DATA EVALUATION REPORT
FOR
LOWER ROUGE RIVER SEDIMENT INVESTIGATION
DETROIT, WAYNE COUNTY, MICHIGAN

Prepared for

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Great Lakes National Program Office
77 West Jackson Boulevard
Chicago, IL 60604

Prepared by

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Troy, MI 48083

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ACRONYMS AND ABBREVIATIONS

%	Percent
µmol/g	Micromole per gram
AVS	Acid volatile sulfide
bss	Below sediment surface
CES	Comprehensive Environmental Solutions
C. tentans	*Chironomus tentans*
DO	Dissolved oxygen
DRO	Diesel-range organic
DWSD	Detroit Water Sewerage Department
EPAH	Expanded list of polycyclic aromatic hydrocarbon
ESB	Equilibrium partitioning sediment benchmark
ESBTU	Equilibrium partitioning sediment benchmark toxic unit
EqP	Equilibrium partitioning
FCV	Final chronic value
foc	fraction organic carbon
ft	Feet
g	Gram
GLNPO	Great Lakes National Program Office
H. azteca	*Hyalella azteca*
LRR	Lower Rouge River
MDNRE	Michigan Department of Natural Resources and Environment
MDEP	Massachusetts Department of Environmental Protection
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
oc	Organic carbon
ORO	Oil-range organic
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PEC	Probable effect concentration
PEC-Q	Mean probable effect concentration quotient
QAPP	Quality Assurance Project Plan

ACRONYMS AND ABBREVIATIONS (CONTINUED)

SEM	Simultaneously extracted divalent metal
SPMD	Semipermeable membrane device
SQG	Sediment quality guideline
SVOC	Semivolatile organic compound
START	Superfund Technical Assistance and Response Team
TDD	Technical Direction Document
TEC	Threshold effect concentration
TOC	Total organic carbon
U.S. EPA	United States Environmental Protection Agency
VSP	Visual Sampling Plan
WESTON	Weston Solutions, Inc.
WDNR	Wisconsin Department of Natural Resources

EXECUTIVE SUMMARY

This report evaluates data from sediment and benthic toxicity investigations conducted for the Lower Rouge River (LRR) in Detroit, Wayne County, Michigan. Specifically, Hot Spots 1 through 6 (HS-1 though HS-6; excluding HS-2), the Zug Island Channel, the area near Outfall 2, the area near Outfall 17, and the West Jefferson Street Bridge and O'Brien Creek. The primary goal of the sediment investigation was to gather additional sediment chemistry data and sediment toxicity data to further delineate the spatial extent and magnitude of sediment contamination impacting aquatic life within the LRR.

A total of 61 locations were sampled during two sampling events in October 2008 and May 2009. Samples collected from each location were analyzed for at least one of the following: metals, polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), expanded list of PAHs (EPAH), diesel-range organics (DRO), oil-range organics (ORO), total organic carbon (TOC), grain size, Atterberg limits, bulk density, and toxicity. The data were compared to the threshold effect concentrations (TEC) and probable effect concentrations (PEC). Based on multiple sampling locations at multiple depths and data of usable quality, the data could be manipulated to determine vertical and horizontal extents of contamination.

At HS-3, HS-4, HS-5, HS-6, Outfall 2, Outfall 17, and the Zug Island Channel, potential impact was associated with all depth intervals. At HS-1 and the West Jefferson Street Bridge, most potential impact was associated with deeper sediments. At O'Brien Creek, potential impact mostly was associated with shallower depth intervals.

Reduced survival was found for *Chironomus tentans (C. tentans)* in sediment from all toxicity test locations, and reduced growth was found in sediment from all but one location. Reduced survival and reduced growth were found for *Hyalella azteca (H. azteca)* at all but three toxicity test locations. Although reduced survival of *H. azteca* was also measured in samples from three additional locations, there was no significant effect on growth.

Recommendations were determined for sediment additional investigation and toxicity testing before a feasibility study is conducted. The recommendations are summarized below.

SEDIMENT ADDITIONAL INVESTIGATION RECOMMENDATIONS

Hot Spot 1

Vertical Delineation Locations

- HS1-A: 7 to 9 feet (ft) below sediment surface (bss), metals
- HS1-C: 3 to 5 ft bss, metals and PAHs

Hot Spot 3

Vertical Delineation Locations

- HS3-D: 3 to 5 ft bss, metals and PAHs
- HS3-C: 5 7 ft bss, metals and PAHs

Horizontal Delineation Location

- Sediment sample core southeast of HS3-C: 7 to 9 ft bss, metals and PAHs

Hot Spot 4

Vertical Delineation Location

- HS4-A: 5 to 7 ft bss, metals and PCBs

Horizontal Delineation Location

- Sediment sample core northwest of HS4-A: 5 to 7 ft bss, metals and PCBs

Hot Spot 5 and West Jefferson Street Bridge

Vertical Delineation Location

- HS5-C: 5 to 7 ft bss, metals

Hot Spot 6

Vertical Delineation Locations

- HS6-Down-2: 1 to 3 ft bss, PAHs
- HS6-D: 1 to 3 ft bss, PCBs and PAHs

- HS6-F: 5 to 7 ft bss, PAHs
- HS6-G: 3 to 5 ft bss, PAHs
- HS6-UP-4: 7 to 9 ft bss, PAHs
- HS6-X-3: 9 to 11 ft bss, PAHs
- HS6-X-4: 3 to 5 ft bss, PAHs
- HS6-X-5: 3 to 5 ft bss, PAHs
- HS6-UP-7: 3 to 5 ft bss, PAHs

Horizontal Delineation Locations

- Sediment sample core west of HS6-A: 1 to 3 ft bss, PAHs
- Sediment sample core east of HS6-X-5: 3 to 5 ft bss, PAHs
- Sediment sample core west of HS6-D: 3 to 5 ft bss, PCBs and PAHs
- Sediment sample cores west and east of HS6-UP-7: 3 to 5 ft bss, PAHs
- Sediment sample core west of HS6-Down-1: 0 to 1 ft bss, PAHs
- Sediment sample core east of HS6-UP-3: 0 to 1 ft bss, PAHs
- Sediment sample cores west and east of HS6-UP-5: 1 to 3 ft bss, metals and PAHs
- Sediment sample cores west and east of HS6-UP-6: 1 to 3 ft bss, metals and PAHs

Zug Island Channel

Vertical Delineation Locations

- ZIC-G: 5 to 7 ft bss, PAHs
- ZIC-E: 9 to 11 ft bss, PAHs

Horizontal Delineation Location

- Sediment sample cores north and south of ZIC-G: 5 to 7 ft bss, PAHs

Outfall 2

Vertical Delineation Locations

- OF2-B: 9 to 11 ft bss, metals, PCBs, and PAHs
- OF2-C: 9 to 11 ft bss, metals, PCBs, and PAHs
- OF2-D: 9 to 11 ft bss, metals, PCBs, and PAHs

- OF2-E: 9 to 11 ft bss, metals, PCBs, and PAHs

Horizontal Delineation Locations

- Sediment sample core south OF2-B: down to 9 to 11 ft bss, metals, PCBs, and PAHs
- Sediment sample core south OF2-D: down to 9 to 11 ft bss, metals and PCBs

Outfall 17

Vertical Delineation Location

- OF17-A: 9 to 11 ft bss, metals and PCBs

Horizontal Delineation Location

- Sediment sample cores north and south OF17-A: down to 9 to 11 ft bss, metals and PCBs

O'Brien Creek

Vertical Delineation Location

- OBC-A: 5 to 7 ft bss, metals

Horizontal Delineation Location

- Sediment sample core north of OBC-A: down to 5 to 7 ft bss, metals

SEDIMENT TOXICITY TESTING RECOMMENDATIONS

The actions summarized below are recommended to clarify confounding factors identified during the initial toxicity testing.

- Re-run toxicity testing for both *C. tentans* and *H. azteca*, monitoring both overlying and pore water ammonia levels and conducting ammonia reduction procedures as necessary. The monitoring of interstitial ammonia should be measured directly (for example, using centrifugation or peepers) at all hot spot locations.
- Conduct a Toxicity Identification Evaluation to determine the chemical class responsible for toxicity at all hot spot locations.

1. INTRODUCTION

Weston Solutions, Inc. (WESTON®) has prepared this data evaluation report for sediment investigation activities performed within the Lower Rouge River (LRR) in Detroit, Wayne County, Michigan. The primary goal of this investigation was to delineate the extent of contamination, both laterally and vertically, within the defined study areas through chemical and toxicity analyses of sediment samples. This report summarizes the investigation and identifies whether the data are sufficient to address this primary goal. The report also identifies data insufficient to address a goal.

All investigation activities were conducted in accordance with the project-specific quality assurance project plan (QAPP) (WESTON 2008) and addendum (WESTON 2009). The investigation was conducted under the Superfund Technical Assistance and Response Team (START) contract, Technical Directive Document (TDD) No. S05-0008-0805-012, in response to a request from the United States Environmental Protection Agency (U.S. EPA) Region V Great Lakes National Program Office (GLNPO).

The following sections discuss the site description, site history, project objectives, and report organization.

1.1 SITE DESCRIPTION

The River Rouge, also known as the Rouge River, is a river in the Detroit metropolitan area in southeastern Michigan (**Figure 1-1**). The overall study area consists of the LRR from its confluence with the Detroit River upstream approximately 3 miles just past the Ford "Turning Basin," including the Zug Island Channel. **Figure 1-1** shows the LRR and the study area. The LRR flows into the Detroit River at the boundary between the cities of Rouge River and Detroit. The Rouge River flows northwest to southeast throughout the study area. The overall study area also includes the channel west and north of Zug Island (the Zug Island Channel, or Old Channel) near the confluence of the LRR with the Detroit River.

The Rouge River, including its three tributary branches (lower, middle, and upper) is approximately 126 miles long. Many industries and sites of environmental impact are located next to the river, particularly downstream of the Ford "Turning Basin" and extending to the river's confluence with the Detroit River. To expedite surface water drainage in this highly developed area, the Rouge River has been straightened throughout the entire study area. In particular, the United States Army Corps of Engineers designed and constructed a "V"-shaped concrete channel in the 1970s that contains the river flow from just north of the Michigan Avenue Bridge to just upstream of the turning basin.

Traditionally, the Rouge River has been heavily polluted. The river's approximately 467-square-mile watershed includes all or part of 48 municipalities with a population of over 1,500,000; a large portion of central and northwest Wayne County; much of southern Oakland County; and a small area in eastern Washtenaw County. Nearly the entire drainage basin is located in urban and suburban areas, with areas of intensive residential and industrial development. However, more than 50 miles of the Rouge River flows through public lands, making the river one of the most accessible in the state.

Historically, limited investigations have been conducted on various portions of the Rouge River, including the study area that is the focus of this investigation (see Section 1.2). These investigations have identified numerous contaminants in both water and sediment in the Rouge River throughout the study area. Some of the most common causes cited for the presence of these contaminants include storm water discharges, combined sewer overflows, municipal and industrial discharges, and non-point pollution sources.

1.2 SITE HISTORY

Over the past several years, state and federal agencies have worked to address potential risks posed by sediments in the LRR contaminated with polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and various metals.

The Rouge River is notable for being the site of the Ford Motor Company River Rouge Plant built between 1915 and 1927. This plant was the first manufacturing facility for automobiles and included virtually everything needed to produce automobile, including blast furnaces, an open hearth mill, a steel rolling mill, a glass plant, a huge power plant, and an assembly line. The LRR was straightened by a “cut off channel” to the Detroit River and widened to allow direct freighter access to the plant and inland facilities. The “cut off channel” effectively cut off the natural flow of the river which flowed north around Zug Island.

Previous studies of the Rouge River include, but are not limited to, the following:

- Annual baseline data summary of water quality and stream flow from 1995 through 2007
- Sediment oxygen demand studies in 1995 and 1996
- 1993 Rouge River watershed sediment reconnaissance survey
- 1994 reconnaissance survey
- 1995 stream bank erosion study
- Ecosystem monitoring and assessment report for 2003 through 2006
- 1996 aquatic habitat survey
- 1996 dry weather toxics assessment survey
- 1995 bathymetric survey of the middle Rouge River impoundments
- 1997 and 1998 sediment sampling event conducted by the Michigan Department of Natural Resources and Environment (MDNRE)
- 2004 sediment sampling event conducted by the MDNRE
- 2007 sediment sampling event conducted by STS Consultants for MDNRE
- River Rouge Stage 1 Remedial Action Plan

The MDNRE 1997 and 1998 sediment sampling event included the collection of 32 sediment cores along the Rouge River from just upstream of the turning basin to the confluence with the Zug Island Channel. The results of the 1997 and 1998 studies indicated the presence of PCBs in sediment at concentrations exceeding 10 milligrams per kilogram (mg/kg) at three locations within the Ford Motor Company Shipping Dock next to the turning basin and at one location in the Fordson Island Channel. Total PAHs were detected at concentrations exceeding 1,000 mg/kg in sediment at two locations downstream of the turning basin.

The MDNRE 2004 sediment sampling event included the collection of seven sediment core samples from the Ford Motor Company Shipping Dock, the turning basin, and downstream of Fordson Island. General conclusions drawn from this limited sampling event indicated that the soft sediment of the study area was impacted by PCBs, PAHs, and metals and that the contamination generally increased with depth.

The 2007 sediment sampling event included the collection of 31 sediment cores and 9 semi permeable membrane device (SPMD) bags. The investigation indicated that the concrete-lined portion of the LRR, the channelized portion extends from just upstream of the Michigan Avenue Bridge to just upstream of the turning basin, contained no appreciable deposits of fine-grained sediment. The thin veneer of sediment in the LRR primarily consisted of sand and gravel. The sediment in the LRR from the Turning Basin to the confluence with Detroit River ranged from 0.5 to more than 9.5 feet (ft) thick. In general, the sediment was thicker near the edges in this area and relatively thin near the center, where there is considerable ship traffic and periodic dredging.

The analytical results indicated a wide range of contaminants within the sediment. The metals cadmium, chromium, lead, mercury, arsenic, silver, and copper were detected at concentrations exceeding applicable U.S. EPA screening levels. The most common semivolatile organic compounds (SVOC) detected at concentrations exceeding screening criteria included benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthrene, and pyrene. PCBs were detected at concentrations exceeding screening criteria in 67 of the 84 total samples collected. The analytical results for the SPMD bags indicated that the following eight SVOCs are present in the water column and bioavailable: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, fluoranthene, phenanthrene, and pyrene. In addition, the analytical results for the SPMD bags indicated that four individual PCB aroclors are present in the water column and bioavailable.

