Minnesota Pollution Control Agency

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July 31, 2015

Mr. John J. Prusiecki, Jr.
Environmental Remediation
United States Steel Corporation
Gary Works
One N. Broadway, MS HB2
Gary, IN 46402-3199

Mr. Mark Rupnow
Environmental Remediation
United States Steel Corporation
1350 Penn Avenue, Suite 200
Pittsburgh, PA 15222-4211

RE: Minnesota Pollution Control Agency Review and Approval with Conditions of the July 16, 2015, Revised Feasibility Study for the Former Duluth Works and Spirit Lake Sediment Site, Duluth, Minnesota

Dear Mr. Prusiecki and Mr. Rupnow:

Thank you for the submittal of the July 16, 2015, Revised Feasibility Study (FS) for the Former Duluth Works and Spirit Lake Sediment Site in Duluth, Minnesota. The FS was prepared and submitted by Barr Engineering Company and AECOM on behalf of United States Steel Corporation (USS) and the Environmental Protection Agency's Great Lakes National Program Office (GLNPO). The FS was prepared to evaluate the feasibility of remedial alternatives to address the risks to human health and the environment from sediment contamination on the former Duluth Works site and in the adjacent Spirit Lake. Also included are several impacted soil units adjacent to sediment units. The work conducted for the Spirit Lake portion of the site has been conducted on behalf of USS and GLNPO under a Great Lakes Legacy Act (GLLA) project agreement. The work conducted for the former Duluth Works upland portion of the site has been conducted by USS in accordance with Section V of the March 26, 1985, Response Order by Consent (Consent Order) issued by the Minnesota Pollution Control Agency (MPCA).

The revised FS addresses comments and incorporates requested modifications on the previous version of the FS submitted in November 2014. In a letter dated February 9, 2015, MPCA requested revisions to the FS which included comments from the MPCA and from resource managers. In March 2015, USS was also directed by GLNPO and MPCA to develop an additional alternative (alternative 12), in order to address input received during GLNPO's formal tribal consultation in accordance with Section 106 requirements. Figures in the revised FS also reflect changes based on collection of additional data that was gathered to address data gaps.

MPCA staff has completed their review of the revised FS and hereby approves the FS with the conditions identified in the enclosed Attachment 1 to this letter. After the MPCA receives and reviews comments on the revised FS from the resource managers, the MPCA will issue a Proposed Plan representing the Agency's preferred remedial action for the site.

If you have any questions regarding this letter, please contact the site Project Leader, Erin Endsley, at 218-302-6619, or Mike Bares, the site Technical Analyst, at 651-757-2210.

Sincerely,

Sandeep R. Burman, PG, Manager
Site Remediation & Redevelopment Section
Remediation Division

SRB/EE:slm

Enclosure

cc: Scott Cieniawski, EPA-GLNPO
Mike Bryant, EPA-GLNPO
Leah Evison, EPA
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John Lindgren, DNR
Dave Warburton, USFWS
Heidi Timm-Bijold, City of Duluth
Nancy Schuldt, Fond du Lac
Dan Breneman, MPCA
Mike Bares, MPCA

Attachment 1

Minnesota Pollution Control Agency conditions attached to the approval of the July 16, 2015 Revised Feasibility Study for the Former Duluth Works and Spirit Lake Sediment Site, Duluth, Minnesota

1. The FS identifies a preferred remedy (Alternative 8). MPCA's approval of the FS does not include approval of the preferred alternative identified in the report as the selected remedy for the site. MPCA remedy selection will be identified in the proposed plan for the site.
2. The outline of sediment exceeding the preliminary remediation goals (PRGs) is adequate for the FS. The PRG outline is subject to revisions as additional investigation is done during the remedial design phase in order to address data gaps and better delineate the extent of contamination. The PRG outline is depicted on figures 2-9, 2-10, 3-1, 5-1 through 5-2, and E-9 (Appendix E).
3. The applicable or relevant and appropriate requirements (ARARs) identified in Appendix H will be updated and finalized prior to remedy implementation. This will include the addition of the National Historic Preservation Act (NHPA), 16 U.S. C. 470 et. seq. as a potential location-specific ARAR.
4. MPCA does not necessarily agree with the flux meter study methodology and the resulting conclusion that there is a predominant downward flux in many of the off-shore areas of the site (section 2.3.2 and Appendix F). However, the MPCA does agree with the conclusion that all the measured flux rates (up or down) are very low and that diffusion rather than advection would likely be the dominant process for potential contaminant transport in remedial capped or covered areas of the site. The MPCA recommends that a low upward flux rate as a conservative assumption be used in modeling or calculating the thickness of the cap isolation zone and the protectiveness of remedial caps in the Remedial Design document.
5. Monitoring requirements during remedy construction, and post-remediation operation, maintenance and monitoring requirements are not detailed in the FS, but will be a requirement for the selected remedy. The requirements will be determined during the remedy selection and the remedial design phases.
6. The FS contains limited discussion of the current and the reasonably anticipated future use of the property, in particular for the portion of the property owned by the City of Duluth. This will be a consideration during remedy selection, and USS will need to negotiate an access agreement with the City prior to remedial action implementation.

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John J. Prusiecki, Jr.
Engineer
Environmental Remediation

Via Electronic Transmittal

July 16, 2015

Ms. Erin Endsley
Site Remediation & Redevelopment Section
Minnesota Pollution Control Agency
525 Lake Avenue South, Suite 400
Duluth, MN 55802

Mr. Michael Bryant
US EPA Region 5
Great Lakes National Program Office
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Chicago, IL 60604-3507

Subject: **Revised Feasibility Study**
Former Duluth Works and Spirit Lake Sediment Site
St. Louis River, Duluth, Minnesota

Dear Ms. Endsley and Mr. Bryant:

Enclosed please find our revised Feasibility Study (FS) report for the Former Duluth Works – Spirit Lake Sediment Site (Site). This report is the result of our collaboration with the US Environmental Protection Agency – Great Lakes National Program Office (GLNPO), to plan for a sediment remediation and restoration project at the Site. We are excited to provide this revised document which reflects the work and input of all the many parties involved - including the Minnesota Pollution Control Agency (MPCA).

We look forward to continuing to work with you in moving this important remediation/restoration project forward into design, permitting and implementation. If you have any questions or comments regarding this document, please contact me at (219) 888-4400.

Sincerely,

John J. Prusiecki, Jr.

cc: M. Bares (MPCA)
S. Cieniawski (GLNPO)
J. Beaver (EA)
M. Rupnow (USS)
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Revised Feasibility Study

Former Duluth Works and Spirit Lake Sediment Site

Prepared for
Great Lakes Legacy Act Partnership between
United States Steel Corporation, and
Unites States, Environmental Protection Agency, Great Lakes
National Program Office, and
Minnesota Pollution Control Agency

In Consultation with
EA Engineering, Science, and Technology, Inc.

Prepared by
Barr Engineering Company
AECOM (formerly URS Corporation)

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July 2015

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1.0 Introduction

1.1 Purpose and Organization of Report

This revised Feasibility Study (FS), prepared on behalf of United States Steel Corporation (U. S. Steel) and the, Great Lakes National Program Office (GLNPO) of Region V, U. S. Environmental Protection Agency (USEPA), presents the results of the FS work for the former U. S. Steel Duluth Works sediment site areas and the U. S. Steel Spirit Lake sediment site in the St. Louis River, Duluth, Minnesota. Figure 1-1 shows the Site location, which includes areas of the U. S. Steel Duluth Works former operations area containing sediment and a portion of the western side of Spirit Lake, within the Saint Louis River in western Duluth, Minnesota. The former operations area sediment site (Duluth Works Site) and the estuary sediment site (Estuary Site) areas evaluated in this FS are shown on Figure 1-2 and referred to collectively as the Site in this FS.

The purpose of the FS is to identify Project options that may be feasible for addressing potential risks to human health and the environment posed by impacts present at both the Duluth Works Site and the Estuary Site. The work conducted for the Estuary portion of the Site has been conducted on behalf of U. S. Steel and the USEPA GLNPO under a Great Lakes Legacy Act (GLLA) Project agreement (Figure 1-2). The work for the Duluth Works Site has been completed by U. S. Steel alone in accordance with Section V of the March 26, 1985 Response Order by Consent (Consent Order) issued by the Minnesota Pollution Control Agency (MPCA) (Figure 1-2) (MPCA, 1985). The evaluation of sediment activities at both the Duluth Works Site and the Estuary Site have been combined in this FS to help identify areas where complimentary actions, for example consolidated on-site disposal, may provide synergies and ultimately a better remedy.

This FS is divided into seven sections:

- *Section 1 Introduction* provides an introduction and purpose, describes the report organization, and provides a background and overview of the Site.
- *Section 2 Conceptual Site Models* describes the conceptual site models (CSM) for the Site, including the environmental setting, the nature and extent of potential environmental impacts associated with the Site, and the potential fate and transport of the constituents of interest (COI). This section also contains a summary of the baseline risk assessment.
- *Section 3 Project Goals* defines the Project goals of protecting human health and the environment in terms of site-specific and location-specific targets for sediment quality at the conclusion of a Project that is developed from this FS process.
- *Section 4 Technology Screening* considers potential technologies that could be used to complete a Project for the Site and contains a summary of the technology screening process. This section also contains a summary of the treatability studies completed for the purpose of evaluating technologies.

- *Section 5 Alternatives Evaluation* presents the development of potential Projects for the Site by combining technologies that have passed the screening process and applying them to specific areas of the Duluth Works or the Estuary Sites. This section also includes an evaluation of alternative Project scenarios and describes the Site sediment management goals and Applicable or Relevant and Appropriate Requirements (ARARs).

- *Section 6 Recommendations and Path Forward* contains the selection of a preferred alternative. This section also contains recommendations, discusses the Project design process and permitting, and presents a schedule for implementation of the preferred alternative.

- *Section 7 References*

1.2 Site Background

1.2.1 Site Location and Description

The Site is located in Sections 34 and 35, T49N, R15W, and Sections 2 and 3, T48N, R15W, in the southern part of the City of Duluth in St. Louis County, Minnesota (United States Geological Survey [USGS] 1954, 1993) (Figure 1-1). The Site is adjacent to the St. Louis River, which discharges into Lake Superior approximately eight miles downstream of the Site. The Estuary portion of the Site is located in an open reach of the St. Louis River referred to as Spirit Lake. The Site layout and relation to the former U. S. Steel Duluth Works are shown on Figure 1-2. A small creek and community storm water conveyance channel, referred to as the Unnamed Creek, carries flows from 2,000 acres of upstream watershed within the City of Duluth and Midway Township. It enters through a large culvert located along the western edge, flows through the western portion of the Site and discharges to the St. Louis River. The Site is bounded by Morgan Park (a neighborhood in Duluth, MN) to the north, the St. Louis River (Spirit Lake section) to the east, the Canadian National Railway (CN) property to the west and U. S. Steel-owned former steel mill facility area to the south.

1.2.2 Early Land Uses

The pre-industrial history of the lower St. Louis River estuary area is discussed in detail in the St. Louis River Citizens Action Committee Lower St. Louis River Habitat Plan document (2002). The earliest written descriptions of land uses near the Site date to the 1600s, which is when "…Europeans came to the area to explore and trade…" with the native American people who occupied the region at that time (St. Louis River Citizens Action Committee, 2002). The Fond du Lac Band of the Lake Superior Chippewa are reported to have had villages at various locations along the lower St. Louis River, including the present-day location of the Fond du Lac neighborhood of Duluth, prior to the 1800s. The Fond du Lac neighborhood is located approximately _5.5 miles upstream of the Site. The Citizens Action Committee document (2002) notes that seasonal camps were reported to have been present at Spirit Lake and nearby Indian Point (2.5 miles down-river from the Site).

