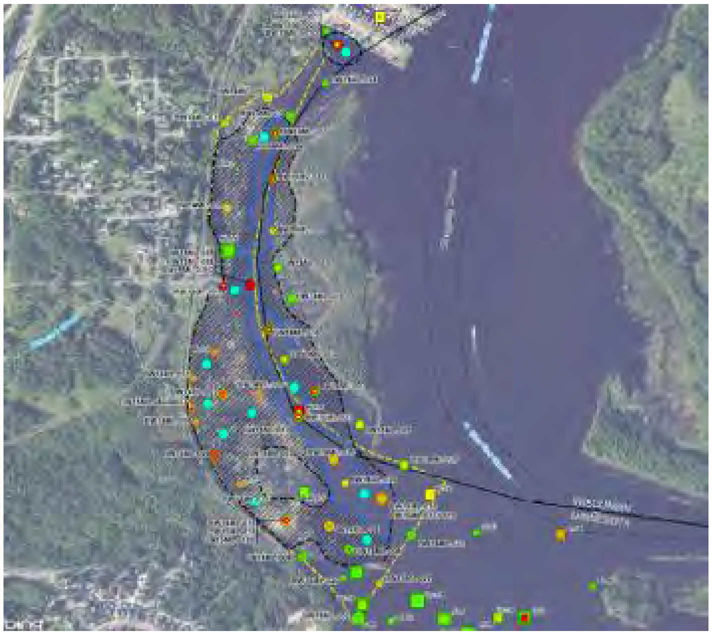
FINAL
FOCUSED FEASIBILITY STUDY
Munger Landing

SR#1015
Duluth, Minnesota
MPCA Work Order #3000014275



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Executive Summary

This Focused Feasibility Study (FFS) for Munger Landing (Site) presents: a summary of current Site conditions; a discussion of remedial action objectives (RAOs); and the identification, screening, evaluation, and comparison of potential alternatives. This report was prepared by Bay West LLC (Bay West) in accordance with the Minnesota Pollution Control Agency (MPCA) Contract Work Order No. 3000014275.

The Site was studied as a part of the St. Louis River (SLR) Area of Concern (AOC). Funding to complete an FFS was obtained through the United States Environmental Protection Agency (USEPA), Great Lakes Legacy Act (GLLA) and state funding through the Minnesota Legacy Fund and the Wisconsin Knowles-Nelson Stewardship Fund.

A remedial investigation (RI) was conducted for the Site in 2015. Contaminants of concern (COCs) identified during the RI were evaluated as part of this FFS and are detailed in **Section 1.4.3.3**. COCs identified for the Site include cadmium, copper, lead, mercury, nickel, zinc, polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and polychlorinated dibenzo-p-dioxins/dibenzofurans (dioxins). Sediments with elevated levels of the COCs were generally identified in open water areas of the Site and are considered to present a high likelihood of significant effects to benthic invertebrates from exposure to surficial sediments and may present a human health risk through direct contact with sediments or ingestion of contaminated biota (i.e., fish consumption).

As identified in the SLR Remedial Action Plans (RAPs): RAP Stage I, MPCA and Wisconsin Department of Natural Resources (WDNR), 1992; and RAP Stage II, MPCA and WDNR, 1995; and later proven with testing, Mud Lake West, Duluth Harbor, Duluth, Minnesota (**Figure 1**), is potentially contributing to two impairments in the SLR AOC:

- Fish consumption advisory; and
- Degradation of the benthos environment.

Areas that are contributing to river sediment impairments should be addressed through remedial activities, as recommended by the RAP. In addition, addressing the contaminated sediments at the Site would also help in the reduction of impaired water resulting from bioaccumulative toxins in the SLR.

Remedial Action Objectives Developed by the MPCA for the Site

RAOs for the Site were developed based on the requirements of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP; 40 Code of Federal Regulations [CFR] §300.430[e][2][i]), which defines RAOs as a listing of the COCs and media of concern, potential exposure pathways, and remediation goals. Specific RAOs were developed from a review of the results of Site characterization activities, site-specific risk and fate and transport evaluations, and an initial review of Applicable or Relevant and Appropriate Requirements (ARARs). The following RAOs for the Site include goals for the protection of human health and the environment:

1. Minimize or remove exposure to sediment contaminants that bioaccumulate in the food chain and contribute to fish consumption advisories.
2. Minimize or remove exposure of the benthic organisms to contaminated sediments above sediment cleanup goals.
3. Preserve water depth to enable the current and/or planned use of the Site.

4. Enhance aquatic habitat, if conditions allow, in a manner that contributes to the removal of BUIs.
5. Minimize or remove human exposure to contaminated sediments above sediment cleanup goals.

The following present remedial alternatives developed to achieve these RAOs. Alternatives were identified and screened to determine if they could meet these RAOs. Areas of the remedial footprint exist within Wisconsin and remedial actions would be funded and implemented in cooperation with the WDNR; however, for the purposes of this FFS, remedies to address contamination at the Site and associated costs have been developed for the entire remedial footprint. The following alternatives were evaluated in this FFS:

Alternative 1: No Action – The NCP at Title 40 CFR provides that a No Action Alternative should be considered at every site. The No Action Alternative should reflect the site conditions described in the baseline risk assessment and remedial investigation. The No Action Alternative included within this FFS does not include any treatment or engineering controls, institutional controls (ICs), or monitoring. There are no costs associated with the No Action Alternative.

Alternative 2: Monitored Natural Recovery – This alternative consists of a monitoring and evaluation period of 30 years and implementation of ICs. Based on hydrodynamic findings at the U.S. Steel site, sufficient sedimentation may be occurring at the Site to reduce availability and concentrations of COCs in sediment and/or reducing toxic/bioaccumulative effects in marine organisms (i.e., benthics and fish). The objective of this alternative is to provide data to monitor natural recovery processes at the Site. The approximate present value cost associated with Alternative 2 is $244,000.

Alternative 3: Enhanced Monitored Natural Recovery with Broadcasted Amendment – This alternative would consist of applying a thin layer of amendment material directly on top of the sediment surface in areas with sediment concentrations of COCs exceeding the cleanup levels (CULs), hereafter referred to as remedial areas. Amendment material would be mixed into the sediments over time through bioturbation. The chosen amendment would reduce the bioavailability of the COCs to aquatic life by absorption to the sediment amendment. Monitoring of sediment chemical concentrations, sediment toxicity, and bioaccumulation of COCs in aquatic life would be conducted until sufficient contaminant sequestration, degradation, transformation, or other natural recovery processes reduce risks to acceptable levels. The approximate present value cost associated with Alternative 3 is $6,687,000.

Alternative 4: Enhanced Monitored Natural Recovery with Thin-Layer Amended Cover – This alternative would consist of constructing a 0.15-meter (6-inch) amended cover on top of the sediment surface in remedial areas, and thus adds an isolation component to Alternative 3. This alternative would incorporate use of the same amendment material as incorporated into Alternative 3 and would likewise The chosen amendment would reduce the bioavailability of the COCs to aquatic life by absorption to the sediment amendment. Long-term mixing of cover materials into underlying in situ sediments from bioturbation would result in delivery of amendment materials to deeper sediment depths. Monitoring of chemical concentrations in sediment and cap material, sediment toxicity, and bioaccumulation of COCs in aquatic life would be conducted until sufficient contaminant sequestration, degradation, transformation, or other natural recovery processes reduce risks to acceptable levels. The approximate present value cost associated with Alternative 4 is $9,367,000.

Comparative Analysis Summary

The comparative analysis of the alternatives narrative discussion and quantitation table ranked Alternatives 3 and 4 highest, indicating that these alternatives may be the most appropriate to address contamination at the Site. The modifying criteria, state/support agency acceptance, and community acceptance are assessed formally after the public comment period. Stakeholder and community input will provide valuable insight as the MPCA considers information for the selection of a preferred alternative. The MPCA will conduct outreach activities to resource managers, current Site users, the public and local units of government prior to the public comment period.

Further studies are recommended during the design phase of the selected alternative. These recommended studies, depending on the alternative selected, may include:

- Hydrodynamic study to understand natural processes such as depositional and scouring forces to inform design and placement cover materials, and effectiveness of Monitored Natural Recovery (MNR), if needed;
- Bench and/or pilot scale testing of amendment materials to determine the most appropriate material for use at the Site. Potential amendment materials include bauxite, biopolymers, permeable Organoclay™, phosphate additives (i.e., apatite), and zeolite (USEPA, 2013); and
- Bench and/or pilot scale testing to determine appropriate application rates for the selected amendment material.

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Acronyms and Abbreviations

%	percent
µg/kg	micrograms per kilogram
AC	activated carbon
amsl	above mean sea level
AOC	area of concern
ARAR	Applicable or Relevant and Appropriate Requirement
BARR	BARR Engineering Company
Bay West	Bay West LLC
bss	below sediment surface
BUI	beneficial use impairment
CAD	confined aquatic disposal
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
ch. or chs.	chapter or chapters
COC	contaminant of concern
COI	contaminant of interest
CSM	conceptual site model
CUL	cleanup level
dioxins	polychlorinated dibenzo-p-dioxins/dibenzofurans
EMNR	Enhanced Monitored Natural Recovery
FFS	Focused Feasibility Study
GHG	Greenhouse Gas
GLI	Great Lakes Initiative
GLLA	Great Lakes Legacy Act
GSR	Green Sustainable Remediation
IC	institutional control
IDT	Interlake/Duluth Tar
ITRC	Interstate Technology and Regulatory Council
IZ	isolation zone
LDB	left descending bank
LTM	long-term monitoring
MDH	Minnesota Department of Health
MDNR	Minnesota Department of Natural Resources
MERLA	Minnesota Environmental Response and Liability Act
mg/kg	milligrams per kilogram
MNR	Monitored Natural Recovery
MPCA	Minnesota Pollution Control Agency
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
ng TEQ/kg	nanograms toxic equivalency per kilogram
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
OIRW	Outstanding International Resource Water
OSWER	Office of Solid Waste and Emergency Response
PAH	polycyclic aromatic hydrocarbon
PBAZ	potentially bioactive zone
PCB	polychlorinated biphenyl
PFC	perfluorochemical
RAO	Remedial Action Objective
RAP	Remedial Action Plan
RBSE	Risk Based Site Evaluation
RCRA	Resource Conservation and Recovery Act
RFP	Request for Proposal
RI	Remedial Investigation
RME	reasonable maximal exposure
ROD	Record of Decision
ROM	rough order of magnitude
SDS	State Disposal System
SLR	St. Louis River
SLRIDT	St. Louis River/Interlake/Duluth Tar
SOMAT	SOMAT Engineering
SQT	sediment quality target
SSV	Sediment Screening Value
SVOC	semi-volatile organic compound
TBC	to be considered
TCLP	Toxicity Characteristic Leaching Potential
U.S.	United States
UECA	Uniform Environmental Covenants Act
USACE	United States Army Corps of Engineers
USC	United States Code
USEPA	United States Environmental Protection Agency
WCA	Wetland Conservation Act
WDNR	Wisconsin Department of Natural Resources
WLSSD	Western Lake Superior Sanitary District

1.0 INTRODUCTION AND BACKGROUND

The St. Louis River (SLR), located on the border between Minnesota and Wisconsin, is the second largest United States (U.S.) tributary to Lake Superior and has a special significance in the region. The lower estuary empties into the Duluth-Superior Harbor, the largest freshwater seaport in North America. It serves as a geographic boundary for Wisconsin and Minnesota, and provides regional shipping access to Lake Superior.

Development along the SLR over the past 130 years has contributed to contaminated sediments. In 1987, concerns over environmental quality conditions prompted the designation of 73 miles of the lower SLR, which includes the segment from Cloquet, Minnesota, to the Duluth/Superior Harbor, as 1 of 43 Great Lakes Areas of Concern (AOCs). The Minnesota Pollution Control Agency (MPCA) and Wisconsin Department of Natural Resources (WDNR) worked together to divide the SLR AOC into Sediment Assessment Areas for the purposes of evaluation and prioritization of remediation and restoration activities. Contaminated sediments were identified and characterized through several studies that included the collection and analysis of sediments and biota samples throughout the AOC.

Historical sediment contamination in the SLR AOC has resulted in impaired uses, including degradation of bottom-feeding invertebrate communities, increased incidence of fish tumors and other abnormalities, fish consumption advisories, and restrictions on dredging, resulting in nine beneficial use impairments (BUIs; MPCA, 2008). BUIs are a change in the chemical, physical or biological integrity of the Great Lakes system sufficient to cause any 1 of the 14 established use impairments, or other related uses, such as the microbial objective for waters used for body contact recreational activities (joint commission). The MPCA and WDNR are currently working together to implement a comprehensive long-term plan to restore beneficial use and delist BUIs in the SLR AOC. Many of the BUIs in the AOC are linked to the presence of sediment contaminants. Some sediment-derived contaminants also appear suspended in the water column and carried by the SLR to Lake Superior.

As identified in the SLR Remedial Action Plans (RAPs): RAP Stage I, MPCA and WDNR, 1992; and RAP Stage II, MPCA and WDNR, 1995; and later proven with testing, Munger Landing (Site), SR#1015, Duluth, Minnesota (**Figure 1**), is potentially contributing to two impairments in the SLR AOC:

- Fish consumption advisory; and
- Degradation of the benthos environment.

Areas that are contributing to river and harbor sediment impairments should be addressed through remedial activities, as recommended by the RAPs. According to the MPCA, it is recommended by many programs that biotoxins be reduced within the SLR estuary and harbor. Removing or isolating the contaminated sediments from the surface water/sediment interface will help in the reduction of the impaired water resulting from bioaccumulative toxins in the SLR AOC.

This Focused Feasibility Study (FFS) was prepared to evaluate remedial alternatives for contaminated sediment at the Site. The scope of this FFS does not consider alternatives for any other matrix such as soil, surface water, or groundwater that may be impacted at the Site.

This report was developed pursuant to the Bay West LLC (Bay West) Master Contract No. 63186 and MPCA Contract Work Order No. 3000014275, dated July 21, 2015, and accompanying the Scope of Work/Cost Estimate for the Site. Funding to complete the FFS for the Site comes from the United States Environmental Protection Agency (USEPA), Great Lakes

Legacy Act (GLLA), and state funding through the Minnesota Legacy Fund and the Wisconsin Knowles-Nelson Stewardship Fund.

This FFS was written in general accordance with the MPCA Site Response Section Guidance Document Draft Guidelines on Remedy Selection (MPCA, 1998), the Minnesota Environmental Response and Liability Act (MERLA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) Part 300, along with other Minnesota and federal rules, statutes, and guidance.

1.1 Report Organization

Section 1.0 presents general background information including the Site history and a summary of current Site conditions. **Section 2.0** discusses Applicable or Relevant and Appropriate Requirements (ARARs) and summarizes Remedial Action Objectives (RAOs) to provide the framework for alternative evaluations for the Site. **Section 3.0** and **Section 4.0** present alternatives descriptions and the NCP remedy selection criteria used in this FFS, respectively. **Section 5.0** presents an evaluation of alternatives against standards and criteria. References are presented in **Section 6.0**.

1.2 Site Location and Current Use

The Site is located approximately 6 to 7 miles upstream of the Blatnick Bridge, which crosses from Rice's Point in Minnesota to Conner's Point in Wisconsin (**Figure 1**). The nearest identifiable landmark is the Munger Landing boat launch and the Smithville neighborhood of Duluth directly west of the Site. Directly upstream of the Site is Spirit Lake, the location of the former U.S. Steel plant and current U.S. Steel Superfund site.

The Site is a cut-off channel, separated from the current shipping channel by a long, narrow island that runs north to south along the majority of the length of the channel. The Site is approximately 1,000 feet wide at its upstream end, and slowly decreases in width towards its downstream (northerly) end, where it is approximately 300 to 400 feet in width. The western and eastern sides of the channel are characterized by shallow emergent vegetation areas and small intermittent islands of vegetation with water depths ranging between 1 and 3 feet. The central historical river channel portion of the Site is primarily characterized by a deeper channel with depths ranging from 6 to 10 feet. Flow direction is generally south to north, but Lake Superior seiche conditions periodically alter the magnitude and direction of the river's flow. Stewart Creek empties into the Site downstream of the boat landing along the left descending bank (LDB) (**Figure 2**). **Figure 3** shows the bathymetry of the Site, which was collected during the 2015 RI, when the Site was completely iced over.

The southern portion of the Site is divided by the Minnesota-Wisconsin state borderline. In order to fully characterize the area, RI sample locations were located in both Minnesota and Wisconsin. The state borders are depicted on each of the figures in this FFS.

1.3 Site History

Historical maps, aerial photographs, and drawings were reviewed for the Site as part of the 2015 RI (Bay West, 2015). Historically, the western shore of the Site was used for railroad transportation. Historical maps also indicate that steel mill operations occurred north and south of the western shore of the Site. Ship building operations occurred in the slips located directly adjacent to the north (downstream) of the Site. The 2015 RI presents additional details on these activities as well as an in-depth description of the historical documentation review for the Site.

1.4 Site Characterization

1.4.1 Site Geology

Regional geology in the Duluth area consists primarily of materials deposited during the last glaciation, and more recently as river sediment, overlying Precambrian igneous and sedimentary bedrock. These materials consist of silts, sands, and gravels that were deposited as the glaciers retreated northward. Fine grained sediment, primarily red silt and clay, was deposited in the ancestral glacial Lake Duluth. This red silt and clay occurs over much of the lower elevations in the Duluth area.

Bedrock units underlying the area consist of olivine gabbro and anorthositic gabbro members of the Duluth Complex, and the sedimentary units of the Fond du Lac Formation. The Duluth Complex is lower Precambrian, and the Fond du Lac Formation is upper Precambrian in age. The gabbroic members of the Duluth Complex form the hills to the west of the SLR and Lake Superior shore (MPCA, 1995).

Sediment in cores collected during the 2015 RI generally consisted of soft, loosely consolidated dark brown silt with occasional rootlets and other organic, woody debris, especially in areas of emergent vegetation within the upper 0.5 meters of sediment. Material observed at depths exceeding 0.5 meters consisted of increasingly stiff brown silt and clay mixtures. Occasional lenses of fine- to very fine-grained sand were encountered; however, these lenses were not laterally extensive and do not appear to be deposited consistently throughout the Site.

1.4.2 Site Hydrology

The regional groundwater flow system in the area generally flows from the Minnesota and Wisconsin uplands and discharges to Lake Superior and the SLR estuary.

Groundwater development within the region is limited and primarily restricted to the glacial lake sands and gravels (Barr, 2014). While not measured during this RI, flow velocities are likely lower at the Site than the main stream channel. The relatively low flow velocities may result in sediment deposition, especially on the margins within areas of emergent vegetation (common in shallow areas, typically on the eastern and western margins). The upper meter of sediment generally consisted of silt and clay with occasional lenses of fine-grained sand, typical of low energy fluvial environments (cut-off channels, oxbows, etc.).

Seiche was also not specifically measured during the 2015 RI; however, Lake Superior seiches are known to create water-level changes ranging from imperceptible to at least 3 feet within a period of 7.9 hours. Lake Superior seiche stirs nutrients and pollutants into the water column and can result in the SLR reversing flow upstream for 11 miles (beyond the Site location in the SLR) when a seiche floods the harbor.

According to the National Oceanic and Atmospheric Administration (NOAA) and the Great Lakes Dashboard Project, Lake Superior water level elevations have ranged from 599.5 feet to 603.4 feet amsl since measurements began in 1918 (NOAA, 2016). Seasonal water level fluctuations of Lake Superior affect water level elevations at the Site and may affect Site remedies; however, these effects have not been studied.

1.4.3 Nature and Extent of Contamination

The nature and extent of contamination at the Site was investigated during several studies between 2011 and 2015. The most recent investigation was an RI conducted specifically for the Site during August 2014 and June of 2015. A summary of previous Site investigations, as presented within the 2015 RI report, is provided in **Section 1.4.3.1**. Screening criteria for application to sediment contaminants identified at the Site are discussed in **Section 1.4.3.2**.

Section 1.4.3.3 presents a discussion of the contaminants of concern (COCs) and **Section 1.4.3.4** presents the known depth, thickness, and volume of contaminated sediments at the Site.

1.4.3.1 Previous Studies

The following is a list of previous investigation reports that include the Site:

- Sediment Investigation Report, Lower St. Louis River, Fond Du Lac Dam to Kingsbury Bay, SOMAT Engineering (SOMAT), 2012a, Study ID 72;
- Sediment Remedial Investigation Report, Spirit Lake Sediment Site, Former U. S. Steel Duluth Works, BARR Engineering Company (BARR), 2013, Study ID 84;
- *St. Louis River Area of Concern Sediment Characterization: Final Report,* prepared by LimnoTech, July 11, 2013 (LimnoTech Report);
- Sediment Remedial Investigation Report, Mud Lake West, Duluth, Minnesota, prepared by Bay West, December 2015 (2015 RI Report); and
- Evaluation of Sediments from Munger Landing for Toxicity to *Hyalella azteca, Chironomus dilutus*, and Bioaccumulation in *Lumbriculus variegatus* Final Report, prepared by Lake Superior Research Institute, University of Wisconsin-Lake Superior, May 31, 2016.

The Site was investigated during the Lower SLR Study in 2011 (SOMAT, 2012a; Study ID 72) and the Spirit Lake Study in 2012 (BARR, 2013; Study ID 84). Analytical results from these investigations indicated that contaminants are present at the Site at concentrations that pose a risk to the environment; however, the number of sediment sample locations was insufficient to completely characterize the sediments. Multiple investigations were conducted directly upstream at the U.S. Steel Superfund Site, mainly within Spirit Lake, beginning as early as 1986 and as recently as 2014. In general, these investigations categorized sediments into pre-industrial, industrial, and post-industrial-related sediments. The contaminants of interest (COIs), as defined in the 2013 BARR report, are polynuclear aromatic hydrocarbons (PAHs), arsenic, chromium, lead, zinc, copper, and nickel.

The 2015 RI Report concluded that exposure pathways are complete or potentially complete for recreational users through direct contact with contaminated sediments and ingestion of biota (i.e., fish consumption) and for ecological receptors through ingestion and dermal contact. The 2015 RI Report identified lead, nickel, and zinc as COIs for risk to sediment dwelling organisms. Polychlorinated dibenzo-p-dioxins/dibenzofurans (dioxins) and polychlorinated biphenyls (PCBs) were also identified as a potential COI for risk to human health and sediment dwelling organisms; however, the 2015 RI noted that these contaminants required further evaluation to define their distribution and to compare the concentrations to background concentrations.

In November 2015, Bay West collected sediment samples for the purpose of conducting bioaccumulation and toxicity testing on benthic organisms under laboratory conditions in order to assess the risk to the benthic community due to contaminated sediments at the Site.

Sediment samples were collected from the upper 0.15 meter of sediment at two control locations and nine Site locations (see the following table and **Figure 2**):

Locations	Treatment Identification	Designation
Control Locations	Silica Sand	Performance Control
	West Bearskin Lake	Natural Sediment Control
Sample Locations	BW15ML-004*	Treatment
	BW15ML-006	Treatment
	BW15ML-010*	Treatment
	BW15ML-018	Treatment
	BW15ML-022	Treatment
	BW15ML-032*	Treatment
	BW15ML-034*	Treatment
	BW15ML-037	Treatment
	BW15ML-038	Treatment

* = bioaccumulation analysis

The following tests were conducted:

- Sediment chemistry including metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc), PCBs, and dioxins at nine locations;
- 10-day sediment toxicity test with Hyalella azteca at nine locations;
- 10-day sediment toxicity test with Chironomus dilutus at nine locations; and
- 28-day bioaccumulation test with Lumbriculus variegatus at four locations.

Survival and growth were determined as endpoints for both 10-day tests. Tissue analysis from bioaccumulation testing included metals, PCBs, and dioxins.

Results of testing indicated that sediment at one location resulted in reduced survival of Chironomus dilutus and reduced weight of Hyalella azteca. Sediment contaminants at three locations resulted in the reduced growth of Hyalella azteca during laboratory testing. Arsenic concentrations in the sediments likely contributed to increased levels of arsenic in Lumbriculus variegatus in all locations and concentrations of chromium, lead, and nickel at one location likely contributed to increased concentrations of these metals in Lumbriculus variegatus after laboratory exposure. In summary, results of this study indicate that contaminated sediments at the Site can potentially have adverse effects on benthic populations; therefore, as determined by the MPCA, remedy is required at the Site. The complete toxicity and bioaccumulation laboratory report is included in **Appendix A**.

1.4.3.2 Screening Criteria

Numerical sediment quality targets (SQTs), adopted for use in the SLR AOC to protect benthic invertebrates, can be used throughout Minnesota as benchmark values for making comparisons to surficial sediment chemistry measurements. Level I and Level II SQTs for the protection of sediment-dwelling organisms are available for 8 trace metals, 13 individual PAHs, total PAHs (all 13 priority PAHs), total PCBs, and 10 organochlorine pesticides. In addition, Level I and Level II SQTs for dioxins were adopted for the protection of fish, as insufficient information is available for sediment-dwelling organisms. SQTs are highly useful when evaluating risk for a specific compound or a group of compounds (i.e., total PCBs and total PAHs).

Contaminant concentrations below the Level I SQTs are unlikely to have harmful effects on sediment-dwelling organisms (i.e., benthic invertebrates). Contaminant concentrations above the Level II SQTs are more likely to result in harmful effects to benthic invertebrates (MPCA, 2007). Based on conversations with the MPCA, a qualitative comparison value midway between the Level I SQTs and Level II SQTs (i.e., Midpoint SQT) were used as criteria to identify, rank, and prioritize sediment-associated COCs within the Site.

Sediment Screening Values (SSVs) were developed to provide a human health-based toxicity value specifically related to sediment for the U.S. Steel Superfund site in the SLR (Minnesota Department of Health [MDH], 2013). The SSVs were developed using reasonable maximal exposures (RMEs) specific to the U.S. Steel site and the Lower SLR. The Updated Human Health Screening Values for SLR Sediments: U.S. Steel site, dated April 2013, describes the updated SSVs. Chemical concentrations in water-covered sediments at or below the SSVs are considered safe for the general public; however, chemical concentrations in sediments exceeding the SSVs should not be considered unsafe because the SSVs were developed using conservative measures of exposure, bioavailability, and toxicity. Based on ongoing ambient concentration studies, some SSVs likely approach, or are less, than ambient concentrations in sediment, including SSVs for mercury, benzo(a)pyrene equivalents, PCBs, and dioxins. Further, the SSVs do not include RMEs specific to the Site and are not intended to be used as sediment cleanup values; therefore, SSVs will not be used to identify, rank, and prioritize sediment-associated COCs within the Site. Following finalization of the ambient concentration studies, SSVs for COCs may need to be reviewed for applicability to the Site.

1.4.3.3 Contaminants of Concern

Potential COIs are discussed in depth in the 2015 RI Report and are summarized below. The 2015 RI determined that exposure pathways are complete or potentially complete for recreational users at the Site and identified PCBs and dioxins as potential COIs for risk to human health; however, these COIs were not carried forward as COCs because the SSVs for these contaminants are expected to be at or below background concentrations.

The 2015 RI Report also determined that exposure pathways are complete or potentially complete for direct exposure of ecological receptors to sediment contaminants through ingestion and dermal contact and identified PCBs, dioxins, lead, nickel, and zinc as potential COIs for risks to ecological health; PCBs and dioxins were not carried forward as COCs in the RI because additional delineation was required for these contaminants.

Through discussions with the MPCA and review of available sediment analytical data, it was determined that for the purposes of this FFS, any contaminate exceeding respective Midpoint SQTs will be considered. Based on the findings of the 2015 RI, lead, nickel, and zinc are considered the primary COCs for the Site. The primary COCs will drive remedial actions at the Site. Concentrations of PAHs, cadmium, copper, mercury, PCBs, and dioxins exceed the respective Midpoint SQTs in a significantly lower number of samples than the primary COCs; therefore, these contaminants are considered secondary COCs. Locations of primary COC Midpoint SQT exceedances are shown for lead, nickel, and zinc on **Figures 4A**, **4B**, and **4C**, respectively. **Table 1** presents a COC summary.

1.4.3.4 Depth, Thickness, and Volume of Contaminated Sediment

The 2015 Remedial Investigation (RI) Report was used to define the COCs, remedial areas, and remedial volumes used to compile this FFS. Distribution of primary COCs at the Site is discussed below. Historical sample locations and corresponding sample results of individual primary COCs (lead, nickel, and zinc) shown as exceedances of the SQTs are presented in **Figures 4A**, **4B**, and **4C**, respectively. Areas to be considered for remedial action are those where primary COCs exceeded their respective Midpoint SQT and are presented in **Figure 5**.

Secondary COC Midpoint SQT exceedance generally occurs within the footprint of the areas of primary COCs; therefore, remedial actions at the Site will also address secondary COCs.

Lead concentrations exceeded the Midpoint SQT at relatively high frequencies in the upper 0.5 meters of sediment, with 23 percent (%) and 19% of samples exceeding the Midpoint SQT in the 0- to 0.15-meter interval and 0.15- to 0.5-meter interval, respectively. Midpoint SQT exceedances were horizontally distributed relatively evenly throughout the Site.

Nickel concentrations exceeded the Midpoint SQT at the highest frequencies in the upper 0.15 meters of sediment, with 21% of samples exceeding in this interval. Nickel Midpoint SQT exceedances decreased with depth from 11% in the 0.15- to 0.5-meter interval followed by 4% in the 0.5- to 1.0-meter interval.

Zinc concentrations exceeded the Midpoint SQT at relatively high frequencies in the upper 0.5 meters of sediment, with 23% and 19% of samples exceeding the Midpoint SQT in the 0- to 0.15-meter interval and 0.15- to 0.5-meter interval, respectively. Midpoint SQT exceedances were horizontally distributed relatively evenly throughout the Site.

Figure 5 identifies remedial areas based on exceedances of the Midpoint SQT for primary COCs at any of the sampled depth intervals and subsequent kriging of sample results. Contaminated sediments are located in both open water and emergent vegetation areas of the Site, which could drive the use of different remedial actions in these areas if established emergent vegetation areas are to be protected from intrusive remedial activities.

Sediments impacted with primary COCs exceeding the Midpoint SQTs at the Site generally occur in an approximately 59-acre area as shown on **Figure 5**; however, 12.5 acres of the remedial footprint exists within Wisconsin and remedial actions will be addressed and funded in cooperation with the WDNR. Further, remedies to address contamination at the Site have been developed for the entire remedial footprint. Contaminated sediments appear to generally exist in this area within the upper 0.5 meter of sediment; however, core shortening during sampling in the area of contamination resulted in an average percent recovery of 50%, indicating that the average depth of contamination in this area may exist as deep as 1 meter or greater. Based on these general estimates, the volume of contaminated sediment in the area shown on **Figure 5** likely ranges between approximately 84,000 and 164,000 cubic meters of contaminated sediment.

1.4.4 Exposure Pathways

Exposure pathways represent the linkages among contaminant sources, release mechanisms, exposure pathways and routes, and receptors to summarize the current understanding of the risks to human health and the environment due to contamination. The 2015 RI concluded that the incidental ingestion and dermal contact exposure routes were potentially complete for human recreational users of the Site. Additionally, the ingestion of biota via fish consumption was complete for human recreational users of the Site. Recreational users of the Site include boat and paddle users accessing the Site from the Munger Landing boat launch. The Site is also included in the proposed National Water Trail, which will attract more recreational users and increase the risk to human receptors.

The 2015 RI also concluded that the exposure routes including the ingestion of and dermal contact with contaminated sediments were complete for ecological receptors. In addition, uptake through the ingestion of biota in contact with contaminated sediment is also complete for ecological human receptors.

The bioaccumulation and toxicity testing conducted in 2015 confirms that ecological exposure pathways are complete and that contaminated sediments at the Site present a potential risk for adverse effects to benthic organisms.

Reduction or isolation of sediment contamination at the Site will likely reduce contaminate concentrations found in biota tissue; therefore, addressing the ecological risk pathway identified for the Site will concurrently address the ingestion of biota via fish consumption pathway for human health.

Further discussions of human and ecological health risks posed by contaminated sediments at the Site are provided within the 2015 RI report.

1.4.5 Conceptual Site Model

The development of a conceptual site model (CSM) allows data obtained during ongoing investigations to be integrated in an iterative approach that increases the understanding of the physical and environmental setting of the Site and the fate and transport of COCs. The CSM provides a baseline for consideration of how remedy alternatives could be implemented to protect human and environmental health at the Site. The CSM is provided within the 2015 RI report and is illustrated in **Figure 6**.

The area surrounding the Site has undergone significant industrial development over the past 100 years. Specifically, development has occurred directly upstream (the U.S. Steel plant) and directly downstream (formerly Barnes-Duluth and McDougall-Duluth Shipbuilders, currently the location of the Riverside Marina) of the Site. Industrial activities related to these sites may have resulted in contaminated sediment at the Site.

Lead, nickel and zinc are known contaminants at the U.S. Steel Superfund Site. It is possible that contaminants from upland or estuary sources on the U.S. Steel Superfund Site have eroded and deposited via the SLR into the Site. Elevated concentrations of primary COCs within the upper 0.5 meter of Site sediments indicate that an ongoing source is present or insignificant sediment deposition is occurring at the Site since industrial activities ended; however, high sedimentation rates would be expected during a high flow event at the Site. High discharge events lead to dramatically increased sediment loads in the river, due to availability of additional sediment from various processes. In addition to overland flooding, the upstream impoundments are less able to trap natural sediment loads, and other significant events can create spikes in the river sediment load. The relatively high sediment loads during these periods are prone to deposition the Site, due to widening of the flow and the associated decrease in velocity through the lake. The size and location of the sediment deposited depends on how the velocities of the river flow are distributed as the flow propagates across the Site (Barr, 2013). Additional details regarding the CSM are contained within the 2015 RI Report. If ongoing sources are present, additional upland investigation and remedial actions may be necessary to protect any remedial actions taken at the Site from future contaminant inputs.

2.0 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND REMEDIAL ACTION OBJECTIVES

Remedial actions for releases and threatened releases of hazardous substances, pollutants, or contaminants must be selected and carried out in accordance with state and federal requirements. The remedial footprint of the Site extends beyond the Minnesota State boundary in to Wisconsin; however, for the purpose of this FFS, Wisconsin requirements were not examined. Remedial actions at the Site will be implemented and funded with cooperation between both Minnesota and Wisconsin remedies have been developed for the entire remedial footprint. These requirements are referred to as ARARs. RAOs specify COCs, media of concern, potential exposure pathways, and remediation goals. Initially, Site remediation goals for the COCs are developed based on readily available information such as chemical-specific ARARs or other reliable information. The Site RAOs are modified, as necessary, as more information becomes available during the FFS process.

This section presents the preliminary ARARs, RAOs, and COCs to be used in the development of this FFS. The final ARARs, RAOs, and COCs will be developed in the Record of Decision (ROD) for the Site.

2.1 Applicable or Relevant and Appropriate Requirements

This preliminary ARAR section summarizes the MPCA, Minnesota Department of Natural Resources (MDNR), and MDH ARARs, and to be considered (TBC) criteria for aquatic sediment associated with the Site. Local and federal ARARs have also been included; however, the list may not include all applicable local and federal ARARs.

The NCP (40 CFR 300.5) defines “applicable” requirements as: “those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility citing laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA [Comprehensive Environmental Response, Compensation, and Liability Act] site.” Only those promulgated state standards identified by a state in a timely manner that are substantive and equally or more stringent than federal requirements may be applicable.

The NCP (40 CFR 300.5) further defines “relevant and appropriate” requirements as: “those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility citing laws that, while not “applicable” to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.” Like “applicable” requirements, the NCP also provides that only those promulgated state requirements that are identified in a timely manner and are more stringent than corresponding federal requirements may be relevant and appropriate.

ARARs generally fall into one of the following three classifications:

- **Chemical-specific:** These ARARs are usually health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in numerical values. These values establish an acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment. These requirements provide the basis for protective Site remediation levels for the COCs in the designated media.

- **Location-specific:** These ARARs generally restrict certain activities or limit concentrations of hazardous substances solely because of geographical or land use concerns. Requirements addressing wetlands, historic places, floodplains, or sensitive ecosystems and habitats are potential location-specific ARARs.
- **Action-specific:** These ARARs are restrictions on the conduct of certain activities or the operation of certain technologies at a particular site. Examples of action-specific ARARs would be regulations dictating the design, construction, and/or operating procedures for dredging, on-site landfilling, or capping. Action-specific requirements do not themselves determine the cleanup alternative, but define how the chosen cleanup alternative should be achieved.

In addition, criteria, advisories, guidance, and proposed standards developed by federal and state environmental and public health agencies that are not legally enforceable, but contain helpful information, are collectively referred to as TBCs. TBCs can be helpful in carrying out selected remedies or in determining the level of protectiveness of selected remedies. TBCs are meant to complement the use of ARARs, not compete with or replace them. TBCs are included, where appropriate, in the chemical-, location-, and action-specific discussions.

Several federal and state laws govern or provide the framework for remedial actions. Remedial actions must comply with substantive portions of these laws or acts, which were also reviewed during the ARAR development process. The following provides a summary of laws and acts that do not readily fall into one of the chemical-, location-, or action-specific classifications, but are applicable to the Site:

ARAR/TBC	Citation	Description/Potential Application
CERCLA	42 United States Code (USC) §§9601 et seq.	Federal Superfund Law.
NCP	40 CFR Part 300	Provides organizational structure and procedures for preparing for and responding to discharges of oil and releases of hazardous substances, pollutants, and contaminants.
MERLA	Minn. Stat. §§115B.01 to 115B.20	State Superfund Law.
Water Pollution Control Act	Minn. Stat. chapter (ch.) 115	Administration and enforcement of all laws relating to the pollution of any waters of the state.
Duty to Notify and Avoid Water Pollution	Minn. Stat. §115.061	Requires notification and recovery of discharge pollutants to minimize or abate pollution of the waters of the state.
Pollution Control Agency	Minn. Stat. ch. 116	Provides organizational structure and procedures for responding to problems relating to water, air, and land pollution.
Water Law	Minn. Stat. chs. 103A, 103B, 103C, 103D, 103E; 103F, and 103G	Provides regulations pertaining to any waters of the state, including surface water, wetlands and groundwater.
Safe Drinking Water Act	42 USC §§300f et seq.	Established to protect the quality of drinking water (above or underground).
Clean Water Act	33 USC §§1251 et seq.	Establishes structure for regulating discharges of pollutants and regulating quality standards for surface waters.

ARAR/TBC	Citation	Description/Potential Application
Resource Conservation and Recovery Act (RCRA)	42 USC §§6901 et seq.	Establishes RCRA Program and Regulations.
Clean Air Act	42 USC §§7401 et seq.	Regulates air remissions from stationary and mobile sources.

2.1.1 Chemical-Specific ARARs and TBCs

The primary COC associated with the sediments includes lead, nickel, and zinc. Secondary COCs include PAHs, cadmium, copper, mercury, PCBs, and dioxins. The following are the chemical-specific ARARs and TBCs associated with the sediments and shall be used to develop site-specific cleanup levels (CULs):

ARAR/TBC	Citation/Source	Description/Application
Sediment		
SSVs	MDH, 2013. Public Health Consultation, Updated Human Health Screening Values for SLR Sediments: U.S. Steel site, April.	To be used as benchmark values for making comparisons to surficial sediment chemistry measurements
SQTs	Guidance for the Use and Application of SQTs for the Protection of Sediment-dwelling Organisms in Minnesota.	To be used as benchmark values for making comparisons to surficial sediment chemistry measurements
All Media		
Contaminated Sediments Remediation	Contaminated Sediments Remediation. http://www.itrcweb.org/contseds_remedy-selection/	Guidance to assist in selecting remedial technology most appropriate for a specific site.
Contaminated Sediment Remediation	Contaminated Sediment Remediation Guidance for Hazardous Waste Sites, USEPA, December 2005.	Guidance to assist in selecting remedial technology most appropriate for a specific site.
Contaminated Sediment Remediation	Use of Amendments for In Situ Remediation at Superfund Sediment Sites, USEPA, April 2013.	Guidance to assist in situ remediation.
Site screening guidelines	Working Draft Site Screening Evaluation Guidelines. MPCA Risk-Based Site Evaluation (RBSE) Manual (09/98).	Guidelines and criteria for screening human health and ecological risks.

Sediment

Human Health Risk

SSVs are tools for screening contaminated sediments for potential impacts to human health; however, as described in **Section 1.4.3.2**, SSVs will not be used to evaluate sediment contamination at the Site until ambient concentrations have been studied. Further, the complete and potentially complete human health exposure pathway will be mitigated by addressing ecological exposure pathways.

Ecological Risk

SQTs values were adopted for use in the SLR AOC to minimize exposure of the benthic organisms to contaminated sediments and movement of contaminants up the food chain. The MPCA does not have sediment quality standards. Instead, SQTs can be used in the SLR AOC and throughout the state as benchmark values for making comparisons to surficial sediment chemistry measurements as described in **Section 1.4.3.2**. For this FFS, the Midpoint SQT was used to identify, evaluate, and prioritize sediment-associated risk to ecological health.

All Media

This guidance document assists in selecting remedial technology most appropriate for a specific site based on contaminated sediment and site specific characteristics (http://www.itrcweb.org/contseds_remedy-selection/).

The USEPA document *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* presents remedial options available for contaminated sediments discussing advantages and limitations associated with the options.

The USEPA document *Use of Amendments for In Situ Remediation at Superfund Sediment Sites* presents remedial options using amendments available for contaminated sediments discussing advantages and limitations associated with the options.

The MPCA *Site Screening and Evaluation Document* presents an overall process for conducting a Tier 1 evaluation of the various exposure pathways at a site. The screening criteria worksheet can be found at the MPCA website (https://www.pca.state.mn.us/waste/risk-based-site-evaluation-guidance).

2.1.2 Location-Specific ARARs and TBCs

The location-specific ARARs and TBCs for the Site are as follows:

ARAR/TBC	Citation/Source	Description/Application
Waters of the State and Groundwater Protection	Minn. Stat. 103G and 103H	Groundwater protection, nondegredation, and best management practices.
Floodplain Management and Wetlands Protection	40 CFR Part 6, Appendix A, Section 6.a.(1)	Requires agencies to evaluate potential effects of actions in a floodplain to avoid adverse impacts
Shoreland and Floodplain Management	Minn. Rules ch. 6120	Conserves economic and natural environmental values (MDNR)
St. Louis County Land Use Ordinances	St. Louis County Zoning Ordinances, ch. 1003	Floodplain management, Manages on-site waste disposal and other site activities
Shoreland Management	Duluth City Code §51-26 et seq.	The City of Duluth requires a permit for any excavation or grading above the Ordinary High Water Mark within 300 feet of a river.
Endangered Species Act	16 USC §§1531 et seq. 50 CFR §17.11-12	Conservation of threatened and endangered plants and animals and their habitats.
Endangered, Threatened, Special Concern Species	Minn. Rules ch. 6134 Minn. Statute, § 84.0895	Protection of endangered, threatened, special concern species (MDNR).
Migratory Bird Treaty Act	16 USC Chapter 7, Subchapter II §§703 and 712.2	Protects migratory birds and their ecosystems
MDH Advisory for St. Louis River	MDH	Provides fish consumption advisories.

The Site is located within the Lake Superior Drainage Basin. Surface water quality standards and provisions for Class 2B and 3B waters apply. In addition, USEPA and the Great Lakes states agreed in 1995 to a comprehensive plan to restore the health of the Great Lakes. The Final Water Quality Guidance for the Great Lakes System, also known as the Great Lakes Initiative (GLI), includes criteria for states to use when setting water quality standards for 29 pollutants, including bioaccumulative chemicals of concern, and prohibits the use of mixing zones for these toxic chemicals. Because the surface water at the Site is within the drainage basin of Lake Superior, the ARARs specified in the GLI, Minn. Rules ch. 7052 are applicable to the Site. Requirements of the Great Lakes Water Quality Agreement of 2012 apply to the Site. In addition, the surface waters adjacent to the Site are identified as an Outstanding International Resource Water (OIRW). The objective for OIRW is to maintain water quality at existing conditions when the quality is better than the water quality standards. Generally, OIRWs are considered surface water quality standards applicable to the SLR for Class 2B and OIRWs, as set forth in Minn. Rules, chs. 7050 and 7052, and to the additional surface water quality standards for the SLR, as set forth in Minn. Rules ch. 7065. The OIRW was established after the ROD was issued.

As stated in Minn. Rules ch. 7050.0210 Subp. 2:

> *Nuisance conditions prohibited. No sewage, industrial waste, or other wastes shall be discharged from either point or nonpoint sources into any waters of the state so as to cause any nuisance conditions, such as the presence of significant amounts of floating solids, scum, visible oil film, excessive suspended solids, material discoloration, obnoxious odors, gas ebullition, deleterious sludge deposits, undesirable slimes or fungus growths, aquatic habitat degradation, excessive growths of aquatic plants, or other offensive or harmful effects.*

Title 40 CFR Part 6, Appendix A, Section 6 Requirements, requires federal agencies to evaluate the potential effects of actions taken within a floodplain to avoid adversely impacting floodplains wherever possible.

Title 40 CFR Part 6, Appendix A, Section 6.a.(1) Floodplain/Wetlands Determination: Before undertaking an Agency action, each program office must determine whether or not the action will be located in or affect a floodplain or wetlands. The Agency shall utilize maps prepared by the Federal Insurance Administration of the Federal Emergency Management Agency (Flood Insurance Rate Maps or Flood Hazard Boundary Maps), Fish and Wildlife Service (National Wetlands Inventory Maps), and other appropriate agencies to determine whether a proposed action is located in or will likely affect a floodplain or wetlands. If there is no floodplain/wetlands impact identified, the action may proceed without further consideration of the remaining procedures set in this section. If floodplain/wetlands impact is identified, this section presents procedures that must be taken.

Shoreland and Floodplain Management (Minn. Rules ch. 6120): Provides standards and criteria intended to preserve and enhance the quality of surface waters, conserve the economic and natural environmental values of shorelands, and provide for the wise use of water and related land resources of the state. St. Louis County Zoning Ordinances, ch. 1003, establish additional floodplain management and manage site activities such as on-site waste disposal.

Shoreland Management Permit (Duluth City Code §51-26 et seq.), as defined by the City of Duluth: Requires a permit for any excavation or grading above the Ordinary High Water Mark within 300 feet of a river. Each alternative will involve some of these activities. The substantive requirements of this permit are found in the ordinance and may govern removal of natural vegetation, grading and filling, placement of roads, sewage and waste disposal, and setbacks.

The Endangered Species Act (16 USC §1531 et seq.) and the Minnesota Endangered, Threatened, Special Concern Species Act (Minn. Rules ch. 6134): Protect threatened and endangered plants and animals and their habitats.

Title 16 USC Chapter 7, Subchapter II §§703 and 712.2. (The Migratory Bird Treaty Act): Protects migratory birds and their ecosystems by specifying the taking, killing, or possessing migratory birds unlawful. Public Law 95-616, an amendment to this act, provides measures to protect identified ecosystems of special importance to migratory birds such as bald eagles against pollution, detrimental alterations, and other environmental degradations.

The MDH has established various fish consumption advisories for the SLR due to the presence of perfluorochemicals (PFCs), PCBs, and mercury in water and sediments (MDH, 2000).

2.1.3 Action-Specific ARARs and TBCs

The following summarizes the action-specific ARARs for the Site. In addition, Occupational Safety and Health Standards (Minn. Rules ch. 5205) for worker health, safety, and training are applicable to remedial actions performed at the Site.

ARAR/TBC	Citation/Source	Description/Application
Waters of the State (both surface and underground)	Minn. Rules ch. 7050 and 7052	Surface water quality during remedy construction.
Wetland Conservation Act (WCA)	Minn. Stat. §§103G.221-.2373	Protection of wetlands.
Wetlands Conservation	Minn. Rules 8420	Protection of wetlands, wetland functions for determining public values.
Floodplain Management Order	Executive Order 11988 and 40 CFR Part 6, Appendix A,	Regulates remedial action implementation in floodplains.
Section 404 Permit and Section 401 Certification (Clean Water Act)	33 CFR pts 320 and 323; 33 USC §1341	Applies to discharge of dredged or fill material into waters of the United States.
National Pollutant Discharge Elimination System (NPDES)/ State Disposal System (SDS) permits	Clean Water Act 33 USC §1342	Surface water quality requirements for discharges of pollutants to waters of the state.
Section 10 (Rivers and Harbors Act of 1899)	33 USC 403	Applies to activities that will obstruct or alter any navigable water of the United States.
Work in Public Waters	Minn. Stat. §103G.245	Permit requirements applicable to work in public waters that will change or diminish its course, current, or cross-section.
Public Water Resources	Minn. Rules ch. 6115	Water appropriation permitting, standards and criteria for alterations to structure of public water (MDNR).
Minnesota Sediment Quality Targets	Guidance for the Use and Application of Sediment Quality Targets for the Protection of Sediment-dwelling Organisms in Minnesota, MPCA Document Number: tdr-gl-04	Establishes procedures for potentially bioactive zone (PBAZ) caps and covers.

ARAR/TBC	Citation/Source	Description/Application
Western Lake Superior Sanitary District (WLSSD)	WLSSD Industrial Pre-Treatment Ordinance	Requirements for any dredge water discharged into public sanitary sewers.
Construction and Use of Public Sewers	Minn. Rules ch. 4715	Governs the use of sewers and public water systems if any dredge water is disposed of in public sewers.
MDNR Invasive Species Management	Minn. Statutes 84D.02	Requirements for sediment transportation if invasive species are present
Solid Waste	Minn. Rules ch. 7035	Requirements and standards for solid waste facilities.
Hazardous Waste	Minn. Rules ch. 7045	Hazardous waste listing, and generator, transport, and facility standards.
Air Pollution Emissions and Abatement	Minn. Stat. §116.061	Duty to notify and abate excessive or abnormal unpermitted air emissions.
Ambient Air Quality Standards	Minn. Rules ch. 7009	Provides air quality standards.
Preventing Particulate Matter From Becoming Airborne and Emission Standards	Minn. Rule Parts 7011.0150 and 7011.8010	Provides measures to control dust and emission standards for hazardous air pollutants.
Noise Pollution Control	Minn. Rules ch. 7030	Noise standards applicable to remedy construction.

Water Quality

If any activity associated with the remedial actions results in an unregulated release, in accordance with the Water Pollution Control Act and Minn. Stat. 115.061, Duty to Notify, a notification and recovery of any pollutants discharged to minimize or abate pollution of the waters of the state is required.

In accordance with Minn. Rules ch. 7050, surface water quality standards for the maintenance and preservation of surface water quality during remedy construction, including discharges from treatment/work and stormwater runoff zones, shall be based on surface water quality standards that currently apply to Class 2B and OIRWs, as set forth in Minn. Rules, chs. 7050 and 7052, and to the additional surface water quality standards for the SLR set forth in Minn. Rules ch. 7065. Therefore, if water is discharged directly to the waters on or adjacent to the Site, it shall be treated to a level that meets applicable surface water discharge standards. Groundwater non-degradation and standards for the protection of groundwater during remedy construction are presented in Minn. Rules 7060.

During remediation, the MPCA would consider the areas in which work is performed as “treatment/work zones,” to which the surface water quality standards normally applicable to the SLR would temporarily not apply. These treatment/work zones would be physically separated from adjacent waters through the use of engineering controls such as single or multiple silt curtains, inflatable dams, sheet piling, or other measures. During construction of the remedy, any discharges occurring within those controlled treatment/work zones, such as the discharge of capping material during capping operations, the release of contaminants during dredging operations, or runoff from activities on shore, would not be subject to water quality standards. Rather, water quality standards would apply outside of the treatment/work zone, beyond the outermost engineering control structure where the water from the treatment/work zone is discharged. Other discharges occurring during remedy construction that are not included in a treatment/work zone, including discharges of treated dredge water, and discharges of stormwater runoff from shoreland modifications outside of the treatment/work zones, would also be subject to regulation.

If water is discharged, it would be treated to a level that meets applicable surface water discharge standards. The MPCA water quality standards may apply to these discharges. Final standards would be determined by the MPCA prior to implementation of the remedial actions. In the event that a standard is exceeded, further management practices would likely be required during remedy construction to reduce the amount of suspended contaminants escaping the treatment/work zone.

Wetlands, Shoreland, and Floodplain Management

In accordance with Minn. Rules ch. 7050, wetlands at the Site are classified as unlisted wetlands, Class 2B and 3B waters. In accordance with Minn. Rules ch. 8420, compliance with wetland ARARs will involve consultation with the MDNR to determine the category of wetlands present at the Site and any avoidance, mitigation, and replacement that may be necessary. Water quality standards for the maintenance and preservation of surface water quality during remedy construction including discharges from treatment/work and stormwater runoff zones shall be based on surface water quality standards that currently apply to Class 2B and 3B waters and shall comply with Minn. Stat. §§103G.221-.2373. Standards and specifications applicable to shoreland and floodplain management can be found in Executive Order 11988 and 40 CFR Part 6, Appendix A, Minn. Rules ch. 6120.

Minn. Stat. §103G.222 provides that a wetland replacement plan must be approved by the Local Governmental Unit before any Wetland Conservation Act (WCA) wetlands may be drained or filled, unless draining or filling falls within the “De Minimis” exemption or another exemption of Minn. Stat. §103G.2241. WCA wetlands are those wetlands that are not public water wetlands regulated by the MDNR and United States Army Corps of Engineers (USACE). WCA wetlands would be located above the Ordinary High Water Mark. The South St. Louis Soil and Water Conservation District provides additional guidance regarding WCA requirements for the Site at the following website: http:// www.southstlouisswcd.org/wcact.html.

Permits and Certifications

Possible permits for cleanup activities include the following:

Section 404 Permit (Clean Water Act): Required for discharge of dredged or fill material into waters of the United States. The substantive requirements of this permit shall be met for alternatives that dredge or fill waters of the state. USACE evaluates applications for Section 404 permits. Substantive requirements that may be incorporated within a Section 404 permit for off-site activities can be found in 33 CFR Parts 320 and 323.

Section 401 Certification: The Clean Water Act, 33 USC §1341, requires that any application for a federal permit that may result in a discharge to a navigable water must be accompanied by a certification from the affected state indicating that the discharge will comply with all applicable water quality standards and effluent limitations of the Act. Thus, a Section 401 certification or a 401 certification waiver for remedial action at the Site would be necessary before the USACE may issue a Section 404 permit, and a certification may be necessary before the USACE may issue a Section 10 permit if that permit authorizes a “discharge.”

National Pollutant Discharge Elimination System (NPDES; Clean Water Act 33 USC §1342): Discharges of pollutants to waters of the state associated with construction of the selected remedy would be subject to the requirements applicable to a NPDES permit. Discharges could include the discharge of capping material, the discharge of contaminants released and suspended by dredging operations, the discharge of treated dredge water during dredging operations, and the discharge of stormwater runoff from shoreland modifications. These types of discharges would be subject to the same regulatory standards and controls that would apply under an MPCA permit. In addition, NPDES General Permit number MNG990000 was required for managing dredged materials; however, this permit has expired and has not been renewed. According to Managing Dredged Materials in the State of Minnesota (MPCA, 2009), an individual NPDES/State Disposal System (SDS) Dredge Materials Management permit may be required. A NPDES Construction Permit and a Stormwater Pollution Prevention Plan are required by the MPCA if more than one acre of land is disturbed by excavation activities.

Section 10 of the Rivers and Harbors Act of 1899 (33 USC 403): A Section 10 permit is required from the USACE for any construction in or over any navigable water, or the excavation or discharge of material into such water, or the accomplishment of any other work affecting the course, location, condition, or capacity of such waters. The substantive requirements that may be incorporated within a Section 10 permit can be found in 33 CFR Parts 320 and 322.

Work in Public Waters (Minn. Stat. §103G.245): A permit from the MDNR is necessary for any work in public waters that will change or diminish its course, current, or cross-section. If an alternative under consideration involves dredging or capping, a public waters permit from the MDNR may be required. The substantive requirements that the MDNR may incorporate within its public waters permit are codified in statute and at Minn. Rules, ch. 6115. These requirements include compensation or mitigation for the detrimental aspects of any major change in the resource. The MDNR permits may require restoration of bathymetry (water depth) and habitat substrate (bottom) as part of the public waters permit. The MDNR would set the specific cover depth and composition requirements.

Additionally, if capping of contaminated sediments is conducted, requirements would include specifications for cap construction. In situ caps constructed for the containment of contaminated sediment must contain an isolation zone (IZ) and a potentially bioactive zone (PBAZ). The IZ is the portion of the cap that is applied directly over the contaminated sediments and is designed to isolate and attenuate the Site contaminants that could potentially be transported upward into the PBAZ at concentrations above the CULs by diffusion or advection transport mechanisms. The PBAZ is the area within the cap above the IZ where significant biological activity may potentially be present. The thickness and material specifications for the IZ and PBAZ should be determined based on pore water transport and attenuation modeling.

Air Emissions and Waste Management Permits: In accordance with Minn. Stat. §116.081, a permit is required for the construction, installation or operation of an emission facility, air contaminant treatment facility, treatment facility, potential air contaminant storage facility, storage facility, or system or facility related to the collection, transportation, storage, processing, or disposal of waste, or any part thereof, unless otherwise exempted by any agency rule now in force or hereinafter adopted, until plans have been submitted to the agency, and a written permit granted by the agency.

On-Site Disposal: The placement of dredged sediment into an on-site confined aquatic disposal (CAD) area and any subsequent seepage from the CAD, if implemented, would be regulated by the MPCA under the requirements applicable to an SDS permit. The legal requirements for an SDS are found in Minn. Stat. §115.07, Minn. Rules, Parts 7065.0100 to 7065.0160 and in other MPCA water quality rules including Minn. Rules chs. 7050 and 7052.

