mullens (2007) notes

  > "solid stands of *Spartina* were found, on average, at 21.3 cm (± 5.6) above ambient marsh (see figure below). As elevations increased, occurrence of *Spartina* began to decline and volunteer colonization of *Distichlis spicata* and *Iva frutescens* was found. *D. spicata* was observed at 31.4 cm (± 6.82) above ambient marsh and *I. frutescens* was more commonly found in the higher elevations, at approximately 37.4 cm (± 11.17) above ambient marsh."

- Mullens (2007) illustrated the change in vegetative species with elevation on constructed terraces as shown in the figure below. The *Spartina* tolerance in the study was approximately -5 cm to approximately +25 cm relative to the ambient marsh elevation (i.e., the starting elevation of the study).



- Matthews and Minello (1994) identified the following as being among the key factors for successfully restoring, creating, and enhancing *Spartina* marshes:

  - The soil must contain adequate nutrients. Graded-down upland soils often need additions of fertilizer to supply sufficient nutrients, while dredged material or natural bay sediments usually have sufficient nutrients.
  - Creating proper elevation (0.2 to 0.5 m above MLW) at the site is essential. Reference should be made to the nearest flourishing natural marsh whenever possible. Spartina will grow over a wide tidal range in the absence of competition. Success also has been achieved when plants are placed at the higher end of the elevation range and allowed to grow into lower elevations on their own.
  - Good water flow and tidal exchange ensure the supply of nutrients and help to prevent salt buildup in the sediment.

Additional citations regarding *Spartina* marsh restoration projects and conditions that foster optimal growth are provided in Attachment I-2.

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6 Thin-Cover Composition to Maximize Recovery Potential

Matching the characteristics of the cover material to existing conditions (e.g., total organic carbon or percent organic matter, particle size distribution such as percent fines, bulk density, and nutrient levels) can help accelerate recovery. This section discusses research on the composition of the cover material and discusses attempts of using amendments to stimulate marsh recovery.

Depending on the site-specific conditions and nature of marsh vegetation, nutrient amendments are sometimes needed. Amendments may be necessary if the organic carbon, particle size distribution, bulk density, or nutrient characteristics of the cover material are not comparable to those found in the existing marsh. Tidal marsh soil properties in the southeast vary depending on salinity, geomorphic position, tidal range, vegetation type, and other factors (Pennings et al. 2012). OU1 may be most comparable to southeast riverine salt marshes, which include the following characteristics (Pennings et al. 2012):

- Total nitrogen in the top 30 cm of sediment is 0.36 ± 0.05% and total phosphorus is 530 ± 100 micrograms per gram (µg/g).
- Percent organic matter in riverine salt marshes in the southeast is 12 ± 2.
- Bulk density is 0.56 ± 0.09 grams per cubic centimeter (g/cm^3).
- Sediment composition consist of sand is 57 ± 10%, silt is 20 ± 7%, and clay is 11 ± 4%.

For Brunswick, given the nature of the existing marsh system, nutrient additions or amendments may not be necessary provided the thin-cover material is composed of finer sands and silts similar to those found in typical clean dredged materials. This is further substantiated by the following studies:

- Mendelssohn and Kuhn (2003) reported a short-lived fertilizer effect to thin-cover sediment additions, which dissipated after three years.
- Broome et al. (1975) and Sullivan and Daiber (1974) reported positive biomass responses to fertilizer additions where these nutrients were limiting *S. alterniflora* marshes. Gibson et al. (1994) have not reported increases in biomass from nitrogen and organic matter additions in Spartina-dominated marshes.
- In a comparison of constructed (25 year old) and reference marshes in North Carolina, Craft et al. (1999) reported much higher nitrogen accumulation rates in constructed marshes (7-12 grams per square meter per year [g/m^2/yr]) compared to natural marshes (2-5 g/m^2/yr).
- Tidal circulation typically provides a natural source of nutrients necessary for plant growth.

In summary, to promote rapid regeneration of *Spartina* and marsh recovery, the design specifications should specify a cover material with physical characteristics similar to those of the existing marsh soils, to the extent practicable.

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7 Bioturbation Related to the Effectiveness of Thin Cover

Bioturbation is the transport process by which a wide range of macrofaunal behavior such as burrowing, feeding, and tube excavation result in the mixing of particles within a sediment column (Kristensen et al. 2012). Bourdreau (1998) estimates that the affected bioturbation depth worldwide is 9.7 cm (<4 inches) from the surface.

At the LCP Site, fiddler crabs, oligochaetes, and polychaetes are the dominant species present (Black and Veatch 2011, Horne et al. 1999). Scientific studies on these organisms and bioturbation in general is provided in Attachment I-3. As summarized in Attachment I-3, the majority of bioturbation is in the upper 15 cm of sediment. However, some fiddler crab burrowing deeper than 15 cm is expected.

At most sites, as for the LCP Site, thin-cover placement is not intended as a complete chemical barrier, but instead serves to substantially reduce surface sediment chemical concentrations to environmentally protective levels while minimizing short- and long-term damage to the existing marsh habitat. Therefore, some bioturbation beyond the cover depth does not diminish the effectiveness of this remedy and does not preclude its beneficial use as a protective remedy. A thin cover is a protective remedy for OU1 when the following elements are considered:

- Element 1: True bioturbators, like oligochaetes and polychaetes, that ingest sediments at depth and deposit materials at the surface, are predominantly in the upper 15 cm of the sediment surface, with the vast majority in the upper 3 to 10 cm. Fiddler crabs are different in their bioturbation characteristics, as described below:
    - The majority of fiddler crab burrows are shallow burrows (within the top 15 cm of the marsh surface) and are used for refuge from the tide or predators. As the tide rises, the crabs plug the burrows and remain inside until the next low tide. At higher densities, these burrows can contribute to sediment turnover.
    - Less frequently, burrows extend to depths of 30 cm. The deeper burrows are the breeding burrows, which are defended and maintained once created, which would inherently limit further movement of sediment from depth to the surface, particularly given that the burrows are plugged during high tide (so the input of water and sediments that might otherwise fill the burrow is limited).
    - There is also a relationship between burrow depth and plant stem and root density. There are fewer burrows in areas with the greatest root density.
- Element 2: The organisms exposed directly to the burrows will not have an adverse impact even if some burrows exceed the 15-cm thin restoration cover.
    - Fiddler crabs are not particularly sensitive to mercury and Aroclor 1268 even in current conditions.
    - Fiddler crab males aggressively defend their burrows, limiting exposures to other species.

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  - Fiddler crabs are deposit feeders, so the majority of food intake occurs at the sediment surface, which would be in the clean restoration layer.
  - The more sensitive species in the marsh (e.g., grass shrimp, amphipods, green heron, and fish) will not be in the burrows.

- Element 3: Bioaccumulation to upper trophic level mammals and birds should be very limited even if some burrows exceed the 15-cm thin restoration cover.
  - Fiddler crabs feed on decaying plant material generally at the sediment surface, thus, the majority of feeding will occur in the portion of the clean, thin restoration cover, limiting the potential for bioaccumulation.
  - Fish do eat fiddler crabs but there are no fish species that exclusively eat fiddler crabs and there is no reason to expect that fish will preferentially consume fiddler crabs from areas with thin restoration covers. For these reasons, the thin layer is protective of fish species, including those that include fiddler crabs in their diet.

- Element 4: The physical movement of some mercury and Aroclor 1268 from depth to the surface could occur if the infrequent establishment of burrows deeper than 15 cm occurs; however, this will affect a small amount of sediment area. Relative to the overall mass and area of the clean-layer application, the area-weighted impact of deep burrowers will be small, particularly in the relatively lower-risk vegetated marsh areas where thin-cover placement is proposed.
  - The overall surface-weighted average concentrations (SWACs) in thin-cover areas will be much lower than the current SWACs for OU1.
  - Bioturbation associated with oligochaetes and polychaetes is primarily confined to the upper 10 cm of sediment, and thus will not contribute to mixing of buried contaminated sediment with the clean cover material.
  - For the following reasons, contaminant mass transfer due to bioirrigation in fiddler crab burrows is expected to be very small:
    - Burrows are concentrated in the upper 15 cm.
    - The very low aqueous solubility of Aroclor 1268 and PAHs will limit their dissolved mass transfer in burrows.
    - Methylmercury is very unstable under aerobic conditions, limiting the potential for methylmercury mass transfer.
    - Dissolved total mercury and lead mass transfer is limited by their relatively low solubility in sediment porewater and the relatively less frequent burrowing to depths beneath 15 cm.

- Element 5: The thin restoration cover will achieve acceptable risk reduction while causing the least amount of harm to the marsh.

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- Studies have shown that *Spartina* can regenerate through thin cover in approximately one to two years creating stands similar to reference conditions.
- Alternatives such as removal and backfill would have even greater impacts to the marsh due to heavy construction, destruction of creeks and channels, and challenges associated with returning the sediment bed to its existing bathymetry, as well as successful reestablishment of marsh vegetation to preexisting densities.

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Appendix I:
Review of Technical Issues: Thin-Cover Placemennt
in *Spartina* Marsh and Potential Bioturbation Effects

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Attachment I-1

Thin-Cover Placement Projects Summary

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Attachment I-1:
Thin-Cover Placement Projects Summary

Project Name	Material Volume (CY)	Placement Thickness (inches)	Project Outcome	Reference
St. Simons Sound, Georgia	Unknown	3, 6, 9, 12, 24, and 36	*Spartina alterniflora* was able to penetrate up to 9 inches of each type of placed material and exhibited biological growth and production nearly equal to that in undisturbed reference marsh areas. Plots covered with 24 inches or more of sediments did not recover. There was little variation in vegetation abundance due to discharge time (stage of plant growth).	Reimold et al. 1978
St. Bernard Parish (Lake Coquille), Louisiana	10,500	7 to 15	Vegetation was still smothered 14 months after placement. Approximately 6 years after placement, no difference between placement sites and reference site in terms of percent cover by dominant plant species. There were some differences in plant species composition.	Cahoon and Cowan 1987, 1988; LaSalle 1992
Terrebonne Parish (Dog Lake), Louisiana	18,900	4 to 6		
Marshes near Venice, Louisiana	Unknown	1	One year after placement, no difference between the placement areas and the reference sites in terms of the extent of marsh accretion, marsh elevation, soil bulk density and organic content, and vegetative characteristics.	Ford et al. 1999

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Project Name	Material Volume (CY)	Placement Thickness (inches)	Project Outcome	Reference
Hydraulic pipeline spill near Venice, Louisiana	Unknown	Less than 6 up to 24	Two years after spill, the total vegetative cover, plant height, and plant biomass was higher at marshes that received material compared to reference marsh areas. Seven years after spill, sites that received 5 to 12 cm of material continued to maintain increased vegetative growth and better soil conditions than reference marshes.	Mendelssohn and Kuhn 2003
Barataria Bay, Louisiana	unknown	0.75 to 2 after 1st lift; 1.6 to 4 after 2nd lift	Material addition resulted in increased aboveground biomass, plant shoot density, leaf-area, aboveground biomass, and culm regeneration. Transpiration rates and leaf conductance were also higher in areas receiving material.	DeLaune et al. 1990
Masonboro Island, North Carolina	unknown	0 to 4	At end of the second summer after placement, deteriorated marsh plots had the same stem density as reference marsh plots. Benthic microalgal biomass tended to be higher in placement areas.	Leonard et al. 2002, Croft et al. 2006
Lake Landing Canal, North Carolina	10,500 to 15,700	0.4 to 4 at one site; 0.4 to 8 at one site	Some decrease in plant shoot density observed. However, the soil bulk densities, organic contents, and faunal distributions indicated productive marshes.	Wilber et al. 1992

Notes:

CY = cubic yards

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Appendix I:
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in *Spartina* Marsh and Potential Bioturbation Effects

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Attachment I-2

Additional Citations for Spartina Restoration

Attachment I-2:
Additional Citations for Spartina Restoration

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Attachment I-3

Overview of Bioturbation Literature

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Attachment I-3:

Overview of Bioturbation Literature

Overview of scientific studies of fiddler crabs (*Uca spp.*), annelids, and bioturbation models.

C.1 Fiddler Crabs

Fiddler crab burrowing has been identified as being responsible for increasing aerobic decomposition, carbon cycling, drainage, and primary production in *Spartina* salt marshes in areas where they are abundant.

- Gribsholt et al. (2003) examined the impact of fiddler crabs and plant roots on sediment biogeochemistry in a Georgia saltmarsh. They found that Spartina influenced biogeochemical processes through root respiration and stimulated carbon cycling through microbial decomposition in the root zone (i.e., iron reducing bacteria). Crabs were found to excavate and maintain permanent burrows in the marsh, which altered sediment biogeochemistry through aerobic processes. Sediments became progressively more oxidized near burrow walls thereby making iron reduction the most important organic carbon oxidation pathway rather than sulfate reduction. Although the extensive root system and efficient oxygen diffusion capacity of Spartina roots appeared to have greater impact on sediment biogeochemistry than fiddler crabs, crab burrowing was clearly influential on sediment biogeochemistry and cycling of iron, sulfur, and carbon, particularly in areas where crab burrows were densest.
- Kostka et al. (2002) investigated the rates and pathways of carbon oxidation in saltmarsh sediments in a salt marsh located on Skidaway Island, Georgia. Sediment geochemistry, rates of microbial metabolism, and abundance of anaerobic respiratory bacteria were determined in areas with different fiddler crab burrow abundance and *Spartina* coverage. The authors conclude that iron (III) reduction was the dominant microbial respiration process coupled to carbon oxidation in vegetated salt marsh sediments, whereas sulfate reduction was the dominant process in sediments not affected by macrofauna or macrophytes. Even in areas reported to be in the middle of the range of fiddler crab burrows and *Spartina* coverage, significant impacts on sediment biogeochemistry were observed when compared to adjacent environments where there were fewer to no crabs.
- McCraith et al. (2003) explored the effect of fiddler crab burrowing on sediment mixing in a South Carolina salt marsh by looking at the distribution of two isotopes (^{210}Pb and ^{137}Cs) in salt marsh sediments. Burrow densities ranged from between 40 and 300 burrows per m^2 with the highest densities reported to be by the creek bank. Results indicated that crab burrowing mixed the top 8 to 15 cm (3 to 6 inches) of salt marsh sediment thereby influencing sediment composition and salt marsh biogeochemistry.
- Bertness (1985) demonstrates the importance of fiddler crabs to *Spartina* primary production at a salt marsh in Rhode Island. Reduction of fiddler crabs for a single growing

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season in tall forms (1 to 2 m, approximately 3 to 7 ft) of Spartina at intermediate tidal elevations decreased aboveground production by 47 percent (%) and increased root density by 35%. Results indicate that crab burrows increased soil drainage, soil oxidation-reduction potential, and decomposition of belowground organic matter. The authors found that burrows typically extended 5 to 25 cm (approximately 2 to 10 inches) below the surface in salt marsh sediments with densities between 224 and 480 burrows per m^2.

- Katz (1980) studied *Spartina* marsh sediment turnover rate and the amount of surface area increase due to fiddler crab burrowing in a Massachusetts salt marsh. Quantitative measurements of burrow volume and surface area were measured in three 5-m^2 quadrats. Depth of fiddler crab burrows were predominantly 15 cm (6 inches) or less. With an average adult crab density of approximately 42 crabs per m^2, it was estimated that over 18% of the sediment in the upper 15 cm (6 inches) was turned over by crab burrowing.
- Allen and Curran (1974) examined the sedimentary structures produced by fiddler crabs in protected lagoon and salt marsh environments near Beaufort, North Carolina. Results indicate that crab distribution was determined primarily by substrate characteristics, salinity, and vegetation cover in the intertidal zone. Fiddler crab and other crab burrows were reported to be up to 15 to 20 cm (6 to 8 inches) deep. Dimensions and shapes of burrows were variable depending on the species.

This evaluation supports the conclusion that the majority of studies show that fiddler crabs burrow in the upper 15 cm of the sediment column.

C.2 Annelids: Oligchaetes and Polychaetes

Annelid worms, such as oligochaetes and polychaetes, are important agents of bioturbation in salt marsh ecosystems. Although studies specific to the salt marshes of the southeast United States were not readily available, a literature review indicated that bioturbation depth of oligochaetes and polychaetes were similar between various study areas.

- Shull (2001) prepared a bioturbation model using published data on benthic organisms collected in Narragansett Bay, Rhode Island. Data for polychaetes and oligocahetes indicate that the bioturbation depth was 15 cm or less.
- Two studies on the polychaete *Nereis diversicolor* in the laboratory indicated that bioturbation depth was within the top 15 of the sediment column (Gribsholt and Kristensen 2002).
- Quantitative measurements of vertical displacement of cadmium due to the bioturbation effect of the deposit-feeding polychaetes, *N. diversicolor* and *Arenicola marina,* indicated that cadmium maximum vertical displacement was 13 cm (Petersen et al. 1998).
- Leorri et al. (2009) examined overall bioturbation in salt marshes from the Bombay Hook National Wildlife Refuge in Delaware. Beads were distributed over the surface of plots of high marsh and low marsh, monitored seasonally for seven years. Results indicated that

sediment mixing was greatest in late spring and early summer with maximum bioturbation occurring in the low marsh at 13 cm depth. The study also concluded that sediment found in the low marsh was also more likely to be subject to physical reworking.

- ENVIRON (2007) conducted a study in a New Jersey estuary examining bioturbation through the use of sediment profile imagery at more than 75 locations. The study demonstrates that bioturbation by oligochaetes and polychaetes occurred within 15 cm with a mean depth being 2.2 and 3.5 cm. There were only two occasions over 75 sample locations with a depth slightly exceeding 15 cm.
- A study of a Superfund site in New York by Thomann et al. (1993) indicates that bioturbation of sediment occurred in the upper 10 cm.
- Francois et al. (2002) also shows that the majority of burrowing occurs in the upper 15 cm of sediment, but some limited burrowing was observed up to a maximum depth of 19 cm.

This evaluation supports the conclusion that the majority of studies show that oligochaetes and polychaetes burrow in the upper 15 cm of the sediment column, and predominantly in the upper 3 to 10 cm.

C.3 Bioturbation Models

There are a variety of bioaccumulation models that are referred to in literature (e.g., Thoms et al. 1995; Kristensen et al. 2012). Models may be categorized as:

- Diffusive Mixing Models – Appropriate for local random burrowing of organisms (over time scales much shorter than that of observed changes that leads to rapid exchange of neighboring particles and porewater within the mixing zone (Image A in Figure A).
- Advective Mixing Models – Appropriate for transport by conveyor-belt feeders in preferential direction (Images B,C,D within Figure A).
- Generalized Mixing Models (Robbins 1986) – Considered both diffusive and advective terms.

Fiddler crabs would show characteristics of B (upward conveyor) as the initial burrows are established, but would show characteristics of C and D thereafter (i.e., sediment from the surface is more likely to encroach into the burrow). Other organisms, like oligochaetes and polychaetes would show characteristics of A, B, C, and D; however, the vast majority of those interactions would occur in the upper 15 cm of sediment so would not extend below the thin-cover layer.

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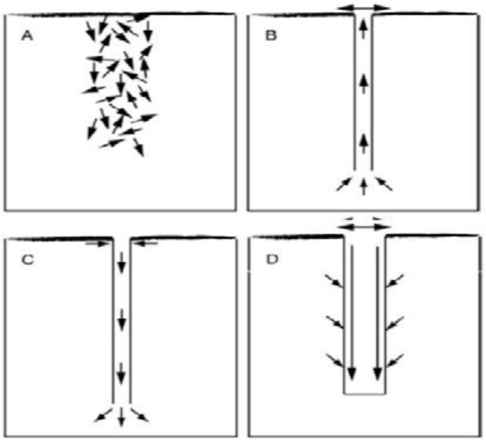

Figure A- Major Type of Bioturbation (adapted from Kristensen et al. 2012): Image A-Biodiffusers; Image B-Upward Conveyors; Image C-Downward Conveyors; Image D-Regenerator

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Appendix J
Effectiveness Evaluations for Thin Cover and Chemical Isolation Cap

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:
Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:
Anchor QEA, LLC

ENVIRON International Corporation

Date:
June 2, 2014

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List of Acronyms and Abbreviations

cm	centimeters
cm/s	centimeters per second
f_{OC}	fraction organic carbon
FS	feasibility study
g/cm^3	grams per cubic centimeter
K_d	equilibrium partitioning coefficient
K_{OC}	organic carbon partitioning coefficient
LCP	Linden Chemicals and Plastics
L/kg	liters per kilogram
mg/kg	milligrams per kilogram
mm/yr	millimeters per year
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
RGO	remedial goal option
Site	LPC Site located in Brunswick, Georgia
SWAC	surface-weighted average concentration
TOC	total organic carbon
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency

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Executive Summary

The feasibility study (FS) evaluates alternatives to remediate contaminated sediments at Operable Unit 1 (OU1) of the LCP Chemicals of Georgia, Inc. (LCP) Site located in Brunswick, Georgia. This appendix to the FS discusses the effectiveness of two remedial technologies being evaluated to address contamination at the Site: 1) placement of thin cover over marsh area sediments; and 2) placement of a sediment cap to address contaminated sediments in the tributaries.

Thin cover involves application of a layer of clean sediment material (usually sand) over contaminated sediments. It is expected to effectively reduce surface contamination in marsh areas, thereby enhancing natural recovery processes. The long-term concentrations in the surface of the thin-cover material are expected to be at least 75 percent (%) lower than current concentrations in the marsh sediment.

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Sediment capping involves placement of materials (such as sand, gravel, and/or cobble) to physically and chemically isolate contaminated sediments from the overlying aquatic ecosystem. Sediment caps evaluated for the tributary sediments in OU1 were conceptualized to include two layers: 1) an erosion protection layer designed to resist forces from currents during normal conditions and storm conditions; and 2) a chemical isolation layer designed to limit upward movement of contaminants through the cap. To evaluate the effectiveness of the chemical isolation component of sediment capping within the tributaries, a computer model developed by Dr. Danny Reible (Lampert and Reible 2009, Go et al. 2009) was used for this evaluation. This model has been used at numerous sites across the United States and is consistent with guidance on cap design developed by the United States Environmental Protection Agency (USEPA) and United States Army Corps of Engineers (USACE). The model predicts the movement of chemicals through sediment caps that could result from upward flow of groundwater and diffusion over time.

The modeling described in this appendix provides an appropriate FS-level screening evaluation of the effectiveness of caps in potential tributary remedial areas, incorporating several conservative assumptions, including the following:

- The erosion protection layer was assumed to not contribute to chemical isolation.
- An infinite mass of contamination was assumed to be present immediately beneath the cap throughout time.
- The estimated rates of upward groundwater flow developed for the tributaries for low tide conditions, (which produce higher rates than those for slack or high tide) were used in the model throughout the simulation.
- It was assumed that no new sediments would deposit on top of the caps in the future (any new deposition, even if minimal, would further isolate the contaminated sediments from the ecosystem by adding separation distance).

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- Natural biological breakdown (biodegradation), which is known to occur for some of the contaminants at the Site, was conservatively assumed to not occur in this analysis.

Under these assumptions, the sediment cap's chemical isolation layer requirements to meet project goals were determined to be a 6-inch layer of sand cap material containing a minimal amount of organic matter. Specifically, for this chemical isolation layer configuration, the model predicts that contaminant concentrations within the upper surface of the sediment cap (called the biologically active zone) would remain below the proposed remedial goal options for more than 100 years. The modeling results indicate that thin covers would also yield a high degree of chemical isolation protection, while enhancing natural recovery processes, with minimal long-term impacts to the existing marsh vegetation at the Site.

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1 Introduction

Two remedial technologies to address contaminated sediments at Operable Unit 1 (OU1) of the LCP Chemicals of Georgia, Inc. (LCP) Site located in Brunswick, Georgia (the Site) are evaluated in this appendix. Thin-cover placement is being evaluated as a means of providing a clean cover over existing sediment surface, and thereby accelerating the rate of natural recovery within the OU1 marsh area. Section 2 of this appendix provides an overview of the effectiveness of thin-cover placement within marsh sediments. Section 3 presents the effectiveness evaluation with respect to chemical isolation by sediment capping, and describes mathematical modeling that was performed to identify the conceptual cap configurations required to meet remedial goals for the Site.

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2 Thin Cover Effectiveness

Thin-cover placement is being considered as a remedial technology to address marsh sediments with low levels of contamination at the Site (Figure J-1). Thin covers generally are less than 15 centimeters (cm) (6 inches) thick and typically are constructed using clean sediment or sand. By providing a clean surface layer following placement, thin-cover placement enhances ongoing natural recovery processes. Contaminant concentrations in the OU1 marsh surface sediments are expected to decrease naturally over time due to the depositional nature of this environment, even if such deposition rates are minimal[1]. The processes responsible for these decreases include burial of the contaminated surface sediment beneath new sediment material that deposits from the surface water and dilution from mixing of existing contaminated sediments with the newly deposited uncontaminated sediment. Sea level rise is expected to contribute to continued deposition in the future.[2] Placement of a thin layer of clean material over the contaminated marsh sediments will immediately reduce aquatic ecosystem and benthic organism exposure to underlying contaminants and will accelerate the rate of these natural recovery or sedimentation processes. While thin covers are not intended to perform as sediment caps, thin covers isolate marsh sediments from potential receptors as they incorporate placement of approximately 6 inches of clean material (Section 3.3). Therefore, thin covers would yield a high degree of protection, particularly when applied over areas of low contamination in marshes, while accelerating natural recovery processes.[3]

During placement, the clean thin-cover material could mix with the underlying contaminated sediments. Over the long term, some mixing between the thin-cover material, native contaminated material, and the sediments depositing as part of natural processes would be expected to occur through benthic organism activity (i.e., the process of bioturbation). Since these conditions may affect the long-term effectiveness of thin-cover placement, the following main contributing factors are discussed below:

- Mixing with native marsh sediment during placement
- The depth and rate of bioturbation
- The rate of natural sediment deposition
- Differences in the properties of the thin cover material and marsh surface sediments

---

[1] A study of a coastal Georgia marsh located approximately 25 miles northeast of the Site found that net sedimentation rates varied from 2 to 6 millimeters per year (mm/yr) within the marsh (Letzsch and Frey 1980).

[2] During the last century, sea level rise has consistently averaged approximately 3 mm/yr. Sea level rise creates conditions that are favorable for continued sediment deposition due to additional biological growth and sediment trapping. Overall, sediment deposition is anticipated to continue in response to ongoing sea level rise over the next century, consistent with the typical response of estuaries to sea level rise.

[3] Because the objective of the thin cover at the LCP marsh site is to provide a clean sediment surface for accelerating natural recovery processes, amendments (that are sometimes used for sediment caps) are not necessary.

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2.1 Mixing During Placement

As presented in the feasibility study (FS), thin covers have been applied at numerous sites as part of remediation projects. Thin covers have been applied to marshes mostly to accelerate the recovery of a subsiding marsh by providing an influx of sediments. However, the thin-cover placement principles that apply in remediation projects also apply to thin covers placed in marsh environments.

Thin cover and cap placement techniques have advanced rapidly in recent years. More precise placement methods and low impact delivery systems have been successfully developed. In addition, several demonstration and full-scale projects where thin layers have been placed have been successfully completed with minimal material loss or mixing with the underlying sediment. These developments and experience indicate that the thin-cover material could be placed to minimize the extent of mixing with existing marsh surface sediments, only affecting the bottom few centimeters of the thin cover (Gardner and Stern 2009; Anchor Environmental, LLC 2007; Shaw et al. 2008; Reible 2009; Melton 2005). Thus, mixing during placement is expected to be minimal, and contaminated sediment would only be entrained within the bottom few centimeters of the thin-cover layer. Thus, the integrity of the thin cover would not be significantly compromised during placement or its long-term (e.g., years or decades) effectiveness affected, as deposition and bioturbation will be the driving processes for such mixing.

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2.2 Bioturbation

Immediately following thin-cover placement, surface concentrations will be essentially zero, as a clean sediment surface will be created and potential for mixing during placement is very limited as described above. Over time, surface concentrations of the thin cover will depend on the rate and depth of bioturbation. If the thickness of the thin-cover layer is greater than the depth of bioturbation, then no contaminants from the underlying marsh sediments would be entrained within the thin cover material due to bioturbation. In cases where bioturbation depths are greater than the thin-cover thickness, the concentrations within the thin-cover material would begin to increase over time due to mixing of the native marsh sediments with the clean thin cover through bioturbation. As presented elsewhere in the FS (Section 4.2.4) and Appendix I (Section 7), the anticipated bioturbation depth for the OU1 marsh benthic organisms is less than 6 inches. This bioturbation depth is equal to the anticipated thickness of the thin-cover layer (i.e., 6 inches). Therefore, mixing by benthic organisms will be largely limited to occur within the 6-inch-thick thin-cover material, and entrainment of underlying contaminated sediments in the thin-cover material via bioturbation is anticipated to be minimal (due to the limited extent to which mixing occurs over depths greater than 6 inches, as discussed in Section 4.2.4 of the FS and Section 7 of Appendix I).

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The time over which mixing between thin-cover material and native marsh sediment could occur via bioturbation is generally expected to be slow and variable across the marsh. One consideration is that the rate of bioturbation is not uniform with depth. In general, the most intense benthic activity occurs right at the sediment surface, with intensity decreasing with depth (oftentimes exponentially). As discussed in Appendix I, fiddler crab “breeding burrows,” which extend to depths of 6 to 12 inches are much less frequent than fiddler crab “refuge burrows,” which are limited to 6 inches or less. The distribution of these deeper burrows is related to

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vegetation density (i.e., intermediate density has the most burrows, low-density grass and high-density grass areas have fewer burrows). Over the entire marsh area, a relatively small fraction of breeding burrows relative to refuge burrows exists, which results in a much lower bioturbation rate at depths greater than 6 inches as compared to that within the upper 6 inches. Therefore, mixing of contaminated marsh sediment through bioturbation will be generally slow for a thin-cover material thickness of 6 inches. An example calculation showing the effects of bioturbation depth is presented in Section 2.5.

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2.3 Deposition

In the absence of thin-cover placement, natural deposition of clean sediment reduces contaminant concentrations in the surface sediment. In conjunction with thin-cover placement, natural sediment deposition results in mixing of newly deposited clean material with the existing surface material, thereby diluting surface concentrations. Deposition also increases the thickness of the clean sediment layer overlying contaminated sediments, thereby increasing the separation distance between the contaminated sediments and the overlying water column and decreasing the amount of bioturbation extending down into the native sediments. Given the relatively slow deposition rates in the marsh (2 to 6 mm/yr; Letzsch and Frey, 1980), natural sediment deposition within OU1 will slowly extend the separation distance and limit bioturbation-driven mixing of the thin-cover material with the underlying marsh sediment.

2.4 Material Characteristics

Differences in the physical characteristics of the existing marsh sediments and the thin-cover material will affect the material mixing process during bioturbation, and the resulting surface contaminant concentrations. Because the dry bulk density of the marsh sediments is expected to differ from that of the clean sand anticipated to be used as thin-cover material, the reduction in surface concentration due to dilution depends on these differences. An example calculation showing the effects of dry bulk density (as well as bioturbation depth) on thin-cover effectiveness is presented in Section 2.5.

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2.5 Bounding Calculation for Long-Term Concentration Reduction

A highly conservative approach for evaluating the long-term effectiveness of thin-cover placement in reducing surface concentrations is to assume that the thin-cover material (sand) is mixed entirely and instantaneously with the underlying marsh sediment, down to the full bioturbation depth. This approach is conservative because, in reality, it would take several years for mixing to occur and the associated concentration increase from the initial value of zero (i.e., clean sand) to the steady state values that are attained once mixing is complete. Furthermore, it is also conservative because this calculation ignores ongoing deposition (discussed below).

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Long-term concentration reductions associated with complete mixing of thin cover material and underlying marsh sediment can be calculated based on the dry bulk density and initial concentrations of the two materials and the thickness of each material mixed (which depends on the depth of bioturbation). This calculation essentially takes the form of a dry density and thickness weighted average. Because the initial concentration of the thin-cover material is zero,

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(i.e., clean sand) the effective reduction in surface concentration following instantaneous mixing can be solved generically (independent of marsh concentration). Such concentration reduction is a function of the differences in dry bulk density between the two materials, the thickness of the thin-cover material, and the depth of bioturbation. Essentially the concentration in the marsh sediments is diluted by the ratio of marsh sediment mass to thin-cover material mass, as described by Equation J-1:

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$$\%Reduction = \frac{(H_{bio} - H_{ThinCover}) \cdot \rho_{marsh}}{H_{ThinCover} \cdot \rho_{ThinCover} + (H_{bio} - H_{ThinCover}) \cdot \rho_{marsh}} \quad \text{(Equation J-1)}$$

Where:
% Reduction is the percent reduction in surface concentration following placement and instantaneous mixing with thin-cover material
H_{bio} is the depth of bioturbation
$H_{ThinCover}$ is the thickness of the thin-cover material
ρ_{marsh} is the dry bulk density of the marsh material
$\rho_{ThinCover}$ is the dry bulk density of the thin-cover material

Percent solids measurements from marsh sediment samples indicate the sediments have relatively high moisture content, resulting in an average estimated dry bulk density value of approximately 0.5 grams per cubic centimeter (g/cm^3), compared with a typical dry bulk density of sand of 1.5 g/cm^3. Based on these dry bulk density values, long-term (i.e., steady-state) reductions in surface concentration that would be achieved by thin-cover placement were calculated using Equation J-1 as a function of thin-cover thickness, for the range of bioturbation depths discussed above (i.e., 6 inches and 12 inches). Based on the approach outlined above, the mechanisms responsible for these reductions are a combination of physical separation, and dilution between the small thickness of marsh sediment subject to bioturbation beneath the thin-cover material. Figure J-2 shows the calculated reduction in surface concentration as a function of bioturbation depth and thin-cover thickness, conservatively ignoring the effects of natural deposition. Ignoring deposition is conservative because it would act to limit the effects of bioturbation (i.e., reduce the amount of mixing with the underlying marsh sediment) because the distance between the mudline and contaminated sediment would increase over time. This figure shows that the percent reduction in surface concentration increases with increased thin-cover layer thickness, and that for a given thin-cover layer thickness, reductions in concentration for a 6-inch bioturbation depth are greater than those for a 12-inch bioturbation depth. At the point where the thin-cover thickness exceeds the depth of bioturbation, concentrations at the surface are zero (i.e., 100% reduction in surface sediment concentration). For a 6-inch layer of thin-cover, the results of this analysis indicate long-term concentration reductions of 75% to 100% for the range of bioturbation depths evaluated.