Maps indicate no settlement features in the immediate Spirit Lake area when the first available map was published in 1861. An archeologist surface walk conducted on Spirit Island in November 2012 found artifacts indicating some occupation of the island; however, no observed cultural features were reported on the surface of the island (Duluth Archeology Center, 2013). No archeological subsurface investigations have been conducted in the area according to this report (Duluth Archeology Center, 2013). The cultural significance of Spirit Island is based on the migration history of the Chippewa, as well as the discovery of wild rice. Spirit Island is considered the sixth stopping place of the journey west, and a meeting location between groups that traveled north of the Great Lakes, and groups that traveled south of the Great Lakes (Duluth Archeology Center, 2013).

The LaPointe Treaty was signed in 1854 between the United States government and the Chippewa which opened the area to settlement (St. Louis River Citizens Action Committee, 2002). The town sites of Duluth and Superior, Wisconsin were then platted. Construction of the first railroad in the lower St Louis River area began in 1861 and was completed in 1870. Historic maps presented in Appendix J of the Remedial Investigation report (Barr, 2013a) show no mapped development in the Spirit Lake area in 1861. The railroad along the river bank was present on a map dated 1889, the next known historic map. A railroad track was also present several miles to the west of the river in 1889, which appears to be the location of the higher elevation Duluth Winnipeg Pacific Railroad (Northern Pacific Railroad). No other development is noted around Spirit Lake on the 1889 map. By 1902, another railroad track was present less than one mile east of the Northern Pacific Railroad, near the current location of Grand Avenue. This newer railroad is listed as the Great Northern Railroad on the 1909 map. The town site of Smithville is on the 1902 map, but, no development, except for the railroad built by 1889 along the river bank, is shown around Spirit Lake in 1902. The property on the Minnesota side of Spirit Lake is titled Spirit Lake Park on the 1902 map. The U. S. Steel property area is labeled as Minnesota Steel Co. Location on a 1909 map, and the steel plant facilities and railroads associated with the plant operations are present on a 1917 map. No additional railroad development along the river bank was noted beyond the tracks built by 1889.

1.2.3 Site Operational History

U. S. Steel built the former steelmaking facility beginning in 1907, with operation beginning in 1915. The facility consisted of a fully integrated steel manufacturing plant including coke production, iron and steel making, casting, primary rolling and roughing, hot and cold finishing, and galvanizing. The majority of the operation was closed in 1979. The approximate former operational area is shown on Figure 1-2.

By the end of 1988, most of the buildings that made up the operation had been demolished and by 1999, the Wire Mill and several smaller buildings used for storage were also removed. Currently, the only structure remaining is a small shed near the Site entrance; this and a few concrete pads and roads are the only remaining surficial features.

The Site is part of a larger Superfund site referred to as the former Duluth Works Superfund site. The Superfund site is overseen by the MPCA under a Consent Order (MPCA, 1985). An administrative record synopsis is provided in Appendix A.

1.2.4 Description of Subject Study Areas

The primary focus of this FS will be several Study Areas (SAs) within the Estuary and adjoining portions of the Site (Figure 1-2). The Estuary portion is comprised of two main SAs along the western shore of Spirit

Lake which closely mirror Operable Units N and R (Figure 1-2). Not all of the Former Duluth Works Superfund sites Operable Units (OUs) are evaluated in this FS; only the following five (5) Former Duluth Works Site OUs, two (2) Estuary Site OUs, and four (4) Former Duluth Works Site SAs are evaluated.

The Former Duluth Works SAs and OUs are described as follows:

Tar Impacted Soil (SAs – T-10 and T-11) – Areas of hardened tar-like material/oil on the surface and tar-like material/oil seeps were identified across the Site during 2008 site reconnaissance. Further response actions at two tar/oil seeps, T-10 and T-11, located in the Unnamed Creek valley near the Coke Plant, will be incorporated into the FS based on recommendations presented in the Supplemental Five Year Review Investigation Report (URS, 2011).

Non-native Material in the Settling Basin (OU-I) – The non-native material is present in the Coke Plant Settling Basin immediately upstream of the basin outlet control structure. This area is approximately 1,400 feet long and up to 330 feet wide, covering approximately 6.3 acres.

Tar and Tar-Impacted Soil in the Coke Plant Settling Basin (SA – Tar between I & J) – This area of tar-like material and tar-like impacted sediment in the Coke Plant Settling Basin is located between, but was not included as part of OU-I or OU-J. The area is approximately 375 feet long by 270 feet wide and encompasses about 1.2 acres. Periodic day-lighting of tar-like material has been observed in the pond area within Tar Between I & J. U. S. Steel has installed absorbent booms to contain the tar-like material and has conducted periodic recovery of the floating tar-like material since 2007.

Stream Channel (OU-L) – The stream channel located between the Coke Plant Settling Basin Control Structure, near the entrance road, and the railroad tracks that parallel the St. Louis River. The stream channel is approximately 1,300 feet long and up to 350 feet wide, encompassing approximately three acres.

Delta and Stream Channel (OU-M) – This area consists of the delta adjacent to the stream channel downstream of the Coke Plant Settling Basin Control Structure, (also called the delta or stream channel area), and includes a former open water area to the west of the railroad tracks. The delta and stream channel SA is characterized by the presence of non-native material. The maximum length and width of the delta and stream channel are 2,830 feet and 1,640 feet, respectively, encompassing about 46 acres.

Wire Mill Pond (OU-P) – The Wire Mill Pond is a portion of the settling basin for process sewer discharge from the Wire Mill and stormwater runoff from a large portion of the Site. The Wire Mill Pond contains non-native material as a consequence of acting as the primary settling basin.

Following initial response actions completed in 1997, the length and width of the Wire Mill Pond area addressed in the FS is approximately 520 feet and 170 feet, respectively, covering an area of approximately 1.1 acres.

Non-native Material and Dredge Spoils in Wire Mill Settling Basin (OU-Q) – Non-native material was dredged to form the Wire Mill Pond Settling Basin and placed along the north and south shore of the Wire Mill Pond within the limits of the historical basin. The maximum length and width of Wire Mill Settling Basin dredge spoils is approximately 1,200 feet and 640 feet, respectively, covering an area of approximately 7.4 acres.

Concrete Disposal Area (SA – CDA) – The Concrete Disposal Area is an earthen embankment on the west side of the property, and east of the CN railroad tracks. This area, measuring approximately 1,000 feet long by 600 feet wide (approximately 14 acres), is devoid of vegetation and appears to be covered with light-colored concrete debris (Figure 1-2). The MPCA has referred to this material as "crushed slag"; however, based on surface reconnaissance, the material consists of mostly crushed concrete.

Unnamed Pond (SA – Unnamed Pond) – Approximately 1.8-acre pond located in the vicinity of the former plant pump station within the northeast quadrant of the Site. Abandoned “oil recovery” equipment was observed at the pond but the actual use of the equipment was never conclusively identified in historic records. Results from Former Duluth Works sediment samples collected after the 2003 Five-Year Review identified residual impacts in the sediments.

The Estuary Site SAs are generally described as follows:

Wire Mill Delta (OU-R) – is approximately 274 acres of water-covered estuary area near the discharge pond from the former Duluth Works wire mill. This study area is located on the south side of a man-made spit of land that separates the two delta areas, with a natural land barrier and wetland defining the southern boundary and the main river channel defining the eastern boundary.

Unnamed Creek Delta (OU-N) – is approximately 110 acres of water-covered estuary north of the Wire Mill Delta at the outlet of Unnamed Creek, where it empties into Spirit Lake. Located north of the spit separating the two deltas, this study area is characterized by a broad, flat delta at the mouth of the creek. Barrier islands are to the east and a dredged shipping channel extends from the main river channel on the north towards the spit on the south.

2.0 Conceptual Site Models

The development of CSMs allows data obtained during on-going 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 COIs. This Section contains a general overview of the regional hydrologic and geologic setting, which is common to both the Former Duluth Works and Estuary Sites, along with detailed descriptions of the CSM for the Duluth Works and the Estuary Site areas. These CSMs are based on site-specific data and observations that have been collected during several investigations over multiple years. The CSMs provide a baseline for consideration of how Project alternatives could be implemented to protect human health and improve the environmental habitat of the Site.

2.1 Hydrologic and Geologic Setting

2.1.1 Regional Hydrology

The Site is located within the St. Louis River watershed, which drains approximately 4,000 square miles of northeastern Minnesota and a portion of northwestern Wisconsin. The region has a typical Midwestern climate with annual average precipitation (rain) of 31 inches, and an average annual snowfall of 85 inches. The regional climate is influenced by the presence of Lake Superior, which has a moderating effect on temperature extremes near the estuary. For example, the mean annual temperature is 39.5 degrees F with a range from minus-39 degrees F to 98 degrees F near the mouth of the St. Louis River in Duluth, while the mean annual temperature in the upper portions of the St. Louis River watershed near Eveleth is 38.75 degrees F with a range from minus-46 degrees F to 103 degrees F.

Groundwater development within the region is limited, and primarily restricted to the glacial lake sands and gravels, due to the inadequate quantity of usable groundwater in the gabbro and thick silt and clay units (Lindholm *et al.*, 1979) as described in Section 2.1.2. Additional details regarding the Site hydrology, hydrogeology, hydrodynamics and geomorphology are integrated throughout the following CSM discussions.

2.1.2 Regional Geology

The geology of the watershed consists primarily of glacial deposits of varying thicknesses and composition overlying igneous and metamorphic bedrock. The primary bedrock unit is the Duluth Complex, a laterally extensive, massive, olivine and anorthositic gabbro formed at or below the ocean floor of a failed Precambrian rift-formed submarine valley. (Lindholm *et al.*, 1979). In the St. Louis River estuary, the bedrock is overlain by 300 to 500 feet of silt and clay lake deposits, with localized saturated glacial lake sands usually less than 10 feet thick.

Quaternary glacial sedimentary deposits in the area of the Site consist of red silt and clay deposited in ancestral Glacial Lake Duluth. These silt and clay lake sediments are prevalent throughout the lower elevations in Duluth including the estuary.

2.1.3 Site-Specific Geology

The Duluth Works Site has been extensively modified and filled during industrial development and activity. Fill material present at the Site consists of gravel, cinders, slag fragments and other materials. The characteristics of the fill material vary throughout the Duluth Works Site. The native soils present beneath the fill material consist of red-brown clay underlain, and at times interbedded with a fine to medium sand (Barr, 1986). The clay unit depth varies from 2 to 48 feet (ft.) beneath the ground surface, and the thickness ranges from 2 to 32 ft. Beneath the clay unit are deposits of sand and gravel. Bedrock was not encountered during any of the investigation activities.

The Estuary Site has a variety of sediment types typical of dynamic fluvial environments: clay, silt, organic silt, sandy silt, silty sand, sand, gravel, and peat. The native sediment types are interlayered, with most layers not laterally extensive. Individual layers of a specific sediment type do not extend completely across the Estuary Site. Silt and organic silt is the predominant surficial sediment type in the estuary, except in the two deltas, which are dominated by sand and separated by a spit of land created primarily from fill. Sand is also present as the surficial sediment in portions of Spirit Lake near the main channel of the St. Louis River.

Non-native sediment classified as fill is present in locations within the estuary, including an area of cemented fill within the Unnamed Creek delta. Fill material includes sand- and gravel-sized anthropogenic materials mixed with natural sediment, metal shavings or fragments, other non-native debris, or particles such as apparent coke or coal fines (generally less than fine-sand sized), apparent mill scale, and naphthalene crystals.

Additional details related to site-specific geologic conditions are included in the Duluth Works Site area and Estuary conceptual models.