Discharge into Sewers: A permit from the Western Lake Superior Sanitary District (WLSSD) will be necessary if any dredge water is discharged into the public sewers. Pretreatment standards that would likely apply can be found at:

http://www.wlssd.duluth.mn.us/pdf/WLSSDPretreatmentOrdinance.pdf.

The permit will also include requirements to ensure that there will be no detrimental effects to their bio-solids program. A WLSSD permit would also represent compliance with Minn. Rule, Part 4715.1600 and the MPCA water rules governing indirect discharges.

Invasive Species: A prohibited/regulated invasive species permit will be required to transport sediment to a landfill, if invasive species are present near the proposed work area.

CERCLA provides for waiving of necessary permits for on-site work, provided the work is conducted in compliance with the substantial conditions of such permits. Although the permits themselves may not be required on CERLCA Sites, compliance with the substantial conditions of these identified permits shall be met.

Construction and Use of Public Sewers

Minn. Rules ch. 4715 governing the use of sewers and public water systems would apply if any water associated with remedial activities is disposed of in public sewers.

Waste Management

Solid and hazardous waste management requirements and standards can be found in Minn. Rules chs. 7035 and 7045, respectively. USEPA guidance has consistently stated that Superfund remedies involving movement of contaminated material within the area of a Site where such material is already located (sometimes referred to as an AOC) do not create a “waste” that is subject to RCRA (42 USC §§6901 et seq.) or other waste management requirements. Remedy alternatives that require contaminated materials to be moved to an off-site land disposal site are considered to generate waste that must be managed under applicable waste management requirements.

St. Louis County Zoning Ordinances, ch. 1003, establish additional floodplain management and manage site activities such as on-site waste disposal.

Ambient Air Quality Standards

Air quality standards applicable to releases into the air from cleanup activities include Min. Stat. 116.061, Air Pollution Emissions and Abatement. During remedy construction, activities such as transportation, storage and placement of capping material may result in particulate matter becoming airborne. Minn. Rules ch. 7009 establishes ambient air quality standards for criteria pollutants regulated under the Clean Air Act. Compliance points shall be selected in accordance with Minn. Rules ch. 7009. The ambient air quality standards for particulate matter that apply to remedial actions are found at: https://www.revisor.mn.gov/rules/?id=7009.0080.

Control of the generation of airborne particulate matter during remedy construction is regulated in Minn. Rule part 7011.0150, *Preventing Particulate Matter from Becoming Airborne*, which includes measures to control dust that may be generated during remedy construction activities such as transportation, storage, and placement of capping material, which shall be addressed in the remedial design plan. Minn. Rules part 7011.8010, Site Remediation, incorporates the National Emission Standards for Hazardous Air Pollutants applicable during Site remediation activities.

Noise Pollution Control

Minn. Rules ch. 7030 establishes noise standards for various land uses. Compliance points will be selected in accordance with Minn. Rules ch. 7030. The noise standards that will apply to the selected remedial action can be found at:

https://www.revisor.leg.state.mn.us/rules/?id=7030.0040

2.1.4 Other Considerations

Other considerations under MERLA set forth the regulatory requirements, RAOs and CULs that must be met by a remedy to meet the legal standard for a remedy under MERLA and the threshold criterion for protection of public health and welfare and the environment. A remedy, as defined under MERLA, must also include any monitoring, maintenance and institutional controls (ICs) and other measures that MPCA determines are reasonably necessary to ensure the protectiveness of the selected remedy over the long term.

It is particularly important to consider the requirements for long-term assurance of protectiveness where the remedy alternatives involve the use of capping or containment to manage contaminated media within the Site. Some requirements may also be necessary to ensure long-term protectiveness of alternatives that involve excavation or dredging and off-site disposal of contaminated soil or sediment.

In addition, MERLA requires the MPCA to consider the planned use of the property where the release of contaminants is located when determining the appropriate standards to be achieved by a remedy.

Long-Term Assurance of Protectiveness

MERLA requires that a remedy include measures that are reasonably required to ensure the ongoing protectiveness of a remedy once the components of the remedy have been constructed and entered their operational phase. Such measures may include, but are not limited to, ICs and monitoring and maintenance requirements. This section discusses the measures that MPCA determines are reasonably necessary to ensure long-term protectiveness.

Institutional Controls

ICs are legally enforceable restrictions, conditions or controls on the use of property, groundwater or surface water at a property that are reasonably required to ensure the protectiveness of a remedy or other response actions taken at the Site. Areas of the Site where contaminated media remains in place after remedial construction will be subject to ICs (such as easements and restrictive covenants) that are legally binding on current and future owners of the property to ensure ongoing protection from disturbance of or exposure to the contamination. Restrictions on use may also be required for areas of the Site where contaminated media are treated and/or removed and where some residual contamination may remain.

Minn. Stat. §115B.16, subd. 2, requires an Affidavit Concerning Real Property Contaminated with Hazardous Substances to be recorded with the St. Louis County recorder by the owner of the property. The Uniform Environmental Covenants Act (UECA) and the authority for requiring environmental covenants can be found in Minn. Stat. ch. 114E. This statute requires MPCA approval of environmental covenants (which include restrictive covenants and access) when there is an environmental response project (which includes superfund cleanups) is overseen by the MPCA. Because the Site is not platted, the UECA may not apply and other ICs such as a City Ordinance may be required to prevent anchoring, fishing, dredging, and other activities that may disturb a cap or contaminated sediments left in place.

Long-Term Operation and Maintenance, Monitoring, and Contingency Action

On-site containment facilities and capping of impacted media (sediment) or any other alternative that may leave impacted media on-site will require post-construction monitoring, operation and maintenance (O&M), and contingency action plan to ensure that ARARs, RAOs and CULs that apply to the alternative are fully achieved and maintained over time.

General details of the post-construction monitoring, O&M, and contingency action plan requirements would be set forth in the FFS, along with an estimate of the cost to carry out each activity.

Sediment traps or other means of limiting incoming sediment to maintain appropriate water depth may be required; this need will be further evaluated in the design phase of this project. If sediment traps are implemented, long-term maintenance of these traps such as sediment removal will be required.

Planned Use of Property

In a provision entitled “Cleanup Standards” (Minn. Stat. §115B.17, subd. 2a), MERLA provides that when MPCA determines the standards to be achieved by response actions to protect public health and welfare and the environment from a release of hazardous substances, the agency must consider the planned use of the property where the release is located. The purpose of this provision of MERLA is to allow the MPCA to select cleanup standards that provide a level of protection that is compatible with the uses of the Site property that can be reasonably foreseen.

The specific properties directly affected by the remedies are currently idle land but under consideration for development in the near future. The cleanup standards must provide protection of public health and welfare and the environment that is consistent with any planned or potential future uses of the Site, including natural resource and habitat restoration, navigation and recreational uses. These cleanup standards are also compatible with the use of the adjacent land for residential, recreational, habitat restoration, or commercial and industrial use.

2.2 Remedial Action Objectives

The RAOs developed by the MPCA for the Site are:

1. Minimize or remove exposure to sediment contaminants that bioaccumulate in the food chain and contribute to fish consumption advisories.
2. Minimize or remove exposure of the benthic organisms to contaminated sediments above sediment cleanup goals.
3. Preserve water depth to enable the current and/or planned use of the Site.
4. Enhance aquatic habitat, if conditions allow, in a manner that contributes to the removal of BUIs.
5. Minimize or remove human exposure to contaminated sediments above sediment cleanup goals.

The following subsection presents preliminary sediment CULs developed to achieve these RAOs.

2.2.1 Preliminary Sediment CULs

The selected remedy should meet the Preliminary Sediment CULs and provide protection of ecological and human health. The CULs should also provide cleanup standards consistent with any planned or potential future uses of the Site. The Midpoint SQT for cadmium, copper, lead, mercury, nickel, zinc, PAHs, PCBs, and dioxins will serve as the CULs for the Site. The SQTs for cadmium, lead, nickel, and zinc are more conservative than the SSVs; therefore, if sediments are cleaned up to the respective Midpoint SQTs to protect ecological receptors, human receptors will also be protected. Copper does not have an SSV; therefore, the sediments will be cleaned up to the Midpoint SQT. The SSVs for mercury, PAHs, PCBs, and dioxins are expected to be below ambient concentrations in the SLR AOC; therefore, based on discussions with the MPCA, the Midpoint SQT was selected for the CULs until ambient concentrations studies are completed. The following table presents the CULs for the COCs identified in **Section 1.4.3.3**.

Contaminant	Units	CUL
Cadmium	mg/kg	3
Copper	mg/kg	91
Lead	mg/kg	83
Mercury	mg/kg	0.64
Nickel	mg/kg	36
Zinc	mg/kg	290
Total PAHs	µg/kg	12,300
PCBs	µg/kg	370
Dioxins	ng TEQ/kg	11.2

Notes:
µg/kg = micrograms per kilogram
mg/kg = milligrams per kilogram
ng TEQ/kg = nanograms toxic equivalency per kilogram

3.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

3.1 Remedial Technology Identification and Screening Process

Potential technologies for addressing conditions at the Site were identified based upon professional experience of Bay West staff, discussions between Bay West and MPCA staff, and guidance developed for the remediation of contaminated sediment sites (USEPA, 2005; Interstate Technology and Regulatory Council [ITRC], 2014). Information collected during the 2015 RI was used to compile the CSM and identify feasible technologies for the Site.

A qualitative approach was used to screen technologies using a three-part ranking system where each technology was evaluated on effectiveness, implementability, and relative cost:

- Effectiveness was evaluated by the predicted ability of the technology under consideration to ensure long-term protection of human health and the environment while minimizing short-term impacts during implementation, as well as the technology's ability to meet RAOs.
- Implementability was evaluated by considering the technical and administrative feasibility of the technology. Technical feasibility includes the ability to achieve RAOs and the avoidance of creating additional risk during implementation, including the degree of disruption in the project area. Administrative feasibility includes the consideration of permits required for technology implementation, availability of disposal facilities and equipment necessary for the technology, and coordination with applicable agencies and stakeholders.
- Relative costs used for technology screening were based on engineering judgment, rather than detailed estimates. Detailed cost estimates were compiled for each individual alternative, which incorporate technologies meeting screening criteria, and are presented in **Section 3.3**.

Table 2 presents a summary of the technology screening results. The following sections describe the technologies that were screened using the three-part ranking system.

3.1.1 Institutional Controls

ICs are legally enforceable restrictions, conditions, or controls on the use of property, ground water, or surface water at a contaminated site that are reasonably required to ensure the protectiveness of a remedy or other response actions taken at the Site. If contaminated sediments remain in place after remedial actions are taken, the Site would be subject to ICs (such as easements and restrictive covenants) that are legally binding on current and future owners of the property to ensure ongoing protection from disturbance of or exposure to the contamination. Most remedial alternatives include ICs until long-term monitoring (LTM) indicates that risk reduction was achieved and the RAOs have been met (ITRC, 2014). The following information obtained from USEPA sediment remediation guidance (USEPA, 2005) details ICs likely appropriate for use at the Site.

Fish consumption advisories are informational devices that are frequently already in place and incorporated into sediment site remedies. Commercial fishing bans are government controls that ban commercial fishing for specific species or sizes of fish or shellfish. Usually, state departments of health are the governmental entities that establish these advisories and bans. An advisory usually consists of informing the public that they should not consume fish from an area, or consume no more than a specified number of fish meals over a specific period of time from a particular area. Sensitive sub-populations or subsistence fishers may be subject to more stringent advisories. Advisories can be publicized through signs at popular fishing locations, pamphlets, or other educational outreach materials and programs. Consumption advisories are not enforceable controls and their effectiveness can be extremely variable (USEPA, 2005).

Waterway use restrictions may be necessary to ensure the integrity of the alternative for any alternative where subsurface contamination remains in place (e.g., capping, Monitored Natural Recovery [MNR], or an in-water confined disposal site). Examples include restricting boat traffic in an area to establish a no-wake zone, or prohibiting anchoring of vessels. In considering boating restrictions, it is important to determine who can enforce the restrictions, and under what authority and how effective such enforcement was in the past. In addition, a restriction on easements for installing utilities, such as fiber optic cables, can be an important mechanism to help ensure the overall protectiveness of a remedy (USEPA, 2005).

It may be necessary to work with private parties, state land management agencies, or local governments to implement use restrictions on nearshore areas and adjacent upland properties where contamination remains in place. For example, construction of boat ramps, retaining walls, or marina development can expose subsurface contamination and compromise the long-term effectiveness of a remedy. Where contaminated sediment exceeding CULs is identified in proximity to utility crossings or other infrastructure and temporary or permanent relocation of utilities in support of a dredging remedy may not be feasible or practical, capping may be desirable even though temporary cap disruption may be necessary periodically (USEPA, 2005).

3.1.2 Monitoring

Monitoring is the collection and analysis of data (chemical, physical, and/or biological) over a sufficient period of time and frequency to determine the status and/or trend in one or more environmental parameters or characteristics. Monitoring should not produce a “snapshot in time” measurement, but rather should involve repeated sampling over time in order to define the trends in the parameters of interest relative to clearly defined management objectives. Monitoring is recommended for all types of sediment remedies both during and after remedial action and can be classified as construction monitoring and performance monitoring (also referred to as LTM), respectively. Monitoring should be conducted for a variety of reasons, including: 1) to assess compliance with design and performance standards; 2) to assess short-term remedy performance and effectiveness in meeting sediment CULs; and/or 3) to evaluate long-term remedy effectiveness in achieving RAOs and in reducing human health and/or environmental risk. In addition, monitoring data are usually needed to complete the five-year review process where a review is conducted.

Monitoring activities applicable to the Site could include one or more of the following based on the selected remedy:

- Collection of sediment chemical data to ensure that CULs have been achieved (due to dredging, in situ treatments, or degradation);
- Measurements of cover/cap thicknesses or other engineered controls to ensure continued isolation of contaminants and physical cap integrity;
- Measurement of COC concentrations in cover/cap material to ensure that contaminants are not migrating into or through the cover/cap; and
- Measurement of toxicity to and bioaccumulation of COCs within aquatic organisms such as benthics and fish in order to evaluate reduction trends.

Construction monitoring may also be performed to ensure that contamination or nuisance materials are not released during construction activities. Construction monitoring activities applicable to the Site include one or more of the following:

- Turbidity monitoring to ensure that the off-site release of suspended sediments containing COCs is mitigated during dredging and/or cover/cap placement;
- Air monitoring to ensure that the off-site release of nuisance and/or contaminated dusts is mitigated during construction activities such as the mixing of sediments and amendment materials, hauling over dirt or gravel roadways, and excavation or other intrusive Site work;
- Periodic sampling of treated dredge contact water to mitigate contaminant inputs to water bodies or local sewage systems and to ensure that treated water meets permit or municipality requirements;
- Periodic sampling of dredged materials to ensure that landfill requirements for acceptance are achieved;
- Periodic sampling of imported materials (e.g., cover/cap materials, shoreline restoration materials, etc.) to mitigate impacts to water bodies or upland areas as a result of placement; and
- Pre- and post-construction soil sampling to access impacts of construction activities on lands used during the construction phase.

Both construction and performance monitoring (referred to as LTM) are incorporated into each of the remedial alternatives developed for this FFS.

3.1.3 Monitored Natural Recovery

MNR is defined by the National Research Council as a remediation practice that relies on natural processes to protect the environment and receptors from unacceptable exposures to contaminants. This remedial approach depends on natural processes to decrease chemical contaminants in sediment to acceptable levels within a reasonable time frame. With MNR, contaminated sediments are left in place and monitored for ongoing physical, chemical, and biological processes that transform, immobilize, isolate, or remove contaminants until they no longer pose a risk to receptors. Natural processes that contribute to MNR may include sediment burial, sediment erosion or dispersion, and contaminant sequestration or degradation (for example, precipitation, adsorption, or transformation). These natural processes can reduce exposure to receptors (and thus reduce risk) and contribute to the recovery of the aquatic habitat and the ecological resources that it supports. MNR can be used alone or in combination with active remediation technologies to meet RAOs (ITRC, 2014).

3.1.4 Enhanced Monitored Natural Recovery

Enhanced Monitored Natural Recovery (EMNR) relies on the same natural processes as MNR to decrease chemical contaminants in sediment but includes the application of material or amendments to enhance these natural recovery processes. EMNR can use several technologies including, but not limited to, thin-layer capping and introduction of reactive amendments such as activated carbon (AC). Thin-layer caps (typically up to 1 foot) are often applied as part of an EMNR approach. These caps enhance ongoing natural recovery processes, while minimizing effects on the aquatic environment. Thin-layer caps are not intended to completely isolate the affected sediment, as in a conventional isolation capping remedy. This layer also accelerates the process of physical isolation, which continues over time by natural sediment deposition (ITRC, 2014).

3.1.5 In Situ Treatment

In situ sediment treatment involves applying or mixing of an amendment into sediments. Mixing may be achieved either passively, through natural biological processes such as bioturbation, or actively through mechanical means such as augers. In situ treatment technologies can achieve risk reduction in environmentally sensitive environments such as wetlands and emergent aquatic vegetation habitats, where sediment removal or containment by capping might be harmful. Treatment amendments typically reduce concentrations of freely dissolved chemicals that are available for exposure to organisms or that may be mobilized and transferred from sediment to the overlying water column (ITRC, 2014). The following in situ treatment technologies were screened in this evaluation:

- Immobilization – Immobilization treatments add chemicals or cements to reduce the leachability of contaminants. Mechanisms include solidification (encapsulation) or stabilization (chemical or absorptive reactions that convert contaminants to less toxic or mobile forms);
- Enhanced bioremediation – Microbial degradation by bacteria or fungi is enhanced by adding materials such as oxygen, nitrate, sulfate, hydrogen, nutrients, or microorganisms to the sediment;
- Oxidation/reduction – Chemicals are injected into sediment to act as an oxidant/electron acceptor to facilitate aerobic decomposition of organic matter;
- Chemical oxidation – The addition of chemical oxidizers to sediment can cause the rapid and complete chemical destruction of many toxic organic chemicals;
- Phytoremediation – Phytoremediation uses plant species to remove, transfer, stabilize, and destroy contaminants in sediment. Generally limited to sediments in shallow water zones and low concentrations; and
- Adsorption – Adsorbents can be used as sediment amendments for in situ treatment of contaminants. Sorption of metals and organics can take place simultaneously with a suitable combination of sorbents.

3.1.6 Capping

Capping is the process of placing a clean layer of sand, sediments, or other material over contaminated sediments in order to mitigate risk posed by those sediments. The cap may also include geotextiles to aid in layer separation or geotechnical stability, amendments to enhance protectiveness, or additional layers to armor and maintain its integrity or enhance its habitat characteristics.

When amendments are mixed directly into sediments, the resulting remedy is termed “in situ treatment.” When these amendments are added to cap material, the remedy is called an “amended cap,” and the amendments enhance the performance of the cap material. The same amendment used in the same proportions is generally more effective at isolating contaminants when used in a cap than when placed directly into sediments. The amended cap provides the benefits of capping in addition to the benefits of the treatment amendment (ITRC, 2014).

A cap should consist of at least two parts; an IZ and a PBAZ. The IZ is the portion of the cap that is applied directly over the contaminated sediments and is designed to isolate and attenuate contaminants that could potentially be transported upward into the PBAZ by diffusion or advection transport mechanisms. The PBAZ is the area within the cap above the IZ where biological activity may potentially be present. The PBAZ thickness can be estimated based on the potential organisms (both plant and animal) that may be present or take up residency once the cap is constructed. Contaminant levels should not exceed CULs for COCs throughout the entire thickness of the PBAZ.

3.1.7 Dredging and Excavation

Dredging consists of the removal of contaminated sediment from water bodies in order to reduce risks to human health and the environment. Removal is particularly effective for source control (mass removal of hot spots) but potentially less effective for overall risk reduction because of resuspension and residual contamination. The three methods of contaminated sediment removal are mechanical dredging, hydraulic dredging, and excavation. As with any type of removal operation, additional technologies are required to appropriately handle the removed sediment. Dredged material handling technologies may involve transport, dewatering, treatment, and or disposal of sediment (ITRC, 2014). Mechanical dredging, hydraulic dredging, and excavation were screened independently in this evaluation.

After removal, the contaminated sediment can be treated or disposed of in a controlled setting, such as an off-site landfill or other treatment, storage, and disposal facility, an on-site aquatic or terrestrial confined disposal facility (CDF), or a facility that converts the sediment to a reusable product. Disposal methods were evaluated independently from dredging and excavation and are described further in **Section 3.1.9**.

3.1.8 Dewatering

Dewatering may be necessary to prepare dredged materials for disposal. Dewatering reduces the water content and hence the volume and weight of the disposed sediment. If the material is to be reused or further treated, dewatering also leads to reduced transportation cost and improves handling properties. The nature and extent of dewatering needed depends on the sediment characteristics and the type of dredging, transport, and disposal methods planned for the removed material (ITRC, 2014). Dewatering technologies may rely upon gravity draining and evaporation processes (e.g., spreading and geotextile bags), mechanical processes (e.g., filter presses), and chemical conditioning (e.g., polymer additions and stabilization additives). The type of dewatering technology selected for use may depend upon the amount of space available for dewatering, the distance of the dewatering space from dredging operations, discharge options for treated dredge contact water, project scope, and cost of implementing the technology.

3.1.9 Disposal

Disposal of dredged or excavated sediment is the placement of materials into a controlled site or facility to permanently contain contaminants within the sediment. Management is achieved through the placement of materials into facilities such as sanitary landfills, hazardous material landfills, CDFs, or CAD facilities. Off-site landfills are generally used for dredged material disposal when on-site disposal is not feasible or when off-site disposal is more cost effective.

Landfills have been used for sediment volumes of over 1 million cubic yards. Typically, some type of on-site or near-site disposal facility is used at sites where dredged material volumes greater than 200,000 cubic yards are generated. Landfilling is also favored at smaller or moderately sized sites, where transportation is feasible. The associated hazards and cost of transporting and landfilling large volumes of sediment make this disposal method somewhat less desirable than other solutions. Other considerations, such as public and stakeholder acceptance, lack of access to suitable on-site land- or water-based disposal facilities, and proximity to an existing off-site landfill may support the landfilling option.

CDFs are constructed to isolate dredged sediment from the surrounding environment. CDFs can be located upland, near shore, or in the water (as an island). Material staging or a temporary CDF may be necessary for dewatering dredged sediment. CDFs represent a common disposal method and typically are built for larger volume sites (200,000 cubic yards or more of sediment).

The CAD method deposits dredged material within a nearby body of water. A pre-existing depression within the sediment surface is preferred, though one can be created if necessary. Dredged sediment is deposited in the depression and capped with clean material. This process carries with it the same risks associated with using capping as a remedy. The goal of moving the contaminated sediment to the aquatic disposal site is to reduce the risk of exposure to contaminated materials (ITRC, 2014).

Disposal at landfills, CDFs, and CADs were screened independently in this evaluation.

3.1.10 Remedial Technology Screening Results

Table 2 documents the technology screening process and results. The following remedial technologies were determined to be the most effective, implementable, and cost-effective and were retained for assembling the alternatives described in **Section 3.3**:

- ICs;
- Monitoring; and
- Enhanced Monitored Natural Recovery.

3.2 Implementation Assumptions

This section describes important factors and assumptions for implementing one or more of the alternatives presented in **Section 3.3**.

Implementation of alternatives involving placement of sand and/or amendment materials would require identification and construction of a staging area in which to receive and stockpile imported materials and for loading of materials into barges for transport to the Site. Based on conversations between Bay West and the Duluth Seaway Port Authority, City of Duluth, and MPCA, the most likely staging area location would be Hallett Dock #7. Hallett Dock #7 is located approximately 3 miles downriver of the Site and is located within part of the Interlake/Duluth Tar (IDT) Superfund site. It is currently being considered for purchase by the Duluth Seaway Port Authority and could serve as a staging facility for future remediation projects throughout the Duluth/Superior Harbor. Although previous remedial activities have resulted in capping of sediments between Hallett Dock #7 and lands to the west, the end of the dock is nearly 500 feet in width and could potentially be used as a mooring location for sediment/cap material transport barges operating between Hallett Dock #7 and remediation sites (Sharrow, 2016).

Hallett Dock #7 is not currently used for barge mooring, berthing, or as a staging area, but has served similar purposes in the past. The facilities are currently in fair to poor condition and may require repairs before use. Inspection of the dock walls and their suitability for use should be conducted prior to the design phase. For the purposes of this FFS, the dock end wall was assumed to be in acceptable condition for mooring barges and the dock suitable for use as a staging area for all alternatives. Satellite imagery indicates the presence of a large paved area at the end of Hallett Dock #7, which is appropriately sized for stockpiling materials.

3.3 Development of Alternatives

This section describes the alternatives developed for the Site. The alternatives were developed using the selected remedial technologies discussed in **Section 3.1**, Site data collected during previous investigations and the 2015 RI, and the CSM. Site sediment chemical data was used to estimate the depth and spatial extent of the remedial areas for COCs as presented in

Figure 5. A summary of the proposed alternatives is presented in **Table 3**. Calculations used to determine volumes, rates, and time frames related to remedy construction are presented in Table 1 in **Appendix B**. Assumptions made to compile cost estimates were incorporated into a Technical Analysis and are also included in **Appendix B**.

The total present value costs for alternatives presented within this FFS should be considered to be rough order of magnitude (ROM) costs. Based on the Association for the Advancement of Cost Engineering ROM classification chart, estimates presented in this FFS are considered Class 4. Class 4 estimates are considered Schematic Designs; 15 to 20% of the level of effort required to have a complete estimate was done. Actual cost of the project could be 50% greater or 30% less (+50/-30) than the estimates developed thus far. ROM cost estimates for the FSS were compiled using a variety of sources. These sources include construction cost data from RSMeans estimating software for open shop pricing in Duluth, Minnesota; current Bay West and state contract rates for labor, equipment, and sample analysis; personal communication with vendors; historic cost data from projects similar in size and scope; other FFS documents, presentations, or technical papers that provided estimated or real construction cost data; and available online vendor pricing of materials. Preset value calculations are included in Table 5 in **Appendix B**.

3.3.1 Alternative 1: No Action

The NCP at Title 40 CFR provides that a No Action Alternative should be considered at every site. A No Action Alternative should reflect the site conditions described in the baseline risk assessment and remedial investigation. The No Action Alternative included within this FFS does not include any treatment or engineering controls, ICs, or monitoring. There are no costs associated with the No Action Alternative. The No Action Alternative could potentially be a viable alternative if a future toxicity/bioaccumulation study indicates that concentrations of Site COCs in sediments pose no significant detrimental effects to aquatic life (i.e., benthics and fish).

3.3.2 Alternative 2: Monitored Natural Recovery

This alternative consists of a monitoring and evaluation period of 30 years and implementation of ICs. Based on hydrodynamic findings at the U.S. Steel site, sufficient sedimentation may be occurring at the Site to reduce availability and concentrations of COCs in sediment and/or reducing toxic/bioaccumulative effects in marine organisms (i.e., benthics and fish). The objective of this alternative is to provide data to determine the potential for natural recovery processes at the Site. The major components of the MNR alternative are described in the following sections.

3.3.2.1 Monitoring and Evaluation

Contaminated sediments would remain in place as part of the MNR alternative and therefore a monitoring and evaluation period would be necessary to evaluate whether COC concentrations in affected media meet RAOs, or continue to decrease and are expected to meet RAOs in an acceptable time frame. A 30-year monitoring period was used to determine monitoring and evaluation costs based on discussions with the MPCA. Monitoring and evaluation events would be performed 1, 3, and 5 years following selection of the MNR remedy. It is likely that the monitoring and evaluation period will be recommended to continue after the initial 5 years. The monitoring and evaluation period includes the following elements:

- Collecting hydrodynamic Site data to include analysis of erosion and sediment deposition rates, flow velocities, and new bathymetric survey data;
- Collection of sediment samples to be analyzed for Site COCs;

- Collection of sediment samples for benthic toxicity and bioaccumulation analysis;
- Collection of fish tissue samples for bioaccumulation analysis;
- Bathymetric survey of the entire Site on Year 5; and
- Review of IC enforcement status.

3.3.2.2 Long-Term Monitoring

LTM would commence if results of the monitoring and evaluation period indicate that MNR is occurring in a reasonable time frame to achieve RAOs. LTM would include collection of Site data to monitor sedimentation rates and sequestration of COCs in sediments; monitor reduction trends in sediment toxicity to benthic organisms and COC bioaccumulation in benthic and fish tissue; and ensure that ICs continue to be enforced as long as COCs remain in sediments above the CUL.

LTM data collection would be conducted periodically for an indefinite period of time or until concentrations of COCs in sediments attenuate to levels below the CULs and are deemed protective of human health and the environment. For the purposes of this FFS, it was assumed that data collection would occur once every 5 years for a period of 30 years. If attenuation of COC concentrations to levels below the CULs does not occur after 30 years then monitoring will likely continue.

Data collection will consist of the following:

- Collection of sediment cores or sediment profile imagery to observe sediment accumulation;
- Collection of sediment samples to be analyzed for Site COCs;
- Collection of sediment samples for benthic toxicity and bioaccumulation analysis;
- Collection of fish tissue samples for bioaccumulation analysis; and
- Review of IC enforcement status.

Potential monitoring locations are presented in **Figure 7**.

3.3.2.3 Institutional Controls

ICs applicable to this alternative include those that would protect against direct human contact with contaminated sediments and ingestion of contaminants through fish consumption. The MDH currently communicates fish consumption guidelines for the lakes and rivers of Minnesota. Advisories for consumption of fish within the SLR and below the Fond du Lac Dam are in place for 11 species of fish due to the presence of mercury and PCBs within fish tissue. No specific advisories are in place related COCs. It is currently unknown whether the meal advice provided within the fish consumption guidelines is protective for these compounds; therefore, the applicability of meal guidelines to COCs would require investigation. Postings warning of contaminated sediments would be posted near potential Site access locations and would be modified according to changes in Site use (e.g., placed at boat launch and fishing dock).

3.3.2.4 Cost

The estimated total present value cost for Alternative 2 is approximately $250,000. **Table 4** presents a general breakdown of the estimated costs associated with Alternative 2.

<u>3.3.3 Alternative 3: Enhanced Monitored Natural Recovery with Broadcasted Amendment</u>

This alternative would consist of broadcasting an amendment material over sediments with COC concentrations exceeding their respective CULs. Areas of the Site exceeding the CULs are presented in **Figure 8** and equal approximately 59 acres; however, 12.5 acres of the remedial footprint exists within Wisconsin, so Alternative 3 would be funded and implemented in cooperation with the WDNR. The objective of applying an amendment material to in situ sediments at the Site is to reduce the bioavailability of the COCs to aquatic life by absorption to the sediment amendment. The reduction in availability of COCs in sediments and sediment pore water limits transfer of chemical contaminants to higher trophic organisms. This alternative was developed to minimize intrusive remedial action construction activities within emergent vegetation areas already established at the Site.

ICs would be implemented and LTM would commence following application of the selected amendment to remedial areas. The major components of Alternative 3 are described in the following sections.

3.3.3.1 Amendment Selection and Application Rate

This alternative consists of applying a thin layer of amendment material directly on top of in situ contaminated sediments. It is anticipated that the amendment material would be mixed into the underlying sediments over time through natural bioturbation processes caused by burrowing organisms, larger animal life, and rooting plants; therefore, this alternative is intended to reduce contaminant availability rather than provide isolation from contaminants as in a traditional capping scenario. The chosen amendment material would reduce exposure of aquatic life to COCs through sequestration of COCs in sediments and sediment pore water. Selection of an amendment material would be conducted during the design phase and would likely be selected based on results of bench and/or pilot scale testing. Potential amendment materials for consideration include permeable Organoclay™, phosphate additives (e.g., apatite), bauxite, biopolymers, and zeolite (USEPA, 2013). Any potential negative effects of these amendments, such as the potential for increased levels of eutrophication for phosphate additives, should also be considered during amendment selection.

The chosen application rate (i.e., thickness) of amendment to be applied should be capable of sequestering COCs in sediments and sediment pore water for an indefinite period of time, assuming that no ongoing source of contamination is present. It was assumed that a 0.05-meter (2-inch) layer of amendment material would be applied to in situ sediments strictly for cost analysis purposes. The final amendment application rate would be determined during the design phase and may largely depend upon COC sediment concentrations, depth of contamination, and the presence or absence of groundwater upwelling.

Implementation of this alternative assumes that approximately 16,000 cubic yards of amendment material would be broadcasted over a 59-acre area at an average thickness of 0.05 meter.

3.3.3.2 Long-Term Monitoring

LTM would commence after remedy implementation and would include collection of Site data to monitor mixing of the amendment material throughout the sediment column over time; monitor sequestration of COCs in sediments; monitor reduction trends in sediment toxicity to benthic organisms and COC bioaccumulation in benthic and fish tissue; and ensure that ICs continue to be enforced as long as COCs remain in sediments above the CUL.

Data collection would be conducted periodically for an indefinite period of time or until remedial goals are achieved. For the purposes of this FFS, it was assumed that data collection would occur once every 5 years, starting at year zero, for a period of 30 years, totaling seven events. If no remedial or developmental activity has taken place to reduce or isolate sediment contamination after 30 years, then monitoring may continue or a different remedy may be evaluated.

Data collection will consist of the following:

- Collection of sediment cores or sediment profile imagery to observe mixing of amendment material throughout the sediment column;
- Collection of sediment samples to be analyzed for Site COCs;
- Collection of sediment samples for benthic toxicity and bioaccumulation analysis;
- Collection of fish tissue samples for bioaccumulation analysis; and
- Review of IC enforcement status.

Potential monitoring locations are presented in **Figure 8**.

3.3.3.3 Institutional Controls

ICs applicable to Alternative 3 are the same as presented in **Section 3.3.2.2** for Alternative 2. No ICs are necessary for maintenance of the cover as cover material is anticipated to mix with underlying sediments; any intrusive activities conducted at the Site in the future would likely serve to further mix cover materials with underlying sediments.

3.3.3.4 Cost

Calculations used to determine unit rate costs for each of the alternatives are presented in Table 2 in **Appendix B**. Other project costs determined on a lump sum basis are presented in Table 3 in **Appendix B**. The monitoring and evaluation program and associated costs developed for each alternative are presented in Table 4 in **Appendix B**. The costs associated with each alternative are presented as Class 4 (+50/-30) estimates and are appropriate for remedial design alternative evaluations only.

The estimated total present value cost for Alternative 3 is $6,700,000. **Table 5** presents a breakdown of the estimated costs associated with Alternative 3.

3.3.4 Alternative 4: Enhanced Monitored Natural Recovery with Thin-Layer Amended Cover

This alternative would consist of constructing a 0.15-meter (0.5-foot) thin-layer amended cover over sediments with COC concentrations exceeding the CULs (**Figure 9**). The objective of this alternative is to reduce the availability of COCs to aquatic organisms through addition of an amendment material and subsequent sequestration of contaminants as discussed for Alternative 3, and to provide some immediate isolation of contaminated sediments through construction of 0.15 meters (6 inches) of clean substrate. Construction of the thin-layer amended cover would take place in both open water and emergent vegetation areas of the Site; however, 12.5 acres of the remedial footprint exists within Wisconsin and Alternative 4 would be funded and implemented in cooperation with the WDNR.

ICs would be implemented and LTM would commence following construction of the thin-layer amended cover. The major components of Alternative 4 are described in the following sections.

3.3.4.1 Cover Design

It was assumed for the purposes of this FFS that a 0.15-meter thin-layer amended cover would be constructed and that the thin-layer amended cover would consist of a 1:1 ratio of sand to amendment material by volume. It is anticipated that a single layer of a sand/amendment mix would be constructed rather than separate amendment and sand layers. Amendments mixed into and applied with soil or sand may provide better dispersion, uniformity, placement controls, and contact time when the required quantity of amendment is small, versus bulk placement of amendment materials (USEPA, 2013). The assumed thin-layer amended cover thickness and amendment ratio was selected strictly for the purposes of the cost analysis and should be refined during the design phase. The chosen application rate (i.e., mix ratio) of amendment to be applied should be capable of sequestering COCs migrating upward through the thin-layer amended cover material and should account for mixing of cover material into underlying sediments over time through bioturbation processes. The chosen amendment material would reduce exposure of aquatic life to COCs through sequestration of COCs in sediments and sediment pore water, as discussed for Alternative 3, and should be selected during the design phase based on bench or pilot scale testing.

Implementation of this alternative assumes that approximately 24,000 cubic yards of amendment material and 24,000 cubic yards of sand would be mixed and applied over a 59-acre area at an average thickness of 0.15 meter. The total volume of material to be placed, amendment plus sand, would be approximately 48,000 cubic yards. The need for burning, mowing, or laying down of vegetation in wetland areas prior to construction of the thin-layer amended cover should be determined during the design phase.

3.3.4.2 Long-Term Monitoring

LTM would commence after remedy implementation and would include collection of Site data to monitor concentrations of COCs in cover material; monitor mixing of cover materials throughout the sediment column over time; monitor attenuation and/or sequestration of COCs in sediments; monitor reduction trends in sediment toxicity to benthic organisms and COC bioaccumulation in benthic and fish tissue; and ensure that ICs continue to be enforced as long as COCs remain in sediments above the CUL.

Data collection would be conducted periodically for an indefinite period of time or until remedial goals are achieved. For the purposes of this FFS, it was assumed that data collection would occur once every 5 years, starting at year zero, for a period of 30 years, totaling seven events. If no remedial or developmental activity has taken place to reduce or isolate sediment contamination after 30 years, then monitoring may continue or a different remedy may be evaluated.

Data collection will consist of the following:

- Collection of thin-layer amended cover samples (0 to 0.15 meter bss) to be analyzed for COCs;
- Collection of sediment samples below 0.15 meter bss to be analyzed for COCs;
- Collection of sediment cores or sediment profile imagery to observe mixing of cover materials throughout the sediment column;
- Collection of sediment samples for benthic toxicity and bioaccumulation analysis;
- Collection of fish tissue samples for bioaccumulation analysis; and
- Review of IC enforcement status.

Potential monitoring locations are presented in **Figure 9**.

3.3.4.3 Institutional Controls

ICs applicable to Alternative 4 are the same as presented in **Section 3.3.2.2** for Alternative 2. No ICs are necessary for maintenance of the thin-layer amended cover as cover material is anticipated to mix with underlying sediments; any intrusive activities conducted at the Site in the future would likely serve to further mix cover materials with underlying sediments.

3.3.4.4 Cost

Calculations used to determine unit rate costs for each of the alternatives are presented in Table 2 in **Appendix B**. Other project costs determined on a lump sum basis are presented in Table 3 in **Appendix B**. The monitoring and evaluation program and associated costs developed for each alternative are presented in Table 4 in **Appendix B** The costs associated with each alternative are presented as Class 4 (+50/-30) estimates and are appropriate for remedial design alternative evaluations only.

The estimated total present value cost for Alternative 4 is $9,400,000. **Table 6** presents a breakdown of the estimated costs associated with Alternative 4.

4.0 REMEDY SELECTION CRITERIA

The alternatives were evaluated and compared using the NCP remedy selection criteria outlined below and in general accordance with USEPA guidelines for feasibility studies (USEPA, 1990). The NCP remedy selection criteria are divided into three groups based on the function of the criteria in remedy selection. The NCP definitions of each criterion are included below. Green Sustainable Remediation (GSR) criteria were also evaluated during this FFS and are included as a fourth group of criteria. Additional detail may be added from MPCA and/or USEPA guidance where appropriate.

4.1 Threshold Criteria

The Threshold Criteria relate to statutory requirements that each alternative must satisfy in order to be eligible for selection and include the following:

4.1.1 Overall Protection of Human Health and the Environment

Alternatives shall be assessed to determine whether they can adequately protect human health and the environment, in both the short term and long term, from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the Site by eliminating, reducing, or controlling exposures to levels established during development of remediation goals. Overall protection of human health and the environment draws on the assessment of other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

4.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

The alternatives shall be assessed to determine whether they attain applicable or relevant and appropriate requirements under federal environmental laws and state environmental or facility citing laws or provide grounds for invoking a waiver.

4.2 Primary Balancing Criteria

The Primary Balancing Criteria are the technical criteria upon which the detailed analysis is primarily based and include the following.

4.2.1 Long-Term Effectiveness and Permanence

Alternatives shall be assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful. Factors that shall be considered, as appropriate, include the following:

1. Magnitude of residual risk remaining from untreated waste or treatment residuals remaining at the conclusion of the remedial activities. The characteristics of the residual should be considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate.

2. Adequacy and reliability of controls, such as containment systems and ICs, necessary to manage treatment residuals and untreated waste. This factor addresses, in particular, the uncertainties associated with land disposal for providing long-term protection from residuals; the assessment of the potential need to replace technical components of the alternative, such as a cap, a slurry wall, or a treatment system; and the potential exposure pathways and risks posted should the remedial action need replacement.

4.2.2 Reduction of Toxicity, Mobility, or Volume Through Treatment

The degree to which alternatives employ recycling or treatment that reduces toxicity, mobility, or volume shall be assessed, including how treatment is used to address the principal threats posed by the Site. Factors that shall be considered, as appropriate, include the following:

1. The treatment or recycling processes the alternatives employ and materials they will treat;
2. The amount of hazardous substances, pollutants, or contaminants that will be destroyed, treated or recycled;
3. The degree of expected reduction in toxicity, mobility, or volume of the waste due to treatment or recycling and the specification of which reductions(s) are occurring;
4. The degree to which the treatment is irreversible;
5. The type and quantity of residuals that will remain following treatment, considering the persistence, toxicity, mobility, and propensity to bioaccumulate of such hazardous substances and their constituents; and
6. The degree to which treatment reduces the inherent hazards posed by principal threats at the Site.

4.2.3 Short-Term Effectiveness

The short-term impacts of alternatives shall be assessed considering the following:

1. Short-term risks that might be posed to the community during implementation of an alternative;
2. Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures;
3. Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigating measures during implementation; and
4. Time until protection is achieved.

4.2.4 Implementability

The ease or difficulty of implementing the alternatives shall be assessed by considering the following types of factors, as appropriate:

1. Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy;
2. Administrative feasibility, including activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions); and
3. Availability of services and materials, including the availability of adequate off-site treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources; the availability of services and materials; and the availability of prospective technologies.

4.2.5 Costs

The types of costs that shall be assessed include the following:

1. Capital costs, including both direct and indirect costs;
2. Annual O&M costs; and
3. Net present value of capital and O&M costs.

The USEPA guidance document *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (USEPA, 2000) was used to develop cost estimates presented in this Revised FFS. The cost estimates developed for this Revised FFS are primarily for the purpose of comparing remedial alternatives during the remedy selection process, not for establishing project budgets.

4.3 Modifying Criteria

The third group is made up of the Modifying Criteria specified below. These last two criteria are assessed formally after the public comment period, although to the extent that they are known will be factored into the identification of the preferred alternative.

4.3.1 State/Support Agency Acceptance

Assessment of state/agency concerns may not be completed until comments on this Revised FFS are received, but may be discussed, to the extent possible, in the proposed plan issued for public comment. The state/agency concerns that shall be assessed include the following:

1. The state's/agency's position and key concerns related to the preferred alternative and other alternatives; and
2. State/agency comments on ARARs or the proposed use of waivers.

4.3.2 Community Acceptance

This assessment includes determining which components of the alternatives interested persons in the community support, have reservations about, or oppose. This assessment may not be completed until comments on the proposed plan are received.

4.4 Green Sustainable Remediation

The last group is made up of the GSR criteria specified below. There are six criteria included with this analysis, which are then summarized to provide each alternative with an overall GSR rating. The six GSR criteria evaluated with this Revised FFS include the following:

- Greenhouse Gas (GHG) Emissions;
- Toxic Chemical Usage and Disposal;
- Energy Consumption;
- Use of Alternative Fuels;
- Water Consumption; and
- Waste Generation.

5.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

The purpose of the comparative analysis is to identify and compare advantages and disadvantages of each evaluated alternative relative to one another with respect to remedy selection criteria presented in **Section 4.0** in order to determine which of the alternatives best meets those criteria. The comparative analysis is documented in this section and summarized in **Table 7** and **8**. **Table 9** presents a numerical comparison of the evaluated alternatives.

5.1 Threshold Criteria

Only those alternatives that would meet the threshold criteria of providing overall protection of human health and the environment, and whether they would attain compliance with ARARs were carried forward with the comparative analysis, with the exception of Alternative 1. Alternative 1 does not meet the threshold criteria, but was carried forward as it is required for analysis under the NCP. Alternative 2 provides a low achievement of threshold criteria because additional study of natural processes at the site to bury and degrade COC-impacted sediment is required.

Alternatives 3 and 4 will achieve protection of human health and the environment and comply with the identified ARARs. Alternatives 3 and 4 would eliminate, reduce, or control exposure to contaminated sediment; however, contaminated sediment would remain in place under both alternatives, requiring monitoring to ensure long-term effectiveness. Alternative 4 would provide the highest level of protection, since this alternative includes a thicker cover than Alternative 3, resulting in increased sequestration of contaminated sediments.

5.2 Balancing Criteria

5.2.1 Long-Term Effectiveness and Permanence

Alternative 1 is not effective in the long term or permanent. Alternative 2 maybe be effective and permanent in the long term; however, RAOs may not be achieved in a reasonable time frame because the natural degradation processes are poorly understood at the Site and a possible contamination source is located directly upstream of the Site. Alternatives 3 and 4 are effective in the long term; however, contaminated sediment would remain in place under both, requiring long-term O&M and ICs to ensure long-term effectiveness.

In summary, Alternatives 3 and 4 will provide a moderate and high achievement of this criterion, respectively, by reducing COC concentrations in sediments with reactive amendments; however, Alternative 4 provides the most long-term effectiveness and permanence because it ensures that COC-contaminated sediments are sequestered with 0.15 meters (6 inches) of clean material.

5.2.2 Reduction of Toxicity, Mobility, or Volume Through Treatment

Treatment of contaminated sediments to reduce toxicity, mobility, or volume is not a component of Alternatives 1 and 2; therefore, these alternatives provide no achievement of this criterion. Alternatives 3 and 4 provide a moderate to high achievement of this criterion because they include the use of addition amendment material such as permeable Organoclay, phosphate additives (e.g., apatite), bauxite, biopolymers, and zeolite. These amendments reduce the toxicity and mobility of COCs in sediments over time. Alternative 4 provides the highest achievement of this criterion because mobility of COCs in sediment is reduced due to the inclusion of a thin-layer cap.

In summary, Alternative 4 will provide the highest achievement of this criterion by applying amendment material in combination with a thin-layer cap. Alternative 3 provides a moderate achievement of this criterion, since it utilizes amendment material broadcasted throughout the

COC-impacted portions of the Site. Alternatives 1 and 2 will provide the lowest achievement of this criterion because treatment of COC-impacted sediment is not a component of these remedies.

5.2.3 Short-Term Effectiveness

There are no short-term risks associated with Alternatives 1 and 2 as no actions would be implemented at the Site. The rest of the alternatives would have some short-term risks during implementation of the remedy. Short-term adverse effects to aquatic habitat and biota would be similar among Alternatives 3 and 4 and would include displacement of fish and smothering of benthic organisms. Alternative 3 would provide the least adverse effects of these alternatives because only a thin 0.05-meter (2-inch) layer of amendment material would be placed rather than a 0.15-meter (6-inch) thin-layer amended cover as in Alternative 4. The effects from Alternatives 3 and 4 would occur during remedy construction and during the recovery period thereafter. Benthic organisms would be expected to be reestablished for all alternatives within several growing seasons.

In summary, Alternatives 1 and 2 would provide a high achievement of the short-term effectiveness criterion as there would be no impact to surrounding community and aquatic habitat and no risk to Site workers. Alternatives 3 and 4 would have a moderate to high achievement of the short term effectiveness criterion due to an increase in short-term adverse effects to aquatic biota during cover construction; however, impacts are anticipated to be small.

5.2.4 Implementability

There are no implementability concerns associated with Alternatives 1 and 2.

Application of cover materials utilized in Alternatives 3 and 4 would require barging of materials from a nearby staging area or a staging area located along the SLR, such as Hallett Dock #7. It is anticipated that Hallett Dock #7 would be available as a staging area but these alternatives assume the use of Hallett Dock #7 and successful coordination of future access agreements. Methods for placement of cover materials are technically feasible and implementable from an engineering perspective.

Weather could significantly impact productivity, particularly if done in the early spring or late fall. High winds in the late fall produce large waves that could impact productivity. Barge traffic and any Site activities would be postponed in the spring until ice melt is completed. Winter or freezing conditions in the fall could shorten the construction season. Alternative 4 has the longest estimated time to complete and, therefore would stand to be the most impacted by weather.

Implementability also includes administrative feasibility of the remedy. As with most sediment remediation activities, multiple state and federal agencies and other stakeholder input is required, providing a lower achievement of administrative feasibility of implementing a remedy. Additional time would be required to obtain any necessary approvals and permits from other agencies. Alternative 4 would require more coordination with regulatory agencies than Alternative 3 because of the additional material required and increased impacts to the ecosystem. For these reasons Alternatives 3 and 4 provide a moderate to high level of achievement of the implementability criterion.

In summary, Alternatives 1 and 2 have no actions to be implemented and thus provides a high achievement of the implementability criterion. Alternative 3 provides a moderate to high level of achievement, and Alternative 4 provides a moderate level of achievement of the implementability criterion since they only require cover construction.

5.2.1 Cost

Cost estimates developed for each alternative are included in **Section 3.0** and summarized in **Table 3**. The cost estimates include the following: capital costs, including both direct and indirect costs; annual O&M costs; and net present value of capital and O&M costs. While this FFS assumes that Former Hallet Dock #7 will be used as a staging area for Alternatives 3 and 4, costs associated with renting it are not included in this estimate as the property may be purchased by the Port Authority. If the property is not purchased by the Port Authority, rental costs could significantly impact the final cost.

In summary, Alternative 1 provides the most cost-effective option with no costs, followed by Alternative 2 ($250,000) because it requires only monitoring. Alternative 3 ($6,700,000) is the next most cost-effective option as less volume of cover materials are required compared to Alternative 4 ($9,400,000), making Alternative 4 the least cost-effective option. **Table 9** presents a numerical score that compares the cost for all alternatives.

5.3 Modifying Criteria

The modifying criteria, state/support agency acceptance and community acceptance, are assessed formally after the public comment period, and to the extent that they are known will be factored into the identification of the preferred alternative.

5.3.1 State Support/Agency Acceptance

State/agency input will be assessed to assist in determining the appropriate alternative for the Site. Key factors that will influence alternative selection include but are not limited to knowledge of future Site use, Site remediation prioritization, and funding source availability. Alternatives 1 through 4 will be formally assessed after public comment period.

5.3.2 Community Acceptance

Lands surrounding the Site are owned by the City of Duluth and private owners and access is generally limited to the Munger Landing boat launch and fishing dock. Any remediation work completed at the Site involving application of amendments or construction of a cover would require construction of a mooring area adjacent to the boat launch (i.e., driving of dolphin pilings); therefore, coordination with the City of Duluth would be required for implementation of Alternatives 3 and 4, which incorporate cover material placement. Additional coordination would be required with the current or future owners of Hallett Dock #7 for use as a material staging area. The total estimated time required for on-site construction activities for Alternative 3 is shorter than Alternative 4, at 21 and 23 weeks, respectively. The majority of work related to implementation of Alternatives 3 and 4 would take place directly on-site and presumably at a privately owned staging area. It is anticipated that community acceptance of Alternatives 3 and 4 will be high based on the factors outlined above.

5.4 Green Sustainable Remediation Criteria

5.4.1 Greenhouse Gas Emissions

Alternative 1 would have no GHG emissions. Alternative 2 would only produce GHG emissions associated with mobilization/demobilization and boat operation associated with sampling efforts. Alternatives 3 and 4 would result in GHG emissions from the mobilization, operation, and demobilization of all fuel-powered construction equipment required to place cover material. Reduction of emissions can be accomplished by using equipment that is compliant with the latest USEPA non-road engine standards and retrofitting older equipment with appropriate filters.

5.4.2 Toxic Chemical Usage and Disposal

There are no known toxic chemicals associated with any alternatives.

5.4.3 Energy Consumption

Alternative 1 would consume no additional energy. Alternative 2 would consume minimal amounts of fossil fuels compared to the other alternatives. Alternatives 3 and 4 would result in the consumption of fossil fuels for the mobilization, operation, and demobilization of all diesel-powered construction equipment associated with the placement of the cover material, with Alternative 4 requiring the most energy consumption due to the volume of materials placed.

5.4.4 Use of Alternative Fuels

Alternatives 1 and 2 would not require the use of alternative fuels. Biodiesel blended fuels (B10 or B20) could be used as a supplemental fuel source for all diesel-powered construction equipment associated with Alternatives 3 and 4.

5.4.5 Water Consumption

Alternatives 1 and 2 would not require the consumption of water and there are few water consumption considerations associated with Alternatives 3 and 4.

5.4.6 Waste Generation

Alternatives 1, 2, 3, and 4 would not generate significant amounts of waste.

5.5 Comparative Analysis Summary

The comparative analysis of alternatives narrative discussion and quantitation table scored Alternatives 3 and 4 similarly, with Alternative 4 scoring the highest to address contamination at the Site. Alternative 1 does not achieve overall protection of human health and the environment, does not achieve ARARs, is not effective in the long term, and does not reduce toxicity, mobility, or volume of contamination through treatment. Natural processes occurring at the Site are currently poorly understood; therefore, Alternative 2 ranks low for overall protection of human health and the environment, achievement ARARs, and effectiveness in the long term and short term. Alternative 2 does not reduce toxicity, mobility, or volume of contamination through treatment. Short-term risks associated with Alternatives 1 and 2 are low, and both are implementable and cost effective.

Alternative 4 provides the highest achievement of protection of human health and the environment and achievement of ARARs, followed by Alternative 3. Alternatives 3 and 4 have similar long term effectiveness and treatment of contaminants sediments to reduce toxicity, mobility, or volume, although Alternative 4 includes a thicker cover than Alternative 3, which further reduces mobility of COCs. Alternative 3 is superior to Alternative 4 in the short-term effectiveness criterion because there is less disturbance of the aquatic community. Alternative 3 is more implementable than Alternative 4. Alternative 3 is more cost effective than Alternative 4.

The modifying criteria, state/support agency acceptance, and community acceptance are assessed formally after the public comment period. Stakeholder and community input will provide valuable insight as the MPCA considers information for the selection of a preferred alternative. The MPCA will conduct outreach activities to resource managers, current Site users, the public and local units of government prior to the public comment period.

Further studies are recommended during the design phase of the selected alternative. These recommended studies, depending on the alternative selected, may include:

- Hydrodynamic study to understand natural processes such as depositional and scouring forces to inform design and placement cover materials, and effectiveness of MNR, if needed;
- Bench and/or pilot scale testing of amendment materials to determine the most appropriate material for use at the Site. Potential amendment materials include bauxite, biopolymers, permeable Organoclay, phosphate additives (i.e., apatite), and zeolite (USEPA, 2013); and
- Bench and/or pilot scale testing to determine appropriate application rates for the selected amendment material.