Accounting for the relatively slow rate of bioturbation at depths below 6 inches (see Section 7 of Appendix I) and the ongoing natural deposition processes (2 to 6 mm/yr; Letzsch and Frey, 1980), even greater surface sediment concentration reductions would be expected. This analysis does not account for the rate of mixing due to benthic activity (bioturbation) nor does it allow for the determination of the time it would take to reach these concentrations although it

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can be reasonably assumed to be a long time due to the limited amount of bioturbation at depths below 6 inches. Therefore, it is anticipated that steady-state concentrations would be reached after an extensive time period, and that prior to complete mixing at steady-state, when the clean sand has not fully mixed with the underlying sediment, the effectiveness of the thin-cover would be greater than that presented on Figure J-2.

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A detailed evaluation regarding material types and specifications for the thin-cover layer will also be evaluated during remedy design.

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3 Chemical Isolation Cap Effectiveness

Preliminary chemical transport modeling was conducted to evaluate the long-term performance of the chemical isolation caps being considered as a component of the various remedial options to address contaminated sediments for the Site. Modeling was performed consistent with USEPA and USACE guidance for designing subaqueous caps for aquatic systems (Palermo et al. 1998).

The chemical isolation layer is being designed to prevent the long-term transport of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and metals (mercury and lead) into the cap surface where organisms would be exposed (termed the bioavailable layer), as well as into the overlying water column. Capping as a remedial option is being evaluated for the following four areas at the Site representative of the proposed 48-acre remedy (Figure J-1):

- Purvis Creek
- Western Creek Complex
- Eastern Creek
- Domain 3 Creek

These areas were evaluated separately based on spatial differences in groundwater flow and chemical concentrations. Although areas to be capped may be modified as more data are evaluated, these areas are considered representative of areas that could be capped under the final remedy. The objective of this appendix is not to delineate sediment management areas, nor define whether or not capping will be employed for each of the areas evaluated. Instead, the intent is to evaluate whether chemical migration through a cap could potentially undermine the use of sediment capping for remediation in the areas identified for this study, and whether design modifications are needed to improve cap effectiveness; minor variations to the extent of these areas should not affect the modeling results presented herein. Thus, the primary goals of modeling were to 1) simulate the transport of chemicals of interest at the Site (i.e., PAHs[4], PCBs, mercury, and lead) within the chemical isolation component of a cap; and 2) to use the model to evaluate the long-term effectiveness of a cap to manage the potential for chemical migration through the cap.

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[4] Because of the wide range of properties associated with individual PAHs, total PAHs were evaluated in the model by simulating 18 individual PAH compounds and summing the results to provide model outputs on a total PAH basis.

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3.1 Methodology

3.1.1 Model Framework

The one-dimensional model of chemical transport within sediment caps developed by Dr. Danny Reible was used for this evaluation (Lampert and Reible 2009, Go et al. 2009). This model simulates the time-variable fate and transport of chemicals (dissolved and sorbed phases) under the following processes:

- **Advection**: upward flow of groundwater within the cap
- **Diffusion**: movement of chemical across a concentration gradient (high concentration to low concentration)
- **Dispersion**: mixing and spreading of contaminants along the flow path resulting from water flow through porous media (i.e., the cap), which occurs at variable velocities, as well as mixing that occurs from hydraulic gradient reversals associated with tidal action, which are represented in the model as a dispersion process
- **Biodegradation**: breakdown, or decay, of the chemical,(in cases where the chemical is degradable)
- **Bioturbation/bioirrigation**: mixing of sediments and porewater from the movement of benthic organisms at the cap surface
- **Exchange with the overlying surface water**: transfer of chemical mass across a concentration gradient at the cap surface boundary

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This model has been used to support the evaluation and design of sediment caps at numerous sites around the United States. Details on the model structure and underlying theory and equations are provided in Lampert and Reible (2009), Go et al. (2009), and the USEPA/USACE capping guidance (Palermo et al. 1998).

3.1.2 Model Setup and Inputs

3.1.2.1 Model Domain and Layers

A schematic of the sediment and cap profile represented in the model is shown on Figure J-3. The conceptual cap design consists of an erosion protection layer (6 inches of fine to coarse gravel) overlying a base layer (6 inches of sand) that will, in turn, be placed over the native sediment. The uppermost layer is intended to armor the cap so it can resist erosive forces and stresses resulting from flow and tidal current velocities. The erosion protection layer often has some sorptive capacity and provides added separation distance between the contaminated sediments and the cap surface; however, for the chemical isolation modeling performed in this evaluation, the erosion protection layer was conservatively assumed not to contribute to chemical isolation (Section 3.1.3). Therefore, the cap profile simulated in the model consisted of only 6 inches of base material overlying the contaminated sediments.

The upper portion of a cap comprises the bioturbation zone, which is the depth over which the most significant mixing by benthic organisms is anticipated to occur. For an armored cap, the bioturbation zone would likely be confined to the armored layer and, thus, would not impact the

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cap base layer; however, for modeling purposes, a 10-cm bioturbation zone within the simulated 15-cm base layer was conservatively assumed. This allows the results of the model to be extrapolated to caps that may not include armoring, including thin-cover placement. The 10-cm bioturbation zone thickness is based on literature, standard practice for cap design (e.g., Clarke et al. 2001, Reible 2012), and the analysis of bioturbation presented in this FS.

3.1.3 Model Input Parameters

Input parameters for the cap model were based on Site-specific data, such as sediment concentrations, TOC measurements, and groundwater parameters from previous evaluations at the Site, as well as information derived from literature and experience with cap design at other sites. Several conservative assumptions were incorporated into the model for the purposes of this screening-level analysis. If results indicate that the cap is sufficiently protective despite the use of these conservative assumptions, then no further adjustment of the model is needed. Alternatively, if results indicate insufficient protection of surface sediment, then one or more of the following conservative assumptions may be modified so the model better represents the actual conditions at the Site:

- The armor layer was assumed to not contribute to chemical isolation, when in reality it would provide added separation distance between contaminated sediments and the cap surface, which would enhance cap performance by decreasing diffusive transport.
- A 10-cm bioturbation layer was assumed to occur within the upper portion of the 15-cm base layer (instead of overlying the 15-cm base layer), regardless of whether the 6 inches of armoring would limit or prevent bioturbation into the base layer.
- No further deposition of sediment was assumed to occur following cap placement. Deposition would further limit chemical transport into the bioavailable surface layer by adding new sediment to the cap surface; however, this is not an overly conservative assumption because deposition in the Site tributaries is relatively slow.
- Chemical and biological degradation within the cap was ignored. Some level of chemical or biodegradation is to be expected in these systems over long timeframes, particularly for methylmercury, which is unstable under oxidized conditions, and for the PAH compounds with lower molecular weight that are more likely to migrate into a cap and are relatively biodegradable.
- Groundwater seepage flux estimates were conservatively based on values that reflect low-tide conditions, when the hydraulic gradient toward the surface water is largest. These conditions represent the highest hydraulic gradient and, thus, the greatest groundwater flow potential through the cap. In reality, the long-term average groundwater seepage flux at the Site would be much less than the flux estimated from the low-tide condition, because lower hydraulic gradients would occur during the remaining portions of the tidal cycle, resulting in lower groundwater seepage flux. In fact, during high tide, when tide elevations are above groundwater elevations, the gradient is reversed (i.e., flow moves in a downward direction), which results in a reduced average groundwater flow.

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- An infinite mass of chemical immediately beneath the cap was assumed for the model. In reality, the mass of chemicals is finite and will reduce over time.

A description of the approach used to develop the key model input parameters is provided in the following subsections.

Diffusion and Partitioning Coefficients

The molecular diffusivity of each compound is a required model input parameter. To obtain values for the various chemicals modeled, the correlation identified from Schwarzenbach et al. (1993) relating diffusivity to a compound's molecular weight was used. The model calculates an effective diffusion coefficient using the chemical-specific input value for the molecular diffusivity and an empirical equation based on the material porosity using the approach developed by Millington and Quirk (1961). Diffusivity values for each chemical are presented in Table J-1.

Partitioning of chemicals between the dissolved and sorbed (i.e., cap material) phases is described in the model by the chemical-specific equilibrium partitioning coefficient (K_d). For PAHs and PCBs, the partitioning coefficient is calculated in the model based on the customary $K_d = f_{OC}{*}K_{OC}$ approach (e.g., Karickhoff 1984), where K_{OC} is the compound's organic carbon partitioning coefficient and f_{OC} is the organic carbon fraction of the solid phase (i.e., cap material). K_{OC} was set to literature-based values for each PAH compound (USEPA 2012) and Aroclor 1268 (Di Toro 1985, Hawker and Connell 1988, and Rushneck et al. 2004). K_d was calculated by the model, as previously described based on the K_{OC} and the cap material f_{OC} (see "Organic Carbon" section below). The K_d for the organic chemicals, although not listed in Table J-1, can be calculated for each cap layer and evaluation area using the cap layer- and area-specific f_{OC} and the chemical-specific K_{OC}. Multiple Kd values were simulated because the f_{OC} differs spatially among the different creeks and between the various components of the model domain (i.e., depths within the cap). For mercury and lead, the f_{OC} was not considered in the partition coefficient because organic carbon is not the dominant sorbent within sediments for metals. For mercury, a log K_d value near the low end of the range of literature values (i.e., 3.8 to 6.0 liters per kilogram [L/kg]; Lyon et al. 1997, Hintelmann and Harris 2004, Allison and Allison 2005) was conservatively used in the model to allow for greater contaminant mobility in the cap. The literature provides an even wider range of log K_d values for lead (e.g., 2.0 to 7.0 L/kg; Allison and Allison 2005); given that the literature range is large, it seemed more appropriate to use a value in the model that is in the middle of that range for lead. The partitioning coefficients used in the model are listed in Table J-1. Due to the variability and uncertainty in literature-based partition coefficients, model sensitivity analysis was performed for certain chemicals (Section 3.4).

Porewater Boundary Concentrations

The porewater boundary concentration defines the source term in the model and represents the concentration of each chemical of interest in the porewater within the native sediment beneath the cap. Porewater concentrations in sediment were calculated based on partitioning theory, using bulk sediment concentrations (organic carbon normalized for PAHs and PCBs) measured in the areas evaluated for capping and an estimate of the partitioning coefficient for each chemical. To simplify this analysis, the cap modeling evaluation was performed for a

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representative remedial footprint that includes Purvis Creek, Domain 3 Creek, Eastern Creek, and Western Creek Complex (Figure J-1). Concentrations from samples within this remedial footprint were used in this evaluation.

Within each of the four areas evaluated, average and maximum porewater concentrations for mercury and PCBs (measured as Aroclor 1268) were computed and used in the model. Use of an average concentration is consistent with the proposed Site-specific cleanup criteria for these two chemicals that are expressed as a surface-weighted average concentration (SWAC), whereas use of a maximum concentration is consistent with the secondary proposed Site-specific cleanup criteria for these two chemicals that are expressed on a point-by-point basis for the benthic community remedial goal option (RGO). For lead and PAHs, maximum calculated porewater concentrations for each of the four areas evaluated were used in the model because the proposed Site-specific cleanup criteria for these two chemicals are expressed on a point-by-point basis. This approach is considered appropriate because the intent of these evaluations is to perform a preliminary evaluation of capping as an effective remedial alternative.

Table J-2 lists the porewater concentrations used as the model input for the 21 chemicals (i.e., Aroclor 1268 PCBs, mercury, 18 individual PAHs, and lead) in each of the four areas evaluated. These inputs were developed using the concentrations from samples collected within the capping footprint evaluated.

Groundwater Seepage Velocity

Direct measurements of groundwater seepage flux through the sediments at the Site were not available; therefore, estimates were developed based on available information on groundwater conditions at the Site. Groundwater flux within the sediments is expected to vary with tidal conditions; the difference between low and high spring tide is approximately 9 feet at the Site (ENVIRON and Anchor QEA 2012). The groundwater hydraulic gradient within the sediments is upward during low tide (i.e., potential for upward flow), and downward during high tide (i.e., potential for downward flow).

Groundwater flux was estimated under low-tide conditions using Darcy's Law, applying a range of Site-specific hydraulic gradients (between 0.1 and 0.6), which were based on measurement of sediment thickness (EPS and ENVIRON 2012), head in sediments (EPS 2007, WMH 2006), and hydraulic conductivity values ranging from 1.8E-08 to 1.3E-07 centimeters per second (cm/s). The hydraulic conductivity values are based on Site-specific values derived from marsh clay laboratory permeability results (Geosyntec 1997). The most conservative groundwater seepage fluxes resulting from the range of Darcy velocities calculated from the range of hydraulic conductivities and low tide hydraulic gradients were used in the cap model for each respective area modeled; these values are listed in Table J-3. These values are conservative because they do not account for the fact that during high tide the gradient is reversed, producing a long-term average groundwater flux that would be less than the low tide estimate. Groundwater fluxes for the range of conditions are listed in Table J-4.

Groundwater transport within the sediments and within a cap is expected to be influenced by tidal action, which results in daily reversals in hydraulic gradient. In the cap model, the

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hydrodynamic dispersivity was set to 20 percent of the model domain length (i.e., 20% of the 6-inch cap thickness) to represent these gradient reversals as a dispersion process, which is a common approach used for representing tidal effects in the groundwater-surface water transition zone (Cooper et al. 1964). Typically, in the absence of flow reversals, when modeling flow through porous media, dispersion is set to between 1 and 10 percent of the model domain (e.g., Gelhar et al. 1992, Neuman 1990). Because the value of 20% used in the base case modeling to represent tidal action is uncertain, the model's sensitivity to this parameter was assessed.

Organic Carbon

The f_{OC} of the bioturbation zone used in the model was based on the assumption that sediments with an organic content similar to the current surface sediments would settle on the surface of the cap and be mixed into its surficial layer over time; therefore, the f_{OC} in the bioturbation zone was set to the average of the Site-specific TOC measurements from sediments collected within each area evaluated for capping as shown in Table J-3.

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The f_{OC} of the cap's chemical isolation layer is used to represent its sorptive capacity and is dependent on the material evaluated. For clean sand material placed for chemical isolation, the f_{OC} was set to a nominal value of 0.1 percent based on experience from other projects where the organic content of the sand isolation capping material was tested. This value was also considered a "design parameter," whereby it was increased as needed based on model results to achieve performance criteria (see below).

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Input Summary

The full listing model input parameters are provided in Table J-3.

3.2 Model Application Approach

The chemical transport model described above was used to predict sorbed-phase concentrations at various depths throughout the full cap thickness, over a 100-year simulation period. The model-predicted concentrations at the cap surface, expressed as a vertical average within the 10-cm bioturbation zone (which is the convention used at other contaminated sites where protection of benthic organisms is the goal), were compared to the following potential criteria to evaluate cap effectiveness:

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- Mercury
  - – 1 milligram per kilogram (mg/kg; SWAC RGO)
  - – 4 mg/kg (Benthic Community RGO)
- PCBs, measured as Aroclor 1268
  - – 2 mg/kg (SWAC RGO)
  - – 6 mg/kg (Benthic Community RGO)
- Lead
  - – 90 mg/kg (Benthic Community RGO)

- Total PAH
  - 4 mg/kg (Benthic Community RGO); individual PAH concentrations predicted by the model were summed to calculate total PAHs for comparison to this criterion.

As described in the section "Porewater Boundary Concentrations" above, results from the simulations using the maximum calculated porewater concentration as the boundary concentration were compared to criteria based on the Benthic Community RGO, whereas the simulations using the average calculated porewater concentrations as the boundary concentration were compared with the SWAC criteria. The values used for comparison with the model results represent the low end of the range of RGOs employed in the FS. Higher values may be permitted, depending on the outcome of the model. Furthermore, whereas a 6-inch chemical isolation layer consisting of sand was simulated, the total organic carbon (TOC) content in the isolation cap material and/or the cap thickness may be modified, if necessary, to achieve the criteria within the surface of the cap.

3.3 Model Results

Results of the cap modeling indicated that a 6-inch isolation layer with nominal TOC (as represented by a model input value of 0.1%) would be protective for more than 100 years (Table J-5). Model-predicted average sorbed-phase concentrations over the bioturbation zone for lead, mercury (average and maximum scenario), and Aroclor 1268 (maximum and average scenario) were very small (essentially zero) at the end of the 100-year simulation. Average total PAH sorbed-phase concentrations within the bioturbation zone at 100 years were predicted to be 1.2 mg/kg in Eastern Creek, 3.5 mg/kg in Domain 3 Creek, 0.35 mg/kg in Western Creek Complex, and 1.2 mg/kg in Purvis Creek.[5]

Model runs with longer simulation times were conducted to assess breakthrough time. The results of this additional modeling effort indicated that the model-predicted concentrations would not exceed the proposed criteria after more than 500 years.

A detailed list of model outputs is presented in Attachment J-1. These outputs include porewater and sorbed-phase concentrations predicted at various depths within the cap at various points in time over the course of the 100-year simulation. Although PAH compounds were simulated on an individual basis in the model, the results were summed to compare the total PAH concentrations to the target criterion. Thus, model outputs for the PAHs are presented as a total PAH.

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[5] As previously indicated, even though thin covers are not meant to serve as an isolation cap, given an anticipated thickness for thin-cover placement of 6 inches, these results also indicate that thin covers would also yield a high degree of chemical isolation protection, while enhancing natural recovery processes in marsh areas (even though the thin cover is not meant to be an isolation cap).

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3.4 Model Sensitivity Analyses

A series of sensitivity analyses was conducted to evaluate potential variability in predicted results of the model. Results are discussed in this section.

3.4.1 Dispersivity

The modeling in Domain 3 Creek also was performed using a dispersivity of 50% of the cap thickness, rather than the 20% value used in the base case modeling. The Domain 3 Creek was selected for this sensitivity analysis because calculated average sorbed concentrations were highest in this area and closest to the proposed target concentration of 4 mg/kg. The results of this sensitivity analysis indicated that the cap would still be protective after 100 years.

3.4.2 Partitioning Coefficients

Sensitivity analyses were also conducted to evaluate the effect a range of partition coefficients could have on model results. These sensitivity analyses were performed for mercury K_d and PCB (Aroclor 1268) K_{OC}.

To evaluate a potential scenario of less PCB sorption in the sediment cap, the literature-derived K_{OC} value for Aroclor 1268 value of $10^{7.4}$ L/kg used in the modeling described above, was reduced to $10^{6.3}$ L/kg in this sensitivity analysis (i.e., more than an order of magnitude less than the base). Likewise, for mercury K_d, a range of values consistent with literature, was evaluated in this sensitivity analysis. Specifically, in addition to the Kd of 10^4 L/kg used in the base model evaluation, Kd values of 10^3 L/kg and 10^5 L/kg were evaluated in this sensitivity analysis. Because the porewater boundary concentrations in sediment were calculated based on partitioning coefficients, the porewater concentrations were re-calculated for this sensitivity analysis from the bulk sediment concentrations and these alternative values for the partitioning coefficients. The resulting porewater boundary concentrations used for these sensitivity analyses are listed in Table J-6.

The results of these additional analyses indicate that the range of partition coefficients evaluated does not affect the overall conclusion of the modeling presented in Section 3.3; that is, model-predicted concentrations at 100 years based on these alternate model inputs are all below the corresponding potential target criteria. Results are presented in Table J-7.

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4 Summary

Placement of thin-cover as a remedial approach to address contaminated marsh sediments is expected to effectively reduce chemical concentrations in the surface of the marsh sediments and enhance ongoing natural recovery in those areas. Surface concentration reduction depends on the rate of ongoing natural deposition, the depth and rate of bioturbation, and differences in the physical characteristics (i.e., dry bulk density) between the thin-cover material and underlying marsh sediments. A conservative estimate is that long-term surface concentrations would be reduced by 75% or more, thereby reducing risk of exposure to benthic organisms. A more detailed evaluation of thin-cover effectiveness would be conducted during design as appropriate.

Consistent with USEPA and USACE guidance for designing subaqueous caps, a one-dimensional model of chemical transport within sediment caps was used to evaluate the effectiveness of potential caps in four representative areas of the Site. The model was configured to represent Site conditions based on available data, literature, and experience from other sites; several conservative assumptions were included in this evaluation. The model predicted that a 6-inch cap with nominal TOC would be effective in isolating the contaminants. Average concentrations at the surface of the cap were predicted to remain below the lowest end of the proposed chemical-concentration range targeted for benthic receptors, for hundreds of years. Model sensitivity analyses conducted to evaluate alternate values for uncertain input parameters (dispersivity and partitioning coefficients) did not significantly affect these conclusions. Furthermore, the results from this modeling indicate that, even though thin covers are not meant to serve as an isolation cap, given an anticipated thickness for thin-cover placement of 6 inches, these modeling results also indicate that thin covers would also yield a high degree of chemical isolation protection, while enhancing natural recovery processes, with minimal long-term impacts to the existing marsh vegetation at the Site.

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Appendix J
Effectiveness Evaluations for
Thin Cover and Chemical Isolation Cap

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Tables

Table J-1
Partitioning Coefficients and Diffusivity Values
LCP Chemical, Brunswick, GA

Chemical Group	Chemical	CAS Number	log K_{OC} (organics)	log K_d (metals)	Water Diffusivity
			(log L/kg)	(log L/kg)	(cm^2/s)
PAH	1-Methyl Naphthalene	90-12-0	3.4		8.00E-06
PAH	2-Methylnaphthalene	91-57-6	3.4		8.00E-06
PAH	Acenaphthene	83-32-9	3.7		7.60E-06
PAH	Acenaphthylene	208-96-8	3.7		7.60E-06
PAH	Anthracene	120-12-7	4.2		6.80E-06
PAH	Benzo(a)anthracene	56-55-3	5.2		5.70E-06
PAH	Benzo(a)pyrene	50-32-8	5.8		5.30E-06
PAH	Benzo(b)fluoranthene	205-99-2	5.8	-	5.30E-06
PAH	Benzo(g,h,i)perylene	191-24-2	6.3	-	5.00E-06
PAH	Benzo(k)fluoranthene	207-08-9	5.8	-	5.30E-06
PAH	Chrysene	218-01-9	5.3	-	5.70E-06
PAH	Dibenzo(a,h)anthracene	53-70-3	6.3	-	5.00E-06
PAH	Fluoranthene	206-44-0	4.7	-	6.20E-06
PAH	Fluorene	86-73-7	4	-	7.20E-06
PAH	Indeno(1,2,3-cd)pyrene	193-39-5	6.3	-	5.00E-06
PAH	Naphthalene	91-20-3	3.2	-	8.60E-06
PAH	Phenanthrene	85-01-8	4.2	-	6.80E-06
PAH	Pyrene	129-00-0	4.7	-	6.20E-06
Metal	Lead	007439-92-1	-	4.6	6.10E-06
Metal	Mercury	7439-97-6	-	4	6.30E-06
PCB	Aroclor 1268	11100-14-4	7.4	-	3.50E-06

CAS	Chemical Abstracts Service
cm^2/s	square centimeter(s) per second
L/kg	liter(s) per kilogram
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl

Table J-2
Boundary Porewater Concentrations
LCP Chemical, Brunswick, GA

Chemical	Porewater Concentration (µg/L)			
	Domain 3 Creek	**Eastern Creek**	**Purvis Creek**	**Western Creek**
Aroclor 1268 (average)	0.002	0.055	0.018	0.006
Aroclor 1268 (maximum)	0.014	2.6	0.064	0.021
Lead (maximum)	163	19	0.98	1.3
Mercury (average)	0.38	2.4	0.45	0.44
Mercury (maximum)	2	28	4	1.6
PAHs (from sample with maximum total PAH porewater concentration from each area)				
1-Methyl Naphthalene	0	0	0	0
2-Methylnaphthalene	0	14	17	4.2
Acenaphthene	11	7.1	8.2	2
Acenaphthylene	0.2	7.1	8.2	2
Anthracene	3.2	2.2	2.5	0.63
Benzo(a)anthracene	0.23	0.2	0.23	0.058
Benzo(a)pyrene	0.049	0.061	0.07	0.018
Benzo(b)fluoranthene	0.04	0.06	0.069	0.017
Benzo(g,h,i)perylene	0.013	0.018	0.021	0.0053
Benzo(k)fluoranthene	0.01	0.061	0.07	0.018
Chrysene	0.45	0.2	0.23	0.057
Dibenzo(a,h)anthracene	0.0029	0.019	0.022	0.0054
Fluoranthene	1.4	0.64	0.75	0.074
Fluorene	12	3.9	4.5	1.1
Indeno(1,2,3-cd)pyrene	0.0049	0.018	0.021	0.0053
Naphthalene	86	23	27	6.7
Phenanthrene	26	2.1	2.5	0.62
Pyrene	6.2	0.66	0.76	0.11
Total PAHs	147	62	72	18

µg/L	microgram(s) per liter
PAH	polycyclic aromatic hydrocarbon

Table J-3
Input Parameter Values for the Chemical Isolation Cap Model
LCP Chemical, Brunswick, GA

Model Input Parameter	Value	Data Source
Chemical-specific Properties		
Organic carbon partitioning coefficient for PAHs, log K_{OC} (log L/kg)	See Table J1	Log K_{OC} values from USEPA's EPI Suite – KOCWIN MCI log K_{OC} (USEPA 2012)
Organic carbon partitioning coefficient for Aroclor 1268 log K_{OC} (log L/kg)	See Table J1	Octanol-water partition coefficient (KOW) for total PCBs estimated from congener specific KOW values reported in Hawker and Connell (1988) converted to KOC by relationship developed by DiToro (1985) and congener composition of Aroclor 1248 from Rushneck et al. (2004).
Partitioning coefficient for metals, log K_d (log L/kg)	See Table J1	Based on values reported in literature as discussed in Section 3.1.3 (Lyon et al. 1997, Hintelmann and Harris 2004, Allison and Allison 2005, USEPA 2012)
Water diffusivity (cm^2/s)	See Table J1	Calculated based on the molecular weight of the compound using the correlation identified from Schwarzenbach et al. (1993) as discussed in Section 3.1.3
Chemical biodegradation rate	0	Assumed no degradation, which is conservative for PAHs, which have been shown to degrade in sediments
Boundary chemical porewater concentration (µg/L)	See Table J2	Calculated from sediment samples within the capping areas and partitioning coefficients
Cap Properties		
Total cap thickness (cm)	15.24	Design parameter; started with 6 inches of sand; refined as necessary based on results
Particle density (g/cm^3)	2.6	Typical value for inorganic particles (e.g., Domenico and Schwartz 1990)
Porosity	0.4	Typical value for sand (e.g., Domenico and Schwartz 1990)
Fraction organic carbon of cap material (%)	Variable	Started with nominal value (0.1%); refined as necessary based on results
Fraction organic carbon of bioturbation zone (%)	Domain 3 Creek: 5.1% Eastern Creek: 4.3% Western Creek Complex: 5.2% Purvis Creek: 3.8%	Based on the current surface sediment averages

Table J-3
Input Parameter Values for the Chemical Isolation Cap Model
LCP Chemical, Brunswick, GA

Model Input Parameter	Value	Data Source
Mass Transport Properties		
Boundary layer mass transfer coefficient (cm/hr)	0.75	Typical value used for capping design (e.g., Reible 2012); consistent with range of values measured in other systems (e.g., Thibodeaux et al. 2001)
Groundwater seepage Darcy velocity (cm/yr)	Domain 3 Creek: 2.3	Calculated based on Darcy's Law estimates using low-tide hydraulic gradients based on sediment thicknesses (EPS and ENVIRON May 2012), head in sediments (EPS 2007, WMH 2006), and hydraulic conductivities from previous groundwater evaluations (Geosyntec 1997). See Table H-4 for calculations.
	Eastern Creek, Purvis Creek, and Western Creek Complex: 0.6	
Depositional velocity (cm/yr)	0	Conservatively assumed no sedimentation
Dispersion length (cm)	3	Calculated based on model domain length (cap thickness); assumed 20% of cap thickness, which is a relatively high value, but was judged appropriate given that gradient reversals associated with tides is approximated as a dispersion process
Bioturbation zone thickness (cm)	10	Typical value for cap design (e.g., Clarke et al. 2001, Reible 2012). This value is conservative because the armor layer will limit the amount of bioturbation.
Porewater biodiffusion coefficient (cm^2/yr)	100	Parameter represents bioturbation rate applied to dissolved phase; typical value used for capping design (e.g., Reible 2012, Tittabawassee & Saginaw River Team, 2011)
Particle biodiffusion coefficient (cm^2/yr)	1	Parameter represents bioturbation rate applied to particulate phase; typical value used for capping design (e.g., Reible 2012, Tittabawassee & Saginaw River Team, 2011)

µg/L	microgram(s) per liter
cm	centimeter(s)
cm/hr	centimeter(s) per hour
cm/yr	centimeter(s) per year
cm^2/s	square centimeter(s) per second
cm^2/yr	square centimeter(s) per year
EPI	Estimation Program Interface
g/cm^3	gram(s) per cubic centimeter
L/kg	liter(s) per kilogram
PAH	polycyclic aromatic hydrocarbon

Table J-4
Groundwater Seepage Darcy Velocity Calculations
LCP Chemical, Brunswick, GA

Tidal Conditions	Area	Hydraulic Conductivity, K (cm/s)	Head[1] (feet)	Sediment Thickness (feet)	Hydraulic Gradient[2], i	Groundwater Seepage Velocity[3] (cm/yr)
Low Tide	Domain 3	1.30E-07	4.0	7.0	0.57	**2.34**
		1.30E-07	4.0	8.0	0.50	2.05
		1.80E-08	4.0	7.0	0.57	0.32
		1.80E-08	4.0	8.0	0.50	0.28
	Eastern Creek, Purvis Creek, Western Creek Complex	1.30E-07	1.0	7.0	0.14	**0.59**
		1.30E-07	1.0	8.0	0.13	0.51
		1.80E-08	1.0	7.0	0.14	0.08
		1.80E-08	1.0	8.0	0.13	0.07
High Tide	Domain 3	1.30E-07	-5.0	7.0	-0.71	-2.93
		1.30E-07	-5.0	8.0	-0.63	-2.56
		1.80E-08	-5.0	7.0	-0.71	-0.41
		1.80E-08	-5.0	8.0	-0.63	-0.35
	Eastern Creek, Purvis Creek, Western Creek Complex	1.30E-07	-8.0	7.0	-1.14	-4.69
		1.30E-07	-8.0	8.0	-1.00	-4.10
		1.80E-08	-8.0	7.0	-1.14	-0.65
		1.80E-08	-8.0	8.0	-1.00	-0.57

cm/s	centimeter(s) per second
cm/yr	centimeter(s) per year

[1] Head at high tide assumes a 9-foot tidal range.

[2] Hydraulic gradient is calculated by dividing head by sediment thickness.

[3] Groundwater seepage Darcy velocity is calculated as K*i and accounts for unit conversions. Most conservative values used in modeling are bold.