2.2 Former Duluth Works Operations Area Conceptual Site Models

Two former Operations area CSMs applicable to this FS were described in detail within the Remedial Investigation Addendum (RIA) submitted by U. S. Steel to the MPCA in October 2013 (URS, 2013). The CSMs considered both terrestrial and aquatic release mechanisms, exposure pathways, migration routes, and potential receptors along the alignment of the Unnamed Creek and Wire Mill Pond drainage courses.

Separate CSM diagrams were prepared for these two areas of the former Duluth Works Operations Site:

- The Unnamed Creek, extending east from the western Site property boundary and CDA area to the OU-M delta (Figure 2-1); and
- The Wire Mill Pond, extending east from the former Site Wire Mill to the St. Louis River estuary (Figure 2-2).

New information that would materially change the former Duluth Works Site area CSMs has not been generated since the submittal of the October 2013 RIA. As such, this FS report section provides a summary of previously submitted information.

2.2.1 Former Operations Area Hydrogeology

Shallow groundwater at the Site flows primarily according to topography and the major drainage patterns. The groundwater elevation map from the RIA is presented on Figure 2-3. Groundwater east of monitoring wells MW-7 through MW-13 appears to flow in an easterly direction toward the St. Louis River. Groundwater north of monitoring well MW-7 appears to flow in a north-northeasterly direction toward the Unnamed Creek. In the area of the Wire Mill Pond groundwater generally flows toward, and discharges to, the pond. Similarly, lowland areas along the St. Louis estuary likely intercept shallow groundwater flow prior to it reaching the river. Groundwater is generally found at 27 to 31 ft. below ground surface (BGS) (UEC, 1993) in the Former Operations portions of the Site and between 0 and 4.9 ft. BGS in the lowland areas.

With the exception of the CDA, no groundwater impacts of concern are related to the SAs addressed in this FS. A general summary of the monitoring and results for the subject SAs was provided in the RIA, at the request of the MPCA, to provide context for the Former Operations Area sediment data and discussion. The reader should refer to the RIA and annual monitoring reports for additional discussion of groundwater quality at the Former Operations Site.

2.2.2 Former Operations Area Hydrology

The portion of Unnamed Creek crossing the Former Operations area of the Site was identified by the U. S. Geological Survey (USGS) in a 2003 and 2004 geomorphic study of the Duluth area as the lower main stem of "U. S. Steel Creek" (Fitzpatrick, *et. al.*, 2006). The artificial channel designation of this surface water body within the USGS study is consistent with its current use as a major storm water drainage conveyance for the City of Duluth. The majority of the base and storm flow in the Unnamed Creek originates in areas of the watershed that are up gradient of the Site (Figure 2-4). Off-site run-on generally flows from the west and northwest from multiple sub-watersheds and is conveyed by Unnamed Creek to the St. Louis River estuary. The largest of these off-site watersheds has an approximate area of 1,600 acres. This watershed has a maximum elevation of approximately 1,300 feet above mean sea level (msl) and a vertical relief of approximately 590 feet. Two smaller sub-watersheds flow onto the site from the northwest and north, respectively. The first is approximately 257 acres, with a vertical relief of approximately 500 feet and discharges to the Unnamed Creek tributary north of OU-K. The second is a Morgan Park, Minnesota residential area covering approximately 51 acres and has a vertical relief of approximately 10 feet. Storm water in this sub-watershed not captured by the City of Duluth storm sewer system is believed to enter Unnamed Creek via overland flow. Peak discharges are summarized in the Upland (Former Operations Area) Surface Water Technical Memorandum provided as Appendix B.

Wire Mill Pond has a drainage area of approximately 34 acres. This 34-acre on-site sub-watershed is located in the east central portion of the site and generally flows to the east and is conveyed by the Wire Mill Pond into the St. Louis River estuary. The sub-watershed has a vertical relief of approximately 60 feet and a low point (or outlet elevation) of approximately 601 feet msl.

Unnamed Pond, a third Former Operations Area surface water body included within the scope of this FS, has an on-site drainage area of approximately 14 acres. Overland flow within the drainage area is to the east with a vertical relief of approximately 40 feet and a low point of approximately 607 feet msl.

Four wetland areas, ranging in size from two to 11 acres, were mapped during a wetland delineation and functional assessment effort conducted in conjunction with this FS (Appendix C). The wetlands identified in this study were aligned with the Unnamed Creek corridor, as well as the Wire Mill and Unnamed Pond areas. All of the wetlands identified in the study were considered to be significantly disturbed and have been subjected to numerous wetland type changes as land use and hydrology have been changed by direct and indirect post-industrial impacts that occurred prior to 1980 (Appendix B).

Surface water quality is addressed via ongoing monitoring and reporting. All surface water data are reported to the MPCA in separate submittals. A general summary of the monitoring and results for the subject SA's was provided in the Remedial Investigation Addendum (RIA), at the request of the MPCA, to provide context for the Former Operations Area sediment data and discussion (URS, 2013). The reader should refer to the RIA and annual monitoring reports for additional discussion of surface water quality.

2.2.3 Description of Former Operations Area Conceptual Site Models

2.2.3.1 Unnamed Creek Conceptual Site Model

Figure 2-1 shows a conceptual cross section and risk pathway diagram for the Unnamed Creek comprising the CDA, OU-I, OU-J, Tar Between I&J, OU-L, and OU-M. Past and present investigations have identified that essentially all the sediment fill above the original natural creek elevation is impacted with coke fines, manifested primarily as elevated PAH concentrations. Historically, the Unnamed Creek channel received coke fines near OU-J. The fines were subsequently transported downstream and make up a significant portion of the sediment in Unnamed Creek (OU-I) and the OU-M delta. While transport of sediment from the upper portion of the Unnamed Creek to the estuary remains a primary concern at the Site, today the OU-M delta and much of the Unnamed Creek is vegetated, which greatly reduces sediment transport.

Potential exposure pathways for the Unnamed Creek sediment include direct exposure to both ecological and potential human receptors (i.e. trespassers). Surface water quality exceedances, in the form of oil blooms in the Tar between OU-I and OU-J and detections of select metals, PAHs and elevated pH have also been noted in the Unnamed Creek corridor. However, the Unnamed Creek is difficult to access and not attractive for wading or other activities, which likely limits the potential for direct human exposure.

The Unnamed Creek is likely a groundwater discharge zone as various seeps have been observed along the shoreline of the creek. While this limits the potential for groundwater to transport COIs away from the creek, it is a potential mechanism for transport into the creek through impacted sediment within the creek-bed. As discussed above in Section 2.2.1, groundwater discharge to the Unnamed Creek is anticipated to represent a small portion of the total Unnamed Creek base flow.

2.2.3.2 Wire Mill Pond Conceptual Site Model

Figure 2-2 presents a conceptual cross section of the Wire Mill Pond (OU-P and OU-Q). This area was historically an inlet on the estuary that was filled over time. Later, dredge spoils from the Wire Mill Pond were placed along the north and south banks of the Wire Mill Pond to create much of the current topography (Figure 2-5). As part of the remediation of the Wire Mill Pond in 1997, the pond was dredged restored with a sand backfill to create a benthic ecology to help contain remaining sediments. The primary risk pathways in this area include sediment transport to the estuary and infrequent oil blooms within the pond. This pathway is currently addressed by the sand material, new vegetation, and absorbent booms, which prevent material from being transported to the estuary. Direct exposure to trespassers and ecological receptors similar to the Unnamed Creek corridor also exists.

The Unnamed Pond exhibits similar hydrogeologic characteristics and risk pathways as the illustration of the conceptual model of the Wire Mill Pond area (thus, a separate figure was not prepared). Based on a 1907 topographic survey, the Unnamed Pond was historically riparian to the St. Louis River estuary at the mouth of a ravine complex. The Unnamed Pond is not visible on historical aerial photographs from 1939 to 1961, but it is visible on the 1972 historical aerial photograph.

2.3 Estuary Conceptual Site Models

Two estuary CSMs were developed for the Remedial Investigation (RI) work plan to help guide investigation activities and provide a basis for understanding the effects of physical and environmental factors impacting the two delta areas in western Spirit Lake. The two delta areas are referred to as the Wire Mill Pond (WM) and Unnamed Creek (UC) deltas. A spit of constructed land extends eastward into Spirit Lake from the western shoreline between the UC and the WM deltas. The initial CSMs were updated during the preparation of the RI report (Barr, 2013a) and a third CSM diagram was developed to represent the Upper Wire Mill (UW) area, which is located between the UC and WM deltas and to the south of the spit. The CSM development process is iterative. These models have been updated as new data were obtained during investigation activities. The CSM discussions and diagrams presented in this report have been updated to include all data collected at the Site to date.

Separate CSM diagrams were prepared for three areas of the Spirit Lake estuary adjacent to the former steel mill site:

- The Wire Mill Pond (WM) Delta; the portion of Spirit Lake adjacent to the Wire Mill Pond discharge (Figure 2-5);
- The Upper Wire Mill (UW): the portion of Spirit Lake north of the Wire Mill Pond delta and adjacent to and south of the spit of land (referred to as the Upper Wire Mill) (Figure 2-6); and
- The Unnamed Creek (UC) Delta: The delta formed where the Unnamed Creek discharges to Spirit Lake, and the portion of the lake adjacent to the delta (Figure 2-7).

2.3.1 Estuary Hydrology, Geomorphology, and Hydrodynamics

The three CSM areas are located on the west side of Spirit Lake. The main channel of the St. Louis River through Spirit Lake is located along the far eastern shore, and is separated from an extensive shallow area in the middle of the lake by a barrier island along the inside turn of the thalweg. The open portion of Spirit Lake is separated from the western portion, where the deltas are located, by a secondary flow channel and Spirit Island along with a series of smaller barrier islands, shoals, and natural levees. These landforms are generally elongate and parallel to the secondary river channel through the middle of Spirit Lake, which includes a formerly dredged, abandoned shipping channel at the outlet of Spirit Lake.

The Estuary Site CSMs identify four geomorphic zones, which can be generalized into two sediment geomorphic zones based on water depth:

- Shallow Zone (includes the following three geomorphic zones) – 36 inches of water or less
    - Land/Shore – above the normal water level (601.1 feet msl, USACE low water datum)
    - Foreshore – 0 to 18 inches of water depth
    - Nearshore – 18 to 36 inches of water depth
- Offshore Zone – greater than 36 inches of water depth

The defining characteristics for each of these four zones presented in the estuary CSMs were developed from the sediment sampling, bathymetric measurements, hydrodynamic modeling, biological sampling and a review of the sediment reworking/movement literature (Barr, 2014a). It should be noted that these geomorphic zone water depth ranges are not analogous to the biological activity zone target depths presented by the MPCA in its March 2014 project communication (MPCA, 2014b). The above information describes the current site conditions, not the post-remediation requirements presented in (MPCA, 2014b).

The hydrodynamics of the St. Louis River, and in particular the potential for sediment deposition or transport within Spirit Lake and the estuaries along the western shore have been studied extensively and modeled to develop a better understanding of current and future sediment transport mechanisms that may have an impact on potential Project alternatives. The hydrodynamic and sediment transport model for the site was developed using Delft3D. A detailed description of the model development and application is included in Appendix D. The following paragraphs summarize the primary findings from the development of the hydrodynamic model regarding the potential for sediment deposition or transport from river current, seiche, wind, and ice within the Estuary Site, as well as the effect of vegetation. Ice and river current are consistent throughout the Estuary Site, so those processes and effects are presented, for the entire river, in this Section. Seiche and wind processes and effects will be discussed in more detail in each individual CSM (Sections 2.3.3.1 through 2.3.3.3).