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Figures

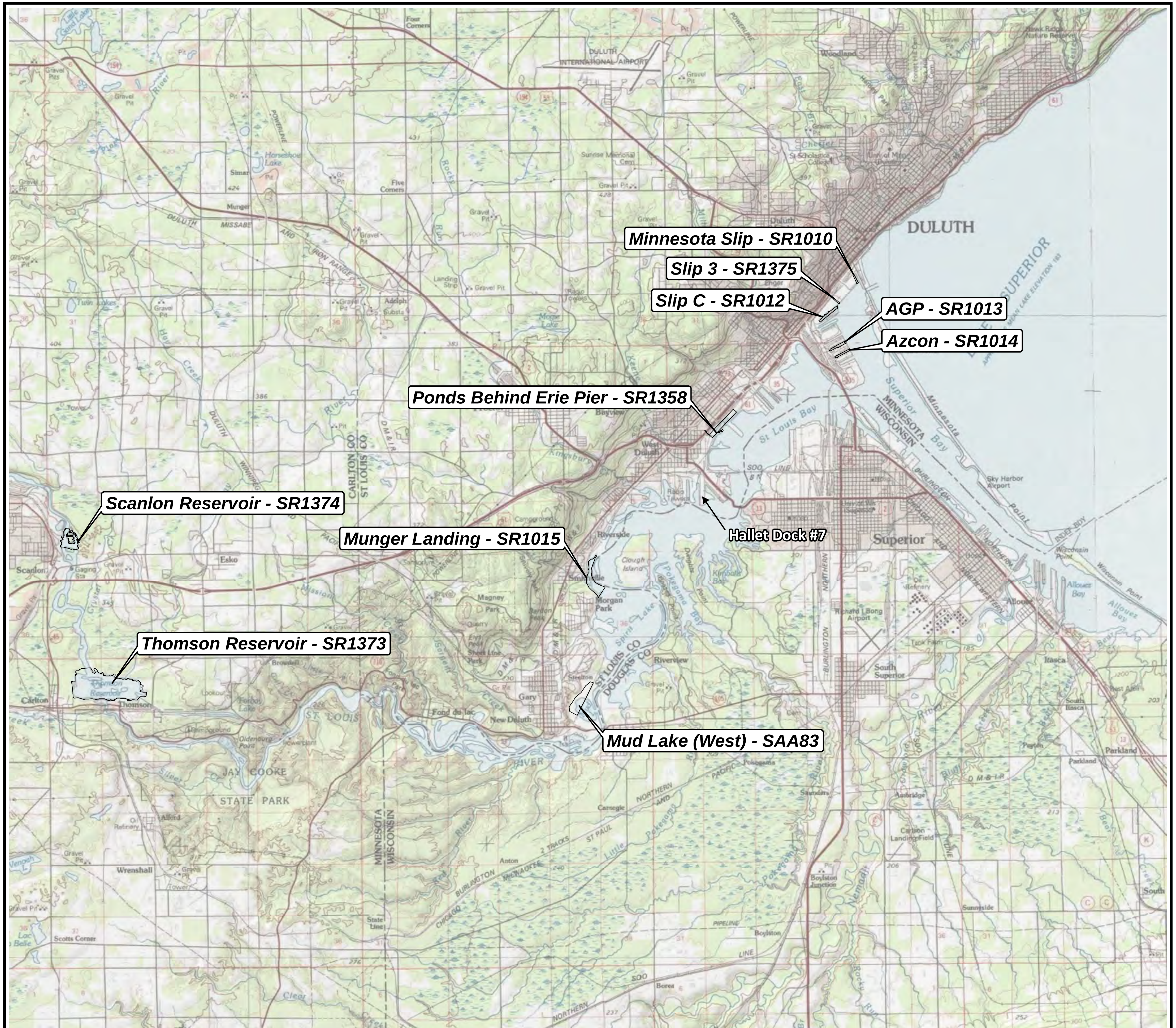
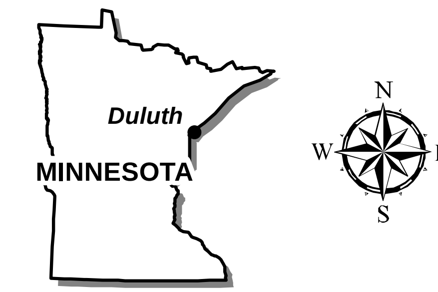


Figure 1

Site Location Map

Munger Landing
SLR Sediment AOCs

Duluth, MN



Map Projection: NAD 1983 UTM Zone 15 N
Basemap: National Geographic Society, i-cubed

0 2 4 Miles

0 3 6 Kilometers

1 inch = 10,000 feet

Site Location (Labeled on map)

CLEAN WATER LAND & LEGACY AMENDMENT

Bay West
Customer-Focused Environmental & Industrial Solutions

Drawn By: SG Date Drawn/Revised:6/7/2016 Project No.J150329

Y:\Clients\MPCA\SLR_Sediment_AOCs\Munger_Landing\MapDocs\J150329 FIG 1 Munger Landing Site Location Map.mxd

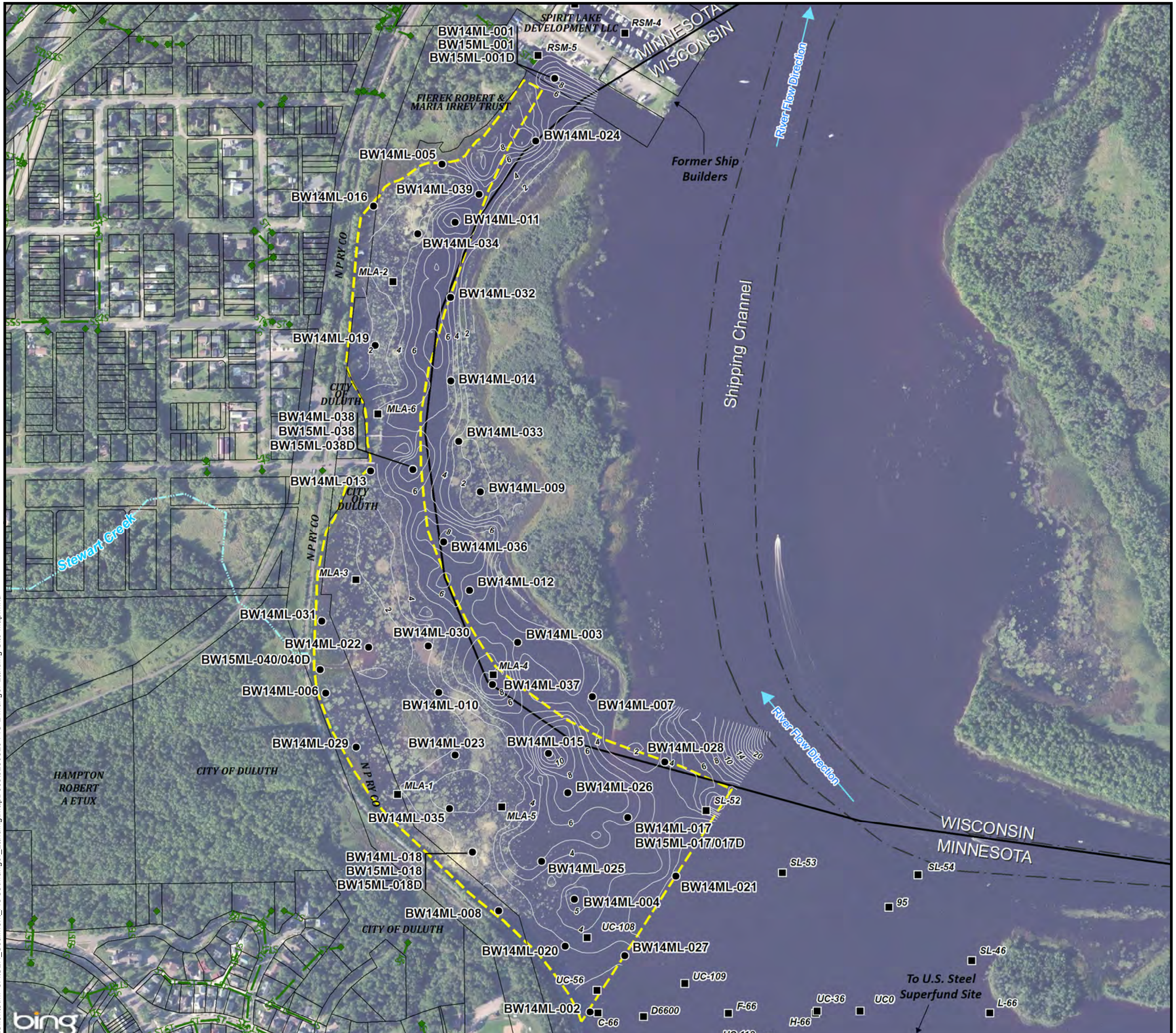
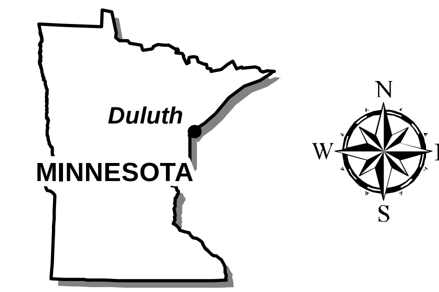


Figure 2

Site Map

Munger Landing SLR Sediment AOCs

Duluth, MN



Map Projection: NAD 1983 UTM Zone 15 N
Basemap: Bing Aerial Imagery WMS (July-September 2011)

0 500 1,000 Feet
0 150 300 Meters
1 inch = 450 feet

- Sediment Sample (Bay West 2014)
- Historical Sediment Sample
- Sewer Outfall
- Sanitary Sewer
- Storm Sewer
- Shipping Channel
- State Border
- Bathymetry Elevation Contour
- Munger Landing Site Boundary
- Parcel Boundary (With Property Owners)

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Y:\Clients\MPCA\SLR_Sediment_AOCs\Munger_Landing\MapDocs\J150329 FIG 2 Munger Landing Site Map.mxd

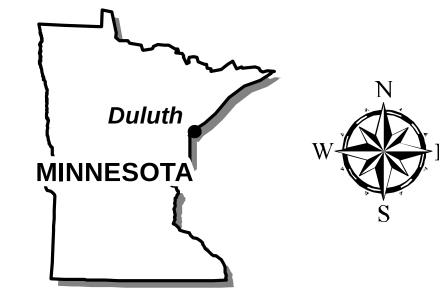
Y:\Clients\MPCA\SLR_Sediment_AOCs\Munger_Landing\MapDocs\J150329 FIG 3 Munger Landing Bathymetry.mxd

Figure 3

Bathymetry

Munger Landing
SLR Sediment AOCs

Duluth, MN



Map Projection: NAD 1983 UTM Zone 15 N
Basemap: Bing Aerial Imagery WMS (July-September 2011)

0 500 1,000 Feet

0 150 300 Meters

1 inch = 450 feet

- Sediment Sample (Bay West 2014)
- Historical Sediment Sample
- Sewer Outfall
- Sanitary Sewer
- Storm Sewer
- Shipping Channel
- State Border
- Bathymetry Elevation Contour
- Munger Landing Site Boundary

Water Depth

ELEVATION ABOVE MSL	DEPTH BELOW CHART DATUM
600 ft	0.9 ft
593 ft	8 ft
575 ft	26 ft

(Based on Jan 2014 GPR Data)
NOTE: Water depth based on 601.1 ft AMSL low water datum

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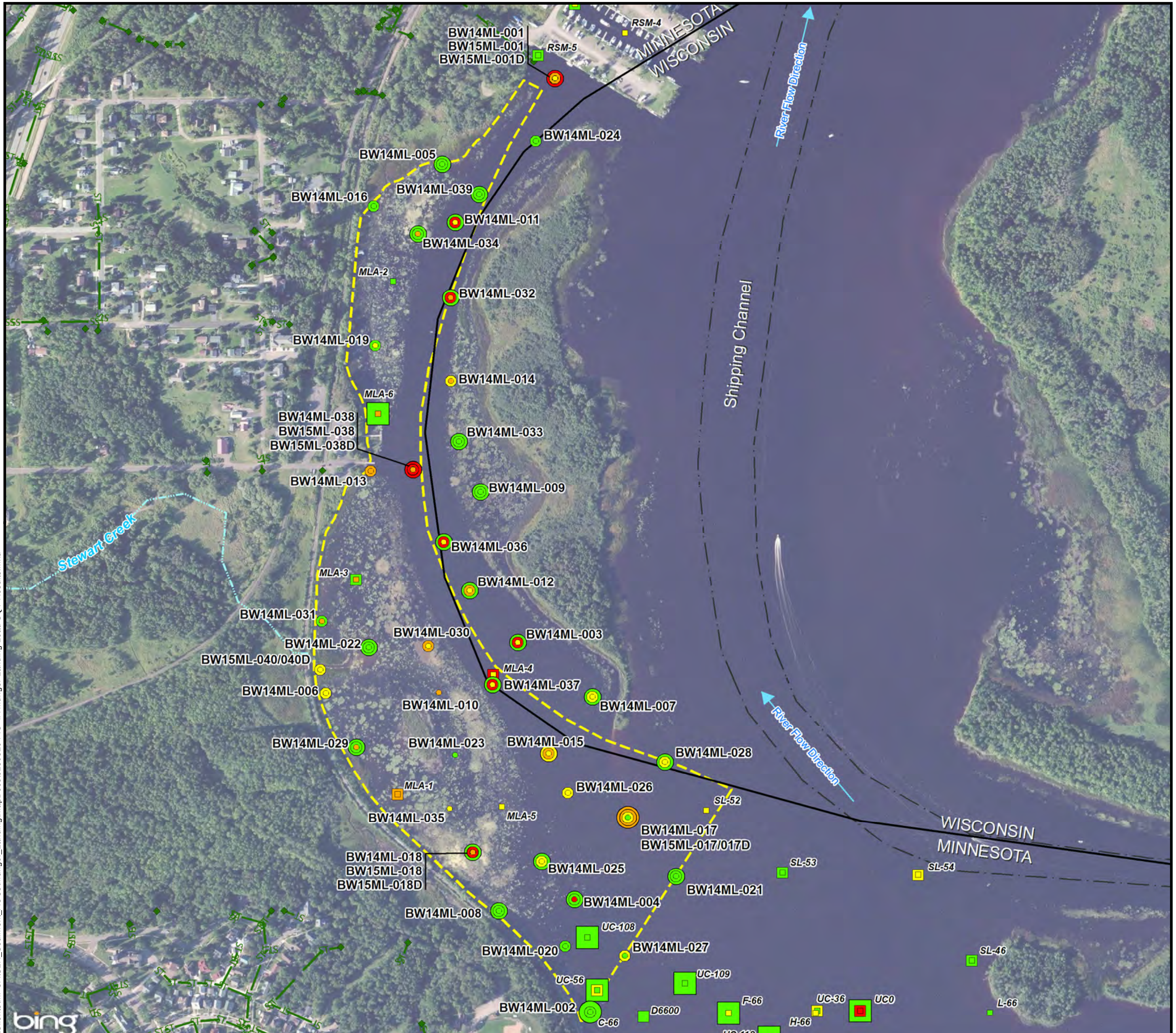


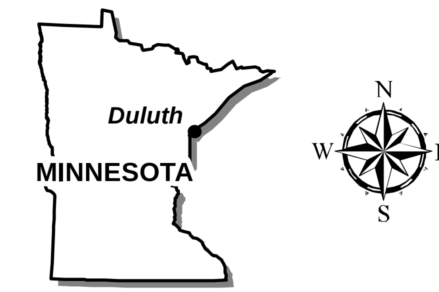
Y:\Clients\MPCA\SLR_Sediment_AOCs\Munger_Landing\MapDocs\J150329 FIG 4A Munger Landing Lead SQT Results.mxd

Figure 4A

Lead SQT Results

Munger Landing SLR Sediment AOCs

Duluth, MN



Map Projection: NAD 1983 UTM Zone 15 N
Basemap: Bing Aerial Imagery WMS (July-September 2011)

0 500 1,000 Feet

0 150 300 Meters

1 inch = 450 feet

- Sewer Outfall
- Sanitary Sewer
- Storm Sewer
- Munger Landing Site Boundary

Sample Type

- Sediment Sample (Bay West 2014/2015)
- Historical Sediment Sample

Sample Interval

- 0-0.15 m
- 0.15-0.50 m
- 0.50-1.0 m
- >1.0 m

Lead SQT Comparison

- Does not exceed Level 1 SQT (36 mg/kg)
- Exceeds Level 1 SQT (36 mg/kg)
- Exceeds Midpoint SQT (83 mg/kg)
- Exceeds Level 2 SQT (130 mg/kg)

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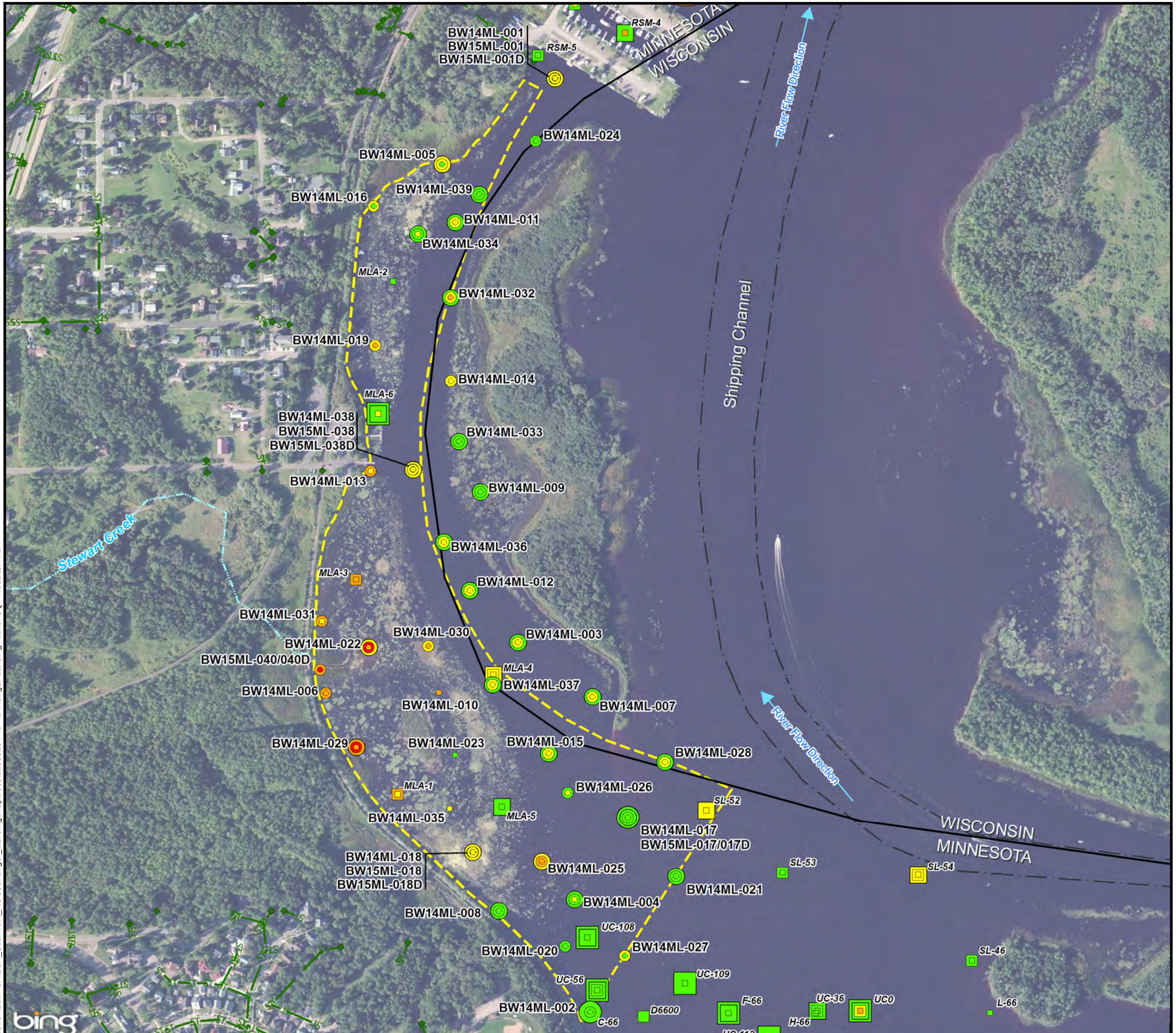
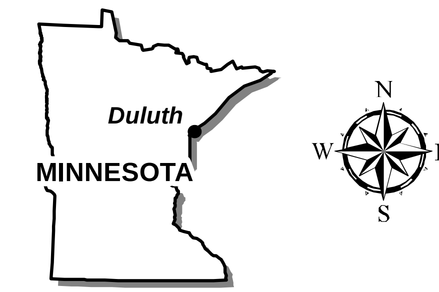


Figure 4B

Nickel SQT Results

Munger Landing SLR Sediment AOCs

Duluth, MN



Map Projection: NAD 1983 UTM Zone 15 N
Basemap: Bing Aerial Imagery WMS (July-September 2011)

0 500 1,000 Feet
0 150 300 Meters
1 inch = 450 feet

Sewer Outfall
Sanitary Sewer
Storm Sewer
Munger Landing Site Boundary

Sample Type

Sediment Sample (Bay West 2014/2015)
Historical Sediment Sample

Sample Interval

0-0.15 m
0.15-0.50 m
0.50-1.0 m
>1.0 m

Nickel SQT Comparison

Does not exceed Level 1 SQT (23 mg/kg)
Exceeds Level 1 SQT (23 mg/kg)
Exceeds Midpoint SQT (36 mg/kg)
Exceeds Level 2 SQT (49 mg/kg)

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Y:\Clients\MPCA\SLR_Sediment_AOCs\Munger_Landing\MapDocs\J150329 FIG 4B Munger Landing Nickel SQT Results.mxd

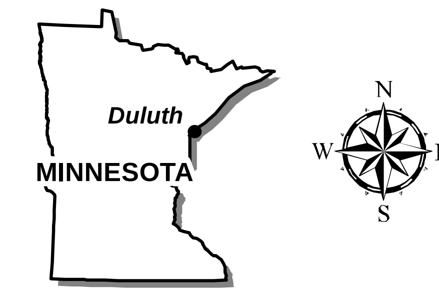
Y:\Clients\MPCA\SLR_Sediment_AOCs\Munger_Landing\MapDocs\J150329 FIG 4C Munger Landing Zinc SQT Results.mxd

Figure 4C

Zinc SQT Results

Munger Landing
SLR Sediment AOCs

Duluth, MN



Map Projection: NAD 1983 UTM Zone 15 N
Basemap: Bing Aerial Imagery WMS (July-September 2011)

0 500 1,000 Feet

0 150 300 Meters

1 inch = 450 feet

Sewer Outfall
Sanitary Sewer
Storm Sewer
Munger Landing Site Boundary

Sample Type

Sediment Sample (Bay West 2014/2015)
Historical Sediment Sample

Sample Interval

0-0.15 m
0.15-0.50 m
0.50-1.0 m
>1.0 m

Zinc SQT Comparison

Does not exceed Level 1 SQT (120 mg/kg)
Exceeds Level 1 SQT (120 mg/kg)
Exceeds Midpoint SQT (290 mg/kg)
Exceeds Level 2 SQT (460 mg/kg)

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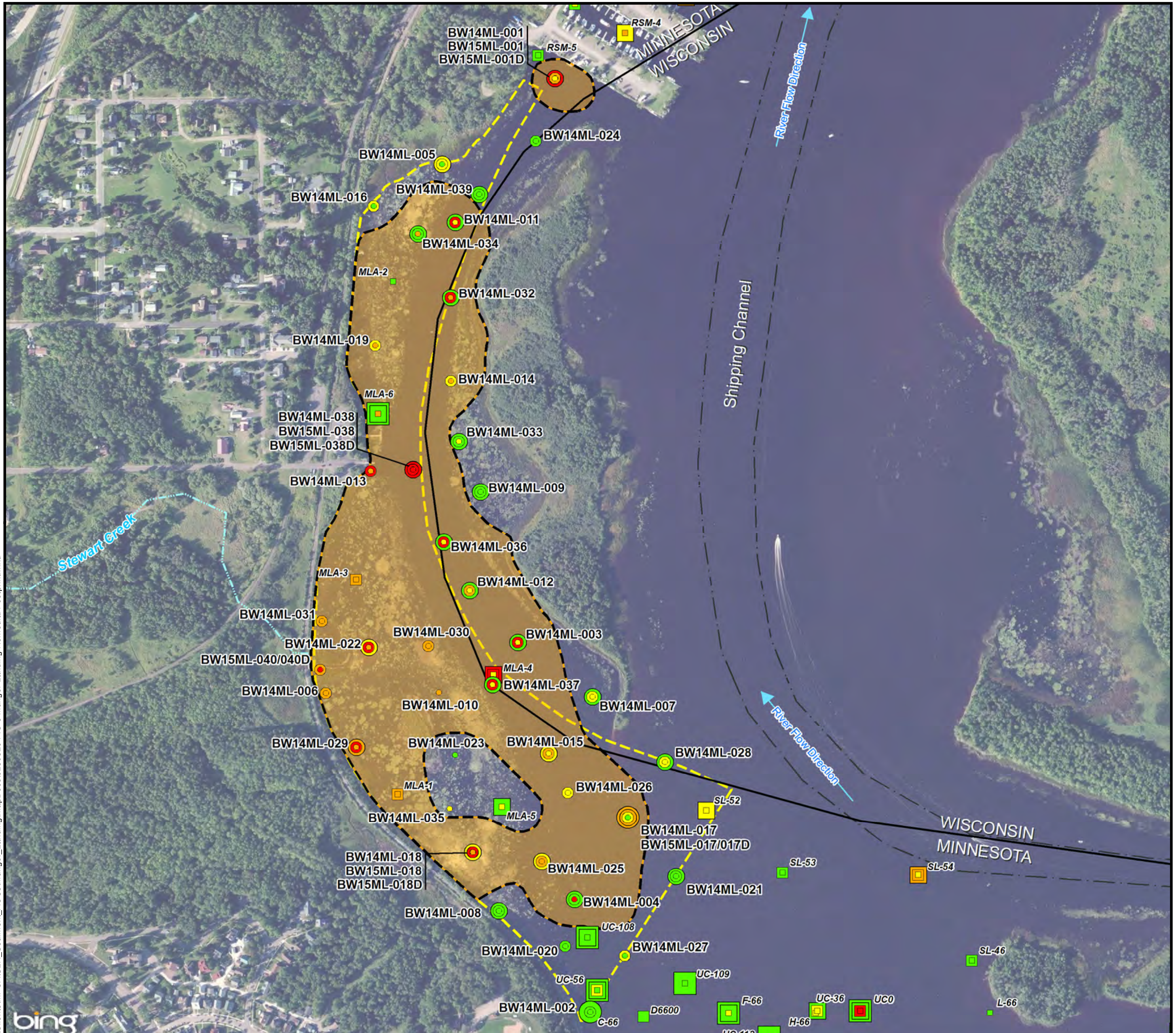


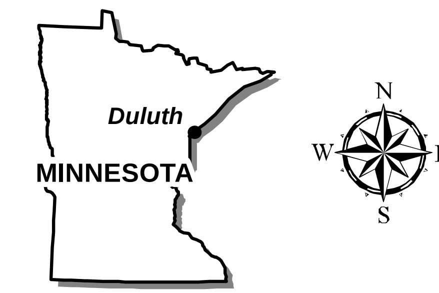
Y:\Clients\MPCA\SLR_Sediment_AOCs\Munger_Landing\MapDocs\J150329 FIG 5 Munger Landing Remedial Footprint.mxd

Figure 5

Remedial Footprint

Munger Landing
SLR Sediment AOCs

Duluth, MN



Map Projection: NAD 1983 UTM Zone 15 N
Basemap: Bing Aerial Imagery WMS (July-September 2011)

0 500 1,000 Feet
0 150 300 Meters

1 inch = 450 feet

Munger Landing Site Boundary

Remedial Footprint (59 Acres)

Sample Type

Sediment Sample (Bay West 2014/2015)

Historical Sediment Sample

Sample Interval

0-0.15 m

0.15-0.50 m

0.50-1.0 m

>1.0 m

Lead/Nickel/Zinc SQT Comparison

Does not exceed Level 1 SQT for lead, nickel, and/or Zinc

Exceeds Level 1 SQT for lead, nickel, and/or zinc

Exceeds Midpoint SQT for lead, nickel, and/or zinc

Exceeds Level 2 SQT for lead, nickel, and/or zinc

Lead/Nickel/Zinc SQT Exceedance Areas

Estimated Area Exceeding Midpoint SQT (46.50 Acres - MN; 12.50 Acres - WI)

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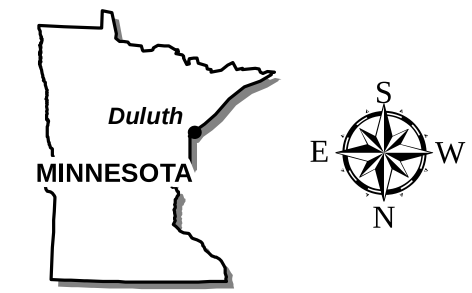
Figure 6

Conceptual Site Model

Munger Landing
SLR Sediment AOCs

Duluth, MN



Map Projection: NAD 1983 UTM Zone 15 N
Basemap: Bing Aerial Imagery WMS (July-September 2011)

DRAWING NOT TO SCALE

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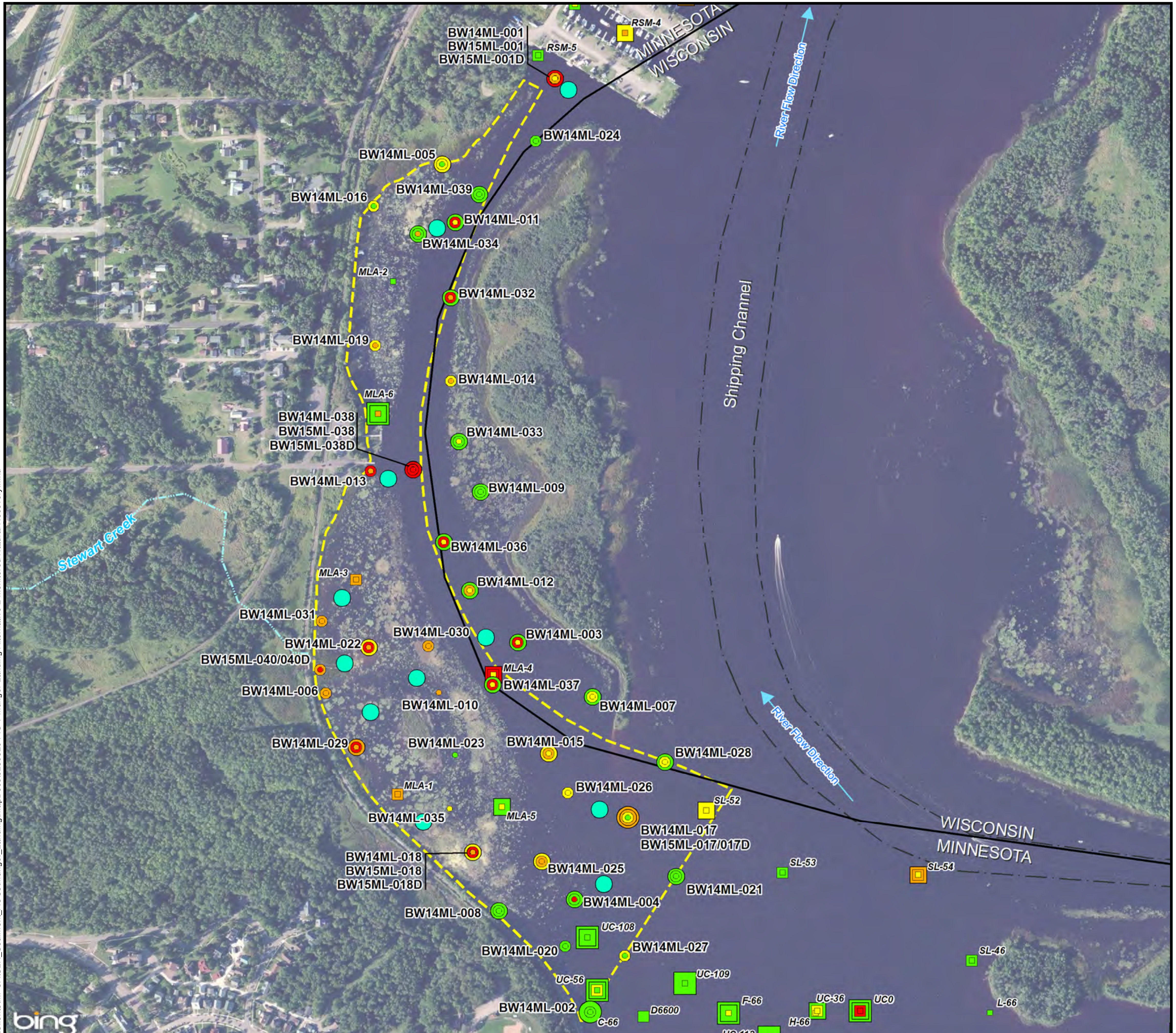


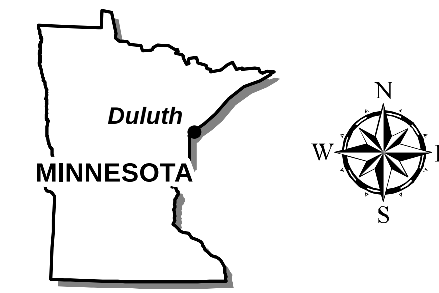
Y:\Clients\MPCA\SLR_Sediment_AOCs\Munger_Landing\MapDocs\J150329 FIG 7 Munger Landing Alternative 2 Monitored Natural Recovery.mxd

Figure 7

Alternative 2 Monitored Natural Recovery

Munger Landing SLR Sediment AOCs

Duluth, MN



Map Projection: NAD 1983 UTM Zone 15 N
Basemap: Bing Aerial Imagery WMS (July-September 2011)

0 500 1,000 Feet

0 150 300 Meters

1 inch = 450 feet

Proposed Monitoring Location

Munger Landing Site Boundary

Sample Type

Sediment Sample (Bay West 2014/2015)

Historical Sediment Sample

Sample Interval

0-0.15 m

0.15-0.50 m

0.50-1.0 m

>1.0 m

Lead/Nickel/Zinc SQT Comparison

Does not exceed Level 1 SQT for lead, nickel, and/or Zinc

Exceeds Level 1 SQT for lead, nickel, and/or zinc

Exceeds Midpoint SQT for lead, nickel, and/or zinc

Exceeds Level 2 SQT for lead, nickel, and/or zinc

Bay West
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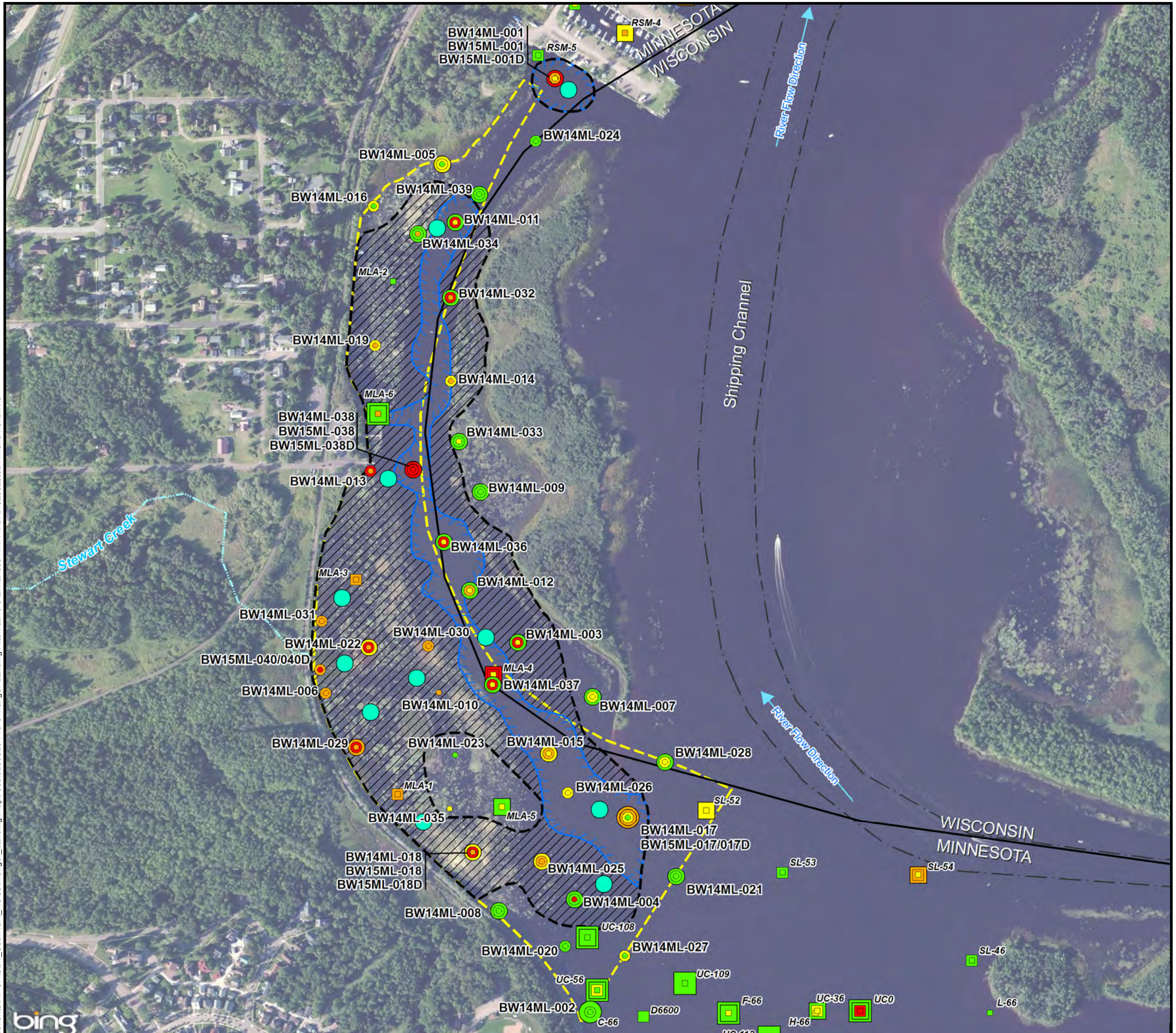

Figure 8

Alternative 3 - Enhanced MNR with Broadcasted Amendment

Munger Landing SLR Sediment AOCs

Duluth, MN

Duluth
MINNESOTA

N W E S

Map Projection: NAD 1983 UTM Zone 15 N
Basemap: Bing Aerial Imagery WMS (July-September 2011)

0 500 1,000 Feet
0 150 300 Meters

1 inch = 450 feet

- Proposed Monitoring Location
- Open Water Areas - 15.04 Acres (0.05m Broadcasted Amendment)
- Emergent Vegetation Areas - 44.06 Acres (0.05m Broadcasted Amendment)
- Remedial Areas (59 Acres)
- Munger Landing Site Boundary

Sample Type

- Sediment Sample (Bay West 2014/2015)
- Historical Sediment Sample

Sample Interval

- 0-0.15 m
- 0.15-0.50 m
- 0.50-1.0 m
- >1.0 m

Lead/Nickel/Zinc SQT Comparison

- Does not exceed Level 1 SQT for lead, nickel, and/or Zinc
- Exceeds Level 1 SQT for lead, nickel, and/or zinc
- Exceeds Midpoint SQT for lead, nickel, and/or zinc
- Exceeds Level 2 SQT for lead, nickel, and/or zinc

Bay West
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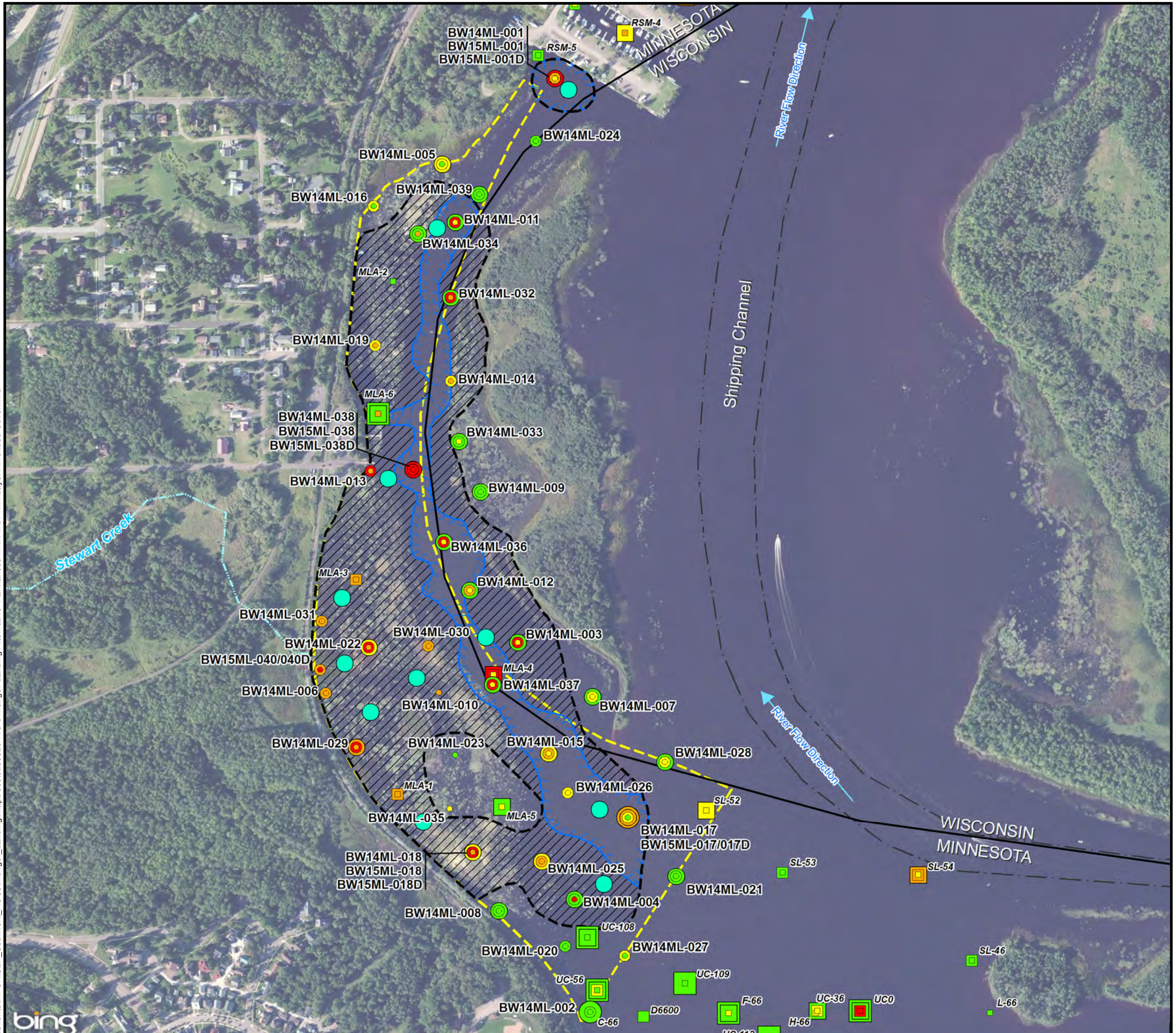
Y:\Clients\MPCA\SLR_Sediment_AOCs\Munger_Landing\MapDocs\J150329 FIG 8 Munger Landing Alternative 3 Enhanced MNR with Broadcasted Amendment.mxd



Y:\Clients\MPCA\SLR_Sediment_AOCs\Munger_Landing\MapDocs\J150329 FIG 9 Munger Landing Alternative 4 Enhanced MNR with Thin Layer Amended Cover.mxd

Figure 9

Alternative 3 - Enhanced MNR with Thin-Layer Amended Cover

Munger Landing SLR Sediment AOCs

Duluth, MN

Duluth
MINNESOTA
N W E S

Map Projection: NAD 1983 UTM Zone 15 N
Basemap: Bing Aerial Imagery WMS (July-September 2011)

0 500 1,000 Feet
0 150 300 Meters

1 inch = 450 feet

Proposed Monitoring Location
Open Water Areas - 15.04 Acres (0.15m amended cover)
Emergent Vegetation Areas - 44.06 Acres (0.15m amended cover)
Remedial Areas (59 Acres)
Munger Landing Site Boundary

Sample Type

Sediment Sample (Bay West 2014/2015)
Historical Sediment Sample

Sample Interval

0-0.15 m
0.15-0.50 m
0.50-1.0 m
>1.0 m

Lead/Nickel/Zinc SQT Comparison

Does not exceed Level 1 SQT for lead, nickel, and/or Zinc
Exceeds Level 1 SQT for lead, nickel, and/or zinc
Exceeds Midpoint SQT for lead, nickel, and/or zinc
Exceeds Level 2 SQT for lead, nickel, and/or zinc

Bay West
Customer-Focused Environmental & Industrial Solutions

Drawn By: S.G. Date Drawn/Revised:6/24/2016 Project No.J150329

Tables

Table 1
Contaminants of Concern Summary
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Chemical	Units	Cleanup Level	Maximum Concentration
Cadmium	mg/kg	3	3.1
Copper	mg/kg	91	140
Lead	mg/kg	83	233
Mercury	mg/kg	0.64	6.3
Nickel	mg/kg	36	52.3
Zinc	mg/kg	290	832
Total PAHs	µg/kg	12,300	35,233
PCBs	µg/kg	370	43,700
Dioxins	ng TEQ/kg	11.2	85.4

mg/kg - milligrams per kilogram
ng TEQ/kg - nanograms toxic equipvalency per kilogram
µg/kg - micrograms per kilogram

Table 2
Technologies Screening Summary
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

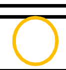
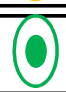
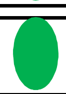
Category	Technology	Description	Applicability	Ranking						Retained for Consideration	Rationale
				Effectiveness		Implementablility		Relative Cost			
Institutional Controls	Institutional Controls	Institutional controls in the form of an environmental restrictive covenant or conditions of future permits may be used to prevent exposure and contact with impacted soil or sediment by restricting land uses or disturbances to the material.	May consist of fish consumption advisories, commercial fishing bans, waterway use restricitons, or deed restrictions	○	Effective in meeting RAOs when combined with other remedies.	●	Easily implemented with little distruption to the Site.	$	Minimal but there are long term costs associated with initiating and maintaining institutional controls.	Yes.	Some institutional controls already in place; however, additional controls are expected to be a required component of any remedy.
Monitoring and Evaluation	Monitoring	The collection and analysis chemical, physical, and/or biological data over a sufficient period of time and frequency to determine the status and/or trend in one or more environmental parameters or characteristics.	Monitoring should be conducted to asses compliance with design and performance standards; to assess short-term remedy performance and effectiveness in meeting sediment cleanup levels; and/or to evaluate long-term remedy effectiveness in achieving RAOs and in reducing human health and/or environmental risk.	○	Effective in meeting RAOs when combined with other remedies.	●	Highly implementable with no disturbance to the Site.	$	The main cost is associated with laboratory analysis.	Yes.	Monitoring is expected to be a required component of any remedy.
Natural Recovery	Monitored Natural Recovery	MNR leaves impacted sediment in place and relies on ongoing, naturally occurring processes to isolate, destroy, or reduce exposure or toxicity of impacted sediment.	Burial of contaminated sediments does not appear to be occuring at the Site and depsotion rates are not likely sufficient to isolate COCs in reasonable timeframe and concentrations do not appear to be reducing.	○	Burial may be occuring based on hydrodynamic studies directly upstream and COC reduction unclear due to nearby source (U.S. Steel).	●	Highly implementable with no disturbance to the Site.	$	The main cost of NR is associated with monitoring.	Yes.	Effectiveness at the Site has not been demonstrated but may be possible based on hydrodynamic studies conducted at U.S. Steel Site.
	Enhanced Monitored Natural Recovery	EMNR adds amendments to the sediment to accelerate physical isolation process and facilitates re-establishment of benthic or plant habitat. May include a granular or carbon sorbent cover (over sediments) or biological stimulants (to soil).	Use of an amendment may increase the rate at which sediment contaminant concentrations are reduced/made less available over time. Natural bioturbation processes will assit in mixing amendments into in-situ sediments.	●	Sediment amendments have been used successfully in the past to reduce the availability of contaminants to biota.	◉	Implementable; however, requires site access, staging area, and placement equipment. Impact to Site operation can be minimal with advanced planning.	$$	Greater initial cost than NR due to thin cover or amendment placement, but less expensive than conventional cap or sediment removal.	Yes.	Effectiveness of chemical contaminant sequestration in sediments via addition of amendments has been demonstrated. Allows for remedial action with limited disturbance to established wetland areas.
Capping	Capping	Capping provides a physical barrier and chemical isolation from COCs. Caps may be constructed from clean sediment, sand, gravel, geotextiles, liners, reactive or absorptive material and may consist of multiple layers. Granular sediment caps can provide erosion protection and limit bioturbation.	Cap thickness depends on bioactive zone (BAZ) thickness requirements, which vary by habitat, substrate and water depth. A cap may alter hydrologic conditions and Site use.	◉	Highly effective and proven technology. Solubilility and eventual migration of COCs through capping material is possible. Would reduce water depth significantly in already shallow areas and may turn wetland areas in upland areas.	⊗	Implementable, but would prohibitively disrupt a well established ecosystem.	$$$	Capping costs are generally less than sediment removal, and depend on cap thickness, material, lateral extent and surface water engineering factors. Material costs for a synthetic cap are generally higher than a granular cap.	No.	Would likely turn wetland areas into upland areas and therefore was not retained for consideration.

Category	Technology	Description	Applicability	Ranking						Retained for Consideration	Rationale
				Effectiveness		Implementablility		Relative Cost			
Excavation and Removal	Mechanical Dredging	Sediment is lifted to the surface using a mechanical excavator or crane and placed on a barge for transport. Removed sediment has a similar moisture content as the in situ material, requiring dewatering prior to disposal. Residual cover is typically needed to manage remaining impacts.	Mechanical dredging is implementable at the Site but no staging area locations are present in which to stabilize sediments. Sediments must be slurried and pumped to an off-site staging area. Sediment controls expected to be required.	●	Highly effective and proven technology; however, resuspension may limit effectiveness.	⊗	Requires dredging equipment and upland staging infrastructure for sediment dewatering and transportation. Less staging space required than hydraulic dredging. Would prohibitively disrupt a well established ecosystem.	$$$	Main capital costs include equipment mobilization, staging area devlopment, equipment operation, residual cover materials, and construction and operation of a containment area for dredged material.	No	Suitible for use at the Site, but mechanically dredged sediments must be slurried with water and pumped to an off-site staging area.
	Hydraulic Dredging	Hydraulic dredging captures water with the sediment and removes it by pumping the sediment slurry typically through a pipeline to the dewatering location or final disposal site. High water content of slurry requires significant dewatering. Residual cover is typically needed to manage remaining impacts.	Hydraulic dredging is implementable at the Site. Sediments must be pumped to an off-site staging area. Sediment controls expected to be required.	●	Highly effective and proven technology; however, resuspension may limit effectiveness.	⊗	Implementable; however, requires large staging area for dewatering equipment, requires more water treatment than mechanical dredging. Would prohibitively disrupt a well established ecosystem.	$$$$	Additional treatment and disposal costs due to greater water content of the slurried sediment.	No	Suitable for use at the Site, but dredged sediments must be pumped to an off-site staging area.
	Mechanical Removal in Dry Conditions	Water is diverted or drained from the excavation area using a containment barrier such as a cofferdam to allow for excavation of dry sediment with conventional equipment (e.g. backhoe). Typically limited to shallow areas.	Well suited for shallow areas and geometry that allows for construction of containment barrier and water diversion.	●	Effective and proven technology. Allows for visual inspection during removal. Minimal resuspension/redeposition. High degree of accuracy.	⊗	Feasible in small-volume removal areas. Site preparation difficult due to water management. Would prohibitively disrupt a well established ecosystem.	$$$	Costs are similar to mechanical dredging, with the added cost to construct diversion or containment structures.	No	Not suitable when compared to mechanical or hydraulic dredging.
Disposal	Off-Site	Removed sediment is transported to an offsite disposal location that will accept the waste. Dewatering of sediments is generally required before transport.	Transportation of large volumes of sediment would create significant truck traffic through the surrounding community for a long duration.	NA	Dredging not implementable at the Site; therefore disposal is not required.	NA	Dredging not implementable at the Site; therefore disposal is not required.	NA	Dredging not implementable at the Site; therefore disposal is not required.	No	Dredging not implementable at the Site; therefore disposal is not required.
	Confined Disposal Facility (CDF)	CDFs are engineered structures enclosed by dikes and specifically designed to contain sediment. CDFs may be located either upland (above the water table), near-shore (partially in the water), or completely in the water (island CDFs).	Creation of a CDF would result in destruction of wetland areas.	NA	Dredging not implementable at the Site; therefore disposal is not required.	NA	Dredging not implementable at the Site; therefore disposal is not required.	NA	Dredging not implementable at the Site; therefore disposal is not required.	No	Dredging not implementable at the Site; therefore disposal is not required.
	On-site Contained Aquatic Disposal (CAD)	Dredged or excavated sediment is disposed within a natural or excavated depression elsewhere in the water body.	A suitable location to accommodate entire sediment volume is not available.	NA	Dredging not implementable at the Site; therefore disposal is not required.	NA	Dredging not implementable at the Site; therefore disposal is not required.	NA	Dredging not implementable at the Site; therefore disposal is not required.	No	Dredging not implementable at the Site; therefore disposal is not required.

Category	Technology	Description	Applicability	Ranking: Effectiveness		Ranking: Implementability		Ranking: Relative Cost		Retained for Consideration	Rationale
In Situ Treatment	Immobilization	Immobilization treatments add chemicals or cements to reduce the leachability of COCs. Mechanisms include solidification (encapsulation) or stabilization (chemical or absorptive reactions that convert COCs to less toxic or mobile forms).	Implementation at a sediment site is difficult due to submerged work requirement and restricting future Site use.	○	Is effective for COCs. Stabilization of sediments reduces erosion potential. May result in poor environment for benthic community.	⊗	Sediment mixing can be difficult. May require dewatering. Requires equipment for mixing. Solidified sediment would restrict future Site use.	$$$	Costs for solidification or stabilization affected by the quantity and type of reagents added to the waste and the need for specialized equipment for mixing reagents with sediment.	No	Not proven to be effective for sediments. Costly and more difficult to implement than other technologies.
	Enhanced Bioremediation	Microbial degradation by bacteria or fungi is enhanced by adding materials such as oxygen, nitrate, sulfate, hydrogen, nutrients, or microorganisms to the sediment.	Can be effective for COCs.	○	Requires specific geochemical parameters to be successful (temperature, Ph, nutrient availability)	○	Easily implemented with little disruption to the Site.	$$$	Costs of enhanced bioremediation are relatively low, but several treatments and monitoring similar to MNR may be required.	No	Difficult to implement sub aqueously.
	Oxidation/Reduction	Chemicals are injected into sediment to act as an oxidant/electron acceptor to facilitate aerobic decomposition of organic matter.	chemical addition may create toxic conditions.	○	Chemical addition may create toxic conditions.	○	Bench-scale testing and pilot-scale testing required to determine the type, concentration, and quantity of oxidant and amendments required.	$$$	Costs include bench- or pilot-scale tests. Monitoring may be required.	No	Not proven safe for subaqueous conditions.
	Chemical Oxidation	The addition of chemical oxidizers to sediment can cause the rapid and complete chemical destruction of many toxic organic chemicals.	Limited effectiveness for Site COCs.	⊗	Addition of chemicals may form temporarily toxic conditions for benthic or aquatic organisms	◉	Pilot studies would be required to determine the effectiveness of specific oxidants for COCs.	$$$	Costs include bench- or pilot-scale tests to determine effectiveness, oxidants for injection, and a delivery system. Monitoring may also be required.	No	Limited effectiveness. Chemical addition may create toxic conditions.
	Phytoremediation	Phytoremediation uses plant species to remove, transfer, stabilize, and destroy COCs in soil and sediment. Generally limited to sediments in shallow water zones and low concentrations.	Habitat restoration not likely necessary, technology not effective in open water areas of Site.	○	Effective only in shallow contaminated areas, which comprise only 1/3 of the Site area.	●	Implementation involves planting and in some cases harvesting with little disruption to the Site.	$$	Primary costs are purchasing and planting applicable species. Monitoring may also be required.	No	May be implemented for habitat restoration, but not effective alone.
	Adsorption	Adsorbents can be used as sediment amendments for in situ treatment of COCs. Sorption organics can take place simultaneously with a suitable combination of sorbents.	May be useful as EMNR amendment.	◉	Sorption of COCs possible with amendment materials.	◉	Amendments can be delivered to the sediment in the form of pellets or mixed into other media (i.e., sand) to resist re-suspension.	$$	The main costs include the adsorbent material, and a method for depositing it on the surface sediment. Monitoring may also be required.	Yes.	Effectiveness of chemical contaminant sequestration in sediments via addition of amendments has been demonstrated. Allows for remedial action with limited disturbance to established wetland areas.

Category	Technology	Description	Applicability	Ranking						Retained for Consideration	Rationale
				Effectiveness		Implementablility		Relative Cost			
Dewatering	Passive Dewatering	Passive dewatering relies on natural evaporation and drainage to remove moisture from the sediment. Drainage may be driven by gravity or assisted with a vacuum pump. Passive dewatering may occur in CDFs, lagoons, tanks, or temporary holding/rehandling facilities.	Could be utilized if sufficient space is available off-site for long-term passive dewatering to take place. Adjacent U.S. Steel Site is currently serving this purpose for Radio Tower Bay sediments.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	No	Dredging not implementable at the Site; therefore dewatering is not required.
	Sediment Reworking	Reworking sediments to promote drainage, and mixing sediments with excavation equipment can enhance passive dewatering.	If a CDF is constructed, sediment reworking could be performed within the CDF.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	No	Dredging not implementable at the Site; therefore dewatering is not required.
	Hydrospoic Amendment Addition	Dredged sediments are mixed with amendments such as slags or cementitious materials to remove moisture and improve strength and stability.	Could be used to enhance dewatering in conjunction with passive dewatering	NA	Dredging not implementable at the Site; therefore dewatering is not required.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	No	Dredging not implementable at the Site; therefore dewatering is not required.
	Geotextile Tube Dewatering	Sediment slurry from hydraulic dredging is pumped into the geotextile tube and filtered by the geotextile fabric. Sediment is retained within the geotextile tube, while free liquids pass through the exterior of the tube.	Applicable to hydraulically dredged sediments or mechancially dredged sediments if slurried and pumped to dewatering area.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	No	Dredging not implementable at the Site; therefore dewatering is not required.
	Mechanical Dewatering	Mechanical dewatering technologies include use of plate filters, presses, centrifuges or other equipment to squeeze, press, or draw water from dredged sediment.	Requires homogeneous waste stream provided by hydraulic dredging methods and site sediments.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	No	Dredging not implementable at the Site; therefore dewatering is not required.
	Rapid Dewatering Systems	A system that continuously processes the slurry from a hydraulic dredge and separates solids into piles of debris; shells; and gravel, sand, and fines. Includes polymer addition and flocculation, which may remove some COCs.	Applicable to hydraulically dredged sediments or mechancially dredged sediments if slurried and pumped to dewatering area.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	NA	Dredging not implementable at the Site; therefore dewatering is not required.	No	Dredging not implementable at the Site; therefore dewatering is not required.