Table J-5
Model-Predicted Average Sorbed-Phase Concentrations within the Bioturbation Zone at 100 Years
LCP Chemical, Brunswick, GA

Chemical	Proposed Criteria	Average Sorbed Phase Concentrations (mg/kg)			
		Domain 3 Creek	Eastern Creek	Purvis Creek	Western Creek Complex
1-Methylnaphthalene	-	0	0	0	0
2-Methylnaphthalene	-	0	0.24	0.24	0.074
Acenaphthene	-	0.31	0.17	0.18	0.051
Acenaphthylene	-	5.80E-03	0.17	0.18	0.051
Anthracene	-	0.12	0.069	0.076	0.02
Benz(a)anthracene	-	9.70E-03	6.80E-03	7.70E-03	2.00E-03
Benzo(a)pyrene	-	1.20E-03	1.10E-03	1.20E-03	3.10E-04
Benzo(b)fluoranthene	-	9.30E-04	1.00E-03	1.20E-03	3.00E-04
Benzo(g,h,i)perylene	-	1.60E-05	1.20E-05	1.40E-05	3.50E-06
Benzo(k)fluoranthene	-	2.30E-04	1.10E-03	1.20E-03	3.10E-04
Chrysene	-	0.019	0.0067	0.0075	2.00E-03
Dibenz(a,h)anthracene	-	3.80E-06	1.30E-05	1.50E-05	3.80E-06
Fluoranthene	-	0.056	0.022	0.025	2.60E-03
Fluorene	-	0.41	0.11	0.12	0.033
Indeno(1,2,3-cd)pyrene	-	6.20E-06	1.20E-05	1.40E-05	3.50E-06
Naphthalene	-	1.3	0.28	0.28	0.089
Phenanthrene	-	0.99	0.068	0.075	0.02
Pyrene	-	0.25	0.023	0.025	4.00E-03
Total PAHs	4	3.5	1.2	1.2	0.35
Aroclor 1268 PCBs (average)	2.0-4.0	< 1E-10	< 1E-10	< 1E-10	< 1E-10
Aroclor 1268 PCBs (maximum)	6.0-16	< 1E-10	< 1E-10	< 1E-10	< 1E-10
Lead	90-177	< 1E-10	< 1E-10	< 1E-10	< 1E-10
Mercury (average)	1.0-2.0	3.83E-10	< 1E-10	< 1E-10	< 1E-10
Mercury (maximum)	4.0-11	2.03E-09	< 1E-10	< 1E-10	< 1E-10

mg/kg	milligram(s) per kilogram
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl

Table J-6
Boundary Porewater Concentrations Used in the Partitioning Sensitivity Analysis
LCP Chemical, Brunswick, GA

Chemical	Log K_d/ Log K_{OC} (L/kg)	Porewater Concentrations (µg/L)			
		Domain 3 Creek	Eastern Creek	Purvis Creek	Western Creek Complex
Aroclor 1268 PCBs (average)	6.3	0.03	0.69	0.23	0.07
Aroclor 1268 PCBs (maximum)	6.3	0.18	32	0.81	0.26
Mercury (average)	3	3.8	24	4.5	4.4
Mercury (maximum)	3	20	284	40	16
Mercury (average)	5	0.04	0.25	0.05	0.04
Mercury (maximum)	5	0.2	2.8	0.4	0.16

µg/L	microgram(s) per liter
L/kg	liter(s) per kilogram
PCB	polychlorinated biphenyl

Table J-7
Sensitivity Analysis: Model-Predicted Average Sorbed-Phase Concentrations within the Bioturbation Zone at 100 Years
LCP Chemical, Brunswick, GA

Chemical	Log K_d/ Log K_{OC} (L/kg)	Proposed Criteria	Average Sorbed-Phase Concentrations at Year 100 (mg/kg)			
			Domain 3 Creek	Eastern Creek	Purvis Creek	Western Creek Complex
Aroclor 1268 PCBs (average)	6.3	2.0-4.0	6.0E-06	4.8E-05	1.6E-05	5.2E-06
Aroclor 1268 PCBs (maximum)	6.3	6.0-16	4.0E-05	2.3E-03	5.6E-05	1.8E-05
Mercury (average)	3	1.0-2.0	0.04	0.19	0.04	0.03
Mercury (maximum)	3	4.0-11	0.21	2.26	0.32	0.13
Mercury (average)	5	1.0-2.0	< 1E-10	< 1E-10	< 1E-10	< 1E-10
Mercury (maximum)	5	4.0-11	< 1E-10	< 1E-10	< 1E-10	< 1E-10

L/kg	liter(s) per kilogram
mg/kg	milligram(s) per kilogram
PCB	polychlorinated biphenyl

Appendix J
Effectiveness Evaluations for
Thin Cover and Chemical Isolation Cap

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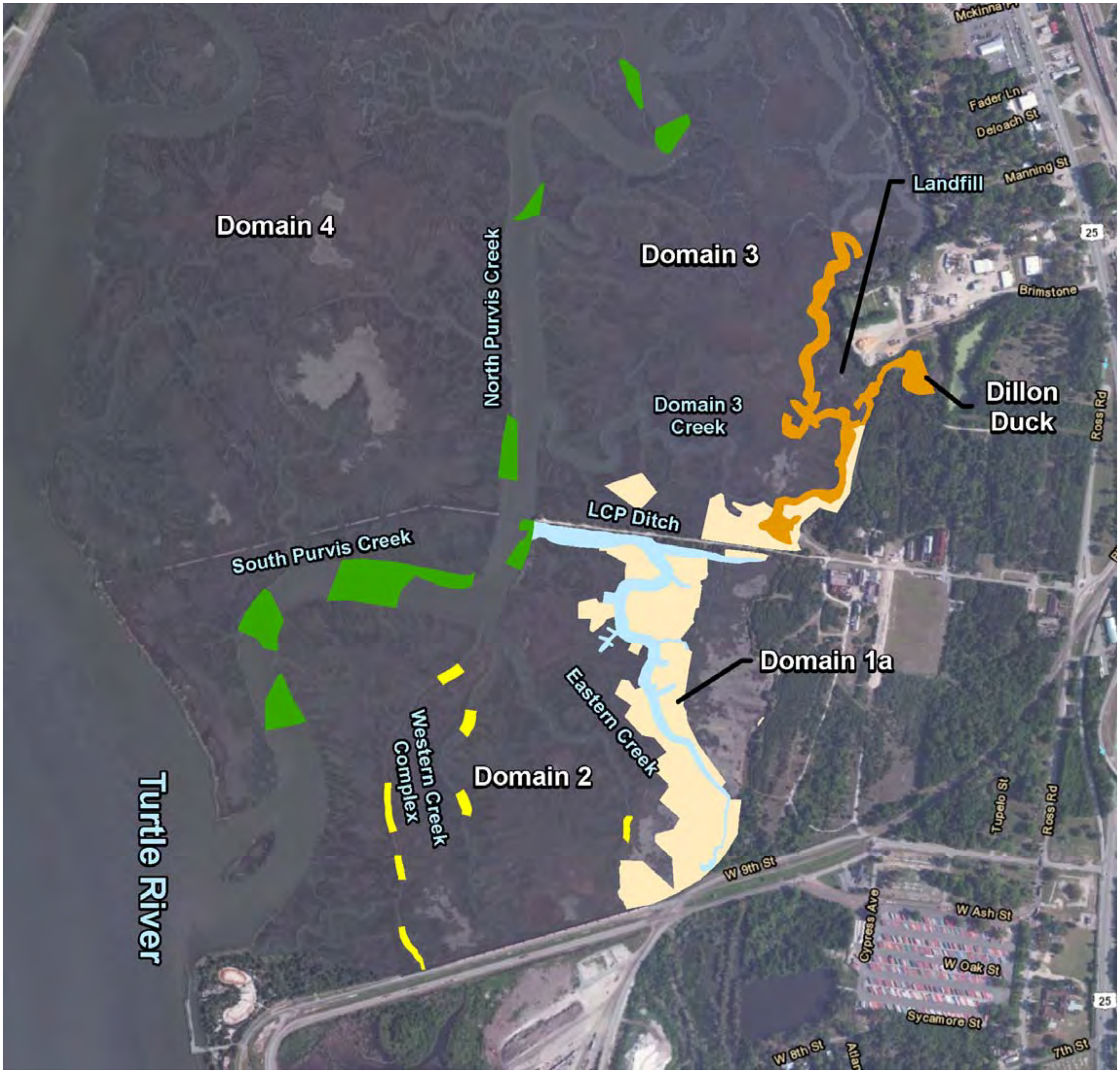
Figures



Legend

🟨 Thin-Cover Areas

Chemical Isolation Cap Areas

🟧 Domain 3

🟦 Eastern Creek

🟩 Purvis Creek

🟨 Western Creek

NOTES:
Aerial image provided by ESRI basemaps.

Feet
0 1,000 2,000

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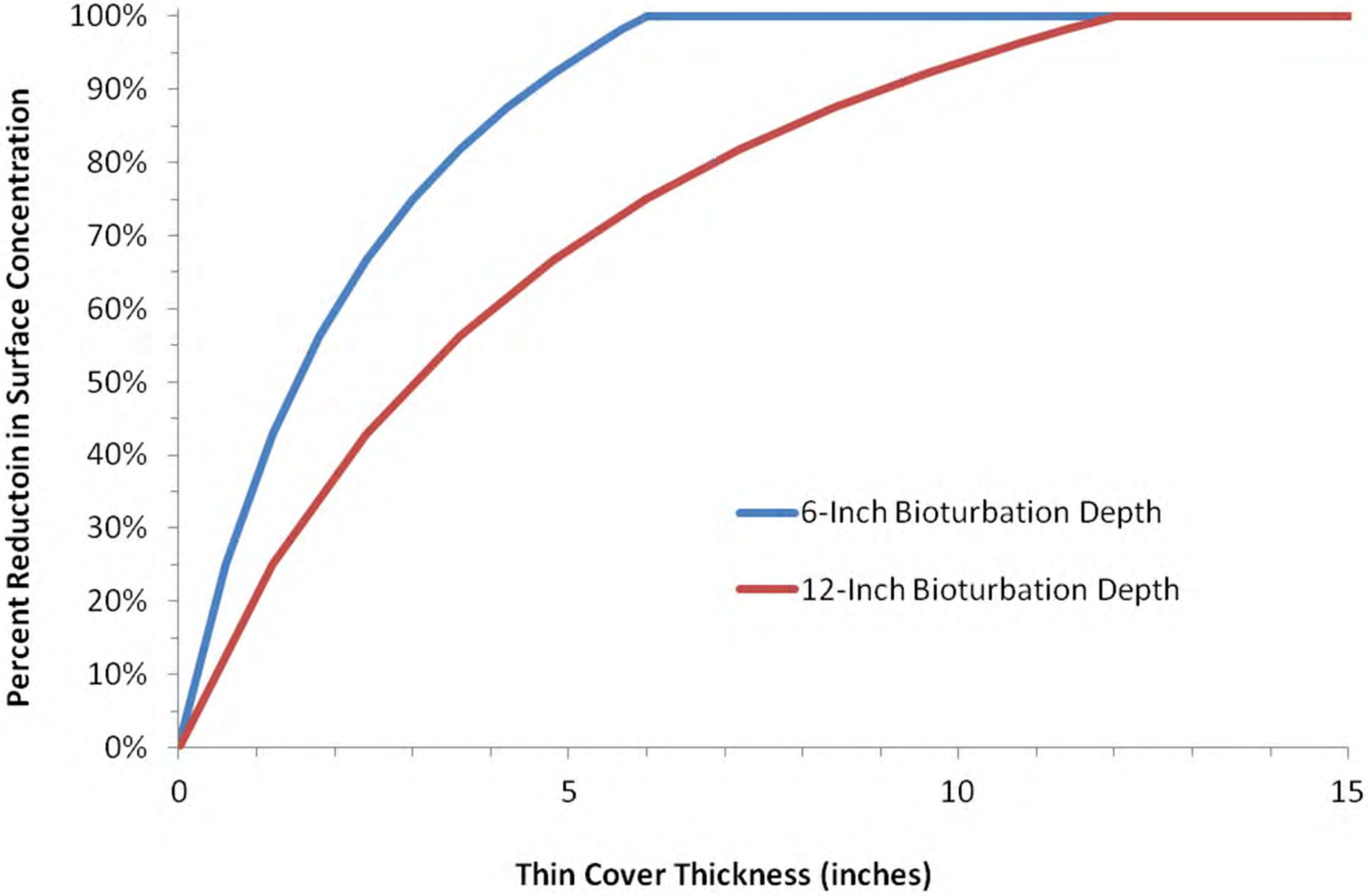
Marsh Sediment Areas with Thin-Cover and Tributary Sediment Areas Evaluated for Chemical Isolation Cap

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure J-1



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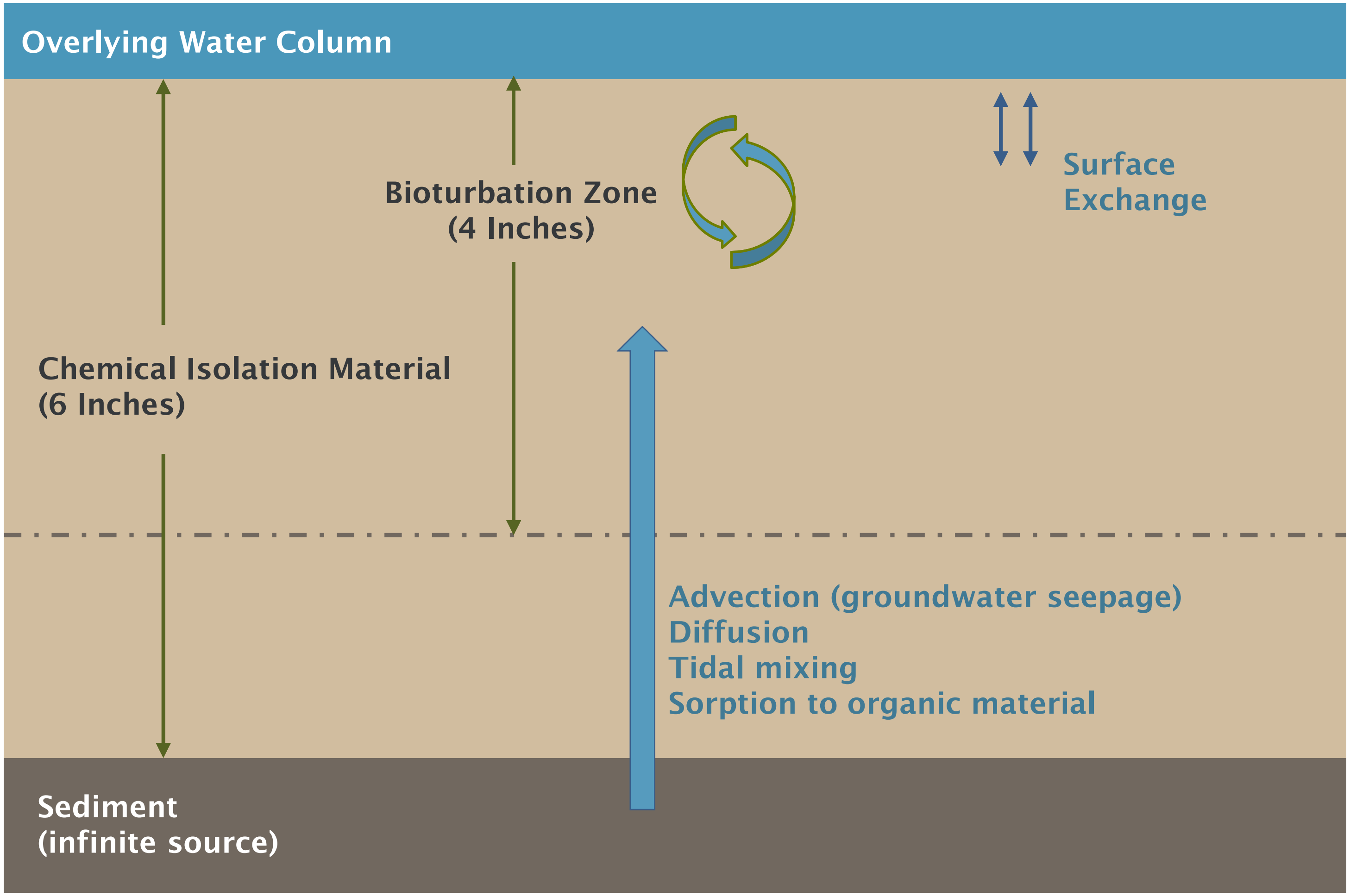
Percent Reductions in Surface Concentration at Steady State as a Function of Thin Cover Thickness and Bioturbation Depth

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

J-2



ENVIRON ANCHOR QEA	**Model Domain and Cap Profile**	**Figure**
	LCP CHEMICAL SITE, BRUNSWICK, GEORGIA	**J-3**

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Appendix K
SWAC Derivation and SMA Development Details

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:
Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:
ENVIRON International Corporation

Anchor QEA, LLC

Date:
June 2, 2014

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Contents

List of Figures

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Acronyms and Abbreviations

COC	chemical of concern
FS	feasibility study
OU1	operable unit 1
PAH	polycyclic aromatic hydrocarbon
RGO	remedial goal options
SMA	sediment management area
SWAC	surface-weighted average concentration
USEPA	United States Environmental Protection Agency

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Executive Summary

This appendix provides details regarding the calculation of surface-weighted average concentrations (SWACs) and the development of sediment management areas (SMAs) for the *Feasibility Study Report for Operable Unit 1 (OU1) (Estuary) – LCP Chemicals Site, Brunswick, Georgia* (the FS). SWACs were used to evaluate area average remedial goal options (RGOs) for mercury and Aroclor-1268. The area represented by each sample location was determined using Thiessen polygons. Pre- and postremediation SWACs were calculated using current sediment concentrations and background concentrations from Blythe Island.

Three SMAs were developed to define the extent of remedial actions required to meet a range of RGOs. Thiessen polygons were used along with morphology to create SMAs. Each polygon contains only one sample location and the boundaries of the polygon are created by drawing lines perpendicular to and equidistant from the neighboring sample locations. SMA footprints based on polygons were adjusted to account for tributaries, topography, previous remedial actions, and area averaging considerations at multiple locations.

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1 Introduction

This appendix supports the *Feasibility Study Report for Operable Unit 1 (OU1) (Estuary) – LCP Chemicals Site, Brunswick, Georgia* (the FS). The focus of this appendix is to provide additional detail regarding the creation of sediment management areas (SMAs) in Section 5.1. Specifically, the appendix explains the derivation of surface-weighted average concentrations (SWACs), the derivation of Thiessen polygons, and the use of Thiessen polygons and estuary morphology for creating the remedial footprints described in Section 5.

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2 Surface-Weighted Average Concentration Derivation

SWACs were calculated to evaluate area average concentrations relative to the remedial goal options (RGOs) for the Site. SWACs are an area averaging technique which takes into account the surface area associated with each sample along with the concentration. SWACs are generally used when evaluating sediment exposures that occur over spatial scales that encompass multiple sample locations. SWACs were calculated for mercury and Aroclor 1268 as follows:

$$SWAC = \frac{\sum_{i=1}^{n}(C_i * A_i)}{\sum_{i=1}^{n}(A_i)}$$

where:

C_i = Sediment concentration at location, i (milligrams per kilogram [mg/kg])

A_i = Area associated with location, i (acres)

n = Number of locations within the area of interest (i.e. within a specific marsh or creek domain boundary)

Existing sediment concentrations were used to calculate preremedy SWACs. For postremedy SWACs, the current surface sediment concentration at remediated sample locations was replaced with a regional background concentration to represent postremedy surface sediment conditions. The regional background values were based on data from the Blythe Island marsh located across the Turtle River. Background values were 0.3 mg/kg for mercury and 0.2 mg/kg for Aroclor 1268. The use of a more pristine estimate of background conditions would be less conservative and would likely underestimate potential long-term conditions in OU1.

Thiessen polygons were used to represent the area associated with each sample location and are discussed further in Section 3. The size and shape of the Thiessen polygons were based on the position of neighboring sediment sample locations within in each domain or creek.

3 Remedial Footprint Details

The following presents details regarding the development and refinement of the SMAs described in Section 5.1 of the FS. A flow chart outlining the SMA development process is provided in Figure K-1.

3.1 Thiessen Polygon Derivation

Thiessen polygons are a spatial weighting technique which assigns an area to each sample location based on its proximity to neighboring samples. Each polygon contains only one sample location and the boundaries of the polygon are created by drawing lines perpendicular to and equidistant from the neighboring sample locations. Since the Thiessen polygon is an expanded representation of the sample location that it contains, there were boundary constraints that were put in place to ensure that a polygon only addressed areas that were representative of the sample location (i.e. polygons for a marsh sample enclosed marsh terrain and polygons for creek samples enclosed creek terrain). Therefore, polygons were not connected across domain/creek boundaries. The Thiessen polygons used for the FS were created in ArcGIS, a publically available geographical information system computer program.

There is a different set of Thiessen polygons for each chemical of concern (COC) because not all locations were sampled for all COCs. The Thiessen polygons for each COC are shown in Figures K-2 through K-5 for mercury, Aroclor 1268, lead, and polycyclic aromatic hydrocarbons (PAHs), respectively. Figures K-2 through K-5 also show the COC-specific concentrations relative to the benthic community RGOs. In more densely sampled areas, the polygons are smaller; in less dense areas the polygons are larger. When a location was sampled for multiple COCs with concentrations above RGOs, the largest polygon associated with an exceedance was used to define the limits of the SMA for that location unless morphology modifications were applied as discussed in the next section.

The SMA-1, SMA-2, and SMA-3 footprints are shown on Figures K-6, K-7, and K-8, respectively. These figures show the SMA footprints with only the mercury polygons shown. One or more polygons were used to define the footprint when a sample location had an exceedance for one or more of the benthic community RGOs (i.e. not every portion of the SMA footprints are a perfect match to every polygon, especially when more than one RGO is exceeded and more than one polygon shape is available for any particular location.

3.2 Morphology Modifications

Estuary morphology was used to refine the SMAs; this included consideration of such features as the presence of tributary channels, topography, and proximity to previously remediated areas in Domain 1. The following presents specific examples and how the remedial area was refined:

- Tributary Channels – During field work in 2012, a number of small tributaries of LCP Ditch and Eastern Creek were identified in Domain 1 and 2. These tributaries are inundated for longer periods than the surrounding marsh and receive sediment from Eastern Creek and LCP Ditch. Where Domain 1 and 2 samples fell within these small tributaries, the remedial footprint was constrained to the boundaries of the tributary since the sample is representative of the tributary, not the surrounding marsh. Figures K-9A and K-9B show sample locations within tributaries and the modifications made to the remedial footprint.

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- Previously remediated areas of Domain 1 – Remedial actions are not proposed in the portion of Domain 1 which was remediated in 1998-1999. The 1998-1999 removal action involved excavation of contaminated sediments in the eastern portion of Domain 1 and placement of clean soil to restore the area to the pre-excavation grade (EPS and ENVIRON, 2012). Figure K-10 shows the extent of SMA-1 and the extent of the 1998-1999 removal action.
- Dillon Duck – The GIS imagery, the topography, and the vegetation observed in Dillon Duck suggest that the eastern half of this area may not have the same characteristics as the western portion where higher concentrations of COCs are observed (Figure K-11). Therefore, the remedial footprint only extends over the western portion of Dillon Duck.
- Domain 1 Nearshore Remediated Area – A shoreline sample in the remediated area of Domain 1 was defined by a single detection of lead at a concentration of 210 mg/kg; this sample was taken from the marsh near the eastern shoreline of Domain 1 on a portion of marsh that is at a slightly higher elevation from the rest of Domain 1. The Thiessen polygon for this sample is large and extends out over the area remediated in 1998-1999 due to the low sample density in this portion of Domain 1 (Figure K-12). Therefore, this area should be characterized by clean fill. Since the Thiessen polygon extends well into areas previously remediated, the remedial extent has been constrained to an area bounded the presence of adjacent sample locations to the north with concentrations less than the lead RGO, the upland-marsh boundary to the east and south, and the western extent of the topographically higher area surrounding the sample location (Figure K-12).
- Domain 3 Marsh Area – Location M-D3-6A is included in SMA-1 but was not included in SMA-2 or 3 due to the concentrations at this location. This location was sampled at 3 points approximately 10 feet away from each other, so the 3 locations are averaged to reflect the single location (see Appendix E for more specific details regarding data handling at this location). This shape reflects an approximately 50-meter area within the Thiessen polygon (shown on Figure K-13). This sample location was taken from an expansive marsh area in Domain 3 which is only temporarily inundated during high tide, particularly close to the shoreline (i.e., the portion of the Thiessen polygon not shaded). The approximately 50-meter area was consistent with areal extents mentioned for sediment-dwelling organisms, as cited in the United States Environmental Protection Agency (USEPA) RGO letter from November 11, 2011.

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- South Purvis Creek – Location SD-LPC-C2 is identified in SMA-1 and SMA-3 footprints due to a detected Aroclor 1268 concentration of 13 mg/kg (Aroclor-1268 benthic RGO range is 6 mg/kg to 16 mg/kg). This sample was collected from the shoreline sediments however a portion of the Thiessen polygon extends into the middle of the channel. As shown in Figure K-14, the shoreline area of Purvis Creek in this area is not continuously submerged like the center channel. Since this sample location is only representative of the shoreline sediments, the extent of shoreline sediments was used to define the remedy area for this location (Figure K-14).
- Creek Averaging Areas in Purvis Creek and Western Creek Complex – In accordance with the USEPA RGO letter (USEPA 2011), samples within a 50 meter square area were averaged for comparison to the RGOs. Samples included within averaging areas that exceed an RGO were included within the SMA, but the averaging area was not used to define the extent because some averaging areas did not have data. Instead, once locations were identified as requiring remedial action based on the 50 meter averaging area, the Thiessen polygon for each sample within the averaging area was used to define

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the extent of the remedial activities. Locations with averaged sample results are provided in Section 3 of the FS. Location-specific polygons within those areas are identified in Figures K-2 through K-5 of this appendix.

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4 References

EPS and ENVIRON. 2012. Remedial Investigation Report Operable Unit 1 – Estuary LCP Chemical Site, Brunswick, Georgia. Prepared for the Site Steering Committee, May.

USEPA. 2011. *Approval of Human Health Baseline Risk Assessment for Operable Unit 1, LCP Chemical Superfund Site, Brunswick GA*. Letter from Galo Jackson, EPA Region 4, to Prashant Gupta, Honeywell, November 30.

Appendix K
SWAC Derivation and SMA
Development Details

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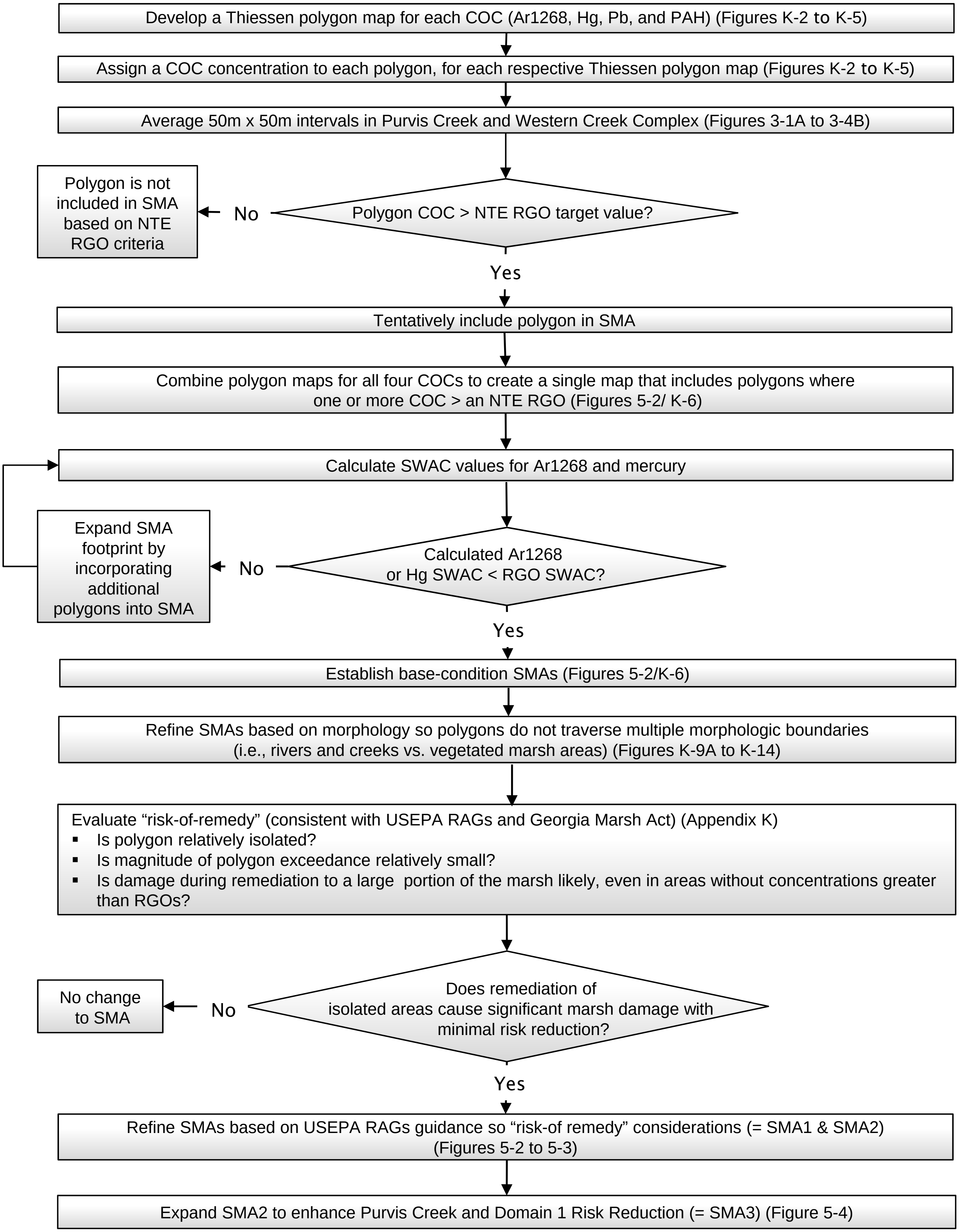
Figures



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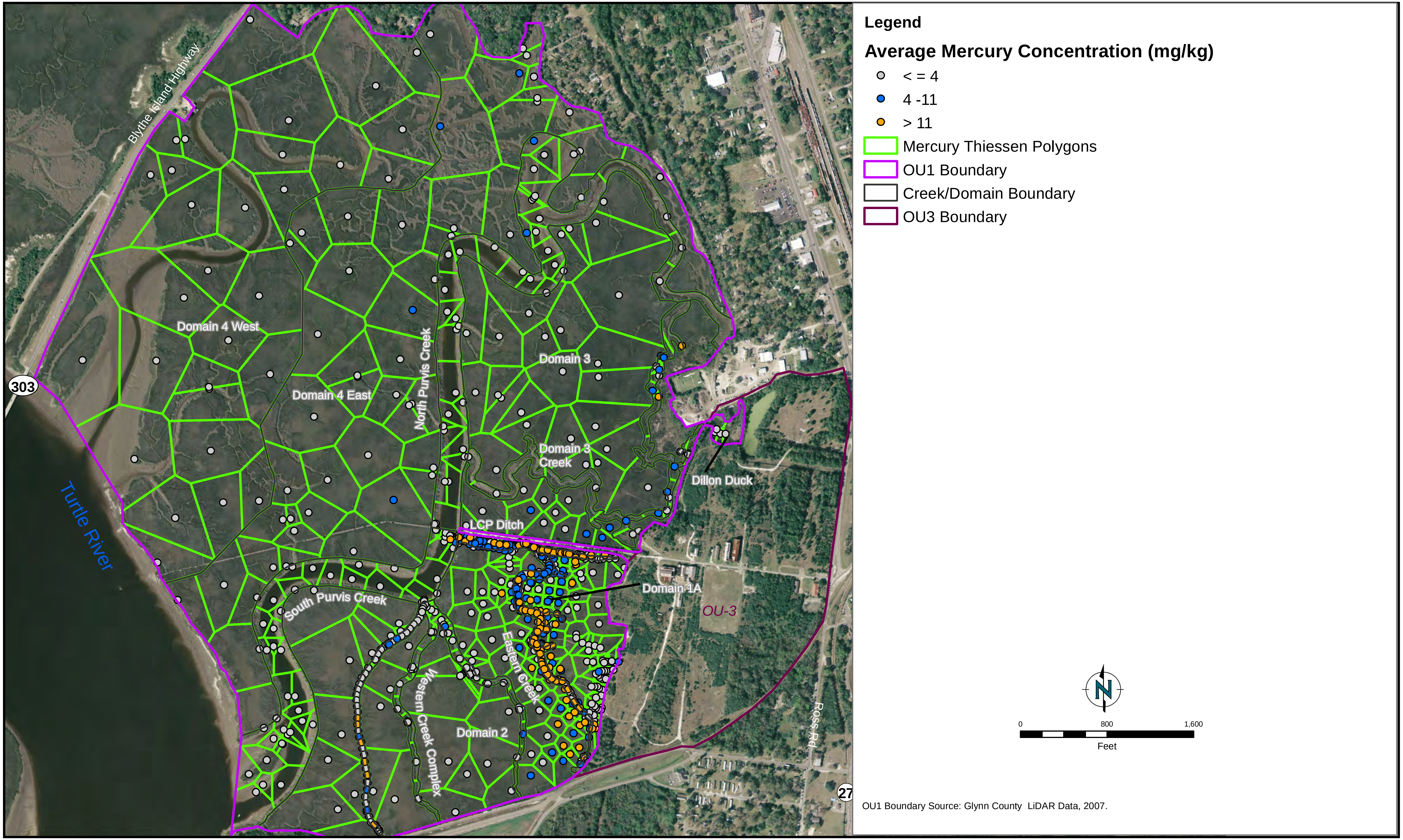
SMA Delineation Flow Chart

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure K-1



Legend

Average Mercury Concentration (mg/kg)

- ● < = 4
- ● 4 -11
- ● > 11
- 🟩 Mercury Thiessen Polygons
- ▭ OU1 Boundary
- ▭ Creek/Domain Boundary
- ▭ OU3 Boundary

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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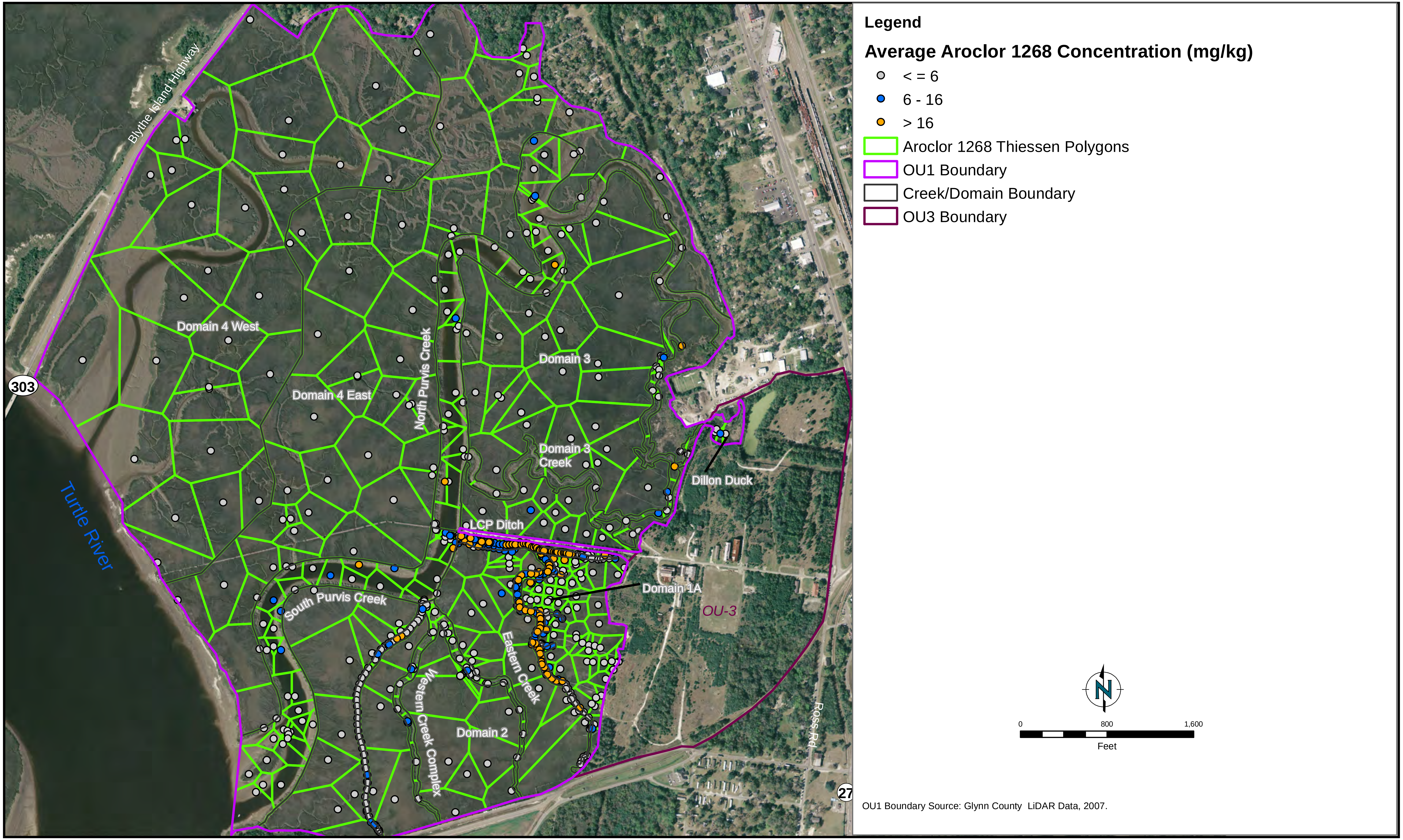
Mercury Thiessen Polygons and Mercury Concentrations in OU1 Surface Sediments