1.3 PROJECT OBJECTIVES

The U.S. EPA goals for this investigation of the LRR are to

- Provide additional chemical and toxicity data to support the development of project-specific remedial target objectives for PAHs, PCBs, metals, and diesel-range organics (DRO) and oil-range organics (ORO);
- Further define the spatial (horizontal and vertical) extent of sediment contamination identified during previous investigations, including at Hot Spots 1 through 6 (HS-1 through HS-6; see Figure 1-1), and determine the identity and extent of contaminants of concern in O'Brien Creek, the area near and Outfall 2, the West Jefferson Street Bridge, the area near Outfall 17, and the Zug Island Channel (see Figure 1-1);

  Note: HS-2 was included in the original work plan, but after revisions, the location was eliminated in response to U.S. EPA comments. HS-2 was eliminated because the MDNRE investigation analytical statistical summary indicated that the maximum detected concentrations of targeted analytes were detected at other hot spot areas and because HS-2 is relatively small. For consistency, the hot spot numbers used in the work plan are used in this report.
- Collect geophysical parameter information to support engineering design efforts and estimate sediment removal volumes;
- Collect toxicity samples and co-variant parameter information to determine sediment toxicity; and
- Identify industrial facilities and outfalls within the subject study area that may have historically contributed or currently contribute to the hot spot contamination.

The data collected during the field investigation and presented in this report could be used to support a focused feasibility study for potential remediation activities if necessary. However additional data gathering is necessary to fully delineate the nature and extent of contamination both horizontally and vertically as identified during the current hot spot sediment investigation activities. Section 6 discusses the locations requiring further delineation and recommended additional work.

1.4 REPORT ORGANIZATION

This report consists of the following sections:

- Executive Summary
- Section 1, Introduction
- Section 2, Study Area Investigation and Data Completeness
- Section 3, Analytical Results

- Section 4, Weight-of-Evidence Evaluation
- Section 5, Conclusions
- Section 6, Recommendations
- Section 7, References

Tables and figures are provided after Section 6 except for Section 4, where tables are embedded in text. In addition, this report contains the following appendices:

- Appendix A, Photographic Log
- Appendix B, Analytical Data
- Appendix C, Sediment Toxicity Test Reports
- Appendix D, Data Validation Reports

2. STUDY AREA INVESTIGATION AND DATA COMPLETENESS

This section discusses the sediment investigation, laboratory analysis of samples collected during the sediment investigation, and the industrial facilities and outfalls river survey.

2.1 SEDIMENT INVESTIGATION

Sediments in the LRR were sampled to determine the nature and extent of contamination. This investigation focused on the following areas:

- HS-1, HS-3, HS-4, and HS-6
- HS-5 and the West Jefferson Street Bridge
- Zug Island Channel
- Area near Outfall 2
- Area near Outfall 17
- O'Brien Creek

Figure 2-1 shows all the sediment sampling locations within the LRR. **Figures 2-2** through **2-9** show the actual sampling locations within each area of interest. Sediment sampling of the LRR was completed during two sampling events in October 2008 and May 2009 because of adverse weather conditions and issues with the U.S. EPA research vessel, the *RV Mudpuppy*. Depending on field conditions, various depth intervals were sampled at each location. **Table 2-1** presents the depth of water to the sediment surface and the latitude and longitude for each sampling location.

The sampling location strategy was based on the "Depth to Top of Sediment Survey" report prepared by STS Consultants in 2007 and on directives from GLNPO directive for previous sediment dredging projects. The sampling locations were randomly selected through the use of Visual Sampling Plan (VSP) software. The sampling area was designated at the selected locations based on a sediment depth of less than 27 ft below the water surface. The VSP software determined sampling locations using a 95 percent (%) probability of locating a hot spot within an area with a 50- to 80-ft radius. The VSP software then randomly plotted sampling locations within that sampling area.

The following sections discuss sediment sampling, sediment toxicity testing, data completeness, and QAPP data quality objectives.

2.1.1 Sediment Sampling

The U.S. EPA field sampling team collected sediment samples from a total of 61 Vibracore and Ponar sampling locations. The sampling locations were pre-determined locations in Hot Spots 1, 3, 4, 5, and 6; the Zug Island Channel; the area near Outfall 2; the area near Outfall 17; the West Jefferson Street Bridge and O'Brien Creek. The proposed sediment sampling design in the work plan proposes 65 Vibracore and 3 Ponar sampling locations. Several sampling locations were omitted or off-set from the originally proposed locations because of the inability of the *RV Mudpuppy* to access areas of low water or because the river bottom was too hard for the Vibracore to collect samples.

The U.S. EPA's *RV Mudpuppy* was used to deploy the Ponar and Vibracore samplers. The Ponar sampler was used to retrieve the upper 6 inches of sediment at each sampling location to collect sediment from the biologically active zone for toxicity testing and other specialized testing to determine contaminants that may be causing toxicity. The Vibracore sampler was advanced to various sampling depths based a combination of historical data, depth channel, and refusal, with up to five samples collected from each core. These samples were sent to an off-site laboratory for chemical analyses. A total of 210 samples (including duplicates and field split samples) were collected from the 61 sampling locations. Section 2.2 discusses the laboratory analyses performed on each sample.

Two locations, one in O'Brien Creek and one at Outfall 2, could not be sampled in October 2008 because of the inability of the *RV Mudpuppy* to access these locations. The MDNRE assisted in the collection of samples from these two locations on October 21, 2008. A Ponar sampler was deployed off the side of a boat to collect the upper 6 inches of sediment at each location.

All samples were collected in accordance with the methodologies and procedures discussed in the QAPP (WESTON 2008).

2.1.2 Sediment Toxicity Testing

The 28-day and 20-day tests for the amphipod *H. azteca* and the dipteran *C. tentans*, respectively, were used to evaluate shallow sediment toxicity. The procedures followed are discussed in U.S. EPA's "Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Fresh Water Invertebrates," Second Edition (U.S. EPA/600/R-99/064). **Figure 2-10** shows the toxicity sampling locations. The following 11 sediment samples were collected to evaluate the toxicity of the LRR:

- LRR-HS1-A-01
- LRR-HS3-A-1
- LRR-HS4-B-01
- LRR-HS5-A-01
- LRR-HS6-DOWN2-1
- LRR-HS6-F-01
- LRR-O17-A-01
- LRR-OBC-B-01
- LRR-OF2-B-01
- LRR-WJB-A-01
- LRR-ZIC-C-1-TOX

For the solid-phase testing, eight replicates per sediment sample were set up for both *Hyalella azteca (H. azteca)* and *Chironomus tentans (C. tentans)* exposures. Test acceptability was based on greater than 80% survival for amphipods and greater than 70% survival for midges in the reference samples. Weight gain in the reference samples also indicates an acceptable test.

2.1.3 Data Completeness

The work plan proposes a total of 68 sampling locations stations in the LRR, and 61 locations were actually sampled during both the October 2008 and May 2009 field events. Samples collected from each location were analyzed for the parameters specified in the QAPP (WESTON 2008). All data were evaluated for usability and found to be usable. The data met and exceeded the 90% completeness goal established in the QAPP.

2.1.4 QAPP Data Quality Objectives

The data were compared to the threshold effect concentrations (TEC) and probable effect concentrations (PEC) as detailed in the data quality objectives portion of the QAPP (WESTON 2008). Section 3 of this report discusses the findings. As set forth in the QAPP, Sections 3 and 4 of this report discuss the extent of contaminants in sediment above the mean PEC quotient (PEC-Q), the extent of acute toxicity in surficial sediments, and the correlation between individual contaminant PEC-Q values and sediment toxicity. Because data from multiple sampling locations and multiple depths were used and because the data were usable, vertical and horizontal extents of contamination could be determined. These extents are not fully defined, but the data do supplement historical results and present a clearer picture of contaminants and contamination levels in the LRR.

2.2 LABORATORY ANALYSIS

The sediment samples were analyzed for the following parameters for each area in at least one location:

- Metals – HS-1, HS-3, HS-4, HS-5, O'Brien Creek, Outfall 2, Outfall 17, and Zug Island Channel

- PCBs – HS-3, HS-4, HS-6, O'Brien Creek, Outfall 2, Outfall 17, and Zug Island Channel
- PAHs – HS-1, HS-3, HS-6, O'Brien Creek, Outfall 2, Outfall 17, and Zug Island Channel
- DROs – HS-1, HS-3, HS-6, O'Brien Creek, Outfall 2, Outfall 17, and Zug Island Channel
- OROs – HS-1, HS-4, HS-5, HS-6, O'Brien Creek, Outfall 2, Outfall 17, and Zug Island Channel
- Total organic carbon (TOC) – HS-1, HS-3, HS-4, HS-5, HS-6, O'Brien Creek, Outfall 2, Outfall 17, and Zug Island Channel
- Geophysical parameters (grain size, Atterberg limits, and bulk density) – HS-1, HS-3, HS-4, HS-5, HS-6, O'Brien Creek, Outfall 2, Outfall 17, and Zug Island Channel
- Toxicity testing (*H. azteca* and *C. tentans*, acid volatile sulfides [AVC]/simultaneously extracted divalent metals [SEM]), and pH) – HS-1, HS-3, HS-4, HS-5, HS-6, Outfall 2, Outfall 17, and Zug Island Channel

Only surface samples from locations where toxicity samples were collected were analyzed for the extended list of PAHs (18 parent PAHs and 16 groups of alkyl PAHs).

The U.S. EPA Contract Laboratory Program laboratory analyzed the samples for PCBs and metals. ASci Corporation Environmental Testing Laboratory in Duluth, Minnesota, conducted the toxicity testing. Columbia Analytical Services in Kelso, Washington, analyzed the samples for all of the remaining parameters. All results were usable. No data were qualified as unusable.

2.3 INDUSTRIAL FACILITIES AND OUTFALLS RIVER SURVEY

On May 30, 2008, U.S. EPA conducted a river survey by boat to inspect shoreline conditions and identify industrial facilities and outfalls near the hot spot areas within the LRR. **Appendix A** provides photographs documenting shoreline conditions at each hot spot area.

Stormwater discharges, combined sewer overflows, municipal and industrial discharges connected to outfalls, and non-point pollution sources are the most common sources of discharge contamination. **Figure 2-11** shows the former and current industrial facilities and discharge outfalls within the LRR around the hot spot areas. A complete study was not performed, but known outfall locations and industrial facilities upstream or next to the study hot spot areas were identified as discussed below. **Figure 2-12** shows LRR sewer districts associated discharge to the outfalls identified in the LRR hot spot study area.

2.3.1 Hot Spot 1

In addition to the outfalls identified at the previous upstream hot spot areas, additional discharge outfalls identified upstream of HS-1 include Outfalls 004D and 004E and the Dix Road Outfall. Outfalls 004D and 004E are associated with the Rouge Steel facility located near the turning basin. The Dix Road Outfall is located immediately upstream of HS-1. Specific discharge wastewater for each outfall is described below.

- Outfall 004D receives some process wastewater and non-contact cooling water from the Basic Oxygen Furnace discharge into the Boat Slip.
- Outfall 004E receives stormwater and non-contact cooling water from Blast Furnace C discharge into the Boat Slip.
- The Dix Road Outfall discharges stormwater to the Rouge River. Land use is primarily industrial and commercial in the sewer collection area. Industrial facilities of note discharging stormwater to the sewer connected to the Dix Road Outfall include the following:
  - Capitol Trucking
  - Former Dearborn Refining
  - Ford Vulcan Forge
  - PhD Converter
  - Waterfront Petroleum
  - Double Eagle

2.3.2 Hot Spot 3

In addition to the outfalls identified at the previous upstream hot spot areas, additional discharge outfalls identified upstream of HS-3 include Outfalls 006, 021, 052 through 056, and 057. Specific discharge wastewater for each outfall is described below.

- Outfall 006 receives stormwater and non-contact cooling water from the Power House flow through the Rouge Steel facility and the Ford Tailrace.
- Outfall 021 receives combined sewer overflow from the Miller Road Pump Station during wet-weather flow events. During dry-weather events, the outfall receives combined wastewater from the following notable industrial facilities:
  - Kasle Steel
  - National Trucking
  - Dearborn Truck Service

- Outfalls 052 through 056 receive combined sewer overflow during wet-weather flow events.
- Outfall 057 receives combined sewer overflow from Baby Creek during wet-weather flow events from the following notable industrial facilities:
  - Kasle Steel
  - National Trucking
  - Dearborn Truck Service
  - D&W Oil
  - Usher Oil
  - Wolverine Oil and Supply

  During wet-weather flow events, Outfall 057 receives combined sewer overflow from the following notable industrial facilities:

  - Capitol Trucking
  - Former Dearborn Refining
  - Ford Vulcan Forge
  - PhD Converter
  - Waterfront Petroleum

Although stormwater and wastewater connections are unknown, additional industrial facilities were identified near or upstream of HS-3, including the following:

- Marathon Petroleum
- Marathon – Detroit Asphalt
- Morton Salt
- Trumbull Asphalt Company
- Detroit Lime
- Electro Cote Chemicals
- United Shredding
- International Salt
- Great Plains Chemical
- International Scrap
- Owens Corning Roofing & Asphalt
- Norfolk Southern Rail Road
- Edwards Oil

Samples collected adjacent to Trumbull Asphalt Company from HS-3 contained asphaltic concrete as noted in the sediment core logs.

2.3.3 Hot Spot 4

In addition to the outfalls identified at the previous upstream hot spot areas, an additional discharge outfall was identified upstream of HS-4: Outfall 051. Specific discharge wastewater for Outfall 051 is described below.

- Outfall 051 receives combined sewer overflow during wet-weather flow events from the following potential industrial facilities:
  - St Mary's Cement
  - Shell Oil Dock
  - Specialty Mineral
  - Buckeye Terminal
  - US Gypsum
  - Marblehead Lime
  - Detroit Water Sewerage Department (DWSD)

2.3.4 Hot Spot 5 and West Jefferson Street Bridge

In addition to the outfalls identified at the previous upstream hot spot areas, additional discharge outfalls identified upstream of HS-5 and the West Jefferson Street Bridge include Outfalls 050 and Outfalls R24 through R27. Specific discharge wastewater for each outfall is described below.

- Outfall 050 is a municipal outfall discharging upstream of the West Jefferson Street Bridge hot spot. This outfall may have historically contributed contamination to the Rouge River as noted by the Rouge River River's Keeper.
- Outfalls R24 through R27 are direct discharge outfalls associated with treated effluent from the DWSD.

Industrial facilities identified near HS-5 and the West Jefferson Street Bridge include the following:

- Detroit Marine Terminals
- US Gypsum

- Marblehead Lime
- Carmeuse Lime
- DWSD

2.3.5 Hot Spot 6 and Zug Island Channel

In addition to the outfalls identified at the previous upstream hot spot areas, additional discharge outfalls identified upstream of HS-6 and the Zug Island Channel include Outfalls R28, 045 through 049, W100, W101, W104, W106, and W107. The Zug Island Channel flows both directions at different stages. Therefore, outfalls located on either side of the two hot spots can be considered both upstream and downstream outfalls. Specific discharge wastewater for these outfalls is described below.