River flow has a significant role in the fluid velocities throughout the water column in each of the CSM areas of Spirit Lake. However, it has a limited role in sediment transport out of Spirit Lake and instead helps contribute to the overall sediment load in the estuary. One key recent weather event is important to the evaluation of the Spirit Lake dynamics and the evaluation of the remedial options. A significant volume of water flowed through Spirit Lake during the record-setting June 2012 flood, but net sediment removal was not observed within the study area. Instead, significant new (post-industrial) sediment deposition was documented within Spirit Lake as a result of this flood through the comparison of bathymetric surveys completed prior to and after the June 2012 flood event. Figure 2-8 shows the post-flood thickness of native (post-industrial) sediment. These observations and measurements were corroborated using the hydrodynamic and sediment transport model (Delft3D) described in Appendix D. Estuary modeling completed using data collected over the past four years identified that in general Spirit Lake is a net sink for fluvial sediment (sometimes also referred to as net depositional), although the amount of sediment deposited is dependent on the upstream load. The net deposition observed in Spirit Lake is consistent with historical observations when a majority of the lake was shallower and contained more aquatic vegetation. The current sediment load to the river is less than historical volumes, likely due to accumulation in the numerous upstream impoundments. However, during floods the sediment load can rise significantly, due to events such as upstream scour and dam failure. When these events occur, the Spirit Lake estuary is the first wide area of the river and a natural location for sediment deposition.

Lake Superior seiches affect the St. Louis River estuary from the harbor to the Site. Within Spirit Lake, the dredged shipping channel at the north end of the lake acts as a conduit for flow both into and out of Spirit Lake. Water level elevation changes caused by the seiche cycle results in significant volume of water exchanged between Spirit Lake and the St. Louis River, primarily through the dredged channel. Superposition of the seiche and the river discharge results in increased effective flow velocities during the falling limb of a seiche cycle, and decreased effective flow velocities during the rise of the seiche. Overall seiche activity increases the complexity of hydrodynamic conditions within the estuary, by affecting effective flow velocities and constantly changing water depths in the nearshore areas.

Wind-driven waves are a potential sediment transport mechanism for each delta and the spit. However, the shallow water depths, significant vegetation, and limited fetch within Spirit Lake limit the ability for significant waves to develop. Winds out of the north and the east present the largest potential for creating a significant wave event. Wave observations detailed in the Sediment Remedial Investigation Report (Barr, 2013a) were corroborated with modeled data discussed in Appendix D. Site observations and model corroboration indicate that wind-driven waves are not a significant sediment transport mechanism along the western shore of Spirit Lake, except on the foreshore where coarse sediment is reworked and fines are removed by wave action. Wave action within the foreshore areas of the Site will be considered during Project alternatives analysis because changing the shoreline and estuary conditions may change the impact of waves (i.e. changing sediment type, removing/adding vegetation, and/or increasing depth within the deltas).

The nearshore areas within the WM and UC delta areas are shallow water littoral zones with changing water depth due to the seiche activity and significant vegetation. Ice cover in this area frequently freezes to the bed and becomes anchored in place. Small localized ridges of sediment on the southern shoreline of the spit, and an ice ridge just off-shore of the eastern tip of the spit, indicate some ice movement that potentially was caused by wind, waves, seiche, and/or river flow. To evaluate the potential role of ice formation on sediment transport in these areas, ice formation and melt-out conditions were observed along the shorelines of the Site at various times in the winters of 2011 through 2014. The results of the ice observation field work are reported in the Barr RI report (2013a) and updated with information in Appendix E. Conditions during the four monitoring years represent a wide range of known climatic variability in the region, including the coldest winter (in terms of average temperature) in 139 years. During the four-year monitoring period no documentation of extreme ice conditions or extensive shoreline sediment removal within the Site was observed. Based on these observations, ice poses a negligible concern with respect to sediment transport along the Site shorelines.

2.3.2 Estuary Hydrogeology

Shallow groundwater discharges to surface water in the Former Operations area (OUs and SAs) portions of the site (See Section 2.2.3.1 and 2.2.3.2). In addition, evidence of an upward groundwater flux has been described in some shoreline and nearshore areas of the Site, including a Shrub-Carr wetland complex, which is representative of a groundwater source and therefore an upward flux, on the northern shoreline of the UC delta (OU-M) area. Groundwater seeps have been observed along the shoreline – west of the railroad tracks in the Wire Mill Pond area, west of the tracks in the northern Unnamed Creek area and near the railroad tracks in the western OU-M Delta area – in these portions of the site at the base of the steep hillside beside the estuary shoreline these seeps act as a hydraulic head relief mechanism, resulting in limited driving head and likely a very small net flux.

However, the flux to or from the offshore portions of the estuary has not been previously studied. To resolve this data-gap, flux meters were installed in the off-shore regions of the estuary to measure the potential for off-shore groundwater-surface water exchange. The results of the flux meter study, which are included in Appendix F, showed a small, measurable, net downward flux from the lake into the sediment. While the velocity of the flow was very low, the downward flux was consistent in the offshore flux meter locations more than 200 feet from shore. These results suggest that the shallow groundwater at the site does not have any effect on pore water movement in the offshore portions of the site. Any potential regional influences associated with deeper groundwater were not observed in the estuary study, likely due to the extensive clay that is present below the Site. The measured flux is very small and net downward based on piezometer and flux meter measurements meaning that diffusion is the primary porewater flux mechanism, not advection. The primary conclusion from these analyses is that flux in the offshore areas is very small and therefore diffusion is the primary porewater flux mechanism, not advection in this area.

Ebullition is not a likely pathway of concern, based on observations that no ebullition was identified in any of the flux meters. Ebullition involves gas bubble transport of sediment upward through overlying sediment to the top of the surface water, where the bubble bursts and the sediment falls on top of the existing sediment surface.

Pore water samples collected from sediment within Spirit Lake were analyzed for the presence of PAH, metals, TOC, and black organic carbon sediment concentrations. The results of these analyses indicated that PAHs were more sorbed to Site sediments than would have been predicted by published equilibrium partitioning coefficients for organic carbon (EA, 2013), but metals pore water results were inconclusive.

2.3.3 Description of Estuary Site Models

2.3.3.1 Wire Mill Pond (WM) Delta Conceptual Site Model

The WM delta is located where the Wire Mill Pond discharges into the southwestern portion of Spirit Lake. As described in Section 2.3, the UM and WM delta areas are generally defined by the man-made spit of land on the north, a natural land barrier, wetland, and the main river channel on the south, and the shallow flats of eastern Spirit Lake on the east. The WM delta CSM is focused on the southern portion of the defined area and the UW CSM was developed for the northern portion of this part of Spirit Lake.

The Wire Mill Pond, which is upstream of the WM delta, was remediated in the 1990s to reduce the flux of contaminants and sediment from the pond to the river. Currently, the pond discharges to Spirit Lake through a narrow, sorbent-boom-lined outlet. As a result of controlling the source, the majority of the WM delta has post-industrial sediment at the surface. Non-native sediment was only identified at the surface of the WM delta in a small area along the shoreline where nearshore wave action and other factors inhibit the deposition of new sediment. The stratigraphy of the WM delta consists predominantly of silt near the surface, with layers of fibrous peat and clay near the shoreline. Silt, fibrous peat and clay are underlain by sandy silt grading into silty sand to a depth of at least 50 feet. Non-native (industrial fill) sediment occurs in thin layers (less than four feet thick, Figure 2-9) and was observed to be present only in the silt, clay and peat overlying the silty sand. COI migration is not anticipated to be a pathway of concern in the WM delta, either downward to the underlying sand or upward to the sediment or surface water through ebullition or advective flow. Post-industrial sediment covers the majority of the non-native sediment in the WM delta area of the Site. This material has gradually accumulated over time after being delivered from flow in the adjacent St. Louis River channel and by seiche flow. Little-to-no post-industrial cover has been deposited in an area extending eastward from the Wire Mill Pond outlet. This area likely receives little sediment because it is farthest from the main channel of the river where new sediment is being deposited and any material that settles in the nearshore is likely reworked by seiche flow and wave action.

Spirit Lake geometry and shallow water depths combine to limit the effect of wind-driven waves on the WM delta. Westerly and southerly winds are limited by a short fetch, while the spit provides protection from northerly winds. Shallow water depths and islands, including Spirit Island; limit the growth of waves from easterly winds. Wave height is further attenuated by bottom roughness due to vegetation and other subsurface features, including a significant amount of submerged logs and trees, located within the WM delta area.

Overall, the WM delta portion of Spirit Lake appears to be stable with respect to sediment impacts from COI due to upgradient source control, post-industrial sedimentation providing cover material, and protection from wind-generated waves by the land forms on the north, south and west.

2.3.3.2 Upper Wire Mill (UW) Conceptual Site Model

The UW area is located south of the constructed spit of land that separates the UC delta from the UW and WM delta areas, and north of the WM delta area. The UW area is generally bounded by the spit of land on the north, the shallow flats of eastern Spirit Lake on the east, and the WM delta area on the south. The

UW is a shallow-water area with a flat bottom and a significant number of submerged stumps, logs, and trees. The vegetation is considered to be a remnant from an area of emergent vegetation that has been seen in historical aerial photographs of the UW area. The UW area also includes two locations where historical dredging occurred. The first is the dredged channel located along the eastern side of the UC delta. This channel extends south past the spit, to the northeast portion of the UW area. The other dredged area is an irregular-shaped hole in the northwest portion of UW the area where the spit of land converges with the natural shoreline. It is generally understood that this hole was dredged to provide a water intake source for the former steel mill.

The UW area is located immediately downstream from the WM delta area. However, no evidence exists that would denote the presence of a historic or current source of potential non-native fill or other contaminants directly into the UW area. As noted previously, the Wire Mill Pond was remediated in the 1990s to reduce the flux of constituents and sediment from the pond to the river.

The stratigraphy of the UW area consists predominantly of silt near the surface, with an area of fibrous peat adjacent to the southeastern end of the spit. Silt, organic silt, and fibrous peat are underlain by silty sand and silt to a depth of at least 50 feet. Non-native sediment was observed to be present only in the silt and organic silt near the surface. The lateral and vertical extent of non-native sediments in the UW area has been defined, with irregular, isolated areas of surface sediment impacts including a thin buried layer in the dredged (water intake) basin and along portions of the western shoreline (Figure 2-9). COI migration, whether downward to the underlying sand or upward to the sediment or surface water through ebullition or advective flow, is not anticipated to be a pathway of concern. Post-industrial sediment, delivered from the adjacent St. Louis River channel by seiche and river flow, covers the majority of the non-native sediment in the UW area (Figure 2-8).

As was the case with the WM delta, the combination of Spirit Lake geometry and shallow water depths works to limit the effect of wind-driven waves on the UW area. Westerly and southerly winds are strongly fetch-limited, while the spit provides protection from northerly winds. Shallow water depths and islands, including Spirit Island; limit the growth of waves from easterly winds. In addition wave height is further attenuated by the abundant submerged stumps, logs and trees located within the UW area. Advective flow, ebullition and pore water dissipation appear unlikely to act as pathways of concern in the offshore portions of the estuary (generally more than 200 feet from shore), as discussed in Section 2.3.2.

The UW portion of Spirit Lake is stable with respect to sediment impacts from COI due to the lack of a direct source of non-native sediment or groundwater, post-industrial sedimentation providing cover material, and protection from wind-generated waves by the land forms on the north, south and west. The UW area is depositional under many river conditions, such as large flow and sediment load. The amount of sediment deposition is directly related to the river flow and upstream sediment load.

2.3.3.3 Unnamed Creek (UC) Delta Conceptual Site Model

The UC delta consists of a broad, flat delta where Unnamed Creek discharges to Spirit Lake. The UC delta area is generally defined by the natural shoreline to the north and west, the constructed spit on the south, and barrier islands on the east near the dredged river channel.