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure K-2



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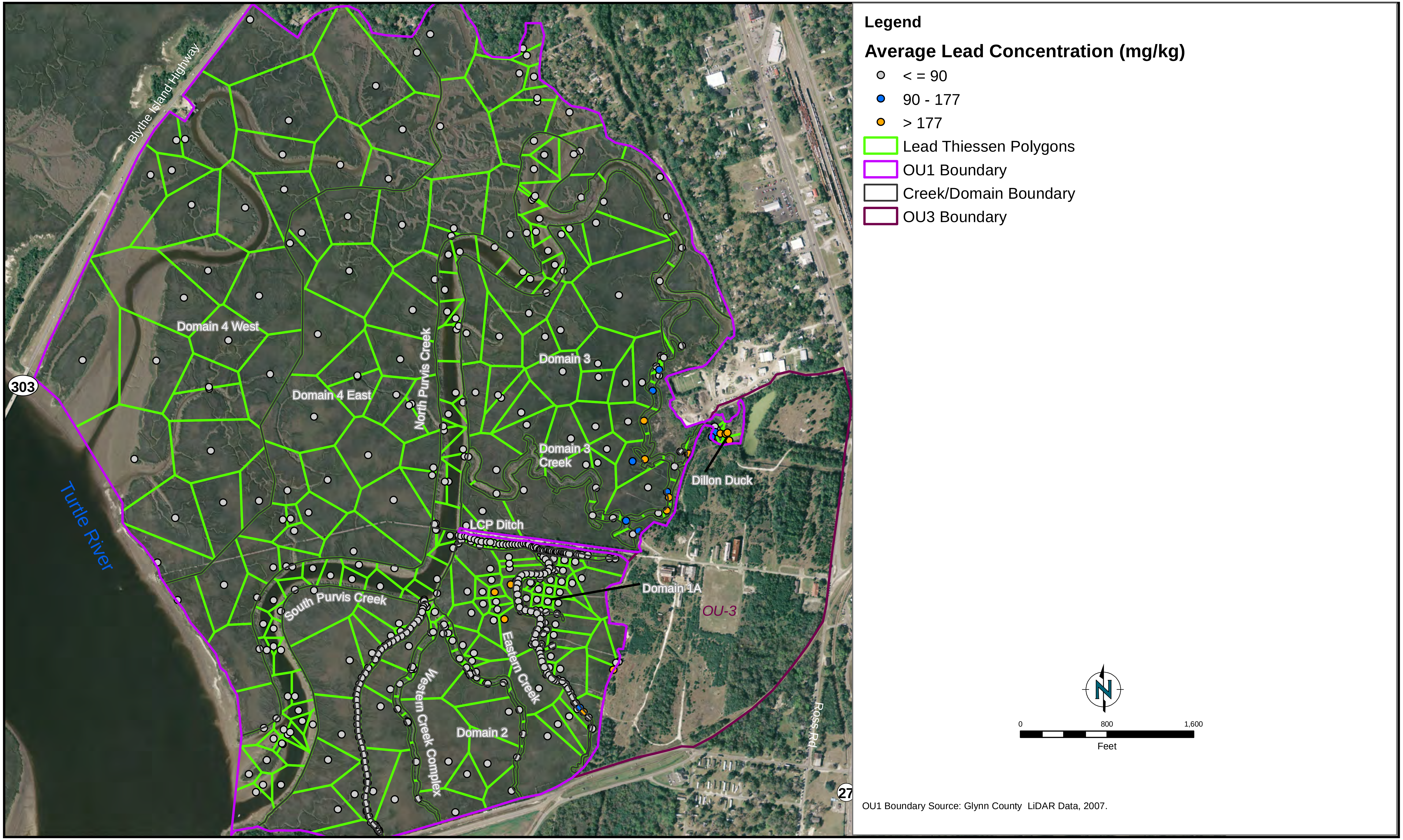
Aroclor 1268 Thiessen Polygons and Aroclor 1268 Concentrations in OU1 Surface Sediments

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure K-3



OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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Lead Thiessen Polygons and Lead Concentrations in OU1 Surface Sediments

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure
K-4

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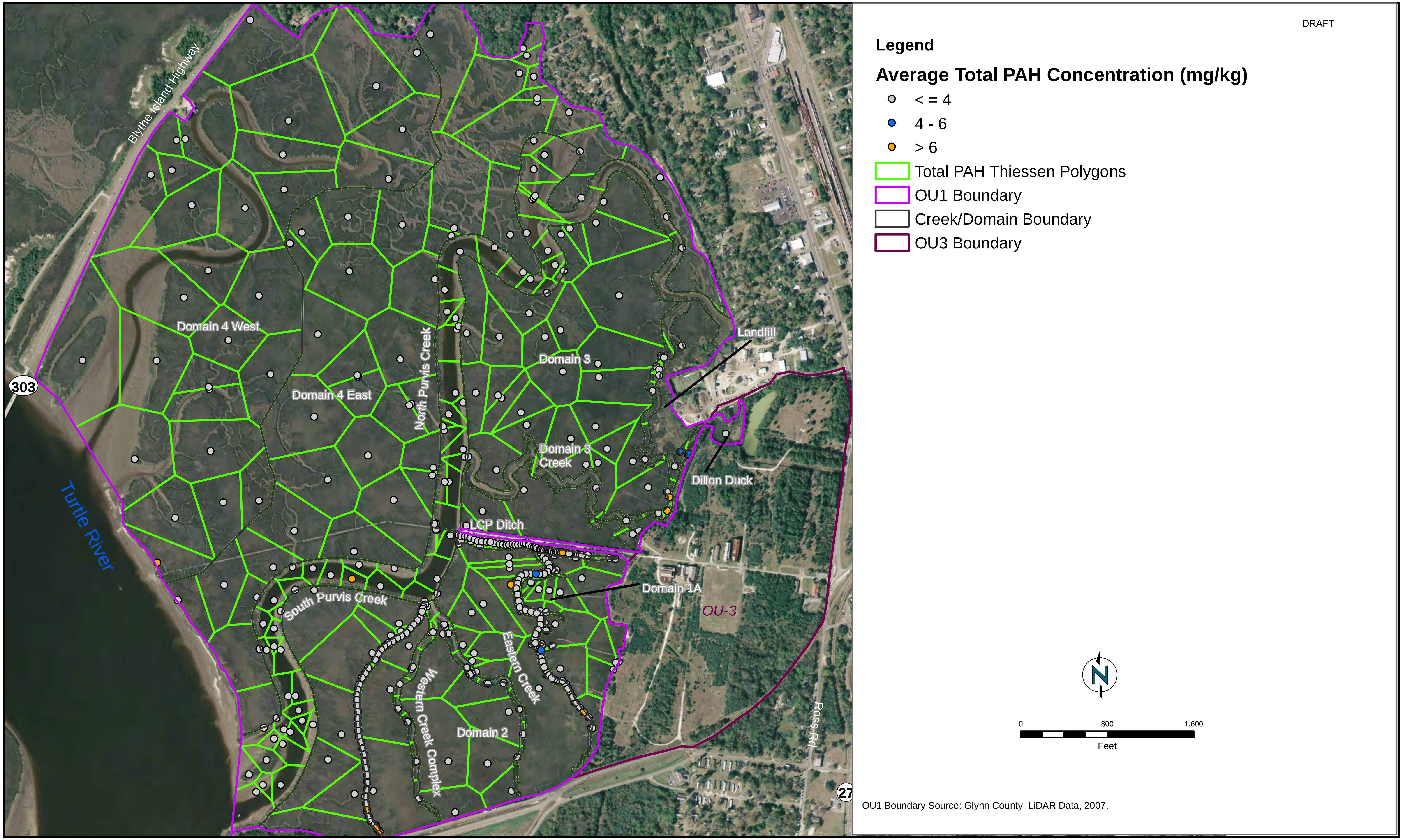

OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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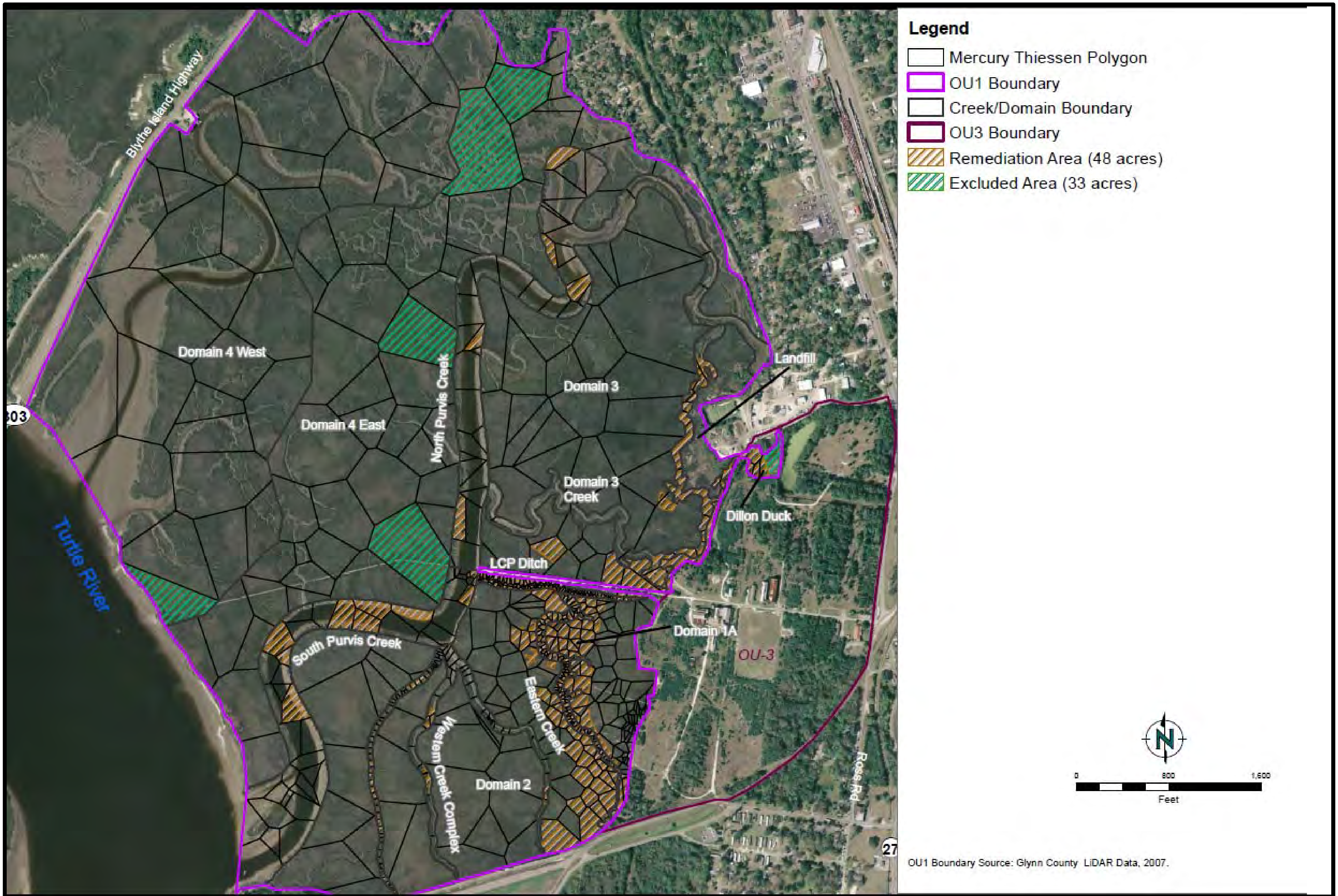
Total PAH Thiessen Polygons and Total PAH Concentrations in OU1 Surface Sediments

LCP CHEMICAL SITE, BRUNSWICK, GA

Figure K-5



OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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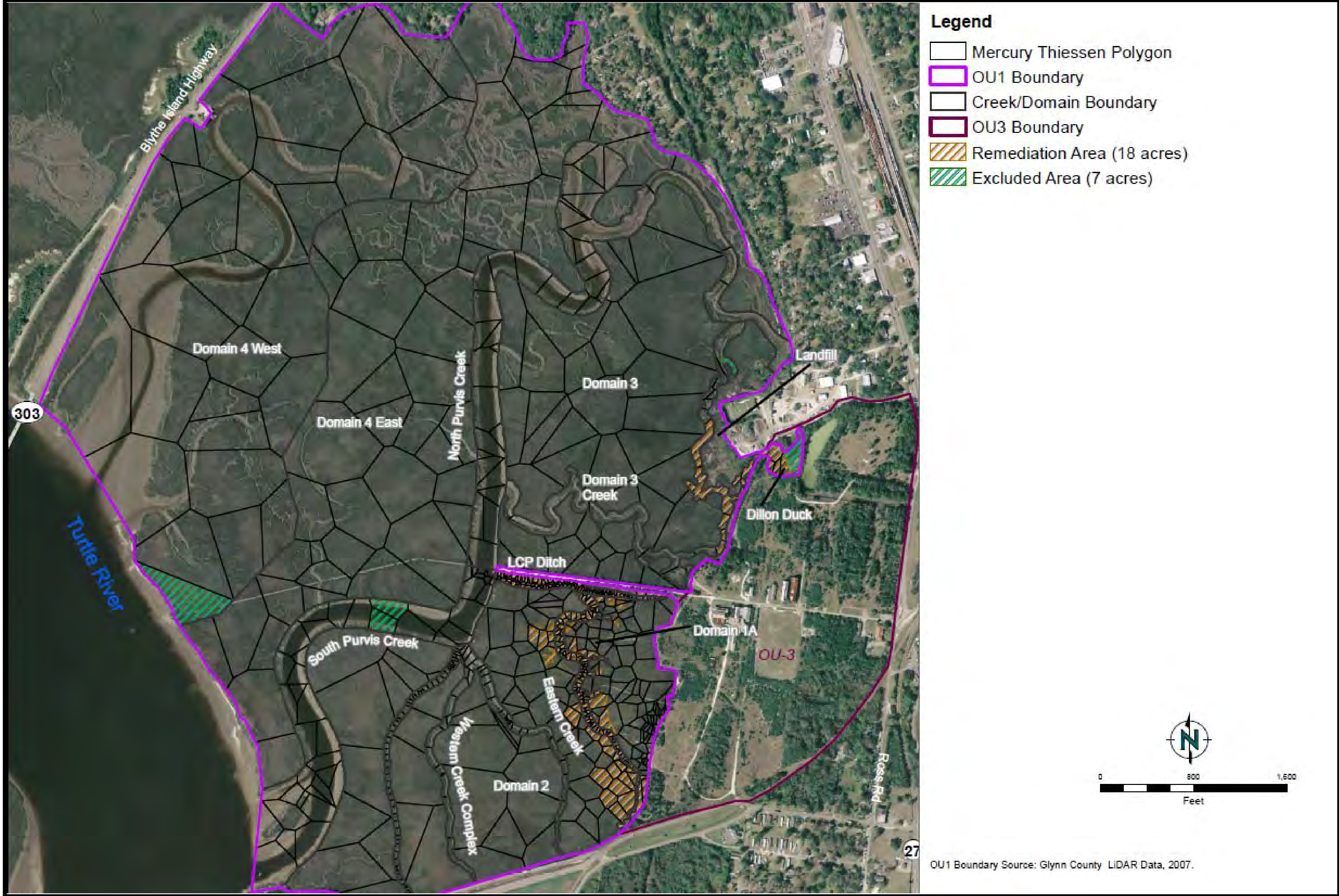
SMA-1 with Thiessen Polygons

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

K-6



OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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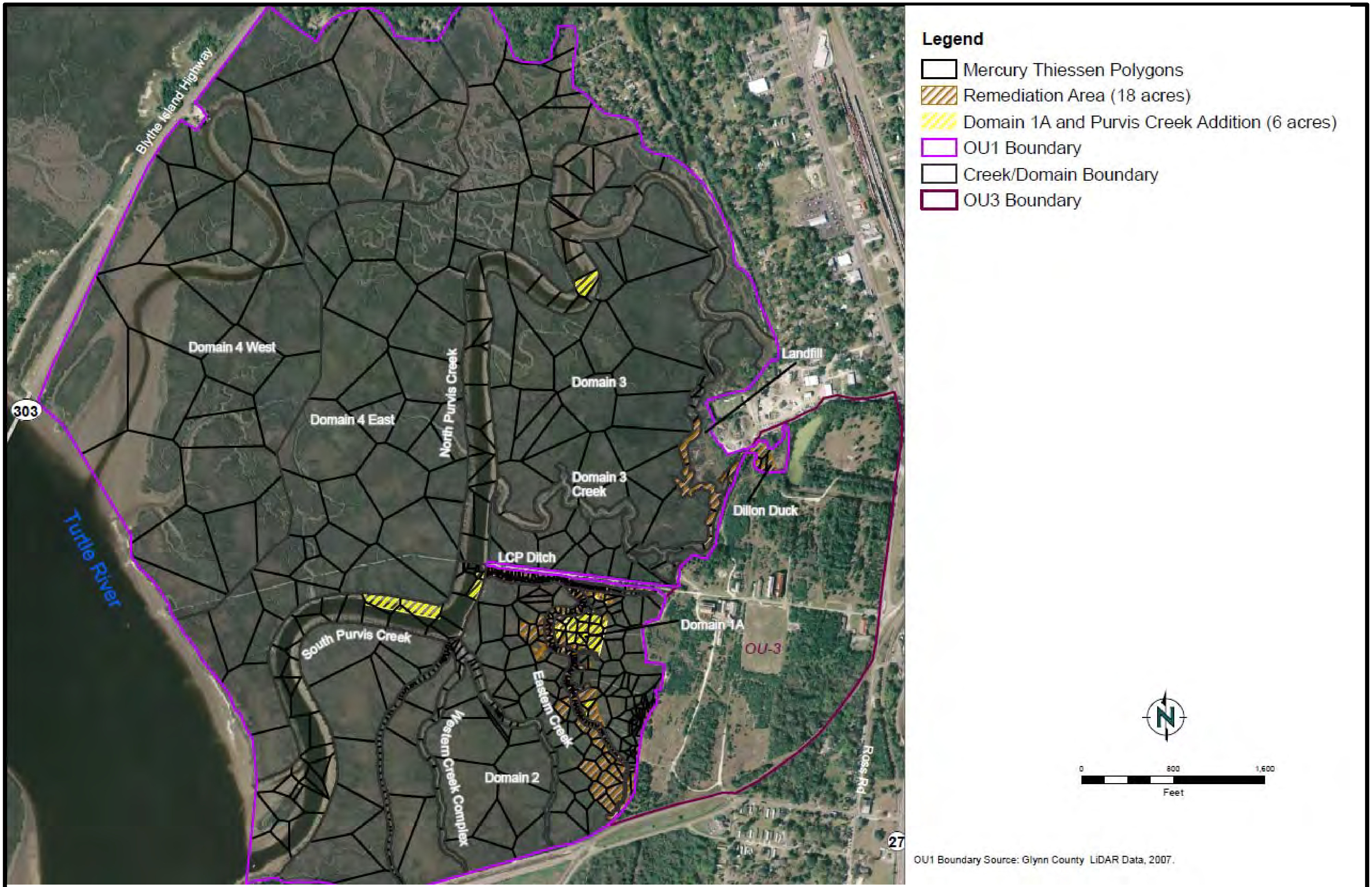
SMA-2 with Thiessen Polygons

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

K-7



OU1 Boundary Source: Glynn County LiDAR Data, 2007.

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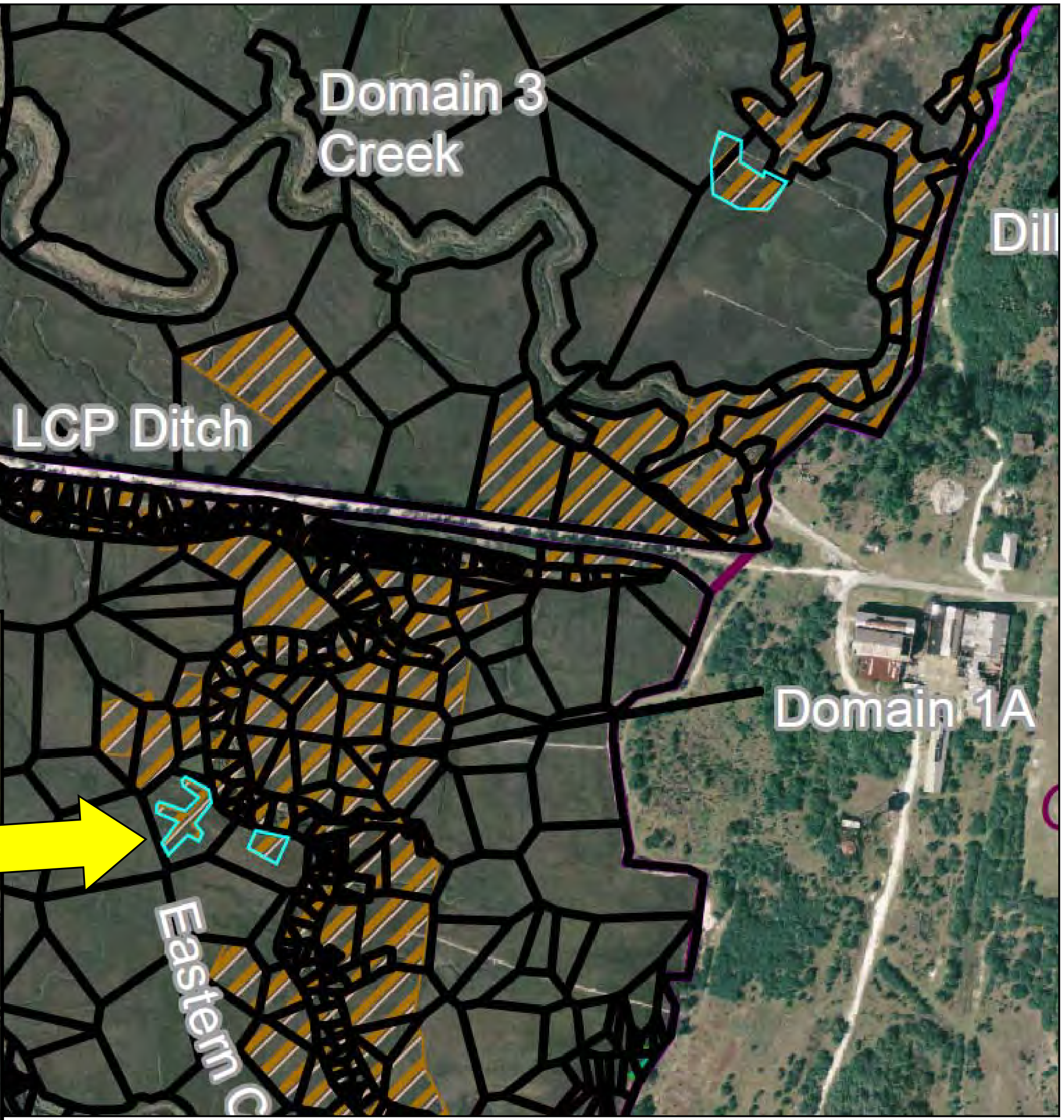
SMA-3 with Thiessen Polygons

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

K-8

The remedy areas in blue were modified based on tributary morphology.



SMA-1 Tributary Modifications

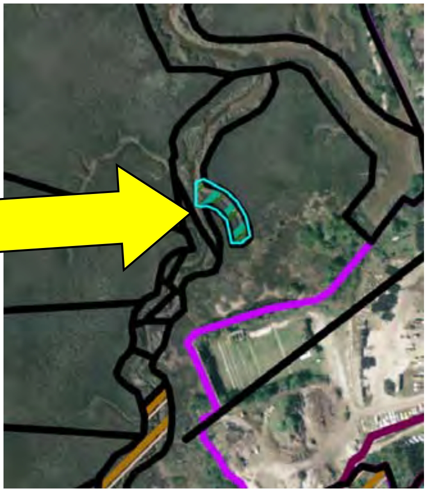
LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

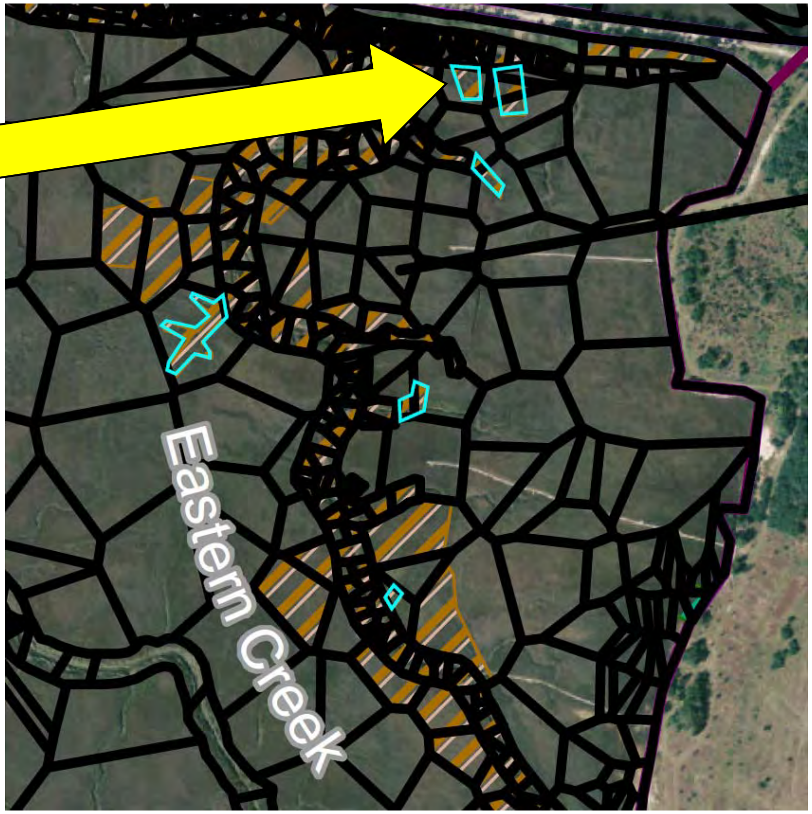
Figure

K-9A

The remedy areas in blue were modified based on tributary morphology.

The remedial area was constrained to the boundary of this tributary where the sample was collected





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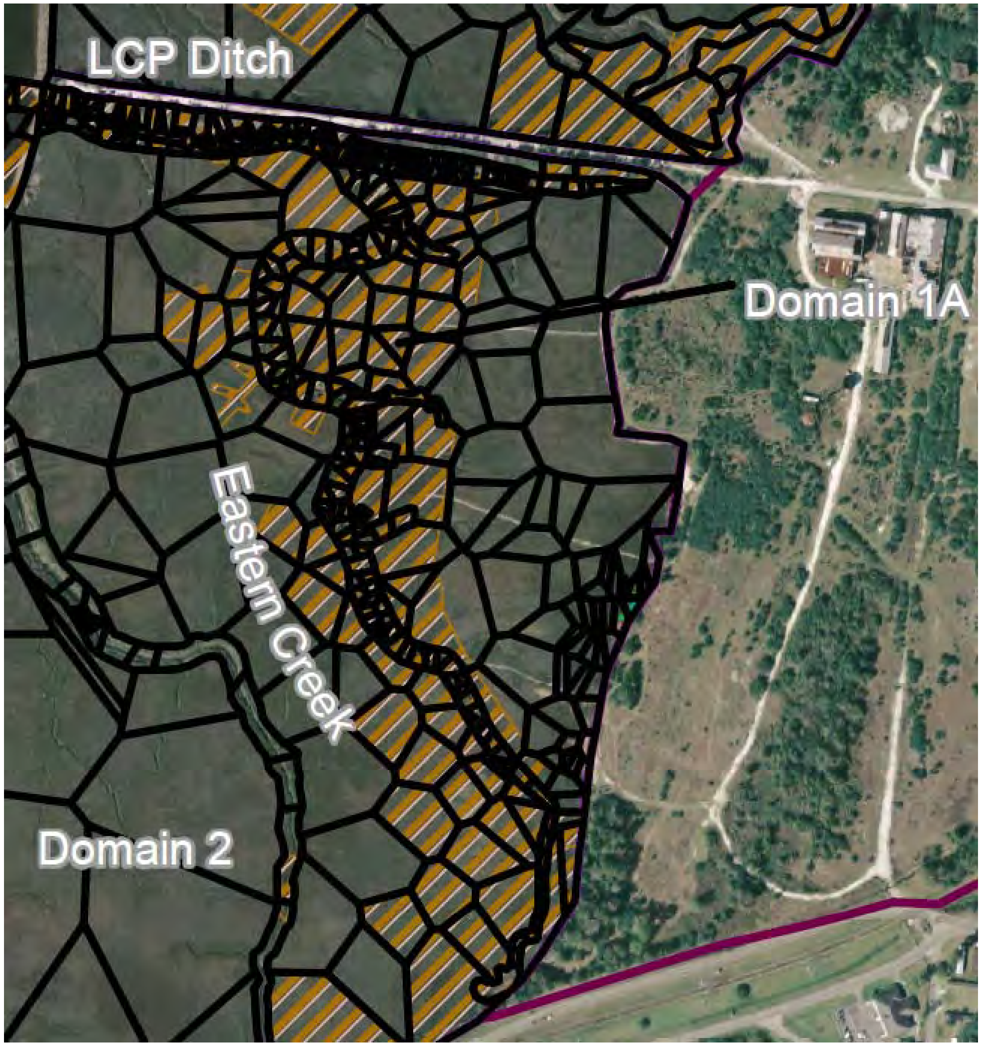
SMA-2 Tributary Modifications

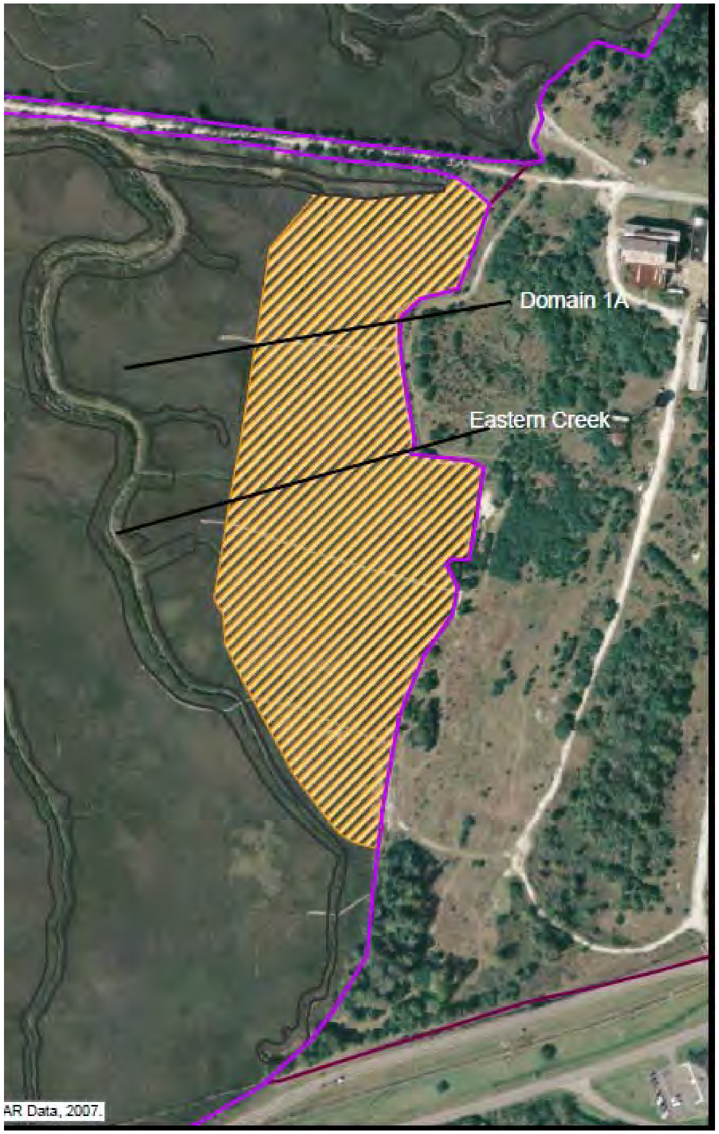
LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

K-9B



Brown shading delineates SMA-1 boundary
Black lines show boundaries of Mercury Thiessen polygons



Mustard shading delineates 1998-1999 remediated area within OU1

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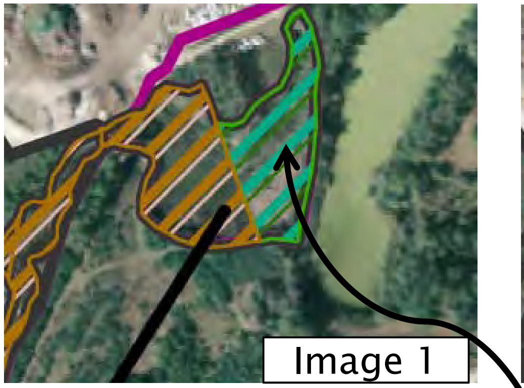
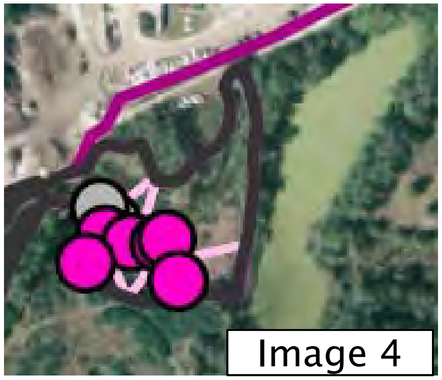
Domain 1 Previously Remediated Area Modifications for SMA-1

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

K-10





- Overall: this area has a wetland cycle that is not typical of the overall OU1 Estuary (i.e., there is no regular tidal inundation). Dillon Duck is separated from the OU1 marsh except during infrequent and extreme tidal flooding conditions.
- Image 1: A portion of Dillon Duck is identified within the SMA footprints (brown) and a portion is excluded (green).
- Image 2: The aerial image shows this area has slightly different elevation and vegetation.
- Image 3: The “tail” of Dillon Duck was defined by a single polygon.
- Image 4: The sample defining the “tail” polygon was collected near the center of the Dillon Duck area, not in the portion of the “tail” with apparent higher elevation and different vegetation. Pink symbol demonstrates a detection of 210 mg/kg lead; gray symbols are less than 90 mg/kg for lead
- Image 5: A site visit confirmed that the “tail” portion of the Dillon Duck appears to have slightly different character and warrants separate consideration.