Category	Technology	Description	Applicability	Ranking						Retained for Consideration	Rationale
				Effectiveness		Implementablility		Relative Cost			
Water Treatment	Filtration	Filters remove solids and sediments from wastewater, also removing absorbed COCs from the waste stream. Flocculants may be added to the waste stream to facilitate solids removal.	Filtration is a standard method for water treatment and would be effective at removing site COCs sorbed to suspended sediments in the waste stream.	NA	Dredging not implementable at the Site; therefore water treatment is not required.	NA	Dredging not implementable at the Site; therefore water treatment is not required.	NA	Dredging not implementable at the Site; therefore water treatment is not required.	No.	Dredging not implementable at the Site; therefore water treatment is not required.
	Liquid Adsorption	Involves pumping water through a vessel containing granular activated carbon (GAC), organoclay, or another adsorbent material; dissolved compounds to adsorb to its surface.	Conventional adsorptive materials would remove metals.	NA	Dredging not implementable at the Site; therefore water treatment is not required.	NA	Dredging not implementable at the Site; therefore water treatment is not required.	NA	Dredging not implementable at the Site; therefore water treatment is not required.	No.	Dredging not implementable at the Site; therefore water treatment is not required.
	Advanced Oxidation	Advanced oxidation uses UV light and the addition of strong oxidizers to primarily destroy organic constituents in water.	Advanced oxidation is applicable for treating most organics, including PAHs; however, it is not applicable to treatment of COCs.		Dredging not implementable at the Site; therefore water treatment is not required.	NA	Dredging not implementable at the Site; therefore water treatment is not required.	NA	Dredging not implementable at the Site; therefore water treatment is not required.	No	Dredging not implementable at the Site; therefore water treatment is not required.

	Effectiveness	Implementability	Relative Cost
	Not effective at reaching RAOs	Not implementable at the Site	$$$$ - High
	Partially effective for some COCs or Site areas	Difficult to implement	$$$ - Medium-high
	Effective under certain conditions	Implementable, requires technical knowledge	$$ - Moderate
	Demonstrated effective technology	Readily implemented	$ - Low

NA - not applicable

Table 3
Alternatives Summary
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Alternative	Alternative 1: No Action	Alternative 2: MNR	Alternative 3: Enhanced MNR with Broadcasted Amendment	Alternative 4: Enhanced MNR with Thin-Layer Amended Cover
Total Present Worth Cost	$0	$250,000	$6,700,000	$9,400,000
Cover/Cap Area	0 acres	0 acres	59.1 acres (0.05-meter [2-inch] amendment "cover")	59.1 acres (0.15-meter [6-inch] amended cover)
Dredge Area	0 acres	0 acres	0 acres	0 acres
Cover Volume - Sand/Amendment	0 CY/ 0 CY	0 CY/ 0 CY	0 CY/ 16,000 CY Total = 16,000 CY	24,000 CY/ 24,000 CY Total = 48,000 CY
Dredge Volume	0 CY	0 CY	0 CY	0 CY
Construction Timeframe	0 weeks	0 weeks	21 weeks	23 weeks
Monitoring Program	None	Chemical and physical sediment; benthic toxicity and bioaccumulation; fish tissue; bathymetric surveys	Chemical and physical sediment; benthic toxicity and bioaccumulation; fish tissue	Chemical and physical sediment and cover; benthic toxicity and bioaccumulation; fish tissue

Table 4
Cost Estimate - Alternative 2: Monitored Natural Recovery
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Description	Unit	Estimated Unit Cost	Estimated Quantity	Extended Value	Present Value	Comments
Construction Costs						
No construction costs associated with this alternative						
Long-Term Monitoring						
Implementation Plan Report	Lump Sum	$ 11,000	1	$ 11,000	$ 11,000	Work Plan, Field Sampling Plan, QAPP
Monitoring and Evaluation Report	Each	$ 4,000	6	$ 24,000	$ 8,631	Every 5 years for 30 years
Field Sampling	Event	$ 34,000	6	$ 204,000	$ 73,366	Every 5 years for 30 years
Sample Analysis	Event	$ 35,920	6	$ 216,000	$ 77,509	Every 5 years for 30 years
Bathymetric Survey	Each	$ 10,000	6	$ 60,000	$ 21,578	Every 5 years for 30 years
Institutional Control Review	Each	$ 1,500	6	$ 9,000	$ 3,237	
			TOTAL	$ 524,000	$ 195,321	
			25% Contingency	$ 131,000	$ 48,830	
			LONG-TERM MONITORING GRAND TOTAL	$ 655,000	$ 244,000	
Professional and Technical Services						
No professional and technical services associated with this alternative						
			TOTAL	**$ 655,000**	**$ 244,000**	

Notes:
All values are based on 2016 dollars with an assumed discount rate of 7 percent per year. See Appendix A for present value calculations.
Assumptions are based on professional judgment and experience of specialists at Bay West. Actual project costs will be highly dependent upon final design.

Table 5
Cost Estimate - Alternative 3: Enhanced MNR with Broadcasted Amendment
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Description	Unit	Estimated Unit Cost	Estimated Quantity	Extended Value	Present Value	Comments
Construction Costs						
Mobilization/Demobilization	Lump Sum	$ 189,000	1	$ 189,000	$ 176,636	All construction occurs on Year 1
Rent Hallett Dock #7 for Staging Area	Month	$ 10,000	6	$ 60,000	$ 56,075	
Install and Remove Dolphin Pilings	Lump Sum	$ 95,000	1	$ 95,000	$ 88,785	
Purchase Amendment Materials and Stockpile at Staging Area	CY	$ 141	15891	$ 2,240,631	$ 2,094,048	
Broadcast Amendment	CY	$ 105.11	15891	$ 1,670,352	$ 1,561,077	Average 2-inch amendment layer
Construction Monitoring/CQA and Oversight	Week	$ 13,000	21	$ 273,000	$ 255,140	
Monthly Operating Expenses and Site Security	Month	$ 21,000	6	$ 126,000	$ 117,757	
Implement Institutional Controls	Lump Sum	$ 10,000.00	1	$ 10,000	$ 9,346	Site postings; restrictions
			SUBTOTAL	$ 4,663,983	$ 4,358,863	
Long-Term Monitoring						
Monitoring and Evaluation Report	Each	$ 4,000	6	$ 24,000	$ 8,631	Every 5 years for 30 years
Field Sampling	Event	$ 34,000	6	$ 204,000	$ 73,366	Every 5 years for 30 years
Sample Analysis	Event	$ 35,920	6	$ 215,520	$ 77,509	Every 5 years for 30 years
			SUBTOTAL	$ 443,520	$ 159,506	
			TOTAL	$ 5,107,503	$ 4,518,369	
			25% Contingency	$ 1,276,876	$ 1,129,592	
			CONSTRUCTION GRAND TOTAL	$ 6,384,379	$ 5,647,961	
Professional and Technical Services						
Remedial Design (6%)	Lump Sum	$ 383,000	1	$ 383,000	$ 383,000	Year 0
Project Management and Permitting (5%)	Lump Sum	$ 319,000	1	$ 319,000	$ 298,131	Year 1
Construction Management (6%)	Lump Sum	$ 383,000	1	$ 383,000	$ 357,944	Year 1
			SUBTOTAL	$ 1,085,000	$ 1,039,075	
			TOTAL	**$ 7,469,000**	**$ 6,687,000**	

Notes:

All values are based on 2016 dollars with an assumed discount rate of 7 percent per year. See Appendix A for present value calculations.

Assumptions are based on professional judgment and experience of specialists at Bay West. Actual project costs will be highly dependent upon final design.

Table 6
Cost Estimate - Alternative 4: Enhanced MNR with Thin-Layer Amended Cover
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Description	Unit	Estimated Unit Cost	Estimated Quantity	Extended Value	Present Value	Comments
Construction Costs						
Mobilization/Demobilization	Lump Sum	$ 205,000	1	$ 205,000	$ 191,589	All construction occurs on Year 1
Rent Hallett Dock #7 for Staging Area	Month	$ 10,000.00	6	$ 60,000	$ 56,075	
Install and Remove Dolphin Pilings	Lump Sum	$ 95,000.00	1	$ 95,000	$ 88,785	
Purchase Amendment Materials and Stockpile at Staging Area	CY	$ 141.00	23837	$ 3,361,017	$ 3,141,137	
Purchase Sand and Stockpile at Staging Area	CY	$ 20.80	23837	$ 495,810	$ 463,373	
Construct Thin-Layer Cover	CY	$ 41.23	47674	$ 1,965,469	$ 1,836,887	
Construction Monitoring/CQA and Oversight	Week	$ 13,000	23	$ 299,000	$ 279,439	
Monthly Operating Expenses and Site Security	Month	$ 21,000	6	$ 126,000	$ 117,757	
Implement Institutional Controls	Lump Sum	$ 10,000	1	$ 10,000	$ 9,346	Site postings; restrictions
			SUBTOTAL	$ 6,617,296	$ 6,184,388	
Long-Term Monitoring						
Monitoring and Evaluation Report	Each	$ 4,000	6	$ 24,000	$ 8,631	Every 5 years for 30 years
Field Sampling	Event	$ 34,000	6	$ 204,000	$ 73,366	Every 5 years for 30 years
Sample Analysis	Event	$ 35,920	6	$ 215,520	$ 77,509	Every 5 years for 30 years
			SUBTOTAL	$ 443,520	$ 159,506	
			TOTAL	$ 7,060,816	$ 6,343,894	
			25% Contingency	$ 1,765,204	$ 1,585,974	
			CONSTRUCTION GRAND TOTAL	$ 8,826,020	$ 7,929,868	
Professional and Technical Services						
Remedial Design (6%)	Lump Sum	$ 530,000	1	$ 530,000	$ 530,000	Year 0
Project Management and Permitting (5%)	Lump Sum	$ 441,000	1	$ 441,000	$ 412,150	Year 1
Construction Management (6%)	Lump Sum	$ 530,000	1	$ 530,000	$ 495,327	Year 1
			SUBTOTAL	$ 1,501,000	$ 1,437,477	
			TOTAL	**$ 10,327,000**	**$ 9,367,000**	

Notes:
All values are based on 2016 dollars with an assumed discount rate of 7 percent per year. See Appendix A for present value calculations.
Assumptions are based on professional judgment and experience of specialists at Bay West. Actual project costs will be highly dependent upon final design.

Table 7
Comparative Analysis Summary - Threshold, Balancing, and Modifying Criteria
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Evaluation Criteria	Alternative 1: No Action	Alternative 2: MNR	Alternative 3: Enhanced MNR with Broadcasted Amendment	Alternative 4: Enhanced MNR with Thin-Layer Amended Cover
		Threshold Criteria		
Overall Protection of Human Health & Environment	Provides **no achievement** of protection of Human Health and the Environment as contaminant concentrations remain with minimal controls to prevent exposure.	Provides **low achievement** of protection of Human Health and the Environment as contaminant concentrations remain with minimal controls to prevent exposure; however RAOs would be achieved over time.	Provides a **moderate achievement** of protection of Human Health and the Environment. Sediment contaminants would be reduced through addition of an amendment material and controlled by providing an amendment layer between contaminated sediments and the water column. May require monitoring to ensure effectiveness and future additions of amendment material.	Provides a **moderate to high achievement** of protection of Human Health and the Environment. Sediment contaminants would be reduced through addition of an amendment material and controlled by providing an amendment layer between contaminated sediments and the water column. May require monitoring to ensure effectiveness and future additions of amendment material.
ARARs	Provides **no achievement** of ARARs since chemical-specific TBCs are not met for sediment. Location and action-specific ARAR s do not apply to this alternative.	Provides a **low achievement** of ARARs; however, COCs may not be reduced to concentrations less than RAOs in a reasonable time frame.	Provides a **moderate achievement** of ARARs if implemented properly; however, COCs may not be reduced to concentrations less than RAOs in a reasonable time frame.	Provides a **moderate to high achievement** of ARARs if implemented properly; however, COCs may not be reduced to concentrations less than RAOs in a reasonable time frame.
		Primary Balancing Criteria		
Long-term Effectiveness and Permanence	Provides **no achievement** of long-term effectiveness and remedy is not long-term effective or permanent.	Provides a **low achievement** of long-term effectiveness and permanence because sediment contaminants would eventually be sequesterd and degraded by natural processes and rendered unavailable to biota within the most biologically active zone; however, natural processes may not occur at rates to achieve RAOs in a reasonable timeframe.	Provides a **moderate achievement** of long-term effectiveness and permanence because sediment contaminants would eventually be sequesterd by amendment materials and rendered unavailable to biota within the most biologically active zone; however, sequestration of contaminants at deeper intervals may not occur and monitoring and possible reapplication of amendment material may be necessary as contaminants would remain in place.	Provides a **high achievement** of long-term effectiveness and permanence because sediment contaminants would eventually be sequesterd by amendment materials and rendered unavailable to biota within the most biologically active zone; however, sequestration of contaminants at deeper intervals may not occur and monitoring and possible reapplication of amendment material may be necessary as contaminants would remain in place.
Reduction of Toxicity, Mobility or Volume through Treatment	Provides a **no achievement** of this criterion as no reduction in toxicity, mobility, or volume through treatment is provided.	Provides a **no achievement** of this criterion as no reduction in toxicity, mobility, or volume through treatment is provided.	Provides a **moderate achievement** of this criterion as the toxicity and mobility of sediment contaminants would be reduced through addition of an amendment material near the sediment surface; however, it is possible that deeper sediment contamination could remain in place indefinitely.	Provides a **high achievement** of this criterion as the toxicity and mobility of sediment contaminants would be reduced through addition of an amendment material near the sediment surface; however, it is possible that deeper sediment contamination could remain in place indefinitely.
Short-term effectiveness	Provides a **high achievement** of this criterion as no actions are implemented, so no risks to the community would result from remedy implementation; however, receptors would continue to be exposed to contaminated sediment.	Provides a **high achievement** of this criterion as no remedial actions are implemented, so no risks to the community would result from remedy implementation and risk to workers is low; however, receptors would continue to be exposed to contaminated sediment.	Provides a **moderate achievement** of this criterion since cover placement would temporarily displace the benthic community. Risks to workers is low.	Provides a **low achievement** of this criterion since cover placement would temporarily displace the benthic community. Risks to workers is low.
Implementability	Provides a **high achievement** of this criterion as no actions would be implemented.	Provides a **high achievement** of this criterion as only moniroting would be required.	Provides a **moderate to high achievement** of implementability since it only requires placement of cover material using proven methods with a low to moderate level of complexity.	Provides a **moderate** of implementability since it only requires placement of cover material using proven methods with a low to moderate level of complexity; however, Alternative 4 requires the placement of more material than Alternative 3, making it more complicated.
Cost (1)	$0	$250,000	$6,700,000	$9,400,000
		Modifying Criteria		
State Support / Agency Acceptance	TBD	TBD	TBD	TBD
Community Acceptance	TBD	TBD	TBD	TBD

Notes
(1) Cost are presented as Present Value.
M = Million
** Not included in numerical comparison on (Table 5-2).*
TBD = To Be Determined

Table 8
Comparative Analysis Summary - Green Sustainable Remediation Criteria
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Evaluation Criteria	Alternative 1: No Action	Alternative 2: MNR	Alternative 3: Enhanced MNR with Broadcasted Amendment	Alternative 4: Enhanced MNR with Thin-Layer Amended Cover
Green Sustainable Remediation (GSR) Criteria*				
Green House Gas (GHG) Emissions	None.	None.	Total GHG emissions produced during cover material delivery and placment and equipment mobilization related to sampling activities.	Total GHG emissions produced during cover material delivery and placment and equipment mobilization related to sampling activities.
Toxic Chemical Usage and Disposal	None.	No toxic chemicals are used or disposed.	No toxic chemicals are used or disposed.	No toxic chemicals are used or disposed.
Energy Consumption	None.	Fossil fuels are limited to the equipment mobilization for sampling activities.	Fossil fuels are limited to the equipment mobilization for sampling activities and cover placement operations.	Fossil fuels are limited to the equipment mobilization for sampling activities and cover placement operations.
Use of Alternative Fuels	None.	None.	Alternative fuels could be used to run heavy construction equipment.	Alternative fuels could be used to run heavy construction equipment.
Water Consumption	None.	No water consumption is necessary.	No water consumption is necessary.	Little water consumption is necessary.
Waste Generation	None.	No waste generation.	No waste generation.	No waste generation.
GSR Criteria Summary	Provides a **high achievement** of the GSR criterion.	Provides a **high achievement** of the GSR criterion.	Provides a **moderate to high achievement** of the GSR criterion.	Provides a **moderate to high achievement** of the GSR criterion.

Notes
(1) Cost are presented as Present Value.
M = Million
** Not included in numerical comparison on (Table 5-2).*
TBD = To Be Determined

Table 9
Numerical Comparative Analysis Summary
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Evaluation Criteria	Alternative 1: No Action	Alternative 2: MNR	Alternative 3: Enhanced MNR with Broadcasted Amendment	Alternative 4: Enhanced MNR with Thin-Layer Amended Cover
Overall Protection of Human Health & Environment	0	1	2	2.5
ARARs	0	1	2	2.5
Long-term Effectiveness and Permanence	0	1	2	3
Reduction of Toxicity, Mobility or Volume through Treatment	0	0	2	3
Short-term effectiveness	3	3	2	1
Implementability	3	3	2.5	2
Cost (1)	3	3	2	1
State Support / Agency Acceptance	TBD	TBD	TBD	TBD
Community Acceptance	TBD	TBD	TBD	TBD
Total Numerical Value	**9**	**12**	**14.5**	**15**

Notes

(1) Cost are presented as Present Value.

Ratings are based on achievement of criterion: no achievement, low achievement; moderate achievement; and high achievement.

Scores are based on 0 = no achievement; 1 = low achievement; 2 = moderate achievement; and 3 = high achievement.

Scoring for cost are based on the following cost breakpoints: > $8 million = low achievement; $4-8 Million = moderate achievement; and < $4 million = high achievement.

GSR criteria not included in this numerical comparison.

See Table 6 for a discussion of each criterion.

Appendix A

Bioaccumulation and Toxicity Laboratory Report

Evaluation of Sediments from Munger Landing for Toxicity to *Hyalella azteca*, *Chironomus dilutus*, and Bioaccumulation in *Lumbriculus variegatus*

By

Matthew TenEyck, Christine Polkinghorne,
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Lake Superior Research Institute
University of Wisconsin-Superior
Superior, WI

Final Report

To

Bay West, LLC
5 Empire Drive
St. Paul, MN 55103
(Chris Musson, Project Officer)

May 31, 2016

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Introduction

The University of Wisconsin-Superior's Lake Superior Research Institute (LSRI) contracted with Bay West, LLC to evaluate sediments from Munger Landing (St. Louis River, Duluth, MN) sites for toxicity and bioaccumulation of chemicals toward several species of benthic invertebrates. Sediment samples were collected from a total of nine sites. The following tests were conducted: a 10-day Sediment Toxicity Test with *Hyalella azteca*, a 10-day Sediment Toxicity Test with *Chironomus dilutus*, and a 28-day Bioaccumulation Test with *Lumbriculus variegatus*. Survival and growth were determined as endpoints for both 10-day tests. All chemical analysis conducted by Pace Analytical was determined by Bay West.

Methods

Sediment Collection, Preparation and Chemical Analysis

Sediment was collected on December 3, 2015 by Bay West staff and placed in clean plastic five-gallon buckets (cleaned with10% Nitric acid rinse, HPLC (high performance liquid chromatography) grade acetone rinse, and copious amounts of deionized water with minimal head space. The Bay West staff delivered the sediment to LSRI on December 3, 2015. The samples were stored at 4.0˚C until they were homogenized. Table 1 describes the treatments and includes control sediments. Asterisks within table 1 indicate the sediments tested in the bioaccumulation test with *L. variegatus*.

Table 1: Sediment Identification and Designation

Treatment Identification	Designation
Silica Sand	Performance Control
West Bearskin Lake	Natural Sediment Control
BW15ML-004 *	Treatment
BW15ML-006	Treatment
BW15ML-010 *	Treatment
BW15ML-018	Treatment
BW15ML-022	Treatment
BW15ML-032 *	Treatment
BW15ML-034 *	Treatment
BW15ML-037	Treatment
BW15ML-038	Treatment

Prior to testing, the sediment was homogenized for two, 5-minute intervals using a commercial drill equipped with a stainless steel mortar paddle. Between the intervals, the sediment was stirred manually with a stainless steel spoon to further ensure homogeneity. After homogenization, sediment was immediately placed into the test exposure containers. Between homogenization of sediments, all equipment was cleaned with a lab soap solution, tap water, 10% nitric acid, HPLC grade acetone, and deionized water. Following homogenization, sediment subsamples were collected from BW15ML-004, BW15ML-010, BW15ML-022, BW15ML-032, BW15ML-034, BW15ML-037, and BW15ML-038 for determining polychlorodibenzo-p-dioxins (PCDDs) and polychlorodibenzofurans (PCDFs) concentrations along with percent moisture. Total Organic Carbon (TOC) concentrations were measured on sediments BW15ML-004, BW15ML-010, BW15ML-032, and BW15ML-034. Sediment subsamples for analysis of selected metals and PCBs as Aroclors were collected from BW15ML-004, BW15ML -006, BW15ML-

010, BW15ML-018, BW15ML-022, BW15ML-032, BW15ML-034, BW15ML-037, and BW15ML-038. All sediment samples were sent to Pace Analytical for analysis.

Solid Phase Sediment Toxicity Tests

Solid phase sediment toxicity tests were performed with the freshwater species *H. azteca*, a crustacean; *C. dilutus*, an insect; and a bioaccumulation test with the oligochaete *L. variegatus*. The LSRI test protocols used were: “Conducting a 10-day Sediment Toxicity Test with *Hyalella azteca*” (LSRI SOP AT/20 v.6); “Conducting a 10-day Sediment Toxicity Test with *Chironomus dilutus*” (LSRI SOP AT/21 v.7); and “Conducting a 28-day Bioaccumulation Test for Sediment with the Oligochaete, *Lumbriculus variegatus*” (LSRI SOP AT/19 v.2). The SOPs are based upon EPA-developed methods (U.S. EPA, 2000). The objectives of each of the tests were slightly different and will be discussed below. In general, the objective was to determine whether the contaminants in the sediment were harmful to the test organisms or if certain contaminants in the sediments accumulated in the selected organism over a 28 day exposure (Table 2).

Toxicity tests with *H. azteca* and *C. dilutus*

For the 10-day tests, approximately 100 mL of homogenized sediment was placed into each 300 mL beaker containing two screened holes about two-thirds of the distance up the beaker walls to allow for water exchange between the beaker and the aquarium in which it was placed. Each aquarium contained eight replicate beakers for each species and sediment type tested. A set of eight replicate beakers were placed into a glass aquarium. The aquaria were then placed within the larger water baths set to maintain the desired test temperature (23.0 ± 1.0˚C).

10 day toxicity tests were initiated with 7-8 days old *H. azteca* and 10-12 day old *C. dilutus* (second and third instar). The tests were performed at water temperatures of 23.0 ± 1.0˚C. Renewal water was added twice each day over two hour renewal periods. The volume of renewal water added was a minimum of two volume replacements of the overlying water in each of the beakers. A 16L:8D photoperiod was maintained.

For all tests, the sediment was added one day prior to the addition of the test animals to allow the sediment to settle and overlying water to clear.

Ten organisms were added to all replicate beakers for both 10-day tests. All replicate beakers were fed equal volumes of food. *H. azteca* received 1.0 mL daily of a yeast, cereal leaves, and trout chow mixture containing approximately 1800 mg/L total suspended solids. *C. dilutus* were fed 1.5 mL daily of a 4.0 g/L Tetrafin® suspension. During all tests, dissolved oxygen and temperature were measured twice daily. For both 10-day tests, pH and conductivity were measured three times a week. Hardness, alkalinity, and ammonia were measured on days 0 and 9. At the end of the appropriate exposure period, sediment from each beaker was sieved through a #40 mesh sieve (0.425 mm), rinsed into a clear Pyrex® pan, placed over a light table, and the surviving organisms retrieved. The *H. azteca* were placed into dried, pre-weighed aluminum pans and dried at approximately 60˚C for at least 24 hours to obtain dry weight measurements. Ash-free dry weights were determined on the *C. dilutus* by placing previously ashed and weighed pans containing the animals in a muffle furnace at 550˚C for approximately 2 hours. After ashing, the pans containing the organisms were cooled in a desiccator and weighed. Weights were determined to 0.01 mg for *H. azteca* and *C. dilutus.*

Bioaccumulation test with *L. variegatus*

For the bioaccumulation test, approximately 3000 g of homogenized sediment was placed in each glass aquaria and renewal water was directly delivered into the aquaria. The aquaria were then placed within the larger water bath to maintain the desired test temperature (23.0 ± 1.0˚C). Approximately 15 g (wet weight) of mixed age *L. variegatus* was added to each of the five replicate aquaria used for the four sediments tested in the bioaccumulation exposures. The *L. variegatus* were not fed during the test. Dissolved oxygen and temperature were measured twice daily while pH, conductivity, hardness, alkalinity, and ammonia were measured on days 1, 7, 14, 21, and 27. At the end of the 28 day exposure period, the sediment containing the *L. variegatus* was sieved through a #60 mesh sieve (0.250 mm), rinsed into a clear Pyrex® pan, placed over a light table, and the surviving organisms retrieved. After separating the organisms from remaining sediment, the organisms were placed in clean lab water and allowed to depurate overnight. Wet weights were determined on *L. variegatus* prior to placing them in amber vials and freezing. Weights were determined to 0.1 g for *L. variegatus*. The *L. variegatus* tissue was sent to Pace Analytical for determining percent moisture and selected metals on all of the tissue samples. Composited tissue samples, consisting of the five replicate samples from each site tested, were also analyzed for PCBs, lipids, PCDDs, and PCDFs.

Table 2: Test Specifics

Test	Method	Condition	Fed	Age of Organisms at Test Initiation	Endpoint
10-day *H. azteca*	USEPA 2000, LSRI SOP AT/20 v.6	Sediment from 9 sites and 2 control sediments.	1.0 mL daily of a yeast, cereal leaves, and trout chow mixture at approximately 1800 mg/L total suspended solids.	7-8 days	Mortality, weight
10-day *C. dilutus*	USEPA 2000, LSRI SOP AT/21 v.7	Sediment from 9 sites and 2 control sediments.	1.5 mL daily of a 4.0 g/L Tetrafin® suspension.	Second or third instar, 10-12 days old.	Mortality, weight
28-day *L. variegatus*	USEPA 2000, LSRI SOP AT/19 v.2	Sediment from 4 sites.	No feeding	Mixed Age	Bioaccumulation

Statistical Analysis

Data were analyzed using the SigmaStat® program (Jandel Corporation, 1995). Data analyses included: general descriptive statistics, normality, homogeneity of variance, one-way analysis of variance (ANOVA), and a suite of tests for comparison between treatment means. Comparisons between control and treatment groups of normal and equal variance data were analyzed using the Bonferroni t-test. Non-normalized data were analyzed using a non-parametric treatment comparison (Kruskal-Wallis one way analysis of variance on ranks). Dunn's test was used for all pairwise comparison tests for nonparametric data. Mean percent survival and mean dry weight values for the laboratory control sediments and the appropriate reference sediment were analyzed with a statistical significance level of 0.05. Statistical analyses raw data files are kept on file in the Lake Superior Research Institute and are available upon request.

Quality Assurance/Quality Control

Toxicity tests were initiated with healthy, vigorous animals. Reference toxicant tests were performed with all test species within three weeks before or after starting the respective test. Percent survival and dry weights of survivors in control sediments were compared to published test acceptability criteria (U.S.EPA, 2000) to determine the overall performance of the animals and the test system. Empty aluminum drying pans along with Class I standardized weights were used as a check for the organisms drying process and the performance of the balance. Test conditions were monitored twice daily for temperature and dissolved oxygen to maintain test acceptability criteria. Temperatures were, on average, to be 23.0 ± 1.0˚C and instantaneously to be 23.0 ± 3.0˚C. Dissolved oxygen was not allowed to drop below 2.5 mg/L. All testing meters were calibrated according to the frequency suggested in the SOPs, depending upon meter type, to ensure optimal performance. Reference standards and duplicate samples were used in the analysis of ammonia, alkalinity, and hardness. For ammonia analysis, spiked samples were used to indicate whether interferences were present that would affect the reported ammonia values.

The LSRI quality assurance and quality control manager staged a competency test on January 5th, 2016 involving all staff with the potential to participate in organism collection on the final day of the 10-day toxicity tests with *H. azteca* and *C. dilutus*. Staff members were required to retrieve 90% of the organisms added to prove competency. According to LSRI SOP AT/20, v.6 and AT/21, v.7, ten *H. azteca* and ten *C. dilutus*, respectively, were added to a 300-mL beaker containing 100 mL West Bearskin Lake control sediment and 175 mL overlying water. After one hour, recovery was determined following the procedure outlined in the "Test Termination" section of each SOP. The competency test method and results were recorded on a "Certificate of Training Completion/Competency Test Form". The quality assurance and quality control manager performed inspections of logbooks, measurements, and instrumentation used during the tests. The sediment tests were conducted with a high degree of quality assurance/quality control criteria.

Results

Sediment Analysis

Pace Analytical determined polychlorodibenzo-p-dioxins (PCDDs) and polychlorodibenzofurans (PCDFs) concentrations for seven sediments. Those seven sediments were some of those used in the *H. azteca* and *C. dilutus* 10-Day sediment toxicity tests and four of them were used in the bioaccumulation exposures with *L. variegatus*. No statistical comparisons were run on the data from Pace Analytical, but a summary of the data can be found in Table 3. Sediment BW15ML-032 had the highest concentration of all PCDDs and PCDFs aside from the total TCDF. Sediment BW15ML-010 contained the highest amount of total TCDF. Sediment BW15ML-032 also contained the highest total 2,3,7,8-TCDD Equivalence (based on 2005 WHO Factors), which signifies potential for toxicity. Total PCDDs and PCDFs are representative of all 2,3,7,8-substituted isomers found in the sediment. The exact concentrations are only given for isomers for which Pace Analytical used carbon 13 labeled internal standards.

Table 3: Analysis of polychlorodibenzo-p-dioxins (PCDDs) and polychlorodibenzofurans (PCDFs) in seven sediments used for 10 day *Hyalella azteca* and *Chironomus dilutus* tests and a 28 day *Lumbriculus variegatus* bioaccumulation test. Concentrations are in ng/Kg. TCDD Equivalence values based on 2005 WHO Factors. Analysis was done by Pace Analytical

Compound	BW15ML-004	BW15ML-010	BW15ML-022	BW15ML-032	BW15ML-034	BW15ML-037	BW15ML-038
2,3,7,8-TCDF	2.60	4.50	0.46 [a b c]	4.8	1.30 [a]	0.90 [a b c]	3.4
Total TCDF	5.60	74.00	10.00	44.0	13.00	11.00	28.0
2,3,7,8-TCDD	ND	0.88 [a]	ND	2.1	0.63 [a]	0.27 [a b c]	0.92 [a b c]
Total TCDD	0.48 [a]	7.40	0.26 [a]	18.0	4.50	1.40 [a]	6.3
1,2,3,7,8-PeCDF	0.33 [a b c]	1.60 [a]	0.23 [a b c]	2.3 [a]	0.55 [a]	0.44 [a d]	1.6 [a]
2,3,4,7,8-PeCDF	1.40 [a]	6.30 [a]	0.69 [a]	7.2 [a]	1.50 [a]	0.91 [a]	4.5 [a]
Total PeCDF	9.80	83.00	11.00	120.0	27.00	14.00	62.0
1,2,3.7.8-PeCDD	1.30 [a]	2.20 [a]	0.14 [a b c]	6.2 [a]	1.60 [a]	0.48 [a]	2.1 [a]
Total PeCDD	5.30 [a]	21.00	1.80[a]	58.0	12.00	3.60 [a]	20.0
1,2,3,4,7,8-HxCDF	1.50 [a]	7.20 [a]	0.77 [a b c]	21.0	3.50 [a]	1.30 [a]	21.0
1,2,3,6,7,8-HxCDF	1.40 [a]	9.00 [a]	0.76 [a]	37.0	6.80 [a]	1.70 [a]	13.0
2,3,4,6,7,8-HxCDF	0.58 [a]	5.40 [a]	0.62 [a]	14.0	2.70 [a]	1.00 [a]	4.8 [a]
1,2,3,7,8,9-HxCDF	ND	1.10 [a]	0.15 [a b c]	3.2 [a b c]	0.71 [a]	0.43 [a]	1.7 [a]
Total HxCDF	61.00	170.00	12.00	350.0	150.00	39.00	190.0
1,2,3,4,7,8-HxCDD	0.89 [a]	2.20 [a]	0.26 [a]	6.0 [a]	1.60 [a]	0.50 [a]	2.1 [a]
1,2,3,6,7,8-HxCDD	5.90 [a]	15.00	1.20 [a]	48.0	11.00	3.30 [a]	14.0
1,2,3,7,8,9-HxCDD	2.70 [a]	7.80 [a]	0.74 [a]	26.0	6.50 [a]	1.70 [a]	7.3 [a]
Total HxCDD	70.00	130.00	9.90	410.0	97.00	30.00	130.0
1,2,3,4,6,7,8-HpCDF	79.00	270.00	16.00	1800.0	250.00	85.00	310.0
1,2,3,4,7,8,9-HpCDF	1.30 [a]	5.50 [a]	0.73 [a]	13.0	2.2 [a b c]	0.85 [a b c]	9.3
Total HpCDF	280.00	560.00	32.00	3300.0	480.00	150.00	610.0
1,2,3,4,6,7,8-HpCDD	91.00	170.00	18.00	420.0	140.00	40.00	200.0
Total HpCDD	280.00	380.00	43.00	1000.0	350.00	99.00	440.0
OCDF	64.00	170.00	17.00	820.0	160.00	50.00	280.0
OCDD	970.00	1600.00	140.00	4200.0	1500.00	410.00	2100.0
Total 2,3,7,8-TCDD Equivalence	5.3	15	1.3	50	11	3.5	17

[a] Value estimated due to falling below the calibrated range of the instrument.
[b] Interference present, incorrect isotope ratios obtained.
[c] Concentration was recorded as an estimated maximum possible concentration (EMPC).
[d] Value less than 10 times higher than the method blank level and may be partially attributed to the background. Not considered statistically different from the background.

Four sediments were analyzed for total organic carbon (TOC) concentrations. The samples were analyzed in quadruplicate. The mean concentrations and standard deviations are provided in Table 4.

Table 4: Average Total Organic Carbon (TOC) value (in mg/kg) for four sediments used in the sediment toxicity tests

Sample ID	Total Organic Carbon (mg/kg)
BW15ML-004	57800 ± 12100
BW15ML-010	43500 ± 9388
BW15ML-032	34100 ± 6225
BW15ML-034	31300 ± 8109

All sediments used in testing were sent to Pace Analytical for metals analysis and the results were reported directly to Bay West. Sediment BW15ML-010 was analyzed in duplicate (ID BW15ML-110) and is kept in Table 5 as a separate Sample ID. The concentrations are provided in Table 5.

Table 5: Sediment Metals Analysis Completed by Pace Analytical

Sample ID	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Lead (mg/L)	Mercury (mg/L)	Nickel (mg/L)	Zinc (mg/L)
BW15ML-004	14.0	1.6	39.6	46.4	162	0.36	30.3	522
BW15ML-006	6.9	1.1	42.7	61.0	73.8	0.22	43.0	261
BW15ML-010	7.1	0.96	46.1	53.9	58.1	0.20	44.1	234
BW15ML-110	7.0	0.91	46.5	53.0	58.7	0.21	43.8	230
BW15ML-018	8.2	1.1	33.9	42.6	81.0	0.34	28.6	285
BW15ML-022	2.7	0.21	30.3	29.1	12.2	0.029	64.3	70.5
BW15ML-032	8.5	1.5	40.6	43.5	99.8	0.41	32.3	375
BW15ML-034	7.4	1.3	38.5	42.3	81.4	0.45	32.0	307
BW15ML-037	7.2	0.91	44.6	42.3	57.5	0.20	37.3	237
BW15ML-038	9.3	1.8	44.3	74.2	110	1.4	34.6	425

All sediments used in testing were also analyzed by Pace Analytical for PCBs as Aroclors. These results were also reported directly to Bay West. Again, sediment BW15ML-010 was analyzed in duplicate (ID BW15ML-110) and is kept in Table 6 as a separate sample ID. Concentrations are given in Table 6.

Table 6: Sediment Aroclor Analysis Completed by Pace Analytical

Sample ID	Aroclor 1016 (µg/kg)	Aroclor 1221 (µg/kg)	Aroclor 1232 (µg/kg)	Aroclor 1242 (µg/kg)	Aroclor 1248 (µg/kg)	Aroclor 1254 (µg/kg)	Aroclor 1260 (µg/kg)	Aroclor 1262 (µg/kg)	Aroclor 1268 (µg/kg)
BW15ML-004	ND	ND	ND	ND	ND	ND	176	ND	ND
BW15ML-006	ND	ND	ND	ND	ND	ND	764	ND	ND
BW15ML-010	ND	ND	ND	ND	ND	ND	307	ND	ND
BW15ML-110	ND	ND	ND	ND	ND	ND	285	ND	ND
BW15ML-018	ND	ND	ND	ND	ND	ND	289	ND	ND
BW15ML-022	ND	ND	ND	ND	ND	ND	86.9	ND	ND
BW15ML-032	ND	ND	ND	ND	ND	ND	397	ND	ND
BW15ML-034	ND	ND	ND	ND	ND	ND	451	ND	ND
BW15ML-037	ND	ND	ND	ND	ND	ND	333	ND	ND
BW15ML-038	ND	ND	ND	ND	ND	ND	2110	ND	ND

Hyalella azteca 10-day Test

Mean percent survival for all exposures was high (80-100%, table 7). The control sediments, Silica Sand and West Bearskin Lake, had values of 83% and 93% respectively (table 7). All treatment exposures ranged from 80-100% survival (table 7). No significant (p>0.05) difference was found for survival when compared to the West Bearskin Lake control.

Table 7: *Hyalella azteca* Average Survival and Percent Survival ± Standard Deviation

Sample ID	Average Survival ± Std. Dev.	Percent Survival ± Std. Dev.
Silica Sand	8.3 ± 1.16	83 ± 12%
West Bearskin Lake	9.3 ± 1.04	93 ± 10%
BW15ML-004	8.0 ± 1.41	80 ± 14%
BW15ML-006	9.4 ± 1.06	94 ± 11%
BW15ML-010	9.8 ± 0.46	98 ± 5%
BW15ML-018	9.1 ± 0.83	91 ± 8%
BW15ML-022	10.0 ± 0.53	100 ± 5%
BW15ML-032	8.9 ± 0.64	89 ± 6%
BW15ML-034	8.9 ± 1.64	89 ± 16%
BW15ML-037	9.1 ± 0.99	91 ± 10%
BW15ML-038	8.1 ± 0.99	81 ± 10%

Control sediments had dry weight values per surviving organism of 0.045 ± 0.008 mg (Sand) and 0.066 ± 0.013 mg (West Bearskin Lake) (table 8). Dry weights per organism in treatment exposures ranged from 0.035 ± 0.015 to 0.079 ± 0.013 mg (table 8). Upon comparing with West Bearskin Lake, significant differences were found with four sediments: BW15ML-018 (p=0.017), BW15ML-032 (p<0.001), BW15ML-037 (p=0.011), and BW15ML-038 (p=0.017) (table 8). The *H. Azteca* exposed to these four sediments had significantly lower weights than the organisms from the West Bearskin Lake sediment exposure.

Table 8: Average *Hyalella azteca* Dry Weight

Sample ID	Weight/org (mg) ± Std. Dev.
Silica Sand	0.045 ± 0.008
West Bearskin Lake	0.066 ± 0.013
BW15ML-004	0.055 ± 0.011
BW15ML-006	0.072 ± 0.010
BW15ML-010	0.063 ± 0.006
BW15ML-018	0.047 ± 0.017 [Q]
BW15ML-022	0.079 ± 0.013
BW15ML-032	0.035 ± 0.015 [Q]
BW15ML-034	0.050 ± 0.007
BW15ML-037	0.046 ± 0.011 [Q]
BW15ML-038	0.047 ± 0.011 [Q]

[Q] Statistically different from West Bearskin Lake control sediment

The average water temperature during the *H. azteca* 10-Day sediment toxicity test was 23.8˚C ± 0.4 (standard deviation) which was within the quality assurance range of 23.0 ± 1.0˚C (table 9). Dissolved oxygen did not drop below 4.3 mg/L (table 9). Mean pH values ranged from 7.55 to 8.09 and average conductivity measurements were in the range of 140.8 to 148.7 (µS/cm) (table 9). Average hardness values ranged from 44.3 to 51.3 mg/L and mean alkalinity concentrations were between 43.7 and 49.8 mg/L (table 9). Ammonia samples were collected and preserved in H_2SO_4 until analyzed. Mean ammonia values ranged from 0.08 to 0.21 mg/L (table 9). The alkalinity and hardness values did not vary by more than 50% during the test. Because the ammonia values were all low (≤0.36 mg/L), there were some values that varied by more than 50% within replicates but the actual differences were small.

Table 9: Average Values (minimum, maximum) for Water Chemistry Parameters of overlying water used in the 10 Day Sediment Toxicity Test with *Hyalella azteca*

Sample ID	Temperature (°C) [a]	Dissolved Oxygen (mg/L) [a]	pH [b]	Conductivity (µS/cm) [c]	Hardness (mg/L $CaCO_3$) [c]	Alkalinity (mg/L $CaCO_3$) [c]	Ammonia (mg/L) [c]
Silica Sand	24.3 (24.0, 24.6)	7.6 (7.0, 8.3)	8.09 (8.01, 8.15)	143.6 (142.2, 145.0)	46.8 (45.2, 48.4)	43.7 (37.6, 46.4)	0.11 (0.06, 0.17)
West Bearskin Lake	23.7 (23.3, 24.1)	7.4 (6.1, 8.3)	7.97 (7.71, 8.06)	140.8 (136.8, 145.3)	44.3 (41.6, 45.6)	44.8 (42.0, 49.2)	0.09 (0.08, 0.10)
BW15ML-004	24.0 (23.3, 24.5)	7.1 (5.5, 8.9)	7.82 (7.60, 8.07)	146.8 (143.5, 149.1)	49.8 (45.6, 54.0)	46.7 (45.2, 47.6)	0.08 (0.06, 0.11)
BW15ML-006	23.8 (23.4, 24.2)	7.1 (4.4, 8.6)	7.55 (7.12, 8.03)	145.2 (143.0, 147.3)	47.0 (46.0, 48.4)	48.0 (47.6, 48.4)	0.21 (0.10, 0.36)
BW15ML-010	23.6 (23.3, 24.1)	7.4 (5.8, 9.0)	7.81 (7.46, 8.18)	147.5 (142.2, 152.8)	51.3 (50.0, 52.4)	48.9 (48.0, 51.2)	0.08 (0.06, 0.11)
BW15ML-018	23.9 (23.3, 24.6)	7.2 (5.8, 8.7)	7.86 (7.58, 8.12)	145.8 (142.4, 149.2)	49.2 (48.0, 50.8)	47.1 (45.6, 49.2)	0.08 (0.06, 0.11)
BW15ML-022	24.0 (23.4, 24.4)	6.9 (4.9, 8.5)	7.69 (7.33, 8.03)	147.0 (143.6, 150.2)	47.6 (44.4, 50.8)	47.9 (45.6, 50.4)	0.13 (0.07, 0.19)
BW15ML-032	23.4 (22.8, 23.8)	7.4 (5.9, 8.7)	7.86 (7.69, 8.06)	146.3 (143.6, 149.1)	46.3 (45.2, 47.2)	49.5 (48.0, 50.4)	0.09 (0.06, 0.13)
BW15ML-034	23.5 (23.0, 24.0)	7.5 (6.4, 8.9)	7.93 (7.64, 8.07)	146.4 (142.5, 148.7)	48.8 (46.4, 51.2)	46.9 (44.0, 48.0)	0.09 (0.07, 0.14)
BW15ML-037	23.4 (23.0, 24.0)	7.6 (6.0, 8.8)	7.99 (7.77, 8.09)	145.3 (142.3, 148.2)	47.7 (46.8, 48.4)	46.5 (45.2, 47.2)	0.08 (0.06, 0.11)
BW15ML-038	24.0 (23.6, 24.4)	7.3 (4.3, 9.0)	8.04 (7.83, 8.21)	148.7 (145.7, 151.9)	50.1 (47.2, 52.4)	49.8 (48.4, 51.2)	0.08 (0.07, 0.10)

[a] Temperature and Dissolved Oxygen were measured twice daily, before and after water renewal
[b] pH was measured on days 0, 2, 4, 7 and 9
[c] Conductivity, Hardness, Alkalinity, and Ammonia were measured on days 0 and 9

Chironomus dilutus 10-day Test

The control sediments, Silica Sand and West Bearskin Lake, had survival values of 94% and 100% respectively (table 10). Treatment exposures ranged from 78-100% survival (table 10). Upon comparing with West Bearskin Lake, survival in sediment BW15ML-032 was found to be statistically lower ($p<0.05$). All other treatment sediments were not found to be statistically different.

Table 10: *Chironomus dilutus* Average Survival and Percent Survival ± Standard Deviation

Sample ID	Average Survival ± Std. Dev.	Average Percent Survival ± Std. Dev.
Silica Sand	9.4 ± 1.18	94 ± 12%
West Bearskin Lake	10 ± 0.00	100 ± 0%
BW15ML-004	8.6 ± 3.11	86 ± 31%
BW15ML-006	9.5 ± 0.76	95 ± 8%
BW15ML-010	10 ± 0.00	100 ± 0%
BW15ML-018	9.7 ± 0.46	98 ± 5%
BW15ML-022	9.5 ± 0.53	95 ± 5%
BW15ML-032	7.8 ± 1.16 [Q]	78 ± 12% [Q]
BW15ML-034	9.1 ± 0.58	91 ± 6%
BW15ML-037	9.4 ± 0.74	94 ± 7%
BW15ML-038	9.1 ± 1.13	91 ± 11%

[Q] Statistically different from West Bearskin Lake control sediment

Mean ash free dry weights for all exposures ranged from 0.55 ± 0.09 to 0.85 ± 0.09 mg/organism (table 11). Control sediments had values of 0.55 ± 0.09 mg/organism (Sand) and 0.66 ± 0.08 mg/organism (West Bearskin) (table 11). Treatment exposures ranged from 0.65 ± 0.08 to 0.85 ± 0.09 mg/organism (table 11). Upon comparing with West Bearskin Lake, statistical differences were found with BW15ML-006 and BW15ML-022 (p<0.05). Weights for both of these sediments were statistically higher than the control sediments.

Table 11: Average *Chironomus dilutus* Ash Free Dry Weight (AFDW) in mg/organism

Sample ID	AFDW (mg/org) ± Std. Dev.
Silica Sand	0.55 ± 0.09
West Bearskin Lake	0.66 ± 0.08
BW15ML-004	0.73 ± 0.33
BW15ML-006	0.80 ± 0.07 [Q]
BW15ML-010	0.73 ± 0.06
BW15ML-018	0.69 ± 0.05
BW15ML-022	0.85 ± 0.09 [Q]
BW15ML-032	0.69 ± 0.10
BW15ML-034	0.71 ± 0.09
BW15ML-037	0.67 ± 0.06
BW15ML-038	0.65 ± 0.08

[Q] Statistically different from West Bearskin control sediment

The average water temperature during the *C. dilutus* 10-Day sediment toxicity test was 22.8˚C ± 0.3 (standard deviation) which was within the quality assurance range of 23.0 ± 1.0˚C (table 12). Dissolved oxygen did not drop below 4.5 mg/L (table 12). Mean pH values ranged from 7.65 to 7.99 and average conductivity measurements were in the range of 145.8 to 163.1 (µS/cm) (table 12). Average hardness values ranged from 46.1 to 61.5 mg/L and mean alkalinity concentrations were between 42.7 and 54.7 mg/L (table 12). Ammonia samples were collected and preserved in H_2SO_4 until analyzed. Mean ammonia values ranged from 0.09 to 0.32 mg/L (table 12). The alkalinity and hardness values did not vary by more than 50% during the test. Because the ammonia values were all low (≤0.38 mg/L), there were some values that varied by more than 50% within replicates but the actual differences were small.

Table 12: Average Values (minimum, maximum) for Water Chemistry Parameters of overlying water used in the 10 Day Sediment Toxicity Test with *Chironomus dilutus*

Sample ID	Temperature (°C) [a]	Dissolved Oxygen (mg/L) [a]	pH [b]	Conductivity (µS/cm) [c]	Hardness (mg/L $CaCO_3$) [c]	Alkalinity (mg/L $CaCO_3$) [c]	Ammonia (mg/L) [c]
Silica Sand	22.9 (22.1, 23.5)	7.7 (6.6, 9.2)	7.99 (7.83, 8.11)	152.7 (149.7, 156.3)	48.5 (48.0, 48.8)	48.5 (46.8, 50.8)	0.22 (0.06, 0.38)
West Bearskin Lake	22.9 (22.1, 23.4)	7.6 (4.5, 9.1)	7.72 (7.28, 8.04)	145.8 (142.2, 149.5)	46.1 (44.4, 50.0)	42.7 (39.2, 44.4)	0.20 (0.13, 0.27)
BW15ML-004	22.8 (22.0, 23.4)	7.8 (5.7, 9.6)	7.85 (7.71, 8.00)	160.8 (157.5, 162.7	57.3 (51.2, 65.2)	47.9 (46.8, 48.8)	0.09 (0.09, 0.11)
BW15ML-006	22.7 (22.1, 23.2)	7.5 (4.9, 9.0)	7.65 (7.25, 7.93)	155.8 (154.5, 158.9)	49.2 (47.6, 52.4)	48.1 (47.6, 48.8)	0.32 (0.27, 0.36)
BW15ML-010	22.9 (22.0, 23.4)	7.4 (5.3, 9.1)	7.72 (7.47, 7.99)	155.9 (149.9, 162.3)	54.5 (50.8, 58.8)	49.2 (48.0, 52.0)	0.10 (0.08, 0.14)
BW15ML-018	22.7 (21.9, 23.2)	7.3 (5.7, 8.9)	7.80 (7.55, 7.98)	156.2 (150.9, 161.9)	56.0 (52.4, 64.4)	50.4 (49.2, 52.8)	0.10 (0.09, 0.11)
BW15ML-022	22.8 (22.0, 23.3)	7.2 (2.9, 8.9)	7.85 (7.69, 8.05)	158.6 (156.1, 161.1)	50.3 (48.0, 52.4)	49.7 (47.6, 51.6)	0.14 (0.12, 0.16)
BW15ML-032	23.1 (22.3, 23.8)	7.9 (6.3, 9.4)	7.92 (7.68, 8.02)	162.6 (162.0, 163.3)	54.9 (50.4, 61.6)	49.7 (48.8, 51.2)	0.14 (0.09, 0.20)
BW15ML-034	22.9 (22.0, 23.4)	7.3 (4.9, 9.2)	7.77 (7.55, 8.02)	158.3 (154.7, 159.7)	52.1 (48.8, 54.4)	45.5 (43.6, 46.5)	0.11 (0.10, 0.14)
BW15ML-037	22.8 (22.2, 23.2)	7.8 (6.2, 9.0)	7.85 (7.63, 7.97)	155.7 (152.6, 158.8)	54.7 (53.2, 56.4)	52.2 (50.0, 54.4)	0.11 (0.10, 0.12)
BW15ML-038	22.8 (22.0, 23.4)	7.6 (5.7, 9.1)	7.86 (7.64, 8.06)	163.1 (162.1, 164.5)	61.5 (56.0, 67.6)	54.7 (53.6, 56.4)	0.13 (0.10, 0.16)

[a] Temperature and Dissolved Oxygen were measured twice daily, before and after water renewal
[b] pH was measured on days 0, 2, 4, 7 and 9
[c] Conductivity, Hardness, Alkalinity, and Ammonia were measured on days 0 and 9

Lumbriculus variegatus 28-day Bioaccumulation Study

Bay West selected four sediments to be used in the bioaccumulation test (BW15ML-004, BW15ML-010, BW15ML-032, BW15ML-034). As observed, no major change of mass was noted from the amount of *L. variegatus* tissue at the beginning of the test verses the end of the test (table 13).

Table 13: Average initial and recovered weight ± Standard Deviation of *Lumbriculus variegatus* tissue used in the 28 Day Bioaccumulation Test

Sample ID	Initial Wet Weight (g)	Recovered Wet Weight (g)
BW15ML-004	15.5 ± 0.1	12.4 ± 1.1
BW15ML-010	15.5 ± 0.2	13.9 ± 0.7
BW15ML-032	15.4 ± 0.2	12.7 ± 0.9
BW15ML-034	15.6 ± 0.4	14.0 ± 1.0

The average water temperature during the *L. variegatus* 28-Day bioaccumulation test was 22.4˚C ± 0.7 which was within the quality assurance range of 23.0 ± 1.0˚C (table 14). Temperatures were within the quality assurance range of 23.0 ± 3.0˚C for instantaneous measurements aside from a minimum value of 19.5 found in replicate 1 of BW15ML-032 on day 0 (table 14). Dissolved oxygen did not drop below 5.8 mg/L (table 14). Mean pH values ranged from 7.67 to 7.76 and average conductivity measurements were in the range of 152.4 to 156.5 (µS/cm) (table 14). Average hardness values during the *L. variegatus* bioaccumulation test ranged from 50.2 – 51.4 mg/L $CaCO_3$ while mean alkalinity values were between 41.7 – 45.4 mg/L $CaCO_3$ (table 14). Ammonia samples were collected and preserved in H_2SO_4 until analyzed. Average ammonia concentrations in the samples ranged from 0.13 – 0.32 mg/L (table 14). The alkalinity and hardness values did not vary by more than 50% during the test. Because the ammonia values were all low (≤0.73 mg/L), there were some values that varied by more than 50% within replicates but the actual differences were small.

Table 14: Average Values (minimum, maximum) for Water Chemistry Parameters of overlying water used in the 28 Day Sediment Bioaccumulation Test with *Lumbriculus variegatus*

Sample ID	Temperature (°C) [a]	Dissolved Oxygen (mg/L) [a]	pH [b]	Conductivity (µS/cm) [b]	Hardness (mg/L $CaCO_3$) [b]	Alkalinity (mg/L $CaCO_3$) [b]	Ammonia (mg/L) [b]
BW15ML-004	22.7 (20.0, 24.2)	7.5 (6.0, 8.5)	7.75 (7.60, 7.96)	156.5 (145.6, 167.8)	51.2 (45.3, 59.2)	44.6 (40.8, 48.0)	0.13 (0.07, 0.18)
BW15ML-010	22.2 (20.4, 23.2)	7.4 (5.8, 9.2)	7.67 (7.54, 7.89)	152.4 (145.0, 158.6)	50.6 (43.3, 64.6)	41.6 (37.6, 46.0)	0.32 (0.12, 0.73)
BW15ML-032	22.5 (19.5, 24.2)	7.6 (6.1, 8.6)	7.76 (7.60, 7.97)	154.3 (143.9, 164.0)	51.4 (45.3, 58.8)	45.4 (42.0, 48.8)	0.13 (0.08, 0.23)
BW15ML-034	22.5 (20.3, 23.6)	7.5 (6.4, 8.5)	7.73 (7.58, 7.97)	153.9 (144.7, 160.3)	50.2 (46.1, 57.4)	45.4 (41.6, 50.8)	0.16 (0.08, 0.24)

[a] Temperature and Dissolved Oxygen were measured twice daily, before and after water renewal
[b] pH, Conductivity, Hardness, Alkalinity, and Ammonia were measured on days 0, 7, 14, 21, and 27

Pace Analytical determined polychlorodibenzo-p-dioxins (PCDDs) and polychlorodibenzofurans (PCDFs) concentrations for *L. variegatus* tissue samples after the 28-Day bioaccumulation sediment test and for a sample of Pre-test *L. variegatus* tissue. Tissue from BW15ML-032 and BW15ML-034 tended to contain the highest total PCDDs and PCDFs (table 15). Total PCDDs and PCDFs are representative of all 2,3,7,8-substituted isomers found in the sediment. The exact concentrations are only given for isomers for which Pace Analytical used carbon 13 labeled internal standards.

Table 15: Concentrations of polychlorodibenzo-p-dioxins (PCDDs) and polychlorodibenzofurans (PCDFs) found in *Lumbriculus variegatus* tissue from a 28 Day Sediment Bioaccumulation Test. Analysis was done by Pace Analytical. All values are in ng/Kg. Concentrations are based on estimated detection limits (EDLs). TCDD Equivalence values based on ITE Factors.