Surface sediment throughout a majority of the UC delta area, as well as Former Operations Area Site sediments, is impacted by PAHs. Work to address non-native sediment sources from the Former Operations Area portion of the Site, which will aid in the restoration of the UC delta, will be included within the Project alternatives that are the focus of this feasibility study. Non-native sediment deposition from up gradient areas of the Site in the UC delta area is expected to be eliminated when ongoing upland source controls are implemented.

The UC delta stratigraphy consists predominantly of PAH-impacted non-native sediments at the surface, including an area with cemented non-native sediments, underlain by thin layers of silty sand and sandy silt. The silty sand/sandy silt is underlain by fibrous peat on the western half to an unknown depth, and clay and silty sand on the eastern half of the UC delta to a depth of at least 50 feet. The non-native sediments are more than 10 feet thick near the shoreline with a thinning wedge extending eastward into the lake (Figure 2-9). The area of non-native sediments in the UC delta appears to be one fairly contiguous area, where little post-industrial cover has occurred (Figure 2-8). The non-native sediments occur in an area extending eastward from the Unnamed Creek outlet and surrounding shoreline to the dredged channel.

Wind-generated waves, predominantly from the north and east, are observed in the UC delta. These waves attenuate as they propagate onto the UC delta due to the increasingly shallow water. The primary effect of wind-generated waves within the UC delta area of the site occurs in the foreshore, where coarse sediment is reworked and fines are removed by wave action with little to no sediment transport observed. This observation was corroborated by model results.

Flow in the main river channel has little influence on sediment transport within the UC delta, due to the presence of the spit and the dredged channel. Observed and modeled flows from the 2012 flood show the primary river flowing past the UC delta, as the flow transited through the dredged channel.

Due to the proximity of the dredged channel to the UC delta, seiche flow can cause changes in water surface elevation and increased water flows into and out of the UC delta area. However, these flows are not expected to contribute to sediment transport to the river because velocities in the delta area are very low compared to the velocity in the dredged channel.

Advective flow, ebullition and pore water dissipation appear unlikely to act as pathways of concern, as discussed in Section 2.3.2

3.0 Project Goals

3.1 Vision for Success

The vision for a successful Project at the Site is defined in the Great Lakes Legacy Act funding request as one that:

- Meets the site specific Remedial Action Objectives (RAOs) as further defined in this Section;
- Contributes to minimizing or eliminating beneficial use impairments, as defined by the St. Louis River System Remedial Action Plan (SRL-CAC, 1992; LimnoTech, 2013) within the Estuary Site;
- Supports betterment through improvement of aquatic habitats in a manner that would not normally be included in the RP Superfund Process while incorporating concepts from the St. Louis River Habitat Plan (SLR-CAC, 2002) and the Spirit Lake Conceptual Habitat Restoration Plan (LimnoTech, 2012); and
- Positions the former U. S. Steel Duluth Works property (Former Operations Area of the Site) for brownfield redevelopment while minimizing the extent of areas used to consolidate and manage historical impacts.

As noted in Section 1, the goal of this FS has been to develop and consider a variety of alternatives that achieve this vision, with varying degrees of effectiveness and a range of costs, while taking advantage of potential synergies associated with a combined Former Operations Area and Estuary sediment Project. The FS process allows stakeholders and all the parties involved to develop a Project that can be designed and implemented to achieve an acceptable outcome that is consistent with this vision.

3.2 Overview of Remedial Action Objectives (RAOs)

To achieve the vision of success for this Project, the work will be focused on achieving a carefully prescribed set of Remedial Action Objectives (RAOs). These RAOs are the numerical and qualitative criteria that, when completed, would provide protection of human health and the environment. The RAOs for this Project include (MPCA, 2014b):

Ecological Receptors

- Reduce risks to benthic invertebrates by reducing sediment concentrations of COIs to protective levels.
- Reduce risks to other aquatic organisms (plants, fish, amphibians, reptiles, birds and mammals) from direct exposure to COIs by reducing concentrations of COIs in sediment and surface water to protective levels,
- Reduce risks to fish, birds and mammals due to bioaccumulation of COIs.

Human Health

- Reduce human health risks associated with exposure to COIs through direct contact with sediments, inhalation, and incidental sediment ingestion by reducing sediment concentrations of COIs to protective levels.
- Reduce human health risks associated with exposure to COIs through direct contact with soil, inhalation, incidental ingestion, and food chain in OU-S, OU-Q and tar areas T10 and T11 in OU-A.

Surface Water

- Achieve surface water standards for the project COIs for waters leaving the Site, within the Site, and for project-defined locations adjoining work areas in the estuary, that contribute to the overall water quality of the St. Louis River. Details will be developed in the design phase and during permitting.
- Reduce risk to surface water in OU-S and OU-Q by preventing transport from run off.

3.3 Former Operations Area Site Remedial Action Considerations

To achieve the vision of success for this Project the work at the Former Operations Area Site will be geared toward achieving the following RAOs, as well as the following additional considerations:

- Providing a stable water course for stormwater conveyance and discharge that achieves the objective of allowing surface waters to meet applicable water quality standards. The final surface water configuration in the Site area will depend on the selected alternative, and the specifics will be determined during the design phase.
- Preserve upland areas for future economic redevelopment.
- Improve habitat (betterment).

Each of the Former Operations Area RAOs and considerations are described in further detail below.

3.3.1 Protect Human Health and the Environment

Protection of human health and the environment guides the FS evaluation process and is a fundamental component of the Project RAOs listed in Section 3.2. Development of alternatives and the analysis of those alternatives must take into consideration the potential exposure pathways for humans and ecological receptors to potential chemicals of concern in the environment and the risk associated with these potential exposures.

In accordance with the FS work plan (Barr, 2012) and Agency guidance, ecological risk screening and human health risk screening evaluations have been performed to identify the nature, extent, and magnitude of potential impacts to human health and the environment based on MPCA-provided criteria. As described in the RAOs (Section 3.1) environmental remediation approaches that are identified by this FS must be protective of human and ecological receptor pathways specific to the Site and its setting.

U. S. Steel updated both the Human Health Risk Evaluation and Ecological Baseline Assessment (HHRE and EBA) for impacted sediment and soil encompassed by the Former Operations Area portion of the Site within the October 2013 RIA (URS, 2013). Risk assessment findings relevant to this FS are discussed in the following sections.

3.3.1.1 Human Health Risk Evaluation

Potentially complete human health exposure pathways in the Former Operations Area SAs were primarily associated with terrestrial areas with potential direct exposure to impacted soil. Exposure to surface water and sediment within the aquatic portions of the SAs is limited for human receptors as the aquatic portions of the Former Operations Area SAs present narrow accessibility or recreational opportunities to swim, drink, fish, or otherwise be exposed. Similarly, exposure to groundwater was not considered a complete exposure pathway as there are no current or projected uses of groundwater at the Site.

Potentially complete exposure pathways identified in the Former Operations Area HHRE included:

- Incidental ingestion, inhalation and dermal exposure to impacted near-surface soil (less than two feet below grade) by future industrial workers, future construction/utility workers and trespassers;
- Incidental ingestion, inhalation and dermal exposure to impacted subsurface soil (greater than two feet below grade) by future construction/utility workers; and
- Inhalation of indoor vapors by future industrial workers from impacted soils.

The Former Operations Area HHRE identified potential cancer risks for one or more receptors exceeding the MPCA target risk level of 1×10^{-5} in all SAs except OU-Q, which was determined to pose an ecological risk. Potential cancer risks exceeded the USEPA upper risk level of 1×10^{-4} at the CDA, T-10, and Tar Between I&J. Hazard indices were less than 1.0 in all SAs. PAHs were the primary contributors to the risk values in all areas where risk exceeded 1×10^{-5}.

The MPCA subsequently provided comments to the HHRE component of the October 2013 RIA in a memorandum dated February 2014, (MPCA, 2014a). The MPCA generally accepted the Former Operations Area HHRE findings in their comments and stated that revision of the evaluation was unnecessary if proposed remedial actions would address items where exceptions were noted related to trespasser risk in the CDA and trespasser/potential recreational user risk in OU-Q.

The HHRE-based RAOs for the Former Operations Area SAs will focus on reducing human health risks associated with exposure to COIs through direct contact with soil.

- Industrial Soil Reference Values (ISRVs) will serve as the primary PRGs for soil to allow for future industrial redevelopment for OU's and SA's in the Former Operations areas of the Site. Secondary Recreational Soil Reference Values (RSRVs) may be applied as PRGs in certain terrestrial areas of the SAs if recreational access is provided as an outcome of response actions.

- The SRVs selected to meet the Human Health RAOs with respect to direct human exposure to upland soil at each of the Study Areas under the anticipated future property use are summarized in Table 3-1.

Direct contact with impacted sediments was considered an incomplete pathway in the HHRE. Further, exposure through the human food chain via uptake from impacted sediment was not believed to be a significant pathway for the Former Operations areas of the Site as fishing and hunting are not associated with the SAs. As such, specific PRGs for human health risks associated with direct contact to impacted sediments have not been established. Human health exposure risk from impacted sediment in the SAs will be addressed through implementation of measures to mitigate ecological risks.

3.3.1.2 Ecological Baseline Assessment

An updated ecological risk evaluation was also presented in the 2013 Upland RIA (URS, 2013) that identified potential risks to relevant ecological receptors in specific areas of the Site. A summary of potential ecological risks is presented in Table 3-2. Attainment of aquatic-based RAOs will address ecological risks in both the Former Operations Area Aquatic and Scrub-Shrub Forested Wetland environments identified in Table 3-2. Since the sediment numerical PRG criteria for the protection of potential ecological receptors within the aquatic areas of the Former Operations Area of the Site match those of the Estuary Site, further discussion pertaining to the development of sediment PRGs is contained in Section 3.4.1.2.

Assessment endpoints for the Terrestrial Habitat were terrestrial birds and mammals that may forage in this area and be exposed to site-related chemicals through ingestion of impacted prey and soil. In all instances the highest hazard quotients (HQs) were observed for invertivorous birds and associated with metals and PAHs. Risks to plants were identified as low in the Terrestrial Habitat. The updated ecological risk evaluation also found a high level of uncertainty in evaluating risks associated with exposures to soils in the Terrestrial Area due to poor habitat quality and high organic carbon in soils which limit PAH bioavailability. Thus, it was concluded that there is a potential for ecological risks in the Terrestrial Habitat.

Reducing risks to birds and mammals due to bioaccumulation of COIs is the only ecological RAO that applies to the Terrestrial Habitat. A remedy that utilizes tiered SRVs as PRGs (for both industrial and recreational end-use scenarios) for reduction of human health risk will also reduce ecological risk within the Terrestrial Habitat. In addition, reducing soil concentrations and/or interrupting exposure pathways will reduce ecological risk.

3.3.1.3 Extent and Magnitude of Former Operations Area Impacted Media

Using the Soil SRVs and the Sediment PRGs defined above, elevated PAHs and metals were used as the primary indicator for defining the extent of impacts at the five Former Operations Area OUs and four SAs as shown on Figure 3-1. Data collected as part of the Remedial Investigation, past investigations, and the conceptual model for the nature of deposition were used to identify the lateral extent and the thickness (vertical extent) of both soil and sediments in the Study Areas. In general terms, the lateral extent of sediment impacts is clearly defined by Site topographic constraints on the areas of historical deposition, while the lateral and vertical extents of the soil impacts were defined by the interpolation of data points from prior investigative work. Collectively, these areas comprise the limits of impacted material to manage in order to protect human health and the environment. The extents of specific Study Areas are summarized in Table 3-3.