- Outfalls R28, 045 through 049, W100, W101, W104, W106, and W107 receive effluent discharge from the DWSD, combined sewer overflows, and stormwater discharge.

Industrial facilities located near these hot spots include the following:

- Detroit Marine Terminals
- Buckeye Terminal
- Shell Oil
- Michigan Marine Terminal
- BP Products
- Carmeuse Lime
- US Steel
- Clawson Concrete
- Detroit Waste Solutions
- Detroit Coke Company
- Former Honeywell Chemical Plant
- Wayne Chemical Products
- Ross Chemical
- Crown Plating

2.3.6 Outfall 2

Discharge outfalls identified upstream of the Outfall 2 hot spot include Outfalls 001, 002, the City of Melvindale Outfall, and five unknown outfalls of various sizes. Outfalls 001 and 002 are associated with the Rouge Steel facility near the turning basin and discharge to the River Rouge. Specific discharge wastewater for these outfalls is described below.

- Outfall 001 receives pretreated process wastewater from the Cold Mill and Hot Strip Mill.
- Outfall 002 receives pretreated wastewater from the Continuous Caster along with some process wastewater from the Cold Mill.

Other industrial facilities located upstream of Outfall 2 along the River Rouge include the following:

- National Asphalt Product
- Buckeye Pipeline
- Stone Transport
- Rust Proofing Plating
- Bob Colber Diesel
- Cayno Corp
- Edward Levy
- Fritz Enterprises
- Cadillac Asphalt
- Precision Diesel
- Sunoco Terminal

2.3.7 Outfall 17

Discharge outfalls identified upstream of the Outfall 17 hot spot include Outfalls 004B, 004D, and 017. Outfalls 004B and 004D are associated with the Rouge Steel facility near the turning basin. Outfall 017 is located at the north end of the Boat Slip. Specific discharge wastewater for these outfalls is described below.

- Outfall 004B receives stormwater, pretreated process wastewater from Blast Furnace B, and non-contact cooling water from the power generation plant discharge into the Boat Slip.
- Outfall 004D receives non-contact cooling water from Cold Mill discharge into the Boat Slip.
- Outfall 017 discharges wastewater and stormwater from various industrial facilities located within the Chase-Schaefer sewer district. During wet-weather flow events, Outfall 017 also receives combined sewage overflow. Notable industrial facilities connected to Outfall 017 include the following:
  - Comprehensive Environmental Solutions (CES), an industrial wastewater treatment and disposal facility
  - Wolverine Oil and Supply, a hydraulic oil and transmission oil manufacturer

  Note: CES was identified as the responsible party for the April 2002 Rouge River oil spill.

2.3.8 O’Brien Creek

In addition to the outfalls identified at the previous upstream hot spot areas, additional discharge outfalls identified upstream of O’Brien Creek include Outfalls 051 and 082. Specific discharge wastewater for these outfalls is described below.

- Outfall 051 is a combined sewer overflow during wet-weather flow events and may or may not be located entirely upstream of O’Brien Creek.
- Outfall 082 receives combined sewer overflow discharge from the Oakwood Interceptor sewer during wet-weather flow events from the following potential industrial facilities:
  - D.A. Stuart Company, a lubricant manufacturer
  - Edwards Oils Service, a manufacturer of coolants, lubricants, and oils, and a waste disposal service
  - Shell Oil
  - Specialty Mineral Company
  - Buckeye Terminal

3. ANALYTICAL RESULTS

This section summarizes the sediment chemistry and toxicity test results for the sediment samples collected from the LRR and provide a detailed description of the physical, chemical, and toxicity test results for the samples. The table below summarizes the samples collected.

Location[a]	**No. of Sampling Locations**	**No. of Samples Collected**[b]
HS-1	6	24
HS-3	5	16
HS-4	6	19
HS-5	4	15
HS-6	21	62
Zug Island Channel	8	35
Outfall 2	5	21
Outfall 17	1	5
O'Brien Creek	4	11
West Jefferson Avenue Bridge	1	2
Total	61	210

Notes:

a Work plan proposes sampling at HS-2, but HS-2 not sampled
b Includes quality control samples

A maximum of five sediment samples were collected at each sampling station. Samples were grouped into the following five zones to aid in the evaluation of the vertical extent of contamination:

- 0 to 12 inches below sediment surface (bss); collected to characterize contaminants in biologically active zone and to evaluate sediment toxicity
- 1 to 3 ft bss
- 3 to 5 ft bss
- 5 to 7 ft bss
- 7 to 9 ft bss; collected to determine vertical extent and spatial distribution of contaminants

Shallow zone sediment samples were collected from the top 6 inches of sediment using a Ponar sampler and analyzed for additional chemical and toxicological parameters, including alkylated PAHs and AVS/SEM. The 28-day test for the amphipod *H. azteca* and the 20-day test for the dipteran *C. tentans* were used to evaluate shallow sediment toxicity.

The following sections discuss the data evaluation methodology, sediment analytical results, and sediment toxicity test results.

3.1 DATA EVALUATION METHODOLOGY

This section discusses PEC-Q calculation, AVS/SEM evaluation, and equilibrium partitioning sediment benchmark (ESB) determination. The bulk sediment chemistry data were evaluated using these sediment toxicity metrics as described below.

3.1.1 PEC-Q Calculation

To predict the toxicity for mixtures of various contaminants in sediments, PEC-Q values can be determined. Consensus-based sediment quality guidelines (SQG) (MacDonald and others 2000) have been developed that represent the geometric mean of published SQGs from a variety of sources. These SQGs are called PECs and TECs. PECs are intended to identify contaminant concentrations above which harmful effects on sediment-dwelling organisms are expected. TECs are intended to identify contaminant concentrations below which harmful effects on sediment-dwelling organisms are not expected. PEC-Q values for mixtures of chemicals (metals, PAHs, and PCBs) were determined using methods adopted from Ingersoll and others (2000 and 2001). Based on existing databases, the reliability for predicting toxicity is greatest for organic compound groups of total PAHs and total PCBs and for the metals arsenic, cadmium, chromium, copper, lead, nickel, and zinc. Inclusion of other compounds or metals that have PEC values when insufficient data are available to evaluate predictive reliability (such as for mercury, dieldrin, DDD, dichlorodiphenyltrichloroethane, endrin, and lindane) into the overall PEC-Q calculation may result in an overall PEC-Q value with lower predictive ability (Wisconsin Department of Natural Resources [WDNR] 2003).

In the case of metals, a PEC-Q_{metals} value was calculated by summing the PEC-Q value for each individual metal and dividing that number by the total number of metals. Mercury was not included in the PEC-Q_{metals} calculations. For non-polar organic compounds (total PCBs and total PAHs), the concentration in sediment first was normalized to 1% organic carbon (oc) to agree with the PEC. Then a PEC-Q_{PAHs} or PEC-Q_{PCBs} value was calculated by summing the PEC-Q for the individual PAH or PCB and dividing that number by the total number of PAHs or PCBs.

The overall PEC-Q then was calculated for the three main classes of chemicals. Ingersoll and others (2001) observed an overall increase in the incidence of toxicity with an increase in the mean quotients in toxicity tests and a consistent increase in toxicity at a mean quotient of greater than 0.5. However, in the Ingersoll study, the overall incidence of toxicity was greater in long-term tests (28 days) using the amphipod *H. azteca* compared to short-term tests such as the ones conducted for this study. The incidence of toxicity percentages correlated with calculated mean PEC-Q of 0.5, 1.0, and 5.0 are 40, 64, and 100%, respectively (MacDonald and others 2000).

3.1.2 AVS/SEM Evaluation

Measurement of AVS and SEM concentrations associated with AVS extraction can provide insight into the bioavailability of metals in anaerobic (anoxic) sediments (U.S. EPA 2001). A model for predicting toxicity from divalent trace metals is based on the binding of these metals to AVS. When the sum of the moles of the SEM (including silver, cadmium, copper, nickel, lead, and zinc) is exceeded by the molar concentration of AVS, the metals are considered insoluble and largely unavailable to biota. However, if the AVS is less than the SEM, metals may or may not be toxic due to other controlling factors (such as TOC content) (U.S. EPA 2001) as discussed below for the ESB determination.

3.1.3 ESB Determination

ESBs are mechanistic sediment quality metrics that use the theories of equilibrium partitioning (EqP) to derive sediment-specific predictions of available contaminant exposures. U.S. EPA has derived ESBs for PAHs and a suite of divalent metals as discussed below.

Equilibrium Partitioning Sediment Benchmark Toxic Unit (ESBTU) values have been derived for PAHs to predict aqueous concentrations of each PAH in sediment with a known TOC content. This concentration is then normalized by its water-only final acute value using the national Water Quality Criteria. The individual ESBTU value for each PAH may then be summed (ΣESBTU). Sediments in which the ΣESBTU value is less than or equal to 1 are considered acceptable for the protection of benthic organisms, and sediments with a ΣESBTU value exceeding 1 may be unacceptable for the protection of benthic organisms (U.S. EPA 2002).

There are potentially more than 1,000 PAH configurations. U.S. EPA currently recommends that a minimum of 34 configurations (18 parents and 16 alkylated PAHs) be used to assess "total PAH" concentrations in sediments (U.S. EPA 2003). Initially, U.S. EPA identified 13 PAHs as parameters of concern. The National Oceanic and Atmospheric Administration began to quantify 10 additional PAHs in sediments, bringing the total number of PAHs measured to 23. More recently, the U.S. EPA Environmental Monitoring and Assessment Program has increased the number of PAHs measured from 23 to 34 by quantifying the C1 through C4 alkylated series for some patent PAHs, where the "C" number indicates an alkyl group substitution (U.S. EPA 2003). Because alkylated PAHs are often more abundant in fresh petroleum products than their un-substituted parent compounds and because the proportion of alkylated PAHs to parent compound PAHs increases as oil ages, it is important to analyze for alkylated PAHs when biological effects are a concern (National Park Service 1997).

The ESBTU of all 34 PAHs (including specific non-alkylated and generic alkylated forms) can be summed to derive an ESB toxicity unit based on final chronic values (FCV) ($\sum ESBTU_{FCV}$) for a sampling location. Benthic organisms should be acceptably protected from the narcotic effects of PAH mixtures in freshwater and saltwater sediments if the $\sum ESBTU_{FCV}$ is less than or equal to 1.0. If the $\sum ESBTU_{FCV}$ is greater than 1.0, sensitive benthic organisms may be adversely affected.

ESB Metals values are derived based on use two lines of evidence to evaluate metal toxicity: the concentrations of sediment-associated metals in excess of the AVS concentration and dissolved metals concentrations in interstitial water (U.S. EPA 2005). This report considers only the AVS model because interstitial metals concentrations were not measured for this study.

AVS ESB values can provide a more accurate prediction of toxicity because the presence of organic carbon (oc) is considered along with AVS using the following equation:

$$\left(\sum SEM - AVS\right)/\ foc \Bigg/ \left(\sum \frac{SEM - AVS}{foc}\right)$$

where

SEM = Simultaneously extracted divalent metal (micromoles [µ/mol])
AVS = Acid volatile sulfides (micromole per gram [µmol])
foc = fraction oc (grams [g])

For the multiple metals (cadmium, copper, lead, nickel, silver and zinc), the assumptions summarized below are useful to derive a benchmark (U.S. EPA 2005).

- Any sediment with an AVS > 0.0 will not cause adverse biological effects due to silver.
- SEM-AVS/foc < 130 µmol/g oc: metals (cadmium, copper, lead, nickel, and zinc) should pose a low risk for adverse biological effects.
- SEM-AVS/foc > 130 µmol/g oc < 3,000 µmol/g oc: metals (cadmium, copper, lead, nickel, and zinc) may have adverse biological effects.
- SEM-AVS/foc > 2,000 µmol/g oc: metals (cadmium, copper, lead, nickel, and zinc) are expected to cause adverse biological effects.

3.2 SEDIMENT ANALYTICAL RESULTS

Data tables are provided for the analytical results for sediment samples collected from the LRR. **Appendix B** provides all analytical data. **Table 3-1** presents the PEC-Q values and ESBs for each sampling location and area. Sediment analytical results and evaluations for each area investigated are included below.

3.2.1 Hot Spot 1

Tables 3-2 through **3-6**, respectively, summarize the analytical results for metals, PAHs, the expanded list of PAHs (EPAH), physical properties, and petroleum hydrocarbons for HS-1. **Table 3-7** summarizes the AVS/SEM data for HS-1. **Figures 3-1** through **3-4**, respectively, graphically depict metals, total PAH, and individual mean PEC exceedances, and PEC-Q and mean PEC-Q distribution. As noted previously, samples from HS-1 were not analyzed for PCBs based on the results of previous MDNRE sampling. The text below provides summary descriptions of the results.

Individual PEC Exceedances

Metals

Table 3-2 summarizes HS-1 metals results, and **Figure 3-1** shows the HS-1 metals PEC exceedances. Individual metal PEC exceedances within HS-1 were identified in four of the six sample core locations, primarily at depth. No metals PEC exceedances occurred within the seven upper sample intervals (0 to 1 ft bss) except for duplicate sample LRR-HS1-B-01-DP, which had one reported PEC exceedance for iron. However, the reported duplicate value was qualified as a "J" value, indicating that the value is considered estimated because one or more quality control parameters were outside control limits. Metals exceeding individual PECs identified at various sample core locations within HS-1 include cadmium, chromium, copper, iron, lead, manganese, nickel, silver, and zinc.

PAHs

Table 3-3 summarizes HS-1 PAH results, and **Figure 3-2** shows the HS-1 PAH PEC exceedances. Total PAH PEC exceedances within HS-1 were identified at every sample core location within the upper sample intervals (0 to 1 ft bss and 1 to 3 ft bss). Total PAH PEC exceedances were also identified below the upper interval at depth at sample core locations HS1-A, HS1-C, HS1-D, HS1-E, and HS1-F. It should be noted that the deepest sample interval at locations HS1-C, HS1-D, and HS1-E was only at 1 to 3 ft bss. Therefore, the vertical extent of total PAHs has not been defined within HS-1.