Compound	MLS-LV-1 PRE	BW15ML-004	BW15ML-010	BW15ML-032	BW15ML-034
2,3,7,8-TCDF	0.47 [a]	1.80	0.92 [a]	1.80	1.9
Total TCDF	1.00 [a]	17.00	21.00	22.00	24.0
2,3,7,8-TCDD	ND	0.66 [a]	ND	0.84 [a]	0.74 [a b c]
Total TCDD	ND	1.90	ND	6.10	6.8
1,2,3,7,8-PeCDF	ND	0.27 [a]	ND	0.67 [a]	0.48 [a b c]
2,3,4,7,8-PeCDF	ND	0.85 [a]	0.65 [a]	1.80 [a]	1.4 [a]
Total PeCDF	ND	11.00	10.00 [a]	29.00	24.0
1,2,3.7.8-PeCDD	ND	0.60 [a]	ND	1.50 [a]	1.6 [a]
Total PeCDD	ND	7.00 [a]	ND	12.00 [a]	11.0 [a]
1,2,3,4,7,8-HxCDF	ND	0.58 [a]	ND	1.30 [a]	1.2 [a]
1,2,3,6,7,8-HxCDF	ND	0.46 [a]	ND	2.50 [a]	2.3 [a]
2,3,4,6,7,8-HxCDF	ND	0.34 [a b c]	ND	0.92 [a]	1.0 [a]
1,2,3,7,8,9-HxCDF	ND	ND	ND	ND	ND
Total HxCDF	ND	14.00	4.10 [a]	47.00	40.0
1,2,3,4,7,8-HxCDD	ND	ND	ND	ND	ND
1,2,3,6,7,8-HxCDD	ND	2.50 [a]	ND	3.70 [a]	3.8 [a]
1,2,3,7,8,9-HxCDD	ND	1.10 [a]	ND	1.50 [a]	1.7 [a]
Total HxCDD	ND	22.00	2.30 [a]	25.00	24.0
1,2,3,4,6,7,8-HpCDF	ND	6.80	2.50 [a]	27.00	20.0
1,2,3,4,7,8,9-HpCDF	ND	ND	ND	ND	ND
Total HpCDF	ND	14.00	2.50 [a]	51.00	40.0
1,2,3,4,6,7,8-HpCDD	ND	6.70	1.30 [a]	8.50	7.8
Total HpCDD	ND	24.00	5.00 [a]	23.00	24.0
OCDF	ND	1.60	1.60 [a]	4.40 [a]	4.6 [a]
OCDD	ND	62.00	11.00	52.00	70.0
Total 2,3,7,8-TCDD Equivalence	0.047	2.3	0.47	4.1	3.8

[a] Value estimated due to falling below the calibrated range of the instrument.
[b] Interference present, incorrect isotope ratios obtained.
[c] Concentration was recorded as an estimated maximum possible concentration (EMPC).

Pace Analytical performed metal analysis on the *L. variegatus* tissue obtained after the 28-Day bioaccumulation test. They were also supplied with a Pre-test sample of *L. variegatus* tissue for before and after comparison. All test samples had increases in arsenic levels as compared to the *L. variegatus* Pre-test concentration of arsenic (table 16). It was also observed that organisms exposed to sediment BW15ML-032 contained higher levels of chromium, lead and nickel when compared to the Pre-test sample and organisms exposed to the other sediments used in the bioaccumulation study (table 16).

Table 16: Average Concentrations (Standard Deviation) of Various Metals found in Tissue Samples (n=5) of *Lumbriculus variegatus* used in a 28 Day Sediment Bioaccumulation Test. Only one sample was analyzed for MLS-LV-1 PRE.

Sample ID	Arsenic (mg/Kg)	Cadmium (mg/Kg)	Chromium (mg/Kg)	Copper (mg/Kg)	Lead (mg/Kg)	Nickel (mg/Kg)	Zinc (mg/Kg)
MLS-LV-1 PRE	0.16	0.040 [y]	0.063 [y]	2.5	0.25	0.17	28.4
BW15ML-004	1.0 (0.1)	0.032 [y] (0.004)	0.17 (0.09)	2.3 (0.2)	0.70 (032)	0.16 (0.06)	28.3 (1.6)
BW15ML-010	1.3 (0.1)	0.016 [y] (0.002)	0.092 [y] (0.040)	1.7 (0.1)	0.22 (0.10)	0.12 (0.05)	23.7 (1.6)
BW15ML-032	1.2 (0.1)	0.038 [y] (0.007)	0.40 (0.22)	2.7 (0.3)	1.1 (0.7)	0.59 (0.69)	28.8 (1.6)
BW15ML-034	1.2 (0.1)	0.030 [y] (0.005)	0.22 (0.09)	2.4 (0.1)	0.55 (0.18)	0.20 (0.06)	28.0 (1.2)

[y] Values estimated due to falling below the Limit of Quantification and above the Limit of Detection.

Quality Assurance and Quality Control

Table 17 summarizes the data quality indicators and performance measurement results for the tests performed with the Munger Landing sediment. Reference toxicant tests were performed within three weeks of sediment testing with all three species of organisms used. All three organisms had LC_{50} values for KCl within two standard deviations of the historical average indicating that the organisms used for the tests were healthy. Control charts are available upon request.

Nine LSRI staff members participated in the organism recovery competency test and all staff members achieved 100% organism recovery for both species. Duplicate counts were done on 100% of the replicates of *H. azteca* and *C. dilutus* recovered from the exposure beakers. There was 0% Relative Percent Difference (RPD) with the *H. azteca* counts and 0.97% RPD with the *C. dilutus* counts.

The required number of samples were analyzed in duplicate to verify precision for alkalinity, hardness and ammonia analysis and the maximum RPD for all three was 8.96% for ammonia analysis in the *C. dilutus* tests. This value is well within the Data Quality Objective of <20% RPD for duplicate analysis. Spike recovery values for ammonia were also within the data quality acceptance range.

Table 17: Quality Assurance and Control Limits for all Sediment Toxicity Tests and Results from Testing

Data Quality Indicator	Evaluation Process/Performance Measurement	Data Quality Objective	Performance Measurement Result		
Bias	**Experiment Bias:** Monthly reference toxicant tests are conducted on test organisms. Performance is measured by sensitivity of the test organisms relative to historical values.	LC_{50} value within 2 standard deviations of the historical LC_{50} average	***H. azteca:*** LC_{50} value from reference toxicant test performed 09 December 2016 (449.5 mg/L KCl)was within 2 SD of the historical average		
			***C. dilutus*:** LC_{50} value from reference toxicant test performed 30 December 2016 (6681 mg/L KCl) was within 2 SD of the historical average		
			***L. variegatus*:** LC_{50} value from reference toxicant test performed 06 January 2016 (794.6 mg/L KCl) was within 2 SD of the historical average		
	Operator Bias: Experimental units (10%) are counted by two separate analysts – with performance measured by Average relative percent difference (RPD) of the number of live test organisms counted for all second analyses.	Organism Addition: 100% replicates checked before and after addition Organism Recovery: At least 90% Recovery of organisms in competency training	***H. azteca* Test:**	**Organism Addition:** 100% replicates checked before and after addition	**Organism Recovery:** All Staff Recovered 100% in Training, 100% replicates checked after recovery; RPD = 0% ± 0
			***C. dilutus* Test:**	**Organism Addition:** 100% replicates checked before and after addition	**Organism Recovery:** All Staff Recovered 100% in Training,100% of replicates checked after recovery; RPD= 0.97% ±3.5
			***L. variegatus* Test:**	Not Applicable – Mass measurements	Not Applicable – Mass measurements
Comparability	Routine procedures are conducted according to appropriate SOPs to ensure consistency between tests.	Not Applicable – Qualitative	The following LSRI SOPs were used for all Solid Phase Sediment Testing: **LSRI/SOP/AT/19v.2** **LSRI/SOP/AT/20v.6** **LSRI/SOP/AT/21v.7**		
			The following LSRI SOPs were used for all water quality analyses conducted during the tests: **LSRI/SOP/GLM/01v.2** – Procedure for Measuring Alkalinity **LSRI/SOP/GLM/02v.2** – Procedure for Measuring Total Hardness **LSRI/SOP/SA/25v.3** – Ammonia (NH_3) Analysis by Specific Ion Electrode		

Data Quality Indicator	Evaluation Process/Performance Measurement	Data Quality Objective	Performance Measurement Result	Data Quality Indicator	Evaluation Process/Performance Measurement
Precision	Samples (10%) are collected and analyzed in duplicate – with performance measured by average relative percent difference (RPD) of all duplicate analyses performed during test trials.	<20% average (± SD) RPD	***H. azteca* Test:**	**Ammonia**: 11% analyzed in duplicate	**Ammonia**: 4.75% (± 2.3%) RPD
				Hardness: 14% analyzed in duplicate	**Hardness**: 1.40% (± 1.9%) RPD
				Alkalinity: 14% analyzed in duplicate	**Alkalinity**: 3.91% (± 4.2%) RPD
			***C. dilutus* Test:**	**Ammonia**: 11% analyzed in duplicate	**Ammonia**: 8.96% (± 4.9%) RPD
				Hardness: 14% analyzed in duplicate	**Hardness**: 3.92% (± 4.0%) RPD
				Alkalinity: 14% analyzed in duplicate	**Alkalinity**: 2.17% (± 2.2%) RPD
			***L. variegatus* Test:**	**Ammonia**:12.5% analyzed in duplicate	**Ammonia**: 7.88% (± 7.0%) RPD
				Hardness: 20% analyzed in duplicate	**Hardness**: 4.42% (± 4.6%) RPD
				Alkalinity: 20% analyzed in duplicate	**Alkalinity**: 1.72% (± 1.3%) RPD
Bias	Performance is measured by average percent spike-recovery (%SPR) of all analyses performed during test trials.	75%-110% average (± SD) SPR	***H. azteca* Test:**		**Ammonia**: 100.1% (± 9.2%) SPR
			***C. dilutus* Test:**		**Ammonia:** 101.6% (± 6.9%) SPR
			***L. variegatus* Test:**		**Ammonia:** 108.1% (± 4.6%) SPR
Representativeness	Control and treatment samples are handled and analyzed in the same manner.	Not Applicable – Qualitative	All control and treatment samples were collected, handled, and analyzed in the same manner (using the appropriate SLRI SOPs).		

Conclusions

The Lake Superior Research Institute (LSRI) contracted with Bay West, LLC to evaluate the toxicity and bioaccumulation potential of sediments collected from Munger Landing.

Sediment BW15ML-032 had significantly reduced survival in the *C. dilutus* test and significantly reduced weight in the *H. azteca* test. Data indicates that the low survival and weights were not from experimental methods as the control and other treatment sediments had high survival and higher weights. During testing, qualitative observations of the *H. azteca* avoiding sediment BW15ML-032 occurred on multiple days after addition to sediment. Sediment avoidance was also observed once with *H. azteca* during testing for BW15ML-038. Sediments BW15ML-018, BW15ML-037, and BW15ML-038 also had significantly lower weights for *H. azteca* when compared to West Bearskin Lake.

In the 10-day *C. dilutus* test, sediments BW15ML-006 and BW15ML-022 produced significantly greater average weight for the *C. dilutus* when compared to West Bearskin Lake. These sediments may have contained more organic matter to supplement the diet of the *C. dilutus*.

During the 28-Day bioaccumulation test with *L. variegatus*, the oligochaetes appeared unaffected in both weight and behavior by sediment BW15ML-032 which caused low survival in the *C. dilutus* test and low weight in the *H. azteca* test. During testing, an observation was made, the oligochaetes burrowed quicker into the BW15ML-010 sediments replicates more than any of the other sediments. No major change in mass of tissue was observed in any of the replicates. The minimal loss that did occur may have been a result of not every organism being recovered or a difference in the amount of moisture present when the wet weights were determined.

In summary, sediment contaminants at location BW15ML-032 resulted in reduced survival of *C. dilutus* and reduced weight of *H. azteca*. Sediment contaminants at locations BW15ML-018, BW15ML-037, and BW15ML-038 resulted in the reduced growth of *H. azteca* during laboratory testing. Arsenic concentrations in the tested sediments likely contributed to increased levels of arsenic in *L. variegatus* and concentrations of chromium, lead, and nickel at location BW15ML-032 likely contributed to increased concentrations of these metals in *L. variegatus* after laboratory exposure.

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Appendices

Appendix 1
Biological and Chemical Analysis Data Tables

Appendix Table 1: Survival and Growth of *H. azteca* following the 10 day Sediment Toxicity Test

Sample ID	Test Sediment	Number of Survivors (10)	Average Survival	Standard Deviation	Percent Survival	Total Dry Weight (g)	Individual Dry Weight (mg)	Average Dry Weight (mg)	Standard Deviation
HA1	Silica Sand	8				0.00037	0.046		
HA2	Silica Sand	8				0.00029	0.036		
HA3	Silica Sand	7				0.00034	0.048		
HA4	Silica Sand	10				0.00043	0.043		
HA5	Silica Sand	8				0.00031	0.038		
HA6	Silica Sand	10				0.00041	0.041		
HA7	Silica Sand	7				0.00034	0.048		
HA8	Silica Sand	8				0.00049	0.061		
HA	**Silica Sand**		**8.25**	**1.16**	**82.5%**			**0.045**	**0.008**
HB1	West Bearskin Lake	9				0.00078	0.087		
HB2	West Bearskin Lake	10				0.00063	0.063		
HB3	West Bearskin Lake	7				0.00054	0.077		
HB4	West Bearskin Lake	9				0.00068	0.076		
HB5	West Bearskin Lake	10				0.00063	0.063		
HB6	West Bearskin Lake	9				0.00056	0.062		
HB7	West Bearskin Lake	10				0.00053	0.053		
HB8	West Bearskin Lake	10				0.00050	0.050		
HB	**West Bearskin Lake**		**9.25**	**1.04**	**92.5%**			**0.066**	**0.013**
HC1	BW15ML-034	10				0.00048	0.048		
HC2	BW15ML-034	11				0.00056	0.051		
HC3	BW15ML-034	10				0.00053	0.053		
HC4	BW15ML-034	10				0.00058	0.058		
HC5	BW15ML-034	8				0.00040	0.050		
HC6	BW15ML-034	6				0.00036	0.060		
HC7	BW15ML-034	8				0.00030	0.038		
HC8	BW15ML-034	8				0.00035	0.044		
HC	**BW15ML-034**		**8.88**	**1.64**	**88.8%**			**0.050**	**0.007**
HD1	BW15ML-018	10				0.00042	0.042		
HD2	BW15ML-018	10				0.00056	0.056		
HD3	BW15ML-018	9				0.00055	0.061		
HD4	BW15ML-018	10				0.00040	0.040		
HD5	BW15ML-018	8				0.00016	0.020		
HD6	BW15ML-018	8				0.00062	0.078		
HD7	BW15ML-018	9				0.00037	0.041		
HD8	BW15ML-018	9				0.00037	0.041		
HD	**BW15ML-018**		**9.13**	**0.83**	**91.3%**			**0.047**	**0.017**
HE1	BW15ML-022	9				0.00066	0.073		
HE2	BW15ML-022	10				0.00089	0.089		
HE3	BW15ML-022	10				0.00079	0.079		
HE4	BW15ML-022	10				0.00086	0.086		
HE5	BW15ML-022	10				0.00087	0.087		
HE6	BW15ML-022	10				0.00094	0.094		
HE7	BW15ML-022	11				0.00076	0.069		
HE8	BW15ML-022	10				0.00056	0.056		
HE	**BW15ML-022**		**10**	**0.53**	**100.0%**			**0.079**	**0.013**

Sample ID	Test Sediment	Number of Survivors (10)	Average Survival	Standard Deviation	Percent Survival	Total Dry Weight (g)	Individual Dry Weight (mg)	Average Dry Weight (mg)	Standard Deviation
HF1	BW15ML-037	10				0.00051	0.051		
HF2	BW15ML-037	7				0.00031	0.044		
HF3	BW15ML-037	9				0.00052	0.058		
HF4	BW15ML-037	9				0.00033	0.037		
HF5	BW15ML-037	10				0.00052	0.052		
HF6	BW15ML-037	9				0.00049	0.054		
HF7	BW15ML-037	10				0.00050	0.050		
HF8	BW15ML-037	9				0.00023	0.026		
HF	**BW15ML-037**		**9.13**	**0.99**	**91.3%**			**0.046**	**0.011**
HG1	BW15ML-032	9				0.00039	0.043		
HG2	BW15ML-032	9				0.00035	0.039		
HG3	BW15ML-032	8				0.00038	0.048		
HG4	BW15ML-032	9				0.00001	0.001		
HG5	BW15ML-032	8				0.00031	0.039		
HG6	BW15ML-032	9				0.00036	0.040		
HG7	BW15ML-032	9				0.00029	0.032		
HG8	BW15ML-032	10				0.00042	0.042		
HG	**BW15ML-032**		**8.88**	**0.64**	**88.8%**			**0.035**	**0.015**
HH1	BW15ML-038	7				0.00025	0.036		
HH2	BW15ML-038	9				0.00038	0.042		
HH3	BW15ML-038	7				0.00038	0.054		
HH4	BW15ML-038	10				0.00035	0.035		
HH5	BW15ML-038	8				0.00049	0.061		
HH6	BW15ML-038	8				0.00050	0.063		
HH7	BW15ML-038	8				0.00035	0.044		
HH8	BW15ML-038	8				0.00035	0.044		
HH	**BW15ML-038**		**8.13**	**0.99**	**81.3%**			**0.047**	**0.011**
HI1	BW15ML-006	9				0.00054	0.060		
HI2	BW15ML-006	10				0.00068	0.068		
HI3	BW15ML-006	10				0.00094	0.094		
HI4	BW15ML-006	9				0.00058	0.064		
HI5	BW15ML-006	11				0.00073	0.066		
HI6	BW15ML-006	8				0.00058	0.073		
HI7	BW15ML-006	10				0.00078	0.078		
HI8	BW15ML-006	8				0.00060	0.075		
HI	**BW15ML-006**		**9.38**	**1.06**	**93.8%**			**0.072**	**0.011**
HJ1	BW15ML-010	10				0.00068	0.068		
HJ2	BW15ML-010	9				0.00062	0.069		
HJ3	BW15ML-010	10				0.00059	0.059		
HJ4	BW15ML-010	9				0.00064	0.071		
HJ5	BW15ML-010	10				0.00065	0.065		
HJ6	BW15ML-010	10				0.00056	0.056		
HJ7	BW15ML-010	10				0.00062	0.062		
HJ8	BW15ML-010	10				0.00055	0.055		
HJ	**BW15ML-010**		**9.75**	**0.46**	**97.5%**			**0.063**	**0.006**

Sample ID	Test Sediment	Number of Survivors (10)	Average Survival	Standard Deviation	Percent Survival	Total Dry Weight (g)	Individual Dry Weight (mg)	Average Dry Weight (mg)	Standard Deviation
HK1	BW15ML-004	6				0.00028	0.047		
HK2	BW15ML-004	10				0.00051	0.051		
HK3	BW15ML-004	10				0.00075	0.075		
HK4	BW15ML-004	7				0.00044	0.063		
HK5	BW15ML-004	8				0.00051	0.064		
HK6	BW15ML-004	7				0.00028	0.040		
HK7	BW15ML-004	8				0.00038	0.048		
HK8	BW15ML-004	8				0.00045	0.056		
HK	**BW15ML-004**		**8.0**	**1.41**	**80.0%**			**0.055**	**0.011**

Appendix Table 2: Temperature (˚C) Water Chemistry Parameter for *H. azteca* during the 10-Day Sediment Toxicity Test

Day	0		1		2		3		4		5		6		7		8		9		10				
am/pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am		Average	Min	Max
HA1	24.0	24.5							24.1										24.2	24.6					
HA2	24.0					24.4								24.5					24.3						
HA3	24.1							24.5		24.5						24.6			24.4						
HA4	24.1	24.5	24.3	24.5	24.2	24.4	24.3	24.6	24.2	24.4	24.3	24.4	24.3	24.5	24.3	24.5	24.3	24.5	24.2	24.5	24.2				
HA5	24.0				24.3								24.2						24.3						
HA6	24.0		24.3								24.3						24.4		24.3		24.6				
HA7	24.0						24.4								24.3				24.3						
HA8	24.0			24.5								24.5						24.6	24.4				24.3	24.0	24.6
HB1	23.3	24.0							23.4										23.6	24.1					
HB2	23.3					23.8								23.8					23.5						
HB3	23.4							23.7		23.9						24.0			23.6						
HB4	23.4	24.0	23.4	23.9	23.5	23.7	23.5	23.8	23.4	23.9	23.5	23.7	23.5	23.9	23.6	24.0	23.5	23.9	23.5	24.1	23.8				
HB5	23.5				23.5								23.6						23.6						
HB6	23.4		23.5								23.6						23.6		23.6		23.8				
HB7	23.5						23.5								23.6				23.6						
HB8	23.5			23.9								23.8						23.9	23.6				23.7	23.3	24.1
HC1	23.1	23.8							23.0										23.3	23.9					
HC2	23.0					23.9								24.0					23.4						
HC3	23.1				23.6			24.0		23.7						23.7			23.4						
HC4	23.1	23.8	23.6	23.9	23.6	23.9	23.5	23.9	23.0	23.8	23.6	23.7	23.4	24.0	23.5	23.7	23.4	23.6	23.4	24.0	23.8				
HC5	23.2												23.5						23.3						
HC6	23.4		23.5								23.6						23.2		23.4		23.6				
HC7	23.3						23.5								23.3				23.3						
HC8	23.4			23.9								23.7						23.6	23.3				23.5	23.0	24.0
HD1	23.5	24.1							23.5										24.0	24.5					
HD2	23.6					24.1								24.3					24.0						
HD3	23.4							24.2		24.1						24.3			23.9						
HD4	23.3	23.9	23.7	24.1	23.7	24.1	23.7	24.2	23.5	24.1	23.9	24.2	23.8	24.3	23.8	24.2	24.0	24.3	23.9	24.4	24.2				
HD5	23.8				23.9								23.8						24.1						
HD6	23.5		23.5								23.9						24.0		23.9		24.6				
HD7	23.4						23.8								23.8				24.0						
HD8	23.3			24.2								24.1						24.3	23.9				23.9	23.3	24.6

Day	0		1		2		3		4		5		6		7		8		9		10				
am/pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am		Average	Min	Max
HE1	23.6	24.2							23.6										24.0	24.2					
HE2	23.7					24.0								24.2					24.0						
HE3	23.6							24.1		24.0						24.3			24.1						
HE4	23.7	24.2	23.7	24.1	23.8	23.8	23.7	24.2	23.4	24.0	24.0	24.1	23.9	24.2	23.9	24.3	24.0	24.3	24.0	24.3	24.3				
HE5	23.7				24.0								24.0						24.1						
HE6	23.7		23.9								24.0						24.1		24.0		24.4				
HE7	23.9						23.8								24.0				24.0						
HE8	23.8			24.2								24.2						24.4	24.0				24.0	23.4	24.4
HF1	23.1	23.5							23.0										23.3	24.0					
HF2	23.0					23.4								23.6					23.2						
HF3	23.1							23.7		23.6						23.8			23.3						
HF4	23.1	23.5	23.3	23.7	23.4	23.6	23.2	23.7	23.0	23.6	23.2	23.5	23.2	23.6	23.2	23.6	23.3	23.7	23.2	23.7	23.7				
HF5	23.1				23.4								23.3						23.2						
HF6	23.2		23.2								23.3						23.2		23.3		23.7				
HF7	23.1						23.3								23.2				23.3						
HF8	23.2			23.7								23.6						23.6	23.2				23.4	23.0	24.0
HG1	23.2	23.7							22.8										23.4	23.4					
HG2	23.2					23.6								23.7					23.3						
HG3	23.2							23.7		23.6						23.5			23.2						
HG4	23.2	23.7	23.3	23.7	23.1	23.4	23.2	23.7	22.9	23.7	23.2	23.5	23.2	23.4	23.0	23.5	23.2	23.7	23.2	23.5	23.6				
HG5	23.4				23.2								23.2						23.2						
HG6	23.3		23.3								23.3						23.2		23.4		23.7				
HG7	23.3						23.2								23.2				23.3						
HG8	23.3			23.8								23.7						23.8	23.3				23.4	22.8	23.8
HH1	23.9	24.1							23.8										24.0	24.4					
HH2	23.8					24.1								24.2					24.0						
HH3	23.7							24.2		24.2						24.3			24.1						
HH4	23.6	24.1	23.9	24.1	23.7	24.2	23.9	24.2	23.8	24.1	24.0	24.1	24.0	24.3	23.7	24.3	24.0	24.3	24.1	24.4	24.3				
HH5	23.8				23.9								23.8						24.1						
HH6	23.8		23.9								24.0						24.0		24.0		24.4				
HH7	24.0						24.0								23.8				24.1						
HH8	24.0			24.2								24.1						24.3	24.0				24.0	23.6	24.4

Day	0		1		2		3		4		5		6		7		8		9		10				
am/pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am		Average	Min	Max
HI1	23.4	23.9							23.4										23.7	24.0					
HI2	23.4					23.9								23.9					23.8						
HI3	23.6							23.8		23.9						24.1			23.7						
HI4	23.6	24.0	23.7	24.1	23.8	23.8	23.8	23.8	23.7	23.9	23.7	23.9	23.5	23.9	23.5	24.1	23.8	24.1	23.8	24.2	23.9				
HI5	23.5				23.6								23.6						23.7						
HI6	23.4		23.7								23.8						23.8		23.8		24.1				
HI7	23.5						23.5								23.8				23.8						
HI8	23.5			24.0								24.0						24.1	23.8				23.8	23.4	24.2
HJ1	23.4	23.7							23.3										23.4	23.9					
HJ2	23.4					23.5								23.9					23.6						
HJ3	23.4							23.9		23.8						23.8			23.5						
HJ4	23.3	23.5	23.4	23.8	23.5	23.6	23.5	23.9	23.4	23.6	23.8	23.9	23.6	23.9	23.4	23.8	23.7	23.9	23.5	24.1	23.9				
HJ5	23.4				23.4								23.5						23.5						
HJ6	23.4		23.5								23.7						23.6		23.5		24.0				
HJ7	23.5						23.5								23.4				23.5						
HJ8	23.5			24.0								23.8						24.0	23.5				23.6	23.3	24.1
HK1	23.7	24.0							23.4										23.9	24.4					
HK2	23.7					24.0								24.2					23.9						
HK3	23.7							24.0		24.0						24.3			23.9						
HK4	23.8	24.2	23.9	24.1	23.4	23.9	23.8	24.0	23.3	24.0	23.8	24.0	23.7	24.2	23.7	24.3	23.5	24.2	24.0	24.4	24.2				
HK5	23.9				24.0								23.9						24.1						
HK6	23.8		23.8								23.9						24.0		24.2		24.5				
HK7	23.8						24.0								23.8				24.2						
HK8	23.9			24.4								24.2						24.4	24.1				24.0	23.3	24.5

Appendix Table 3: Dissolved Oxygen (mg/L) Water Chemistry Parameter for *H. azteca* during the 10-Day Sediment Toxicity Test

Day	0		1		2		3		4		5		6		7		8		9		10				
am/pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am		Average	Min	Max
HA1	7.1	7.8							7.4										7.5	8.0					
HA2	7.3					7.4								7.8					7.4						
HA3	7.3							7.4		7.7						7.8			7.1						
HA4	7.2	8.3	7.7	7.4	7.6	7.6	7.6	7.1	7.5	7.9	7.1	7.9	7.7	7.8	8.2	7.7	7.6	7.4	7.7	8.2	8.2				
HA5	7.1				7.6								7.7						7.4						
HA6	7.2		7.4								7.6						7.0		7.5		7.6				
HA7	7.0						7.2								8.1				7.8						
HA8	7.1			7.5								7.9						7.7	7.2				7.6	7.0	8.3
HB1	7.0	8.0							7.3										7.2	7.9					
HB2	6.5					7.7								7.8					7.6						
HB3	6.8							7.1		7.4						7.5			7.5						
HB4	6.4	7.9	7.7	8.1	7.5	8.3	7.3	7.0	7.3	7.4	7.6	7.6	7.5	7.8	8.1	7.4	7.3	7.5	7.3	7.7	7.9				
HB5	6.8				7.5								7.7						7.3						
HB6	6.4		7.6								7.7						7.4		6.9		8.0				
HB7	6.9						6.6								8.2				7.0						
HB8	6.8			7.7								6.1						7.6	7.2				7.4	6.1	8.3
HC1	6.8	7.9							8.7										7.1	8.1					
HC2	6.6					7.4								7.4					7.0						
HC3	6.4							7.1		8.9						7.4			7.4						
HC4	6.4	8.3	7.7	7.7	7.5	7.3	7.2	6.9	8.3	8.8	7.6	8.1	8.0	7.8	8.3	7.6	7.3	8.3	7.4	8.1	7.7				
HC5	6.4				7.3								7.5						7.2						
HC6	6.4		7.7								7.6						7.1		7.9		7.7				
HC7	6.6						7.2								8.5				7.2						
HC8	6.9			7.5								7.7						7.8	7.4				7.5	6.4	8.9
HD1	6.6	7.4							8.7										8.1	7.4					
HD2	6.5					6.8								7.4					7.1						
HD3	6.3							6.5		7.4						7.3			6.5						
HD4	6.0	8.1	7.3	7.6	6.8	6.8	6.0	6.7	8.1	7.6	7.2	7.5	7.6	7.6	8.4	7.4	7.0	7.2	7.0	7.4	7.4				
HD5	6.1				7.7								7.8						6.7						
HD6	6.0		8.2								7.4						7.5		7.1		7.4				
HD7	5.8						6.6								8.0				6.8						
HD8	6.1			7.5								7.5						7.3	6.7				7.2	5.8	8.7

Day	0		1		2		3		4		5		6		7		8		9		10				
am/pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am		Average	Min	Max
HE1	4.9	7.2							6.3										6.9	7.2					
HE2	5.6					7.2								7.3					7.2						
HE3	5.5							6.7		7.6						7.3			6.6						
HE4	5.2	7.3	6.6	8.5	7.0	7.6	6.4	6.5	6.8	7.0	7.6	7.4	7.2	7.3	7.6	7.4	7.1	7.2	6.7	7.3	7.2				
HE5	5.5				7.0								7.3						6.5						
HE6	5.9		8.1								6.9						6.8		6.7		6.8				
HE7	5.4						6.8								7.6				6.7						
HE8	5.1			7.6								7.1						7.2	7.1				6.9	4.9	8.5
HF1	6.7	8.4							8.0										7.1	7.6					
HF2	6.4					8.7								7.9					7.4						
HF3	6.9							7.5		7.9						7.6			7.3						
HF4	6.0	8.6	8.7	8.5	7.4	7.3	7.3	7.2	8.6	7.7	7.7	7.5	7.7	7.6	8.2	7.8	7.7	7.8	7.8	8.2	7.7				
HF5	6.5				7.3								7.7						7.4						
HF6	7.0		8.1								7.6						7.7		7.4		8.8				
HF7	7.1						7.2								8.0				7.2						
HF8	7.0			7.6								7.6						7.5	7.4				7.6	6.0	8.8
HG1	5.9	8.1							8.5										8.4	8.4					
HG2	6.0					7.4								8.0					7.2						
HG3	6.5							7.3		7.6						7.2			7.2						
HG4	6.0	7.8	7.8	7.2	7.2	7.7	7.3	6.9	8.3	7.4	7.7	7.6	7.7	8.4	8.6	7.3	7.1	7.1	6.5	8.2	7.6				
HG5	6.2				7.0								7.2						6.9						
HG6	6.6		8.7								7.6						7.3		7.6		7.4				
HG7	6.7						7.9								7.9				7.1						
HG8	6.4			7.5								7.4						7.4	6.5				7.4	5.9	8.7
HH1	5.5	8.2							8.1										7.6	7.9					
HH2	4.3					7.1								8.1					7.4						
HH3	6.6							7.4		7.9						7.1			6.9						
HH4	6.5	8.2	7.9	8.8	7.7	7.2	6.9	7.0	9.0	8.3	7.2	7.6	7.6	7.8	8.5	7.4	6.9	7.1	6.9	7.8	7.0				
HH5	5.9				7.6								7.4						7.1						
HH6	6.3		7.3								7.4						7.1		6.5		7.0				
HH7	6.3						6.8								8.0				6.6						
HH8	6.6			8.2								7.4						7.5	6.8				7.3	4.3	9.0

Day	0		1		2		3		4		5		6		7		8		9		10				
am/pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am		Average	Min	Max
HI1	5.1	7.7							7.6										7.1	7.7					
HI2	6.4					7.5								7.5					7.3						
HI3	6.7							7.6		7.7						7.4			7.1						
HI4	5.9	6.8	7.6	7.2	7.3	7.4	7.1	7.3	8.6	7.7	7.0	7.6	7.6	7.4	7.2	7.4	7.3	7.4	7.0	7.5	7.4				
HI5	5.1				7.0								7.6						7.3						
HI6	4.4		7.6								7.6						7.5		7.2		8.0				
HI7	6.0						6.0								7.6				7.5						
HI8	4.5			7.7								7.3						7.6	8.1				7.1	4.4	8.6
HJ1	5.8	7.6							7.9										7.0	7.5					
HJ2	6.3					8.5								7.5					6.9						
HJ3	5.8							6.6		7.7						7.2			7.4						
HJ4	5.9	8.4	8.4	8.7	7.3	8.0	6.7	6.8	7.8	8.0	7.4	7.7	7.6	8.0	7.5	7.5	7.1	8.0	7.9	7.6	8.0				
HJ5	6.5				7.9								7.6						7.4						
HJ6	6.2		9.0								7.3						6.9		6.6		7.2				
HJ7	7.1						6.8								7.3				6.4						
HJ8	6.4			8.3								7.3						7.5	7.3				7.4	5.8	9.0
HK1	6.0	8.2							7.4										7.1	7.2					
HK2	6.1					8.1								7.3					7.5						
HK3	5.5							6.8		6.8						6.8			6.5						
HK4	6.1	7.7	7.2	7.7	7.1	6.5	6.6	6.4	7.9	6.7	6.2	7.1	8.0	7.4	7.9	7.0	7.0	7.8	7.4	7.3	6.9				
HK5	6.8				8.2								7.8						7.1						
HK6	6.4		8.9								7.3						7.2		7.1		7.6				
HK7	6.5						7.6								6.4				7.3						
HK8	5.9			7.2								7.6						7.5	7.2				7.1	5.5	8.9

Appendix Table 4: pH Water Chemistry Parameter for *H. azteca* during the 10-Day Sediment Toxicity Test

Day	0	2	4	7	9			
am/pm	am	am	am	am	am	Average	Min	Max
HA1	8.01		8.09		8.07			
HA4	8.07	8.03	8.14	8.07	8.11			
HA5	8.09	8.15			8.11			
HA7				8.1				
HA8	8.08				8.11	8.09	8.01	8.15
HB1	7.97		8.02		8.04			
HB4	7.71	8.02	8.02	7.97	8.01			
HB5	7.95	8			8.06			
HB7				7.98				
HB8	7.88				8.04	7.97	7.71	8.06
HC1	7.64		8.03		8			
HC4	7.91	8.01	8.07	8.07	8.03			
HC5	7.66	7.96			8.01			
HC7				8.04				
HC8	7.97				8	7.93	7.64	8.07
HD1	7.58		7.99		8.06			
HD4	7.67	7.74	7.94	8.03	8.07			
HD5	7.67	7.96			8.09			
HD7				8.02				
HD8	7.65				8.12	7.86	7.58	8.12
HE1	7.38		7.7		7.93			
HE4	7.51	7.76	7.74	7.94	8			
HE5	7.43	7.94			8.03			
HE7				7.98				
HE8	7.33				7.92	7.69	7.33	8.03
HF1	7.92		8.03		8.06			
HF4	7.89	8.08	8.09	8.02	8.06			
HF5	7.77	8.06			8.05			
HF7				8.02				
HF8	7.94				8.05	7.99	7.77	8.09

Day	0	2	4	7	9			
am/pm	am	am	am	am	am	Average	Min	Max
HG1	7.72		8.06		7.96			
HG4	7.69	7.81	8.05	8.02	7.83			
HG5	7.74	7.83			7.91			
HG7				7.97				
HG8	7.79				7.87	7.86	7.69	8.06
HH1	7.83		8.12		8.17			
HH4	7.88	7.93	8.13	8.13	8.2			
HH5	7.9	8.05			8.16			
HH7				8.12				
HH8	7.97				8.21	8.04	7.83	8.21
HI1	7.16		7.95		7.92			
HI4	7.3	7.93	8.02	7.78	7.89			
HI5	7.12	7.74			7.92			
HI7				8.03				
HI8	7.16				7.91	7.55	7.12	8.03
HJ1	7.46		7.92		8.17			
HJ4	7.51	7.87	7.97	8.08	8.16			
HJ5	7.58	7.88			8.16			
HJ7				8.1				
HJ8	7.52				8.18	7.814	7.46	8.18
HK1	7.66		7.76		7.98			
HK4	7.71	7.6	7.74	7.88	7.99			
HK5	7.97	8.04			8.07			
HK7				7.67				
HK8	7.8				8.05	7.823	7.6	8.07

Appendix Table 5: Conductivity (µS/cm) Water Chemistry Parameter for *H. azteca* during the 10-Day Sediment Toxicity Test

Day	0	9			
am/pm	am	am	Average	Min	Max
HA1	142.3	144.7			
HA8	142.2	145	143.6	142.2	145.0
HB1	136.8	145.3			
HB8	136.9	144.3	140.8	136.8	145.3
HC1	146	148.7			
HC8	142.5	148.2	146.4	142.5	148.7
HD1	143.6	147.9			
HD8	142.4	149.2	145.8	142.4	149.2
HE1	144.8	149.3			
HE8	143.6	150.2	147.0	143.6	150.2
HF1	142.3	147.6			
HF8	143.2	148.2	145.3	142.3	148.2
HG1	144.6	148			
HG8	143.6	149.1	146.3	143.6	149.1
HH1	145.7	150.6			
HH8	146.7	151.9	148.7	145.7	151.9
HI1	144.6	146			
HI8	143	147.3	145.2	143.0	147.3
HJ1	142.2	152.8			
HJ8	142.6	152.3	147.5	142.2	152.8
HK1	143.5	149.1			
HK8	145.6	148.8	146.8	143.5	149.1

Appendix Table 6: Ammonia (mg/L) Water Chemistry Parameter for *H. azteca* during the 10-Day Sediment Toxicity Test

Day	0	9			
am/pm	am	am	Average	Min	Max
HA1	0.063	0.17			
HA8	0.063	0.16	0.11	0.06	0.17
HB1	0.08	0.10			
HB8	0.08	0.10	0.09	0.08	0.10
HC1	0.14	0.07			
HC8	0.07	0.07	0.09	0.07	0.14
HD1	0.07	0.063			
HD8	0.11	0.063	0.08	0.06	0.11
HE1	0.17	0.07			
HE8	0.185	0.09	0.13	0.07	0.19
HF1	0.11	0.07			
HF8	0.08	0.06	0.08	0.06	0.11
HG1	0.11	0.063			
HG8	0.13	0.063	0.09	0.06	0.13
HH1	0.095	0.08			
HH8	0.09	0.07	0.08	0.07	0.10
HI1	0.36	0.12			
HI8	0.25	0.10	0.21	0.10	0.36
HJ1	0.11	0.07			
HJ8	0.08	0.063	0.08	0.06	0.11
HK1	0.1	0.063			
HK8	0.11	0.063	0.08	0.06	0.11

Appendix Table 7: Hardness (mg/L $CaCO_3$) Water Chemistry Parameter for *H. azteca* during the 10-Day Sediment Toxicity Test

Day	0	9			
am/pm	am	am	Average	Min	Max
HA3	45.2	48.4			
HA6	45.6	48	46.8	45.2	48.4
HB3	44.8	45.6			
HB6	41.6	45.2	44.3	41.6	45.6
HC3	51.2	48			
HC6	46.4	49.6	48.8	46.4	51.2
HD3	50.8	49.2			
HD6	48.8	48	49.2	48.0	50.8
HE3	45.6	50.8			
HE6	44.4	49.6	47.6	44.4	50.8
HF3	46.8	48			
HF6	48.4	47.6	47.7	46.8	48.4
HG3	45.2	45.6			
HG6	47.2	47.2	46.3	45.2	47.2
HH3	52.4	47.2			
HH6	51.2	49.6	50.1	47.2	52.4
HI3	47.2	46			
HI6	48.4	46.4	47.0	46.0	48.4
HJ3	52.4	52.4			
HJ6	50	50.4	51.3	50	52.4
HK3	52	47.6			
HK6	54.0	45.6	49.8	45.6	54

Appendix Table 8: Alkalinity (mg/L $CaCO_3$) Water Chemistry Parameter for *H. azteca* during the 10-Day Sediment Toxicity Test

Day	0	9			
am/pm	am	am	Average	Min	Max
HA2	46	44.8			
HA5	46.4	37.6	43.7	37.6	46.4
HB2	43.2	49.2			
HB5	44.8	42	44.8	42.0	49.2
HC2	48	48			
HC5	44	47.6	46.9	44.0	48.0
HD2	46	47.6			
HD5	45.6	49.2	47.1	45.6	49.2
HE2	46	50.4			
HE5	45.6	49.6	47.9	45.6	50.4
HF2	45.2	47.2			
HF5	46.4	47.2	46.5	45.2	47.2
HG2	50	48			
HG5	50.4	49.6	49.5	48.0	50.4
HH2	50.4	49.2			
HH5	51.2	48.4	49.8	48.4	51.2
HI2	48	47.6			
HI5	48.4	48	48.0	47.6	48.4
HJ2	48.4	51.2			
HJ5	48	48	48.9	48	51.2
HK2	47.2	45.2			
HK5	46.8	47.6	46.7	45.2	47.6

Appendix Table 9: Survival and Growth of *C. dilutus* following the 10 day Sediment Toxicity Test

Sample ID	Test Sediment	Number of Survivors (10)	Average Survival	Standard Deviation	Percent Survival	Total Dry Weight (mg)	Individual Dry Weight (mg)	Average Dry Weight (mg)	Standard Deviation
CA1	Silica Sand	10				5.55	0.555		
CA2	Silica Sand	10				5.63	0.563		
CA3	Silica Sand	10				5.43	0.543		
CA4	Silica Sand	8				4.84	0.605		
CA5	Silica Sand	10				6.31	0.631		
CA6	Silica Sand	7				4.68	0.669		
CA7	Silica Sand	10				4.1	0.410		
CA8	Silica Sand	10				4.23	0.423		
CA	**Silica Sand**		**9.38**	**1.19**	**93.8%**			**0.550**	**0.092**
CB1	West Bearskin Lake	10				5.51	0.551		
CB2	West Bearskin Lake	10				5.57	0.557		
CB3	West Bearskin Lake	10				6.53	0.653		
CB4	West Bearskin Lake	10				6.63	0.663		
CB5	West Bearskin Lake	10				7.74	0.774		
CB6	West Bearskin Lake	10				6.75	0.675		
CB7	West Bearskin Lake	10				6.57	0.657		
CB8	West Bearskin Lake	10				7.49	0.749		
CB	**West Bearskin Lake**		**10**	**0.00**	**100.0%**			**0.660**	**0.079**
CC1	BW15ML-034	10				6.61	0.661		
CC2	BW15ML-034	8				5.15	0.644		
CC3	BW15ML-034	9				7.72	0.858		
CC4	BW15ML-034	10				5.85	0.585		
CC5	BW15ML-034	11				7.39	0.672		
CC6	BW15ML-034	8				6.03	0.754		
CC7	BW15ML-034	8				6.21	0.776		
CC8	BW15ML-034	9				6.55	0.728		
CC	**BW15ML-034**		**9.13**	**0.58**	**91.3%**			**0.710**	**0.086**
CD1	BW15ML-018	10				6.77	0.677		
CD2	BW15ML-018	10				6.99	0.699		
CD3	BW15ML-018	10				6.83	0.683		
CD4	BW15ML-018	10				6.88	0.688		
CD5	BW15ML-018	10				6.14	0.614		
CD6	BW15ML-018	9				7.24	0.804		
CD7	BW15ML-018	9				6.45	0.717		
CD8	BW15ML-018	10				6.65	0.665		
CD	**BW15ML-018**		**9.75**	**0.46**	**97.5%**			**0.693**	**0.054**
CE1	BW15ML-022	10				7.67	0.767		
CE2	BW15ML-022	9				7.25	0.806		
CE3	BW15ML-022	10				8.26	0.826		
CE4	BW15ML-022	9				8.06	0.896		
CE5	BW15ML-022	9				7.92	0.880		
CE6	BW15ML-022	10				10.3	1.030		
CE7	BW15ML-022	10				7.57	0.757		
CE8	BW15ML-022	9				7.83	0.870		
CE	**BW15ML-022**		**9.50**	**0.53**	**95.0%**			**0.854**	**0.088**

Sample ID	Test Sediment	Number of Survivors (10)	Average Survival	Standard Deviation	Percent Survival	Total Dry Weight (mg)	Individual Dry Weight (mg)	Average Dry Weight (mg)	Standard Deviation
CF1	BW15ML-037	10				6.14	0.614		
CF2	BW15ML-037	10				6.37	0.637		
CF3	BW15ML-037	8				6.1	0.762		
CF4	BW15ML-037	9				6.69	0.743		
CF5	BW15ML-037	9				6.12	0.680		
CF6	BW15ML-037	10				6.37	0.637		
CF7	BW15ML-037	9				5.95	0.661		
CF8	BW15ML-037	10				6.3	0.630		
CF	**BW15ML-037**		**9.38**	**0.744**	**93.8%**			**0.671**	**0.055**
CG1	BW15ML-032	9				5.89	0.654		
CG2	BW15ML-032	8				5.74	0.718		
CG3	BW15ML-032	7				5.73	0.819		
CG4	BW15ML-032	7				5.01	0.716		
CG5	BW15ML-032	9				5.73	0.637		
CG6	BW15ML-032	7				5.76	0.823		
CG7	BW15ML-032	9				5.04	0.560		
CG8	BW15ML-032	6				3.41	0.568		
CG	**BW15ML-032**		**7.75**	**1.17**	**77.5%**			**0.687**	**0.101**
CH1	BW15ML-038	7				5.42	0.774		
CH2	BW15ML-038	9				6.06	0.673		
CH3	BW15ML-038	10				5.67	0.567		
CH4	BW15ML-038	9				6.06	0.673		
CH5	BW15ML-038	8				5.93	0.741		
CH6	BW15ML-038	10				6.18	0.618		
CH7	BW15ML-038	10				5.98	0.598		
CH8	BW15ML-038	10				5.66	0.566		
CH	**BW15ML-038**		**9.13**	**1.13**	**91.3%**			**0.651**	**0.078**
CI1	BW15ML-006	8				7.01	0.876		
CI2	BW15ML-006	10				6.83	0.683		
CI3	BW15ML-006	10				7.79	0.779		
CI4	BW15ML-006	10				7.99	0.799		
CI5	BW15ML-006	10				7.44	0.744		
CI6	BW15ML-006	10				8.49	0.849		
CI7	BW15ML-006	9				7.87	0.874		
CI8	BW15ML-006	9				7.08	0.787		
CI	**BW15ML-006**		**9.50**	**0.76**	**95.0%**			**0.799**	**0.067**
CJ1	BW15ML-010	10				7.35	0.735		
CJ2	BW15ML-010	10				7.36	0.736		
CJ3	BW15ML-010	10				7.95	0.795		
CJ4	BW15ML-010	10				7	0.700		
CJ5	BW15ML-010	10				7.1	0.710		
CJ6	BW15ML-010	10				7.85	0.785		
CJ7	BW15ML-010	10				7.75	0.775		
CJ8	BW15ML-010	10				6.14	0.614		
CJ	**BW15ML-010**		**10**	**0.00**	**100.0%**			**0.731**	**0.059**

Sample ID	Test Sediment	Number of Survivors (10)	Average Survival	Standard Deviation	Percent Survival	Total Dry Weight (g)	Individual Dry Weight (mg)	Average Dry Weight (mg)	Standard Deviation
CK1	BW15ML-004	9				5.58	0.620		
CK2	BW15ML-004	10				6.5	0.650		
CK3	BW15ML-004	9				5.57	0.619		
CK4	BW15ML-004	10				6.19	0.619		
CK5	BW15ML-004	10				5.16	0.516		
CK6	BW15ML-004	1				1.54	1.540		
CK7	BW15ML-004	10				6.47	0.647		
CK8	BW15ML-004	10				6.06	0.606		
CK	**BW15ML-004**		**8.63**	**3.11**	**86.3%**			**0.727**	**0.331**

Appendix Table 10: Temperature (˚C) Water Chemistry Parameter for *C. dilutus* during the 10-Day Sediment Toxicity Test

Day	0		1		2		3		4		5		6		7		8		9		10				
am/pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am		Average	Min	Max
CA1	22.1	22.8							22.8										22.8	23.0					
CA2	22.4					22.9								23.1					22.9						
CA3	22.3							22.9		23.0						23.1			22.9						
CA4	22.3	22.9	23.0	23.1	23.0	23.0	23.2	23.0	22.9	23.1	23.2	23.3	23.2	23.1	22.8	23.1	23.0	22.8	22.9	23.0	23.1				
CA5	22.3				23.0								23.3						22.9						
CA6	22.3		22.8								23.2						23.1		23.0		23.1				
CA7	22.5						23.5								23.1				23.0						
CA8	22.4			23.0								23.3						22.8	23.0				22.9	22.1	23.5
CB1	22.2	22.9							22.8										23.1	23.0					
CB2	22.2					23.3								23.2					23.2						
CB3	22.2							23.3		22.6						23.2			23.2						
CB4	22.1	22.8	22.8	23.0	22.6	23.1	23.4	23.4	22.6	22.7	23.3	23.3	23.3	23.1	22.9	23.1	22.9	23.0	23.1	23.1	23.1				
CB5	22.1				22.7								23.1						23.0						
CB6	22.2		22.8								23.1						22.9		23.0		23.0				
CB7	22.3						23.2								23.0				23.1						
CB8	22.3			22.9								23.3						22.8	23.1				22.9	22.1	23.4
CC1	22.0	22.8							22.6										23.1	23.0					
CC2	22.1					23.1								23.1					23.2						
CC3	22.1							23.3		22.5						23.1			23.1						
CC4	22.1	22.8	22.8	22.8	22.8	23.1	23.1	23.4	22.7	22.8	23.1	23.2	23.0	23.0	22.7	23.2	22.9	23.2	23.1	23.0	23.0				
CC5	22.1				22.8								23.1						23.1						
CC6	22.0		22.9								23.2						22.7		23.1		23.1				
CC7	22.3						23.3								23.0				23.2						
CC8	22.2			23.2								23.2						23.2	23.1				22.9	22.0	23.4
CD1	22.1	22.8							22.5										22.9	22.7					
CD2	22.1					22.9								22.9					22.8						
CD3	21.9							23.2		22.9						22.8			22.9						
CD4	21.9	22.8	22.7	22.7	22.6	22.8	23.0	23.1	22.5	22.8	22.9	23.0	22.9	23.0	22.7	22.8	22.7	22.8	22.8	22.8	22.8				
CD5	22.0				22.7								23.0						23.0						
CD6	22.0		22.6								22.8						22.7		22.9		22.8				
CD7	22.0						22.9								23.0				23.0						
CD8	22.1			22.9								23.1						23.0	22.9				22.7	21.9	23.2

Day	0		1		2		3		4		5		6		7		8		9		10				
am/pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am		Average	Min	Max
CE1	22.0	22.8							22.4										22.9	22.7					
CE2	22.1					23.0								23.1					22.9						
CE3	22.1							23.3		22.7						22.8			22.9						
CE4	22.1	23.0	23.1	23.1	22.7	23.0	23.0	23.3	22.4	22.8	22.9	23.1	22.9	23.0	22.9	22.9	22.6	22.7	22.8	22.7	22.7				
CE5	22.2				22.8								23.0						22.9						
CE6	22.2		22.9								22.9						22.7		22.8		22.8				
CE7	22.2						23.1								22.9				22.9						
CE8	22.3			23.2								23.1						22.8	23.0				22.8	22.0	23.3
CF1	22.2	22.9							22.5										22.8	22.7					
CF2	22.2					23.1								23.0					22.9						
CF3	22.2							23.2		22.7						23.1			22.8						
CF4	22.2	22.8	22.7	23.1	22.6	23.1	23.1	23.2	22.3	22.7	22.9	22.9	23.0	23.0	23.0	23.2	22.8	22.7	22.8	22.6	22.8				
CF5	22.2				22.8								23.1						22.9						
CF6	22.2		22.9								22.9						22.8		22.8		22.8				
F7	22.3						23.0								23.1				22.8						
CF8	22.3			23.2								23.0						23.0	22.9				22.8	22.2	23.2
CG1	22.6	23.4							22.7										23.0	23.2					
CG2	22.4					23.3								23.0					23.0						
CG3	22.4							23.7		22.9						23.4			23.0						
CG4	22.4	23.4	23.2	23.8	23.1	23.2	23.1	23.6	22.4	23.1	23.2	23.3	23.1	23.0	23.3	23.5	23.1	23.3	23.1	23.1	23.2				
CG5	22.3				23.0								23.2						23.1						
CG6	22.4		23.2								23.2						23.0		23.2		23.2				
CG7	22.4						23.2								23.3				23.2						
CG8	22.6			23.7								23.3						23.3	23.3				23.1	22.3	23.8
CH1	22.0	23.1							22.6										22.9	22.6					
CH2	22.1					23.0								22.9					23.0						
CH3	22.0							23.4		22.8						22.9			22.9						
CH4	22.0	23.0	22.9	23.0	22.9	22.8	22.9	23.3	22.6	22.9	22.8	23.0	22.9	22.8	23.0	22.9	22.5	23.0	22.9	22.9	22.9				
CH5	22.0				22.8								23.0						22.9						
CH6	22.0		22.9								22.8						22.8		22.9		22.9				
CH7	22.0						22.8								22.9				23.0						
CH8	22.1			23.4								23.1						23.0	23.0				22.8	22.0	23.4

Day	0		1		2		3		4		5		6		7		8		9		10				
am/pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am		Average	Min	Max
CI1	22.1	22.8							22.2										22.6	22.5					
CI2	22.1					22.8								22.7					22.9						
CI3	22.1							23.1		22.6						23.1			22.7						
CI4	22.1	22.7	22.7	23.0	22.8	22.9	22.8	23.0	22.4	22.7	22.8	22.9	22.8	22.7	22.8	23.0	22.6	22.8	22.7	22.6	22.7				
CI5	22.2				22.8								22.8						22.7						
CI6	22.2		22.7								22.6						22.5		22.6		22.8				
CI7	22.1						22.7								22.9				22.7						
CI8	22.2			23.2								22.9						22.7	22.8				22.7	22.1	23.2
CJ1	22.0	23.1							23.0										22.9	22.7					
CJ2	22.0					22.9								23.0					22.8						
CJ3	22.0							23.4		22.9						23.2			22.9						
CJ4	22.3	23.2	22.9	23.0	22.9	23.0	22.8	23.4	22.9	23.0	23.0	23.1	23.0	23.0	23.0	23.3	22.9	23.1	22.9	22.4	22.8				
CJ5	22.1				23.0								23.0						22.9						
CJ6	22.2		22.9								23.0						23.0		22.9		22.8				
CJ7	22.2						22.9								23.1				23.0						
CJ8	22.3			23.3								23.1						23.0	23.2				22.9	22.0	23.4
CK1	22.0	23.1							22.8										23.0	22.6					
CK2	22.0					22.8								22.8					23.0						
CK3	22.1							23.0		22.7						22.9			23.1						
CK4	22.0	23.1	22.8	23.2	22.8	22.8	22.7	23.0	22.7	22.8	22.8	22.9	22.8	22.8	22.9	23.1	22.7	22.8	23.1	22.5	22.8				
CK5	22.1				22.9								22.9						23.2						
CK6	22.0		23.0								22.8						22.8		23.1		22.8				
CK7	22.2						22.7								22.9				23.1						
CK8	22.1			23.4								22.9						22.8	23.1				22.8	22.0	23.4

Appendix Table 11: Dissolved Oxygen (mg/L) Water Chemistry Parameter for *C. dilutus* during the 10-Day Sediment Toxicity Test

Day	0		1		2		3		4		5		6		7		8		9		10				
am/pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am		Average	Min	Max
CA1	6.7	7.8							7.4										7.1	8.2					
CA2	7.2					9.2								8.2					7.4						
CA3	7.5							6.6		8.1						7.8			7.6						
CA4	7.3	8.9	7.5	7.6	7.3	8.0	7.0	7.5	8.1	7.6	7.6	7.6	8.1	8.6	7.8	7.7	8.3	7.9	7.5	7.9	8.1				
CA5	7.1				6.8								7.9						7.0						
CA6	7.2		7.3								7.7						8.4		7.5		7.5				
CA7	7.0						7.5								7.8				7.3						
CA8	6.8			8.4								7.8						8.4	7.4				7.7	6.6	9.2
CB1	6.6	8.5							9.0										7.5	8.1					
CB2	6.9					8.2								8.6					7.8						
CB3	6.7							7.6		8.9						7.9			7.9						
CB4	6.0	7.9	7.5	8.9	5.5	7.8	7.9	7.3	9.1	9.0	7.3	7.8	7.5	8.7	8.9	8.3	8.9	9.0	7.7	8.0	7.3				
CB5	5.8				4.5								7.1						7.6						
CB6	6.1		7.0								6.1						8.9		7.5		7.6				
CB7	6.1						5.4								8.4				7.7						
CB8	6.4			8.1								7.2						8.7	7.4				7.6	4.5	9.1
CC1	6.2	7.6							9.1										7.9	7.9					
CC2	5.3					7.8								9.2					7.8						
CC3	6.3							7.7		8.8						7.6			7.5						
CC4	6.2	7.6	6.2	8.8	8.0	9.1	7.1	7.3	8.4	7.8	6.4	7.7	8.3	9.1	8.4	7.5	8.6	8.8	7.1	8.2	8.5				
CC5	5.9				6.5								5.3						6.5						
CC6	6.5		5.6								4.9						7.2		6.0		5.7				
CC7	6.1						6.6								6.7				6.9						
CC8	7.0			7.4								8.0						8.0	6.8				7.3	4.9	9.2
CD1	7.1	7.8							7.7										6.5	7.7					
CD2	7.2					8.9								8.6					7.2						
CD3	6.7							7.8		6.9						7.6			7.0						
CD4	7.3	7.4	6.6	8.7	7.1	8.7	6.7	7.4	6.7	6.6	6.4	7.9	6.4	8.2	6.6	7.3	6.6	7.4	7.0	7.7	7.0				
CD5	7.9				7.0								8.6						7.4						
CD6	6.2		8.2								5.7						7.7		6.8		6.9				
CD7	7.2						5.9								7.5				7.1						
CD8	7.2			7.0								7.8						8.1	7.4				7.3	5.7	8.9