3.3.1.4 Extent of COIs related to PRGs

The areal extent of soil and sediment requiring a response action is determined by COI concentrations that exceed PRGs (MPCA, 2104 a,b). PRGs have been established for PAHs, lead, copper, and zinc, and represent a subset of the COIs. Analytical testing has been conducted for a longer list of parameters as presented in Table 1 of the RI Report (Barr, 2013a) and Section 2.5 of the Upland RI Report (URS, 2013). The analytical results have been compared to SRVs, SQTs, and SSVs to determine a list of COIs (Barr, 2013a; URS, 2013).

Concentrations of COIs from sediment samples were compared to concentrations detected in sediment samples collected from throughout the estuary during other investigation conducted by the MPCA. The data comparison identified potential sediment COIs, while identifying other constituents that are not associated specifically with potential Spirit Lake sediment Site management and FS evaluation needs. These screened out COIs include: PCBs, dioxin/furans, cadmium, and mercury. A focused list of sediment COIs was included in Table 14 of the RI Report (Barr, 2103a).

The list of COIs from the OUs and SAs for this FS evaluation are listed in Section 1.2.4 and are presented by area on Table 3-4. The extent of the COIs for these areas are shown on Figure 3-1. The COIs consist of PAHs and various metals. The areas where metals and PAHs exceed screening criteria are largely co-located. Therefore, a remediation of the parameters for which PRGs have been established will result in remediation of all COIs.

3.3.2 Prevent Migration and Transport of COIs and Maintain Surface Water Quality

If sediments with COIs remain in or near stormwater drainageways, the RAO of preventing migration and transport of COIs while maintaining compliance with surface water quality will be obtained in part by providing a stable water course for storm water passing through the Former Operations Area of the Site. FS alternatives will be evaluated with respect to the manner in which a stable water course will also help to ensure the long-term viability of the Estuary Site RAOs and provide protection of potential estuary habitat enhancements. Eliminating the potential for residual materials that may remain at the Former Operations Area of the Site from migrating to the Estuary Site via stormwater is an important component in the overall success of the Project and a key reason for linking the proposed work at the two areas of the Site (Operations area and Estuary). Providing a stable water course may require physical separation of the stormwater from residual materials in the Operations Area of the Site containing concentrations of COIs in excess of the sediment management goals. In addition to physical separation, the channel must be designed to pass a large storm event, referred to as the design storm. Proposed site grades and channel improvements associated with the final remedy will be designed to effectively convey large storm events.

A naturally stable water course designed to convey run-off from this watershed would need to achieve several objectives, including:

- Flood management to limit adverse on-site impacts from flooding and to avoid raising flood levels downstream of the site;
- Management of smaller, more frequent storms as well as the Unnamed Creek base flow to avoid localized erosion or other damage and minimize routine maintenance; and
- Integration of the function of potential remedies, such as caps and CDFs within the storm water conveyance system so that all components function effectively and remain protective.

Criteria used for defining and designing the storm water conveyance components of the Project are summarized in Table 3-5.

3.3.3 Preserve Areas for Economic Development

The goal of facilitating potential future uses of the Site, including the potential for industrial redevelopment on portions of the U. S. Steel Former Operations Site area, will also be considered when evaluating potential Project Alternatives. The future redevelopment area would be offset from the shoreline area, so that redevelopment could be compatible with habitat restoration activities in the estuary.

3.3.4 Improve Habitat (Betterment)

Another important reason for considering the Former Operations Area and Estuary sites as a combined Project for the purpose of this FS was to allow for potential synergies between betterment in the portions of the site that are currently Former Operations Areas, but have the potential to be returned to open water and the existing Estuary. This was a key opportunity identified in the St. Louis River conceptual plan (LimnoTech, 2012). While this is included as a Former Process Area goal, the potential for habitat improvement originates in the Estuary. Thus, this goal is described in further detail along with the Estuary goals in Section 3.4.3.

3.4 Estuary Remedial Action Considerations

Similar to the Former Operations Area of the Site, the Estuary Site will have specific remedial action considerations in addition to the overall RAOs. The RAOs and considerations will need to be met for the Project to achieve the overall vision for success. The Estuary-specific considerations will include:

- Reduce beneficial use impairments for St. Louis River Area of Concern
- Improve habitat (betterment)

The Estuary RAOs and considerations are described in further detail in the following paragraphs.

3.4.1 Protection of Human Health and the Environment

The RAO for protection of human health and the environment includes the development of Project-specific, numeric criteria that will adequately protect future human and ecological users of the estuary resources while also improving the overall use of the area. These two topics are discussed separately in the following sections.

3.4.1.1 Human Health Risk Evaluation

Potentially complete exposure pathways for human exposure were presented in the Human Health Risk Evaluation (HHRE) in the RI (Barr, 2013a). These pathways included:

- Incidental ingestion or inhalation of sediment containing COIs while wading or swimming;
- Dermal exposure to sediments; and
- Fish consumption.

The HHRE concluded that adverse human health effects from exposure to sediment by incidental ingestion and dermal contact were not expected based on reasonable exposure assumptions. Potential risks are already partially controlled via institutional controls, including fish consumption advisories in the area, and additional institutional controls will be evaluated during the alternative evaluation process.

Since the completion of the RI, additional assessment of potential human health risks have been explored through the calculation of Benzo(a)pyrene [B(a)P] equivalents for a combination of exposure scenarios, and comparison of the B(a)P equivalent values to site data. As noted in the updated human health risk screening evaluation (Barr, 2014b), the Estuary Site sediments with B(a)P equivalents values exceeding B(a)P equivalents predicted to be protective of human health lie within the aerial extent of Estuary Site sediments that have the potential to impact ecological resources (as described in Section 3.4.1.2). Therefore, a remedy that reduces sediment concentrations of PAHs for ecological receptors will also reduce human health risk. Thus, the ecological risk-based limits for improvement of the Estuary Site provide the basis for the development and consideration of alternatives that could achieve the vision of success for this Project.

3.4.1.2 Ecological Risk Screening

Potential ecological exposure pathways of interest include benthic invertebrates contacting and consuming sediment and surface water; wildlife contacting or consuming sediment; wildlife consuming aquatic plants, fish, or invertebrates; and aquatic plants contacting sediment and fish. As stated in the RI (Barr, 2013a), the primary focus of sediment management activities at the Estuary Site will be to reduce the potential for unacceptable risk to these ecological receptors. This area of focus has been incorporated into the RAOs for the Project as listed in Section 3.2.

To establish numerical criteria for the RAO for the protection of potential ecological receptors within the Estuary Site, preliminary remediation goals (PRGs) were provided by MPCA (MPCA, 2014b). Project alternatives will be targeted at sediments containing COIs at concentrations exceeding the PRGs.

The PRGs were set at the midpoint between the Level I and Level II MPCA Sediment Quality Targets (SQTs) (MPCA, 2007). Level I SQTs identify concentrations for COIs below which adverse effects to benthic organisms are unlikely. Level II SQTs identify concentrations for COIs above which potentially adverse effects to benthic organisms are likely to occur (MPCA, 2007). The midpoint between these two values was chosen for PRGs to be protective of benthic receptors when applied on a point-by-point basis. The PRGs for sediment (MPCA, 2014b) are summarized in Table 3-6.

These PRGs were developed to be used within the potentially bioactive zone, which varies in thickness based on habitat type. The potentially bioactive zone is defined by the MPCA to have a specified thickness of uncontaminated ecological substrate for the viability of vegetation, benthic organisms, and burrowing wildlife (MPCA, 2014b). Depending upon the habitat type and receptors expected to be present, different substrate thicknesses were determined to be applicable as shown in Table 3-7.

3.4.1.3 Extent and Magnitude of Estuary Impacted Sediment

The lateral and vertical extent of sediment exceeding PRGs for the COIs has been defined based on a point-by-point comparison of all samples collected in the Estuary Site (Figure 3-1). The extent of sediment exceeding the ecological risk-based PRGs includes all sediment exceeding the human health risk-based values, as described in Section 3.4.1.1, and therefore also defines the area of Estuary Site sediments to be managed in order to protect human health and the environment for consideration of Project Alternatives in this FS.

3.4.2 Reduction of Beneficial Use Impairments for the St. Louis River Area of Concern

Because the Site is located within the St. Louis River Area of Concern (AOC), remediation work, once completed, is anticipated to positively aid efforts by resource management agencies to address beneficial use impairments (BUIs) in the larger AOC. Identifying Project Alternatives that meet the RAOs and also have the potential to reduce BUIs within the St. Louis River AOC is an important goal for this Project. The current BUIs include the following (LimnoTech, 2013):

- Restrictions on fish and wildlife consumption
- Excessive loading of sediment and nutrients
- Degradation of fish and wildlife populations
- Beach closings
- Fish tumors or other deformities
- Degradation of aesthetics (this BUI was removed August 29, 2014)
- Degradation of benthos

- Restriction on dredging activities
- Loss of fish and wildlife habitat

These BUIs are related to the presence of COIs from various sources along the river, as well as physical loss and degradation of habitat in some portions of the AOC. The AOC will be delisted when these beneficial uses have been restored, as indicated through achievement of established delisting targets (LimnoTech, 2013).

COIs in sediment at the Site contribute to beach closings, degradation of aesthetics, degradation of benthos, loss of fish and wildlife habitat, and to restrictions on fish and wildlife consumption. Sediment management and remediation at the Site will be designed to address local contributions to these BUIs, as outlined in Section 3.4.1.2 for protection of ecological resources, and will therefore support removal of BUIs and ultimate delisting of the larger Area of Concern. It should be noted that the work at the Site can only address these issues within the Site and immediate local area, while the AOC covers a much larger area that encompasses impacts and BUI issues not related to, or within the scope of the subject Site remediation plans.

3.4.3 Improve Habitat (betterment)

The Habitat Characterization Report (Barr, 2013b) found that the Site contains a variety of aquatic, shoreline, and terrestrial habitats with varied quality. The Unnamed Creek shoreline was observed to have better habitat quality, with dense vegetation and a high level of species diversity. Lower quality habitat was observed along the shoreline of the Wire Mill Pond, with low diversity of vegetation. Non-native, invasive species were observed onshore in both areas.

Habitat betterment components consistent with the Spirit Lake Conceptual Habitat Restoration Plan (LimnoTech, 2012) could be incorporated in the selected alternative to provide a shoreline that is similar to native estuary shorelines and a productive substrate for local flora and fauna. The habitat betterment components for the selected alternative will be discussed in more detail in the proposed Project plan. The subsequent Project design will likely include both the habitat enhancement components and habitat mitigations, if necessary, as determined during Project permitting.

Potential betterment components that could be incorporated into the Project are included in the alternative screening and detailed analysis evaluation processes (Sections 4 and 5).

3.5 Other Project Considerations

In addition to the primary objectives of protecting human health and the environment, reducing beneficial use impairments, improving the habitat of Spirit Lake, and providing for future economic development; the Project will consider several other factors including:

- Consideration of cultural and recreational values for the region;

- Providing an example for future sediment projects by considering green and sustainable principles;
- Consistency with U.S. EPA's Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites, OSWER Directive 9285.6-08 (EPA, 2002);
- Complying with environmental review and oversight requirements; and
- Maintaining a Project Schedule that will facilitate completion of the Project in the GLLA program.

Each of these items is described below.

3.5.1 Consideration of Cultural and Recreational Values

The cultural significance of Spirit Lake is an important factor to consider in developing the vision for the overall success of this Project. The Site is adjacent to Spirit Island, owned by the Fond du Lac Band of Lake Superior Chippewa, which is an important part of the history of the Ojibwe people and considered a sacred place (LimnoTech, 2012). Spirit Island and the lands owned by the Fond du Lac Band of Lake Superior Chippewa are beyond the Project Area and are not anticipated to be directly affected by a potential Project remedy.