Mean PEC-Q Threshold Exceedances

Table 3-1 summarizes the HS-1 mean PEC-Q values calculated for each sample interval within HS-1, and **Figure 3-3** shows the HS-1 mean PEC-Q exceedances. In addition to the overall mean PEC-Q values, **Table 3-1** summarizes the HS-1 mean PAH and metals PEC-Q values, and **Figure 3-4** shows a cross section of the HS-1 PEC-Q and mean PEC-Q values. The mean PAH and metals PEC-Q values provide an understanding of the greatest contributor to each overall mean PEC-Q value. **Figure 3-4** also shows the mean PEC-Q threshold isoconcentration values of 0.5, 1.0, and 5.0. The incidence of toxicity percentages correlated with calculated mean PEC-Q values of 0.5, 1.0, and 5.0 are 40, 64, and 100%, respectively (MacDonald and others 2000).

The mean PEC-Q threshold value of 1.0 was exceeded in the deeper interval (5 to 7 ft bss) at sample core location HS1-A, with the highest mean PEC-Q value of 2.30. The mean PEC-Q threshold value of 1.0 also was exceeded in the second interval (1 to 3 ft bss) at sample core location HS1-C. The mean PEC-Q threshold value of 1.0 was exceeded at sample core location HS1-F at the three deeper intervals (3 to 9 ft bss) but not at the top intervals (0 to 3 ft bss). These exceedances of the mean PEC-Q threshold value of 1.0 indicate that metals are the primary contributor to the potential risk for biological effects, with influence from PAHs within the deeper sample intervals.

The mean PEC-Q threshold value of 0.5 was exceeded in the upper two sample intervals at all of the HS-1 sample core locations except at HS1-B, where the mean PEC-Q threshold value of 0.5 was exceeded only the top interval (0 to 1 ft bss). These exceedances of the mean PEC-Q threshold value of 0.5 indicate that PAHs are the primary contributor to the potential risk for biological effects, with some influence from the metals

ESBTU

Table 3-4 summarizes the derivation of HS-1 ESBTUs for EPAHs. The PAH $\sum ESBTU_{FCV}$ greatly exceeded the threshold of 1 at LRR-HS1-A-01 and LRR-HS1-A-01-R, which strongly indicates that benthic organisms may be impacted by PAHs.

Physical Properties

Table 3-5 summarizes the HS-1 physical properties results. The geotechnical results for the four samples collected from HS1-A indicate that the material sampled consisted primarily of clay material mixed with some very fine sand and silt. In general, the percentage of clay increases and the percentage of sand and silt decreases with increasing depth at HS-1A.

Petroleum Hydrocarbons

Table 3-6 summarizes the HS-1 petroleum hydrocarbon results. No PEC or TEC criteria are available for DROs and OROs. However, all of the samples from HS-1 contained detected concentrations of DROs and OROs. The DRO values ranged from 110 to 16,000 mg/kg. The highest concentration was detected in the deeper interval (5 to 7 ft) at LRR-HS1-A. The ORO values ranged from 160 to 28,000 mg/kg. The highest concentration was detected in the deeper interval (5 to 7 ft bss) at LRR-HS1-A. At sample core locations HS1-A and HS1-F, DRO and ORO concentrations increased with depth from the upper to the bottom sample intervals. A direct correlation between the presence of the petroleum hydrocarbons and PEC-Q values and depths could not be identified.

The Massachusetts Department of Environmental Protection (MDEP) has developed sediment benchmarks for petroleum hydrocarbon fractions, with values of 3,167 mg/kg oc for C9 through C18 aliphatic hydrocarbons and 9,883 mg/kg oc for C19 through C36 aliphatic hydrocarbons (MDEP 2007). The DRO analysis measures C10 through C24 hydrocarbon assemblages, and the ORO analysis measures less than C24 hydrocarbon assemblages. The maximum detected DRO and ORO concentrations exceeded the MDEP benchmarks.

AVS ESB

Table 3-7 summarizes the derivation of the HS-1 AVS/SEM values. In contrast to PAHs, the HS-1 metals ESB values ([Sum SEM – AVS]/foc) for samples LRR-HS1-A-01 and LRR-HS1-A-01-R both yielded results less than 130 µmol/g oc, indicating low risk of adverse biological effects from metals. This conclusion is also supported by the AVS/SEM ratios for these samples, which are both less than 1. Comparison of the mean metals PEC-Q values and the overall mean PEC-Q calculation for this upper sample interval also supports this conclusion. It should be noted that evaluation of the mean PEC-Q values for metals and PAHs at depth indicates an opposite trend where metals tend to be the major contributor to adverse biological effects rather than PAHs. However, laboratory analysis for EPAHs and AVS/SEM and toxicity testing were conducted only for the upper sample interval where the benthic community primarily exists.

3.2.2 Hot Spot 3

Tables 3-8 through **3-13**, respectively, summarize the analytical results for metals, PCBs, PAHs, EPAHs, physical properties, and petroleum hydrocarbons for HS-3. **Table 3-14** summarizes the AVS/SEM data for HS-3. **Figures 3-5** through **3-8**, respectively, graphically depict metals, total PAH, and individual mean PEC exceedances, and PEC-Q and mean PEC-Q distribution. The text below provides summary descriptions of the results.

Individual PEC Exceedances

Metals

Table 3-8 summarizes HS-3 metals results, and **Figure 3-5** shows the HS-3 metals PEC exceedances. Individual metal PEC exceedances within HS-3 were identified in four of the five sample core locations. PEC exceedances were found as deep as the third interval (3 to 5 ft bss) at sample core locations HS3-A, HS3-B, and HS3-C. Metals exceeding individual PECs identified at various sample core locations and depths within HS-3 include cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, and zinc.

PCBs

Table 3-9 summarizes the HS-3 PCB results. HS-3 PCB concentrations did not exceed the total PCB PEC values.

PAHs

Table 3-10 summarizes HS-3 PAH results, and **Figure 3-6** shows the HS-3 PAH PEC exceedances. Total PAH PEC exceedances within HS-3 were identified at every sample core location within the upper sample intervals (0 to 1 ft bss) and at all other sample intervals except for HS3-E-02 (1 to 3 ft bss).

Mean PEC-Q Threshold Exceedances

Table 3-1 summarizes the HS-3 mean PEC-Q values calculated for each sample interval within HS-3, and **Figure 3-7** shows the HS-3 mean PEC-Q exceedances. In addition to the overall mean PEC-Q values, **Table 3-1** summarizes the HS-3 individual PAH, PCB, and metals mean PEC-Q values, and **Figure 3-8** shows a cross section of the HS-3 PEC-Q and mean PEC-Q values. The mean PAH, PCB, and metals PEC-Q values provide an understanding of the greatest contributor to each calculated mean PEC-Q values. **Figure 3-8** also shows the mean PEC-Q threshold isoconcentration values of 0.5, 1.0, and 5.0. The incidence of toxicity percentages correlated with calculated mean PEC-Q values of 0.5, 1.0, and 5.0 are 40, 64, and 100%, respectively (MacDonald and others 2000).

The mean PEC-Q threshold value of 1.0 was exceeded in the second interval (1 to 3 ft bss) and third interval (3 to 5 ft bss) at sample core location HS3-C. The highest mean PEC-Q value of 3.83 was identified at HS1-D-02 in the second sample interval (1 to 3 ft bss). These exceedances of the mean PEC-Q threshold value of 1.0 indicate that PAHs are the primary contributor to the potential risk for biological effects, with a strong influence from metals.

The mean PEC-Q threshold value of 0.5 was exceeded at the same locations discussed above with the addition of HS3-E, where the mean PEC-Q threshold value of 0.5 was exceeded only in the top interval (0 to 1 ft bss). Again, PAHs appear to be the primary contributor to the potential risk for biological effects, with a strong influence from metals.

ESBTU

Table 3-11 summarizes the derivation of HS-3 ESBTUs for EPAHs. The PAH ∑ESBTUFCV exceeded the threshold of 1 at LRR-HS3-A-01, LRR-HS3-A-01-FS, LRR-HS3-A-02, LRR-HS3-A-02-DP, and LRR-HS3-A-03, which indicates that benthic organisms may be impacted by PAHs in shallow sediment down to 5 ft bss.

Physical Properties

Table 3-12 summarizes the HS-3 physical properties results. The geotechnical results for the four samples collected from HS1-A indicates the material sampled consisted primarily of clay material mixed with some very fine sand and silt.

Petroleum Hydrocarbons

Table 3-13 summarizes the HS-3 petroleum hydrocarbon results. No PEC or TEC criteria are available for DROs and OROs. However, all of the samples from HS-3 contained detected concentrations of DROs and OROs. The DRO values ranged from 53 to 25,000 mg/kg. The highest concentration was detected in the deeper interval (5 to 7 ft bss) at LRR-HS3-C. The ORO values ranged from 120 to 34,000 mg/kg. The highest concentration was detected in the deeper interval (5 to 7 ft bss) at LRR-HS3-C and LRR-HS3-D and in the second interval (1 to 3 ft bss). A direct correlation between the presence of the petroleum hydrocarbons and PEC-Q values and depths could not be identified.

The MDEP has developed sediment benchmarks for petroleum hydrocarbon fractions, with values of 3,167 mg/kg oc for C9 through C18 aliphatic hydrocarbons and 9,883 mg/kg oc for C19 through C36 aliphatic hydrocarbons (MDEP 2007). The DRO analysis measures C10 through C24 hydrocarbon assemblages, and the ORO analysis measures less than C24 hydrocarbon assemblages. The maximum detected DRO and ORO concentrations exceeded the MDEP benchmarks.

AVS ESB

Table 3-14 summarizes the derivation of the HS-3 AVS/SEM values. In contrast to PAHs, the HS-3 metals ESB values ([Sum SEM – AVS]/foc) for samples LRR-HS3-A-01 and LRR-HS3-A-01-FS both yielded results less than 130 µmol/g oc, indicating low risk of adverse biological effects from metals. This conclusion is also supported by the AVS/SEM ratios for these samples, which are both less than 1.

3.2.3 Hot Spot 4

Tables 3-15 through **3-18**, respectively, summarize the analytical results for metals, PCBs, physical properties, and petroleum hydrocarbons for HS-4. **Table 3-19** summarizes the AVS/SEM data for HS-4. **Figures 3-9** through **3-12,** respectively, graphically depict metals, PCB, and individual mean PEC exceedances and, PEC-Q and mean PEC-Q distribution. As noted previously, samples from HS-4 were not analyzed for PAHs based on the results of previous MDNRE sampling. Consequently, PAH PEC and PAH ESBTU evaluations were not performed for HS-4. The text below provides summary descriptions of the results.

Individual PEC Exceedances

Metals

Table 3-15 summarizes HS-4 metals results, and **Figure 3-9** shows the HS-4 metals PEC exceedances. Individual metal PEC exceedances within HS-4 were identified in five of the six sample core locations. PEC exceedances were found in the third interval (3 to 5 ft bss) at sample core location HS4-A and at all sample core locations in the upper intervals (0 to 1 and 1 to 3 ft bss). Metals exceeding individual PECs identified at various sample core locations within HS-4 include cadmium, chromium, copper, lead, nickel, silver, and zinc.

PCBs

Table 3-16 summarizes HS-4 PAH results, and **Figure 3-10** shows the HS-4 PAH PEC exceedances. Total PCB PEC exceedances within HS-4 were identified in four of the six sample core locations. Total PCB PEC exceedances were also identified in the upper interval (0 to 1 ft bss) only at sample core location HS4-E. Total PCB PEC exceedances were identified at sample core locations HS4-A, HS4-C, and HS4-D in the next deeper interval (1 to 3 ft bss) as well as in the third interval (3 to 5 ft bss) at sample core locations HS4-C and HS4-D.

Mean PEC-Q Threshold Exceedances

Table 3-1 summarizes the HS-4 mean PEC-Q values calculated for each sample interval within HS-4, and **Figure 3-11** shows the HS-4 mean PEC-Q exceedances. In addition to the overall mean PEC-Q values, **Table 3-1** summarizes the HS-4 mean PCB and metals PEC-Q values, and **Figure 3-12** shows a cross section of the HS-4 PEC-Q and mean PEC-Q values. The mean PAH and metals PEC-Q values provide an understanding of the greatest contributor to each overall mean PEC-Q value. **Figure 3-12** also shows the mean PEC-Q threshold isoconcentration values of 0.5, 1.0, and 5.0. The incidence of toxicity percentages correlated with calculated mean PEC-Q values of 0.5, 1.0, and 5.0 are 40, 64, and 100%, respectively (MacDonald and others 2000).

The mean PEC-Q threshold value of 1.0 was exceeded at only one location within HS-4. The mean PEC-Q threshold value of 1.0 was exceeded in the deepest interval (3 to 5 ft bss) at LRR-HS4-A (PEC-Q value of 1.15) and its duplicate (PEC-Q value of 1.78). These exceedances of the mean PEC-Q threshold value of 1.0 indicate that PCBs as the primary contributor to the potential risk for biological effects, with some influence from metals.

The mean PEC-Q threshold value of 0.5 was exceeded at four of the seven sample core locations (HS4-A, HS4-C, HS4-D, and HS4-E) at various depths. These exceedances of the mean PEC-Q threshold value of 0.5 indicate that PCBs and metals are the primary contributors to the potential risk for biological effects.

Physical Properties

Table 3-17 summarizes the HS-4 physical properties results. The geotechnical results for the four samples collected from HS4-B indicate the material sampled consisted primarily of clay material mixed with some very fine to coarse sand and silt, with occasional fine gravel.

Petroleum Hydrocarbons

Table 3-18 summarizes the HS-4 petroleum hydrocarbon results. No PEC or TEC criteria are available for DROs and OROs. However, all of the samples from HS-4 contained detected concentrations of DROs and OROs. The DRO values ranged from 1,600 to 8,400 mg/kg. The highest concentration was detected in the deeper interval (5 to 7 ft bss) at LRR-HS4-A. The ORO values ranged from 3,500 to 16,000 mg/kg. The highest concentration also was detected in the deeper interval (5 to 7 ft bss) at LRR-HS4-A. A direct correlation between the presence of the petroleum hydrocarbons and PEC-Q values and depths could not be identified.

The MDEP has developed sediment benchmarks for petroleum hydrocarbon fractions, with values of 3,167 mg/kg oc for C9 through C18 aliphatic hydrocarbons and 9,883 mg/kg oc for C19 through C36 aliphatic hydrocarbons (MDEP 2007). The DRO analysis measures C10 through C24 hydrocarbon assemblages, and the ORO analysis measures less than C24 hydrocarbon assemblages. The maximum detected ORO concentrations exceeded the MDEP benchmarks, and the maximum DRO concentration fell within the benchmarks.

AVS ESB

Table 3-19 summarizes the derivation of the HS-4 AVS/SEM values. The metals ESB value ([Sum SEM – AVS]/foc) for sample LRR-HS4-B-01 was less than 130 µmol/g oc, indicating low risk of adverse biological effects from metals. This conclusion is also supported by the AVS/SEM ratio for this sample, which is less than 1.