Day	0		1		2		3		4		5		6		7		8		9		10				
am/pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am		Average	Min	Max
CE1	6.9	8.0							8.0										7.1	7.7	7.6				
CE2	7.2					8.1								8.4					6.8						
CE3	6.1							7.5		6.5						8.1			5.7						
CE4	6.9	8.1	7.6	8.0	7.7	8.8	7.0	7.3	8.1	7.1	5.2	7.8	8.0	8.5	7.5	7.6	8.9	8.6	6.8	7.9	7.1				
CE5	7.0				8.0								7.1						6.5						
CE6	6.9		7.2								4.4						4.5		5.9		2.9				
CE7	7.3						7.1								6.6				5.0		7.0				
CE8	7.4			8.2								8.1						8.0	6.6				7.2	2.9	8.9
CF1	7.5	9.0							8.2										7.9	8.6					
CF2	7.5					8.4								8.7					7.9						
CF3	6.8							7.8		8.8						8.7			7.9						
CF4	7.2	8.2	7.6	7.9	7.8	8.7	6.8	7.6	8.5	8.1	7.6	8.5	8.3	8.7	7.5	8.1	7.5	8.1	6.2	8.3	6.2				
CF5	7.3				7.8								8.1						7.7						
CF6	7.2		6.6								7.0						7.9		7.0		8.2				
F7	7.1						6.2								7.7				7.6						
CF8	7.3			7.7								8.2						7.9	7.6				7.8	6.2	9.0
CG1	6.9	8.9							8.8										7.5	8.1					
CG2	7.2					7.3								8.2					7.3						
CG3	7.1							7.6		8.5						8.2			7.4						
CG4	7.4	8.1	8.2	8.9	8.2	8.6	6.9	7.8	8.0	9.2	7.7	8.5	8.0	8.6	9.0	8.5	9.4	7.9	7.8	7.9	8.8				
CG5	6.3				8.1								8.1						7.7						
CG6	6.3		7.5								7.7						7.9		7.4		7.6				
CG7	7.2						7.0								7.3				7.5						
CG8	7.2			9.3								8.5						7.8	7.7				7.9	6.3	9.4
CH1	6.4	8.6							8.9										7.8	8.3					
CH2	5.8					8.2								8.1					8.0						
CH3	6.6							7.8		8.5						7.2			7.3						
CH4	6.4	8.3	8.2	8.2	7.9	9.1	7.4	8.3	8.7	7.3	7.4	7.9	7.7	8.7	6.6	7.3	8.0	8.0	7.1	7.4	5.7				
CH5	6.9				8.2								7.3						7.4						
CH6	6.6		8.6								7.7						8.8		7.7		7.5				
CH7	6.3						6.4								5.9				7.5						
CH8	6.4			8.1								7.7						8.4	7.2				7.6	5.7	9.1

Day	0		1		2		3		4		5		6		7		8		9		10				
am/pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am		Average	Min	Max
CI1	6.4	8.8							7.9										6.8	8.8					
CI2	6.4					8.1								7.8					7.6						
CI3	7.5							6.6		8.1						8.2			7.3						
CI4	7.7	8.0	5.7	8.6	7.7	9.0	6.3	6.8	7.4	8.1	5.5	7.9	7.7	8.0	8.1	8.1	8.6	8.2	7.4	8.1	8.1				
CI5	7.5				8.9								7.4						7.3						
CI6	6.6		8.6								5.8						8.4		7.2		8.2				
CI7	6.4						5.4								7.2				4.9						
CI8	6.5			8.4								7.9						7.4	7.4				7.5	4.9	9.0
CJ1	7.2	8.8							8.2										6.6	8.3					
CJ2	6.7					7.4								8.0					5.3						
CJ3	7.1							7.2		8.1						8.1			7.1						
CJ4	7.6	8.2	8.1	8.6	6.0	8.0	7.4	7.3	8.2	8.3	8.1	7.9	7.3	8.0	7.9	7.7	7.6	7.9	7.1	8.2	7.5				
CJ5	6.4				6.2								6.7						6.0						
CJ6	7.3		7.7								7.6						7.6		6.3		6.2				
CJ7	7.4						5.8								6.2				5.8						
CJ8	7.3			9.1								7.5						7.9	7.1				7.4	5.3	9.1
CK1	7.7	9.0							8.1										8.3	9.1					
CK2	6.7					8.7								8.2					8.3						
CK3	7.4							7.1		9.0						8.4			7.6						
CK4	7.4	8.0	7.9	9.1	8.9	8.7	7.0	7.5	8.1	7.6	5.7	8.1	7.5	7.8	7.5	6.7	7.8	8.5	7.5	8.9	7.8				
CK5	7.6				8.5								7.6						7.7						
CK6	6.5		8.1								6.7						9.2		7.7		8.0				
CK7	6.2						6.6								7.8				7.6						
CK8	7.2			9.6								8.2						7.6	7.1				7.8	5.7	9.6

Appendix Table 12: pH Water Chemistry Parameter for *C. dilutus* during the 10-Day Sediment Toxicity Test

Day	0	2	4	7	9			
am/pm	am	am	am	am	am	Average	Min	Max
CA1	8.07		7.83		8.01			
CA4	8.1	7.88	8.01	7.98	8			
CA5	8.1	7.89			7.89			
CA7				8.07				
CA8	8.11				8.04	7.99	7.83	8.11
CB1	7.95		8.02		7.92			
CB4	7.75	7.42	8.04	8.01	7.88			
CB5	7.48	7.28			7.83			
CB7				7.98				
CB8	7.66				7.81	7.72	7.28	8.04
CC1	7.6		8.02		7.93			
CC4	7.58	7.78	7.96	7.93	7.88			
CC5	7.55	7.62			7.73			
CC7				7.76				
CC8	7.92				7.88	7.77	7.55	8.02
CD1	7.93		7.7		7.58			
CD4	7.92	7.88	7.55	7.6	7.81			
CD5	7.92	7.83			7.97			
CD7				7.98				
CD8	7.93				7.93	7.80	7.55	7.98
CE1	7.88		7.71		7.87			
CE4	7.96	7.93	7.7	7.92	7.85			
CE5	7.94	8.05			7.78			
CE7				7.69				
CE8	7.99				7.87	7.85	7.69	8.05
CF1	7.97		7.78		7.94			
CF4	7.9	7.66	7.77	7.89	7.63			
CF5	7.89	7.93			7.93			
CF7				7.97				
CF8	7.97				7.93	7.85	7.63	7.97

Day	0	2	4	7	9			
am/pm	am	am	am	am	am	Average	Min	Max
CG1	7.98		8.01		7.97			
CG4	7.91	7.9	7.93	7.99	7.95			
CG5	7.68	7.82			7.92			
CG7				7.97				
CG8	7.98				8.02	7.92	7.68	8.02
CH1	7.75		8.04		7.97			
CH4	7.64	8.04	8.06	7.83	7.84			
CH5	7.83	7.99			7.93			
CH7				7.64				
CH8	7.8				7.99	7.86	7.64	8.06
CI1	7.48		7.63		7.65			
CI4	7.75	7.89	7.51	7.78	7.76			
CI5	7.79	7.93			7.74			
CI7				7.75				
CI8	7.25				7.76	7.65	7.25	7.93
CJ1	7.78		7.93		7.69			
CJ4	7.94	7.47	7.99	7.93	7.82			
CJ5	7.55	7.57			7.7			
CJ7				7.59				
CJ8	7.92				7.69	7.72	7.47	7.99
CK1	7.91		7.86		8			
CK4	7.77	7.77	7.78	7.89	7.9			
CK5	7.8	7.8			7.99			
CK7				7.89				
CK8	7.71				7.91	7.85	7.71	8.00

Appendix Table 13: Conductivity (µS/cm) Water Chemistry Parameter for *C. dilutus* during the 10-Day Sediment Toxicity Test

Day	0	9			
am/pm	am	am	Average	Min	Max
CA1	150.2	154.7			
CA8	149.7	156.3	152.7	149.7	156.3
CB1	142.2	148.9			
CB8	142.4	149.5	145.8	142.2	149.5
CC1	159.3	159.5			
CC8	154.7	159.7	158.3	154.7	159.7
CD1	150.9	161.9			
CD8	151.3	160.8	156.2	150.9	161.9
CE1	156.6	160.6			
CE8	156.1	161.1	158.6	156.1	161.1
CF1	152.6	158.2			
CF8	153.3	158.8	155.7	152.6	158.8
CG1	162.7	162.0			
CG8	163.3	162.2	162.6	162.0	163.3
CH1	162.6	163.1			
CH8	162.1	164.5	163.1	162.1	164.5
CI1	154.5	154.9			
CI8	158.9	154.7	155.8	154.5	158.9
CJ1	149.9	162.3			
CJ8	150.0	161.2	155.9	149.9	162.3
CK1	157.5	160.9			
CK8	162.7	162.2	160.8	157.5	162.7

Appendix Table 14: Ammonia (mg/L) Water Chemistry Parameter for *C. dilutus* during the 10-Day Sediment Toxicity Test

Day	0	9			
am/pm	am	am	Average	Min	Max
CA1	0.063	0.38			
CA8	0.063	0.37	0.22	0.06	0.38
CB1	0.16	0.27			
CB8	0.13	0.23	0.20	0.13	0.27
CC1	0.135	0.1			
CC8	0.1	0.1	0.11	0.10	0.14
CD1	0.10	0.11			
CD8	0.09	0.09	0.10	0.09	0.11
CE1	0.16	0.12			
CE8	0.15	0.12	0.14	0.12	0.16
CF1	0.11	0.10			
CF8	0.12	0.10	0.11	0.10	0.12
CG1	0.18	0.09			
CG8	0.20	0.09	0.14	0.09	0.20
CH1	0.16	0.10			
CH8	0.16	0.10	0.13	0.10	0.16
CI1	0.36	0.33			
CI8	0.31	0.27	0.32	0.27	0.36
CJ1	0.09	0.14			
CJ8	0.08	0.10	0.10	0.08	0.14
CK1	0.09	0.09			
CK8	0.09	0.11	0.09	0.09	0.11

Appendix Table 15: Hardness (mg/L CaCO3) Water Chemistry Parameter for *C. dilutus* during the 10-Day Sediment Toxicity Test

Day	0	9			
am/pm	am	am	Average	Min	Max
CA3	48.8	48			
CA6	48.8	48.4	48.5	48.0	48.8
CB3	44.4	44.8			
CB6	50.0	45.2	46.1	44.4	50.0
CC3	54.4	48.8			
CC6	53.2	*	52.1	48.8	54.4
CD3	54.4	64.4			
CD6	52.4	52.8	56.0	52.4	64.4
CE3	51.6	49.2			
CE6	52.4	48	50.3	48.0	52.4
CF3	54	53.2			
CF6	55.2	56.4	54.7	53.2	56.4
CG3	55.6	50.4			
CG6	61.6	52.0	54.9	50.4	61.6
CH3	64.4	58.0			
CH6	67.6	56.0	61.5	56.0	67.6
CI3	48.4	47.6			
CI6	52.4	48.4	49.2	47.6	52.4
CJ3	58.8	52.8			
CJ6	55.6	50.8	54.5	50.8	58.8
CK3	65.2	51.2			
CK6	59.2	53.6	57.3	51.2	65.2

* Buffer was not added to sample prior to titration so this value was not included.

Appendix Table 16: Alkalinity (mg/L $CaCO_3$) Water Chemistry Parameter for *C. dilutus* during the 10-Day Sediment Toxicity Test

am/pm	am	am	Average	Min	Max
CA2	46.8	50.8			
CA5	47.2	49.2	48.5	46.8	50.8
CB2	43.2	44			
CB5	39.2	44.4	42.7	39.2	44.4
CC2	46.4	43.6			
CC5	46.5	45.6	45.5	43.6	46.5
CD2	49.2	52.8			
CD5	49.6	50.0	50.4	49.2	52.8
CE2	50.4	49.2			
CE5	51.6	47.6	49.7	47.6	51.6
CF2	50.0	52.8			
CF5	51.6	54.4	52.2	50.0	54.4
CG2	50.0	48.8			
CG5	48.8	51.2	49.7	48.8	51.2
CH2	53.6	54.8			
CH5	54.0	56.4	54.7	53.6	56.4
CI2	47.6	48.0			
CI5	48.0	48.8	48.1	47.6	48.8
CJ2	48.4	52.0			
CJ5	48.0	48.4	49.2	48.0	52.0
CK2	48.8	48.4			
CK5	46.8	47.6	47.9	46.8	48.8

Appendix Table 17: Analysis of polychlorodibenzo-p-dioxins (PCDDs) and polychlorodibenzofurans (PCDFs) in seven sediments used for 10-day *H. azteca* and *C. dilutus* tests and the 28-day *L. variegatus* bioaccumulation test

Client ID	Compound	Result	EMPC	RL	Units	Qualifiers	TEQ	Matrix	EDL
BW15ML-038-0-0.15	2,3,7,8-TCDF	3.4	0	0.15	ng/Kg		0.34	Soil	0.15
	2,3,7,8-TCDD	0	0.92	0.22	ng/Kg	IJ	0.92	Soil	0.22
	1,2,3,7,8-PeCDF	1.6	0	0.11	ng/Kg	J	0.049	Soil	0.11
	2,3,4,7,8-PeCDF	4.5	0	0.077	ng/Kg	J	1.4	Soil	0.077
	1,2,3,7,8-PeCDD	2.1	0	0.11	ng/Kg	J	2.1	Soil	0.11
	1,2,3,4,7,8-HxCDF	21	0	0.072	ng/Kg		2.1	Soil	0.072
	1,2,3,6,7,8-HxCDF	13	0	0.12	ng/Kg		1.3	Soil	0.12
	2,3,4,6,7,8-HxCDF	4.8	0	0.082	ng/Kg	J	0.48	Soil	0.082
	1,2,3,7,8,9-HxCDF	1.7	0	0.12	ng/Kg	J	0.17	Soil	0.12
	1,2,3,4,7,8-HxCDD	2.1	0	0.2	ng/Kg	J	0.21	Soil	0.2
	1,2,3,6,7,8-HxCDD	14	0	0.2	ng/Kg		1.4	Soil	0.2
	1,2,3,7,8,9-HxCDD	7.3	0	0.19	ng/Kg	J	0.73	Soil	0.19
	1,2,3,4,6,7,8-HpCDF	310	0	0.25	ng/Kg		3.1	Soil	0.25
	1,2,3,4,7,8,9-HpCDF	9.3	0	0.24	ng/Kg		0.093	Soil	0.24
	1,2,3,4,6,7,8-HpCDD	200	0	0.95	ng/Kg		2	Soil	0.95
	OCDF	280	0	0.19	ng/Kg		0.085	Soil	0.19
	OCDD	2100	0	0.21	ng/Kg		0.63	Soil	0.21
	Total TCDF	28	0	0.15	ng/Kg		0	Soil	0.15
	Total TCDD	6.3	0	0.22	ng/Kg		0	Soil	0.22
	Total PeCDF	62	0	0.094	ng/Kg		0	Soil	0.094
	Total PeCDD	20	0	0.11	ng/Kg		0	Soil	0.11
	Total HxCDF	190	0	0.098	ng/Kg		0	Soil	0.098
	Total HxCDD	130	0	0.2	ng/Kg		0	Soil	0.2
	Total HpCDF	610	0	0.25	ng/Kg		0	Soil	0.25
	Total HpCDD	440	0	0.95	ng/Kg		0	Soil	0.95
	TEQ	17	0	0	ng/Kg		0	Soil	0
BW15ML-032-0-0.15	2,3,7,8-TCDF	4.8	0	0.3	ng/Kg		0.48	Soil	0.3
	2,3,7,8-TCDD	2.1	0	0.26	ng/Kg		2.1	Soil	0.26
	1,2,3,7,8-PeCDF	2.3	0	0.13	ng/Kg	J	0.068	Soil	0.13
	2,3,4,7,8-PeCDF	7.2	0	0.11	ng/Kg	J	2.2	Soil	0.11
	1,2,3,7,8-PeCDD	6.2	0	0.09	ng/Kg	J	6.2	Soil	0.09
	1,2,3,4,7,8-HxCDF	21	0	0.28	ng/Kg		2.1	Soil	0.28
	1,2,3,6,7,8-HxCDF	37	0	0.25	ng/Kg		3.7	Soil	0.25
	2,3,4,6,7,8-HxCDF	14	0	0.23	ng/Kg		1.4	Soil	0.23
	1,2,3,7,8,9-HxCDF	0	3.2	0.18	ng/Kg	IJ	0.32	Soil	0.18
	1,2,3,4,7,8-HxCDD	6	0	0.33	ng/Kg	J	0.6	Soil	0.33
	1,2,3,6,7,8-HxCDD	48	0	0.28	ng/Kg		4.8	Soil	0.28
	1,2,3,7,8,9-HxCDD	26	0	0.27	ng/Kg		2.6	Soil	0.27
	1,2,3,4,6,7,8-HpCDF	1800	0	0.41	ng/Kg		18	Soil	0.41
	1,2,3,4,7,8,9-HpCDF	13	0	0.38	ng/Kg		0.13	Soil	0.38
	1,2,3,4,6,7,8-HpCDD	420	0	0.84	ng/Kg		4.2	Soil	0.84
	OCDF	820	0	0.13	ng/Kg		0.25	Soil	0.13
	OCDD	4200	0	0.14	ng/Kg		1.3	Soil	0.14
	Total TCDF	44	0	0.3	ng/Kg		0	Soil	0.3
	Total TCDD	18	0	0.26	ng/Kg		0	Soil	0.26
	Total PeCDF	120	0	0.12	ng/Kg		0	Soil	0.12
	Total PeCDD	58	0	0.09	ng/Kg		0	Soil	0.09
	Total HxCDF	350	0	0.23	ng/Kg		0	Soil	0.23
	Total HxCDD	410	0	0.29	ng/Kg		0	Soil	0.29
	Total HpCDF	3300	0	0.4	ng/Kg		0	Soil	0.4
	Total HpCDD	1000	0	0.84	ng/Kg		0	Soil	0.84
	TEQ	50	0	0	ng/Kg		0	Soil	0

Client ID	Compound	Result	EMPC	RL	Units	Qualifiers	TEQ	Matrix	EDL
BW15ML-034-0-0.15	2,3,7,8-TCDF	1.3	0	0.31	ng/Kg	J	0.13	Soil	0.31
	2,3,7,8-TCDD	0.63	0	0.28	ng/Kg	J	0.63	Soil	0.28
	1,2,3,7,8-PeCDF	0.55	0	0.12	ng/Kg	J	0.017	Soil	0.12
	2,3,4,7,8-PeCDF	1.5	0	0.11	ng/Kg	J	0.45	Soil	0.11
	1,2,3,7,8-PeCDD	1.6	0	0.13	ng/Kg	J	1.6	Soil	0.13
	1,2,3,4,7,8-HxCDF	3.5	0	0.096	ng/Kg	J	0.35	Soil	0.096
	1,2,3,6,7,8-HxCDF	6.8	0	0.14	ng/Kg	J	0.68	Soil	0.14
	2,3,4,6,7,8-HxCDF	2.7	0	0.11	ng/Kg	J	0.27	Soil	0.11
	1,2,3,7,8,9-HxCDF	0.71	0	0.077	ng/Kg	J	0.071	Soil	0.077
	1,2,3,4,7,8-HxCDD	1.6	0	0.12	ng/Kg	J	0.16	Soil	0.12
	1,2,3,6,7,8-HxCDD	11	0	0.092	ng/Kg		1.1	Soil	0.092
	1,2,3,7,8,9-HxCDD	6.5	0	0.19	ng/Kg	J	0.65	Soil	0.19
	1,2,3,4,6,7,8-HpCDF	250	0	0.17	ng/Kg		2.5	Soil	0.17
	1,2,3,4,7,8,9-HpCDF	0	2.2	0.14	ng/Kg	IJ	0.022	Soil	0.14
	1,2,3,4,6,7,8-HpCDD	140	0	0.53	ng/Kg		1.4	Soil	0.53
	OCDF	160	0	0.13	ng/Kg		0.048	Soil	0.13
	OCDD	1500	0	0.14	ng/Kg		0.45	Soil	0.14
	Total TCDF	13	0	0.31	ng/Kg		0	Soil	0.31
	Total TCDD	4.5	0	0.28	ng/Kg		0	Soil	0.28
	Total PeCDF	27	0	0.11	ng/Kg		0	Soil	0.11
	Total PeCDD	12	0	0.13	ng/Kg		0	Soil	0.13
	Total HxCDF	150	0	0.1	ng/Kg		0	Soil	0.1
	Total HxCDD	97	0	0.13	ng/Kg		0	Soil	0.13
	Total HpCDF	480	0	0.15	ng/Kg		0	Soil	0.15
	Total HpCDD	350	0	0.53	ng/Kg		0	Soil	0.53
	TEQ	11	0	0	ng/Kg		0	Soil	0
BW15ML-037-0-0.15	2,3,7,8-TCDF	0	0.9	0.23	ng/Kg	IJ	0.09	Soil	0.23
	2,3,7,8-TCDD	0	0.27	0.26	ng/Kg	IJ	0.27	Soil	0.26
	1,2,3,7,8-PeCDF	0.44	0	0.14	ng/Kg	BJ	0.013	Soil	0.14
	2,3,4,7,8-PeCDF	0.91	0	0.14	ng/Kg	J	0.27	Soil	0.14
	1,2,3,7,8-PeCDD	0.48	0	0.19	ng/Kg	J	0.48	Soil	0.19
	1,2,3,4,7,8-HxCDF	1.3	0	0.084	ng/Kg	J	0.13	Soil	0.084
	1,2,3,6,7,8-HxCDF	1.7	0	0.1	ng/Kg	J	0.17	Soil	0.1
	2,3,4,6,7,8-HxCDF	1	0	0.063	ng/Kg	J	0.1	Soil	0.063
	1,2,3,7,8,9-HxCDF	0.43	0	0.1	ng/Kg	J	0.043	Soil	0.1
	1,2,3,4,7,8-HxCDD	0.5	0	0.15	ng/Kg	J	0.05	Soil	0.15
	1,2,3,6,7,8-HxCDD	3.3	0	0.21	ng/Kg	J	0.33	Soil	0.21
	1,2,3,7,8,9-HxCDD	1.7	0	0.21	ng/Kg	J	0.17	Soil	0.21
	1,2,3,4,6,7,8-HpCDF	85	0	0.083	ng/Kg		0.85	Soil	0.083
	1,2,3,4,7,8,9-HpCDF	0	0.85	0.17	ng/Kg	IJ	0.0085	Soil	0.17
	1,2,3,4,6,7,8-HpCDD	40	0	0.29	ng/Kg		0.4	Soil	0.29
	OCDF	50	0	0.19	ng/Kg		0.015	Soil	0.19
	OCDD	410	0	0.26	ng/Kg		0.12	Soil	0.26
	Total TCDF	11	0	0.23	ng/Kg		0	Soil	0.23
	Total TCDD	1.4	0	0.26	ng/Kg	J	0	Soil	0.26
	Total PeCDF	14	0	0.14	ng/Kg		0	Soil	0.14
	Total PeCDD	3.6	0	0.19	ng/Kg	J	0	Soil	0.19
	Total HxCDF	39	0	0.088	ng/Kg		0	Soil	0.088
	Total HxCDD	30	0	0.19	ng/Kg		0	Soil	0.19
	Total HpCDF	150	0	0.13	ng/Kg		0	Soil	0.13
	Total HpCDD	99	0	0.29	ng/Kg		0	Soil	0.29
	TEQ	3.5	0	0	ng/Kg		0	Soil	0

Client ID	Compound	Result	EMPC	RL	Units	Qualifiers	TEQ	Matrix	EDL
BW15ML-004-0-0.15	2,3,7,8-TCDF	2.6	0	0.54	ng/Kg		0.26	Soil	0.54
	2,3,7,8-TCDD	ND	0	0.35	ng/Kg		0	Soil	0.35
	1,2,3,7,8-PeCDF	0	0.33	0.1	ng/Kg	IJ	0.01	Soil	0.1
	2,3,4,7,8-PeCDF	1.4	0	0.14	ng/Kg	J	0.41	Soil	0.14
	1,2,3,7,8-PeCDD	1.3	0	0.26	ng/Kg	J	1.3	Soil	0.26
	1,2,3,4,7,8-HxCDF	1.5	0	0.16	ng/Kg	J	0.15	Soil	0.16
	1,2,3,6,7,8-HxCDF	1.4	0	0.1	ng/Kg	J	0.14	Soil	0.1
	2,3,4,6,7,8-HxCDF	0.58	0	0.095	ng/Kg	J	0.058	Soil	0.095
	1,2,3,7,8,9-HxCDF	ND	0	0.52	ng/Kg		0	Soil	0.52
	1,2,3,4,7,8-HxCDD	0.89	0	0.062	ng/Kg	J	0.089	Soil	0.062
	1,2,3,6,7,8-HxCDD	5.9	0	0.13	ng/Kg	J	0.59	Soil	0.13
	1,2,3,7,8,9-HxCDD	2.7	0	0.12	ng/Kg	J	0.27	Soil	0.12
	1,2,3,4,6,7,8-HpCDF	79	0	0.41	ng/Kg		0.79	Soil	0.41
	1,2,3,4,7,8,9-HpCDF	1.3	0	0.17	ng/Kg	J	0.013	Soil	0.17
	1,2,3,4,6,7,8-HpCDD	91	0	0.17	ng/Kg		0.91	Soil	0.17
	OCDF	64	0	0.19	ng/Kg		0.019	Soil	0.19
	OCDD	970	0	0.23	ng/Kg		0.29	Soil	0.23
	Total TCDF	5.6	0	0.54	ng/Kg		0	Soil	0.54
	Total TCDD	0.48	0	0.35	ng/Kg	J	0	Soil	0.35
	Total PeCDF	9.8	0	0.12	ng/Kg		0	Soil	0.12
	Total PeCDD	5.3	0	0.26	ng/Kg	J	0	Soil	0.26
	Total HxCDF	61	0	0.22	ng/Kg		0	Soil	0.22
	Total HxCDD	70	0	0.1	ng/Kg		0	Soil	0.1
	Total HpCDF	280	0	0.29	ng/Kg		0	Soil	0.29
	Total HpCDD	280	0	0.17	ng/Kg		0	Soil	0.17
	TEQ	5.3	0	0	ng/Kg		0	Soil	0
BW15ML-010-0-0.15	2,3,7,8-TCDF	4.5	0	0.38	ng/Kg		0.45	Soil	0.38
	2,3,7,8-TCDD	0.88	0	0.33	ng/Kg	J	0.88	Soil	0.33
	1,2,3,7,8-PeCDF	1.6	0	0.15	ng/Kg	J	0.048	Soil	0.15
	2,3,4,7,8-PeCDF	6.3	0	0.15	ng/Kg	J	1.9	Soil	0.15
	1,2,3,7,8-PeCDD	2.2	0	0.14	ng/Kg	J	2.2	Soil	0.14
	1,2,3,4,7,8-HxCDF	7.2	0	0.15	ng/Kg	J	0.72	Soil	0.15
	1,2,3,6,7,8-HxCDF	9	0	0.09	ng/Kg	J	0.9	Soil	0.09
	2,3,4,6,7,8-HxCDF	5.4	0	0.11	ng/Kg	J	0.54	Soil	0.11
	1,2,3,7,8,9-HxCDF	1.1	0	0.17	ng/Kg	J	0.11	Soil	0.17
	1,2,3,4,7,8-HxCDD	2.2	0	0.14	ng/Kg	J	0.22	Soil	0.14
	1,2,3,6,7,8-HxCDD	15	0	0.13	ng/Kg		1.5	Soil	0.13
	1,2,3,7,8,9-HxCDD	7.8	0	0.16	ng/Kg	J	0.78	Soil	0.16
	1,2,3,4,6,7,8-HpCDF	270	0	0.16	ng/Kg		2.7	Soil	0.16
	1,2,3,4,7,8,9-HpCDF	5.5	0	0.29	ng/Kg	J	0.055	Soil	0.29
	1,2,3,4,6,7,8-HpCDD	170	0	0.36	ng/Kg		1.7	Soil	0.36
	OCDF	170	0	0.23	ng/Kg		0.051	Soil	0.23
	OCDD	1600	0	0.18	ng/Kg		0.48	Soil	0.18
	Total TCDF	74	0	0.38	ng/Kg		0	Soil	0.38
	Total TCDD	7.4	0	0.33	ng/Kg		0	Soil	0.33
	Total PeCDF	83	0	0.15	ng/Kg		0	Soil	0.15
	Total PeCDD	21	0	0.14	ng/Kg		0	Soil	0.14
	Total HxCDF	170	0	0.13	ng/Kg		0	Soil	0.13
	Total HxCDD	130	0	0.15	ng/Kg		0	Soil	0.15
	Total HpCDF	560	0	0.22	ng/Kg		0	Soil	0.22
	Total HpCDD	380	0	0.36	ng/Kg		0	Soil	0.36
	TEQ	15	0	0	ng/Kg		0	Soil	0

Client ID	Compound	Result	EMPC	RL	Units	Qualifiers	TEQ	Matrix	EDL
BW15ML-022-0-0.15	2,3,7,8-TCDF	0	0.46	0.18	ng/Kg	IJ	0.046	Soil	0.18
	2,3,7,8-TCDD	ND	0	0.15	ng/Kg		0	Soil	0.15
	1,2,3,7,8-PeCDF	0	0.23	0.15	ng/Kg	IJ	0.007	Soil	0.15
	2,3,4,7,8-PeCDF	0.69	0	0.1	ng/Kg	J	0.21	Soil	0.1
	1,2,3,7,8-PeCDD	0	0.14	0.074	ng/Kg	IJ	0.14	Soil	0.074
	1,2,3,4,7,8-HxCDF	0	0.77	0.049	ng/Kg	IJ	0.077	Soil	0.049
	1,2,3,6,7,8-HxCDF	0.76	0	0.044	ng/Kg	J	0.076	Soil	0.044
	2,3,4,6,7,8-HxCDF	0.62	0	0.053	ng/Kg	J	0.062	Soil	0.053
	1,2,3,7,8,9-HxCDF	0	0.15	0.033	ng/Kg	IJ	0.015	Soil	0.033
	1,2,3,4,7,8-HxCDD	0.26	0	0.066	ng/Kg	J	0.026	Soil	0.066
	1,2,3,6,7,8-HxCDD	1.2	0	0.12	ng/Kg	J	0.12	Soil	0.12
	1,2,3,7,8,9-HxCDD	0.74	0	0.05	ng/Kg	J	0.074	Soil	0.05
	1,2,3,4,6,7,8-HpCDF	16	0	0.063	ng/Kg		0.16	Soil	0.063
	1,2,3,4,7,8,9-HpCDF	0.73	0	0.057	ng/Kg	J	0.0073	Soil	0.057
	1,2,3,4,6,7,8-HpCDD	18	0	0.087	ng/Kg		0.18	Soil	0.087
	OCDF	17	0	0.13	ng/Kg		0.0052	Soil	0.13
	OCDD	140	0	0.11	ng/Kg		0.043	Soil	0.11
	Total TCDF	10	0	0.18	ng/Kg		0	Soil	0.18
	Total TCDD	0.26	0	0.15	ng/Kg	J	0	Soil	0.15
	Total PeCDF	11	0	0.12	ng/Kg		0	Soil	0.12
	Total PeCDD	1.8	0	0.074	ng/Kg	J	0	Soil	0.074
	Total HxCDF	12	0	0.045	ng/Kg		0	Soil	0.045
	Total HxCDD	9.9	0	0.079	ng/Kg		0	Soil	0.079
	Total HpCDF	32	0	0.06	ng/Kg		0	Soil	0.06
	Total HpCDD	43	0	0.087	ng/Kg		0	Soil	0.087
	TEQ	1.3	0	0	ng/Kg		0	Soil	0

Compounds were marked with the qualifier “I” when incorrect isotopes were found during analysis. Compounds were marked with the qualifier “J” when concentrations found were below the calibration range and should be considered estimates.

Appendix Table 18: Percent Moisture and Total Organic Carbon for Four Sediments used in the 10-Day *H. azteca* and *C. dilutus* tests and the 28-Day *L. variegatus* test

Sample ID	Matrix	Analyte	Result	Units	PRL	MDL	RPD
BW15ML-032-0-0.15	Solid	Percent Moisture	55.8	%	0.10	0.10	
	Solid	Total Organic Carbon	25200	mg/kg	3130	1010	
	Solid	Total Organic Carbon	43200	mg/kg	3210	1030	
	Solid	Total Organic Carbon	27400	mg/kg	3210	1040	
	Solid	Total Organic Carbon	29500	mg/kg	3170	1020	
	Solid	Mean Total Organic Carbon	31300	mg/kg	3180	1020	
BW15ML-034-0-0.15	Solid	Percent Moisture	55.8	%	0.10	0.10	
	Solid	Total Organic Carbon	31300	mg/kg	2510	811	
	Solid	Total Organic Carbon	41700	mg/kg	2740	882	
	Solid	Total Organic Carbon	27300	mg/kg	2690	866	
	Solid	Total Organic Carbon	36200	mg/kg	2480	798	
	Solid	Mean Total Organic Carbon	34100	mg/kg	2600	839	
BW15ML-004-0-0.15	Solid	Percent Moisture	62.5	%	0.10	0.10	
	Solid	Total Organic Carbon	64900	mg/kg	3790	1220	
	Solid	Total Organic Carbon	63900	mg/kg	4270	1380	
	Solid	Total Organic Carbon	62700	mg/kg	4370	1410	
	Solid	Total Organic Carbon	39700	mg/kg	4180	1350	
	Solid	Mean Total Organic Carbon	57800	mg/kg	4150	1340	
BW15ML-010-0-0.15	Solid	Percent Moisture	68.7	%	0.10	0.10	
	Solid	Total Organic Carbon	35300	mg/kg	4240	1370	
	Solid	Total Organic Carbon	54000	mg/kg	3710	1200	
	Solid	Total Organic Carbon	35900	mg/kg	3500	1130	
	Solid	Total Organic Carbon	48900	mg/kg	4050	1310	
	Solid	Mean Total Organic Carbon	43500	mg/kg	3880	1250	
DUP	Solid	Percent Moisture	56.2	%	0.10	0.10	1
BLANK	Solid	Mean Total Organic Carbon	ND	mg/kg	391	126	
LCS	Solid	Mean Total Organic Carbon	79	%	1240	399	
MS	Solid	Mean Total Organic Carbon	95	%	7380	2380	
MSD	Solid	Mean Total Organic Carbon	81	%	5970	1920	24

Appendix Table 19: Initial and Recovered Wet Weight of *L. variegatus* tissue for the 28-day Bioaccumulation Test

Sample ID	Test Sediment	Initial Weight	Average Initial Weight	Standard Deviation	Weight Recovered	Average Recovered Weight	Standard Deviation
LA1	BW15ML-032	15.2			11.3		
LA2	BW15ML-032	15.7			12.9		
LA3	BW15ML-032	15.3			12.4		
LA4	BW15ML-032	15.4			13.4		
LA5	BW15ML-032	15.3			13.3		
LA	**BW15ML-032**		**15.4**	**0.19**		**12.7**	**0.856**
LB1	BW15ML-004	15.3			12		
LB2	BW15ML-004	15.5			11.1		
LB3	BW15ML-004	15.6			13.7		
LB4	BW15ML-004	15.6			13.4		
LB5	BW15ML-004	15.5			11.7		
LB	**BW15ML-004**		**15.5**	**0.12**		**12.4**	**1.121**
LC1	BW15ML-034	15.3			15.6		
LC2	BW15ML-034	15.4			13.7		
LC3	BW15ML-034	15.9			13		
LC4	BW15ML-034	15.2			13.2		
LC5	BW15ML-034	16			14.3		
LC	**BW15ML-034**		**15.6**	**0.37**		**14.0**	**1.045**
LD1	BW15ML-010	15.4			13.9		
LD2	BW15ML-010	15.3			14.5		
LD3	BW15ML-010	15.5			13		
LD4	BW15ML-010	15.4			13.7		
LD5	BW15ML-010	15.8			14.6		
LD	**BW15ML-010**		**15.5**	**0.19**		**13.9**	**0.650**

Appendix Table 20: Temperature (˚C) Water Chemistry Parameter for *L. variegatus* during the 28-Day Bioaccumulation Test

Day	am/pm	LA1	LA2	LA3	LA4	LA5	LB1	LB2	LB3	LB4	LB5	LC1	LC2	LC3	LC4	LC5	LD1	LD2	LD3	LD4	LD5
0	am	19.5	21.3	21.6	20.9	20.6	20.4	21.2	21.7	20.3	20.0	20.8	21.6	20.3	20.9	20.9	20.7	21.1	21.2	20.4	20.7
	pm	21.0		22.6		21.8	22.2		22.7		21.5	21.5		22.3		22.1	21.5		22.2		21.5
1	am		22.3		22.8			22.1		22.7			22.4		22.7			22.0		22.2	
	pm	21.3		23.0		22.4	22.9		23.0		22.0	22.0		22.8		22.7	22.0		22.7		22.3
2	am		22.3		23.3			22.1		23.1			22.6		23.1			22.0		22.9	
	pm	22.0		23.2		22.8	23.3		23.4		22.2	22.2		23.0		23.1	22.4		22.9		22.8
3	am		21.7		23.0			21.8		22.8			22.7		22.2			21.8		22.5	
	pm	21.5		22.8		22.1	22.2		23.0		21.9	21.3		22.4		22.2	21.6		22.1		21.6
4	am		21.2		22.5			21.5		22.1			21.7		22.2			21.3		21.9	
	pm	21.1		22.4		21.9	22.2		22.6		21.5	21.2		22.2		22.1	21.4		21.9		21.4
5	am		21.1		22.4			21.4		22.1			21.5		22.2			21.0		21.6	
	pm	21.4		22.5		22.0	22.2		22.6		21.9	21.3		22.2		22.1	21.2		21.9		21.4
6	am		21.6		22.4			21.8		22.3			21.9		22.0			21.4		21.7	
	pm	21.2		22.3		22.0	22.2		22.1		21.4	21.3		21.5		22.2	21.1		21.8		21.5
7	am		21.7		21.9			22.0		21.8			21.9		22.0			21.6		21.4	
	pm	21.5		22.5		22.1	22.5		22.6		21.5	21.3		22.3		22.4	21.2		22.0		21.8
8	am		22.0		23.0			22.4		23.1			22.3		22.7			22.1		22.6	
	pm	21.8		22.7		22.3	22.7		22.7		21.8	21.3		22.5		22.6	21.3		22.3		22.0
9	am		21.9		22.9			22.1		23.0			22.2		22.8			21.9		22.3	
	pm	21.7		22.9		22.4	22.7		22.9		22.0	21.7		22.3		22.7	21.7		22.4		22.1
10	am		22.0		22.8			22.4		22.9			22.4		22.6			22.3		22.1	
	pm	21.9		23.0		22.5	22.6		23.2		22.4	21.4		22.3		22.6	21.9		22.4		21.9
11	am		22.3		23.6			22.7		23.3			22.6		22.9			22.4		22.6	
	pm	22.0		23.1		22.8	23.2		23.2		22.4	22.0		22.7		23.0	22.3		22.7		22.4
12	am		22.4		23.8			23.2		23.7			23.0		23.1			22.9		22.8	
	pm	21.8		23.2		22.8	23.2		23.1		22.3	22.0		23.0		23.1	22.6		22.9		22.6
13	am		22.3		23.5			22.5		23.5			22.7		23.0			22.5		22.5	
	pm	21.6		23.2		22.6	23.1		23.0		22.2	21.9		23.0		22.9	21.8		22.7		22.2
14	am		22.3		22.6			22.4		22.6			22.6		22.5			22.2		21.8	
	pm	21.6		23.1		22.7	23.1		23.0		22.1	21.8		22.9		22.9	21.8		22.6		22.3
15	am		22.5		23.5			22.6		23.5			22.7		22.9			22.3		22.6	
	pm	21.8		23.1		22.8	23.2		22.8		22.3	22.2		22.8		23.1	22.0		22.3		22.1
16	am		22.3		23.4			22.8		23.4			22.9		23.0			22.5		22.7	
	pm	21.5		23.3		23.0	23.3		23.0		22.5	21.9		23.1		23.2	22.0		22.7		22.5
17	am		22.5		23.9			23.0		23.4			23.0		23.1			22.8		22.8	
	pm	22.4		23.6		23.2	23.6		23.3		23.0	22.4		23.3		23.4	22.5		23.1		22.4
18	am		22.7		24.0			23.3		23.9			23.3		23.5			23.0		23.2	
	pm	22.4		23.6		23.2	23.5		23.3		23.0	22.5		23.0		23.2	22.6		23.0		22.3
19	am		22.8		24.1			23.2		24.1			23.1		23.3			22.9		23.1	
	pm	21.9		23.6		23.4	23.5		22.8		22.8	22.9		23.3		23.6	22.6		23.1		22.4

Day	am/ pm	LA1	LA2	LA3	LA4	LA5	LB1	LB2	LB3	LB4	LB5	LC1	LC2	LC3	LC4	LC5	LD1	LD2	LD3	LD4	LD5
20	am		22.8		23.9			23.2		24.1			23.1		23.2			22.9		23.0	
	pm	21.6		23.5		23.1	23.4		23.0		22.7	22.8		23.2		23.2	22.5		22.9		22.3
21	am		22.6		22.6			22.9		22.9			22.8		22.3			22.5		22.0	
	pm	21.7		23.2		22.8	23.1		22.6		22.4	22.6		22.7		23.0	22.3		22.6		22.0
22	am		22.3		23.5			22.7		23.7			22.7		22.8			22.3		22.1	
	pm	20.8		23.0		22.4	22.7		22.5		22.1	22.3		22.5		22.6	21.8		22.4		21.9
23	am		22.3		23.5			22.4		23.5			22.5		22.8			22.2		22.4	
	pm	21.0		23.1		22.8	23.1		22.7		22.3	22.5		22.8		23.0	22.1		22.6		22.0
24	am		22.3		23.4			22.7		23.5			22.6		22.5			22.4		22.3	
	pm	22.0		23.4		22.9	23.3		23.1		22.5	22.1		23.2		23.1	22.2		22.8		22.3
25	am		23.3		24.2			23.1		24.2			23.2		23.3			22.9		23.2	
	pm	22.5		23.7		23.3	23.5		23.4		23.1	22.7		23.2		23.3	22.7		23.2		22.5
26	am		22.6		23.7			22.7		23.8			22.8		22.8			22.4		22.5	
	pm	21.3		23.0		22.4	22.7		22.7		22.2	21.7		22.6		22.7	21.9		22.4		21.8
27	am	21.1	22.0	22.8	23.0	22.2	22.5	22.3	22.5	22.9	21.9	21.5	22.1	22.3	22.5	22.4	21.5	22.0	22.1	21.8	21.4
	pm	21.3		22.9		22.2	22.7		22.5		22.0	21.3		22.6		22.5	21.6		22.2		21.9
28	am		21.6		22.7			21.9		22.5			21.8		22.4			21.6		21.6	
29	am		-		-			-		-			21.8		22.2			21.1		22.1	
Average					**22.5**					**22.7**					**22.5**					**22.2**	
	Min				**19.5**					**20.0**					**20.3**					**20.4**	
	Max				**24.2**					**24.2**					**23.6**					**23.2**	

Appendix Table 21: Dissolved Oxygen (mg/L) Water Chemistry Parameter for *L. variegatus* during the 28-Day Bioaccumulation Test

Day	am/ pm	LA1	LA2	LA3	LA4	LA5	LB1	LB2	LB3	LB4	LA5	LC1	LC2	LC3	LC4	LC5	LD1	LD2	LD3	LD4	LD5
0	am	8.0	7.8	7.9	7.3	7.7	8.1	7.6	7.4	8.1	8.0	7.6	7.7	7.9	7.4	7.5	7.6	7.8	8.1	8.1	7.5
	pm	7.7		7.3		7.1	6.5		6.2		7.2	7.5		7.4		7.0	6.7		7.2		7.3
1	am		7.6		6.9			7.5		7.4			7.6		7.1			7.4		7.4	
	pm	7.8		7.5		7.3	6.9		6.9		7.5	7.4		7.2		7.2	7.1		7.5		7.1
2	am		7.7		7.4			7.4		7.3			7.4		7.1			7.3		7.4	
	pm	7.8		7.3		7.5	6.9		7.1		7.5	7.6		7.6		7.3	6.7		7.2		6.8
3	am		8.3		7.8			7.6		8.1			7.7		7.6			7.0		7.3	
	pm	8.1		7.9		7.9	8.0		7.3		7.8	7.9		8.0		7.5	7.5		7.6		7.1
4	am		7.9		7.4			7.8		7.6			7.7		7.4			7.3		7.4	
	pm	8.2		7.7		7.8	7.8		7.2		7.6	7.6		7.8		7.3	7.7		7.5		7.3
5	am		8.3		8.1			8.0		8.0			8.0		7.7			7.6		7.3	
	pm	8.0		7.6		7.8	7.6		7.4		7.7	7.8		7.8		7.6	7.9		7.5		7.1
6	am		7.9		7.9			7.4		7.3			7.7		7.3			6.9		7.8	
	pm	8.2		7.6		7.8	7.6		8.1		7.8	8.1		7.7		7.3	7.7		7.6		7.2
7	am		7.9		7.6			7.5		7.5			7.7		7.2			6.9		7.1	
	pm	7.9		7.5		7.5	7.3		7.1		7.5	7.6		7.6		7.3	7.4		7.1		6.9
8	am		7.7		7.3			7.4		7.3			7.3		6.9			6.8		6.7	
	pm	7.8		7.5		7.6	7.6		7.2		7.5	7.6		7.5		7.1	7.5		7.0		6.9
9	am		7.7		7.4			7.5		7.3			7.5		7.3			6.7		7.1	
	pm	8.1		7.5		7.7	7.9		7.1		7.7	7.8		7.7		7.2	7.1		7.2		6.6
10	am		7.2		6.8			7.0		6.9			7.0		6.5			6.3		6.7	
	pm	7.6		7.3		7.2	6.8		6.6		7.0	7.2		7.2		6.7	6.5		6.5		6.4
11	am		7.7		7.4			6.7		7.4			7.6		7.2			7.1		7.2	
	pm	7.1		6.6		7.2	7.0		6.3		6.9	7.2		6.9		6.7	5.8		6.0		5.8
12	am		7.6		7.1			6.3		7.0			7.3		7.0			6.5		7.0	
	pm	7.8		7.3		7.4	7.4		7.1		7.3	7.5		7.4		7.1	6.4		6.8		6.4
13	am		7.6		7.3			7.5		7.1			7.6		7.0			6.8		7.5	
	pm	7.9		7.9		7.7	7.6		6.9		7.3	7.4		7.4		7.4	7.4		7.7		7.6
14	am		7.5		7.4			7.2		7.2			7.3		6.9			7.2		7.1	
	pm	7.5		7.0		7.2	6.8		6.5		7.0	7.2		7.3		7.0	7.2		6.4		7.2
15	am		7.6		7.0			7.3		6.9			7.3		7.2			6.9		7.0	
	pm	7.7		7.2		7.3	7.2		7.3		7.1	7.0		7.4		6.7	7.4		7.5		7.4
16	am		7.4		7.6			7.5		7.0			7.5		7.4			7.5		7.2	
	pm	7.7		6.9		7.3	7.4		7.2		7.0	7.6		7.2		6.7	7.4		6.9		7.0
17	am		6.2		6.1			6.7		6.0			6.8		6.7			6.7		7.0	
	pm	7.8		7.0		7.3	7.3		7.3		7.1	7.3		7.1		6.8	7.2		6.8		7.3
18	am		6.6		6.8			6.9		6.5			6.5		6.4			6.5		6.9	
	pm	7.1		6.7		6.8	6.9		6.8		6.7	6.7		6.7		6.5	6.4		6.5		7.1
19	am		7.3		7.9			7.3		7.9			7.3		7.4			7.4		7.3	
	pm	7.1		7.0		7.3	7.5		7.6		7.1	6.9		7.4		6.6	7.2		6.9		7.4

Day	am/ pm	LA1	LA2	LA3	LA4	LA5	LB1	LB2	LB3	LB4	LA5	LC1	LC2	LC3	LC4	LC5	LD1	LD2	LD3	LD4	LD5
20	am		7.4		7.0			7.3		7.0			7.5		7.0			7.4		7.5	
	pm	8.3		7.8		8.1	8.2		8.3		8.2	8.1		8.1		7.8	7.8		7.7		8.0
21	am		7.9		7.9			8.4		8.1			7.9		7.4			7.9		8.0	
	pm	8.4		7.8		7.8	8.2		8.1		7.7	8.0		8.0		7.2	7.9		7.8		8.3
22	am		8.1		7.8			8.1		7.8			8.1		7.5			8.3		8.1	
	pm	8.5		7.7		7.9	8.2		8.5		8.4	8.0		8.2		7.5	8.1		7.9		8.6
23	am		8.2		7.9			8.3		7.7			8.3		7.8			8.0		8.1	
	pm	8.6		7.8		7.9	7.9		8.3		8.0	7.7		8.2		7.6	8.2		8.2		8.3
24	am		8.1		8.1			8.0		8.0			8.0		7.9			8.0		8.0	
	pm	7.9		7.5		7.7	8.0		8.0		7.7	7.7		8.0		7.8	8.5		8.3		8.2
25	am		7.7		7.4			8.1		7.5			7.8		7.8			8.2		7.8	
	pm	7.9		7.4		7.7	7.9		7.9		7.6	7.8		7.8		7.8	7.9		7.6		8.1
26	am		8.0		7.6			8.2		7.7			8.4		7.9			8.1		8.4	
	pm	8.5		7.7		7.9	8.1		8.5		8.0	8.2		8.1		8.2	8.1		8.1		8.6
27	am	8.4	8.2	7.8	8.1	8.1	8.5	8.3	8.4	7.9	8.2	8.1	8.5	8.4	7.8	7.7	8.4	8.3	8.3	8.7	9.2
	pm	8.3		7.6		7.6	8.1		8.2		7.7	8.0		8.4		7.4	8.0		7.9		8.0
28	am		8.0		7.4			8.0		8.2			8.3		7.8			8.5		8.6	
29	am		-		-			-		-			7.7		7.6			7.8		7.8	
Average					7.6					7.5					7.5					7.4	
	Min				6.1					6.0					6.4					5.8	
	Max				8.6					8.5					8.5					9.2	

Appendix Table 22: pH Water Chemistry Parameter for *L. variegatus* during the 28-Day Bioaccumulation Test

Day	0	7	14	21	27			
am/pm	am	am	am	pm	pm	Average	Min	Max
LA1	7.97				7.68			
LA2		7.80						
LA3			7.70					
LA4	7.95	7.83	7.76	7.60	7.74			
LA5				7.70		7.76	7.60	7.97
LB1	7.93				7.77			
LB2		7.84						
LB3			7.60					
LB4	7.96	7.84	7.72	7.64	7.72			
LB5				7.64		7.75	7.60	7.96
LC1	7.96				7.70			
LC2		7.84						
LC3			7.76					
LC4	7.97	7.70	7.68	7.62	7.69			
LC5				7.58		7.73	7.58	7.97
LD1	7.89				7.71			
LD2		7.54						
LD3			7.58					
LD4	7.89	7.59	7.60	7.67	7.73			
LD5				7.64		7.67	7.54	7.89

Appendix Table 23: Conductivity (µS/cm) Water Chemistry Parameter for *L. variegatus* during the 28-Day Bioaccumulation Test

Day	0	7	14	21	27			
am/pm	am	am	am	pm	pm	Average	Min	Max
LA1	164.0				147.2			
LA2		159.0						
LA3			155.8					
LA4	162.0	156.8	152.2	152.5	143.9			
LA5				149.3		154.3	143.9	164.0
LB1	166.0				145.6			
LB2		159.4						
LB3			156.0					
LB4	167.8	160.2	156.4	153.4	146.0			
LB5				154.3		156.5	145.6	167.8
LC1	158.7				146.7			
LC2		157.9						
LC3			154.6					
LC4	160.3	158.1	153.1	152.1	144.7			
LC5				152.4		153.9	144.7	160.3
LD1	158.6				147.3			
LD2		153.0						
LD3			149.0					
LD4	157.6	153.2	153.6	152.9	145.0			
LD5				154.2		152.4	145.0	158.6

Appendix Table 24: Ammonia (mg/L) Water Chemistry Parameter for *L. variegatus* during the 28-Day Bioaccumulation Test

Day	0	7	14	21	27			
am/pm	am	am	am	pm	pm	Average	Min	Max
LA1	0.23	0.08	0.14	0.14	0.11			
LA5	0.18	0.08	0.11	0.10	0.09	0.13	0.08	0.23
LB1	0.16	0.07	0.18	0.15	0.10			
LB5	0.16	0.07	0.15	0.13	0.09	0.13	0.07	0.18
LC1	0.20	0.08	0.17	0.13	0.11			
LC5	0.23	0.10	0.24	0.18	0.12	0.16	0.08	0.24
LD1	0.20	0.24	0.65	0.26	0.12			
LD5	0.19	0.34	0.73	0.30	0.12	0.32	0.12	0.73

Appendix Table 25: Hardness (mg/L CaCO3) Water Chemistry Parameter for *L. variegatus* during the 28-Day Bioaccumulation Test

Day	0	7	14	21	27			
am/pm	am	am	am	pm	pm	Average	Min	Max
LA1	51.6	54.0	52.6	48.1	48.5			
LA3	52.4	58.8	54.2	48.1	45.3	51.4	45.3	58.8
LB1	50.8	56.0	55.8	47.3	45.3			
LB3	52.8	59.2	50.6	45.7	48.1	51.2	45.3	59.2
LC1	46.8	52.4	53.8	47.7	46.1			
LC3	49.2	56.0	57.4	46.5	46.1	50.2	46.1	57.4
LD1	47.6	51.2	46.1	46.1	46.9			
LD3	49.2	64.4	64.6	46.1	43.3	50.6	43.3	64.6

Appendix Table 26: Alkalinity (mg/L CaCO3) Water Chemistry Parameters for *L. variegatus* during the 28-Day Bioaccumulation Test

Day	0	7	14	21	27			
am/pm	am	am	am	pm	pm	Average	Min	Max
LA2	46.8	48.4	45.2	44.0	42.0			
LA4	45.6	45.6	48.8	43.6	44.0	45.4	42.0	48.8
LB2	44.4	47.6	47.6	40.8	41.6			
LB4	44.8	47.2	48.0	42.8	40.8	44.6	40.8	48.0
LC2	45.2	48.0	46.4	43.2	41.6			
LC4	44.4	50.8	47.6	44.0	43.2	45.4	41.6	50.8
LD2	44.0	43.6	38.8	37.6	40.8			
LD4	44.4	46.0	39.2	40.4	41.6	41.6	37.6	46.0

Appendix Table 27: Analysis of polychlorodibenzo-p-dioxins (PCDDs) and polychlorodibenzofurans (PCDFs) in *L. variegatus* tissue upon completion of the 28-Day Bioaccumulation Test