The Estuary also hosts a variety of potential recreational activities, including boating, fishing, and bird watching. To provide the opportunity for continued recreational activities in the Estuary, the selected alternative should be compatible with these and other outdoor activities. The constructed Project at the Estuary site could have the potential to increase public access to natural areas of the Site, and this factor will be evaluated during design.

Two distinct bathymetric depression features at the Site are considered important for recreational fishing. The first is a bathymetric "hole," which has greater water depths than the surrounding nearshore areas, located near Wire Mill Delta. This depression was created by dredging for a water intake and currently is used recreationally for fishing. The second bathymetric feature is a remnant channel on the north side of the Project footprint. This channel has remained largely unchanged likely due to seiche events from the north minimizing sedimentation and filling of this feature over time. Both of these features should be maintained to the extent practical when considering the Project alternatives.

3.5.2 Consideration of Green and Sustainable Principles

Conservation of natural resources, waste minimization, and reduced energy consumption are all important factors to be considered in the selection of the Remedial Alternative for the Project. When applied to environmental improvement projects, conservation and impact minimization concepts are often referred to as "green remediation." EPA guidance identifies many concepts for making remediation greener (EPA, 2010). Examples include:

- Conservation of natural resources;
- Reusing materials otherwise considered waste;

- Maximizing energy efficiency;
- Decreasing air emissions;
- Conserving water resources;
- Planning work to include consideration of green practices materials; and
- Helping to increase the understanding and awareness of green technologies.

As stated above, goals for this Project include habitat enhancement. While the Project will involve some disturbance of natural resources at the Site during construction, it will produce overall benefits for fish and wildlife, and will improve plant communities, in the estuary. It is anticipated that the Project will create additional habitat and recreational opportunities that do not currently exist. Measures may also be taken to minimize the amount of waste requiring disposal, and thus reduce the amount of energy used and air emissions produced in transporting. Waste minimization should be balanced with requirements to ensure that the Project objectives are achieved. Opportunities to optimize water conservation during the Project will also be assessed.

Specific opportunities for green remediation will be incorporated into the Project alternatives as appropriate. These may include methods for increasing energy efficiency, decreasing air emissions, planning with green concepts in mind, and increasing public awareness. These and other green remediation components can produce environmental benefits when their use is balanced with remedy protectiveness, implementability, and cost. Careful consideration must be given to where and how green components can be incorporated, while maintaining compatibility with the Project objectives, with regulations, and with Project schedule and budget.

3.5.3 Consistency with EPA Sediment Management Principles

The U.S. EPA has published principles (EPA, 2002) for site managers to make scientifically sound and nationally consistent risk management decisions for impacted sediment sites. This OSWER Directive presents eleven risk management principles that were used to develop and evaluate the Estuary sediment remedies discussed in Sections 5 and 6.

3.5.4 Compliance with Oversight and Environmental Permitting Requirements

Oversight and permitting of the Project could include Federal, State, and Local provisions. The potential permits that may be necessary to complete the work are presented in Appendix G.

Because the Former Operations Area Site work is being completed under the terms of a Consent Decree with the MPCA, the MPCA has the authority to waive or defer some of the administrative requirements of State permitting to facilitate the timely and efficient implementation of a selected alternative. However, substantive permit requirements will still be identified as ARARs (Appendix H). Local ordinances will still need to be followed including any potential construction permitting that may include operating restrictions to minimize noise, light, or other disruptions to the community.

Given that the Project activities within Spirit Lake are expected to affect large areas of open water and wetlands, it is anticipated that compliance with the Clean Water Act and Minnesota regulations regarding water resources and wetlands will constitute the most substantive requirements for coordination and documentation and may entail mitigation. State regulations regarding dredged material placement and federal and state disposal regulations will also require significant coordination, as will permitting of process water discharges for dredging and dewatering. Forestry, sensitive species, and cultural resources permitting/coordination will also require documentation and coordination. Section 6.2 of this FS provides a detailed discussion of anticipated permitting requirements for the preferred Project alternative.

3.5.4.1 Environmental Review

Although some permitting requirements may be waived, the environmental review process will still need to be considered for Project work at the Site. National Environmental Policy Act (NEPA) established a framework for environmental planning and decision-making by federal agencies. Federal agencies must conduct a complete environmental review prior to undertaking a major federal action, which will significantly affect environmental resources. Under NEPA, federal agencies are required to complete this environmental review by preparing either an environmental assessment or environmental impact statement, both of which assess the potential for, and significance of, environmental impacts from alternative courses of action. Federal approval of remediation activities to remove COIs from the Former Operations Area of the Site would require the preparation of either an environmental assessment or environmental impact statement depending on the significance of environmental impacts.

As part of MPCA's environmental review process, the Project will require completion of an Environmental Assessment Worksheet (EAW). This review procedure uses a worksheet with a standardized list of questions to screen Projects that may have the potential for significant environmental effects. The EAW is subject to a 30-day public review period prior to the decision on whether the Project requires an Environmental Impact Statement (EIS).

3.5.5 GLLA Scheduling Considerations

The final component of the vision for a successful Project is that the work must be completed in a timely manner. This will begin by completing this FS and all associated alternative evaluation components in a time-frame that will ensure the availability of GLLA funding for the Project implementation. The use of GLLA funding is expected to further accelerate the rate of on-site Project activities with the goal of completing all of the Project work within two construction seasons.

4.0 Technology Screening

4.1 Technology Identification and Screening Process

Potential technologies for addressing conditions at the Estuary and Former Operations Area Sites were identified through many sources, including guidance specifically developed for the remediation of contaminated soil and sediment sites (EPA, 2005; ITRC, 2014). Information collected during the RI site characterization and the development of the CSMs was used to identify feasible technologies for the Site.

The screening of potential technologies and process options for management of sediment and water impacts associated with the Site is described in Sections 4.2 and 4.3 respectively. A qualitative approach was used to screen technologies using a three-part ranking system where each technology was evaluated on protectiveness, effectiveness, implementability, and relative cost, using the following criteria:

- Effectiveness was evaluated by the predicted ability of the alternative under consideration to ensure long-term protection of human health and the environment, while minimizing short-term impacts during implementation. For this screening, effectiveness was measured by whether the technology could potentially meet the Former Operations Area RAOs or Estuary SMGs; the overarching goals for the Project as defined in Section 3. Effectiveness also considered whether a technology could incorporate habitat betterment or redevelopment of the Site.

- Implementability was evaluated by considering both the technical and administrative feasibility of a technology. Technical feasibility includes: the ability to achieve the remedial goals; the avoidance of creating additional risk during implementation (risk of remedy); the ability to handle the necessary quantities or reach required depths; the need for specialized equipment; the time needed to meet remedial goals; the degree of disruption in the Project area; and the ability to undertake an additional remedial action if the selected remedy fails. Administrative feasibility includes consideration of the permits needed for technology implementation; availability and capacity of treatment, storage, and disposal facilities; availability of required equipment or workers; and coordination with applicable agencies and stakeholders. For this screening, the implementability ranking of each technology focused on the degree of disruption in the Project area, the time needed for permitting and implementation, the estimated quantities of material handling or area required, and the need for specialized equipment or technical knowledge.

- Relative costs used for the technology screening were based on engineering judgment, rather than detailed estimates. The cost evaluation considered direct and indirect expenses such as costs for dredging and capping, transportation, treatment and/or disposal of sediment and long-term costs for operation, maintenance, and monitoring during and after the implementation of the technology.

4.2 Sediment Technologies

Technologies for addressing estuary sediment, and Former Operations Area sediment and soil, impacts were identified in USEPA guidance (EPA, 2005). The sediment technologies and other controls screened in this Section include:

- Institutional Controls
- Natural Recovery
- Capping
- Excavation and Removal
- Disposal
- In-Situ Treatment

The technology and process screening results are summarized in Table 4-1 for sediments, and soils, where appropriate. Technologies and process options deemed most favorable were retained for assembling the alternatives described in Section 5.

4.2.1 Institutional Controls

Institutional controls in the form of an environmental restrictive covenant may be needed to prevent unacceptable exposure and contact with the impacted sediment and soil or to minimize future disturbances in areas where impacts are managed in place or residuals remain at depth. Other potential forms of institutional controls may include governmental regulations or permitting limitations.

4.2.1.1 Applicability to the Former Operations Area of the Site

Former Operations Area institutional controls may include land use restrictions (e.g. restriction on types of development, excavation, etc.). Institutional controls are anticipated to be included as a component of most Former Operations Area Site alternatives; the specific restrictions will depend on the final Site alternative that is selected.

4.2.1.2 Applicability to the Estuary Site

Institutional controls are also anticipated to be included as a component of the Estuary Site alternatives. The specific restrictions will depend on the selected Site alternative. Institutional controls may include waterway use restrictions (e.g., no wake zones, no anchor zones, etc.), land use restrictions (e.g. restriction on construction of boat landings or docks), permitting restrictions on future dredging or fish consumption advisories or fishing bans (EPA, 2005).

4.2.1.3 Screening

Effectiveness: Institutional controls are effective for minimizing human exposure at the Site, and would be effective at achieving Estuary SMGs and Former Operations Area RAOs when used in combination with other remedies. Institutional controls may be used to protect the selected remedy from physical disturbance.

Implementability: Institutional controls are easily implemented in a short time frame and would not cause disruption to the site or surrounding community. However, institutional controls may limit the potential for future betterment activities in the estuary or future redevelopment of Former Operations areas.

Relative Cost: The cost to implement institutional controls alone is considered to be very low compared to other remedial approaches, with no construction costs. However, institutional controls will likely be integrated with other technologies.

4.2.1.4 Screening Results

Institutional controls are retained for the assembly of alternatives based on the likelihood that they will be a required component for use with other technologies.

4.2.2 Natural Recovery

Natural recovery (NR) is a technology that uses ongoing naturally occurring processes to contain, destroy or reduce the bioavailability of COIs by physical (burial and dispersion), chemical (sequestration and transformation), or biological mechanisms (biodegradation). NR can reduce COI concentrations to below levels of concern, but time frames can be longer.

Under the correct conditions, NR processes can be accelerated through enhanced natural recovery (ENR). In Former Operations Area sediments, ENR amendments may include a biological stimulant (i.e., a degradable carbon source) or an oxidation agent injected into the surface of the soil or sediments to enhance plant growth or other actions that would promote degradation. Accelerated remediation of deeper impacts to soil and sediment are addressed in the discussion of in situ treatment (Section 4.2.6).

In estuary sediments, ENR amendments may include a thin-layer sediment cover or injection of a carbon-based sorbent or incorporation of other materials into the sediment surface. ENR accelerates the process of physically isolating COIs that is already occurring naturally with sediment deposition. The ENR amendment speeds the development of a clean sediment layer at the surface, which results in the reduction in surface chemical concentrations and facilitates the re-establishment of benthic habitat (ITRC, 2014).

NR or ENR can be implemented as a sole technology or may be part of a larger remedy for a Site and may be combined with other technologies such as capping or removal. Institutional and/or engineering controls are commonly employed in conjunction with NR to minimize exposure during the recovery period and the potential for disruption of the natural recovery processes.

Natural recovery has the following advantages over other remedial approaches (EPA, 2005):

- It is easily implementable, and is less disruptive and expensive than sediment removal because it does not require material handling, dewatering and disposal.

- ENR quickly reduces exposure to COIs and provides a clean substrate at the sediment surface for benthic recolonization.
- NR and ENR do not result in disturbance of sediments and short term release of COIs to the water column as may occur during sediment removal.

The main limitations of NR or ENR include the following:

- COIs are left in place, so restrictions to site use, monitoring, and replenishment of an ENR cover may be needed.
- The time frame for NR or ENR to meet SMGs may be longer than for sediment removal or capping.
- Sediment stability must be demonstrated where NR and ENR are selected as the remedial technology.