3.2.4 Hot Spot 5 and West Jefferson Street Bridge

Tables 3-20 through **3-25**, respectively, summarize the analytical results for metals, PCBs, PAHs, EPAHs, physical properties, and petroleum hydrocarbons for HS-5 and West Jefferson Street Bridge. **Table 3-26** summarizes the AVS/SEM data for HS-5 and the West Jefferson Street Bridge. **Figures 3-13** through **3-17,** respectively, graphically depict metals, PAH, PCB, and individual mean PEC exceedances and, PEC-Q and mean PEC-Q distribution. As noted previously, only one shallow sample (HS-5-A-01 and HA-5-A-01-R) was analyzed for PCBs based on the results of previous MDNRE sampling. The text below provides summary descriptions of the results.

Individual PEC Exceedances

Metals

Table 3-15 summarizes HS-5 and West Jefferson Street Bridge metals results, and **Figure 3-13** shows the HS-5 and West Jefferson Street Bridge metals PEC exceedances. Individual metal PEC exceedances were limited primarily to the deeper sample interval (3 to 5 ft bss) within HS-5 except for metals exceedances identified at sample core locations HS5-C and HS5-D in the second interval (1 to 3 ft bss). Metals exceeding individual PECs identified at various sample core locations within HS-5 include cadmium, chromium, copper, lead, nickel, silver, and zinc. No individual metal PEC exceedances were identified for either of the two samples collected from the West Jefferson Bridge area.

PCBs

Table 3-21 summarizes West Jefferson Street Bridge PCB results, and **Figure 3-14** shows the West Jefferson Street Bridge PCB PEC exceedance. Total PCB PEC exceedances were limited to the single sampling location in the West Jefferson Street Bridge area. The exceedance was identified in the second interval (1 to 3 ft bss). HS-5 samples were not analyzed for PCBs.

PAHs

Table 3-22 summarizes HS-5 and West Jefferson Street Bridge PAH results, and **Figure 3-15** shows the HS-5 and West Jefferson Street Bridge PAH PEC exceedances. Total PAH PEC exceedances within HS-5 and West Jefferson Street Bridge were identified at two locations in the upper intervals. PAH PEC exceedances were identified in the first interval (0 to 1 ft bss) at HS5-A and in the second interval (1 to 3 ft bss) at WJB-A.

Mean PEC-Q Threshold Exceedances

Table 3-1 summarizes the HS-5 and West Jefferson Street Bridge mean PEC-Q values calculated for each sample interval within HS-5 and West Jefferson Street Bridge, and **Figure 3-16** shows the HS-5 and West Jefferson Street Bridge mean PEC-Q exceedances. In addition to the overall mean PEC-Q values, **Table 3-1** summarizes the HS-5 and West Jefferson Street Bridge mean PAH, PCB, and metals PEC-Q values**,** and **Figure 3-17** shows a cross section of the HS-5 and West Jefferson Street Bridge PEC-Q and mean PEC-Q values. The mean PAH and metals PEC-Q values provide an understanding of the greatest contributor to each overall mean PEC-Q value. **Figure 3-17** also shows the mean PEC-Q threshold isoconcentration values of 0.5, 1.0, and 5.0. At HS-5, only one sample from the first interval (0 to 1 ft bss) was analyzed for PAHs. The incidence of toxicity percentages correlated with calculated mean PEC-Q values of 0.5, 1.0, and 5.0 are 40, 64, and 100%, respectively (MacDonald and others 2000).

The mean PEC-Q threshold value of 1.0 was exceeded at only one location within HS-5 and West Jefferson Street Bridge in the deeper interval (3 to 5 ft bss) at LRR-HS5-C, where analysis for metals only was conducted. The exceedance of the mean PEC-Q threshold value of 1.0 indicates that metals are the primary contributor to the potential risk for biological effects.

The mean PEC-Q threshold value of 0.5 was exceeded at all of the sampling locations within HS-5 and West Jefferson Street Bridge except in the upper interval (0 to 1 ft bss) at LRR-HS5-A, LRR-HS5-B, and LRR-WJB-A. The exceedances of the mean PEC-Q threshold value of 0.5 indicate that metals are the primary contributor to the potential risk for biological effects at HS-5 and that PCBs are the primary contributor to the potential risk for biological effects at the West Jefferson Street Bridge in the deeper sample interval.

ESBTU

Table 3-23 summarizes the derivation of HS-5 and West Jefferson Street Bridge ESBTUs for EPAHs. The PAH $\sum \text{ESBTU}_{\text{FCV}}$ slightly exceeded 1 at LRR-HS5-A-01, LRR-HS5-A-01-R, and LRR-WJB-A-01, indicating that benthic organisms may be impacted by PAHs.

Physical Properties

Table 3-24 summarizes the HS-5 and West Jefferson Street Bridge physical properties results. The geotechnical results for the four samples collected from HS5-A indicate that the material sampled consisted primarily of clay material mixed with some very fine to coarse sand and silt. In general, the percentage of clay slightly decreases with depth at HS5-A. The geotechnical results for the two samples collected from the West Jefferson Street Bridge indicate that the material sampled consisted primarily of clay material mixed with silt and very fine sand to medium gravel.

Petroleum Hydrocarbons

Table 3-25 summarizes the HS-5 and West Jefferson Street Bridge petroleum hydrocarbon results. No PEC or TEC criteria are available for DROs and OROs. However, all of the samples collected from HS-5 contained detected concentrations of DROs and OROs. The HS-5 DRO values ranged from 870 to 6,100 mg/kg. The highest concentration was detected in the deeper interval (3 to 5 ft bss) at LRR-HS5-D. The HS-5 ORO values ranged from 2,100 to 15,000 mg/kg. The highest concentration also was detected in the deeper interval (3 to 5 ft bss) at LRR-HS5-D. The West Jefferson Street Bridge DRO and ORO values were 870 to 5,700 mg/kg and 2,100 to 9,700 mg/kg, respectively. The higher concentrations were detected in the sample interval from 1 to 3 ft bss.

The MDEP has developed sediment benchmarks for petroleum hydrocarbon fractions, with values of 3,167 mg/kg oc for C9 through C18 aliphatic hydrocarbons and 9,883 mg/kg oc for C19 through C36 aliphatic hydrocarbons (MDEP 2007). The DRO analysis measures C10 through C24 hydrocarbon assemblages, and the ORO analysis measures less than C24 hydrocarbon assemblages. The maximum detected ORO concentrations for HS-5 exceeded the MDEP benchmarks, and all other maximum DRO and ORO concentrations fell within the benchmark range.

AVS ESB

Table 3-26 summarizes the derivation of the HS-5 and West Jefferson Street Bridge AVS/SEM values. In contrast to PAHs, the HS-5 and West Jefferson Street Bridge metals ESB values ([Sum SEM – AVS]/foc) for samples LRR-HS5-A-01, LRR-HS5-A-01-R, and LRR-WJB-A-01 were less than 130 µmol/g oc, indicating low risk of adverse biological effects from metals. This conclusion is also supported by the AVS/SEM ratios for these samples, which are less than 1 for the West Jefferson Street Bridge. However, at HS-5, the mean PEC-Q evaluation suggests that metals may contribute to the potential risk for adverse biological effects, especially in the deeper zone.

3.2.5 Hot Spot 6

Tables 3-27 through **3-32**, respectively, summarize the analytical results for metals, PCBs, PAHs, EPAHs, physical properties, and petroleum hydrocarbons for HS-6. **Table 3-33** summarizes the AVS/SEM data for HS-6. **Figures 3-18** through **3-23,** respectively, graphically depict metals, total PAH, total PCB, and individual mean PEC exceedances, and PEC-Q and mean PEC-Q distribution. The text below provides summary descriptions of the results.

Individual PEC Exceedances

Metals

Table 3-27 summarizes HS-6 metals results, and **Figure 3-18** shows the HS-6 metals PEC exceedances. Individual metals PEC exceedances within HS-6 were identified along the northern shoreline of the Zug Island Channel and limited to the upper sample interval (0 to 1 ft bss). Metals exceeding individual PECs identified in this area within HS-6 include lead, nickel, and manganese. Individual metals PEC exceedances also were identified along the southern shoreline of the Zug Island Channel and limited primarily to the upper sample interval (0 to 1 ft bss). Metals exceeding individual PECs identified in this area within HS-6 include cadmium, chromium, copper, lead, manganese, mercury, nickel, and zinc. In addition, at UP-5, the manganese PEC was exceeded in the second sample interval (1 to 3 ft bss).

PCBs

Table 3-28 summarizes HS-6 PCB results, and **Figure 3-19** shows the HS-6 PCB PEC exceedances. Total PCBs PEC exceedances were limited to one sampling location (HS6-D) along the northern shoreline of the Zug Island Channel within the upper sample interval (0 to 1 ft bss). No other total PCB PEC exceedances were identified within HS-6.

PAHs

Table 3-29 summarizes HS-6 PAH results, and **Figure 3-20** shows the HS-6 PAH PEC exceedances. Total PAH PEC exceedances within HS-6 were identified along the northern shoreline of the Zug Island Channel at every sampling location within the upper sample interval (0 to 1 ft bss). Total PAH PEC exceedances were also identified below the upper interval at depth at sample core locations UP-4, X-4, and X-5. Total PAH PEC exceedances also were identified along the southern shoreline of the Zug Island Channel at all sampling locations within the upper sample interval (0 to 1 ft bss) except at HS6-B and UP-1, where the total PAH PEC was not exceeded. Total PAH PEC exceedances also were identified within the second sample interval (1 to 3 ft bss) at HS6-B, UP-4 and UP-5.

Mean PEC-Q Threshold Exceedances

Table 3-1 summarizes the HS-6 mean PEC-Q values calculated for each sample interval within HS-6, and **Figure 3-21** shows the HS-6 mean PEC-Q exceedances. In addition to the overall mean PEC-Q values, **Table 3-1** summarizes the HS-6 mean PAH, PCB, and metals PEC-Q values, and **Figures 3-22** and **3-23** show cross sections of the HS-6 PEC-Q and mean PEC-Q values. The mean PAH, PCB, and metals PEC-Q values provide an understanding of the greatest contributor to each overall mean PEC-Q value. **Figures 3-22** and **3-23** also show the mean PEC-Q threshold isoconcentration values of 0.5, 1.0, and 5.0. The incidence of toxicity percentages correlated with calculated mean PEC-Q values of 0.5, 1.0, and 5.0 are 40, 64, and 100%, respectively (MacDonald and others 2000).

The mean PEC-Q threshold value of 5.0 was exceeded at six upper interval (0 to 1 ft bss) and two deeper interval (1 to 3 ft bss) sampling locations (LRR-HS6-D-01, LRR-HS6-F-01, LRR-HS6-G-01, LRR-HS6-UP4-01, LRR-HS6-X4-01, LRR-HS6-X5-01, LRR-HS6-X5-02 and LRR-HS6-UP4-02). These exceedances of the mean PEC-Q threshold value of 5.0 indicate that PAHs are the primary contributor to the potential risk for biological effects.

The mean PEC-Q threshold value of 1.0 was exceeded in all upper interval (0 to 1 ft bss) sampling locations along the northern shore of Zug Island Channel, with the highest mean PEC-Q value (2,640) occurring in the upper interval (0 to 1 ft bss) at HS6-G. Except at X-2 and X-4, the mean PEC-Q values at the deepest interval (5 to 7 ft bss) at all sampling locations along the northern shoreline exceeded the mean PEC-Q threshold value of 1.0. These exceedances of the mean PEC-Q threshold value of 1.0 indicate that PAHs are the primary contributor to the potential risk for biological effects.

The mean PEC-Q threshold value of 0.5 was exceeded at all of the sampling locations along the southern shore of Zug Island Channel except at HS6-A and UP-1, where no mean PEC-Q threshold values were exceeded. These threshold exceedances occurred in the upper two sample intervals (0 to 1 and 1 to 3 ft bss), except at UP-5, where the mean PEC-Q threshold exceedances extended down to the third sample interval (3 to 5 ft bss).

ESBTU

Table 3-4 summarizes the derivation of HS-6 ESBTUs for EPAHs. The PAH $\sum \text{ESBTU}_{\text{FCV}}$ exceeded the threshold of 1 at LRR-HS6-DOWN2-01 and LRR-HS6-F-01, indicating that benthic organisms may be impacted by PAHs.

Physical Properties

Table 3-31 summarizes the HS-6 physical properties results. The geotechnical results for the six samples collected from HS-6 indicate that the material sampled consisted primarily of clay material mixed with some very fine to coarse sand and silt.

Petroleum Hydrocarbons

Table 3-32 summarizes the HS-6 petroleum hydrocarbon results. No PEC or TEC criteria are available for DROs and OROs. However, all of the samples from HS-6 contained detected concentrations of DROs and OROs. The DRO values ranged from 29 to 590,000 mg/kg. The highest concentration was detected in the upper interval (0 to 1 ft bss) at LRR-HS6-G. The ORO values ranged from 29 to 34,000 mg/kg. The highest concentration was detected in the upper interval (0 to 1 ft bss) at LRR-HS6-X4.

The MDEP has developed sediment benchmarks for petroleum hydrocarbon fractions, with values of 3,167 mg/kg oc for C9 through C18 aliphatic hydrocarbons and 9,883 mg/kg oc for C19 through C36 aliphatic hydrocarbons (MDEP 2007). The DRO analysis measures C10 through C24 hydrocarbon assemblages, and the ORO analysis measures less than C24 hydrocarbon assemblages. The maximum detected DRO and ORO concentrations exceeded the MDEP benchmarks.

AVS ESB

Table 3-33 summarizes the derivation of the HS-6 AVS/SEM values. In contrast to PAHs, the HS-6 metals ESB values ([Sum SEM – AVS]/foc) for samples LRR-HS6-DOWN2-01 and LRR-HS6-F-01 both yielded results less than 130 µmol/g oc, indicating low risk of adverse biological effects from metals. This conclusion is also supported by the AVS/SEM ratio for these samples, which are both less than 1.

3.2.6 Zug Island Channel

Tables 3-27 through **3-32**, respectively, summarize the analytical results for metals, PCBs, PAHs, EPAHs, physical properties, and petroleum hydrocarbons for the Zug Island Channel. **Table 3-33** summarizes the AVS/SEM data for the Zug Island Channel. **Figures 3-18** through **3-23,** respectively, graphically depict metals, total PAH, total PCB, and individual mean PEC exceedances, and PEC-Q and mean PEC-Q distribution. The text below provides summary descriptions of the results.

Individual PEC Exceedances

Metals

Table 3-27 summarizes Zug Island Channel metals results, and **Figure 3-1** shows the Zug Island Channel metals PEC exceedances. Individual metal PEC exceedances within the Zug Island Channel were limited to the upper sample interval (0 to 1 ft bss), which contained lead at ZIC-D, and the deeper interval (5 to 7 ft bss), which contained cadmium and silver at ZIC-E.