Client ID	Compound	Result	EMPC	RL	Units	Qualifiers	TEQ	Matrix	EDL
BW15ML-004 COMP	2,3,7,8-TCDF	1.8	0	0.73	ng/Kg		0.18	Tissue	0.73
	2,3,7,8-TCDD	0.66	0	0.48	ng/Kg	J	0.66	Tissue	0.48
	1,2,3,7,8-PeCDF	0.27	0	0.27	ng/Kg	J	0.013	Tissue	0.27
	2,3,4,7,8-PeCDF	0.85	0	0.2	ng/Kg	J	0.43	Tissue	0.2
	1,2,3,7,8-PeCDD	0.6	0	0.27	ng/Kg	J	0.3	Tissue	0.27
	1,2,3,4,7,8-HxCDF	0.58	0	0.25	ng/Kg	J	0.058	Tissue	0.25
	1,2,3,6,7,8-HxCDF	0.46	0	0.3	ng/Kg	J	0.046	Tissue	0.3
	2,3,4,6,7,8-HxCDF	0	0.34	0.28	ng/Kg	IJ	0.034	Tissue	0.28
	1,2,3,7,8,9-HxCDF	ND	0	0.2	ng/Kg		0	Tissue	0.2
	1,2,3,4,7,8-HxCDD	ND	0	0.37	ng/Kg		0	Tissue	0.37
	1,2,3,6,7,8-HxCDD	2.5	0	0.37	ng/Kg	J	0.25	Tissue	0.37
	1,2,3,7,8,9-HxCDD	1.1	0	0.4	ng/Kg	J	0.11	Tissue	0.4
	1,2,3,4,6,7,8-HpCDF	6.8	0	0.47	ng/Kg		0.068	Tissue	0.47
	1,2,3,4,7,8,9-HpCDF	ND	0	0.72	ng/Kg		0	Tissue	0.72
	1,2,3,4,6,7,8-HpCDD	6.7	0	0.51	ng/Kg		0.067	Tissue	0.51
	OCDF	1.6	0	0.91	ng/Kg	J	0.0016	Tissue	0.91
	OCDD	62	0	1.3	ng/Kg		0.062	Tissue	1.3
	Total TCDF	17	0	0.73	ng/Kg		0	Tissue	0.73
	Total TCDD	1.9	0	0.48	ng/Kg		0	Tissue	0.48
	Total PeCDF	11	0	0.23	ng/Kg		0	Tissue	0.23
	Total PeCDD	7	0	0.27	ng/Kg	J	0	Tissue	0.27
	Total HxCDF	14	0	0.26	ng/Kg		0	Tissue	0.26
	Total HxCDD	22	0	0.38	ng/Kg		0	Tissue	0.38
	Total HpCDF	14	0	0.6	ng/Kg		0	Tissue	0.6
	Total HpCDD	24	0	0.51	ng/Kg		0	Tissue	0.51
	TEQ	2.3	0	0	ng/Kg		0	Tissue	0
BW15ML-032 COMP	2,3,7,8-TCDF	1.8	0	0.66	ng/Kg		0.18	Tissue	0.66
	2,3,7,8-TCDD	0.84	0	0.33	ng/Kg	J	0.84	Tissue	0.33
	1,2,3,7,8-PeCDF	0.67	0	0.41	ng/Kg	J	0.033	Tissue	0.41
	2,3,4,7,8-PeCDF	1.8	0	0.27	ng/Kg	J	0.89	Tissue	0.27
	1,2,3,7,8-PeCDD	1.5	0	0.34	ng/Kg	J	0.77	Tissue	0.34
	1,2,3,4,7,8-HxCDF	1.3	0	0.31	ng/Kg	J	0.13	Tissue	0.31
	1,2,3,6,7,8-HxCDF	2.5	0	0.28	ng/Kg	J	0.25	Tissue	0.28
	2,3,4,6,7,8-HxCDF	0.92	0	0.27	ng/Kg	J	0.092	Tissue	0.27
	1,2,3,7,8,9-HxCDF	ND	0	0.23	ng/Kg		0	Tissue	0.23
	1,2,3,4,7,8-HxCDD	ND	0	0.47	ng/Kg		0	Tissue	0.47
	1,2,3,6,7,8-HxCDD	3.7	0	0.49	ng/Kg	J	0.37	Tissue	0.49
	1,2,3,7,8,9-HxCDD	1.5	0	0.69	ng/Kg	J	0.15	Tissue	0.69
	1,2,3,4,6,7,8-HpCDF	27	0	0.39	ng/Kg		0.27	Tissue	0.39
	1,2,3,4,7,8,9-HpCDF	ND	0	0.5	ng/Kg		0	Tissue	0.5
	1,2,3,4,6,7,8-HpCDD	8.5	0	0.87	ng/Kg		0.085	Tissue	0.87
	OCDF	4.4	0	1	ng/Kg	J	0.0044	Tissue	1
	OCDD	52	0	1.9	ng/Kg		0.052	Tissue	1.9
	Total TCDF	22	0	0.66	ng/Kg		0	Tissue	0.66
	Total TCDD	6.1	0	0.33	ng/Kg		0	Tissue	0.33
	Total PeCDF	29	0	0.34	ng/Kg		0	Tissue	0.34
	Total PeCDD	12	0	0.34	ng/Kg	J	0	Tissue	0.34
	Total HxCDF	47	0	0.27	ng/Kg		0	Tissue	0.27
	Total HxCDD	25	0	0.55	ng/Kg		0	Tissue	0.55
	Total HpCDF	51	0	0.45	ng/Kg		0	Tissue	0.45
	Total HpCDD	23	0	0.87	ng/Kg		0	Tissue	0.87
	TEQ	4.1	0	0	ng/Kg		0	Tissue	0

Client ID	Compound	Result	EMPC	RL	Units	Qualifiers	TEQ	Matrix	EDL
MLS-LV-1 PRE	2,3,7,8-TCDF	0.47	0	0.21	ng/Kg	J	0.047	Tissue	0.21
	2,3,7,8-TCDD	ND	0	0.29	ng/Kg		0	Tissue	0.29
	1,2,3,7,8-PeCDF	ND	0	0.16	ng/Kg		0	Tissue	0.16
	2,3,4,7,8-PeCDF	ND	0	0.16	ng/Kg		0	Tissue	0.16
	1,2,3,7,8-PeCDD	ND	0	0.24	ng/Kg		0	Tissue	0.24
	1,2,3,4,7,8-HxCDF	ND	0	0.24	ng/Kg		0	Tissue	0.24
	1,2,3,6,7,8-HxCDF	ND	0	0.2	ng/Kg		0	Tissue	0.2
	2,3,4,6,7,8-HxCDF	ND	0	0.22	ng/Kg		0	Tissue	0.22
	1,2,3,7,8,9-HxCDF	ND	0	0.36	ng/Kg		0	Tissue	0.36
	1,2,3,4,7,8-HxCDD	ND	0	0.4	ng/Kg		0	Tissue	0.4
	1,2,3,6,7,8-HxCDD	ND	0	0.3	ng/Kg		0	Tissue	0.3
	1,2,3,7,8,9-HxCDD	ND	0	0.39	ng/Kg		0	Tissue	0.39
	1,2,3,4,6,7,8-HpCDF	ND	0	0.4	ng/Kg		0	Tissue	0.4
	1,2,3,4,7,8,9-HpCDF	ND	0	0.57	ng/Kg		0	Tissue	0.57
	1,2,3,4,6,7,8-HpCDD	ND	0	0.48	ng/Kg		0	Tissue	0.48
	OCDF	ND	0	0.87	ng/Kg		0	Tissue	0.87
	OCDD	ND	0	1.3	ng/Kg		0	Tissue	1.3
	Total TCDF	1	0	0.21	ng/Kg	J	0	Tissue	0.21
	Total TCDD	ND	0	0.29	ng/Kg		0	Tissue	0.29
	Total PeCDF	ND	0	0.16	ng/Kg		0	Tissue	0.16
	Total PeCDD	ND	0	0.24	ng/Kg		0	Tissue	0.24
	Total HxCDF	ND	0	0.25	ng/Kg		0	Tissue	0.25
	Total HxCDD	ND	0	0.36	ng/Kg		0	Tissue	0.36
	Total HpCDF	ND	0	0.48	ng/Kg		0	Tissue	0.48
	Total HpCDD	ND	0	0.48	ng/Kg		0	Tissue	0.48
	TEQ	0.047	0	0	ng/Kg		0	Tissue	0
BW15ML-034 COMP	2,3,7,8-TCDF	1.9	0	0.38	ng/Kg		0.19	Tissue	0.38
	2,3,7,8-TCDD	0	0.74	0.35	ng/Kg	IJ	0.74	Tissue	0.35
	1,2,3,7,8-PeCDF	0	0.48	0.28	ng/Kg	IJ	0.024	Tissue	0.28
	2,3,4,7,8-PeCDF	1.4	0	0.21	ng/Kg	J	0.7	Tissue	0.21
	1,2,3,7,8-PeCDD	1.6	0	0.33	ng/Kg	J	0.78	Tissue	0.33
	1,2,3,4,7,8-HxCDF	1.2	0	0.3	ng/Kg	J	0.12	Tissue	0.3
	1,2,3,6,7,8-HxCDF	2.3	0	0.3	ng/Kg	J	0.23	Tissue	0.3
	2,3,4,6,7,8-HxCDF	1	0	0.24	ng/Kg	J	0.1	Tissue	0.24
	1,2,3,7,8,9-HxCDF	ND	0	0.22	ng/Kg		0	Tissue	0.22
	1,2,3,4,7,8-HxCDD	ND	0	0.31	ng/Kg		0	Tissue	0.31
	1,2,3,6,7,8-HxCDD	3.8	0	0.48	ng/Kg	J	0.38	Tissue	0.48
	1,2,3,7,8,9-HxCDD	1.7	0	0.55	ng/Kg	J	0.17	Tissue	0.55
	1,2,3,4,6,7,8-HpCDF	20	0	0.45	ng/Kg		0.2	Tissue	0.45
	1,2,3,4,7,8,9-HpCDF	ND	0	0.63	ng/Kg		0	Tissue	0.63
	1,2,3,4,6,7,8-HpCDD	7.8	0	0.65	ng/Kg		0.078	Tissue	0.65
	OCDF	4.6	0	1	ng/Kg	J	0.0046	Tissue	1
	OCDD	70	0	1.5	ng/Kg		0.07	Tissue	1.5
	Total TCDF	24	0	0.38	ng/Kg		0	Tissue	0.38
	Total TCDD	6.8	0	0.35	ng/Kg		0	Tissue	0.35
	Total PeCDF	24	0	0.24	ng/Kg		0	Tissue	0.24
	Total PeCDD	11	0	0.33	ng/Kg	J	0	Tissue	0.33
	Total HxCDF	40	0	0.26	ng/Kg		0	Tissue	0.26
	Total HxCDD	24	0	0.45	ng/Kg		0	Tissue	0.45
	Total HpCDF	40	0	0.54	ng/Kg		0	Tissue	0.54
	Total HpCDD	24	0	0.65	ng/Kg		0	Tissue	0.65
	TEQ	3.8	0	0	ng/Kg		0	Tissue	0

Client ID	Compound	Result	EMPC	RL	Units	Qualifiers	TEQ	Matrix	EDL
BW15ML-010 COMP	2,3,7,8-TCDF	0.92	0	0.21	ng/Kg	J	0.092	Tissue	0.21
	2,3,7,8-TCDD	ND	0	0.36	ng/Kg		0	Tissue	0.36
	1,2,3,7,8-PeCDF	ND	0	0.24	ng/Kg		0	Tissue	0.24
	2,3,4,7,8-PeCDF	0.65	0	0.18	ng/Kg	J	0.32	Tissue	0.18
	1,2,3,7,8-PeCDD	ND	0	0.23	ng/Kg		0	Tissue	0.23
	1,2,3,4,7,8-HxCDF	ND	0	0.33	ng/Kg		0	Tissue	0.33
	1,2,3,6,7,8-HxCDF	ND	0	0.33	ng/Kg		0	Tissue	0.33
	2,3,4,6,7,8-HxCDF	ND	0	0.32	ng/Kg		0	Tissue	0.32
	1,2,3,7,8,9-HxCDF	ND	0	0.4	ng/Kg		0	Tissue	0.4
	1,2,3,4,7,8-HxCDD	ND	0	0.43	ng/Kg		0	Tissue	0.43
	1,2,3,6,7,8-HxCDD	ND	0	0.41	ng/Kg		0	Tissue	0.41
	1,2,3,7,8,9-HxCDD	ND	0	0.35	ng/Kg		0	Tissue	0.35
	1,2,3,4,6,7,8-HpCDF	2.5	0	0.38	ng/Kg	J	0.025	Tissue	0.38
	1,2,3,4,7,8,9-HpCDF	ND	0	0.58	ng/Kg		0	Tissue	0.58
	1,2,3,4,6,7,8-HpCDD	1.3	0	0.65	ng/Kg	J	0.013	Tissue	0.65
	OCDF	1.6	0	1.2	ng/Kg	J	0.0016	Tissue	1.2
	OCDD	11	0	1.8	ng/Kg		0.011	Tissue	1.8
	Total TCDF	21	0	0.21	ng/Kg		0	Tissue	0.21
	Total TCDD	ND	0	0.36	ng/Kg		0	Tissue	0.36
	Total PeCDF	10	0	0.21	ng/Kg	J	0	Tissue	0.21
	Total PeCDD	ND	0	0.23	ng/Kg		0	Tissue	0.23
	Total HxCDF	4.1	0	0.34	ng/Kg	J	0	Tissue	0.34
	Total HxCDD	2.3	0	0.4	ng/Kg	J	0	Tissue	0.4
	Total HpCDF	2.5	0	0.48	ng/Kg	J	0	Tissue	0.48
	Total HpCDD	5	0	0.65	ng/Kg	J	0	Tissue	0.65
	TEQ	0.47	0	0	ng/Kg		0	Tissue	0

Compounds were marked with the qualifier “I” when incorrect isotopes were found during analysis. Compounds were marked with the qualifier “J” when concentrations found were below the calibration range and should be considered estimates.

Appendix Table 28: Metal, PCB, Tetrachloro-m-xylene, Decachlorobiphenyl, and Lipid Analysis for *L. variegatus* tissue following the 28-Day Bioaccumulation Test

Field ID	Parameter	Result	LOD	LOQ	EQL	Units	Code	Matrix
BW15ML-004 REP 1	Percent Moisture	88.6	0.10	0.10	0.10	%		Tissue
	Arsenic	0.91	0.012	0.10	0.10	mg/kg		Tissue
	Cadmium	0.034	0.0064	0.10	0.10	mg/kg	J	Tissue
	Chromium	0.12	0.024	0.10	0.10	mg/kg		Tissue
	Copper	2.2	0.023	0.10	0.10	mg/kg		Tissue
	Lead	0.49	0.0025	0.10	0.10	mg/kg		Tissue
	Nickel	0.12	0.030	0.10	0.10	mg/kg		Tissue
	Zinc	26.5	0.64	2.0	2.0	mg/kg		Tissue
	Mercury	0.0091	0.0048	0.0098	0.0098	mg/kg	J	Tissue
BW15ML-004 REP 2	Percent Moisture	87.9	0.10	0.10	0.10	%		Tissue
	Arsenic	0.98	0.012	0.10	0.10	mg/kg		Tissue
	Cadmium	0.035	0.0064	0.10	0.10	mg/kg	J	Tissue
	Chromium	0.25	0.024	0.10	0.10	mg/kg		Tissue
	Copper	2.3	0.023	0.10	0.10	mg/kg		Tissue
	Lead	0.94	0.0025	0.10	0.10	mg/kg		Tissue
	Nickel	0.20	0.030	0.10	0.10	mg/kg		Tissue
	Zinc	27.2	0.64	2.0	2.0	mg/kg		Tissue
	Mercury	0.0089	0.0044	0.0092	0.0092	mg/kg	J	Tissue
BW15ML-004 REP 3	Percent Moisture	87.2	0.10	0.10	0.10	%		Tissue
	Arsenic	1.1	0.012	0.098	0.098	mg/kg		Tissue
	Cadmium	0.031	0.0063	0.098	0.098	mg/kg	J	Tissue
	Chromium	0.21	0.024	0.098	0.098	mg/kg		Tissue
	Copper	2.6	0.023	0.098	0.098	mg/kg		Tissue
	Lead	0.85	0.0025	0.098	0.098	mg/kg		Tissue
	Nickel	0.17	0.029	0.098	0.098	mg/kg		Tissue
	Zinc	29.4	0.63	2.0	2.0	mg/kg		Tissue
	Mercury	0.011	0.0047	0.0098	0.0098	mg/kg		Tissue
BW15ML-004 REP 4	Percent Moisture	88.2	0.10	0.10	0.10	%		Tissue
	Arsenic	1.1	0.012	0.098	0.098	mg/kg		Tissue
	Cadmium	0.026	0.0063	0.098	0.098	mg/kg	J	Tissue
	Chromium	0.038	0.024	0.098	0.098	mg/kg	J	Tissue
	Copper	2.1	0.023	0.098	0.098	mg/kg		Tissue
	Lead	0.25	0.0025	0.098	0.098	mg/kg		Tissue
	Nickel	0.069	0.030	0.098	0.098	mg/kg	J	Tissue
	Zinc	28.0	0.63	2.0	2.0	mg/kg		Tissue
	Mercury	0.0090	0.0047	0.0098	0.0098	mg/kg	J	Tissue
BW15ML-004 REP 5	Percent Moisture	87.5	0.10	0.10	0.10	%		Tissue
	Arsenic	0.97	0.012	0.094	0.094	mg/kg		Tissue
	Cadmium	0.033	0.0060	0.094	0.094	mg/kg	J	Tissue
	Chromium	0.22	0.023	0.094	0.094	mg/kg		Tissue
	Copper	2.4	0.022	0.094	0.094	mg/kg		Tissue
	Lead	0.99	0.0024	0.094	0.094	mg/kg		Tissue
	Nickel	0.22	0.028	0.094	0.094	mg/kg		Tissue
	Zinc	30.5	0.61	1.9	1.9	mg/kg		Tissue
	Mercury	0.0093	0.0047	0.0097	0.0097	mg/kg	J	Tissue
BW15ML-004 COMP	PCB-1016 (Aroclor 1016)	29.4	29.4	58.9	58.9	ug/kg	U	Tissue
	PCB-1221 (Aroclor 1221)	29.4	29.4	58.9	58.9	ug/kg	U	Tissue
	PCB-1232 (Aroclor 1232)	29.4	29.4	58.9	58.9	ug/kg	U	Tissue
	PCB-1242 (Aroclor 1242)	29.4	29.4	58.9	58.9	ug/kg	U	Tissue
	PCB-1248 (Aroclor 1248)	29.4	29.4	58.9	58.9	ug/kg	U	Tissue
	PCB-1254 (Aroclor 1254)	29.4	29.4	58.9	58.9	ug/kg	U	Tissue
	PCB-1260 (Aroclor 1260)	368	29.4	58.9	58.9	ug/kg		Tissue
	PCB-1262 (Aroclor 1262)	29.4	29.4	58.9	58.9	ug/kg	U	Tissue
	PCB-1268 (Aroclor 1268)	29.4	29.4	58.9	58.9	ug/kg	U	Tissue
	PCB, Total	368	29.4	58.9	58.9	ug/kg		Tissue
	Tetrachloro-m-xylene (S)	86				%		Tissue
	Decachlorobiphenyl (S)	84				%		Tissue
	Lipid	1.6				%		Tissue

Field ID	Parameter	Result	LOD	LOQ	EQL	Units	Code	Matrix
BW15ML-032 REP 1	Percent Moisture	87.7	0.10	0.10	0.10	%		Tissue
	Arsenic	1.1	0.012	0.099	0.099	mg/kg		Tissue
	Cadmium	0.041	0.0063	0.099	0.099	mg/kg	J	Tissue
	Chromium	0.45	0.024	0.099	0.099	mg/kg		Tissue
	Copper	3.1	0.023	0.099	0.099	mg/kg		Tissue
	Lead	1.2	0.0025	0.099	0.099	mg/kg		Tissue
	Nickel	0.36	0.030	0.099	0.099	mg/kg		Tissue
	Zinc	29.2	0.63	2.0	2.0	mg/kg		Tissue
	Mercury	0.012	0.0048	0.010	0.010	mg/kg		Tissue
BW15ML-032 REP 2	Percent Moisture	88.1	0.10	0.10	0.10	%		Tissue
	Arsenic	1.2	0.011	0.094	0.094	mg/kg		Tissue
	Cadmium	0.043	0.0060	0.094	0.094	mg/kg	J	Tissue
	Chromium	0.62	0.023	0.094	0.094	mg/kg		Tissue
	Copper	2.7	0.022	0.094	0.094	mg/kg		Tissue
	Lead	1.9	0.0024	0.094	0.094	mg/kg		Tissue
	Nickel	0.51	0.028	0.094	0.094	mg/kg		Tissue
	Zinc	28.7	0.60	1.9	1.9	mg/kg		Tissue
	Mercury	0.012	0.0048	0.0099	0.0099	mg/kg		Tissue
BW15ML-032 REP 3	Percent Moisture	86.8	0.10	0.10	0.10	%		Tissue
	Arsenic	1.3	0.012	0.095	0.095	mg/kg		Tissue
	Cadmium	0.045	0.0060	0.095	0.095	mg/kg	J	Tissue
	Chromium	0.58	0.023	0.095	0.095	mg/kg		Tissue
	Copper	3.0	0.022	0.095	0.095	mg/kg		Tissue
	Lead	1.6	0.0024	0.095	0.095	mg/kg		Tissue
	Nickel	1.8	0.028	0.095	0.095	mg/kg		Tissue
	Zinc	31.2	0.61	1.9	1.9	mg/kg		Tissue
	Mercury	0.013	0.0048	0.0099	0.0099	mg/kg		Tissue
BW15ML-032 REP 4	Percent Moisture	87.8	0.10	0.10	0.10	%		Tissue
	Arsenic	1.2	0.012	0.10	0.10	mg/kg		Tissue
	Cadmium	0.036	0.0064	0.10	0.10	mg/kg	J	Tissue
	Chromium	0.26	0.024	0.10	0.10	mg/kg		Tissue
	Copper	2.4	0.023	0.10	0.10	mg/kg		Tissue
	Lead	0.68	0.0025	0.10	0.10	mg/kg		Tissue
	Nickel	0.21	0.030	0.10	0.10	mg/kg		Tissue
	Zinc	27.0	0.64	2.0	2.0	mg/kg		Tissue
	Mercury	0.012	0.0048	0.0098	0.0098	mg/kg		Tissue
BW15ML-032 REP 5	Percent Moisture	87.5	0.10	0.10	0.10	%		Tissue
	Arsenic	1.2	0.011	0.091	0.091	mg/kg		Tissue
	Cadmium	0.027	0.0058	0.091	0.091	mg/kg	J	Tissue
	Chromium	0.086	0.022	0.091	0.091	mg/kg	J	Tissue
	Copper	2.5	0.021	0.091	0.091	mg/kg		Tissue
	Lead	0.31	0.0023	0.091	0.091	mg/kg		Tissue
	Nickel	0.093	0.027	0.091	0.091	mg/kg		Tissue
	Zinc	27.8	0.58	1.8	1.8	mg/kg		Tissue
	Mercury	0.0084	0.0045	0.0094	0.0094	mg/kg	J	Tissue
BW15ML-032 COMP	PCB-1016 (Aroclor 1016)	60.3	60.3	121	121	ug/kg	U	Tissue
	PCB-1221 (Aroclor 1221)	60.3	60.3	121	121	ug/kg	U	Tissue
	PCB-1232 (Aroclor 1232)	60.3	60.3	121	121	ug/kg	U	Tissue
	PCB-1242 (Aroclor 1242)	60.3	60.3	121	121	ug/kg	U	Tissue
	PCB-1248 (Aroclor 1248)	60.3	60.3	121	121	ug/kg	U	Tissue
	PCB-1254 (Aroclor 1254)	60.3	60.3	121	121	ug/kg	U	Tissue
	PCB-1260 (Aroclor 1260)	1120	60.3	121	121	ug/kg		Tissue
	PCB-1262 (Aroclor 1262)	60.3	60.3	121	121	ug/kg	U	Tissue
	PCB-1268 (Aroclor 1268)	60.3	60.3	121	121	ug/kg	U	Tissue
	PCB, Total	1120	60.3	121	121	ug/kg		Tissue
	Tetrachloro-m-xylene (S)	82				%		Tissue
	Decachlorobiphenyl (S)	86				%		Tissue
	Lipid	1.6				%		Tissue

Field ID	Parameter	Result	LOD	LOQ	EQL	Units	Code	Matrix
BW15ML-034 REP 1	Percent Moisture	86.7	0.10	0.10	0.10	%		Tissue
	Arsenic	1.1	0.012	0.097	0.097	mg/kg		Tissue
	Cadmium	0.030	0.0062	0.097	0.097	mg/kg	J	Tissue
	Chromium	0.20	0.024	0.097	0.097	mg/kg		Tissue
	Copper	2.2	0.022	0.097	0.097	mg/kg		Tissue
	Lead	0.48	0.0024	0.097	0.097	mg/kg		Tissue
	Nickel	0.19	0.029	0.097	0.097	mg/kg		Tissue
	Zinc	26.5	0.62	1.9	1.9	mg/kg		Tissue
	Mercury	0.012	0.0048	0.010	0.010	mg/kg		Tissue
BW15ML-034 REP 2	Percent Moisture	86.8	0.10	0.10	0.10	%		Tissue
	Arsenic	1.2	0.011	0.093	0.093	mg/kg		Tissue
	Cadmium	0.038	0.0059	0.093	0.093	mg/kg	J	Tissue
	Chromium	0.36	0.023	0.093	0.093	mg/kg		Tissue
	Copper	2.5	0.022	0.093	0.093	mg/kg		Tissue
	Lead	0.85	0.0023	0.093	0.093	mg/kg		Tissue
	Nickel	0.29	0.028	0.093	0.093	mg/kg		Tissue
	Zinc	28.0	0.60	1.9	1.9	mg/kg		Tissue
	Mercury	0.012	0.0048	0.0098	0.0098	mg/kg		Tissue
BW15ML-034 REP 3	Percent Moisture	87.2	0.10	0.10	0.10	%		Tissue
	Arsenic	1.2	0.012	0.098	0.098	mg/kg		Tissue
	Cadmium	0.026	0.0063	0.098	0.098	mg/kg	J	Tissue
	Chromium	0.13	0.024	0.098	0.098	mg/kg		Tissue
	Copper	2.4	0.023	0.098	0.098	mg/kg		Tissue
	Lead	0.38	0.0025	0.098	0.098	mg/kg		Tissue
	Nickel	0.13	0.029	0.098	0.098	mg/kg		Tissue
	Zinc	27.1	0.63	2.0	2.0	mg/kg		Tissue
	Mercury	0.0095	0.0046	0.0095	0.0095	mg/kg	J	Tissue
BW15ML-034 REP 4	Percent Moisture	86.3	0.10	0.10	0.10	%		Tissue
	Arsenic	1.3	0.012	0.099	0.099	mg/kg		Tissue
	Cadmium	0.029	0.0063	0.099	0.099	mg/kg	J	Tissue
	Chromium	0.16	0.024	0.099	0.099	mg/kg		Tissue
	Copper	2.4	0.023	0.099	0.099	mg/kg		Tissue
	Lead	0.46	0.0025	0.099	0.099	mg/kg		Tissue
	Nickel	0.16	0.030	0.099	0.099	mg/kg		Tissue
	Zinc	29.5	0.64	2.0	2.0	mg/kg		Tissue
	Mercury	0.011	0.0046	0.0096	0.0096	mg/kg		Tissue
BW15ML-034 REP 5	Percent Moisture	87.2	0.10	0.10	0.10	%		Tissue
	Arsenic	1.3	0.011	0.090	0.090	mg/kg		Tissue
	Cadmium	0.028	0.0058	0.090	0.090	mg/kg	J	Tissue
	Chromium	0.25	0.022	0.090	0.090	mg/kg		Tissue
	Copper	2.5	0.021	0.090	0.090	mg/kg		Tissue
	Lead	0.59	0.0023	0.090	0.090	mg/kg		Tissue
	Nickel	0.22	0.027	0.090	0.090	mg/kg		Tissue
	Zinc	28.9	0.58	1.8	1.8	mg/kg		Tissue
	Mercury	0.011	0.0048	0.0099	0.0099	mg/kg		Tissue
BW15ML-034 COMP	PCB-1016 (Aroclor 1016)	32.0	32.0	63.9	63.9	ug/kg	U	Tissue
	PCB-1221 (Aroclor 1221)	32.0	32.0	63.9	63.9	ug/kg	U	Tissue
	PCB-1232 (Aroclor 1232)	32.0	32.0	63.9	63.9	ug/kg	U	Tissue
	PCB-1242 (Aroclor 1242)	32.0	32.0	63.9	63.9	ug/kg	U	Tissue
	PCB-1248 (Aroclor 1248)	32.0	32.0	63.9	63.9	ug/kg	U	Tissue
	PCB-1254 (Aroclor 1254)	32.0	32.0	63.9	63.9	ug/kg	U	Tissue
	PCB-1260 (Aroclor 1260)	993	32.0	63.9	63.9	ug/kg		Tissue
	PCB-1262 (Aroclor 1262)	32.0	32.0	63.9	63.9	ug/kg	U	Tissue
	PCB-1268 (Aroclor 1268)	32.0	32.0	63.9	63.9	ug/kg	U	Tissue
	PCB, Total	993	32.0	63.9	63.9	ug/kg		Tissue
	Tetrachloro-m-xylene (S)	88				%		Tissue
	Decachlorobiphenyl (S)	91				%		Tissue
	Lipid	1.9				%		Tissue

Field ID	Parameter	Result	LOD	LOQ	EQL	Units	Code	Matrix
BW15ML-010 REP 1	Percent Moisture	88.3	0.10	0.10	0.10	%		Tissue
	Arsenic	1.2	0.011	0.088	0.088	mg/kg		Tissue
	Cadmium	0.015	0.0056	0.088	0.088	mg/kg	J	Tissue
	Chromium	0.086	0.021	0.088	0.088	mg/kg	J	Tissue
	Copper	1.6	0.020	0.088	0.088	mg/kg		Tissue
	Lead	0.18	0.0022	0.088	0.088	mg/kg		Tissue
	Nickel	0.10	0.026	0.088	0.088	mg/kg		Tissue
	Zinc	23.6	0.57	1.8	1.8	mg/kg		Tissue
	Mercury	0.014	0.0044	0.0092	0.0092	mg/kg		Tissue
BW15ML-010 REP 2	Percent Moisture	88.1	0.10	0.10	0.10	%		Tissue
	Arsenic	1.3	0.011	0.093	0.093	mg/kg		Tissue
	Cadmium	0.018	0.0059	0.093	0.093	mg/kg	J	Tissue
	Chromium	0.16	0.023	0.093	0.093	mg/kg		Tissue
	Copper	1.8	0.021	0.093	0.093	mg/kg		Tissue
	Lead	0.39	0.0023	0.093	0.093	mg/kg		Tissue
	Nickel	0.20	0.028	0.093	0.093	mg/kg		Tissue
	Zinc	24.1	0.60	1.9	1.9	mg/kg		Tissue
	Mercury	0.013	0.0047	0.0097	0.0097	mg/kg		Tissue
BW15ML-010 REP 3	Percent Moisture	88.2	0.10	0.10	0.10	%		Tissue
	Arsenic	1.3	0.012	0.096	0.096	mg/kg		Tissue
	Cadmium	0.018	0.0061	0.096	0.096	mg/kg	J	Tissue
	Chromium	0.088	0.023	0.096	0.096	mg/kg	J	Tissue
	Copper	1.8	0.022	0.096	0.096	mg/kg		Tissue
	Lead	0.20	0.0024	0.096	0.096	mg/kg		Tissue
	Nickel	0.13	0.029	0.096	0.096	mg/kg		Tissue
	Zinc	23.1	0.62	1.9	1.9	mg/kg		Tissue
	Mercury	0.014	0.0046	0.0095	0.0095	mg/kg		Tissue
BW15ML-010 REP 4	Percent Moisture	87.8	0.10	0.10	0.10	%		Tissue
	Arsenic	1.3	0.011	0.087	0.087	mg/kg		Tissue
	Cadmium	0.016	0.0056	0.087	0.087	mg/kg	J	Tissue
	Chromium	0.064	0.021	0.087	0.087	mg/kg	J	Tissue
	Copper	1.7	0.020	0.087	0.087	mg/kg		Tissue
	Lead	0.17	0.0022	0.087	0.087	mg/kg		Tissue
	Nickel	0.090	0.026	0.087	0.087	mg/kg		Tissue
	Zinc	25.9	0.56	1.7	1.7	mg/kg		Tissue
	Mercury	0.014	0.0045	0.0093	0.0093	mg/kg		Tissue
BW15ML-010 REP 5	Percent Moisture	88.9	0.10	0.10	0.10	%		Tissue
	Arsenic	1.2	0.012	0.097	0.097	mg/kg		Tissue
	Cadmium	0.014	0.0062	0.097	0.097	mg/kg	J	Tissue
	Chromium	0.061	0.024	0.097	0.097	mg/kg	J	Tissue
	Copper	1.5	0.023	0.097	0.097	mg/kg		Tissue
	Lead	0.15	0.0024	0.097	0.097	mg/kg		Tissue
	Nickel	0.089	0.029	0.097	0.097	mg/kg	J	Tissue
	Zinc	21.6	0.63	1.9	1.9	mg/kg		Tissue
	Mercury	0.013	0.0048	0.010	0.010	mg/kg		Tissue
BW15ML-010 COMP	PCB-1016 (Aroclor 1016)	22.9	22.9	45.8	45.8	ug/kg	U	Tissue
	PCB-1221 (Aroclor 1221)	22.9	22.9	45.8	45.8	ug/kg	U	Tissue
	PCB-1232 (Aroclor 1232)	22.9	22.9	45.8	45.8	ug/kg	U	Tissue
	PCB-1242 (Aroclor 1242)	22.9	22.9	45.8	45.8	ug/kg	U	Tissue
	PCB-1248 (Aroclor 1248)	22.9	22.9	45.8	45.8	ug/kg	U	Tissue
	PCB-1254 (Aroclor 1254)	22.9	22.9	45.8	45.8	ug/kg	U	Tissue
	PCB-1260 (Aroclor 1260)	480	22.9	45.8	45.8	ug/kg		Tissue
	PCB-1262 (Aroclor 1262)	22.9	22.9	45.8	45.8	ug/kg	U	Tissue
	PCB-1268 (Aroclor 1268)	22.9	22.9	45.8	45.8	ug/kg	U	Tissue
	PCB, Total	480	22.9	45.8	45.8	ug/kg		Tissue
	Tetrachloro-m-xylene (S)	90				%		Tissue
	Decachlorobiphenyl (S)	90				%		Tissue
	Lipid	1.5				%		Tissue

Field ID	Parameter	Result	LOD	LOQ	EQL	Units	Code	Matrix
MLS-LV-1 PRE	Percent Moisture	84.2	0.10	0.10	0.10	%		Tissue
	Arsenic	0.16	0.012	0.10	0.10	mg/kg		Tissue
	Cadmium	0.040	0.0064	0.10	0.10	mg/kg	J	Tissue
	Chromium	0.063	0.024	0.10	0.10	mg/kg	J	Tissue
	Copper	2.5	0.023	0.10	0.10	mg/kg		Tissue
	Lead	0.25	0.0025	0.10	0.10	mg/kg		Tissue
	Nickel	0.17	0.030	0.10	0.10	mg/kg		Tissue
	Zinc	28.4	0.64	2.0	2.0	mg/kg		Tissue
	Mercury	0.0048	0.0048	0.010	0.010	mg/kg	U	Tissue
	PCB-1016 (Aroclor 1016)	16.4	16.4	32.8	32.8	ug/kg	U	Tissue
	PCB-1221 (Aroclor 1221)	16.4	16.4	32.8	32.8	ug/kg	U	Tissue
	PCB-1232 (Aroclor 1232)	16.4	16.4	32.8	32.8	ug/kg	U	Tissue
	PCB-1242 (Aroclor 1242)	16.4	16.4	32.8	32.8	ug/kg	U	Tissue
	PCB-1248 (Aroclor 1248)	16.4	16.4	32.8	32.8	ug/kg	U	Tissue
	PCB-1254 (Aroclor 1254)	16.4	16.4	32.8	32.8	ug/kg	U	Tissue
	PCB-1260 (Aroclor 1260)	16.4	16.4	32.8	32.8	ug/kg	U	Tissue
	PCB-1262 (Aroclor 1262)	16.4	16.4	32.8	32.8	ug/kg	U	Tissue
	PCB-1268 (Aroclor 1268)	16.4	16.4	32.8	32.8	ug/kg	U	Tissue
	PCB, Total	16.4	16.4	32.8	32.8	ug/kg	U	Tissue
	Tetrachloro-m-xylene (S)	85				%		Tissue
	Decachlorobiphenyl (S)	87				%		Tissue
	Lipid	2.1				%		Tissue

Compounds were marked with the code “J” when concentrations found were at or above the limit of detection (LOD) and below the limit of quantitation (LOQ). They are considered estimates. Compounds were marked with the code “U” when the compound was analyzed for, but not detected at or above the adjusted LOD.

Appendix Table 29: Pace Analytical Results from Sediment Analysis for Metals and PCBs

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Minneapolis, MN 55414
(612)607-1700

ANALYTICAL RESULTS

Project: J150329 SLR Sediment AOCs
Pace Project No.: 10334678

Sample: BW15ML-038-0-0.15' **Lab ID: 10334678001** Collected: 12/28/15 13:10 Received: 12/28/15 18:15 Matrix: Solid

Results reported on a "dry weight" basis and are adjusted for percent moisture, sample size and any dilutions.

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
8082A GCS PCB	Analytical Method: EPA 8082A Preparation Method: EPA 3550								
PCB-1016 (Aroclor 1016)	ND	ug/kg	85.9	15.0	1	12/29/15 10:29	01/07/16 21:13	12674-11-2	
PCB-1221 (Aroclor 1221)	ND	ug/kg	85.9	35.1	1	12/29/15 10:29	01/07/16 21:13	11104-28-2	
PCB-1232 (Aroclor 1232)	ND	ug/kg	85.9	15.6	1	12/29/15 10:29	01/07/16 21:13	11141-16-5	
PCB-1242 (Aroclor 1242)	ND	ug/kg	85.9	40.1	1	12/29/15 10:29	01/07/16 21:13	53469-21-9	
PCB-1248 (Aroclor 1248)	ND	ug/kg	85.9	25.9	1	12/29/15 10:29	01/07/16 21:13	12672-29-6	
PCB-1254 (Aroclor 1254)	ND	ug/kg	85.9	9.7	1	12/29/15 10:29	01/07/16 21:13	11097-69-1	
PCB-1260 (Aroclor 1260)	**2110**	ug/kg	85.9	10	1	12/29/15 10:29	01/07/16 21:13	11096-82-5	
PCB-1262 (Aroclor 1262)	ND	ug/kg	85.9	13.2	1	12/29/15 10:29	01/07/16 21:13	37324-23-5	
PCB-1268 (Aroclor 1268)	ND	ug/kg	85.9	9.1	1	12/29/15 10:29	01/07/16 21:13	11100-14-4	
Surrogates									
Tetrachloro-m-xylene (S)	80	%.	52-125		1	12/29/15 10:29	01/07/16 21:13	877-09-8	
Decachlorobiphenyl (S)	74	%.	47-125		1	12/29/15 10:29	01/07/16 21:13	2051-24-3	
6020A MET ICPMS	Analytical Method: EPA 6020A Preparation Method: EPA 3050								
Arsenic	**9.3**	mg/kg	1.0	0.25	20	12/29/15 09:27	12/29/15 21:49	7440-38-2	
Cadmium	**1.8**	mg/kg	0.17	0.056	20	12/29/15 09:27	12/29/15 21:49	7440-43-9	
Chromium	**44.3**	mg/kg	1.0	0.39	20	12/29/15 09:27	12/29/15 21:49	7440-47-3	
Copper	**74.2**	mg/kg	2.1	0.67	20	12/29/15 09:27	12/29/15 21:49	7440-50-8	
Lead	**110**	mg/kg	0.21	0.090	20	12/29/15 09:27	12/29/15 21:49	7439-92-1	
Nickel	**34.6**	mg/kg	1.0	0.31	20	12/29/15 09:27	12/29/15 21:49	7440-02-0	
Zinc	**425**	mg/kg	10.3	2.8	20	12/29/15 09:27	12/29/15 21:49	7440-66-6	
7471B Mercury	Analytical Method: EPA 7471B Preparation Method: EPA 7471B								
Mercury	**1.4**	mg/kg	0.047	0.016	1	12/29/15 09:11	01/03/16 16:18	7439-97-6	
	Analytical Method: ASTM D2974								
Percent Moisture	**61.6**	%	0.10	0.10	1		01/07/16 11:43		

REPORT OF LABORATORY ANALYSIS

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ANALYTICAL RESULTS

Project: J150329 SLR Sediment AOCs
Pace Project No.: 10334678

Sample: BW15ML-032-0-0.15' **Lab ID: 10334678002** Collected: 12/28/15 11:48 Received: 12/28/15 18:15 Matrix: Solid

Results reported on a "dry weight" basis and are adjusted for percent moisture, sample size and any dilutions.

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
8082A GCS PCB	Analytical Method: EPA 8082A Preparation Method: EPA 3550								
PCB-1016 (Aroclor 1016)	**ND**	ug/kg	78.4	13.7	1	12/29/15 10:29	01/07/16 21:29	12674-11-2	
PCB-1221 (Aroclor 1221)	**ND**	ug/kg	78.4	32.1	1	12/29/15 10:29	01/07/16 21:29	11104-28-2	
PCB-1232 (Aroclor 1232)	**ND**	ug/kg	78.4	14.2	1	12/29/15 10:29	01/07/16 21:29	11141-16-5	
PCB-1242 (Aroclor 1242)	**ND**	ug/kg	78.4	36.6	1	12/29/15 10:29	01/07/16 21:29	53469-21-9	
PCB-1248 (Aroclor 1248)	**ND**	ug/kg	78.4	23.6	1	12/29/15 10:29	01/07/16 21:29	12672-29-6	
PCB-1254 (Aroclor 1254)	**ND**	ug/kg	78.4	8.9	1	12/29/15 10:29	01/07/16 21:29	11097-69-1	
PCB-1260 (Aroclor 1260)	**397**	ug/kg	78.4	9.1	1	12/29/15 10:29	01/07/16 21:29	11096-82-5	
PCB-1262 (Aroclor 1262)	**ND**	ug/kg	78.4	12.0	1	12/29/15 10:29	01/07/16 21:29	37324-23-5	
PCB-1268 (Aroclor 1268)	**ND**	ug/kg	78.4	8.3	1	12/29/15 10:29	01/07/16 21:29	11100-14-4	
Surrogates									
Tetrachloro-m-xylene (S)	72	%.	52-125		1	12/29/15 10:29	01/07/16 21:29	877-09-8	
Decachlorobiphenyl (S)	68	%.	47-125		1	12/29/15 10:29	01/07/16 21:29	2051-24-3	
6020A MET ICPMS	Analytical Method: EPA 6020A Preparation Method: EPA 3050								
Arsenic	**8.5**	mg/kg	0.84	0.20	20	12/29/15 09:27	12/29/15 21:52	7440-38-2	
Cadmium	**1.5**	mg/kg	0.13	0.045	20	12/29/15 09:27	12/29/15 21:52	7440-43-9	
Chromium	**40.6**	mg/kg	0.84	0.32	20	12/29/15 09:27	12/29/15 21:52	7440-47-3	
Copper	**43.5**	mg/kg	1.7	0.54	20	12/29/15 09:27	12/29/15 21:52	7440-50-8	
Lead	**99.8**	mg/kg	0.17	0.073	20	12/29/15 09:27	12/29/15 21:52	7439-92-1	
Nickel	**32.3**	mg/kg	0.84	0.25	20	12/29/15 09:27	12/29/15 21:52	7440-02-0	
Zinc	**375**	mg/kg	8.4	2.2	20	12/29/15 09:27	12/29/15 21:52	7440-66-6	
7471B Mercury	Analytical Method: EPA 7471B Preparation Method: EPA 7471B								
Mercury	**0.41**	mg/kg	0.046	0.016	1	12/29/15 09:11	01/03/16 16:20	7439-97-6	
	Analytical Method: ASTM D2974								
Percent Moisture	**57.9**	%	0.10	0.10	1		01/07/16 11:43		

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ANALYTICAL RESULTS

Project: J150329 SLR Sediment AOCs
Pace Project No.: 10334678

Sample: BW15ML-034-0-0.15' **Lab ID: 10334678003** Collected: 12/28/15 09:35 Received: 12/28/15 18:15 Matrix: Solid

Results reported on a "dry weight" basis and are adjusted for percent moisture, sample size and any dilutions.

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
8082A GCS PCB	Analytical Method: EPA 8082A Preparation Method: EPA 3550								
PCB-1016 (Aroclor 1016)	ND	ug/kg	74.6	13.1	1	12/29/15 10:29	01/07/16 21:45	12674-11-2	
PCB-1221 (Aroclor 1221)	ND	ug/kg	74.6	30.5	1	12/29/15 10:29	01/07/16 21:45	11104-28-2	
PCB-1232 (Aroclor 1232)	ND	ug/kg	74.6	13.6	1	12/29/15 10:29	01/07/16 21:45	11141-16-5	
PCB-1242 (Aroclor 1242)	ND	ug/kg	74.6	34.8	1	12/29/15 10:29	01/07/16 21:45	53469-21-9	
PCB-1248 (Aroclor 1248)	ND	ug/kg	74.6	22.5	1	12/29/15 10:29	01/07/16 21:45	12672-29-6	
PCB-1254 (Aroclor 1254)	ND	ug/kg	74.6	8.5	1	12/29/15 10:29	01/07/16 21:45	11097-69-1	
PCB-1260 (Aroclor 1260)	**451**	ug/kg	74.6	8.7	1	12/29/15 10:29	01/07/16 21:45	11096-82-5	
PCB-1262 (Aroclor 1262)	ND	ug/kg	74.6	11.5	1	12/29/15 10:29	01/07/16 21:45	37324-23-5	
PCB-1268 (Aroclor 1268)	ND	ug/kg	74.6	7.9	1	12/29/15 10:29	01/07/16 21:45	11100-14-4	
Surrogates									
Tetrachloro-m-xylene (S)	81	%.	52-125		1	12/29/15 10:29	01/07/16 21:45	877-09-8	
Decachlorobiphenyl (S)	72	%.	47-125		1	12/29/15 10:29	01/07/16 21:45	2051-24-3	
6020A MET ICPMS	Analytical Method: EPA 6020A Preparation Method: EPA 3050								
Arsenic	**7.4**	mg/kg	0.79	0.19	20	12/29/15 09:27	12/29/15 21:55	7440-38-2	
Cadmium	**1.3**	mg/kg	0.13	0.043	20	12/29/15 09:27	12/29/15 21:55	7440-43-9	
Chromium	**38.5**	mg/kg	0.79	0.30	20	12/29/15 09:27	12/29/15 21:55	7440-47-3	
Copper	**42.3**	mg/kg	1.6	0.51	20	12/29/15 09:27	12/29/15 21:55	7440-50-8	
Lead	**81.4**	mg/kg	0.16	0.069	20	12/29/15 09:27	12/29/15 21:55	7439-92-1	
Nickel	**32.0**	mg/kg	0.79	0.24	20	12/29/15 09:27	12/29/15 21:55	7440-02-0	
Zinc	**307**	mg/kg	7.9	2.1	20	12/29/15 09:27	12/29/15 21:55	7440-66-6	
7471B Mercury	Analytical Method: EPA 7471B Preparation Method: EPA 7471B								
Mercury	**0.45**	mg/kg	0.039	0.013	1	12/29/15 09:11	01/03/16 16:22	7439-97-6	
	Analytical Method: ASTM D2974								
Percent Moisture	**55.7**	%	0.10	0.10	1		01/07/16 11:43		

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ANALYTICAL RESULTS

Project: J150329 SLR Sediment AOCs
Pace Project No.: 10334678

Sample: BW15ML-037-0-0.15' **Lab ID: 10334678004** Collected: 12/28/15 11:20 Received: 12/28/15 18:15 Matrix: Solid

Results reported on a "dry weight" basis and are adjusted for percent moisture, sample size and any dilutions.

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
8082A GCS PCB	Analytical Method: EPA 8082A Preparation Method: EPA 3550								
PCB-1016 (Aroclor 1016)	**ND**	ug/kg	103	18.1	1	12/29/15 10:29	01/07/16 22:01	12674-11-2	
PCB-1221 (Aroclor 1221)	**ND**	ug/kg	103	42.3	1	12/29/15 10:29	01/07/16 22:01	11104-28-2	
PCB-1232 (Aroclor 1232)	**ND**	ug/kg	103	18.8	1	12/29/15 10:29	01/07/16 22:01	11141-16-5	
PCB-1242 (Aroclor 1242)	**ND**	ug/kg	103	48.3	1	12/29/15 10:29	01/07/16 22:01	53469-21-9	
PCB-1248 (Aroclor 1248)	**ND**	ug/kg	103	31.1	1	12/29/15 10:29	01/07/16 22:01	12672-29-6	
PCB-1254 (Aroclor 1254)	**ND**	ug/kg	103	11.7	1	12/29/15 10:29	01/07/16 22:01	11097-69-1	
PCB-1260 (Aroclor 1260)	**333**	ug/kg	103	12.0	1	12/29/15 10:29	01/07/16 22:01	11096-82-5	
PCB-1262 (Aroclor 1262)	**ND**	ug/kg	103	15.9	1	12/29/15 10:29	01/07/16 22:01	37324-23-5	
PCB-1268 (Aroclor 1268)	**ND**	ug/kg	103	10.9	1	12/29/15 10:29	01/07/16 22:01	11100-14-4	
Surrogates									
Tetrachloro-m-xylene (S)	81	%.	52-125		1	12/29/15 10:29	01/07/16 22:01	877-09-8	
Decachlorobiphenyl (S)	82	%.	47-125		1	12/29/15 10:29	01/07/16 22:01	2051-24-3	
6020A MET ICPMS	Analytical Method: EPA 6020A Preparation Method: EPA 3050								
Arsenic	**7.2**	mg/kg	1.1	0.28	20	12/29/15 09:27	12/29/15 22:18	7440-38-2	
Cadmium	**0.91**	mg/kg	0.18	0.062	20	12/29/15 09:27	12/29/15 22:18	7440-43-9	
Chromium	**44.6**	mg/kg	1.1	0.43	20	12/29/15 09:27	12/29/15 22:18	7440-47-3	
Copper	**42.3**	mg/kg	2.3	0.74	20	12/29/15 09:27	12/29/15 22:18	7440-50-8	
Lead	**57.5**	mg/kg	0.23	0.099	20	12/29/15 09:27	12/29/15 22:18	7439-92-1	
Nickel	**37.3**	mg/kg	1.1	0.35	20	12/29/15 09:27	12/29/15 22:18	7440-02-0	
Zinc	**237**	mg/kg	11.4	3.1	20	12/29/15 09:27	12/29/15 22:18	7440-66-6	
7471B Mercury	Analytical Method: EPA 7471B Preparation Method: EPA 7471B								
Mercury	**0.20**	mg/kg	0.054	0.019	1	12/29/15 09:11	01/03/16 16:24	7439-97-6	
	Analytical Method: ASTM D2974								
Percent Moisture	**68.1**	%	0.10	0.10	1		01/07/16 11:44		

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ANALYTICAL RESULTS

Project: J150329 SLR Sediment AOCs
Pace Project No.: 10334678

Sample: BW15ML-004-0-0.15' **Lab ID: 10334678005** Collected: 12/28/15 14:40 Received: 12/28/15 18:15 Matrix: Solid

Results reported on a "dry weight" basis and are adjusted for percent moisture, sample size and any dilutions.

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
8082A GCS PCB	Analytical Method: EPA 8082A Preparation Method: EPA 3550								
PCB-1016 (Aroclor 1016)	ND	ug/kg	88.6	15.5	1	12/29/15 10:29	01/07/16 22:17	12674-11-2	
PCB-1221 (Aroclor 1221)	ND	ug/kg	88.6	36.3	1	12/29/15 10:29	01/07/16 22:17	11104-28-2	
PCB-1232 (Aroclor 1232)	ND	ug/kg	88.6	16.1	1	12/29/15 10:29	01/07/16 22:17	11141-16-5	
PCB-1242 (Aroclor 1242)	ND	ug/kg	88.6	41.4	1	12/29/15 10:29	01/07/16 22:17	53469-21-9	
PCB-1248 (Aroclor 1248)	ND	ug/kg	88.6	26.7	1	12/29/15 10:29	01/07/16 22:17	12672-29-6	
PCB-1254 (Aroclor 1254)	ND	ug/kg	88.6	10.0	1	12/29/15 10:29	01/07/16 22:17	11097-69-1	
PCB-1260 (Aroclor 1260)	**176**	ug/kg	88.6	10.3	1	12/29/15 10:29	01/07/16 22:17	11096-82-5	
PCB-1262 (Aroclor 1262)	ND	ug/kg	88.6	13.6	1	12/29/15 10:29	01/07/16 22:17	37324-23-5	
PCB-1268 (Aroclor 1268)	ND	ug/kg	88.6	9.4	1	12/29/15 10:29	01/07/16 22:17	11100-14-4	
Surrogates									
Tetrachloro-m-xylene (S)	76	%.	52-125		1	12/29/15 10:29	01/07/16 22:17	877-09-8	
Decachlorobiphenyl (S)	85	%.	47-125		1	12/29/15 10:29	01/07/16 22:17	2051-24-3	
6020A MET ICPMS	Analytical Method: EPA 6020A Preparation Method: EPA 3050								
Arsenic	**14.0**	mg/kg	1.3	0.31	20	12/29/15 09:27	12/29/15 22:20	7440-38-2	
Cadmium	**1.6**	mg/kg	0.20	0.068	20	12/29/15 09:27	12/29/15 22:20	7440-43-9	
Chromium	**39.6**	mg/kg	1.3	0.47	20	12/29/15 09:27	12/29/15 22:20	7440-47-3	
Copper	**46.4**	mg/kg	2.5	0.81	20	12/29/15 09:27	12/29/15 22:20	7440-50-8	
Lead	**162**	mg/kg	0.25	0.11	20	12/29/15 09:27	12/29/15 22:20	7439-92-1	
Nickel	**30.3**	mg/kg	1.3	0.38	20	12/29/15 09:27	12/29/15 22:20	7440-02-0	
Zinc	**522**	mg/kg	12.5	3.4	20	12/29/15 09:27	12/29/15 22:20	7440-66-6	
7471B Mercury	Analytical Method: EPA 7471B Preparation Method: EPA 7471B								
Mercury	**0.36**	mg/kg	0.046	0.016	1	12/29/15 09:11	01/03/16 16:27	7439-97-6	
	Analytical Method: ASTM D2974								
Percent Moisture	**62.8**	%	0.10	0.10	1		01/07/16 11:44		

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ANALYTICAL RESULTS

Project: J150329 SLR Sediment AOCs
Pace Project No.: 10334678

Sample: BW15ML-018-0-0.15' **Lab ID: 10334678006** Collected: 12/28/15 10:14 Received: 12/28/15 18:15 Matrix: Solid

Results reported on a "dry weight" basis and are adjusted for percent moisture, sample size and any dilutions.

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
8082A GCS PCB	Analytical Method: EPA 8082A Preparation Method: EPA 3550								
PCB-1016 (Aroclor 1016)	ND	ug/kg	89.0	15.6	1	12/29/15 10:29	01/07/16 22:33	12674-11-2	
PCB-1221 (Aroclor 1221)	ND	ug/kg	89.0	36.4	1	12/29/15 10:29	01/07/16 22:33	11104-28-2	
PCB-1232 (Aroclor 1232)	ND	ug/kg	89.0	16.2	1	12/29/15 10:29	01/07/16 22:33	11141-16-5	
PCB-1242 (Aroclor 1242)	ND	ug/kg	89.0	41.5	1	12/29/15 10:29	01/07/16 22:33	53469-21-9	
PCB-1248 (Aroclor 1248)	ND	ug/kg	89.0	26.8	1	12/29/15 10:29	01/07/16 22:33	12672-29-6	
PCB-1254 (Aroclor 1254)	ND	ug/kg	89.0	10.1	1	12/29/15 10:29	01/07/16 22:33	11097-69-1	
PCB-1260 (Aroclor 1260)	**289**	ug/kg	89.0	10.4	1	12/29/15 10:29	01/07/16 22:33	11096-82-5	
PCB-1262 (Aroclor 1262)	ND	ug/kg	89.0	13.7	1	12/29/15 10:29	01/07/16 22:33	37324-23-5	
PCB-1268 (Aroclor 1268)	ND	ug/kg	89.0	9.4	1	12/29/15 10:29	01/07/16 22:33	11100-14-4	
Surrogates									
Tetrachloro-m-xylene (S)	74	%.	52-125		1	12/29/15 10:29	01/07/16 22:33	877-09-8	
Decachlorobiphenyl (S)	72	%.	47-125		1	12/29/15 10:29	01/07/16 22:33	2051-24-3	
6020A MET ICPMS	Analytical Method: EPA 6020A Preparation Method: EPA 3050								
Arsenic	**8.2**	mg/kg	1.1	0.27	20	12/29/15 09:27	12/29/15 22:23	7440-38-2	
Cadmium	**1.1**	mg/kg	0.18	0.060	20	12/29/15 09:27	12/29/15 22:23	7440-43-9	
Chromium	**33.9**	mg/kg	1.1	0.41	20	12/29/15 09:27	12/29/15 22:23	7440-47-3	
Copper	**42.6**	mg/kg	2.2	0.71	20	12/29/15 09:27	12/29/15 22:23	7440-50-8	
Lead	**81.0**	mg/kg	0.22	0.095	20	12/29/15 09:27	12/29/15 22:23	7439-92-1	
Nickel	**28.6**	mg/kg	1.1	0.33	20	12/29/15 09:27	12/29/15 22:23	7440-02-0	
Zinc	**285**	mg/kg	11.0	2.9	20	12/29/15 09:27	12/29/15 22:23	7440-66-6	
7471B Mercury	Analytical Method: EPA 7471B Preparation Method: EPA 7471B								
Mercury	**0.34**	mg/kg	0.049	0.017	1	12/29/15 09:11	01/03/16 16:29	7439-97-6	
	Analytical Method: ASTM D2974								
Percent Moisture	**62.9**	%	0.10	0.10	1		01/07/16 11:44		

REPORT OF LABORATORY ANALYSIS

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ANALYTICAL RESULTS

Project: J150329 SLR Sediment AOCs
Pace Project No.: 10334678

Sample: BW15ML-010-0-0.15' **Lab ID: 10334678007** Collected: 12/28/15 14:08 Received: 12/28/15 18:15 Matrix: Solid

Results reported on a "dry weight" basis and are adjusted for percent moisture, sample size and any dilutions.