Modifications Dillon Duck SMA Extent

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

K-11

Concentration map close-up. Pink symbol along shoreline illustrates detection of 210 mg/kg lead. Gray symbols are less than 90 mg/kg for lead. Pink lines illustrate lead polygons.

Small area of brown hatching shows this location as part of the SMA-1 footprint. Rationales for small size are provided to the right.

Photograph of this area August 2013

Rationales:

- A lead sample concentration of 210 mg/kg exceeds the range of benthic community RGOs.
- This area is defined by a large Thiessen polygon (~1 acre).
- Due to infrequent inundation during high tide, there is little exposure for benthic community other than fiddler crabs, which are abundant.
- This area was previously remediated as part of the 1998-1999 removal action.
- Therefore, a small portion of the area immediately adjacent to the shoreline was identified in the SMA-1 footprint.

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Modifications to Domain 1 SMA Extent

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

K-12

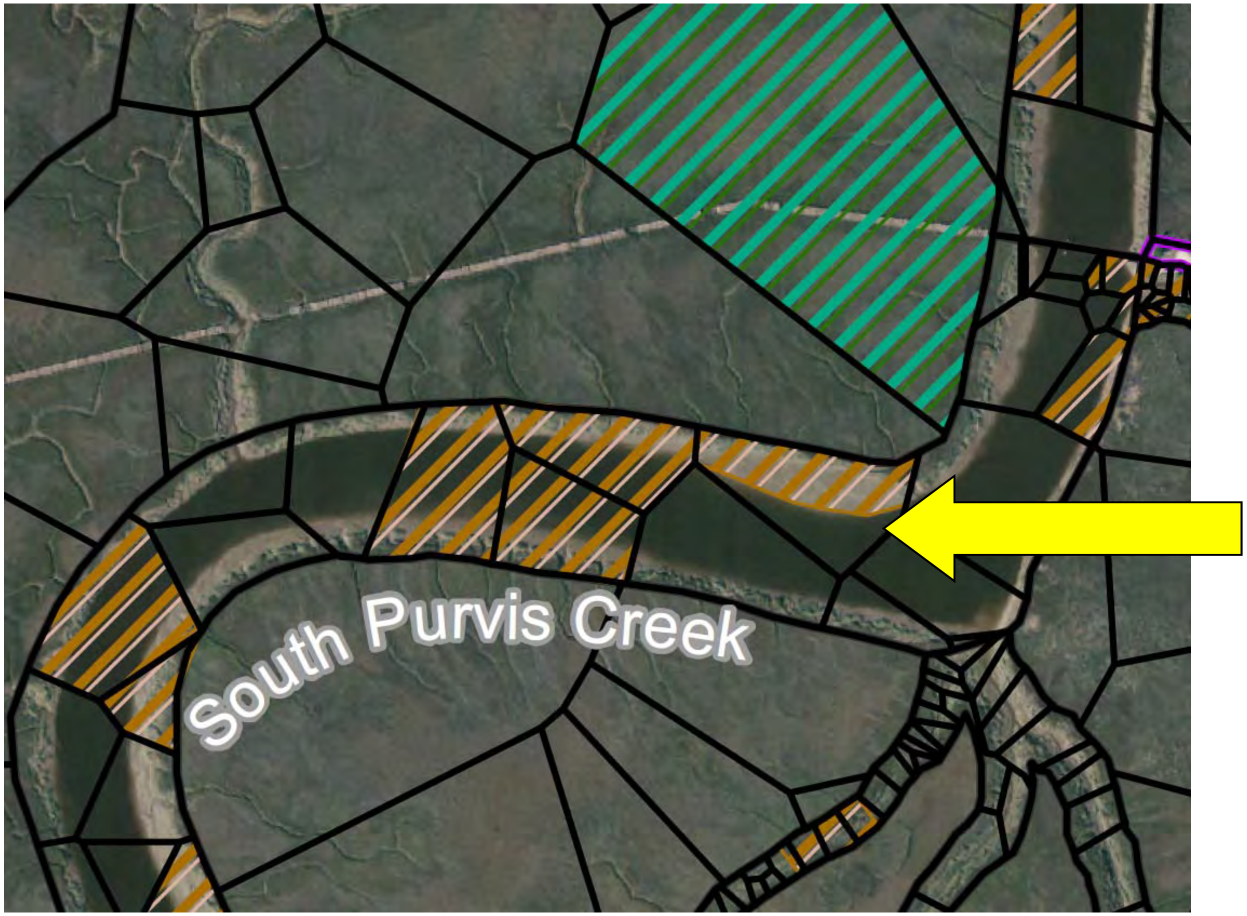
Domain 3 Sample location

Modifications to Domain 3 SMA Extent

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

K-13



This example shows the stream channel was used to define a portion of the SMA-1 and SMA-3 footprint. This polygon extended into the center of the creek, but the sediment deposits of the shoreline were used to define the area for capping.

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Modifications to South Purvis Creek SMA Extent

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

K-14

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Appendix L
Technical Approach for Remedy Evaluation and Uncertainty Evaluation

LCP Chemical Superfund Site,
Operable Unit No. 1 (Estuary)
Brunswick, Georgia

Responsible Parties:
Honeywell
Atlantic Richfield Company
Georgia Power Company

Prepared by:
ENVIRON International Corporation

Anchor QEA, LLC

Date:
June 2, 2014

Deleted: October 18, 2013

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Contents

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Acronyms and Abbreviations

%	percent
95%UCL	95 percent upper confidence limit on the mean
BAF	bioaccumulation factors
BERA	baseline ecological risk assessment
BSAF	biota sediment accumulation factor
BW	body weight of wildlife
COPC	constituent of potential concern
FS	feasibility study
HQ	hazard quotients
kg	kilogram
L/day	liters per day
LOAEL	lowest observable adverse effect level
µg/kg	micrograms per kilogram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
NOAEL	no observable adverse effect level
OU1	operable unit 1
RGO	remedial goal option
SIR	sediment ingestion rate
SMA	Sediment Management Area
SWAC	surface-weighted average concentration
TDI	total daily intake
TRV	toxicity reference values
USEPA	United States Environmental Protection Agency

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1 Introduction

This appendix to the operable unit 1 (OU1) feasibility study (FS) provides supporting information for the remedy effectiveness evaluation provided in Section 6 of the FS, for the six alternatives:

- Alternative 1: No Action
- Alternative 2: Sediment Removal in Sediment Management Area (SMA)-1
- Alternative 3: Sediment Removal, Capping, and Thin-Cover Placement in SMA-1
- Alternative 4: Sediment Removal in SMA-2
- Alternative 5: Sediment Removal, Capping, and Thin-Cover Placement in SMA-2
- Alternative 6: Sediment Removal, Capping, and Thin-Cover Placement in SMA-3

The remedy effectiveness evaluation is based on surface-weighted average concentrations (SWACs) (FS Section 3, Table 3-5) and the methods and calculations developed by the United States Environmental Protection Agency (USEPA) in the baseline ecological risk assessment (BERA) for OU1 (Black and Veatch 2011) as well as discussions with USEPA in the development of this FS. The evaluation documented in Section 6 of the FS and supported in this appendix identifies baseline conditions in a manner consistent with the BERA.

This appendix includes the following sections:

- Section 2: Mammal and bird remedy effectiveness evaluation approach
- Section 3 Finfish remedy effectiveness evaluation approach
- Section 4 Supporting information related to the sediment-dwelling community
- Section 5 Additional uncertainties related to the remedy effectiveness evaluation
- Section 6 References

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2 Mammal and Bird Remedy Effectiveness Evaluation

Data supporting the remedy effectiveness evaluation (FS Section 6) originates from the BERA or was generated with BERA formulae and supporting technical information. This appendix includes information supporting the following figures in FS Section 6:

- FS Figure 6-1A: Current Conditions and Baseline Ecological Risk Assessment Findings for Mammals and Birds Exposed to Mercury
- FS Figure 6-1B: Current Conditions and Baseline Ecological Risk Assessment Findings for Mammals and Birds Exposed to Aroclor 1268
- FS Figure 6-2A: Remedy Effectiveness Evaluation for the Mercury Exposures and the Green Heron Exposed to All Areas
- FS Figure 6-2B: Remedy Effectiveness Evaluation for Mercury and the Green Heron in Areas with HQs Exceeding a Threshold Value of 1

2.1 Technical Supporting Information for FS Figures 6-1A and 6-1B

FS Figures 6-1A and 6-1B reflect current conditions, as documented by the BERA, and thus represent the No Action alternative. The BERA estimates mercury and Aroclor 1268 risks for six mammal and bird receptors (Black and Veatch 2011; Section 4.11, and Appendix H):

- Clapper Rail (*Rallus longirostris*)
- Green Heron (*Butorides striatus*)
- Marsh Rabbit (*Sylvilagus palustris*)
- Raccoon (*Procyon lotor*)
- Red-Winged Blackbird (*Agelaius phoeniceus*)
- River otter (*Lutra canadensis*)

FS Figures 6-1A and 6-1B are based on lowest observable adverse effect level (LOAEL) hazard quotients (HQs). Figures L-1A and L-1B are similar but show the no observable adverse effect level (NOAEL) for wildlife HQs. These data are summarized in Table L-1A (Black and Veatch 201; Appendix H, Tables H-1 through H-7).

Green heron is the most sensitive species to mercury, with LOAEL HQs exceeding 1 (FS Section 6, Figure 6-1A). LOAEL HQs for other mammals and birds were less than 1. Therefore, the green heron was the focus of the mercury remedy effectiveness evaluation (FS Figures 6-2A and 6-2B). The LOAEL HQs for mammals and birds did not exceed 1 for Aroclor 1268, so a similar risk reduction evaluation is not provided for Aroclor 1268.

Lead is not considered in the mammal and bird remedy effectiveness calculations because NOAEL and LOAEL HQs in the current conditions/No Action alternative are less than 1. These HQs are summarized on Table L-1B.

PAHs are not considered in the mammal and bird remedy effectiveness calculations because the BERA determined that they were not toxic at this Site.

> “HQs were not developed for PAHs because a previous investigation… indicated that PAHs were almost never detected in evaluated prey of wildlife

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and were demonstrated not to be hazardous in worst-case examples." (Black and Veatch 2011; Appendix H).

2.2 Remedy Effectiveness Calculations Used in FS Figures 6-2A and 6-2B

Remedy effectiveness was evaluated for the No Action alternative (Alternative 1), SMA-1 (Alternatives 2 and 3), SMA-2 (Alternatives 4 and 5), and SMA-3 (Alternative 6) by comparing No Action conditions (LOAEL HQs described in Section 2.1 of the FS) to estimated HQs calculated using the SWACs for each of the SMAs (FS Table 3-5).

2.2.1 Green Heron Intake Estimates

USEPA requested that green heron intake estimates be calculated using the USEPA spreadsheets that were used in the BERA. The SWACs for SMA-1, SMA-2, and SMA-3 were used in the food web daily intake formula described below (Black and Veatch 2011; Section 4.11).

$$(1) \qquad TDI = \frac{\{[(\mathrm{CF1}*\mathrm{P1})+(\mathrm{CF2}*\mathrm{P2})+(\mathrm{CF3}*\mathrm{P3})]*\mathrm{FIR}+(\mathrm{CS}*\mathrm{SIR})+(\mathrm{CW}*\mathrm{WIR})\}\{\mathrm{AUF}\}\{\mathrm{TUF}\}}{\mathrm{BW}}$$

And:

$$(2) \qquad \mathrm{HQ} = \frac{TDI}{TRV}$$

Where:

AUF	area-use factor
BW	body weight of wildlife (kilograms [kg]/wet weight)
CF1	mean concentrations of constituent of potential concern (COPC) in fiddler crabs (*Uca spp.*) (milligrams per kilogram [mg/kg], dry weight)
CF2	mean concentrations of COPC in blue crab (*Callinectes sapidus*) (mg/kg, dry weight)
CF3	mean concentrations of COPC in mummichog (*Fundulus heteroclitus*) (mg/kg, dry weight)
CS	mean concentration of COPC in sediment (mg/kg, dry weight)
CW	mean concentration of COPC in water (milligrams per liter [mg/L])
FIR	food ingestion rate (kg dry weight/day)
P1	proportion of fiddler crabs in diet (unitless)
P2	proportion of blue crabs in diet (unitless)
P3	proportion of mummichogs in diet (unitless)
SIR	sediment ingestion rate (kg dry weight/day);
TDI	total daily intake (mg/kg wet weight/day)
TRV	toxicity reference value (mg/kg wet weight/day)
TUF	time-use factor
WIR	water ingestion rate (liters per day [L/day])

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Concentrations and other parameters in the total daily intake formula (1) for the green heron (i.e., CF1, CF2, and CF3) are based on BERA bioaccumulation relationships, calculations, and methods (Black and Veatch 2011; Section 7.1, Table 7-6: Table 7-7). The BERA table of bioaccumulation factors (BAFs) is reproduced in this appendix as Table L-2. The table of green heron receptor parameters is reproduced in this appendix as Table L-3.

2.2.2 Toxicity Reference Values

LOAEL and NOAEL TRVs for the green heron are listed in Table L-4 (Black and Veatch 2011; Table 4-27).

2.2.3 Postremedy Estimated HQ Tabular Results

Results for the green heron are calculated in Table L-5, including predicted dietary items for fiddler crabs, blue crabs, and mummichogs for each alternative. Table L-6 summarizes the HQs from Table L-5; this summary of HQs was used to create FS Figures 6-2A and 6-2B.

2.3 Uncertainties in the Green Heron Remedy Effectiveness Evaluation

FS Figures 6-2A and 6-2B provide HQs for the Domain 3 Creek and also provide the HQs for the average of the Domain 3 Creek, the Domain 3 marsh, and Purvis Creek because Domain 3 Creek is too small to support green heron. Herons spend time in different areas of the marsh due to changes in tides and prey availability. Averaging the Purvis Creek, Domain 3, and Domain 3 Creek areas realistically estimates risks for herons, particularly when the tide is in or out, as the mummichogs that are 90 percent (%) of the green heron diet move in and out of Domain 3 Creek with the tide.

Estimates of uptake into mummichogs, blue crabs, and fiddler crabs are uncertain; however, remedy effectiveness evaluation methods were consistent with the BERA to ensure a sound basis for comparison with baseline values.

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3 Finfish Remedy Effectiveness Evaluation Approach

This section provides the supporting information for the following figures in Section 6 of the FS, based on information from the BERA (Black and Veatch 2011):

- FS Figure 6-3: Remedy Effectiveness Evaluation for Mercury and Finfish
- FS Figure 6-4A: Remedy Effectiveness Evaluation for Aroclor 1268 and Finfish
- FS Figure 6-4B: Striped Mullet Aroclor 1268 Fish Tissue Concentrations Over Time

3.1 Technical Information Supporting FS Section 6 Finfish Figures

FS Figures 6-3 and 6-4A summarize conditions for finfish for methylmercury and Aroclor 1268 under the six alternatives. The No Action alternative conditions are based on BERA-estimated mercury and Aroclor 1268 risks for five fish species (Black and Veatch 2011; Table 4-11A, Table 4-11B, and Table 4-29). The BERA data are from samples collected during 2000 to 2007 and include whole-body concentrations for the following species:

- Black Drum (*Pogonias cromis*)
- Red Drum (*Sciaenops ocellatus*)
- Silver Perch (*Bairdiella chrysoura*)
- Spotted Seatrout (*Cynoscion nebulosus)*
- Striped Mullet (*Mugil cephalus*)

The finfish No Action alternative values reflect the LOAEL HQs from the BERA and are reproduced on Table L-7. Note that the 2011 whole-body fish tissue data are not included in this summary, as these data are from a collection effort that occurred after the BERA was completed. Rather, the 2011 whole-body fish tissue data are discussed as an uncertainty. Appendix F of this FS provides a compilation of whole-body fish tissue data graphically illustrated over time.

3.2 Remedy Effectiveness Calculation Approach for Finfish

Although the BERA provides multiple ways to model finfish tissue, extensive consultations with USEPA determined that a linear reduction model was the most appropriate method to assess the remedy effectiveness associated with Alternatives 2 through 6. The No Action alternative HQs for finfish from the BERA were scaled in proportion to sediment concentration reduction for each SWAC. This linear reduction approach assumes that fish tissue concentrations will be reduced proportionally with reductions in sediment concentrations. Fish tissue concentrations were scaled based on the Total Creeks SWACs because fish are expected to be exposed to all creeks, as they migrate under tidal ebbs and flood (FS Table 3-5). The fish likely spend a greater proportion of time in Purvis Creek than the other creeks and this uncertainty is discussed further in Section 3.3 and Section 5 of this appendix.

The linear reduction approach is as follows:

(3) $$Linear\ Reduction\ in\ HQ = (No\ Action\ Alternative\ HQ)\ X\ (\%SWAC\ Reduction)$$

Fish tissue concentrations (Table L-8) were calculated the same way (multiplying the No Action alternative fish tissue concentration by the % SWAC reduction).

For example, the original concentration of Aroclor 1268 in red drum is 1.43 mg/kg dry weight (Table L-7), so the predicted fish tissue concentration for SMA-1 for red drum is 0.37 mg/kg dry weight (1.43 mg/kg dry weight x 26%). FS Figure 6-3A and 6-4A show the HQs for mercury and

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Aroclor 1268 in finfish. Table L-8 identifies the SWAC reductions and estimated HQs with each of the alternatives.

3.3 Uncertainties in the Fish Estimation Approaches

The linear reduction approach discussed above was agreed upon with USEPA during discussions of how remedy effectiveness would be presented in the FS. Because this approach is uncertain, it was also agreed that this appendix would address some of those uncertainties.

- There is a difference between BERA fish tissue data and more recent fish tissue data. BERA data was collected between 2000 and 2007 (Black and Veatch 2011; Table 4-11A). FS Figures 6-4B shows data for fish tissue body residues for striped mullet (Aroclor 1268) collected in 2011.[1] Figures L-2A and L-2B show measured fish tissue concentrations from the BERA. The 95% upper confidence limit on the mean (95%UCL) and mean concentrations are compared to the NOAEL and LOAEL TRVs[2]. Consideration of only the 2000-2007 data overpredict constituent concentrations for some species, as Appendix F shows that concentrations for some species have declined over time for samples collected from OU1.
- There are multiple approaches that can be used to estimate fish tissue concentrations. This appendix and discussions in Section 6 of the FS focus on the linear reduction approach. The BERA used two types of BAFs to explore potential risks, the area-weighted approach and the yearly-average approach (Black and Veatch 2011; Section 7). The BERA explains the uncertainties associated with its fish tissue models (Black and Veatch 2011; Section 7.1.4). The different models are not congruent with the measured fish tissue concentration. Figures L-3A and L-3B compare measured fish tissue concentrations to three different modeling approaches (linear reduction, area-weighted, and yearly average). The data supporting these graphics are provided in Tables L-7 and L-9. These figures indicate that there is variability in any approach considered. The yearly-average approach consistently overestimates HQs for Aroclor 1268. The area-weighted and linear reduction approaches provide similar estimates for mercury and Aroclor 1268.
- Figures L-3A and L-3B show the uncertainty evaluation for the remedial alternatives comparing the three estimation approaches (i.e., linear reduction, area-weighted, and yearly-average). These graphics are based on data provided in Tables L-9, L-10, and L-11.

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[1] A full set of whole-body fish tissue graphics for all species with available data is provided in Appendix F.

[2] NOAEL and LOAEL TRVs are in dry weight so they are not directly comparable to wet-weight tissue data presented in Appendix F.

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4 Sediment-Dwelling Community Supporting Information

FS Section 2 refers to studies of the sediment-dwelling community, described in the BERA (FS Section 2.4), which are summarized below:

- Grass shrimp laboratory toxicity testing was assessed at 10 to 20 stations per year, three replicates per station (2000, 2002, 2003, 2004, 2005). This was a total of approximately 80 separate tests at approximately 40 locations over five years (plus controls). These locations were also part of the amphipod studies. The most sensitive endpoint was embryo development. According to the BERA, there was no discernible COPC exposure-response relationship of high predictive value. The grass shrimp tests may be influenced by a variety of factors "multiple contaminant effects, other stressors such as pathogens in the test chambers, redox conditions, sulfides, TOC, grain size, or other chemical and physical factors. However, these studies provided valuable insight for the development of sediment effects concentrations ultimately used to derive the low end and the upper end of the RGO range used in the FS. For example, the BERA indicates that all locations with residual mercury concentrations above the AET of 11 mg/kg are expected to be toxic to grass shrimp, based on testing that continuously exposed developing shrimp to sediment for 2 months, which is an exposure that is far greater than how grass shrimp are exposed in OU1. Therefore, the sediment effects concentrations provide a conservative basis of understanding risks to grass shrimp and other organisms in OU1.
- Grass shrimp toxicity testing was carried out from 2000-2007 (Black and Veatch 2011, Section 4.7, Tables 4-21 through 4-24). Wild-caught or laboratory-reared grass shrimp were put in test chambers with site sediment for two months. Survival, growth, and reproduction were measured during this time. Embryos were detached, cultured, and assessed for DNA strand damage. Wild-caught animals were assessed at 10 stations per year (8 stations in OU1 and two reference stations), three replicates per station (2002, 2003, 2004, 2005, 2006, 2007). These studies of indigenous grass shrimp discussed in the BERA (Appendix J) are illustrated on Figures L-5A, and L-5B. The results showed that shrimp embryos hatched with the same success from OU1 as from reference areas, even when collected from locations within the Eastern Creek and LCP Ditch where elevated levels of mercury and Aroclor 1268 have consistently been detected. Only two locations showed toxic responses between 2000 and 2007, and those locations were in LCP Ditch and Eastern Creek, where COC concentrations are highest in OU1 (Figure L-5A). A further study of indigenous grass shrimp (Wall et al. 2001) is illustrated in Figure L-5B (Black and Veatch 2011, Appendix J). This study illustrates that, except for the two locations where toxicity was observed, grass shrimp measurements were similar to those at reference locations even in areas with elevated chemical concentrations.
- The indigenous grass shrimp studies (Black and Veatch 2011, Appendix J) also provide valuable information about how organisms use the estuary. Grass shrimp are mobile and unlikely to be exposed to any single location for long periods. As tides ebb, grass shrimp follow the tides. They prefer to live atop submerged grasses and carry their broods against their bodies, which limits their exposure to sediment contaminants. Therefore, indigenous grass shrimp are likely to be less prone to toxic effects predicted by laboratory toxicity

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studies, which tend to keep grass shrimp in direct contact with sediments for prolonged periods.

- Two benthic community assessments are presented in the BERA. The main body of the BERA identifies a benthic community assessment from four stations at the Site and at two reference locations in 2000 (Black and Veatch 2011, Section 4.9, Table 4-25). Three replicate samples were collected at each station. Potentially negative major differences in the macrobenthos community between Site and reference areas (Black and Veatch 2011,Table 4-25) were a lesser number of taxa, individuals, and density of individuals at two of the four Site stations. The BERA stated that given the relatively high variability of substrate type, TOC, and density among replicates, it cannot be ascertained if any "shifts" in the benthic community between stations have actually occurred from this one study. Since benthic community data were not collected during the long-term monitoring program (2002 – 2007), the BERA stated that any potential contaminant-related effects are unknown. The results from the 2000 study is illustrated in Figure L-6.
- An earlier study from Horne et al. (1999) (Black and Veatch 2011, Appendix J, section B) addressed the effects of total mercury, PCBs (primarily Aroclor 1268), and other COPC on the benthic invertebrate community of the LCP estuary using samples collected in 1995. This study included four locations; two of the four locations showed lower species diversity than the reference location (Black and Veatch 2011; Appendix J). These two locations, which exceed RGOs, are host to 5 to 9 species compared to the 12 to 23 species seen at the Crescent River and Troop Creek reference areas, respectively. Both locations are included in the SMAs addressed by Alternatives 2 through 6. A location that performed better than the reference location is also included in the SMAs because it exceeds RGOs (Location C7 in Eastern Creek). Thus, RGO exceedance does not necessarily indicate impairment of the sediment-dwelling community.
- Laboratory studies of amphipod and grass shrimp sediment toxicity testing was conducted results were presented in the BERA (Black and Veatch 2011, Section 4.4, Tables 4-14 through 4-19a). Amphipod tests were conducted at five to twenty locations, five replicates each, over six years (2000, 2002, 2003, 2004, 2005, 2006). This was a total of approximately 100 separate tests at approximately 40 stations six years. These locations were also part of the grass shrimp studies. In addition, in 2006, extensive toxicity testing was conducted to evaluate apparent effects thresholds at approximately 150 additional locations (plus controls). Measurement endpoints for the 28-day test were survival, growth (weight), and reproductive response (calculated as one-half of the number of juveniles produced in a replicate divided by the number of surviving adult females). Based on these evaluations, there was no discernable COPC exposure-response relationship of high predictive value. Detailed analysis of the toxicity test results indicate that other factors such as the COPC mixtures, total organic carbon, sulfide content, and sediment grain size confounded predictions of sediment toxicity to amphipods. These study results also provided valuable insight for the development of sediment effects concentrations ultimately used to derive the low end and the upper end of the RGO range used in the FS.

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- Figure L-7 summarizes the BERA discussion of a mysid shrimp surface water toxicity study (Black and Veatch 2011, Appendix J). Survival and growth were evaluated. No impacts to survival were observed at any locations (all survival was 94%-100%). Shrimp growth was greater than or equal to that seen in reference areas (Black and Veatch 2011; Section 4.3.1).

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5 Additional Uncertainties Related to the Remedy Effectiveness Evaluation

Some uncertainties in the remedy effectiveness evaluation apply to both the wildlife and fish risk assessments. Although many of these uncertainties are adequately explained in the BERA (Black and Veatch 2011) some are worth additional consideration.

- Methylmercury accumulation in tissues is highly variable on spatial and temporal scales. The accumulation of mercury was predicted using the methods from the BERA which was based on fish collection from OU1.
- Risk estimates based on the HQ approach are insensitive to spatial variability of contamination in sediment/biota and insensitive to habitat considerations. SWACs account for some of this variability in sediment concentrations.
- Purvis Creek represents approximately 85% of fish habitat during both low and high tides; Eastern Creek represents approximately 10% of finfish habitat mostly during high tide. The Total Creeks SWAC integrates sediment concentrations throughout the creeks into a single range; however, exposure differences among different species with different movement and habitat use patterns are not accounted for when predicting tissue concentrations.
- BAFs may vary between less contaminated areas and moderate or heavily contaminated areas. The BERA BAFs may underestimate or overestimate tissue concentrations compared to measured finfish tissue concentrations (Figures L-3A and L-3B and Table L-11).
- The mean measured tissue concentrations in biota (finfish, crabs, and mummichogs) have large standard deviations and high coefficients of variance that result in large uncertainty around the mean. The elevated 95%UCLs should equal or exceed the true mean of the tissue concentrations 95% of the time.
- SWACs are tied to SMAs such that Alternatives 2 and 3 share SWACs and Alternatives 4 and 5 share SWACs. The SWACs used for SMA-1 and SMA-2 were not subdivided into SWACs for Alternatives 2 and 3 (SMA-1) and Alternatives 4 and 5 (SMA-2) because an uncertainty evaluation showed that this subdivision was not likely to significantly impact SWAC values. Table L-12 shows the uncertainty evaluation. In Table L-12, for thin-cover placement areas, the values used in the uncertainty evaluation were 10% of the initial SWACs (based on the initial Thiessen polygon values). Use of 10% SWAC values was considered a reasonable estimated value that accounts for some mixing of the thin cover with the existing sediment. The numbers change the most for Domain 1, but are still well below the SWAC RGOs identified in Section 3.3 of the FS.
- The use of SWACs incorporates uncertainties about the variability of constituent concentrations over the site and the presence of "hot-spots". SWACs are a way of estimating the central tendency of constituent concentrations over an area. This is appropriately protective of wildlife since the wildlife move throughout the estuary, and are exposed to a spectrum of concentrations. The wildlife does not stay in small, isolated areas of high (or low) concentration.

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- The two approaches used in the BERA (yearly average and area weighted BAF) do not rely on a literature biota sediment accumulation factor (BSAF); they calculated a site-specific BSAF. While various literature studies (such as Burkhard et al., 2005) might recommend other BSAFs, the literature, particularly Burkhard et al., recommend the use of site-specific studies as the BSAFs differ from ecosystem to ecosystem. The Burkhard et al., study recommended a BSAF of 10 (mg/kg lipid)/(mg/kg organic carbon) for PCB 180. The values used in the BERA are not organic carbon normalized. For wet-weight values, they range from 0.192 (for red drum, BERA Table 7-6, Black and Veatch, 2011) to 1.775 (for striped mullet, also from the BERA) with units of mg (mg PCB/kg fish tissue)/(mg PCB/kg sediment). The site-specific measured BAFs from the BERA for Aroclor 1268 average to about 0.8 (mg PCB/kg fish tissue)/(mg PCB/kg sediment) as an average of the values on BERA Table 7-6, Black and Veatch, 2011. If one assumes the sediment is 2% organic carbon, and that the fish are 5% lipid, this equates to a lipid normalized BSAF of approximately 2 (mg/kg lipid)/(mg/kg oc). This difference is natural and to be expected given the differences in the ecosystems and the fish used in the study. Furthermore, because the BERA used actual, measured, site-specific BSAFs, the effects of lipid/carbon normalization are already accounted for in the measured values.