PCBs

Table 3-28 summarizes Zug Island Channel PCB results. Total PCB PEC exceedances were not identified in any samples collected from the Zug Island Channel.

PAHs

Table 3-29 summarizes Zug Island Channel PAH results, and **Figure 3-20** shows the Zug Island Channel PAH PEC exceedances. Total PAH PEC exceedances within the Zug Island Channel were identified at three sampling locations. Total PAH PEC exceedances also were identified below the upper intervals (0 to 1 and 1 to 3 ft bss) at ZIC-A, ZIC-E, and ZIC-G. Total PAH PEC exceedances also were identified at ZIC-E down to a depth of 9 ft bss and at ZIC-G down to a depth of 5 ft bss.

Mean PEC-Q Threshold Exceedances

Table 3-1 summarizes the Zug Island Channel mean PEC-Q values calculated for each sample interval within the Zug Island Channel, and **Figure 3-24** shows the Zug Island Channel mean PEC-Q exceedances. In addition to the overall mean PEC-Q values, **Table 3-1** summarizes the Zug Island Channel mean PAH, PCB, and metals PEC-Q values, and **Figures 3-25** and **3-26** show cross sections of the Zug Island Channel PEC-Q and mean PEC-Q values. The mean PAH, PCB, and metals PEC-Q values provide an understanding of the greatest contributor to each overall mean PEC-Q value. **Figures 3-25** and **3-26 also** show mean PEC-Q threshold isoconcentration values of 0.5, 1.0, and 5.0. The incidence of toxicity percentages correlated with calculated mean PEC-Q values of 0.5, 1.0, and 5.0 are 40, 64, and 100%, respectively (MacDonald and others 2000).

The mean PEC-Q threshold value of 1.0 was exceeded in the upper interval (0 to 1 ft bss) at ZIC-A, ZIC-E, and ZIC-G. At ZIC-A, the mean PEC-Q threshold value of 1.0 was exceeded in the second interval (1 to 3 ft bss). At ZIC-E, the mean PEC-Q threshold value of 1.0 was exceeded in the deeper intervals down to 9 ft bss except in the interval from 3 to 5 ft bss. The highest mean PEC-Q value of 4.84 was detected in the deeper interval (5 to 7 ft bss) at ZIC-E. Results for the entire core length down to 5 ft bss exceeded the PEC-Q threshold value of 1.0 at ZIC-G. These exceedances of the mean PEC-Q threshold value of 1.0 indicate that PAHs are the primary contributor to the potential risk for biological effects within the Zug Island Channel.

The mean PEC-Q threshold value of 0.5 was exceeded at ZIC-A, ZIC-E, and ZIC-G. These threshold exceedances occurred over the entire sample core. At ZIC-D, the mean PEC-Q threshold value of 0.5 was exceeded within the upper interval (0 to 1 ft bss).

ESBTU

Table 3-30 summarizes the derivation of Zug Island Channel ESBTUs for EPAHs. The PAH $\sum \text{ESBTU}_{FCV}$ exceeded 1 at LRR-ZIC-C-01-TOX, which indicates that benthic organisms may be impacted by PAHs.

Physical Properties

Table 3-31 summarizes the Zug Island Channel physical properties results. The geotechnical result for the sample collected from the Zug Island Channel indicates that the material sampled consisted almost entirely of clay material, with some fine sand.

Petroleum Hydrocarbons

Table 3-32 summarizes the Zug Island Channel petroleum hydrocarbon results. No PEC or TEC criteria are available for DROs and OROs. However, all of the samples from the Zug Island Channel contained detected concentrations of DROs and OROs. The DRO values ranged from

16 to 1,300 mg/kg. The highest concentration was detected in the deeper interval (5 to 7 ft bss) at LRR-ZIC-E. The ORO values ranged from 35 to 3,100 mg/kg. The highest concentration was detected in the deeper interval (5 to 7 ft bss) at LRR-ZIC-E.

The MDEP has developed sediment benchmarks for petroleum hydrocarbon fractions, with values of 3,167 mg/kg oc for C9 through C18 aliphatic hydrocarbons and 9,883 mg/kg oc for C19 through C36 aliphatic hydrocarbons (MDEP 2007). The DRO analysis measures C10 through C24 hydrocarbon assemblages, and the ORO analysis measures less than C24 hydrocarbon assemblages. The maximum detected DRO and ORO concentrations exceeded the MDEP benchmarks.

AVS ESB

Table 3-33 summarizes the derivation of the Zug Island Channel AVS/SEM values. In contrast to PAHs, the metals ESB values ([Sum SEM – AVS]/foc) for samples LRR-TOX-C-01-TOX were less than 130 µmol/g oc, indicating low risk of adverse biological effects from metals.

3.2.7 Outfall 2

Tables 3-34 through **3-39**, respectively, summarize the analytical results for metals, PCBs, PAHs, EPAHs, physical properties, and petroleum hydrocarbons for Outfall 2. **Table 3-40** summarizes the AVS/SEM data for Outfall 2. **Figures 3-27** through **3-31**, respectively, graphically depict metals, total PCB, total PAH, and individual mean PEC exceedances, and PEC-Q and mean PEC-Q distribution. The text below provides summary descriptions of the results.

Individual PEC Exceedances

Metals

Table 3-34 summarizes Outfall 2 metals results, and **Figure 3-27** shows the Outfall 2 metals PEC exceedances. Individual metal PEC exceedances were identified in the upper sample interval (0 to 1 ft bss) at OF2-A, OF2-B, OF2-C, and OF2-E. Individual metal PEC exceedances were identified in the deeper intervals (1 to 9 ft bss) at OF2-B, OF2-C, OF2-D, and OF2-E. Metals exceeding individual PECs identified at sample core locations OF2-B, OF2-C, OF2-D, and OF2-E at Outfall 2 include cadmium, chromium, copper, lead, manganese, nickel, silver, and zinc.

PCBs

Table 3-35 summarizes Outfall 2 PCB results, and **Figure 3-28** shows the Outfall 2 PCB PEC exceedances. Total PCB PEC exceedances were identified in four of the five sample locations collected from the Outfall 2 area. Total PCB PEC exceedances were limited to the deeper intervals (3 to 9 ft bss) in the northern portion of Outfall 2. In the central and southern areas of the Outfall 2 area, total PCB PEC exceedances were identified throughout all sample depth intervals.

PAHs

Table 3-36 summarizes Outfall 2 PAH results, and **Figure 3-29** shows the Outfall 2 PAH PEC exceedances. Total PAH PEC exceedances were identified at every sampling location within every sample depth interval in the Outfall 2 area.

Mean PEC-Q Threshold Exceedances

Table 3-1 summarizes the Outfall 2 mean PEC-Q values calculated for each sample interval within the Outfall 2 area, and **Figure 3-30** shows the Outfall 2 mean PEC-Q exceedances. In addition to the overall mean PEC-Q values, **Table 3-1** summarizes the mean PAH, PCB, and metals PEC-Q values, and **Figure 3-31** shows a cross section of the Outfall 2 PEC-Q and mean PEC-Q values. The mean PAH, PCB, and metals PEC-Q values provide an understanding of the greatest contributor to each overall mean PEC-Q value. **Figure 3-31** also shows the mean PEC-Q threshold isoconcentration values of 0.5, 1.0, and 5.0. The incidence of toxicity percentages correlated with calculated mean PEC-Q values of 0.5, 1.0, and 5.0 are 40, 64, and 100%, respectively (MacDonald and others 2000).

The mean PEC-Q threshold value of 1.0 was exceeded at all sampling locations within the Outfall 2 area except for the upper interval (0 to 1 ft bss) at LRR-OF2-A and LRR-OF2-D and the second interval (1 to 3 ft bss) at LRR-OF2-D. The highest mean PEC-Q value was 5.34 in the deeper interval (7 to 9 ft bss) at OF2-B. Except for OF2-A and OF2-D, the mean PEC-Q values at the deeper core intervals at all sample locations exceeded the mean PEC-Q threshold value of 1.0. These exceedances of the mean PEC-Q threshold value of 1.0 indicate that PCBs are the primary contributor to the potential risk for biological effects.

The mean PEC-Q threshold value of 0.5 was exceeded at all sampling locations within the Outfall 2 area. Again, these exceedances of the mean PEC-Q threshold value of 0.5 indicate that PCBs are the primary contributor to the potential risk for biological effects, with contributions from metals and PAHs.

ESBTU

Table 3-37 summarizes the derivation of Outfall 2 ESBTUs for EPAHs. The PAH $\sum ESBTU_{FCV}$ exceeded 1 at all locations within the Outfall 2 area, which indicates that benthic organisms may be impacted by PAHs.

Physical Properties

Table 3-38 summarizes the Outfall 2 physical properties results. The geotechnical result for the sample collected from the Outfall 2 area indicates that the material sampled consisted almost entirely of clay material, with some fine sand.

Petroleum Hydrocarbons

Table 3-39 summarizes the Outfall 2 petroleum hydrocarbon results. No PEC or TEC criteria are available for DROs and OROs. However, all of the samples from Outfall 2 contained detected concentrations of DROs and OROs. The DRO values ranged from 630 to 11,000 mg/kg. The highest concentration was detected in the deeper interval (7 to 9 ft bss) at LRR-OF2-C. The ORO values ranged from 2,300 to 24,000 mg/kg. The highest concentration was detected in the upper interval (0 to 1 ft bss) at LRR-OF2-E.

The MDEP has developed sediment benchmarks for petroleum hydrocarbon fractions, with values of 3,167 mg/kg oc for C9 through C18 aliphatic hydrocarbons and 9,883 mg/kg oc for C19 through C36 aliphatic hydrocarbons (MDEP 2007). The DRO analysis measures C10 through C24 hydrocarbon assemblages, and the ORO analysis measures less than C24 hydrocarbon assemblages. The maximum detected DRO and ORO concentrations exceeded the MDEP benchmarks.

AVS ESB

Table 3-40 summarizes the derivation of the Outfall 2 AVS/SEM values. In contrast to PAHs, the metals ESB values ([Sum SEM – AVS]/foc) for sample LRR-OF2-B-01 were less than 130 µmol/g oc, indicating low risk of adverse biological effects from metals.

3.2.8 Outfall 17

Tables 3-41 through **3-46**, respectively, summarize the analytical results for metals, PCBs, PAHs, EPAHs, physical properties, and petroleum hydrocarbons for Outfall 17. **Table 3-47** summarizes the AVS/SEM data for Outfall 17. **Figures 3-32** through **3-36**, respectively, graphically depict metals, total PCB, total PAH, and individual mean PEC exceedances, and PEC-Q and mean PEC-Q distribution. The text below provides summary descriptions of the results.

Individual PEC Exceedances

Metals

Table 3-41 summarizes Outfall 17 metals results, and **Figure 3-32** shows the Outfall 17 metals PEC exceedances. Individual metal PEC exceedances were identified in every sample interval in the Outfall 17 area. Metals exceeding individual PECs included cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc.

PCBs

Table 3-42 summarizes Outfall 17 PCB results, and **Figure 3-33** shows the Outfall 17 PCB PEC exceedances. Total PCB PEC exceedances were identified in all the sampled intervals except for the top interval (0 to 1 ft bss).

PAHs

Table 3-43 summarizes Outfall 17 PAH results, and **Figure 3-34** shows the Outfall 17 PAH PEC exceedances. Total PAH PEC exceedances were identified in all the sampled sample intervals.

Mean PEC-Q Threshold Exceedances

Table 3-1 summarizes the Outfall 17 mean PEC-Q values calculated for each sample interval within the Outfall 17 area, and **Figure 3-35** shows the Outfall 17 mean PEC-Q exceedances. In addition to the overall mean PEC-Q values, **Table 3-1** summarizes the mean PAH, PCB, and metals PEC-Q values, and **Figure 3-36** shows a cross section of the Outfall 2 PEC-Q and mean PEC-Q values. The mean PAH, PCB, and metals PEC-Q values provide an understanding of the greatest contributor to each overall mean PEC-Q value. **Figure 3-36** also shows the mean PEC-Q threshold isoconcentration values of 0.5, 1.0, and 5.0. The incidence of toxicity percentages correlated with calculated mean PEC-Q values of 0.5, 1.0, and 5.0 are 40, 64, and 100%, respectively (MacDonald and others 2000).

The mean PEC-Q threshold value of 1.0 was exceeded in all samples collected from the Outfall 17 area except for the upper interval (0 to 1 ft bss). The highest mean PEC-Q value was 18.74 in the deepest interval (7 to 9 ft bss), and the mean PEC-Q value increased with depth for this sample. These exceedances of the mean PEC-Q threshold value of 1.0 indicate that PCBs are the primary contributor to the potential risk for biological effects.

The mean PEC-Q threshold value of 0.5 was exceeded in all sampling locations in the Outfall 17 area. These exceedances of the mean PEC-Q threshold value of 0.5 indicate that PCBs are the primary contributor to the potential risk for biological effects.

ESBTU

Table 3-44 summarizes the derivation of Outfall 17 ESBTUs for EPAHs. The PAH $\sum ESBTU_{FCV}$ exceeded 1 at LRR-O17-A-01, which indicates that benthic organisms may be impacted by PAHs.

Physical Properties

Table 3-45 summarizes the Outfall 17 physical properties results. The geotechnical result for the sample collected from the Outfall 17 area indicates that the material sampled consisted almost entirely of clay material, with some fine sand and silt.

Petroleum Hydrocarbons

Table 3-46 summarizes the Outfall 17 petroleum hydrocarbon results. No PEC or TEC criteria are available for DROs and OROs. However, all of the samples from Outfall 17 contained detected concentrations of DROs and OROs. The DRO values ranged from 3,200 to 61,000 mg/kg. The highest concentration was detected in the deeper interval (5 to 7 ft bss) at LRR-017-A. The ORO values ranged from 8,200 to 77,000 mg/kg. The highest concentration was detected in the deeper interval (5 to 7 ft bss) at LRR-017-A.

The MDEP has developed sediment benchmarks for petroleum hydrocarbon fractions, with values of 3,167 mg/kg oc for C9 through C18 aliphatic hydrocarbons and 9,883 mg/kg oc for C19 through C36 aliphatic hydrocarbons (MDEP 2007). The DRO analysis measures C10 through C24 hydrocarbon assemblages, and the ORO analysis measures less than C24 hydrocarbon assemblages. The maximum detected DRO and ORO concentrations exceeded the MDEP benchmarks.

AVS ESB

Table 3-47 summarizes the derivation of the Outfall 17 AVS/SEM values. In contrast to PAHs, the metals ESB values ([Sum SEM – AVS]/foc) for sample LRR-O17-A-01 are less than 130 μmol/g oc, indicating low risk of adverse biological effects from metals.