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
8082A GCS PCB	Analytical Method: EPA 8082A Preparation Method: EPA 3550								
PCB-1016 (Aroclor 1016)	ND	ug/kg	106	18.6	1	12/29/15 10:29	01/07/16 23:20	12674-11-2	
PCB-1221 (Aroclor 1221)	ND	ug/kg	106	43.5	1	12/29/15 10:29	01/07/16 23:20	11104-28-2	
PCB-1232 (Aroclor 1232)	ND	ug/kg	106	19.3	1	12/29/15 10:29	01/07/16 23:20	11141-16-5	
PCB-1242 (Aroclor 1242)	ND	ug/kg	106	49.6	1	12/29/15 10:29	01/07/16 23:20	53469-21-9	
PCB-1248 (Aroclor 1248)	ND	ug/kg	106	32.0	1	12/29/15 10:29	01/07/16 23:20	12672-29-6	
PCB-1254 (Aroclor 1254)	ND	ug/kg	106	12.0	1	12/29/15 10:29	01/07/16 23:20	11097-69-1	
PCB-1260 (Aroclor 1260)	**307**	ug/kg	106	12.4	1	12/29/15 10:29	01/07/16 23:20	11096-82-5	
PCB-1262 (Aroclor 1262)	ND	ug/kg	106	16.3	1	12/29/15 10:29	01/07/16 23:20	37324-23-5	
PCB-1268 (Aroclor 1268)	ND	ug/kg	106	11.2	1	12/29/15 10:29	01/07/16 23:20	11100-14-4	
Surrogates									
Tetrachloro-m-xylene (S)	81	%.	52-125		1	12/29/15 10:29	01/07/16 23:20	877-09-8	
Decachlorobiphenyl (S)	74	%.	47-125		1	12/29/15 10:29	01/07/16 23:20	2051-24-3	
6020A MET ICPMS	Analytical Method: EPA 6020A Preparation Method: EPA 3050								
Arsenic	**7.1**	mg/kg	1.2	0.30	20	12/29/15 09:27	12/29/15 21:57	7440-38-2	
Cadmium	**0.96**	mg/kg	0.19	0.066	20	12/29/15 09:27	12/29/15 21:57	7440-43-9	
Chromium	**46.1**	mg/kg	1.2	0.46	20	12/29/15 09:27	12/29/15 21:57	7440-47-3	M6
Copper	**53.9**	mg/kg	2.4	0.78	20	12/29/15 09:27	12/29/15 21:57	7440-50-8	
Lead	**58.1**	mg/kg	0.24	0.11	20	12/29/15 09:27	12/29/15 21:57	7439-92-1	
Nickel	**44.1**	mg/kg	1.2	0.37	20	12/29/15 09:27	12/29/15 21:57	7440-02-0	
Zinc	**234**	mg/kg	12.1	3.2	20	12/29/15 09:27	12/29/15 21:57	7440-66-6	M6
7471B Mercury	Analytical Method: EPA 7471B Preparation Method: EPA 7471B								
Mercury	**0.20**	mg/kg	0.064	0.022	1	12/29/15 09:11	01/03/16 16:39	7439-97-6	
	Analytical Method: ASTM D2974								
Percent Moisture	**69.0**	%	0.10	0.10	1		01/07/16 11:44		

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ANALYTICAL RESULTS

Project: J150329 SLR Sediment AOCs

Pace Project No.: 10334678

Sample: BW15ML-022-0-0.15' **Lab ID: 10334678008** Collected: 12/28/15 10:45 Received: 12/28/15 18:15 Matrix: Solid

Results reported on a "dry weight" basis and are adjusted for percent moisture, sample size and any dilutions.

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
8082A GCS PCB	Analytical Method: EPA 8082A Preparation Method: EPA 3550								
PCB-1016 (Aroclor 1016)	ND	ug/kg	50.6	8.9	1	12/29/15 10:29	01/07/16 23:36	12674-11-2	
PCB-1221 (Aroclor 1221)	ND	ug/kg	50.6	20.7	1	12/29/15 10:29	01/07/16 23:36	11104-28-2	
PCB-1232 (Aroclor 1232)	ND	ug/kg	50.6	9.2	1	12/29/15 10:29	01/07/16 23:36	11141-16-5	
PCB-1242 (Aroclor 1242)	ND	ug/kg	50.6	23.6	1	12/29/15 10:29	01/07/16 23:36	53469-21-9	
PCB-1248 (Aroclor 1248)	ND	ug/kg	50.6	15.2	1	12/29/15 10:29	01/07/16 23:36	12672-29-6	
PCB-1254 (Aroclor 1254)	ND	ug/kg	50.6	5.7	1	12/29/15 10:29	01/07/16 23:36	11097-69-1	
PCB-1260 (Aroclor 1260)	**86.9**	ug/kg	50.6	5.9	1	12/29/15 10:29	01/07/16 23:36	11096-82-5	
PCB-1262 (Aroclor 1262)	ND	ug/kg	50.6	7.8	1	12/29/15 10:29	01/07/16 23:36	37324-23-5	
PCB-1268 (Aroclor 1268)	ND	ug/kg	50.6	5.3	1	12/29/15 10:29	01/07/16 23:36	11100-14-4	
Surrogates									
Tetrachloro-m-xylene (S)	75	%.	52-125		1	12/29/15 10:29	01/07/16 23:36	877-09-8	
Decachlorobiphenyl (S)	75	%.	47-125		1	12/29/15 10:29	01/07/16 23:36	2051-24-3	
6020A MET ICPMS	Analytical Method: EPA 6020A Preparation Method: EPA 3050								
Arsenic	**2.7**	mg/kg	0.63	0.15	20	12/29/15 09:27	12/29/15 22:25	7440-38-2	
Cadmium	**0.21**	mg/kg	0.10	0.034	20	12/29/15 09:27	12/29/15 22:25	7440-43-9	
Chromium	**30.3**	mg/kg	0.63	0.24	20	12/29/15 09:27	12/29/15 22:25	7440-47-3	
Copper	**29.1**	mg/kg	1.3	0.41	20	12/29/15 09:27	12/29/15 22:25	7440-50-8	
Lead	**12.2**	mg/kg	0.13	0.055	20	12/29/15 09:27	12/29/15 22:25	7439-92-1	
Nickel	**64.3**	mg/kg	0.63	0.19	20	12/29/15 09:27	12/29/15 22:25	7440-02-0	
Zinc	**70.5**	mg/kg	6.3	1.7	20	12/29/15 09:27	12/29/15 22:25	7440-66-6	
7471B Mercury	Analytical Method: EPA 7471B Preparation Method: EPA 7471B								
Mercury	**0.029**	mg/kg	0.028	0.0097	1	12/29/15 09:11	01/03/16 16:45	7439-97-6	
	Analytical Method: ASTM D2974								
Percent Moisture	**34.7**	%	0.10	0.10	1		01/07/16 11:45		

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ANALYTICAL RESULTS

Project: J150329 SLR Sediment AOCs
Pace Project No.: 10334678

Sample: BW15ML-006-0-0.15' **Lab ID: 10334678009** Collected: 12/28/15 13:35 Received: 12/28/15 18:15 Matrix: Solid

Results reported on a "dry weight" basis and are adjusted for percent moisture, sample size and any dilutions.

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
8082A GCS PCB	Analytical Method: EPA 8082A Preparation Method: EPA 3550								
PCB-1016 (Aroclor 1016)	ND	ug/kg	105	18.3	1	12/29/15 10:29	01/07/16 23:52	12674-11-2	
PCB-1221 (Aroclor 1221)	ND	ug/kg	105	42.8	1	12/29/15 10:29	01/07/16 23:52	11104-28-2	
PCB-1232 (Aroclor 1232)	ND	ug/kg	105	19.0	1	12/29/15 10:29	01/07/16 23:52	11141-16-5	
PCB-1242 (Aroclor 1242)	ND	ug/kg	105	48.9	1	12/29/15 10:29	01/07/16 23:52	53469-21-9	
PCB-1248 (Aroclor 1248)	ND	ug/kg	105	31.5	1	12/29/15 10:29	01/07/16 23:52	12672-29-6	
PCB-1254 (Aroclor 1254)	ND	ug/kg	105	11.9	1	12/29/15 10:29	01/07/16 23:52	11097-69-1	
PCB-1260 (Aroclor 1260)	**764**	ug/kg	105	12.2	1	12/29/15 10:29	01/07/16 23:52	11096-82-5	
PCB-1262 (Aroclor 1262)	ND	ug/kg	105	16.1	1	12/29/15 10:29	01/07/16 23:52	37324-23-5	
PCB-1268 (Aroclor 1268)	ND	ug/kg	105	11.1	1	12/29/15 10:29	01/07/16 23:52	11100-14-4	
Surrogates									
Tetrachloro-m-xylene (S)	81	%.	52-125		1	12/29/15 10:29	01/07/16 23:52	877-09-8	
Decachlorobiphenyl (S)	70	%.	47-125		1	12/29/15 10:29	01/07/16 23:52	2051-24-3	
6020A MET ICPMS	Analytical Method: EPA 6020A Preparation Method: EPA 3050								
Arsenic	**6.9**	mg/kg	1.1	0.27	20	12/29/15 09:27	12/29/15 22:30	7440-38-2	
Cadmium	**1.1**	mg/kg	0.18	0.061	20	12/29/15 09:27	12/29/15 22:30	7440-43-9	
Chromium	**42.7**	mg/kg	1.1	0.43	20	12/29/15 09:27	12/29/15 22:30	7440-47-3	M6
Copper	**61.0**	mg/kg	2.3	0.73	20	12/29/15 09:27	12/29/15 22:30	7440-50-8	M6
Lead	**73.8**	mg/kg	0.23	0.098	20	12/29/15 09:27	12/29/15 22:30	7439-92-1	M6
Nickel	**43.0**	mg/kg	1.1	0.34	20	12/29/15 09:27	12/29/15 22:30	7440-02-0	
Zinc	**261**	mg/kg	11.3	3.0	20	12/29/15 09:27	12/29/15 22:30	7440-66-6	M6
7471B Mercury	Analytical Method: EPA 7471B Preparation Method: EPA 7471B								
Mercury	**0.22**	mg/kg	0.059	0.021	1	12/29/15 09:11	01/03/16 16:47	7439-97-6	
	Analytical Method: ASTM D2974								
Percent Moisture	**68.5**	%	0.10	0.10	1		01/07/16 11:45		

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(612)607-1700

ANALYTICAL RESULTS

Project: J150329 SLR Sediment AOCs
Pace Project No.: 10334678

Sample: BW15ML-110-0-0.15' **Lab ID: 10334678010** Collected: 12/28/15 14:08 Received: 12/28/15 18:15 Matrix: Solid

Results reported on a "dry weight" basis and are adjusted for percent moisture, sample size and any dilutions.

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
8082A GCS PCB	Analytical Method: EPA 8082A Preparation Method: EPA 3550								
PCB-1016 (Aroclor 1016)	ND	ug/kg	108	18.9	1	12/29/15 10:29	01/08/16 00:08	12674-11-2	
PCB-1221 (Aroclor 1221)	ND	ug/kg	108	44.2	1	12/29/15 10:29	01/08/16 00:08	11104-28-2	
PCB-1232 (Aroclor 1232)	ND	ug/kg	108	19.6	1	12/29/15 10:29	01/08/16 00:08	11141-16-5	
PCB-1242 (Aroclor 1242)	ND	ug/kg	108	50.4	1	12/29/15 10:29	01/08/16 00:08	53469-21-9	
PCB-1248 (Aroclor 1248)	ND	ug/kg	108	32.5	1	12/29/15 10:29	01/08/16 00:08	12672-29-6	
PCB-1254 (Aroclor 1254)	ND	ug/kg	108	12.2	1	12/29/15 10:29	01/08/16 00:08	11097-69-1	
PCB-1260 (Aroclor 1260)	**285**	ug/kg	108	12.6	1	12/29/15 10:29	01/08/16 00:08	11096-82-5	
PCB-1262 (Aroclor 1262)	ND	ug/kg	108	16.6	1	12/29/15 10:29	01/08/16 00:08	37324-23-5	
PCB-1268 (Aroclor 1268)	ND	ug/kg	108	11.4	1	12/29/15 10:29	01/08/16 00:08	11100-14-4	
Surrogates									
Tetrachloro-m-xylene (S)	75	%.	52-125		1	12/29/15 10:29	01/08/16 00:08	877-09-8	
Decachlorobiphenyl (S)	73	%.	47-125		1	12/29/15 10:29	01/08/16 00:08	2051-24-3	
6020A MET ICPMS	Analytical Method: EPA 6020A Preparation Method: EPA 3050								
Arsenic	**7.0**	mg/kg	1.2	0.28	20	12/29/15 09:27	12/29/15 22:28	7440-38-2	
Cadmium	**0.91**	mg/kg	0.19	0.063	20	12/29/15 09:27	12/29/15 22:28	7440-43-9	
Chromium	**46.5**	mg/kg	1.2	0.44	20	12/29/15 09:27	12/29/15 22:28	7440-47-3	
Copper	**53.0**	mg/kg	2.3	0.75	20	12/29/15 09:27	12/29/15 22:28	7440-50-8	
Lead	**58.7**	mg/kg	0.23	0.10	20	12/29/15 09:27	12/29/15 22:28	7439-92-1	
Nickel	**43.8**	mg/kg	1.2	0.35	20	12/29/15 09:27	12/29/15 22:28	7440-02-0	
Zinc	**230**	mg/kg	11.6	3.1	20	12/29/15 09:27	12/29/15 22:28	7440-66-6	
7471B Mercury	Analytical Method: EPA 7471B Preparation Method: EPA 7471B								
Mercury	**0.21**	mg/kg	0.063	0.022	1	12/29/15 09:11	01/03/16 16:53	7439-97-6	
	Analytical Method: ASTM D2974								
Percent Moisture	**69.4**	%	0.10	0.10	1		01/07/16 11:45		

Appendix 2

Statistical Analysis Data

Appendix Table 30: *H. azteca* Survival Statistics

One Way Analysis of Variance Monday, April 18, 2016, 3:29:33 PM

Data source: Data 1 in HA_Surviv.SNB

Normality Test: Failed ($P < 0.050$)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Monday, April 18, 2016, 3:29:33 PM

Data source: Data 1 in HA_Surviv.SNB

Group	N	Missing	Median	25%	75%
HB	8	0	9.500	9.000	10.000
HC	8	0	9.000	8.000	10.000
HD	8	0	9.000	8.500	10.000
HE	8	0	10.000	10.000	10.000
HF	8	0	9.000	9.000	10.000
HG	8	0	9.000	8.500	9.000
HH	8	0	8.000	7.500	8.500
HI	8	0	9.500	8.500	10.000
HJ	8	0	10.000	9.500	10.000
HK	8	0	8.000	7.000	9.000

H = 21.998 with 9 degrees of freedom. ($P = 0.009$)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference ($P = 0.009$)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

Multiple Comparisons versus Control Group (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05
HH vs HB	22.875	1.969	No
HK vs HB	21.438	1.845	Do Not Test
HE vs HB	15.813	1.361	Do Not Test
HG vs HB	10.875	0.936	Do Not Test
HJ vs HB	10.313	0.888	Do Not Test
HC vs HB	5.250	0.452	Do Not Test
HD vs HB	4.250	0.366	Do Not Test
HF vs HB	3.313	0.285	Do Not Test
HI vs HB	1.250	0.108	Do Not Test

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Appendix Table 31: *H. azteca* Dry Weight Statistics

One Way Analysis of Variance Monday, April 18, 2016, 3:43:20 PM

Data source: Data 1 in HA_weights.SNB

Normality Test: Passed (P = 0.415)

Equal Variance Test: Passed (P = 0.899)

Group Name	N	Missing	Mean	Std Dev	SEM
HB	8	0	0.0663	0.0125	0.00443
HC	8	0	0.0501	0.00730	0.00258
HD	8	0	0.0474	0.0172	0.00610
HE	8	0	0.0792	0.0125	0.00443
HF	8	0	0.0465	0.0106	0.00376
HG	8	0	0.0355	0.0146	0.00515
HH	8	0	0.0473	0.0108	0.00381
HI	8	0	0.0723	0.0105	0.00373
HJ	8	0	0.0631	0.00609	0.00215
HK	8	0	0.0554	0.0114	0.00402

Source of Variation	DF	SS	MS	F	P
Between Groups	9	0.0132	0.00147	10.644	<0.001
Residual	70	0.00968	0.000138		
Total	79	0.0229			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Power of performed test with alpha = 0.050: 1.000

Multiple Comparisons versus Control Group (Bonferroni t-test):

Comparisons for factor:

Comparison	Diff of Means	t	P	P<0.050
HB vs. HG	0.0308	5.246	<0.001	Yes
HB vs. HF	0.0199	3.377	0.011	Yes
HB vs. HH	0.0190	3.234	0.017	Yes
HB vs. HD	0.0190	3.226	0.017	Yes
HB vs. HC	0.0162	2.752	0.068	No
HB vs. HE	0.0129	2.186	0.289	Do Not Test
HB vs. HK	0.0109	1.862	0.602	Do Not Test
HB vs. HI	0.00597	1.014	1.000	Do Not Test
HB vs. HJ	0.00320	0.544	1.000	Do Not Test

A result of "Do Not Test" occurs for a comparison when no significant difference is found between two means that enclose that comparison. For example, if you had four means sorted in order, and found no difference between means 4 vs. 2, then you would not test 4 vs. 3 and 3 vs. 2, but still test 4 vs. 1 and 3 vs. 1 (4 vs. 3 and 3 vs. 2 are enclosed by 4 vs. 2: 4 3 2 1). Note that not testing the enclosed means is a procedural rule, and a result of Do Not Test should be treated as if there is no significant difference between the means, even though one may appear to exist.

Appendix Table 32: *C. dilutus* Survival Statistics

One Way Analysis of Variance Tuesday, April 19, 2016, 8:30:09 AM

Data source: Data 1 in Chiro_Surv_19Aor2016.SNB

Normality Test: Failed $(P < 0.050)$

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Tuesday, April 19, 2016, 8:30:09 AM

Data source: Data 1 in Chiro_Surv_19Aor2016.SNB

Group	N	Missing	Median	25%	75%
CB	8	0	10.000	10.000	10.000
CC	8	0	9.000	8.000	10.000
CD	8	0	10.000	9.500	10.000
CE	8	0	9.500	9.000	10.000
CF	8	0	9.500	9.000	10.000
CG	8	0	7.500	7.000	9.000
CH	8	0	9.500	8.500	10.000
CI	8	0	10.000	9.000	10.000
CJ	8	0	10.000	10.000	10.000
CK	8	0	10.000	9.000	10.000

$H = 27.258$ with 9 degrees of freedom. $(P = 0.001)$

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference $(P = 0.001)$

To isolate the group or groups that differ from the others use a multiple comparison procedure.

Multiple Comparisons versus Control Group (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05
CG vs CB	44.500	3.830	Yes
CC vs CB	22.750	1.958	No
CH vs CB	20.563	1.770	Do Not Test
CF vs CB	18.188	1.565	Do Not Test
CE vs CB	16.500	1.420	Do Not Test
CK vs CB	15.188	1.307	Do Not Test
CI vs CB	14.063	1.210	Do Not Test
CD vs CB	8.250	0.710	Do Not Test
CJ vs CB	0.000	0.000	Do Not Test

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Appendix Table 33: *C. dilutus* Ash Free Dry Weight Statistics

One Way Analysis of Variance Tuesday, April 19, 2016, 8:37:21 AM

Data source: Data 1 in Chiro_weights_19Apr2016.SNB

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Tuesday, April 19, 2016, 8:37:21 AM

Data source: Data 1 in Chiro_weights_19Apr2016.SNB

Group	N	Missing	Median	25%	75%
CB	8	0	0.660	0.605	0.712
CC	8	0	0.700	0.652	0.765
CD	8	0	0.686	0.671	0.708
CE	8	0	0.848	0.786	0.888
CF	8	0	0.649	0.633	0.712
CG	8	0	0.685	0.603	0.768
CH	8	0	0.646	0.583	0.707
CI	8	0	0.793	0.761	0.862
CJ	8	0	0.736	0.705	0.780
CK	8	0	0.619	0.612	0.648

H = 32.354 with 9 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

Multiple Comparisons versus Control Group (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05
CE vs CB	40.750	3.507	Yes
CI vs CB	34.000	2.926	Yes
CJ vs CB	18.625	1.603	No
CC vs CB	11.500	0.990	Do Not Test
CD vs CB	9.750	0.839	Do Not Test
CG vs CB	6.500	0.559	Do Not Test
CK vs CB	5.875	0.506	Do Not Test
CH vs CB	2.875	0.247	Do Not Test
CF vs CB	1.375	0.118	Do Not Test

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Appendix B

Technical Analysis

Appendix B – Technical Analysis
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Two remedial alternatives involving construction activities, one alternative involving monitoring only, and one alternative involving a no action approach were developed and evaluated as part of the Munger Landing Focused Feasibility Study (FFS) and include the following:

Alternative 1 – No Action

Alternative 2 – Monitored Natural Recovery

Alternative 3 – Enhanced Monitored Natural Recovery with Broadcasted Amendment

Alternative 4 – Enhanced Monitored Natural Recovery with Thin-Layer Amended Cover

Class 4 rough order of magnitude cost analyses (+50/-30) were developed for each of these alternatives and are summarized within **Section 3** of the FFS document. This Technical Analysis serves to provide the calculations and outline the assumptions used to compile each of the alternative cost analyses.

Cost estimates were compiled using a variety of sources. These sources include construction cost data from RSMeans estimating software for open shop pricing in Duluth, Minnesota; current Bay West LLC (Bay West) and state contract rates for labor, equipment, and sample analysis; personal communication with vendors; historic cost data from projects similar in size and scope; other FFS documents, presentations, or technical papers that provided estimated or real construction cost data; and available online vendor pricing of materials.

The selection of construction equipment, production rates, remedial volumes, remedial action areas, and other "design-type" elements used as a starting point to develop alternative costs are based on a current understanding of Site conditions at this early feasibility study-level stage.

This document is divided into the following sections:

Section 1: Remedial Areas and Volumes
Section 2: Construction Implementation Assumptions and Production Rates
Section 3: Material Staging Area
Section 4: Environmental Controls and Construction Monitoring
Section 5: Cover/Cap Materials and Volumes

The following tables were used to calculate values incorporated into each alternative cost analysis and are included within this Technical Analysis:

Appendix B Table 1: Volume, Rate, and Time Frame Calculations
Appendix B Table 2: Unit Rate Calculations
Appendix B Table 3: Lump Sum Costs
Appendix B Table 4: Monitoring and Evaluation Costs
Appendix B Table 5: Present Value Calculations

Many of the assumptions used to compile the cost analyses for the alternatives are included within the tables. Those aspects of alternative development not readily apparent within the tables and the Munger Landing FFS text are described in the following sections.

Section 1: Remedial Areas and Volumes

Areas targeted for remedial action (remedial areas) include those with lead, nickel, and/or zinc concentrations in sediments exceeding the Midpoint Sediment Quality Target (SQT), also referred to as the preliminary cleanup level (CUL). These compounds are considered primary contaminants of concern (COCs) for the Site. Cadmium, copper, mercury, PAHs, PCBs, and dioxins/furans are also prevalent at the Site and are considered a secondary COCs. Secondary COC exceedances generally occur within the footprint of lead, nickel, and/or zinc exceedances; therefore, remedial actions taken at the Site would address both primary and secondary COCs. Remedial areas are presented in **Figure 5** of the FFS document. Remedial areas were developed based on sample results obtained during the 2015 Remedial Investigation (RI), bathymetric data, and professional judgement. Remedial areas total approximately 59 acres in size. It is anticipated that these areas would be further defined during the design phase.

Data collected during the 2015 RI indicates that sediment contamination in exceedance of the CULs exists within the upper 0.5 meter to 1.0 meter of sediment across the remedial areas. However, there is some evidence that contamination may extend to depths greater than 1.0 meter below the sediment surface (bss) within some areas of the Site:

1) A single sample was collected from depths greater than 1.0 meter bss and contained sediments in exceedance of the CULs.
2) Core shortening observed during the 2015 RI resulted in an average sediment recovery of 50 percent (%); therefore, sediments may have originated from deeper in situ sediment depths than represented by their location/interval within core samples.

The volume of contaminated sediment at the Site was estimated for two scenarios. The first assumes that contamination extends to an average depth of 0.5 meter bss across the entire 59-acre remedial area. This scenario resulted in an estimated 156,000 cubic yards of sediment. The second scenario assumes that contamination extends to an average depth of 1.0 meter bss and resulted in an estimated 312,000 cubic yards of contaminated sediment.

Removal of contaminated sediments was not evaluated as part of the FFS because dredging of sediments could result in destruction of well-established and beneficial ecological communities. The extent of contamination at the Site may be investigated further if sediment removal is evaluated as a remedy in the future.

Section 2: Construction Implementation Assumptions and Production Rates

Unit rate costs were developed for amendment placement and cover construction activities by summing labor and equipment costs and dividing by an assumed production rate; therefore, the production rate has a substantial impact on the unit rate cost of these activities and the overall project cost. The following sections detail the construction methods developed for remedy implementation and their associated production rates. It is important to note that these methods were developed solely to assist in developing cost estimates for each alternative, and final construction methods would be determined during the design and/or construction bidding phase.

Amendment Placement

A general order of operations was assumed in order to facilitate costing of Alternative 3, which incorporates broadcasting of an amendment material over remedial areas of the Site. This order of operations was used to assist in selecting construction equipment, labor, production rates, time frames, etc.

The general order of placement is described as follows:

- Amendment materials would be purchased from a supplier, shipped to the staging area at Hallett Dock #7, and stockpiled.
- Amendment materials would be loaded into a large material transport barge moored at the staging area at Hallett Dock #7 during non-placement (e.g., late evening or early morning) hours. The loaded barge would travel upriver to the Site in time for commencement of daily work activities. The transport barge would spud down or moor to dolphin pilings driven into the river.
- An excavator with clamshell bucket would be staged on the material transport barge. The excavator would be used to load two small 12-cubic yard placement barges with amendment material on a periodic basis.

- Two 12-cubic yard placement barges, each equipped with a sand slinger or equivalent broadcasting device, would be used to broadcast amendment material over the remedial areas. A push boat attached to each hopper barge would be used to transport the hopper barges from the loading area (transport barge with onboard excavator) to the active placement areas.
- Once the material transport barge was emptied, cover construction would cease for the day. The material transport barge would return to the staging area at Hallett Dock #7 where it would again be loaded during overnight hours.
- These activities would be conducted until amendment placement is complete.

The production rate for broadcasting of amendment material was estimated at 168 cubic yards per day. This estimate assumes that each 12 cubic yard placement barge would require 72 minutes to empty (6 minutes per cubic yard), and that two placement barges would operate for approximately 11 hours each day. Ten minutes of travel time to and from the loading area and a 5-minute load time for each cycle were also incorporated into the production rate.

Thin-Layer Amended Sand Cover Construction

A general order of operations was assumed in order to facilitate costing of Alternative 4, which incorporates construction of a thin-layer amended sand cover over remedial areas of the Site. This order of operations was used to assist in selecting construction equipment, labor, production rates, time frames, etc.

The general order of cover construction is described as follows:

- Clean washed sand meeting project specifications would be purchased from a local upland borrow source and imported to the staging area located at Hallett Dock #7. Amendment materials would be purchased from a supplier, shipped to the staging area, and stockpiled. Mixing of amendment materials would be conducted mechanically using an end loader, excavator, or similar equipment.
- Cover materials would be loaded into a large material transport barge moored at the staging area at Hallett Dock #7 during non-construction (e.g., late evening or early morning) hours. The loaded barge would travel upriver to the Site in time for commencement of daily work activities. The transport barge would spud down or moor to dolphin pilings driven into the river.
- An excavator with clamshell bucket would be staged on the material transport barge. The excavator would be used to load two small 25-cubic yard hopper barges with cover material on a periodic basis.
- A single work boat or small tug would be used to manage the two hopper barges. The work boat would transfer the hopper barges between the material loading area and a cover placement barge on a regular basis. A full hopper barge would be delivered to the placement barge by the time the second hopper barge had been emptied. The emptied hopper barge would then be returned to the loading area and filled again with cover material.
- Once the material transport barge was emptied, cover construction would cease for the day. The material transport barge would return to the staging area at Hallett Dock #7 where it would again be loaded during overnight hours.
- These activities would be conducted until cover construction is complete.

The production rate for thin-layer sand cover construction was estimated using a bucket size of 2 cubic yards, a 70% fill rate, and 2 minutes per cycle. The bucket size was selected at 2 cubic yards to allow for ease of placement within the small 25-cubic yard hopper barges. A placement time frame of 11 hours per day equates to a total daily production for a single excavator of 462 cubic yards.

Placement of amendment/cover materials via the methods detailed above assumes that sufficient draft is available across the Site to float the smaller hopper and amendment/cover placement barges. Areas with insufficient draft may require placement via other methods. Based on available bathymetry, it is assumed that sufficient water depth is available for amendment/cover placement via the method outlined above.

Section 3: Material Staging Area

The Munger Landing Site may not be suitable for use as an upland material staging area due to widespread public use of the boat launch facilities, multiple train tracks routed along the shoreline, and presence of nearby residences. It was, therefore, assumed that materials would be barged to the Site from an off-site location along the SLR. Hallett Dock #7 has been identified as a potential staging area through conversations between Bay West, the Minnesota Pollution Control Agency (MPCA), and Duluth Seaway Port Authority. Satellite imagery indicates the presence of a large paved area at the end of Hallett Dock #7, which is appropriately sized for stockpiling materials. The dock end is nearly 500 feet in length and was assumed to be useable for barge mooring and material onloading/offloading in its current condition. Staging area upgrades would likely include installation of site fencing to protect construction equipment and prevent unauthorized personnel from entering the staging area while the remedy is being implemented.

Section 4: Environmental Controls and Construction Monitoring

Environmental controls and construction monitoring are important elements in mitigating environmental impacts occurring as a direct result from construction activities and also in ensuring remedial/construction goals are achieved. Environmental controls can include surface water control structures (e.g., silt curtains, sheet piling, and absorbent boom), lined sediment dewatering pads, tire washes, stormwater controls, and site fencing (for protection of human health). Construction monitoring can include turbidity monitoring during dredging activities, air monitoring during intrusive site activities, treated dredge contact water sampling, post-dredge verification sampling, cap thickness verification coring, bathymetric surveys, imported materials sampling, dewatered sediment sampling, and collection of pre- and post-construction upland soil samples within the staging area footprint. Alternatives involving amendment application or thin-layer cover construction as a remedy would likely require less controls and monitoring than alternatives incorporating dredging.

For the purposes of this FFS, it was assumed that alternatives consisting of amendment placement or cover construction would incorporate the following control and monitoring elements:

- Fencing at the Hallett Dock #7 staging area;
- Chemical and physical sampling of imported cover materials to ensure that they are suitable for use; and
- Cover thickness verification coring to ensure that project specifications are achieved.

Section 5: Amendment/Cover Materials and Volumes

Purchasing and shipping of amendment materials can have a large impact on total project cost. For the purposes of this FFS, it was assumed that a 5 cm (2-inch) layer of amendment material would be broadcasted across the entire remedial area. This thickness was selected for inclusion in the cost analysis to provide a conservative cost scenario and to account for the following factors that could result in a loss of material during or following placement:

1) If broadcasted, amendment materials would be placed within a river channel without further armoring or mixing with a bulking material such as sand; therefore, the amendment material would be susceptible to scour or other erosive forces until bioturbation mixed amendment materials into in situ sediments.

2) Amendment materials often have low densities and can be difficult to place in high energy environments; therefore, placement within a river channel could result in migration of amendment material downstream during placement or difficulty in placing material to the designed thickness.

3) Realistic placement tolerances during broadcasting of amendment material is unknown. Placement of additional amendment material may be required to ensure that the designed thickness is achieved.
4) Sequestration of metals and dioxins may require multiple amendments. Only a single amendment was accounted for in the cost analysis at $135 per ton (assumed cost for apatite). The use of two or more amendments could result in additional material required for placement.

Potential sources of cover materials include materials from an upland borrow location (e.g., sand and gravel pit), sediments previously dredged for navigational purposes, and common earth upland soil. Natural materials such as dredged sediments and common earth upland soils often contain fine-grained components that make placement more difficult (Interstate Technology and Regulatory Council [ITRC], 2014). It was assumed for the purposes of the cost analyses that upland borrow materials would be used as no apparent source of dredged materials is readily available near the Site. Upland borrow material consisting of clean, washed sand was assumed for alternatives incorporating construction of a sand cover. The exact grain size specifications would be developed during the design phase but would likely consist of medium to coarse grain sands that would withstand mild erosive forces.

Appendix B: Table 1
Volume, Rate, and Time Frame Calculations
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Remedial Areas		
Total Remedial Area		
Total wetland areas for remediation (acres)	44.1	
Total open water areas for remediation (acres)	15.0	
Total remedial area (acres)	59.1	
Contaminated Sediment		
Volume of Contaminated Sediment in Wetland Areas		
Wetland areas (acres)	44.1	
Estimated depth of contamination (feet)	1.64	0.5 (meter)
Volume of contamination (cubic yards)	116577	
Volume of Contaminated Sediment in Open Water Areas		
Open water area (acres)	15.0	
Estimated depth of contamination (feet)	1.64	0.5 (meter)
Volume of contamination (cubic yards)	39794	
Total Volume of Contaminated Sediment		
Wetland areas (cubic yards)	116577	
Open water areas (cubic yards)	39794	
Total volume of contaminated sediment (cubic yards)	156371	
Amendment/Cover Volumes		
Alternative 3: EMNR with Broadcasted Amendment (Apatite or Similar for Sequestration of Metals)		
Wetland areas (acres)	44.1	
Amendment thickness (inches)	2	0.05 (meter)
Amendment required (cubic yards)	11847	
Open water areas (acres)	15.0	
Amendment thickness (inches)	2	0.05 (meter)
Amendment required (cubic yards)	4044	
Total volume of amendment required for Alternative 2 (cubic yards)	15891	
Alternative 3: EMNR with Broadcasted Amendment (Activated Carbon for Dioxins/PCBS - Incoporated into Text but not Costs)		
Amendment ratio (percent carbon by weight in upper 0.15 meter)	5	
Remedial area (acres)	59.1	
Volume of sediment in upper 0.15 meter (cubic yards)	46923	
Assumed density of in-situ sediment (tons per cubic yard)	1.4	
Assumed weight of sediment in upper 0.15 meter (tons)	65693	
Amount of activated carbon to be added (tons)	3285	
Assumed density of activated carbon (tons per cubic yard)	1.72	127.5 lbs/ft3
Volume of activated carbon to be added (cubic yards)	1908	
Amount of activated carbon to be placed (cubic yards per square yard)	0.006671	
Thickness of amendment (centimeter)	0.610022	
Conservative factor	1	
Assumed amount of activated carbon to be purchased (tons)	3285	
Alternative 4: EMNR with Thin-Layer Amended Cover		
Wetland areas (acres)	44.1	
Cover thickness (inches)	6	0.15 (meter)
Sand content by volume (percent)	50	
Sand required (cubic yards)	17771	
Amendment content by volume (percent)	50	
Amendment required (cubic yards)	17771	
Total materials required (cubic yards)	35542	
Open water areas (acres)	15.0	
Cover thickness (inches)	6	0.15 (meter)
Sand content by volume (percent)	50	
Sand required (cubic yards)	6066	
Amendment content by volume (percent)	50	
Amendment required (cubic yards)	6066	
Total materials required (cubic yards)	12132	
Total volume of sand required for Alternative 4 (cubic yards)	23837	
Total volume of amendment required for Alternative 4 (cubic yards)	23837	
Total volume of materials required for Alternative 4 (cubic yards)	47674	

Appendix B: Table 1
Volume, Rate, and Time Frame Calculations
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Production Rates		
Stone Slinger Barge Production Rate (Alternative 3)		
Cycle Time		
Hopper capacity (cubic yards)	12	
Application time per cubic yard placed (minutes)	6	
Application time per load (minutes)	72	1.2 hours
Load time (minutes)	5	0.083 hours
Add in time for travel (minutes)	10	0.17 hours
Total cycle time (hours)	1.45	
Production Rate		
Active placement time per day (hours)	11	
Number of cycles per day per barge	7	
Number of barges	2	
Total volume of amendment applied per day (cubic yards)	168	
Thin-Layer Cover Placement Production Rate (Alternative 4)		
Bucket size (cubic yards)	2	
Percent fill	70	
Material per bucket (cubic yards)	1.4	
Minutes per cycle	2	
Active placement duration per day (hours)	11	
Daily production (cubic yards)	462	

Construction Timeframe		
Alternative 3: Enhanced MNR with Broadcasted Amendment		
Construct staging area and mobilize/setup equipment (days)	5	
Place amendment (days)	95	
Breakdown equipment/demobilize and site restoration (days)	5	
Total time on-site (days)	105	21 weeks
Alternative 4: Enhanced MNR with Thin-Layer Amended Cover		
Construct staging area and mobilize/setup equipment (days)	5	
Place amendment (days)	104	
Breakdown equipment/demobilize and site restoration (days)	5	
Total time on-site (days)	114	23 weeks

Appendix B: Table 2
Unit Rate Calculations
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Surface Broadcast Amendment (Alternative 3)					
Description	Unit	Unit Cost	Quantity	Extended	Comments
Equipment					
End loader	Day	580.00	1	$580.00	Manage imported materials at Hallett Dock #7
Staging area Derrick crane with clamshell bucket	Day	536.00	1	$536.00	Load transport hopper barges
Material transport barge	Day	684.00	1	$684.00	400 ton barge for material transport; on-barge excavator for loading smaller transport barges on-site
Material transport barge tug	Day	551.00	1	$551.00	Transport material barge between staging area and Site
Material transport barge excavator with clamshell bucket	Day	1335.00	1	$1,335.00	Onboard excavator to load stone slinger hopper barges
Hopper barge with stone slinger	Day	637.00	2	$1,274.00	12 cubic yard capacity hopper; stone slinger to broadcast amendment
Push boats	Day	373.00	2	$746.00	Move stone slinger hopper barges for placement and loading
Pickup trucks	Day	97.00	3	$291.00	Site supervisor, foreman, mechanic
			SUBTOTAL	$5,997.00	
Labor					
On-site project management	Day	1200.00	1	$1,200.00	
Foreman	Day	854.00	1	$854.00	
Mechanic	Day	980.00	1	$980.00	
Operator at staging area	Day	1106.00	1	$1,106.00	Manage and load incoming materials
Laborer at staging area	Day	812.00	1	$812.00	Manage and load incoming materials
Material transport barge operator	Day	1106.00	1	$1,106.00	Transport materials between staging area and Site; load hopper barges
Stone slinger operators	Day	1036.00	2	$2,072.00	
Push boat operators	Day	1036.00	2	$2,072.00	
Lodging and Per-Diem	Day	146.00	10	$1,460.00	
			SUBTOTAL	$11,662.00	
			TOTAL	$17,659.00	
			DAILY PRODUCTION (CY)	168.00	
			UNIT RATE (CY)	$105.11	

Place Materials via Barge-Mounted Excavator (Alternative 4)					
Description	Unit	Unit Cost	Quantity	Extended	Comments
Equipment					
End loader	Day	$580.00	1	$580.00	Manage imported materials at Hallett Dock #7
Staging area Derrick crane with clamshell bucket	Day	$536.00	1	$536.00	Load transport hopper barges
Material transport barge	Day	$827.00	1	$827.00	800 ton barge for material transport; on-barge excavator for loading smaller transport barges on-site
Material transport barge tug	Day	$551.00	1	$551.00	Transport material barge between staging area and Site
Onboard skid steer	Day	$366.00	1	$366.00	Manage materials onboard dredge
Material transport barge excavator with clamshell bucket	Day	$1,335.00	1	$1,335.00	Onboard excavator to load hopper barges
Transport hopper barges	Day	$129.00	2	$258.00	25 cubic yard capacity hopper barges
Transport tug/boat	Day	$373.00	1	$373.00	Small tug/work boat to transport hopper barges
Excavator barge	Day	$355.00	1	$355.00	With spuds and winches
Barge-mounted excavator with clamshell bucket	Day	$1,335.00	1	$1,335.00	Place amendment
RTK DGPS for dredge	Day	$190.00	1	$190.00	
Survey boat with multibeam survey equipment	Day	$1,500.00	1	$1,500.00	
Pickup trucks	Day	$97.00	3	$291.00	Site supervisor, foreman, mechanic
			SUBTOTAL	$8,497.00	
Labor					
On-site project management	Day	$1,200.00	1	$1,200.00	
Foreman	Day	$854.00	1	$854.00	
Mechanic	Day	$980.00	1	$980.00	
Operator at staging area	Day	$1,106.00	1	$1,106.00	Manage and load incoming materials
Laborer at staging area	Day	$812.00	1	$812.00	Manage and load incoming materials
Material transport barge operator	Day	$1,106.00	1	$1,106.00	Transport materials between staging area and Site; load hopper barges
Placement excavator operator	Day	$1,106.00	1	$1,106.00	Place cover material
Tug/workboat operator	Day	$1,036.00	1	$1,036.00	Transport hopper barges between material barge and placement area
Skid steer operator/bargehand	Day	$1,036.00	1	$1,036.00	
Lodging and Per-Diem	Day	$146.00	9	$1,314.00	
			SUBTOTAL	$10,550.00	
			TOTAL	$19,047.00	
			DAILY PRODUCTION (CY)	462	
			UNIT RATE (CY)	$41.23	

Purchase and Import Amendment					
Purchase amendment material	Ton	$135.00	1	$135.00	Estimated Cost for Apatite
Import amendment material to staging area	Ton	$63.00	1	$63.00	20 tons per trailer; $2.52/mile; 500 miles shipping
			UNIT RATE (TON)	$198.00	
			UNIT RATE (CY)	$141.00	Assume 1.4 tons per CY

Purchase and Import Sand					
Purchase sand from upland borrow source	CY	$6.90	1	$6.90	
Import sand to staging area	CY	$13.90	1	$13.90	40 mile cycle; 15 minute wait
			UNIT RATE (CY)	$20.80	

Construction Quality Assurance and Oversight					
Description	Unit	Unit Cost	Quantity	Extended	Comments
QA/QC and federal oversight personnel	Week	$10,200.00	1	$10,200	Two staff
Lodging and per-diem	Week	$1,460.00	1	$1,460	Two staff
Truck and mileage	Week	$1,142.00	1	$1,142	Includes mileage
			UNIT RATE (WEEK)	$13,000	

Monthly Operating Expenses and Site Security					
Description	Unit	Unit Cost	Quantity	Extended	Comments
Field Offices					
Office trailers and storage boxes (3)	Month	$942.00	1	$3,888.00	Includes utilities, equipment, and supplies for three units
Security Guard	Month	$17,280.00	1	$17,280.00	$40 per hour; 108 hours per week
			UNIT RATE (MONTH)	$21,000	Rounded

Appendix B: Table 3
Lump Sum Costs
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Lump Sum Costs - Alternative 1: No Action

No lump sum costs associated with Alternative 1.

Lump Sum Costs - Alternative 2: Monitored Natural Recovery

No lump sum costs associated with Alternative 2.

Lump Sum Costs - Alternative 3: Enhanced MNR with Broadcasted Amendment

Description	Unit	Unit Cost	Quantity	Extended	Comments
Mobilization/Demobilization					
Office trailers (3) and connex boxes to staging area	Mile	$12.26	240	$2,942.40	To staging area; within 20 miles of site
End loader	Each	$5,592.00	1	$5,592.00	To staging area
Staging area Derrick crane with clamshell bucket	Each	$5,592.00	1	$5,592.00	To staging area
Material transport barge	Hour	$1,634.00	8	$13,072.00	To staging area; sourced from Duluth Harbor
Material transport barge tug	Hour	$1,634.00	0	$0.00	To staging area; sourced from Duluth Harbor
Material transport barge excavator with clamshell bucket	Each	$1,914.00	1	$1,914.00	To staging area
Hopper barge with stone slinger	Each	$1,914.00	2	$3,828.00	To staging area
Push boats (2)	Each	$1,914.00	1	$1,914.00	To staging area; 1 load
Pickup trucks (3)	Mile	$0.56	1500	$840.00	To staging area; 250 miles each way
Additional mileage for non-local equipment	Mile	$2.52	1500	$3,780.00	Assume 3 loads non-local; 250 miles away
Install staging area fencing	LF	$5.39	1500	$8,085.00	Install fencing around staging area perimeter
Assemble and launch equipment; setup staging area	Day	$17,659.00	4	$70,636.00	
Remove and load equipment; disassemble staging area	Day	$17,659.00	4	$70,636.00	
				$189,000.00	Rounded
Install and Remove Dolphin Pilings					
Equipment and Labor					
Work barge	Day	$855.00	1	$855.00	Monthly rate times 1.25
Tug	Day	$2,985.30	1	$2,985.30	Monthly rate times 1.25
Crane	Day	$2,150.10	1	$2,150.10	Monthly rate times 1.25
Hammer	Day	$143.48	1	$143.48	Monthly rate times 1.25
Tug captain/crane operator	Day	$1,106.00	1	$1,106.00	12-hour workday with overtime
Laborers	Day	$812.00	2	$1,624.00	12-hour workday with overtime
			TOTAL DAILY COST	$8,863.88	
Installation Work Activities					
Prep/"de-prep" equipment	Day	$8,863.88	1	$8,863.88	
Travel to/from Duluth; launch/pull equipment	Day	$8,863.88	3	$26,591.63	
Travel to/from Site; drive pilings	Day	$8,863.88	1	$8,863.88	
Removal Work Activities	Lump Sum	$44,319.38	1	$44,319.38	Same costs as installation
Materials	Lump Sum	$6,000.00	1	$6,000.00	
			TOTAL PROJECT COST	$95,000.00	Rounded

Lump Sum Costs - Alternative 3: Enhanced MNR with Thin-Layer Amended Cover

Description	Unit	Unit Cost	Quantity	Extended	Comments
Mobilization/Demobilization					
Office trailers (3) and connex boxes to staging area	Mile	$12.26	240	$2,942.40	To staging area; within 20 miles of site
End loader	Each	$5,592.00	1	$5,592.00	To staging area
Staging area Derrick crane with clamshell bucket	Each	$5,592.00	1	$5,592.00	To staging area
Material transport barge	Hour	$1,634.00	8	$13,072.00	To staging area; sourced from Duluth Harbor
Material transport barge tug	Hour	$1,634.00	0	$0.00	To staging area; sourced from Duluth Harbor
Excavators	Each	$1,914.00	3	$5,742.00	To staging area
Transport hopper barges	Each	$1,914.00	2	$3,828.00	To staging area
Transport tug/boat; survey boat	Each	$1,914.00	1	$1,914.00	To staging area
Onboard skid steer	Each	$1,578.00	1	$1,578.00	To staging area
Pickup trucks (3)	Mile	$0.56	1500	$840.00	To staging area; 250 miles each way
Additional mileage for non-local equipment	Mile	$2.52	1500	$3,780.00	Assume 3 loads non-local; 250 miles away
Install staging area fencing	LF	$5.39	1500	$8,085.00	Install fencing around staging area perimeter
Assemble and launch equipment; setup staging area	Day	$19,047.00	4	$76,188.00	
Remove and load equipment; disassemble staging area	Day	$19,047.00	4	$76,188.00	
				$205,000.00	Rounded
Install Dolphin Pilings	Lump Sum	$95,000.00	1	$95,000	Same cost as shown for Alternative 2

Appendix B: Table 4
Monitoring Elements
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Monitoring and Evaluation Costs - Alternative 1: No Action

No monitoring and evaluation costs associated with Alternative 1.

Monitoring and Evaluation Costs - Alternative 2: MNR

Monitoring Elements	Unit	Cost	Extended	Total	Comment
Monitoring and Evaluation Report	Each	$4,000.00	6	$24,000	Every 5 years for 30 years
Field Sampling	Event	$34,000.00	6	$204,000	Every 5 years for 30 years
Sample Analysis	Event	$35,920.00	6	$215,520	Every 5 years for 30 years
Lead, Nickel, and Zinc (EPA 6020A)	*Sample*	*$48.00*	*25*	*$1,200.00*	*11 locations; 2 intervals; QA/QC samples*
Grain Size (ASTM D422 w/ Hydrometer)	*Sample*	*$375.00*	*5*	*$1,875.00*	*Needed for tox/bio; 5 locations*
TOC Quad Burn (EPA 9060A)	*Sample*	*$105.00*	*5*	*$525.00*	*Needed for tox/bio; 5 locations*
10-d toxicity C. tentans	*Sample*	*$1,638.00*	*5*	*$8,190.00*	*5 locations*
28-d toxicity H. azteca	*Sample*	*$2,013.00*	*5*	*$10,065.00*	*5 locations*
28-d bioaccumulation	*Sample*	*$2,013.00*	*5*	*$10,065.00*	*5 locations*
Lead, Nickel, and Zinc (Benthic Tissue)	*Sample*	*$100.00*	*25*	*$2,500.00*	*Individual replicate analysis*
Lipids content (Pace SOP)	*Sample*	*$100.00*	*10*	*$1,000.00*	*One composite per sample; benthics and fish*
Lead, Nickel, and Zinc (Benthic Tissue)	*Sample*	*$100.00*	*5*	*$500.00*	*Five composite samples from five species*
				$35,920.00	
				$444,000	Rounded

Monitoring and Evaluation Costs - Alternative 3: Enhanced MNR with Broadcasted Amendment

Monitoring Elements	Unit	Cost	Extended	Total	Comment
Monitoring and Evaluation Report	Each	$4,000.00	6	$24,000	Every 5 years for 30 years
Field Sampling	Event	$34,000.00	6	$204,000	Every 5 years for 30 years
Sample Analysis	Event	$35,920.00	6	$215,520	Every 5 years for 30 years
Lead, Nickel, and Zinc (EPA 6020A)	*Sample*	*$48.00*	*25*	*$1,200.00*	*11 locations; 2 intervals; QA/QC samples*
Grain Size (ASTM D422 w/ Hydrometer)	*Sample*	*$375.00*	*5*	*$1,875.00*	*Needed for tox/bio; 5 locations*
TOC Quad Burn (EPA 9060A)	*Sample*	*$105.00*	*5*	*$525.00*	*Needed for tox/bio; 5 locations*
10-d toxicity C. tentans	*Sample*	*$1,638.00*	*5*	*$8,190.00*	*5 locations*
28-d toxicity H. azteca	*Sample*	*$2,013.00*	*5*	*$10,065.00*	*5 locations*
28-d bioaccumulation	*Sample*	*$2,013.00*	*5*	*$10,065.00*	*5 locations*
Lead, Nickel, and Zinc (Benthic Tissue)	*Sample*	*$100.00*	*25*	*$2,500.00*	*Individual replicate analysis*
Lipids content (Pace SOP)	*Sample*	*$100.00*	*10*	*$1,000.00*	*One composite per sample; benthics and fish*
Lead, Nickel, and Zinc (Benthic Tissue)	*Sample*	*$100.00*	*5*	*$500.00*	*Five composite samples from five species*
				$35,920.00	

Monitoring and Evaluation Costs - Alternative 4: Enhanced MNR with Thin-Layer Amended Cover

Monitoring Elements	Unit	Cost	Extended	Total	Comment
Monitoring and Evaluation Report	Each	$4,000.00	6	$24,000	Every 5 years for 30 years
Field Sampling	Event	$34,000.00	6	$204,000	Every 5 years for 30 years
Sample Analysis	Event	$35,920.00	6	$215,520	Every 5 years for 30 years
Lead, Nickel, and Zinc (EPA 6020A)	*Sample*	*$48.00*	*25*	*$1,200.00*	*11 locations; 2 intervals; QA/QC samples*
Grain Size (ASTM D422 w/ Hydrometer)	*Sample*	*$375.00*	*5*	*$1,875.00*	*Needed for tox/bio; 5 locations*
TOC Quad Burn (EPA 9060A)	*Sample*	*$105.00*	*5*	*$525.00*	*Needed for tox/bio; 5 locations*
10-d toxicity C. tentans	*Sample*	*$1,638.00*	*5*	*$8,190.00*	*5 locations*
28-d toxicity H. azteca	*Sample*	*$2,013.00*	*5*	*$10,065.00*	*5 locations*
28-d bioaccumulation	*Sample*	*$2,013.00*	*5*	*$10,065.00*	*5 locations*
Lead, Nickel, and Zinc (Benthic Tissue)	*Sample*	*$100.00*	*25*	*$2,500.00*	*Individual replicate analysis*
Lipids content (Pace SOP)	*Sample*	*$100.00*	*10*	*$1,000.00*	*One composite per sample; benthics and fish*
Lead, Nickel, and Zinc (Benthic Tissue)	*Sample*	*$100.00*	*5*	*$500.00*	*Five composite samples from five species*
				$35,920.00	
				$444,000	Rounded

Field Sampling Event

Description	Unit	Cost	Extended	Total	Comment
Project Management	Hour	$115.00	30	$3,450.00	Project coordination
Scientist II	Hour	$84.00	10	$840.00	Field event planning and coordination
QA/QC	Hour	$94.00	20	$1,880.00	Chemical, tox/bio, tissue results
Field Sampling					
Field Labor	Person	$4,452.00	4	$17,808.00	5 hours meetings; 40 sampling; 8 mob/demob
Truck	Day	$75.00	10	$750.00	2 trucks; boat and office trailer
Mileage	Mile	$0.57	750	$423.75	
Pontoon	Day	$200.00	5	$1,000.00	
Vibracore rental	Lump Sum	$2,500.00	1	$2,500.00	Includes freight
Disposables	Lump Sum	$1,500.00	1	$1,500.00	Vibracore tubing
Office trailer	Day	$75.00	5	$375.00	
GPS	Day	$75.00	5	$375.00	
Generator	Day	$45.00	5	$225.00	
Drum	Each	$105.00	2	$210.00	
Sediment bundle	Day	$65.00	5	$325.00	
Fuel	Lump Sum	$50.00	1	$50.00	
IDW Disposal	Lump Sum	$250.00	1	$250.00	
Lodging	Night	$100.00	16	$1,600.00	
Per-Diem	Day	$35.00	20	$700.00	
			TOTAL	$34,000.00	Rounded

Appendix B: Table 4
Monitoring Elements
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Bathymetric Survey Break-Down					
Parameter	Unit	Cost	Extended	Total Cost	
Daily labor cost					
Scientist III	Hour	$109	16	$1,744	Prep equipment; mob/demob; perform survey
Field Tech II	Hour	$64	16	$1,024	Prep equipment; mob/demob; perform survey
Lodging	Night	$100	2	$200	1 night each
Per-diem	Day	$36	4	$144	2 days each
Daily equipment cost					
Boat	Day	$200	2	$400	
Fuel	Day	$25	1	$25	
Multi-beam survey equipment	Day	$1,500	2	$3,000	
GPS	Day	$75	2	$150	
Truck	Day	$75	2	$150	
Mileage	Mile	$0.56	350	$196	
Data reduction/mapping	Hour	$109	20	$2,180	
GIS	Hour	$64	10	$640	
			TOTAL	$10,000	Rounded

Appendix B: Table 5
Present Value Calculations
Focused Feasibility Study
Munger Landing
Minnesota Pollution Control Agency

Discount rate used for present worth calculations:	7.00%
Present worth calculation is: [(2016 Cost)/(1.07^Event Year 1)]+[(2016 Cost)/(1.07^Event Year 2)]+…	
Year 0 is 2016.	

Alternative 1: No Action	2016 Costs	Years						Total Present Worth	Note
No Costs Associated with this Alternative									

Alternative 2: MNR	2016 Costs	Years						Total Present Worth	Note
Construction Costs									
No construction costs associated with this alternative									
Long-Term Monitoring									
Implementation Plan Report	$11,000	0						$11,000	
Monitoring and Evaluation Report	$4,000	5	10	15	20	25	30	$8,631	
Field Sampling	$34,000	5	10	15	20	25	30	$73,366	
Sample Analysis	$35,920	5	10	15	20	25	30	$77,509	
Bathymetric Survey	$10,000	5	10	15	20	25	30	$21,578	
Institutional Control Review	$1,500	5	10	15	20	25	30	$3,237	
Professional and Technical Services									
No professional and technical services associated with this alternative									

Alternative 3: Enhanced MNR with Broadcasted Amendment	2016 Costs	Years						Total Present Worth	Note
Construction Costs									
Mobilization/Demobilization	$189,000	1						$176,636	
Rent Hallett Dock #7 for Staging Area	$60,000	1						$56,075	
Install and Remove Dolphin Pilings	$95,000	1						$88,785	
Purchase Amendment Materials and Stockpile at Staging Area	$2,240,631	1						$2,094,048	
Broadcast Amendment	$1,670,352	1						$1,561,077	
Construction Monitoring/CQA and Oversight	$273,000	1						$255,140	
Monthly Operating Expenses and Site Security	$126,000	1						$117,757	
Implement Institutional Controls	$10,000	1						$9,346	
Long-Term Monitoring									
Monitoring and Evaluation Report	$4,000	5	10	15	20	25	30	$8,631	
Field Sampling	$34,000	5	10	15	20	25	30	$73,366	
Sample Analysis	$35,920	5	10	15	20	25	30	$77,509	
Professional and Technical Services									
Remedial Design (6%)	$383,000	0						$383,000	
Project Management and Permitting (5%)	$319,000	1						$298,131	
Construction Management (6%)	$383,000	1						$357,944	

Alternative 4: Enhanced MNR with Thin-Layer Amended Cover	2016 Costs	Years						Total Present Worth	Note
Construction Costs									
Mobilization/Demobilization	$205,000	1						$191,589	
Rent Hallett Dock #7 for Staging Area	$60,000	1						$56,075	
Install and Remove Dolphin Pilings	$95,000	1						$88,785	
Purchase Amendment Materials and Stockpile at Staging Area	$3,361,017	1						$3,141,137	
Purchase Sand and Stockpile at Staging Area	$495,810	1						$463,373	
Construct Thin-Layer Cover	$1,965,469	1						$1,836,887	
Construction Monitoring/CQA and Oversight	$299,000	1						$279,439	
Monthly Operating Expenses and Site Security	$126,000	1						$117,757	
Implement Institutional Controls	$10,000	1						$9,346	
Long-Term Monitoring									
Monitoring and Evaluation Report	$4,000	5	10	15	20	25	30	$8,631	
Field Sampling	$34,000	5	10	15	20	25	30	$73,366	
Sample Analysis	$35,920	5	10	15	20	25	30	$77,509	
Professional and Technical Services									
Remedial Design (6%)	$ 530,000	0						$530,000	
Project Management and Permitting (5%)	$ 441,000	1						$412,150	
Construction Management (6%)	$ 530,000	1						$495,327	