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6 References

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Appendix L
Technical Approach for Remedy
Evaluation and Uncertainty Evaluation

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Tables

Table L-1A
Wildlife Hazard Quotients from the BERA
LCP Chemical Site, Brunswick, Georgia

95%UCL Methyl Mercury LOAEL Hazard Quotients from The BERA

Area	Green Heron	Clapper Rail	Red-winged blackbird	Raccoon	River otter	Marsh rabbit	Diamondback terrapin
Domain 1	**2.77**	0.99	0.33	0.135	0.02	0.01	0.0006
Domain 2	0.78	0.29	0.14	0.1	0.07	0.005	0.0002
Domain 3	0.83	0.28	0.14	0.1	0.08	0.003	0.0002
Domain 4	0.59	0.23	0.13	0.1	0.22	0.002	0.0001
Purvis Creek	0.58	0.14	0.1	0.09	0.03	0.001	0.0001
Main Canal	**1.48**	0.58	0.22	0.11	0.001	0.04	0.0004
Eastern Creek	**3.53**	0.86	0.29	0.13	0.003	0.009	0.0006
Western Creek Complex	0.78	0.29	0.14	0.1	0.001	0.005	0.0002

Aroclor 1268 LOAEL 95% UCL Hazard Quotients from the BERA

Area	Green Heron	Clapper Rail	Red-winged blackbird	Raccoon	River otter	Marsh rabbit	Diamondback terrapin
Domain 1	0.2	0.11	0.043	0.26	0.034	0.3	0.004
Domain 2	0.07	0.04	0.01	0.11	0.139	0.09	0.002
Domain 3	0.1	0.03	0.009	0.1	0.169	0.05	0.002
Domain 4	0.04	0.02	0.007	0.08	0.39	0.05	0.001
Purvis Creek	0.04	0.03	0.01	0.1	0.058	0.09	0.002
Main Canal	0.17	0.16	0.07	0.37	0.002	0.32	0.007
Eastern Creek	0.25	0.21	0.09	0.49	0.009	0.48	0.008
Western Creek Complex	0.07	0.03	0.01	0.1	0.002	0.08	0.002

95%UCL Methyl Mercury NOAEL Hazard Quotients from The BERA

Area	Green Heron	Clapper Rail	Red-winged blackbird	Raccoon	River otter	Marsh rabbit	Diamondback terrapin
Domain 1	**8.3**	**2.96**	**1**	0.27	0.03	0.03	0.006
Domain 2	**2.33**	0.88	0.43	0.2	0.14	0.01	0.002
Domain 3	**2.48**	0.84	0.42	0.2	0.17	0.005	0.002
Domain 4	**1.77**	0.68	0.38	0.19	0.44	0.004	0.001
Purvis Creek	**1.75**	0.42	0.3	0.19	0.06	0.003	0.001
Main Canal	**4.44**	**1.74**	0.67	0.23	0.002	0.09	0.004
Eastern Creek	**10.59**	**2.59**	0.86	0.27	0.007	0.02	0.006
Western Creek Complex	**2.33**	0.88	0.43	0.2	0.002	0.01	0.002

Aroclor 1268 NOAEL 95% UCL Hazard Quotients from the BERA

Area	Green Heron	Clapper Rail	Red-winged blackbird	Raccoon	River otter	Marsh rabbit	Diamondback terrapin
Domain 1	0.6	0.33	0.13	**2.61**	0.34	**3.01**	0.04
Domain 2	0.2	0.11	0.04	**1.11**	**1.39**	0.89	0.02
Domain 3	0.29	0.08	0.03	0.97	**1.69**	0.48	0.02
Domain 4	0.12	0.06	0.02	0.77	**3.94**	0.53	0.01
Purvis Creek	0.12	0.1	0.04	**1.02**	0.58	0.94	0.02
Main Canal	0.52	0.49	0.21	**3.67**	0.02	**3.2**	0.07
Eastern Creek	0.75	0.63	0.28	**4.87**	0.09	**4.82**	0.08
Western Creek Complex	0.2	0.1	0.04	**1.05**	0.02	0.81	0.02

From the BERA (2011): Appendix H, Tables H-1 through H-7

95% UCL	95% upper confidence level of the mean
BERA	baseline ecological risk assessment (USEPA, 2011)
LOAEL	lowest observed apparent effects level
MeHg	methylmercury
NOAEL	no observed apparent effects level
PCB	polychlorinated biphenyl (aroclor 1268)

Table L-1B
Wildlife Hazard Quotients for Lead from the BERA
LCP Chemical Site, Brunswick, Georgia

	Diamondback terrapin		Red-Winged Blackbird		Clapper Rail		Green Heron		Marsh Rabbit		Raccoon		River Otter	
	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
Troop Creek Reference	0.003	0.03	0.01	0.03	0.01	0.04	0.02	0.06	0.003	0.028	0.001	0.009	0.001	0.01
Main Canal	0.005	0.05	0.04	0.12	0.11	0.33	0.02	0.07	0.004	0.04	0.002	0.02	0.000003	0.00003
Eastern Creek	0.013	0.13	0.03	0.08	0.02	0.06	0.03	0.08	0.004	0.04	0.001	0.01	0.00001	0.0001
Western Creek Complex	0.003	0.03	0.06	0.18	0.08	0.23	0.32	0.95	0.009	0.09	0.004	0.04	0.000004	0.00004
Purvis Creek	0.003	0.03	0.01	0.03	0.01	0.03	0.01	0.04	0.004	0.04	0.001	0.01	0.00009	0.0009
Domain 1	0.02	0.18	0.01	0.03	0.01	0.03	0.01	0.02	0.002	0.02	0.001	0.005	0.00007	0.0007
Domain 2	0.005	0.05	0.02	0.05	0.02	0.07	0.01	0.04	0.005	0.05	0.001	0.008	0.0004	0.004
Domain 3	0.02	0.18	0.03	0.1	0.08	0.24	0.02	0.06	0.004	0.04	0.002	0.02	0.002	0.02
Domain 4	0.003	0.03	0.01	0.04	0.01	0.04	0.02	0.06	0.004	0.04	0.001	0.008	0.0006	0.006
Blythe Island	0.002	0.02	0.01	0.04	0.02	0.05	0.01	0.04	0.004	0.04	0.001	0.007	0.0005	0.005
Area A	0.013	0.13	0.03	0.09	0.08	0.24	0.02	0.06	0.004	0.04	0.001	0.01	0.00002	0.0002

These Values are from Table 4-30 of the BERA.

BERA	baseline ecological risk assessment (USEPA 2011)
LOAEL	lowest observed apparent effects level
HQ	hazard quotient

Table L-2
Bioaccumulation Factors for Biota from the BERA
LCP Chemical Site, Brunswick, Georgia

	Total Mercury in Sediment to Total Mercury in Biota (a)					Aroclor 1268 in Sediment to Aroclor 1268 in Biota				
Receptor	**a**	**b**	**R^2**	**Curve Fit Type**	**Source from BERA**	**a**	**b**	**R^2**	**Curve Fit Type**	**Source from BERA**
Cordgrass	Not Evaluated					0.022	0		Linear	Figure 7-20
Fiddler Crabs	0.2187	0.4733	0.8725	Power	Figure 7-2	0.1995	0	0.9167	Linear	Figure 7-3
Blue Crabs	1.303	0		Linear	Figure 7-9	0.426	0		Linear	Figure 7-8
Mummichogs	0.2348	0.4706	0.884	Power	Figure 7-7	1.2188	0.4918	0.8117	Power	Figure 7-6
BAFs formed from Plots of Data Aggregated by Years										
Silver Perch	1.6511	0.7371	0.7917	Power	Figure 7-15	2.4556	0.8834	0.8876	Power	Figure 7-14
Red Drum	1.2095	0.7002	0.7205	Power	Figure 7-11	0.7748	0.6803	0.7492	Power	Figure 7-10
Black Drum	0.9084	1.0323	0.8967	Power	Figure 7-13	2.5436	0.9589	0.8972	Power	Figure 7-12
Spotted Seatrout	1.9818	0.8641	0.7301	Power	Figure 7-17	2.1172	0.8997	0.913	Power	Figure 7-16
Striped Mullet	0.2144	0.8472	0.8657	Power	Figure 7-19	3.9936	1.0458	0.8887	Power	Figure 7-18

Area-Weighted BAFs

Receptor	**BAF**	**Source**		**BAF**	**Source**	
Silver Perch	0.584	Table 7-4	BERA (USEPA 2011)	0.762	Table 7-4	BERA (USEPA 2011)
Red Drum	0.416	Table 7-4	BERA (USEPA 2011)	0.192	Table 7-4	BERA (USEPA 2011)
Black Drum	0.307	Table 7-4	BERA (USEPA 2011)	0.741	Table 7-4	BERA (USEPA, 2011)
Spotted Seatrout	0.829	Table 7-4	BERA (USEPA 2011)	0.661	Table 7-4	BERA (USEPA 2011)
Striped Mullet	0.084	Table 7-4	BERA (USEPA 2011)	1.775	Table 7-4	BERA (USEPA 2011)

Curve Fit Type:

Linear	$y = a x + b$
Logarithmic (Log)	$y = a \ln(x) + b$
Power	$y = a x^{b}$

BAF	bioaccumulation factor
BERA	baseline ecological risk assessment (USEPA 2011)

(a) These values are from Table 7-6 of the BERA.

Table L-3
Key Parameters for Green Heron Wildlife Food Chain Model
LCP Chemical Site, Brunswick, Georgia

Receptor	Food Ingestion Rate (kg dry wt/day)	Body Weight (kg wet weight)	Fraction Incidental Ingestion of dry food rate Unitless	Sediment Ingestion Rate (kg dry wt/d)	Water Ingestion Rate (L/day)	Dietary Fraction			Area Use Factor Unitless
						Blue Crabs	Fiddler Crabs	Mummi-chogs	
Green Heron	0.024	0.2	0.12	0.00048	0.023	0.05	0.05	0.9	1

These values are from Table 7-7 of the BERA.

BERA	baseline ecological risk assessment (USEPA 2011)
kg/dry wt/day	kilogram per dry weight per day
kg wet weight	kilogram per wet weight
L/day	liter per day

Table L-4
Toxicity Reference Values for Finfish and Birds
LCP Chemical Site, Brunswick, Georgia

Birds

Methyl Mercury	LOAEL = 0.06	Spalding et al. 2000 growth reduction in great egret.
Aroclor 1268	LOAEL = 3.9	NOAEL-to-LOAEL adjustment factor of 3 applied to chicken NOAEL

Fishes

Methyl Mercury	LOAEL = 0.30	Median highest LOAEL reported for 7 species of mostly freshwater fishes (as reviewed by Dillon, 2006b) (1.2 mg/kg dry weight conversion).
Aroclor 1268	LOAEL = 1.3	LOAEL value from Matta et al. (2001). (5.2 mg/kg dry weight conversion)

These values are from Table 4-27 of the BERA.

BERA	baseline ecological risk assessment (USEPA 2011)
LOAEL	lowest observed apparent effects level

Table L-5
Calculation of Green Heron Mercury Hazard Quotients
LCP Chemical Site, Brunswick, Georgia

				Fiddler Crabs			Blue Crabs			Mummichogs									
Preremedy	**Total Hg Sediment Conc. mg/kg**	**MeHg Sediment Conc. mg/kg**	**Sediment Ingestion Rate kg/day**	**Predicted Total Hg Conc. mg/kg dry**	**Predicted MeHg Conc. mg/kg**	**Fraction of Diet**	**Predicted Total Hg Conc. mg/kg dry**	**Predicted MeHg Conc. mg/kg**	**Fraction of Diet**	**Predicted Total Hg Conc. mg/kg dry**	**Predicted MeHg Conc. mg/kg**	**Fraction of Diet**	**Food Ingestion Rate kg/day**	**Body Weight kg**	**Total Dose mg/kg /day**	**MeHg NOAEL mg/kg /day**	**NOAEL Hazard Quotient**	**MeHg LOAEL mg/kg /day**	**LOAEL Hazard Quotient**
Dillon Duck	1.43E+00	1.07E-02	0.00048	2.59E-01	1.76E-01	0.05	1.86E+00	1.86E+00	0.05	2.78E-01	2.56E-01	0.9	0.024	0.2	3.99E-02	0.02	2	0.06	0.66
Domain 1	5.11E+00	3.83E-02	0.00048	4.73E-01	3.22E-01	0.05	6.66E+00	6.66E+00	0.05	5.06E-01	4.65E-01	0.9	0.024	0.2	9.22E-02	0.02	4.6	0.06	**1.5**
Domain 2	2.55E+00	1.91E-02	0.00048	3.40E-01	2.32E-01	0.05	3.32E+00	3.32E+00	0.05	3.65E-01	3.35E-01	0.9	0.024	0.2	5.76E-02	0.02	2.9	0.06	0.96
Domain 3	1.73E+00	1.30E-02	0.00048	2.83E-01	1.93E-01	0.05	2.25E+00	2.25E+00	0.05	3.04E-01	2.80E-01	0.9	0.024	0.2	4.49E-02	0.02	2.2	0.06	0.75
Domain 4 East	1.98E+00	1.49E-02	0.00048	3.02E-01	2.06E-01	0.05	2.58E+00	2.58E+00	0.05	3.24E-01	2.98E-01	0.9	0.024	0.2	4.89E-02	0.02	2.4	0.06	0.82
Domain 4 West	6.89E-01	5.17E-03	0.00048	1.83E-01	1.25E-01	0.05	8.98E-01	8.98E-01	0.05	1.97E-01	1.81E-01	0.9	0.024	0.2	2.57E-02	0.02	1.3	0.06	0.43
Total Domains	1.70E+00	1.27E-02	0.00048	2.81E-01	1.91E-01	0.05	2.21E+00	2.21E+00	0.05	3.01E-01	2.77E-01	0.9	0.024	0.2	4.44E-02	0.02	2.2	0.06	0.74
Domain 3 Creek	5.94E+00	4.45E-02	0.00048	5.08E-01	3.46E-01	0.05	7.74E+00	7.74E+00	0.05	5.43E-01	5.00E-01	0.9	0.024	0.2	1.03E-01	0.02	5.1	0.06	**1.7**
Eastern Creek	1.46E+01	1.09E-01	0.00048	7.77E-01	5.29E-01	0.05	1.90E+01	1.90E+01	0.05	8.29E-01	7.62E-01	0.9	0.024	0.2	2.00E-01	0.02	10	0.06	**3.3**
LCP Ditch	7.67E+00	5.76E-02	0.00048	5.74E-01	3.90E-01	0.05	1.00E+01	1.00E+01	0.05	6.13E-01	5.64E-01	0.9	0.024	0.2	1.23E-01	0.02	6.2	0.06	**2.1**
Purvis Creek	1.17E+00	8.79E-03	0.00048	2.36E-01	1.60E-01	0.05	1.53E+00	1.53E+00	0.05	2.53E-01	2.33E-01	0.9	0.024	0.2	3.53E-02	0.02	1.8	0.06	0.59
Western Creek Complex	2.14E+00	1.60E-02	0.00048	3.13E-01	2.13E-01	0.05	2.78E+00	2.78E+00	0.05	3.36E-01	3.09E-01	0.9	0.024	0.2	5.13E-02	0.02	2.6	0.06	0.86
Total Creek	2.59E+00	1.94E-02	0.00048	3.43E-01	2.33E-01	0.05	3.37E+00	3.37E+00	0.05	3.67E-01	3.38E-01	0.9	0.024	0.2	5.82E-02	0.02	2.9	0.06	0.97
Total Estuary	1.81E+00	1.36E-02	0.00048	2.90E-01	1.97E-01	0.05	2.36E+00	2.36E+00	0.05	3.11E-01	2.86E-01	0.9	0.024	0.2	4.63E-02	0.02	2.3	0.06	0.77
SMA 1																			
Dillon Duck	3.00E-01	2.25E-03	0.00048	1.24E-01	8.41E-02	0.05	3.91E-01	3.91E-01	0.05	1.33E-01	1.23E-01	0.9	0.024	0.2	1.61E-02	0.02	0.8	0.06	0.27
Domain 1	6.31E-01	4.73E-03	0.00048	1.76E-01	1.20E-01	0.05	8.22E-01	8.22E-01	0.05	1.89E-01	1.74E-01	0.9	0.024	0.2	2.44E-02	0.02	1.2	0.06	0.41
Domain 2	8.60E-01	6.45E-03	0.00048	2.04E-01	1.38E-01	0.05	1.12E+00	1.12E+00	0.05	2.19E-01	2.01E-01	0.9	0.024	0.2	2.93E-02	0.02	1.5	0.06	0.49
Domain 3	1.48E+00	1.11E-02	0.00048	2.63E-01	1.79E-01	0.05	1.93E+00	1.93E+00	0.05	2.83E-01	2.60E-01	0.9	0.024	0.2	4.08E-02	0.02	2	0.06	0.68
Domain 4 East	1.98E+00	1.49E-02	0.00048	3.02E-01	2.06E-01	0.05	2.58E+00	2.58E+00	0.05	3.24E-01	2.98E-01	0.9	0.024	0.2	4.89E-02	0.02	2.4	0.06	0.82
Domain 4 West	6.89E-01	5.17E-03	0.00048	1.83E-01	1.25E-01	0.05	8.98E-01	8.98E-01	0.05	1.97E-01	1.81E-01	0.9	0.024	0.2	2.57E-02	0.02	1.3	0.06	0.43
Total Domains	1.22E+00	9.15E-03	0.00048	2.40E-01	1.63E-01	0.05	1.59E+00	1.59E+00	0.05	2.58E-01	2.37E-01	0.9	0.024	0.2	3.62E-02	0.02	1.8	0.06	0.6
Domain 3 Creek	1.05E+00	7.87E-03	0.00048	2.24E-01	1.52E-01	0.05	1.37E+00	1.37E+00	0.05	2.40E-01	2.21E-01	0.9	0.024	0.2	3.30E-02	0.02	1.6	0.06	0.55
Eastern Creek	3.00E-01	2.25E-03	0.00048	1.24E-01	8.41E-02	0.05	3.91E-01	3.91E-01	0.05	1.33E-01	1.23E-01	0.9	0.024	0.2	1.61E-02	0.02	0.8	0.06	0.27
LCP Ditch	3.16E-01	2.37E-03	0.00048	1.27E-01	8.62E-02	0.05	4.12E-01	4.12E-01	0.05	1.37E-01	1.26E-01	0.9	0.024	0.2	1.66E-02	0.02	0.83	0.06	0.28
Purvis Creek	8.70E-01	6.53E-03	0.00048	2.05E-01	1.39E-01	0.05	1.13E+00	1.13E+00	0.05	2.20E-01	2.02E-01	0.9	0.024	0.2	2.95E-02	0.02	1.5	0.06	0.49
Western Creek Complex	1.24E+00	9.31E-03	0.00048	2.42E-01	1.65E-01	0.05	1.62E+00	1.62E+00	0.05	2.60E-01	2.39E-01	0.9	0.024	0.2	3.65E-02	0.02	1.8	0.06	0.61
Total Creek	8.88E-01	6.66E-03	0.00048	2.07E-01	1.41E-01	0.05	1.16E+00	1.16E+00	0.05	2.22E-01	2.04E-01	0.9	0.024	0.2	2.99E-02	0.02	1.5	0.06	0.5
Total Estuary	1.18E+00	8.83E-03	0.00048	2.36E-01	1.61E-01	0.05	1.53E+00	1.53E+00	0.05	2.53E-01	2.33E-01	0.9	0.024	0.2	3.54E-02	0.02	1.8	0.06	0.59

Table L-5
Calculation of Green Heron Mercury Hazard Quotients
LCP Chemical Site, Brunswick, Georgia

				Fiddler Crabs			Blue Crabs			Mummichogs									
	Total Hg Sediment Conc. mg/kg	**MeHg Sediment Conc. mg/kg**	**Sediment Ingestion Rate kg/day**	**Predicted Total Hg Conc. mg/kg dry**	**Predicted MeHg Conc. mg/kg**	**Fraction of Diet**	**Predicted Total Hg Conc. mg/kg dry**	**Predicted MeHg Conc. mg/kg**	**Fraction of Diet**	**Predicted Total Hg Conc. mg/kg dry**	**Predicted MeHg Conc. mg/kg**	**Fraction of Diet**	**Food Ingestion Rate kg/day**	**Body Weight kg**	**Total Dose mg/kg /day**	**MeHg NOAEL mg/kg /day**	**NOAEL Hazard Quotient**	**MeHg LOAEL mg/kg /day**	**LOAEL Hazard Quotient**
SMA 2																			
Dillon Duck	3.00E-01	2.25E-03	0.00048	1.24E-01	8.41E-02	0.05	3.91E-01	3.91E-01	0.05	1.33E-01	1.23E-01	0.9	0.024	0.2	1.61E-02	0.02	0.8	0.06	0.27
Domain 1	1.63E+00	1.22E-02	0.00048	2.76E-01	1.87E-01	0.05	2.12E+00	2.12E+00	0.05	2.95E-01	2.72E-01	0.9	0.024	0.2	4.33E-02	0.02	2.2	0.06	0.72
Domain 2	1.25E+00	9.39E-03	0.00048	2.43E-01	1.65E-01	0.05	1.63E+00	1.63E+00	0.05	2.61E-01	2.40E-01	0.9	0.024	0.2	3.67E-02	0.02	1.8	0.06	0.61
Domain 3	1.73E+00	1.30E-02	0.00048	2.83E-01	1.93E-01	0.05	2.25E+00	2.25E+00	0.05	3.04E-01	2.80E-01	0.9	0.024	0.2	4.49E-02	0.02	2.2	0.06	0.75
Domain 4 East	1.98E+00	1.49E-02	0.00048	3.02E-01	2.06E-01	0.05	2.58E+00	2.58E+00	0.05	3.24E-01	2.98E-01	0.9	0.024	0.2	4.89E-02	0.02	2.4	0.06	0.82
Domain 4 West	6.89E-01	5.17E-03	0.00048	1.83E-01	1.25E-01	0.05	8.98E-01	8.98E-01	0.05	1.97E-01	1.81E-01	0.9	0.024	0.2	2.57E-02	0.02	1.3	0.06	0.43
Total Domains	1.36E+00	1.02E-02	0.00048	2.53E-01	1.72E-01	0.05	1.77E+00	1.77E+00	0.05	2.71E-01	2.50E-01	0.9	0.024	0.2	3.86E-02	0.02	1.9	0.06	0.64
Domain 3 Creek	3.73E+00	2.80E-02	0.00048	4.08E-01	2.77E-01	0.05	4.86E+00	4.86E+00	0.05	4.36E-01	4.01E-01	0.9	0.024	0.2	7.42E-02	0.02	3.7	0.06	**1.2**
Eastern Creek	3.00E-01	2.25E-03	0.00048	1.24E-01	8.41E-02	0.05	3.91E-01	3.91E-01	0.05	1.33E-01	1.23E-01	0.9	0.024	0.2	1.61E-02	0.02	0.8	0.06	0.27
LCP Ditch	3.90E-01	2.92E-03	0.00048	1.40E-01	9.52E-02	0.05	5.08E-01	5.08E-01	0.05	1.51E-01	1.39E-01	0.9	0.024	0.2	1.86E-02	0.02	0.93	0.06	0.31
Purvis Creek	1.17E+00	8.79E-03	0.00048	2.36E-01	1.60E-01	0.05	1.53E+00	1.53E+00	0.05	2.53E-01	2.33E-01	0.9	0.024	0.2	3.53E-02	0.02	1.8	0.06	0.59
Western Creek Complex	2.14E+00	1.60E-02	0.00048	3.13E-01	2.13E-01	0.05	2.78E+00	2.78E+00	0.05	3.36E-01	3.09E-01	0.9	0.024	0.2	5.13E-02	0.02	2.6	0.06	0.86
Total Creek	1.52E+00	1.14E-02	0.00048	2.67E-01	1.82E-01	0.05	1.99E+00	1.99E+00	0.05	2.86E-01	2.63E-01	0.9	0.024	0.2	4.15E-02	0.02	2.1	0.06	0.69
Total Estuary	1.38E+00	1.04E-02	0.00048	2.55E-01	1.73E-01	0.05	1.80E+00	1.80E+00	0.05	2.73E-01	2.51E-01	0.9	0.024	0.2	3.90E-02	0.02	2	0.06	0.65
SMA 3																			
Dillon Duck	3.00E-01	2.25E-03	0.00048	1.24E-01	8.41E-02	0.05	3.91E-01	3.91E-01	0.05	1.33E-01	1.23E-01	0.9	0.024	0.2	1.61E-02	0.02	0.8	0.06	0.27
Domain 1	1.06E+00	7.93E-03	0.00048	2.24E-01	1.53E-01	0.05	1.38E+00	1.38E+00	0.05	2.41E-01	2.22E-01	0.9	0.024	0.2	3.31E-02	0.02	1.7	0.06	0.55
Domain 2	1.25E+00	9.39E-03	0.00048	2.43E-01	1.65E-01	0.05	1.63E+00	1.63E+00	0.05	2.61E-01	2.40E-01	0.9	0.024	0.2	3.67E-02	0.02	1.8	0.06	0.61
Domain 3	1.73E+00	1.30E-02	0.00048	2.83E-01	1.93E-01	0.05	2.25E+00	2.25E+00	0.05	3.04E-01	2.80E-01	0.9	0.024	0.2	4.49E-02	0.02	2.2	0.06	0.75
Domain 4 East	1.98E+00	1.49E-02	0.00048	3.02E-01	2.06E-01	0.05	2.58E+00	2.58E+00	0.05	3.24E-01	2.98E-01	0.9	0.024	0.2	4.89E-02	0.02	2.4	0.06	0.82
Domain 4 West	6.89E-01	5.17E-03	0.00048	1.83E-01	1.25E-01	0.05	8.98E-01	8.98E-01	0.05	1.97E-01	1.81E-01	0.9	0.024	0.2	2.57E-02	0.02	1.3	0.06	0.43
Total Domains	1.34E+00	1.01E-02	0.00048	2.51E-01	1.71E-01	0.05	1.75E+00	1.75E+00	0.05	2.70E-01	2.48E-01	0.9	0.024	0.2	3.83E-02	0.02	1.9	0.06	0.64
Domain 3 Creek	3.73E+00	2.80E-02	0.00048	4.08E-01	2.77E-01	0.05	4.86E+00	4.86E+00	0.05	4.36E-01	4.01E-01	0.9	0.024	0.2	7.42E-02	0.02	3.7	0.06	**1.2**
Eastern Creek	3.00E-01	2.25E-03	0.00048	1.24E-01	8.41E-02	0.05	3.91E-01	3.91E-01	0.05	1.33E-01	1.23E-01	0.9	0.024	0.2	1.61E-02	0.02	0.8	0.06	0.27
LCP Ditch	3.90E-01	2.92E-03	0.00048	1.40E-01	9.52E-02	0.05	5.08E-01	5.08E-01	0.05	1.51E-01	1.39E-01	0.9	0.024	0.2	1.86E-02	0.02	0.93	0.06	0.31
Purvis Creek	1.06E+00	7.95E-03	0.00048	2.25E-01	1.53E-01	0.05	1.38E+00	1.38E+00	0.05	2.41E-01	2.22E-01	0.9	0.024	0.2	3.32E-02	0.02	1.7	0.06	0.55
Western Creek Complex	2.14E+00	1.60E-02	0.00048	3.13E-01	2.13E-01	0.05	2.78E+00	2.78E+00	0.05	3.36E-01	3.09E-01	0.9	0.024	0.2	5.13E-02	0.02	2.6	0.06	0.86
Total Creek	1.44E+00	1.08E-02	0.00048	2.60E-01	1.77E-01	0.05	1.88E+00	1.88E+00	0.05	2.79E-01	2.57E-01	0.9	0.024	0.2	4.01E-02	0.02	2	0.06	0.67
Total Estuary	1.35E+00	1.02E-02	0.00048	2.52E-01	1.72E-01	0.05	1.77E+00	1.77E+00	0.05	2.71E-01	2.49E-01	0.9	0.024	0.2	3.86E-02	0.02	1.9	0.06	0.64

Conc.	concentration
mg/kg dry	milligrams per kilogram dry weight
SMA	Sediment Management Area
1.2	Hazard quotient is above 1.

Table L-6
Summary Green Heron Mercury LOAEL Hazard Quotients
LCP Chemical Site, Brunswick, Georgia

Green Heron Mercury LOAEL Hazard Quotients	Preremedy	SMA 1	SMA 2	SMA 3
Dillon Duck	0.66	0.27	0.27	0.27
Domain 1	**1.5**	0.41	0.72	0.55
Domain 2	0.96	0.49	0.61	0.61
Domain 3	0.75	0.68	0.75	0.75
Domain 4 East	0.82	0.82	0.82	0.82
Domain 4 West	0.43	0.43	0.43	0.43
Total Domains	0.74	0.6	0.64	0.64
Domain 3 Creek	**1.7**	0.55	**1.2**	**1.2**
Eastern Creek	**3.3**	0.27	0.27	0.27
LCP Ditch	**2.1**	0.28	0.31	0.31
Purvis Creek	0.59	0.49	0.59	0.55
Western Creek Complex	0.86	0.61	0.86	0.86
Total Creek	0.97	0.5	0.69	0.67
Total Estuary	0.77	0.59	0.65	0.64
Purvis Creek, Domain 3, and Domain 3 Creek Average	**1.0**	0.6	0.8	0.8

🟥	hazard quotients equal to or above one
LOAEL	lowest observable adverse effects level toxicity reference value

Table L-7
No Action Alternative Fish Tissue Concentrations and HQs
LCP Chemical Site, Brunswick, Georgia

Constituent Measure	Methyl Mercury		Aroclor 1268	
	mg/kg dry weight	HQ	mg/kg dry weight	HQ
Red Drum	1.01	0.84	1.43	0.28
Black Drum	0.76	0.63	5.51	**1.1**
Silver Perch	1.6	**1.3**	5.67	**1.1**
Spotted Seatrout	2.27	**1.9**	4.92	0.95
Striped Mullet	0.09	0.075	13.2	**2.5**
LOAEL TRV	1.2		5.2	

Fish tissue concentrations are means from Table 4-29 in the BERA.
TRVs are from LOAELs from Table 7-8 of the BERA and Table L-4: of this appendix.

LOAEL TRV	lowest observable adverse effects level toxicity reference value
HQ	hazard quotient
mg/kg	milligrams per kilogram

Table L-8
Calculation of Finfish Tissue Concentrations and Hazard Quotients
LCP Chemical Site, Brunswick, Georgia

REMEDY EVALUATION FOR Aroclor 1268

REMEDY	Total Creeks SWAC mg/kg sediment	% Of original constituent left	Fish Tissue TRV mg/kg dry weight (a)
Preremedy/No Action	6.01	100%	LOAEL
SMA 1	1.56	26%	5.2
SMA 2	3.26	54%	NOAEL
SMA 3	2.67	44%	1.36

CONCENTRATION	Fish Tissue Concentrations mg/kg dry weight					
	Red Drum	Black Drum	Silver Perch	Spotted Seatrout	Striped Mullet	
Preremedy/No Action	1.43	5.51	5.67	4.92	13.2	(b)
SMA 1	0.37	1.43	1.47	1.28	3.43	
SMA 2	0.78	2.99	3.08	2.67	7.16	
SMA 3	0.64	2.45	2.52	2.19	5.86	

HQ	Fish LOAEL Tissue Mean Hazard Quotients				
	Red Drum	Black Drum	Silver Perch	Spotted Seatrout	Striped Mullet
Preremedy/No Action	0.28	**1.1**	**1.1**	0.95	**2.5**
SMA 1	0.071	0.28	0.28	0.25	0.66
SMA 2	0.15	0.58	0.59	0.51	**1.4**
SMA 3	0.12	0.47	0.48	0.42	**1.1**

HQ	Fish NOAEL Tissue Mean Hazard Quotients				
	Red Drum	Black Drum	Silver Perch	Spotted Seatrout	Striped Mullet
Preremedy/No Action	1.1	4.1	4.2	3.6	9.7
SMA 1	0.27	1.1	1.1	0.94	2.5
SMA 2	0.57	2.2	2.3	2	5.3
SMA 3	0.47	1.8	1.9	1.6	4.3

Table L-8
Calculation of Finfish Tissue Concentrations and Hazard Quotients
LCP Chemical Site, Brunswick, Georgia

REMEDY EVALUATION FOR METHYL MERCURY

REMEDY	Total Creeks SWAC mg/kg sediment	% Of original constituent left	Fish Tissue TRV mg/kg dry weight (a)
Preremedy/No Action	2.59	100%	LOAEL
SMA 1	0.89	34%	1.2
SMA 2	1.52	59%	NOAEL
SMA 3	1.44	56%	0.6

CONCENTRATION	Fish Tissue Concentrations mg/kg dry weight					
	Red Drum	Black Drum	Silver Perch	Spotted Seatrout	Striped Mullet	
Preremedy/No Action	1.01	0.76	1.6	2.27	0.09	(b)
SMA 1	0.35	0.26	0.55	0.78	0.03	
SMA 2	0.59	0.45	0.94	1.34	0.05	
SMA 3	0.56	0.42	0.89	1.27	0.05	

HQ	Fish LOAEL Tissue Mean Hazard Quotients				
	Red Drum	Black Drum	Silver Perch	Spotted Seatrout	Striped Mullet
Preremedy/No Action	0.84	0.63	**1.3**	**1.9**	0.075
SMA 1	0.29	0.22	0.46	0.65	0.026
SMA 2	0.5	0.37	0.79	**1.1**	0.044
SMA 3	0.47	0.35	0.74	**1.1**	0.042

HQ	Fish NOAEL Tissue Mean Hazard Quotients				
	Red Drum	Black Drum	Silver Perch	Spotted Seatrout	Striped Mullet
Preremedy/No Action	1.7	1.3	2.7	3.8	1.5
SMA 1	0.25	0.19	0.39	0.56	0.22
SMA 2	0.43	0.32	0.68	0.96	0.38
SMA 3	0.4	0.3	0.64	0.91	0.36

HQ	hazard quotient
LOAEL	lowest observable adverse effects level toxicity reference value
mg/kg dry	miligrams per kilogram dry weight
NOAEL	no observable adverse effects level toxicity reference value
SMA	Sediment Management Area
SWAC	surface weighted area concentration
TRV	toxicity reference value

(a) TRVs are from Table 7-8 of the BERA.

(b) Preremedy/ not action alternative fish tissue concentrations are means from Table 4-29 in the BERA.