3.2.9 O'Brien Creek

Tables 3-48 through **3-53**, respectively, summarize the analytical results for metals, PCBs, PAHs, EPAHs, physical properties, and petroleum hydrocarbons for O'Brien Creek. **Table 3-54** summarizes the AVS/SEM data for O'Brien Creek. **Figures 3-37** through **3-41,** respectively, graphically depict metals, total PCB, total PAH, and individual mean PEC exceedances, and PEC-Q and mean PEC-Q distribution. The text below provides summary descriptions of the results.

Individual PEC Exceedances

<u>Metals</u>

Table 3-48 summarizes O'Brien Creek metals results, and **Figure 3-37** shows the O'Brien metals PEC exceedances. Individual metals PEC exceedances were identified in the upper sample interval (0 to 1 ft bss) in all four samples collected from the O'Brien Creek area. Individual metals PEC exceedances also were identified in the three samples collected from the mouth of the creek in the sample interval from 1 to 3 ft bss and at OBC-A in the deeper interval (3 to 5 ft bss). The metals exceeding individual PECs include cadmium, chromium, copper, lead, manganese, mercury, nickel, silver, and zinc.

<u>PCBs</u>

Table 3-49 summarizes O'Brien Creek PCB results, and **Figure 3-38** shows the O'Brien Creek 2 PCB PEC exceedances. Total PCB PEC exceedances were identified in one of the four sampling locations (OBC-B) in the upper interval (0 to 1 ft bss) only.

<u>PAHs</u>

Table 3-50 summarizes O'Brien Creek PAH results, and **Figure 3-39** shows the O'Brien Creek PAH PEC exceedances. Total PAH PEC exceedances were identified in the upper interval (0 to 1 ft bss) in all four samples collected from the O'Brien Creek area. Total PAH PEC exceedances also were identified in the three samples collected from the mouth of the creek in the sample interval from 1 to 3 ft bss and at OBC-A in the deeper interval (3 to 5 ft bss).

Mean PEC-Q Threshold Exceedances

Table 3-1 summarizes the O'Brien Creek mean PEC-Q values calculated for each sample interval within the O'Brien Creek area, and **Figure 3-40** shows the O'Brien Creek mean PEC-Q exceedances. In addition to the overall mean PEC-Q values, **Table 3-1** summarizes the mean PAH, PCB, and metals PEC-Q values, and **Figure 3-41** shows a cross section of the O'Brien Creek PEC-Q and mean PEC-Q values. The mean PAH, PCB, and metals PEC-Q values provide an understanding of the greatest contributor to each overall mean PEC-Q value. **Figure 3-41** also shows the mean PEC-Q threshold isoconcentration values of 0.5, 1.0, and 5.0. The incidence of toxicity percentages correlated with calculated mean PEC-Q values of 0.5, 1.0, and 5.0 are 40, 64, and 100%, respectively (MacDonald and others 2000).

The mean PEC-Q threshold value of 1.0 was exceeded in seven of the samples collected from the O'Brien Creek area. The mean PEC-Q values in the upper interval (0 to 1 ft bss) exceeded the threshold in all samples except for LRR-OBC-A. The highest mean PEC-Q value was 2.30 in the upper interval (0 to 1 ft bss) at OBC-B. PCBs appear to be the primary contributor to the potential risk for OBC-B (3 to 5 ft bss), and PAHs and metals also contribute to the potential risk at other locations.

The mean PEC-Q threshold value of 0.5 was exceeded at all of the O'Brien Creek sampling locations except for the deeper interval at LRR-OBC-B.

ESBTU

Table 3-51 summarizes the derivation of O'Brien Creek ESBTUs for EPAHs. The PAH $\sum \text{ESBTU}_{FCV}$ exceeded 1 at all locations within the O'Brien Creek area, which indicates that benthic organisms may be impacted by PAHs.

Physical Properties

Table 3-52 summarizes the O'Brien Creek physical properties results. The geotechnical result for the sample collected from the O'Brien Creek area indicates the material sampled consisted of clay material, with some fine- to medium-grained sand and silt.

Petroleum Hydrocarbons

Table 3-53 summarizes the O'Brien Creek petroleum hydrocarbon results. No PEC or TEC criteria are available for DROs and OROs. However, all of the samples from O'Brien Creek contained detected concentrations of DROs and OROs. The DRO values ranged from 58 to 14,000 mg/kg. The highest concentration was detected at LRR-OBC-B-02 (1 to 3 ft bss). The ORO values ranged from 110 to 24,000 mg/kg. The highest concentration was detected at LRR-OBC-A-03 (3 to 5 ft bss).

The MDEP has developed sediment benchmarks for petroleum hydrocarbon fractions, with values of 3,167 mg/kg oc for C9 through C18 aliphatic hydrocarbons and 9,883 mg/kg oc for C19 through C36 aliphatic hydrocarbons (MDEP 2007). The DRO analysis measures C10 through C24 hydrocarbon assemblages, and the ORO analysis measures less than C24 hydrocarbon assemblages. The maximum detected DRO and ORO concentrations exceeded the MDEP benchmarks.

AVS ESB

Table 3-54 summarizes the derivation of the O'Brien Creek AVS/SEM values. In contrast to PAHs, the Metals ESB values ([SUM SEM – AVS]/foc) for sample LRR-OBC-B-01 were less than 130 µmol/g oc, indicating low risk of adverse biological effects from metals. This conclusion also is supported by the AVS/SEM ratio for this sample, which is less than 1.

3.3 SEDIMENT TOXICITY TEST RESULTS

ASci Corporation Environmental Testing Laboratory conducted the toxicity tests for LRR sediment during two separate evaluations in October 2008 and May 2009. Seven sampling locations were tested in 2008. Two of these locations were retested in May 2009 in addition to four new sampling locations. **Table 3-55** summarizes the survival and growth results for *H. azteca* and *C, tentans* after exposure to LRR sediment. **Appendix C** presents the sediment toxicity test reports in full. These data evaluation reports evaluate toxicity using procedures recommended by U.S. EPA (2000).

Water quality data were generally within the recommended protocol range, and controls met test acceptability criteria for growth and survival of *C. tentans* and *H. azteca*. Water quality data were evaluated further because of low survival for samples from some locations, and ammonia was considered a potential factor in the low survival rate for the 2008 samples.

During the 2008 study for the *C. tentans* tests, dissolved oxygen (DO) levels fell below the required level of 2.5 milligrams per liter (mg/L) for samples from two locations. The endpoint survival rate was 0% for both these locations, but low DO levels were not considered a factor in the low survival rate. According to U.S. EPA, "periodic depressions of [DO] below 2.5 mg/L (but not below 1.5 mg/L) are not likely to adversely affect test results, and thus should not be a reason to discard test data" (U.S. EPA 2000). Ammonia concentrations ranged from less than 1.00 to 12.2 mg/L. These high ammonia concentrations were considered a potential factor in the low survival rates of *C. tentans*. However, U.S. EPA (2000) states that ammonia toxicity to *C. tentans* depends on a solution's pH. When ammonia levels were compared to pH values, the pH values did not indicate that the low survival rate was attributable to ammonia toxicity.

During the May 2009 study, overlying water DO levels in the *H. azteca* and *C, tentans* test chambers ranged from 2.0 to 8.1 mg/L. DO levels fell below the recommended level of 2.5 mg/L at three locations. The *C. tentans* survival rate was 0%, and the *H. azteca* endpoint survival rates were 65, 21.3, and 16.3% for LRR-HS1-A-01-R, LRR-HS3-01, and LRR-HS5-A-01-R, respectively. The low DO levels were not considered a factor in these low survival rates. As discussed above, U.S. EPA (2000) states that "periodic depressions of DO below 2.5 mg/L (but not below 1.5 mg/L) are not likely to adversely affect test results and thus should not be a reason to discard test data" (U.S. EPA 2000).

Sediments are predicted to be toxic to benthic organisms when the mean test organism response (survival or growth rate)

- Is statistically reduced compared to reference exposed organisms;
- Shows reduced survival in excess of 30% for *C. tentans* and 20% for *H. azteca* compared to U.S. EPA minimum criteria (U.S. EPA 2000); and
- Shows reduced growth in excess of 20% relative to the U.S. EPA minimum criterion (U.S. EPA 2000).

Based on these definitions, *C. tentans* had reduced survival rates at all locations tested and reduced growth at all but LRR-ZIC-C-1-TOX (**Table 3-55**). *H. azteca* had reduced survival and reduced growth at all but LRR-HS-6-DOWN2-1, LRR-OF2-B-01, and LRR-ZIC-C-1-TOX. Although *H. azteca* survival rates were reduced, at three additional locations (LRR-HS1-A-1-R, LRR-HS4-B-01, LRR-HS6-F-01) the growth rate was not reduced. Samples from most locations contained elevated PAH and petroleum hydrocarbon concentrations, and some samples had elevated PCB PECs and metal PECs from O'Brien Creek (LRR-OBC-B-01) and Outfall 2 (LRR-OF2-B-01).

4. WEIGHT-OF-EVIDENCE EVALUATION

A weight-of-evidence approach was applied to determine which pollutants, if any, may be causing toxicity to either the midge, *C. tentans,* or the amphipod, *H. azteca,* within surficial sediments in the LRR. This approach incorporates an evaluation of sediment chemistry, including the PEC-Q values for metals, PAHs, PCBs, PAHs, and ESTBU, and the SEM/AVS ratios (Section 3) as well as an evaluation of the toxicity test results and conditions to ensure that confounding factors during toxicity testing did not affect the final toxicity results.

As discussed in Section 3.3, samples were collected for toxicity testing in 2008 and 2009 and analyzed along with the sediment chemistry samples. To summarize the test results, toxicity to both *C. tentans* and *H. azteca* was observed for most of the samples. The *C. tentans* survival rates were significantly lower than the reference rate for all samples, and the *C. tentans* growth rates (ash-free dry weight) were significantly lower than the reference rate for all samples except LRR-ZIC-C-01-TOX. The *H. azteca* survival rates were significantly lower than the reference rate for all samples except LRR-HS6-DOWN2-01, LRR-ZIC-C-01-TOX, and LRR-OF2-B-01. However, *H. azteca* growth endpoints (dry weight [milligram per organism] and length [milligram per organism]) were not significantly lower than the reference rate for eight of the samples. In conclusion, toxicity was observed for most of the samples and for the growth endpoints of all samples except for *H. azteca* results for LRR-HS6-DOWN2-01, LRR-ZIC-C-01-TOX, and LRR-OF2-B-01.

Table 4-1 below summarizes the PEC quotients, ESTBU, and SEM/AVS ratios with toxicity survival results.

TABLE 4-1
SUMMARY OF PEC QUOTIENTS, ESTBU, AND SEM/AVS RATIOS WITH TOXICITY SURVIVAL RESULTS

Sample No.	Metals PEC-Q	PAH PEC-Q	PCB PEC-Q	PAH ESTBU FCV	Ratio SEM/AVS	*C. tentans* Survival Rate (%)	*H. azteca* Survival Rate (%)
LRR-HS1-A-01	0.50	0.83	NA	836	0.4983	0	35
LRR-HS1-A-01-R	NA	0.80	NA	793	0.1142	0.0	65.0
LRR-HS3-A-01	0.74	0.69	0.38	16	0.15556	0.0	21.3
LRR-HS4-B-01	0.48	NA	0.28	NA	0.2766	0.0	6.3
LRR-HS5-A-01	0.63	0.24	NA	4.5	0.3473	0.0	8.8
LRR-HS5-A-01-R	NA	0.34	NA	6.3	0.2346	0.0	3.8
LRR-WJB-A-01	0.18	0.18	0.51	6.3	0.5181	0.0	0.0
LRR-HS6-DOWN2-01	0.30	4.57	0.36	17	0.4801	29.2	87.5
LRR-HS6-F-01	0.13	102.87	0.07	202	0.5626	0.1	63.8
LRR-ZIC-C-01-TOX	NA	0.09	ND	2.3	7.5508	52	81
LRR-OF2-B-01	4.15	0.60	6.21	25	2.9708	0	80
LRR-O17-A-01	0.80	0.12	0.99	3.34	0.6223	0	0
LRR-OBC-B-01	1.57	0.89	4.44	71	0.2085	0	0

Notes:

PEC-Q ratios exceeding 1 but less than 5 are highlighted in yellow.
PEC-Q ratios exceeding 5 are highlighted in orange.
PAH ESTBU values less than or equal to 1 are not predicted to cause toxicity. ESTBU values exceeding 1 are highlighted in yellow.
SEM/AVS ratios less than 1 are not predicted to cause toxicity. Ratios exceeding 1 are highlighted in yellow.
NA Not applicable

Based on the benchmarks presented in Section 3.1.1, in general, PAH PEC-Q values exceeded 0.5 for nearly all the hot spots (HS-1, HS-3, HS-6, Outfall 2, Outfall 17, and O'Brien Creek) and metals PEC-Q values exceeded 0.5 for samples collected from HS-1, HS-3, HS-5, Outfall 17, and O'Brien Creek (**Table 4-1**). PEC-Q values exceeding than 1 are of greater concern because this situation indicates that the average individual PAH, PCB, or metal concentration exceeded its corresponding PEC value. Therefore, results exceeding 1 but less than 5 are highlighted in yellow in **Table 4-1**. PEC-Q values exceeding 5 indicate that the associated constituents likely contribute to toxicity and are highlighted in orange in **Table 4-1**. Metals PEC-Q ratios exceeded 1 for two samples: LRR-OF2-B-01 and LRR-OBC-B-01. The PAH PEC-Q ratio exceeded 1 for one sample (LRR-HS6-DOWN2-01) and exceeded 5 for one sample (LRR-HS6-F-01). The PCB PEC-Q ratio exceeded 1 for one sample (LRR-OBC-B-01) and exceeded 5 for one sample (LRR-OF2-B-011).

The PAH ESTBU is a measure of the bioavailability of PAHs to benthic organisms, with values exceeding 1 suggesting increasing bioavailability. The ESTBU exceeded 1 for all samples for which it was calculated (**Table 4-1**), indicating that PAHs may be contributing to toxicity for these samples. However, the PAH ESTBU does not appear to be strongly correlated to the survival results for either species. For example, for LRR-HS6-DOWN2-01, although the PAH PEC-Q value exceeded 1 and the PAH ESTBU results exceeded 1, survival of *H. azteca* was at an acceptable level (87.5%). Similarly, for LRR-OF2-B-01, the *H. azteca* survival rate was 80%, and the *C. tentans* survival rate was the highest for any sample even though the metals PEC-Q value, PCB PEC-Q value, PAH ESTBU, and SEM/AVS ratio all exceeded the benchmarks presented in Section 3.1.