Table L-9
Calculation of Predicted Finfish Tissue Concentrations and Hazard Quotients Using Two Models
LCP Chemical Site, Brunswick, Georgia

MERCURY RISKS: YEARLY AVERAGE METHOD/PURVIS CREEK

Remedy	Species	Area	Sediment Concentration mg/kg	Predicted Hg Concentration mg/kg dw fish tissue	Predicted MeHg Concentration mg/kg dw fish tissue	Methyl Mercury LOAEL mg/kg dw fish tissue	Ratio Body/ LOAEL	LOAEL HQ
No Action	Black Drum	Purvis Creek	1.172	1.070	0.974	1.2	0.812	0.81
No Action	Red Drum	Purvis Creek	1.172	1.352	1.203	1.2	1.003	1
No Action	Silver Perch	Purvis Creek	1.172	1.856	1.856	1.2	1.547	1.5
No Action	Spotted Seatrout	Purvis Creek	1.172	2.273	2.273	1.2	1.894	1.9
No Action	Striped Mullet	Purvis Creek	1.172	0.245	0.091	1.2	0.076	0.076
SMA 1	Black Drum	Purvis Creek	0.870	0.787	0.716	1.2	0.597	0.6
SMA 1	Red Drum	Purvis Creek	0.870	1.097	0.977	1.2	0.814	0.81
SMA 1	Silver Perch	Purvis Creek	0.870	1.490	1.490	1.2	1.242	1.2
SMA 1	Spotted Seatrout	Purvis Creek	0.870	1.757	1.757	1.2	1.464	1.5
SMA 1	Striped Mullet	Purvis Creek	0.870	0.191	0.071	1.2	0.059	0.059
SMA 2	Black Drum	Purvis Creek	1.172	1.070	0.974	1.2	0.812	0.81
SMA 2	Red Drum	Purvis Creek	1.172	1.352	1.203	1.2	1.003	1
SMA 2	Silver Perch	Purvis Creek	1.172	1.856	1.856	1.2	1.547	1.5
SMA 2	Spotted Seatrout	Purvis Creek	1.172	2.273	2.273	1.2	1.894	1.9
SMA 2	Striped Mullet	Purvis Creek	1.172	0.245	0.091	1.2	0.076	0.076
SMA 3	Black Drum	Purvis Creek	1.060	0.965	0.878	1.2	0.732	0.73
SMA 3	Red Drum	Purvis Creek	1.060	1.260	1.121	1.2	0.934	0.93
SMA 3	Silver Perch	Purvis Creek	1.060	1.724	1.724	1.2	1.436	1.4
SMA 3	Spotted Seatrout	Purvis Creek	1.060	2.084	2.084	1.2	1.737	1.7
SMA 3	Striped Mullet	Purvis Creek	1.060	0.225	0.083	1.2	0.069	0.069

Table L-9
Calculation of Predicted Finfish Tissue Concentrations and Hazard Quotients Using Two Models
LCP Chemical Site, Brunswick, Georgia

MERCURY RISKS: AREA WEIGHTED METHOD/TOTAL CREEKS

Remedy	Species	Area	Sediment Concentration mg/kg	Predicted Hg Concentration mg/kg dw fish tissue	Predicted MeHg Concentration mg/kg dw fish tissue	Methyl Mercury LOAEL mg/kg dw fish tissue	Ratio Body/ LOAEL	LOAEL HQ
No Action	Black Drum	Total Creeks	2.589	0.795	0.723	1.2	0.603	0.6
No Action	Red Drum	Total Creeks	2.589	1.077	0.958	1.2	0.799	0.8
No Action	Silver Perch	Total Creeks	2.589	1.512	1.512	1.2	1.260	1.3
No Action	Spotted Seatrout	Total Creeks	2.589	2.146	2.146	1.2	1.788	1.8
No Action	Striped Mullet	Total Creeks	2.589	0.217	0.080	1.2	0.067	0.067
SMA 1	Black Drum	Total Creeks	0.888	0.273	0.248	1.2	0.207	0.21
SMA 1	Red Drum	Total Creeks	0.888	0.370	0.329	1.2	0.274	0.27
SMA 1	Silver Perch	Total Creeks	0.888	0.519	0.519	1.2	0.432	0.43
SMA 1	Spotted Seatrout	Total Creeks	0.888	0.737	0.737	1.2	0.614	0.61
SMA 1	Striped Mullet	Total Creeks	0.888	0.075	0.028	1.2	0.023	0.023
SMA 2	Black Drum	Total Creeks	1.525	0.468	0.426	1.2	0.355	0.35
SMA 2	Red Drum	Total Creeks	1.525	0.634	0.564	1.2	0.470	0.47
SMA 2	Silver Perch	Total Creeks	1.525	0.890	0.890	1.2	0.742	0.74
SMA 2	Spotted Seatrout	Total Creeks	1.525	1.264	1.264	1.2	1.053	1.1
SMA 2	Striped Mullet	Total Creeks	1.525	0.128	0.047	1.2	0.039	0.039
SMA 3	Black Drum	Total Creeks	1.444	0.443	0.404	1.2	0.336	0.34
SMA 3	Red Drum	Total Creeks	1.444	0.601	0.535	1.2	0.446	0.45
SMA 3	Silver Perch	Total Creeks	1.444	0.844	0.844	1.2	0.703	0.7
SMA 3	Spotted Seatrout	Total Creeks	1.444	1.197	1.197	1.2	0.998	1
SMA 3	Striped Mullet	Total Creeks	1.444	0.121	0.045	1.2	0.037	0.037

Table L-9
Calculation of Predicted Finfish Tissue Concentrations and Hazard Quotients Using Two Models
LCP Chemical Site, Brunswick, Georgia

Aroclor 1268 RISKS: YEARLY AVERAGE METHOD/PURVIS CREEK

Remedy	Species	Area	Sediment Concentration mg/kg	Predicted Aroclor 1268 Concentration mg/kg dw fish tissue	Aroclor 1268 LOAEL mg/kg dw fish tissue	Ratio Body/ LOAEL	LOAEL HQ
No Action	Black Drum	Purvis Creek	3.552	8.577	5.2	1.649	1.6
No Action	Red Drum	Purvis Creek	3.552	1.835	5.2	0.353	0.35
No Action	Silver Perch	Purvis Creek	3.552	7.525	5.2	1.447	1.4
No Action	Spotted Seatrout	Purvis Creek	3.552	6.623	5.2	1.274	1.3
No Action	Striped Mullet	Purvis Creek	3.552	15.035	5.2	2.891	2.9
SMA 1	Black Drum	Purvis Creek	1.740	4.327	5.2	0.832	0.83
SMA 1	Red Drum	Purvis Creek	1.740	1.129	5.2	0.217	0.22
SMA 1	Silver Perch	Purvis Creek	1.740	4.006	5.2	0.770	0.77
SMA 1	Spotted Seatrout	Purvis Creek	1.740	3.485	5.2	0.670	0.67
SMA 1	Striped Mullet	Purvis Creek	1.740	7.128	5.2	1.371	1.4
SMA 2	Black Drum	Purvis Creek	3.552	8.577	5.2	1.649	1.6
SMA 2	Red Drum	Purvis Creek	3.552	1.835	5.2	0.353	0.35
SMA 2	Silver Perch	Purvis Creek	3.552	7.525	5.2	1.447	1.4
SMA 2	Spotted Seatrout	Purvis Creek	3.552	6.623	5.2	1.274	1.3
SMA 2	Striped Mullet	Purvis Creek	3.552	15.035	5.2	2.891	2.9
SMA 3	Black Drum	Purvis Creek	2.725	6.653	5.2	1.279	1.3
SMA 3	Red Drum	Purvis Creek	2.725	1.533	5.2	0.295	0.29
SMA 3	Silver Perch	Purvis Creek	2.725	5.954	5.2	1.145	1.1
SMA 3	Spotted Seatrout	Purvis Creek	2.725	5.218	5.2	1.004	1
SMA 3	Striped Mullet	Purvis Creek	2.725	11.396	5.2	2.192	2.2

Table L-9
Calculation of Predicted Finfish Tissue Concentrations and Hazard Quotients Using Two Models
LCP Chemical Site, Brunswick, Georgia

Aroclor 1268 RISKS: AREA WEIGHTED METHOD/TOTAL CREEKS

Remedy	Species	Area	Sediment Concentration mg/kg	Predicted Aroclor 1268 Concentration mg/kg dw fish tissue	Aroclor 1268 LOAEL mg/kg dw fish tissue	Ratio Body/ LOAEL	LOAEL HQ
No Action	Black Drum	Total Creeks	6.008	4.452	5.2	0.856	0.86
No Action	Red Drum	Total Creeks	6.008	1.154	5.2	0.222	0.22
No Action	Silver Perch	Total Creeks	6.008	4.578	5.2	0.880	0.88
No Action	Spotted Seatrout	Total Creeks	6.008	3.971	5.2	0.764	0.76
No Action	Striped Mullet	Total Creeks	6.008	10.665	5.2	2.051	2.1
SMA 1	Black Drum	Total Creeks	1.559	1.156	5.2	0.222	0.22
SMA 1	Red Drum	Total Creeks	1.559	0.299	5.2	0.058	0.058
SMA 1	Silver Perch	Total Creeks	1.559	1.188	5.2	0.229	0.23
SMA 1	Spotted Seatrout	Total Creeks	1.559	1.031	5.2	0.198	0.2
SMA 1	Striped Mullet	Total Creeks	1.559	2.768	5.2	0.532	0.53
SMA 2	Black Drum	Total Creeks	3.261	2.417	5.2	0.465	0.46
SMA 2	Red Drum	Total Creeks	3.261	0.626	5.2	0.120	0.12
SMA 2	Silver Perch	Total Creeks	3.261	2.485	5.2	0.478	0.48
SMA 2	Spotted Seatrout	Total Creeks	3.261	2.156	5.2	0.415	0.41
SMA 2	Striped Mullet	Total Creeks	3.261	5.789	5.2	1.113	1.1
SMA 3	Black Drum	Total Creeks	2.669	1.978	5.2	0.380	0.38
SMA 3	Red Drum	Total Creeks	2.669	0.513	5.2	0.099	0.099
SMA 3	Silver Perch	Total Creeks	2.669	2.034	5.2	0.391	0.39
SMA 3	Spotted Seatrout	Total Creeks	2.669	1.764	5.2	0.339	0.34
SMA 3	Striped Mullet	Total Creeks	2.669	4.738	5.2	0.911	0.91

HQ	hazard quotient
LOAEL	lowest observed apparent effects level
mg/kg dw	miligrams per kilogram dry weight
SMA	Sediment Management Area

Table L-10
Summary of Predicted Finfish Tissue Concentrations and Hazard Quotients
LCP Chemical Site, Brunswick, Georgia

METHYL MERCURY CONCENTRATION (mg/kg dw)		Area	Black Drum	Red Drum	Silver Perch	Spotted Seatrout	Striped Mullet
Measured Fish Tissue Concentration (a)	95UCL	Meas	0.87	1.25	1.85	2.65	0.1
	Mean	Meas	0.76	1.01	1.6	2.27	0.09
Modeled No Action Alternative Concentrations (b)	YA BAF	Purvis Creek	0.974	1.203	1.856	2.273	0.091
	AW BAF	Total Creeks	0.723	0.958	1.512	2.146	0.080
SMA 1 (c)	YA BAF	Purvis Creek	0.716	0.977	1.490	1.757	0.071
	AW BAF	Total Creeks	0.248	0.329	0.519	0.737	0.028
SMA 2 (c)	YA BAF	Purvis Creek	0.974	1.203	1.856	2.273	0.091
	AW BAF	Total Creeks	0.426	0.564	0.890	1.264	0.047
SMA 3 (c)	YA BAF	Purvis Creek	0.878	1.121	1.724	2.084	0.083
	AW BAF	Total Creeks	0.404	0.535	0.844	1.197	0.045

METHYL MERCURY HAZARD QUOTIENT		Area	Black Drum	Red Drum	Silver Perch	Spotted Seatrout	Striped Mullet
Measured Fish Tissue Concentration (a)	95UCL	Meas	0.73	1	1.5	2.2	0.083
	Mean	Meas	0.63	0.84	1.3	1.9	0.075
Modeled No Action Alternative Concentrations (b)	YA BAF	Purvis Creek	0.81	1	1.5	1.9	0.076
	AW BAF	Total Creeks	0.6	0.8	1.3	1.8	0.067
SMA 1 (c)	YA BAF	Purvis Creek	0.6	0.81	1.2	1.5	0.059
	AW BAF	Total Creeks	0.21	0.27	0.43	0.61	0.023
SMA 2 (c)	YA BAF	Purvis Creek	0.81	1	1.5	1.9	0.076
	AW BAF	Total Creeks	0.35	0.47	0.74	1.1	0.039
SMA 3 (c)	YA BAF	Purvis Creek	0.73	0.93	1.4	1.7	0.069
	AW BAF	Total Creeks	0.34	0.45	0.7	1	0.037

Aroclor 1268 CONCENTRATION (mg/kg dw)		Area	Black Drum	Red Drum	Silver Perch	Spotted Seatrout	Striped Mullet
Measured Fish Tissue Concentration (a)	95UCL	Meas	6.45	1.87	7.05	5.91	21
	Mean	Meas	5.51	1.43	5.67	4.92	13
Modeled No Action Alternative Concentrations (b)	YA BAF	Purvis Creek	8.577	1.835	7.525	6.623	15.035
	AW BAF	Total Creeks	4.452	1.154	4.578	3.971	10.665
SMA 1 (c)	YA BAF	Purvis Creek	4.327	1.129	4.006	3.485	7.128
	AW BAF	Total Creeks	1.156	0.299	1.188	1.031	2.768
SMA 2 (c)	YA BAF	Purvis Creek	8.577	1.835	7.525	6.623	15.035
	AW BAF	Total Creeks	2.417	0.626	2.485	2.156	5.789
SMA 3 (c)	YA BAF	Purvis Creek	6.653	1.533	5.954	5.218	11.396
	AW BAF	Total Creeks	1.978	0.513	2.034	1.764	4.738

Table L-10
Summary of Predicted Finfish Tissue Concentrations and Hazard Quotients
LCP Chemical Site, Brunswick, Georgia

Aroclor 1268 HAZARD QUOTIENT		**Area**	**Black Drum**	**Red Drum**	**Silver Perch**	**Spotted Seatrout**	**Striped Mullet**
Measured Fish Tissue Hazard Quotient (a)	95UCL	Meas	1.2	0.36	1.4	1.1	4
	Mean	Meas	1.1	0.28	1.1	0.95	2.5
Modeled No Action Alternative Hazard Quotients (b)	YA BAF	Purvis Creek	1.6	0.35	1.4	1.3	2.9
	AW BAF	Total Creeks	0.86	0.22	0.88	0.76	2.1
SMA 1 (c)	YA BAF	Purvis Creek	0.83	0.22	0.77	0.67	1.4
	AW BAF	Total Creeks	0.22	0.058	0.23	0.2	0.53
SMA 2 (c)	YA BAF	Purvis Creek	1.6	0.35	1.4	1.3	2.9
	AW BAF	Total Creeks	0.46	0.12	0.48	0.41	1.1
SMA 3 (c)	YA BAF	Purvis Creek	1.3	0.29	1.1	1	2.2
	AW BAF	Total Creeks	0.38	0.099	0.39	0.34	0.91

95UCL	95% upper confidence limit on the mean
AW BAF	area weighted bioaccumulation factor from the baseline ecological risk assessment
HQ	hazard quotient
mg/kg dw	miligrams per kilogram dry weight
SMA	Sediment Management Area
YA BAF	yearly average bioaccumulation factor from the baseline ecological risk assessment

(a) Measured fish tissue concentrations and HQs are from Table 4-29 in the BERA (USEPA, 2011).

(b) The modeled No Action alternative HQs and concentrations are calculated using the two models from the BERA (the Yearly Average BAF and the Area Weighted BAF).

(c) The modeled remedy HQs and concentrations are calculated using the two models from the BERA (the Yearly Average BAF and the Area Weighted BAF).

Table L-11
Summary of Model Predictions
LCP Chemical Site, Brunswick, Georgia

Model	Constituent	Comparison	Black Drum	Red Drum	Silver Perch	Spotted Seatrout	Striped Mullet	Average Ratio	Different?
Area Weighted BAF	Mercury	95% UCL	0.831	0.767	0.817	0.810	0.805	0.81	Underpredict
Area Weighted BAF	Mercury	Mean	0.952	0.949	0.945	0.945	0.894	0.94	Similar
Area Weighted BAF	Aroclor 1268	95% UCL	0.690	0.617	0.649	0.672	0.508	0.63	Underpredict
Area Weighted BAF	Aroclor 1268	Mean	0.808	0.807	0.807	0.807	0.820	0.81	Underpredict
Yearly Average BAF	Mercury	95% UCL	1.119	0.962	1.003	0.858	0.907	0.97	Similar
Yearly Average BAF	Mercury	Mean	1.281	1.191	1.160	1.001	1.008	1.13	Slight overpredict
Yearly Average BAF	Aroclor 1268	95% UCL	1.330	0.981	1.067	1.121	0.716	1.04	Similar
Yearly Average BAF	Aroclor 1268	Mean	1.557	1.283	1.327	1.346	1.157	1.33	Overpredict

BAF	bioaccumulation factor
Similar	within 10% of the measured concentration
Slight	within 20% of the measured concentration
UCL	upper confidence limit

Table L-12
Estimated SWACs for the Different Remedy Alternatives
LCP Chemical Site, Brunswick, Georgia

Mercury			**SMA 1 (Bkgd)**	**SMA 1 (Bkgd & 10% TLC)**	**SMA 2 (Bkgd)**	**SMA 2 (Bkgd & 10% TLC)**	**SMA 3 (Bkgd)**	**SMA 3 (Bkgd & 10% TLC)**
Domain	**Domain Area (acres)**	**Before SWAC (mg/kg)**	**After SWAC (mg/kg)**	**After SWAC (mg/kg)**	**After SWAC (mg/kg)**	**After SWAC (mg/kg)**	**After SWAC (mg/kg)**	**After SWAC (mg/kg)**
Dillon Duck	1.8	1.43	0.30	0.30	0.30	0.30	0.30	0.30
Domain 1	21.0	5.11	0.63	0.97	1.63	1.93	1.06	1.38
Domain 2	114.6	2.55	0.86	1.00	1.25	1.37	1.25	1.37
Domain 3	107.7	1.73	1.48	1.49	1.73	1.73	1.73	1.73
Domain 4 East	191.9	1.98	1.98	1.98	1.98	1.98	1.98	1.98
Domain 4 West	224.5	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Landfill	NA	NA	NA	NA	NA	NA	NA	NA
Total Domains	661.5	1.70	1.22	1.26	1.36	1.39	1.34	1.37
Domain 3 Creek	12.4	5.94	1.05	1.05	3.73	3.73	3.73	3.73
Eastern Creek	4.2	14.58	0.30	0.30	0.30	0.30	0.30	0.30
LCP Ditch	2.5	7.67	0.32	0.32	0.39	0.39	0.39	0.39
Purvis Creek	70.5	1.17	0.87	0.87	1.17	1.17	1.06	1.06
Western Creek Complex	9.0	2.14	1.24	1.24	2.14	2.14	2.14	2.14
Total Creek	98.5	2.59	0.89	0.89	1.52	1.52	1.44	1.44
Total Estuary	760.0	1.81	1.18	1.21	1.38	1.41	1.35	1.38

Aroclor 1268			**SMA 1 (Bkgd)**	**SMA 1 (Bkgd & 10% TLC)**	**SMA 2 (Bkgd)**	**SMA 2 (Bkgd & 10% TLC)**	**SMA 3 (Bkgd)**	**SMA 3 (Bkgd & 10% TLC)**
Domain	**Domain Area (acres)**	**Before SWAC (mg/kg)**	**After SWAC (mg/kg)**	**After SWAC (mg/kg)**	**After SWAC (mg/kg)**	**After SWAC (mg/kg)**	**After SWAC (mg/kg)**	**After SWAC (mg/kg)**
Dillon Duck	1.8	2.12	0.20	0.20	0.20	0.20	0.20	0.20
Domain 1	21.0	3.15	0.65	0.83	1.16	1.32	0.89	1.06
Domain 2	114.6	1.89	1.36	1.39	1.52	1.54	1.52	1.54
Domain 3	107.7	1.72	1.54	1.55	1.72	1.72	1.72	1.72
Domain 4 East	191.9	2.12	2.12	2.12	2.12	2.12	2.12	2.12
Domain 4 West	224.5	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Landfill	NA	NA	NA	NA	NA	NA	NA	NA
Total Domains	661.5	1.59	1.38	1.39	1.45	1.46	1.45	1.45
Domain 3 Creek	12.4	5.72	1.15	1.15	3.42	3.42	3.42	3.42
Eastern Creek	4.2	43.46	0.20	0.20	0.20	0.20	0.20	0.20
LCP Ditch	2.5	25.36	0.24	0.24	0.33	0.33	0.33	0.33
Purvis Creek	70.5	3.55	1.74	1.74	3.55	3.55	2.73	2.73
Western Creek Complex	9.0	2.98	1.70	1.70	2.98	2.98	2.98	2.98
Total Creeks	98.5	6.01	1.56	1.56	3.26	3.26	2.67	2.67
Total Estuary	760.0	2.16	1.40	1.41	1.69	1.70	1.60	1.61

Bkgd	background
mg/kg	miligrams per kilogram.
SMA	Sediment Management Area
SWAC	suface weighted area concentration
TLC	thin-layer cap

Appendix L
Technical Approach for Remedy
Evaluation and Uncertainty Evaluation

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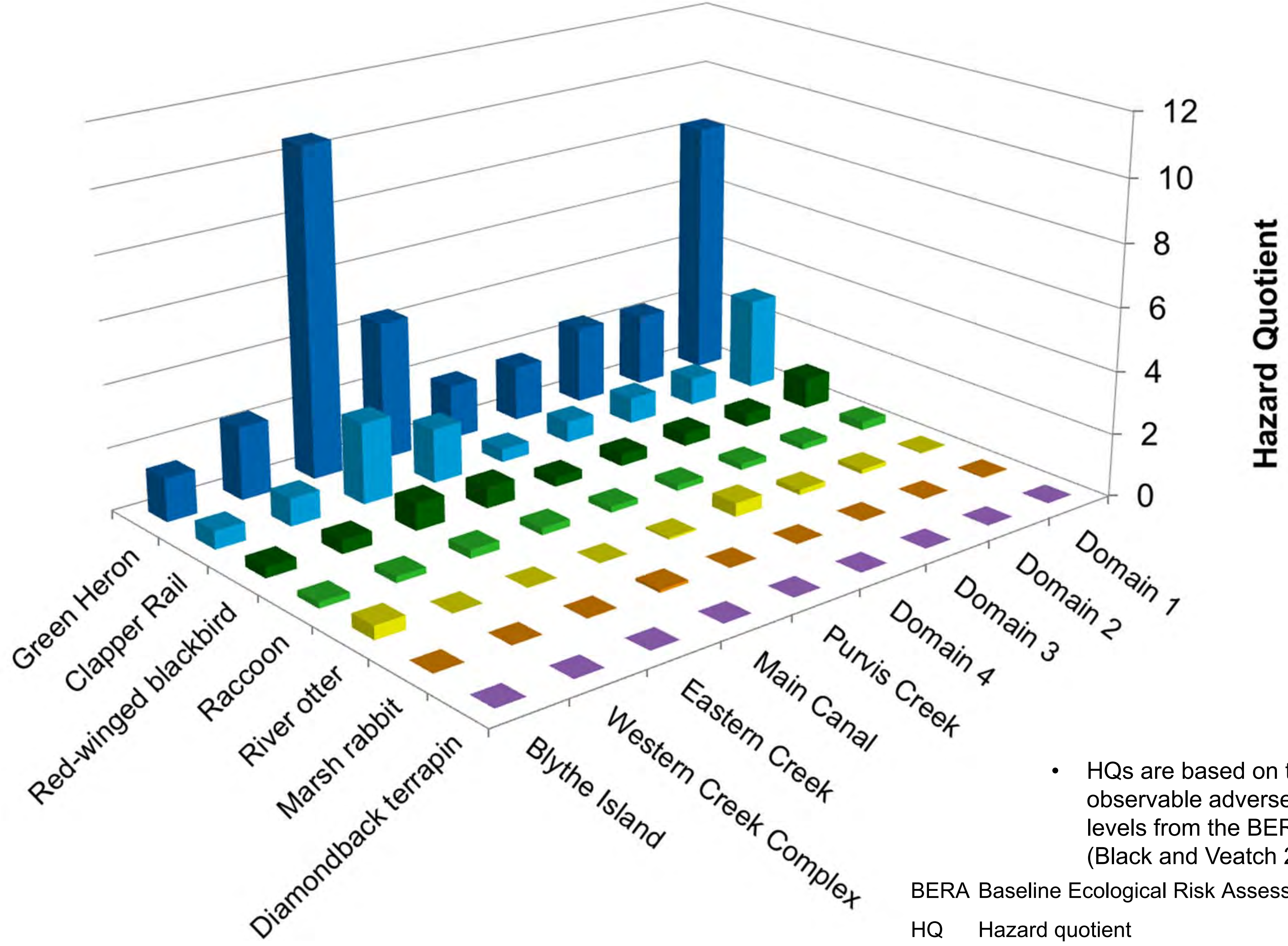
Figures



- HQs are based on the no observable adverse effects levels from the BERA (Black and Veatch 2011).

BERA	Baseline Ecological Risk Assessment
HQ	Hazard quotient

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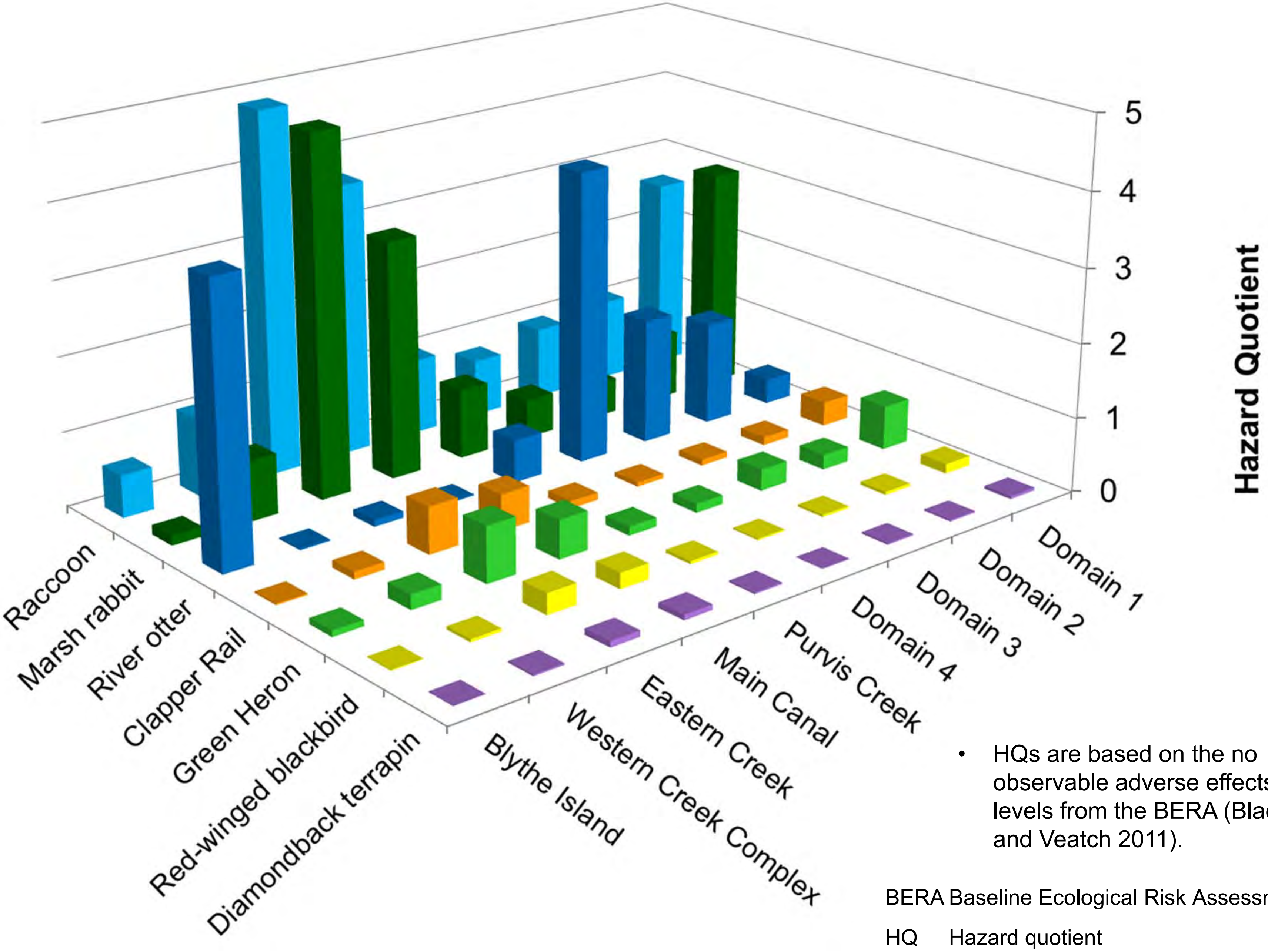
Current Conditions and Baseline Ecological Risk Assessment Findings for Mammals and Birds for Methylmercury (NOAEL)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

L-1A



- HQs are based on the no observable adverse effects levels from the BERA (Black and Veatch 2011).

BERA Baseline Ecological Risk Assessment

HQ Hazard quotient

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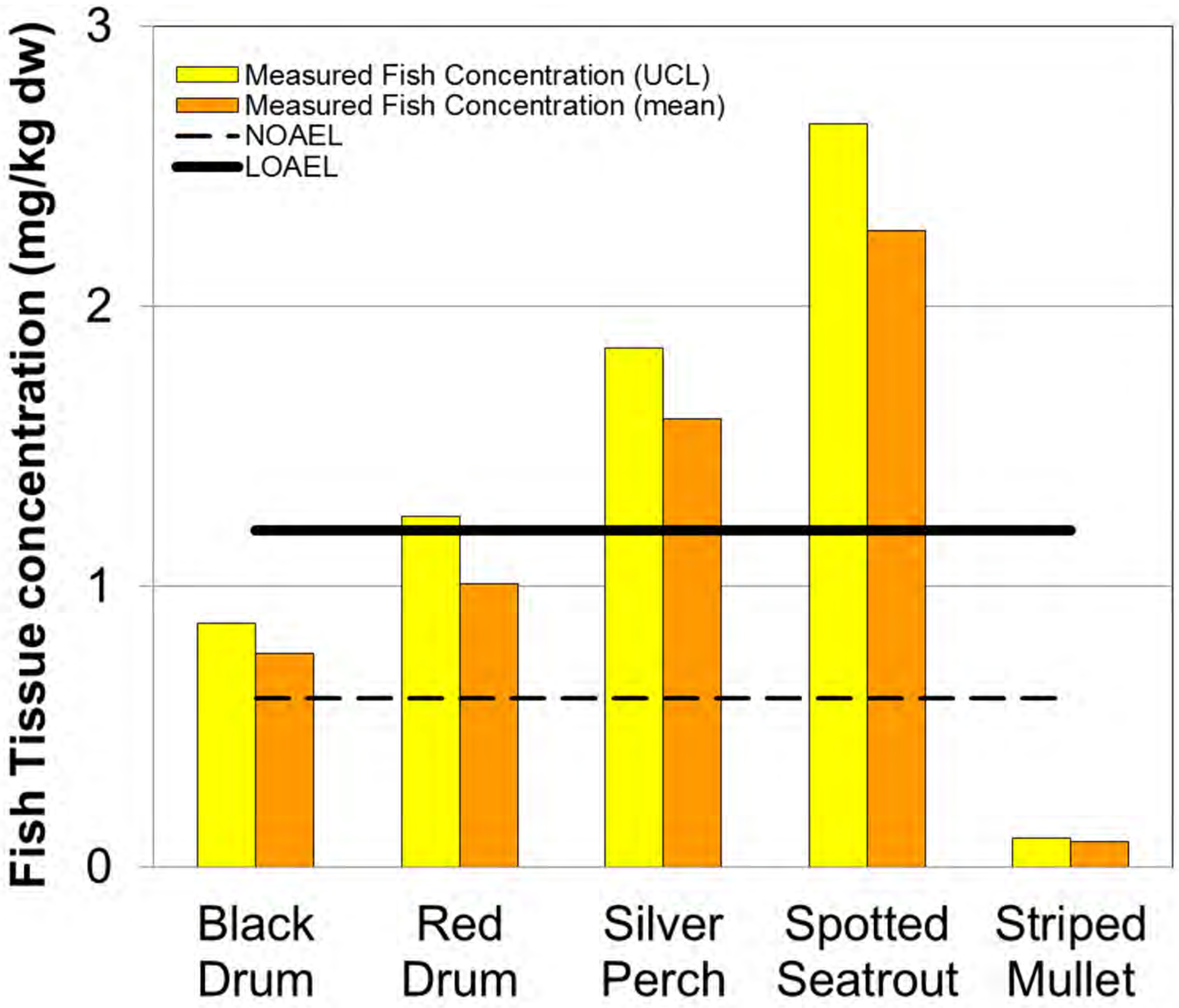
Current Conditions and Baseline Ecological Risk Assessment Findings for Mammals and Birds for Aroclor 1268 (NOAEL)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

L-1B



Fish tissue concentrations are in mg/kg dry weight

UCL	The 95% upper confidence level on the mean.
NOAEL	No observable adverse effects level toxicity reference value
LOAEL	Lowest observable adverse effects level toxicity reference value

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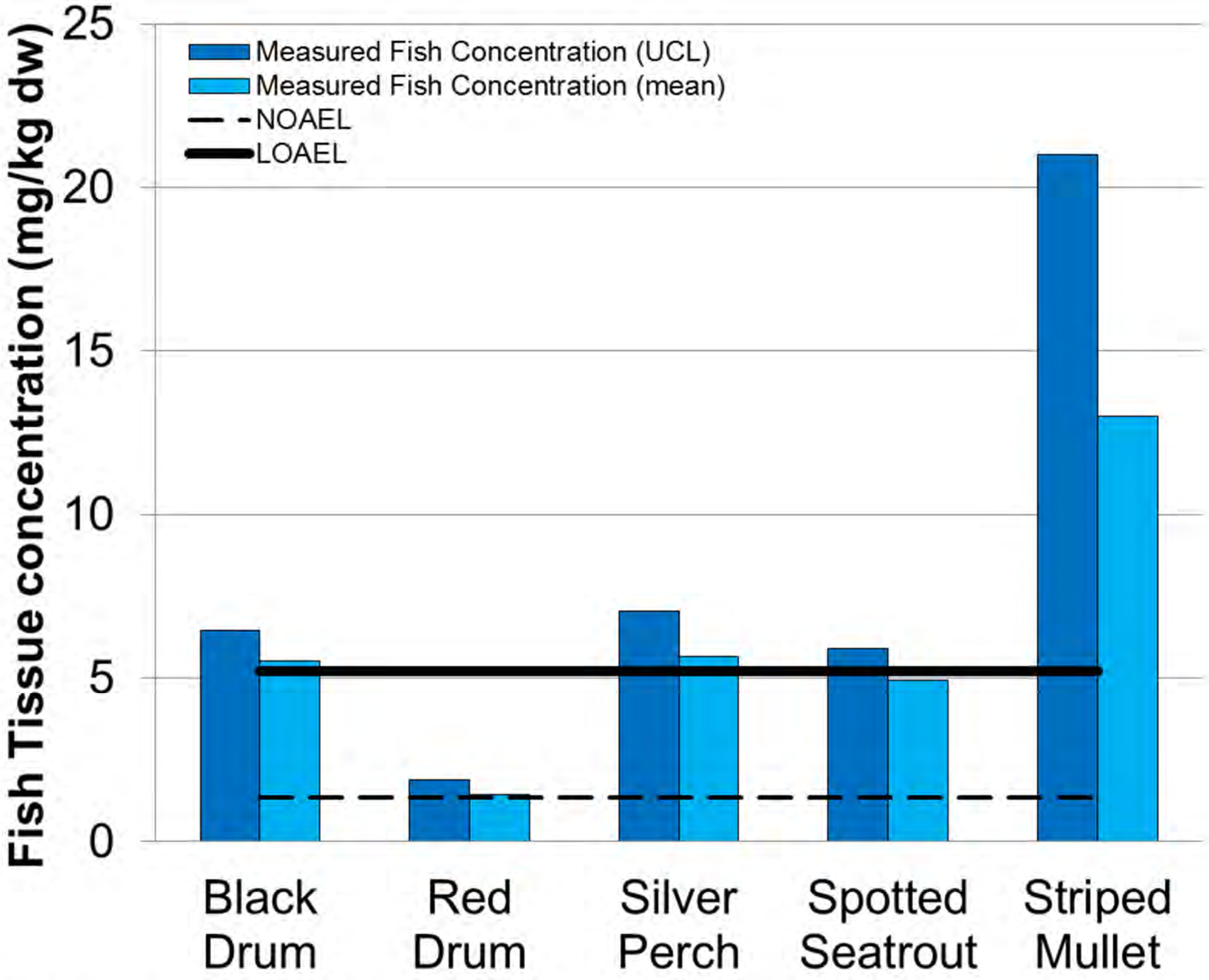
No Action Alternative Methylmercury Fish Tissue Concentrations

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

L-2A



Fish tissue concentrations are in mg/kg dry weight

UCL	The 95% upper confidence level on the mean.
NOAEL	No observable adverse effects level toxicity reference value
LOAEL	Lowest observable adverse effects level toxicity reference value

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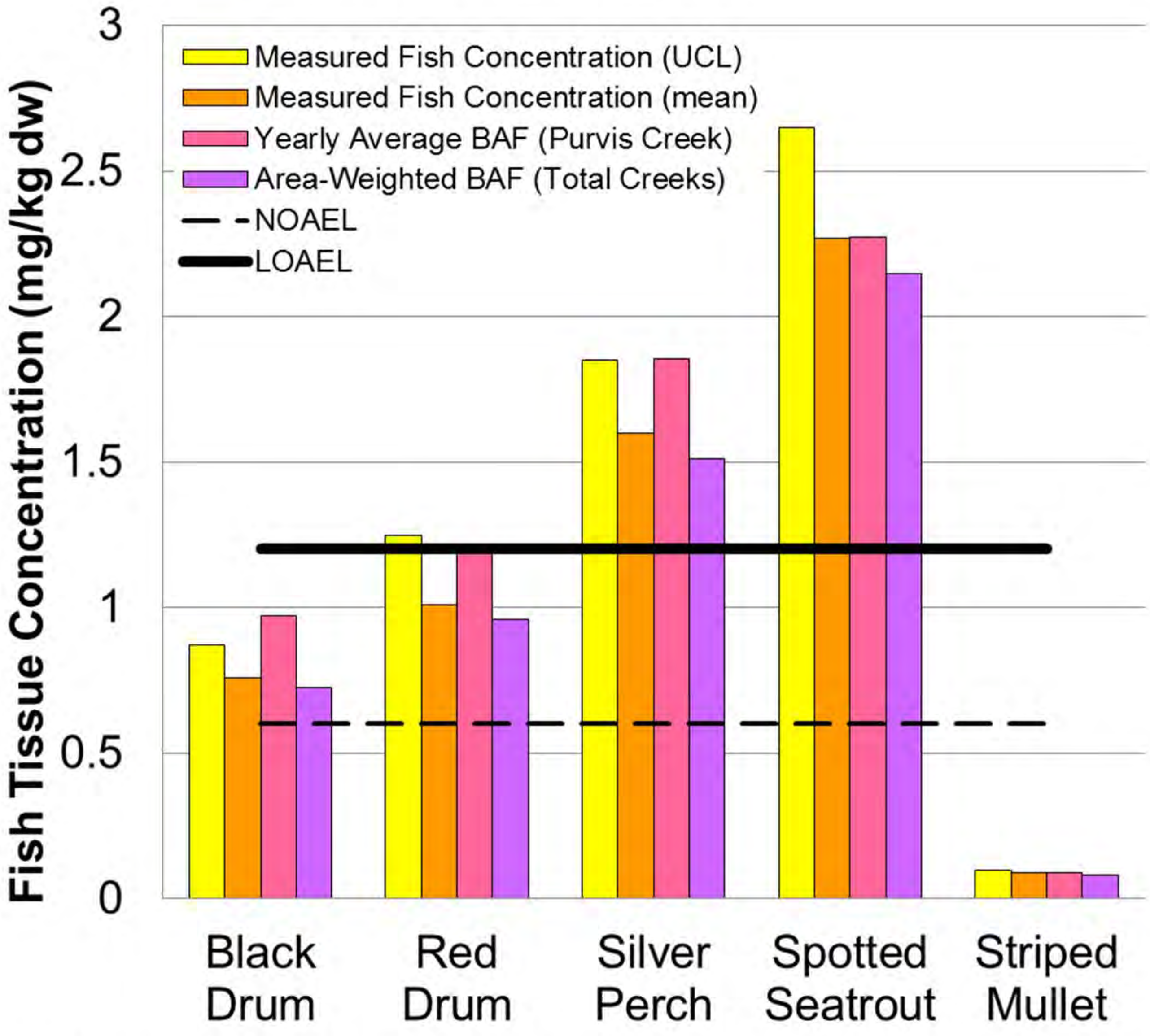
No Action Alternative Aroclor 1268 Fish Tissue Concentrations

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

L-2B



Fish tissue concentrations are in mg/kg dry weight

- The Yearly Average BAF and Area-Weighted BAF methods are described in the BERA.
- The Yearly Average BAF model is based on the Purvis Creek SWAC. The Area-Weighted BAF model is based on the Total Creeks SWAC sediment concentrations.

HQ	Hazard Quotient
UCL	95% UCL on the mean
BERA	Baseline ecological risk assessment
BAF	Bioaccumulation factor
mg/kg dw	Milligrams per kilogram dry weight
NOAEL	No observable adverse effects level toxicity reference value
LOAEL	Lowest observable adverse effects level toxicity reference value

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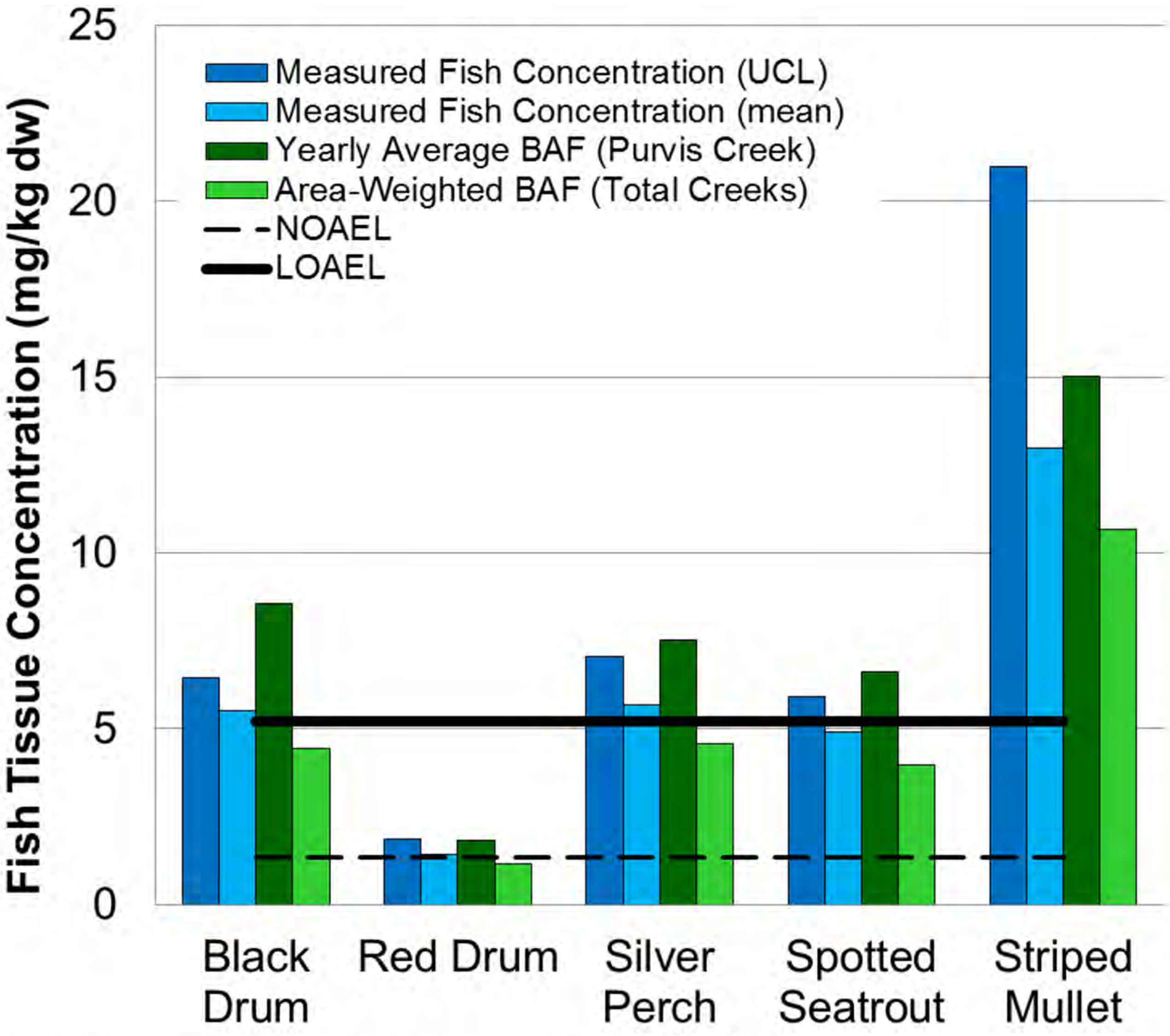
Measured vs. Estimated Methylmercury Concentration in Finfish

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

L-3A



Fish tissue concentrations are in mg/kg dry weight

- The Yearly Average BAF and Area-Weighted BAF methods are described in the BERA.
- The Yearly Average BAF model is based on the Purvis Creek SWAC. The Area-Weighted BAF model is based on the Total Creeks SWAC sediment concentrations.

HQ	Hazard Quotient
UCL	95% UCL on the mean
BERA	Baseline ecological risk assessment.
BAF	Bioaccumulation factor
mg/kg dw	Milligrams per kilogram dry weight.
NOAEL	No observable adverse effects level toxicity reference value
LOAEL	Lowest observable adverse effects level toxicity reference value

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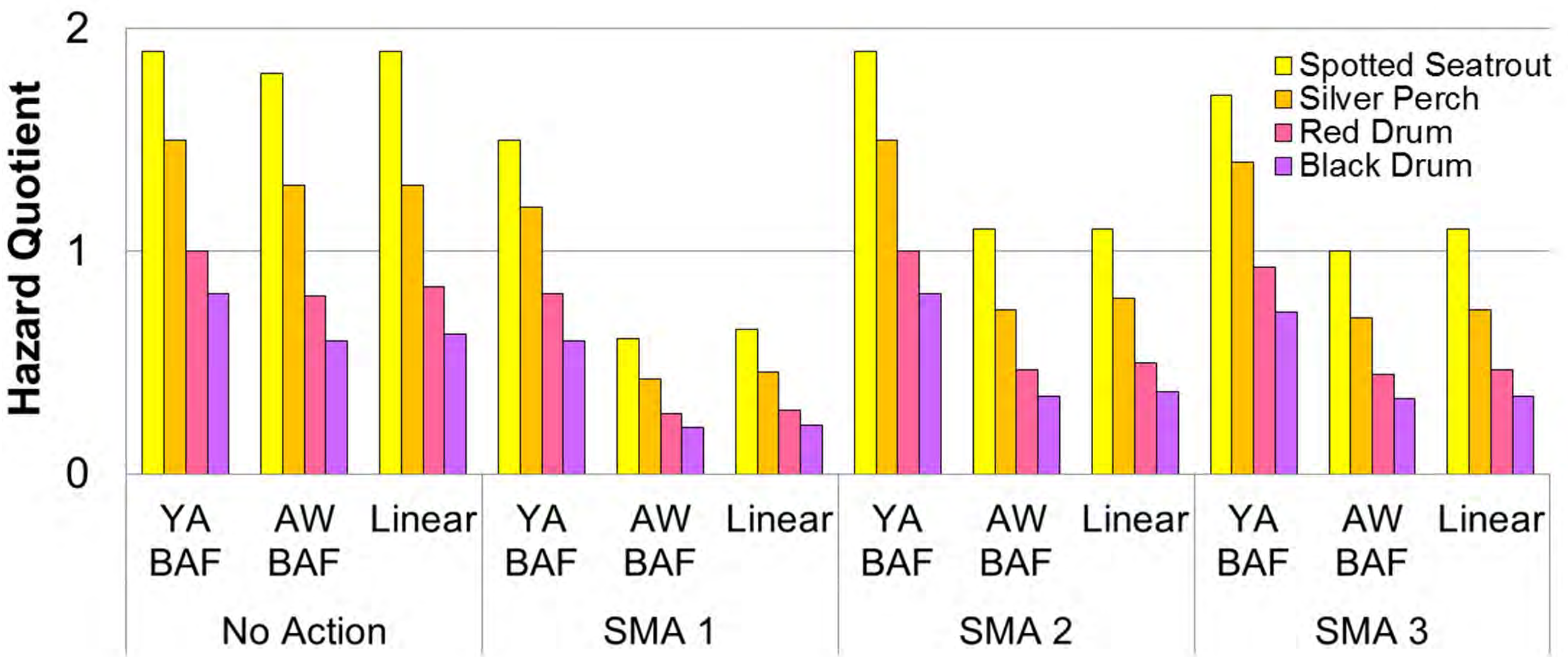
Measured vs. Estimated Aroclor 1268 Concentration in Finfish

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

L-3B



- This is a comparison of the hazard quotients in the four remedial options using three different models. This shows the potential range of predicted risks in the remedial alternatives.
- Striped mullet is not shown. LOAEL risks for this receptor are below 1 (see no-action values on Figure E2-2A).

- The YA BAF (Yearly Average) model is based on the Purvis Creek SWACs.
- The AW BAF (Area Weighted) model is based on the Total Creeks SWACs.

SMA 1	Remedy Alternatives 2 and 3
SMA 2	Remedy Alternatives 4 and 5
SMA 3	Remedy Alternative 6

AW	Area Weighted
BAF	Bioaccumulation factor
HQ	Hazard Quotient
LOAEL	Lowest Observable Adverse Effects Value toxicity reference value
PC	Based on the Purvis Creek SWAC
SWAC	Surface Weighted Area Concentration
SMA	Sediment Management Area
TC	Based on the Total Creek SWAC
YA	Yearly Average

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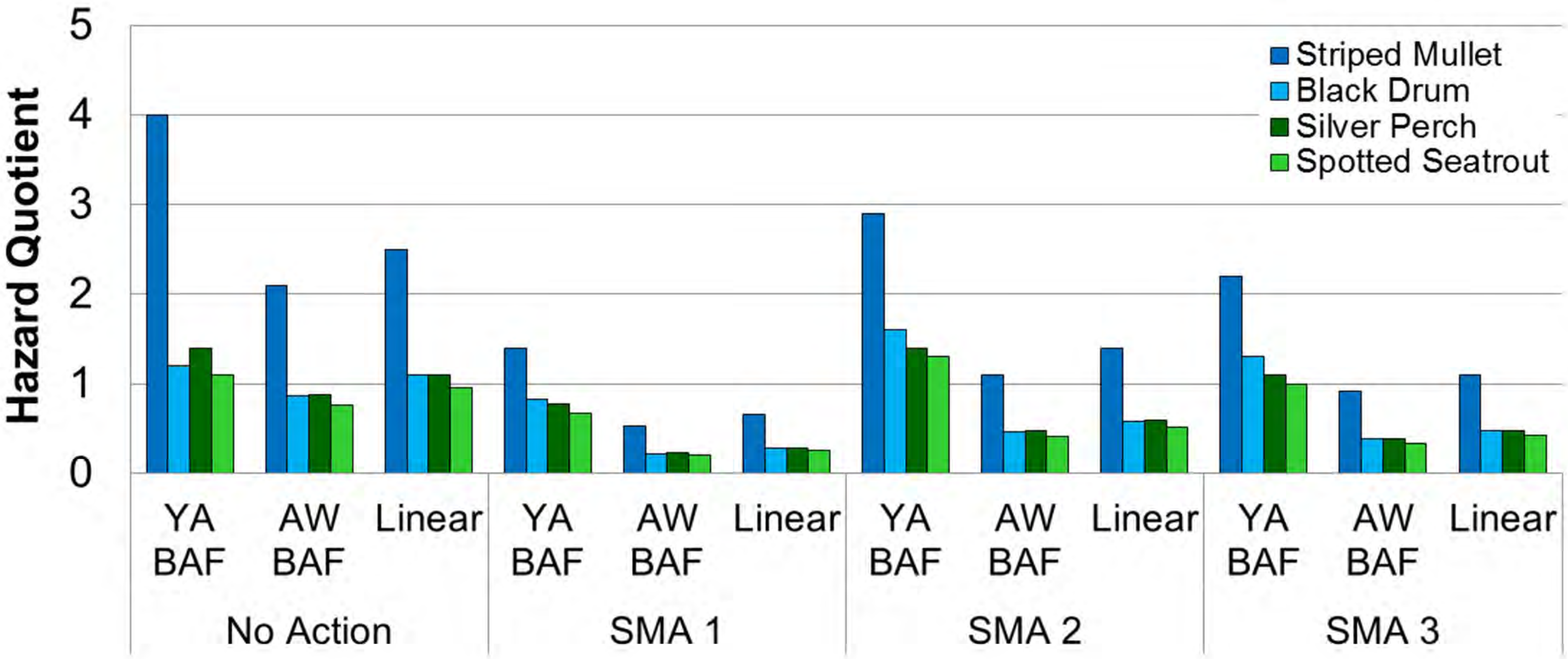
Methylmercury Hazard Quotients in Finfish Using Three Models

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

L-4A



- This is a comparison of the hazard quotients in the four remedial options using three different models. This shows the potential range of predicted risks in the remedial alternatives.

- The YA BAF (Yearly Average) model is based on the Purvis Creek SWACs.
- The AW BAF (Area Weighted) model is based on the Total Creeks SWACs.

SMA 1	Remedy Alternatives 2 and 3
SMA 2	Remedy Alternatives 4 and 5
SMA 3	Remedy Alternative 6

AW	Area Weighted Site
BAF	Bioaccumulation factor
HQ	Hazard Quotient
LOAEL	Lowest Observable Adverse Effects Value toxicity reference value
PC	Based on the Purvis Creek SWAC
SWAC	Surface Weighted Area Concentration
SMA	Sediment Management Area
TC	Based on the Total Creek SWAC
YA	Yearly Average

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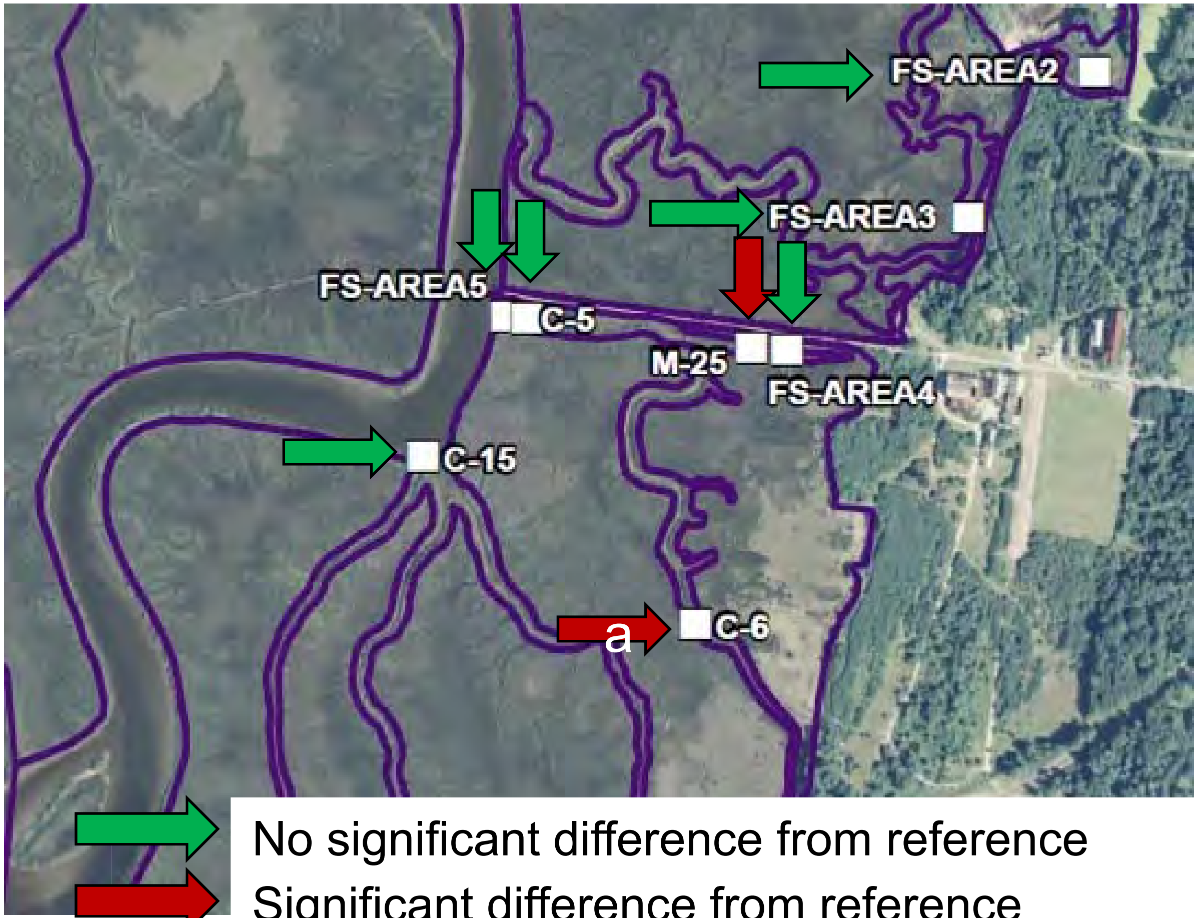
Aroclor 1268 Hazard Quotients in Finfish Using Three Models

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

L-4B

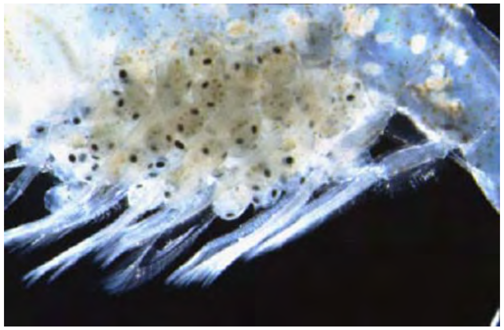


🟩 No significant difference from reference

🟥 Significant difference from reference

- Grass shrimp toxicity improved after the 1998-1998 removal action in Domain 1.
- Monitoring between 2000 and 2007 focused on endpoints of embryo hatching and DNA damage, which were not the most sensitive endpoints identified in the BERA, but do inform some understanding of improvements over time and areas of toxicity.
- Only 2 locations reported with results less than references and these areas are captured in all of the Remedy Alternatives 2 through 6.
- (a) observed less than reference on only 1 event.

- Figures to the right show female shrimp carrying developing embryos. Grass shrimp preferentially forage among the grasses and carry the embryos while doing so. This limits the direct exposure to sediment by the embryo life stage.



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Indigenous Grass Shrimp Monitoring Locations (2000 – 2007)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

L-5A

Measurement Endpoints for Grass Shrimp in LCP Estuary and Reference Location (Wall *et al.*, 2001)

Grass Shrimp Measurement	***LCP Estuary*** Sediment concentration (mg/kg, dw; mean and standard deviation) -- Hg:18.4 ± 21.9 sd ; PCBs: 46.0 ± 52.7	***Reference (CR) Location*** Sediment concentration (mg/kg, dw; mean and standard deviation) -- (Hg:0.49 ± 0.08; PCBs: 0.32 ± 0.07)	***Statistical Significance (P Value)***
Length (mm)	35.2	32.7	0.0003
Female mass (g)	0.087	0.065	0.0001
Brood size (# eggs)	302.7	289.0	>0.05
Brood mass (mg)	16.3	16.3	>0.05
Individual egg mass (mg)	0.054	0.056	>0.05
Mean egg area (mm^2)	0.37	0.34	>0.05

Note: Four of the differences between the two areas are not statistically significant and both of the remaining differences (length of shrimp and female mass) appear to be advantageous to shrimp from the LCP Site

Wall, et al. 2001. Arch. Environ. Contam. Toxicol. 40: 10-17.

- Wall et al. (2001) performed an indigenous grass shrimp study , evaluated a variety of metrics as identified in the table above.
- All of the metrics were similar to slightly better than in the LCP Site estuary than the reference location.

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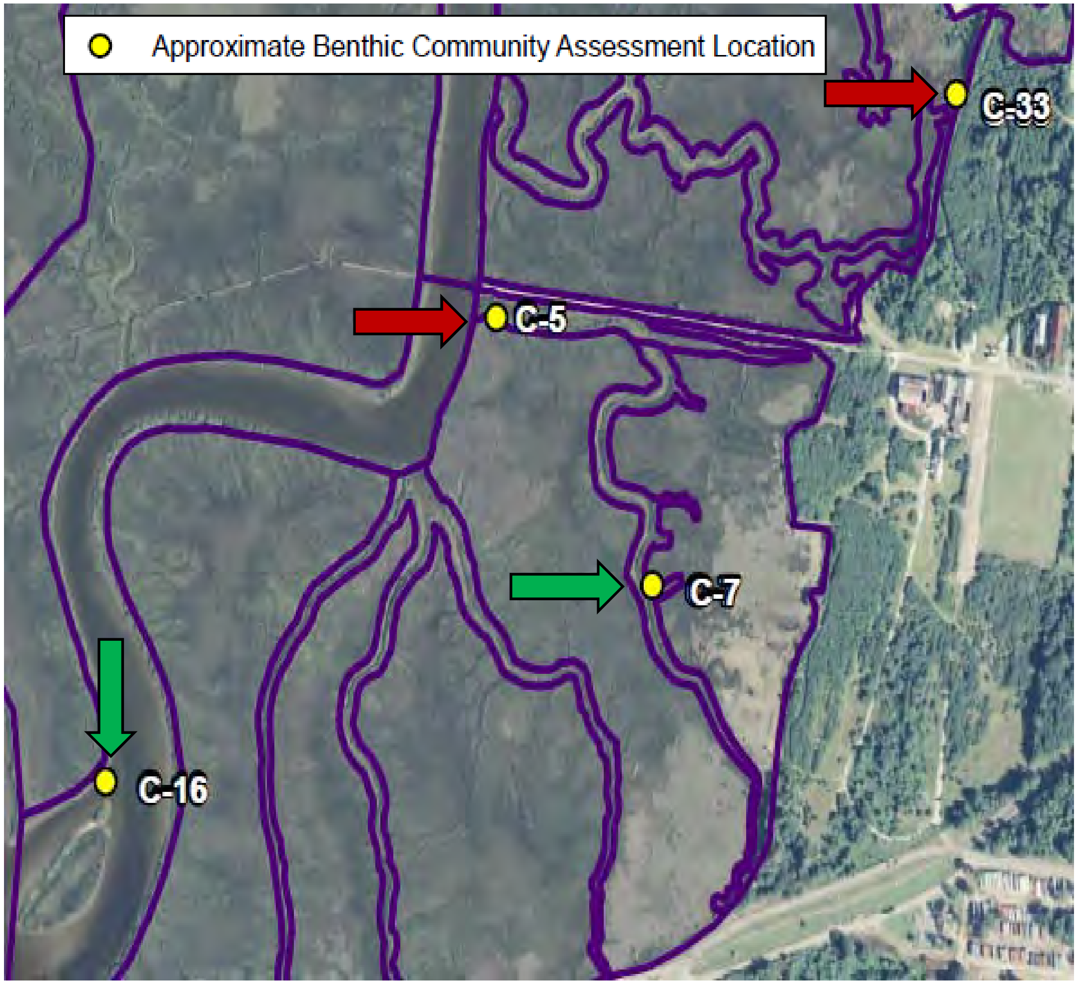
Indigenous Grass Shrimp (Wall et al. 2001)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

L-5B

- This benthic community assessment (2000) was described in the BERA but this figure is new.
- Two locations (C5 and C33) reported with lower diversity than reference. Even these two area showed five to nine species were present in areas that have been shown in the FS to be above RGOs.
- Both areas included in proposed alternatives. C7 in Eastern Creek performed better than the reference area and this area too is slated for removal in each of the Remedy Alternatives described in the FS.
- This information is provided to show that the exceedance of an RGO does not mean definitively that the sediment dwelling community is impaired. This insight can be used to inform the balance of remedies with significant short-term impacts against those with less significant short-term impacts.



🟩 No significant difference from reference

🟥 Significant difference from reference

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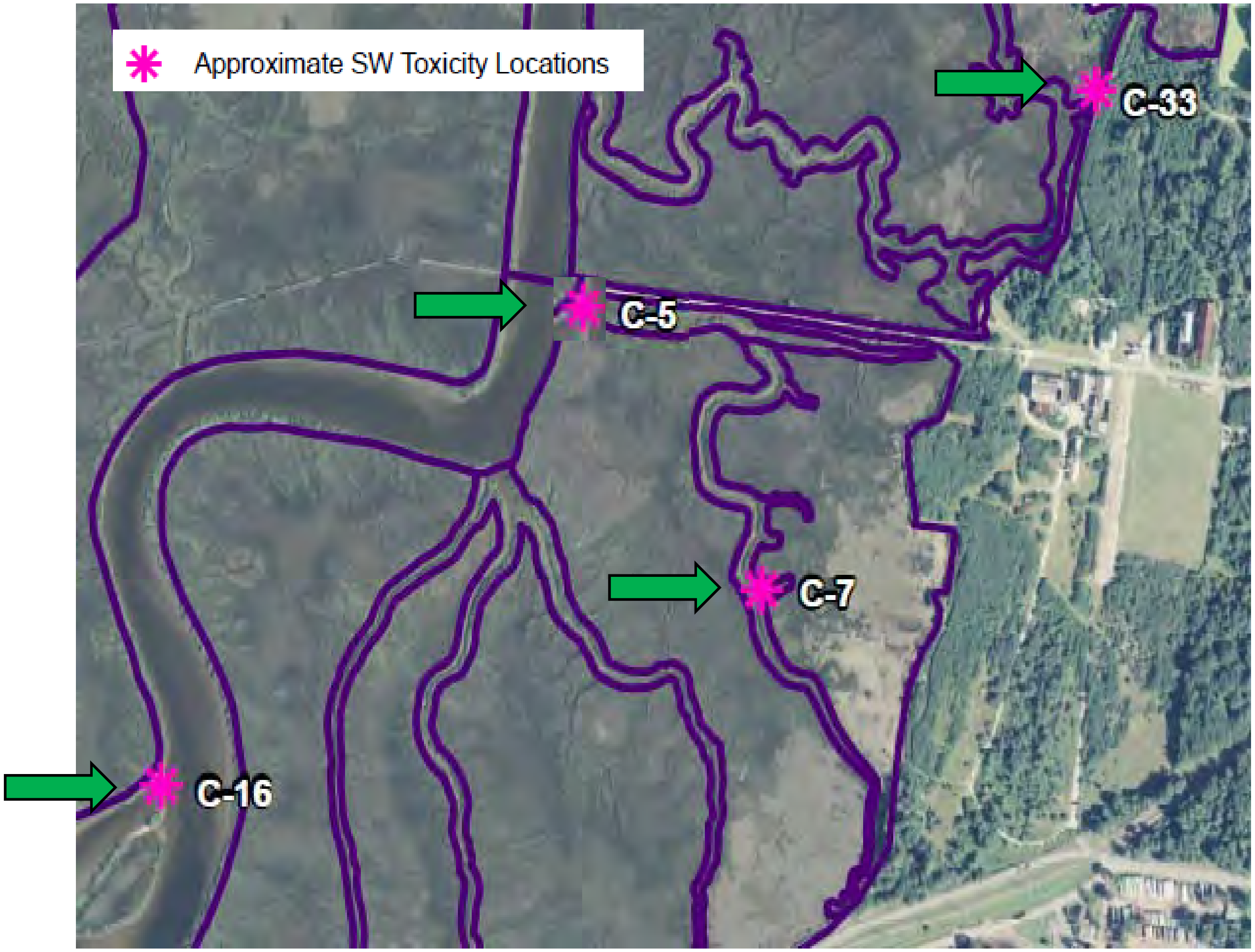
Benthic Community Assessment (2000)

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

L-6

- This surface water toxicity testing study was described in the BERA but this summary figure is new.
- A toxicity testing study was provided for mysid shrimp. Survival and growth was evaluated.
- No impacts to survival were observed (all survival was 94-100%). Growth was greater than or equal to that seen in reference areas.



🟩 No significant difference from reference

🟥 Significant difference from reference

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Surface Water Toxicity Testing

LCP CHEMICAL SITE, BRUNSWICK, GEORGIA

Figure

L-7