The ratio of SEM/AVS gives a measure of the bioavailability of metals to benthic organisms. Ratios exceeding 1 indicate that metals are bioavailable. The SEM/AVS ratios for most of the samples were below 1 (**Table 4-1**). However, for LRR-ZIC-C-01-TOX and LRR-OF2-B-01, the ratios exceeded 1, indicating that metals were bioavailable and potentially contributing to toxicity for these samples. Further examination of the survival results shows that although the AVS/SEM ratios exceeded 1 for LRR-ZIC-C-01-TOX and LRR-OF2-B-01, the *H. azteca* survival rates were some of the highest.

To summarize the results in **Table 4-1**, the PEC-Q values, ESTBU, and AVS/SEM ratios do not appear to be strongly correlated to survival of either *C. tentans* or *H. azteca,* but this conclusion is difficult to verify because of the low survival rates of *C. tentans* for most of the samples. Therefore, an evaluation of potential confounding factors was conducted, including an analysis of ammonia levels in overlying water during the toxicity testing.

Table 4-2 below summarizes overlying ammonia concentrations and survival results for both species during the first and final days of toxicity testing.

TABLE 4-2
OVERLYING AMMONIA CONCENTRATIONS DURING TOXICITY TESTING

Sample No.	*C. tentans*			*H. azteca*		
	Survival (%)	**Day 1 (mg/L)**	**Day 20 (mg/L)**	**Survival (%)**	**Day 1 (mg/L)**	**Day 28 (mg/L)**
LRR-HS6-DOWN2-01	29.2	1.6	<1.00	87.5	1.6	<1.00
LRR-ZIC-C-01-TOX	52	<1.00	<1.00	81	<1.00	<1.00
LRR-OF2-B-01	0	1.39	4.32	80	1.39	<1.00
LRR-HS1-A-01-R	0.0	1.16	1.44	65.0	1.16	1.84
LRR-HS6-F-01	0.1	1.22	<1.00	63.8	1.22	<1.00
LRR-HS1-A-01	0	6.52	8.76	35	6.52	<1.00
LRR-HS3-A-01	0.0	9.07	<1.00	21.3	9.07	<1.00
LRR-HS5-A-01	0.0	5.77	12.2	8.8	5.77	<1.00
LRR-HS4-B-01	0.0	1.86	5.91	6.3	1.86	<1.00
LRR-HS5-A-01-R	0.0	2.13	--	3.8	2.13	--
LRR-WJB-A-01	0.0	1.25	2.88	0.0	1.25	<1.00
LRR-O17-A-01	0	5.28	4.28	0	5.28	<1.00
LRR-OBC-B-01	0	1.84	10.5	0	1.84	<1.00

Note:

-- Not tested

Ammonia concentrations in overlying water during the testing were relatively high. The results in **Table 4-2** are sorted in descending order of ammonia concentrations for *H. azteca*. Because *C. tentans* lives within sediment, it receives more exposure to high levels of ammonia in the pore water of the sediment samples. However, *C. tentans* survival rates were so low overall that the evaluation focused on *H. azteca* survival rates. Pore water concentrations of ammonia were not monitored. However, the high levels of ammonia in the overlying water can be assumed to have come from the sediments because water uncontaminated with ammonia is used during toxicity testing. In general (although not always), higher ammonia concentrations are positively correlated to *H. azteca* survival rates; that is, the higher the ammonia concentration, the higher the toxicity. Although corrections were made to the toxicity testing during the second round of testing in 2009 to reduce ammonia, findings indicate that ammonia levels during toxicity testing may have contributed to poor survival of both species. Therefore, toxicity test results may not be fully attributable to the chemical concentrations detected in the sediment samples.

5. CONCLUSIONS

This section summarizes the project objectives, extent of contaminants of concern, toxicity test results, and the potential for indirect effects through bioaccumulation and trophic transfer.

5.1 PROJECT OBJECTIVES

The primary goal of the sediment investigation was to gather additional sediment chemistry data and sediment toxicity data to further delineate the spatial extent and magnitude of sediment contamination. A sediment investigation was conducted in October 2008 and May 2009 to collect the necessary data. This document presents the results of the sediment investigation and an evaluation of the significance of these results. The primary goals of the data evaluation were to

- Use sediment chemistry data from this investigation to examine the extent of the contamination, and
- Use laboratory toxicity tests to determine whether the sediments impact benthic organisms.

Conclusions drawn to address these specific goals are discussed below.

5.2 EXTENT OF CONTAMINANTS OF CONCERN

At HS-1, metals contributed the most to the elevated PEC-Q values, although PAHs also contributed. Most potential impact was associated with deeper sediments and in the 7- to 9-ft bss interval. The highest lead and zinc concentrations were detected at HS1-A-04. At HS-3, PAHs and metals contributed to elevated PEC-Q values. Potential impact was associated with shallow and deeper sediments up to 3 to 5 ft bss. PAHs had the highest concentrations at LRR-HS3-C-01, LRR-HS3-C-02, LRR-HS3-C-03, LRR-HS3-D-01, LRR-HS3-D-02, and LRR-HS3-D-03. The highest zinc concentration was detected at LRR-HS3-D-02. At HS-4, metals and PCBs contributed to elevated PEC-Q values. Potential impact was associated with sediments from 1 to 3 and 3 to 5 ft bss. The highest lead, zinc, and PCB concentrations were detected at LRR-HS4-A-03. At HS-5, metals contributed to the elevated PEC-Q values. Potential impact was associated with shallow and deeper sediments up to the 3- to 5-ft-bss interval. The highest metals concentrations were detected at LRR-HS5-C-03, although the metal concentrations were only slightly elevated compared to SQGs. At HS-6, PAHs contributed to elevated PEC-Q values. The PEC-Q values for PAHs especially were elevated at shallow sampling locations LRR-HS6-D-01, LRR-HS6-F-01, and LRR-HS6-G-01.

At Outfall 2, PCBs and metals contributed to the elevated PEC-Q values. Potential impact was associated with all depths sampled at this location up to 7 to 9 ft bss. The highest concentrations of lead, zinc, and PCBs were detected at LRR-OF2-B-01, LRR-OF2-B-02, LRR-OF2-B-03, LRR-OF2-B-04, LRR-OF2-B-05, LRR-OF2-C-01, LRR-OF2-C-02, LRR-OF2-C-03, LRR-OF2-C-04, and LRR-OF2-C-05. At Outfall 17, PCBs primarily contributed to the elevated PEC-Q values. Potential impact was associated with all depths sampled at this location up to 7 to 9 ft bss. PCBs concentrations increased with depth. The highest PCB concentration (35 mg/kg) was detected at 7 to 9 ft bss at LRR-OF17-A-05. The highest metals concentrations were detected in deeper samples (3 to 5 and 7 to 9 ft bss at LRR-OF17-A). At the Zug Island Channel, PAHs primarily contributed to the elevated PEC-Q values. Potential impact was associated with all depth intervals, including the 7- to 9-ft-bss interval. The PEC-Q values for PAHs were elevated at LRR-ZIC-A-02, LRR-ZIC-E-01, LRR-ZIC-E-02, LRR-ZIC-E-04, LRR-ZIC-E-05, LRR-ZIC-G-01, LRR-ZIC-G-02, and LRR-ZIC-G-03. At O'Brien Creek, metals, PCBs, and PAHs contributed to the elevated PEC-Q values. Potential impact was associated mostly with shallow (0 to 1 and 1 to 3 ft bss) intervals. The highest copper, zinc, and PCB concentrations were detected at LRR-OBC-D-01, LRR-OBC-B-01, and LRR-OBC-02. At the West Jefferson Street Bridge, PCBs contributed to elevated PEC-Q values in the deeper sample from LRR-WJB-A-02.

5.3 TOXICITY TEST RESULTS

Reduced survival was found for *C. tentans* in sediment from all toxicity test locations, and reduced growth was found at all but one location (LRR-ZIC-C-1-TOX). Reduced survival and reduced growth were found for *H. azteca* at all but three toxicity test locations (LRR-HS-6-DOWN2-1, LRR-OF2-B-01, and LRR-ZIC-C-1-TOX). Although reduced survival of *H. azteca* was also indicated for samples from three additional locations (LRR-HS1-A-1-R, LRR-HS4-B-01, and LRR-HS6-F-01), there was no significant effect on growth.

5.4 POTENTIAL FOR INDIRECT EFFECTS THROUGH BIOACCUMULATION AND TROPHIC TRANSFER

The evaluations in this report address the likelihood of toxic effects of contaminants on sediment-inhabiting organisms. However, the methods do not address the possibility that certain contaminants may bioaccumulate in organisms, resulting in a potential adverse effect upon their predators, including humans. For PCBs and mercury, protection of human health or wildlife may require more restrictive concentrations than the ones applied in this report to screen for direct toxicity.

Assessments of these more restrictive concentrations are outside the scope of this assessment but may be highly relevant for an environmentally protective feasibility study. In particular, surface PCB concentrations in Outfall 2 sediments as high as 4.2 mg/kg and surface PCB concentrations in O'Brien Creek sediments as high as 3 mg/kg may be problematic. The highest total PCB concentration was 35 mg/kg at a depth of 7 to 9 ft bss at Outfall 17. Mercury toxicity is particularly problematic because the elemental form of mercury (which is relatively bound to sediments) becomes more toxic and bioavailable when it is methylated by bacterial action or other processes. For this reason, the levels of concern for higher level ecological receptors can be lower than the PEC or TEC guideline values for benthic organism toxicity. The highest surface mercury concentration (0.88 mg/kg) was found at Outfall 2. This result is between the TEC (0.18 mg/kg) and PEC (1.06 mg/kg). Site-specific assessment of associated with trophic transfer would require a more refined risk assessment approach, including conceptual site model development, review of bioaccumulation information and site-specific studies, and analysis and estimation of trophic transfer for food-chain effects.

6. RECOMMENDATIONS

This section discusses recommendations for sediment additional investigation and toxicity testing before a feasibility study is conducted. The recommendations are based on the sediment sample chemical and toxicological data discussed above.

6.1 SEDIMENT ADDITIONAL INVESTIGATION RECOMMENDATIONS

Horizontal and vertical sediment contaminant delineation was evaluated by comparing mean PEC-Q values in either the lowest sample core interval or outermost sample core location within a given hot spot area with the mean PEC-Q threshold value of 1.0. Exceedance of this threshold in the lowest sample core interval or outermost sample core location requires consideration of additional investigation either vertically or horizontally. Recommended additional investigation is discussed below for each hot spot area. Suggested sample core intervals and additional chemical analyses are also discussed.

Hot Spot 1

<u>Vertical Delineation Locations</u>

- HS1-A: 7 to 9 ft bss, metals
- HS1-C: 3 to 5 ft bss, metals and PAHs

Hot Spot 3

<u>Vertical Delineation Locations</u>

- HS3-D: 3 to 5 ft bss, metals and PAHs
- HS3-C: 5 7 ft bss, metals and PAHs

<u>Horizontal Delineation Location</u>

- Sediment sample core southeast of HS3-C: 7 to 9 ft bss, metals and PAHs

Hot Spot 4

Vertical Delineation Location

- HS4-A: 5 to 7 ft bss, metals and PCBs

Horizontal Delineation Location

- Sediment sample core northwest of HS4-A: 5 to 7 ft bss, metals and PCBs

Hot Spot 5 and West Jefferson Street Bridge

Vertical Delineation Location

- HS5-C: 5 to 7 ft bss, metals

Hot Spot 6

Vertical Delineation Locations

- HS6-Down-2: 1 to 3 ft bss, PAHs
- HS6-D: 1 to 3 ft bss, PCBs and PAHs
- HS6-F: 5 to 7 ft bss, PAHs
- HS6-G: 3 to 5 ft bss, PAHs
- HS6-UP-4: 7 to 9 ft bss, PAHs
- HS6-X-3: 9 to 11 ft bss, PAHs
- HS6-X-4: 3 to 5 ft bss, PAHs
- HS6-X-5: 3 to 5 ft bss, PAHs
- HS6-UP-7: 3 to 5 ft bss, PAHs

Horizontal Delineation Locations

- Sediment sample core west of HS6-A: 1 to 3 ft bss, PAHs
- Sediment sample core east of HS6-X-5: 3 to 5 ft bss, PAHs
- Sediment sample core west of HS6-D: 3 to 5 ft bss, PCBs and PAHs
- Sediment sample cores west and east of HS6-UP-7: 3 to 5 ft bss, PAHs
- Sediment sample core west of HS6-Down-1: 0 to 1 ft bss, PAHs
- Sediment sample core east of HS6-UP-3: 0 to 1 ft bss, PAHs

- Sediment sample cores west and east of HS6-UP-5: 1 to 3 ft bss, metals and PAHs
- Sediment sample cores west and east of HS6-UP-6: 1 to 3 ft bss, metals and PAHs

Zug Island Channel

Vertical Delineation Locations

- ZIC-G: 5 to 7 ft bss, PAHs
- ZIC-E: 9 to 11 ft bss, PAHs

Horizontal Delineation Location

- Sediment sample cores north and south of ZIC-G: 5 to 7 ft bss, PAHs

Outfall 2

Vertical Delineation Locations

- OF2-B: 9 to 11 ft bss, metals, PCBs, and PAHs
- OF2-C: 9 to 11 ft bss, metals, PCBs, and PAHs
- OF2-D: 9 to 11 ft bss, metals, PCBs, and PAHs
- OF2-E: 9 to 11 ft bss, metals, PCBs, and PAHs

Horizontal Delineation Locations

- Sediment sample core south OF2-B: down to 9 to 11 ft bss, metals, PCBs, and PAHs
- Sediment sample core south OF2-D: down to 9 to 11 ft bss, metals and PCBs

Outfall 17

Vertical Delineation Location

- OF17-A: 9 to 11 ft bss, metals and PCBs

Horizontal Delineation Location

- Sediment sample cores north and south OF17-A: down to 9 to 11 ft bss, metals and PCBs

O'Brien Creek

<u>Vertical Delineation Location</u>

- OBC-A: 5 to 7 ft bss, metals

<u>Horizontal Delineation Location</u>

- Sediment sample core north of OBC-A: down to 5 to 7 ft bss, metals

6.2 SEDIMENT TOXICITY TESTING RECOMMENDATIONS

The actions summarized below are recommended to clarify confounding factors identified during the initial toxicity testing.

- Re-run toxicity testing for both *C. tentans* and *H. azteca*, monitoring both overlying and pore water ammonia levels and conducting ammonia reduction procedures as necessary. The monitoring of interstitial ammonia should be measured directly (for example, using centrifugation or peepers) at all hot spot locations.
- Conduct a Toxicity Identification Evaluation to determine the chemical class responsible for toxicity at all hot spot locations.

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