4.2.2.1 Applicability to the Former Operations Area of the Site

NR is the technology selected in the ROD for Former Operation Area sediments, including sediment in the Unnamed Creek channel (OU-I, OU-L, and OU-M) and the wire mill dredge material (OU-Q) (MPCA, 1989). This initial decision was affirmed with the acceptance of a treatability study that showed limited potential for treatment of the non-native sediments in these operable units (Barr, 1990). Vegetation has returned to many of these areas over the years and some natural recovery is occurring. While the rate of recovery is slow, and could likely be enhanced with the addition of nutrients or other amendments, the potential for exposure to these areas is limited by the vegetation that has been established.

4.2.2.2 Applicability to the Estuary Site

NR is also the technology described in the ROD for estuary sediments (MPCA, 1989). NR processes have been occurring at the Estuary Site; reducing COI bioavailability and mobility, primarily by the natural deposition of new sediment layers over impacted sediments (See Section 2). However, NR on its own may not meet the MPCA PRGs (MPCA, 2014b) at all locations. NR and ENR are most applicable to areas that have very thin sediment layers where concentrations exceed the PRGs, and/or are not significantly greater than the PRG concentration levels, where the sediment bed is stable, disturbance to the sediments is unlikely, and the rate of new deposition is adequate.

4.2.2.3 Screening

Effectiveness: NR processes have been effective at achieving RAOs at a variety of petroleum-impacted sites and have been effective at achieving the estuary PRGs through sediment deposition over portions of the estuary as shown on Figure 2-8 and discussed in (Barr, 2013a). NR may be marginally effective in the Former Operations Area due to the thickness of the impacts and the limited potential for degradation in the subsurface. The PRGs could be achieved in the Estuary Site within a shorter time frame than NR by implementing ENR at additional locations. NR and ENR alone will not meet PRGs at all locations, but these technologies are considered highly effective when used in select areas of the estuary and when combined with other technologies and institutional controls.

Implementability: NR is a naturally occurring process that is highly implementable, and is likely already occurring within some areas of the estuary. Implementing ENR is expected to only cause moderate disruption relative to sediment removal and conventional capping. ENR would be technically challenging in areas of deep Former Operations Area Site sediment accumulation and consolidated coke fines, but could be implemented with standard sediment remediation equipment and resuspension controls in the Estuary Site.

Relative Cost: NR can be implemented for relatively no cost other than routine monitoring. Costs for ENR are low relative to most technologies, although somewhat higher than NR because of the enhancements that are added to the system.

4.2.2.4 Screening Results

NR and ENR are both retained for assembly of alternatives as components that may be effective in portions of the Estuary Site or in combination with other technologies, based on the likely effectiveness, implementability, and cost of this technology. However, NR and ENR are not retained for use in the Former Operations Area of the Site for assembly of alternatives, based on the limited effectiveness of this technology in the Former Operations Area Site setting.

4.2.3 Capping

Capping comprises a variety of methods of encapsulating materials under an engineered cover. Generally, capping is the process of placing sand, sediments, soil, low permeability soil, or any variety of synthetic or composite engineered fabrics over impacted materials to mitigate potential risk posed by direct contact to the impacted solid material. Capping may be either over in-situ materials or excavated and placed materials. A cap provides a physical barrier, physical stabilization, erosion protection, and chemical isolation to reduce exposure to COIs (EPA, 2005). A low permeability cap can be used with or without a liner to reduce infiltration and leachate generation.

Capping, as applied to the Former Operations Area of the Site, may be either in-situ or in a designed consolidation cell. Capping is a well-established technology and is used for a variety of solid waste and mono-fill applications.

Capping, as applied to the Estuary Site, generally consists of natural granular material including clean sediment, sand or gravel. Sediment caps may also be constructed of synthetic materials including geotextiles, liners, and reactive or absorptive media. A cap may consist of multiple layers for optimal functionality (ASCE, 2007). When choosing capping materials, the following four main factors are considered: physical and chemical compatibility with the existing sediment, geotechnical compatibility, placement methods, and performance objectives.

Sediment capping can be implemented as a sole technology, or in conjunction with other technologies. To minimize cap disturbance and prevent future human or ecological exposure to the COIs, institutional or engineering controls are often employed, which may include restrictions on access and future dredging.

4.2.3.1 Applicability to the Former Operations Area of the Site

The primary risk factors for Former Operations Area soil and sediments are direct exposure and the potential for movement into the estuary. Capping is an acceptable method to control direct exposure to contaminated materials and prevent erosion of the capped material.

The main limitations of capping in Former Operations areas include:

- Water courses are subject to wide variations in flow due to storm events potentially requiring armoring or other methods to control erosion.
- Capping in the Former Operations areas will be designed with consideration of potential development opportunities.
- COIs are left on site, so restrictions to site use, monitoring, and maintenance are needed to ensure the cap is not disturbed and remains an effective barrier.
- Caps may alter conditions in the stream or wetland flow patterns, and habitat.

4.2.3.2 Applicability to the Estuary Site

COIs at the Estuary Site are low in solubility and mobility, which makes a granular cap an effective means of preventing exposure to COIs by potential receptors. The MPCA has identified potentially bioactive zone (BAZ) thicknesses that need to be considered at the Site when evaluating capping. These thicknesses (50 cm to 120 cm) are based on habitat zone, water depth and substrate that must remain below the sediment PRGs listed in Section 3 following remedy implementation (MPCA, 2014b). These capping thicknesses could be met in various areas of the estuary, either alone, or in some shallow locations removal would need to precede cap placement so that the necessary cap thickness may be placed while still maintaining an acceptable water depth for the desired habitat.

As described in the CSMs in Section 2, the hydrodynamic conditions at the Site are relatively stable with limited potential for sediment transport in the Wire Mill Delta due to the protection from wind-driven waves, and little to no sediment transport observed in Unnamed Creek Delta due to wave action effects being primarily in the foreshore. Cap erosion under such conditions is not a significant concern compared to high velocity flow conditions that exist in many river systems.

Sediment capping has the following advantages over other remedial approaches (EPA, 2005):

- It immediately reduces exposure to COIs and provides a clean substrate at the sediment surface for benthic recolonization.
- It is less disruptive and less expensive than sediment removal because it does not require material dewatering and disposal.
- Resuspension of impacted sediment is less likely during cap placement than during sediment removal.

The main limitations of sediment capping include the following:

- COIs are left in place, so restrictions to site use, monitoring, and maintenance may be needed to ensure the cap is not disturbed and remains an effective barrier.
- Caps may alter conditions in the water body such as navigation depths, flow patterns, and habitat.

4.2.3.3 Screening

Effectiveness. Capping has the potential to significantly reduce long term exposure pathways from impacted sediments at the Site, by isolating impacts from potential receptors. Short-term impacts from capping may include transient movement of porewater from impacted sediment into the cap during placement. An effective cap material, thickness, and maintenance program can be selected to meet the Former Operations Area and estuary remediation goals and prevent future erosion. Capping is considered a highly effective technology for both the Former Operations and Estuary Sites.

Implementability. Caps can be installed with standard construction and remediation equipment. Depending on proposed water depth and habitat zone, temporary or permanent surface water diversion may be needed during construction. Capping is considered more easily implemented than sediment removal and disposal, but less easily implemented than institutional controls alone. Capping in the estuary will require resuspension controls. Depending on proposed water depth and habitat zone, some dredging may also be needed to accommodate the required cap thickness. Erosion and maintenance of a cap at the Estuary Site would be manageable considering the relatively stable hydrodynamic conditions. For both the Former Operations Area and the Estuary, capping is considered more easily implemented than sediment removal and disposal, but less easily implemented than natural recovery or institutional controls alone. The treatability study (EA, 2014) and geotechnical evaluations (AECOM, 2014 and Barr, 2014c) indicate that capping is a feasible remedial element.

Relative Cost. Costs for capping are dependent on cap thickness, materials, and surface water engineering factors. Relative costs for capping are considered moderate; less than for sediment removal and disposal, but significantly more than natural recovery or institutional controls.

4.2.3.4 Screening Results

Capping is retained for assembly of alternatives based on the likely effectiveness, implementability, and cost of this technology for both the Former Operations and Estuary Sites.

4.2.4 Excavation and Removal

Excavation can be used to remove soil from Former Operations areas and sediment from a stream channel or wetland. Excavation is a proven technology for removing impacted soil and sediment. For the Former Operations Site, sediment removal would consist of mechanical excavation using standard construction equipment. Control measures such as containment barriers, stream diversion, and cofferdams would be used to minimize sediment migration and control stream flow during excavation activities. Excavation would require dewatering and disposal of the removed sediment (EPA, 2005). Some key considerations for excavation include the assessment of the physical environment (e.g., storm water flow, surface water diversion or damming, and habitat alteration).

Dredging would be used to remove sediments from the Estuary Site. Dredging is a proven technology for removing impacted sediments. Sediment removal can be completed using a hydraulic dredge, or mechanically, using excavation equipment. Dredging can be completed while sediment is submerged (wet) or when water is removed from the dredging area (dry). Control measures such as silt curtains, air bubble curtains, or containment barriers would be used to minimize sediment migration during dredging activities. Dredging is frequently paired with a residual cover or NR to manage dredge residuals that will remain after dredging (USACE, 2008) and typically requires dewatering and disposal of the removed sediment (EPA, 2005). Some key considerations for dredging include the assessment of the physical environment (e.g., bathymetry, sediment materials, presence of debris or hard pan, and depth), resuspension controls, required dredging accuracy, waterway uses and infrastructure, and habitat alteration.

Mechanical dredging of wet sediments removes sediment through mechanical force, typically an excavator or crane equipped with a traditional or environmental bucket placed on a working barge. Sediment is lifted to the surface with approximately the same moisture content as in situ material and placed on a transport barge. Mechanical dredging is often needed for the removal of large debris, cemented material, or in tighter spaces, where access with hydraulic dredge equipment and associated pipelines may be difficult. Mechanical dredging typically results in higher sediment resuspension rates than hydraulic dredging, although environmental dredge buckets can be used to reduce resuspension (ITRC, 2014).

Mechanical removal of sediments can also be completed under dry conditions, after water has been diverted or drained from the removal area following construction of a containment barrier such as a cofferdam. Typically this technology is limited to shallow areas and smaller sized projects. Dry removal has been used successfully on a number of projects and greatly reduces the potential for resuspension of sediment when compared to wet dredging. Dry removal allows for visual inspection of the work area, use of more traditional excavating equipment, and less sediment dewatering than wet dredging. However, there have been issues with dewatering the sediment enough to effectively excavate and handle the material at a number of sites.

Hydraulic dredging removes and transports sediment in the form of a slurry using large volumes of water in the process. Slurries from hydraulic dredging therefore have higher water content than mechanically dredged sediments, requiring more space and time for dewatering and water management. Many types of hydraulic dredging equipment are available, and are selected to meet site-specific needs, sediment characteristics, transportation requirements, accuracy levels, removal depths and production rates, with cutterhead equipment being the most commonly used (EPA, 1994 and 2005). Hydraulic dredging equipment can typically achieve overall higher production rates than mechanical dredging, especially when used to dredge very large volumes of sediment (EPA, 1994). Hydraulic dredging is also beneficial over mechanical methods in cases where the dredged sediment needs to be transported a large distance to the disposal site.

Advantages to sediment removal over other remedial technologies include:

- COIs are removed, reducing the uncertainty associated with long term effectiveness.
- Removal of COIs allows for more flexibility and fewer restrictions for future betterment or redevelopment activities compared to capping or NR, which require monitoring and management.

General disadvantages of sediment removal include:

- Mobilization of previously contained COIs may occur, resulting in impacts to the water column and remobilization and deposition of COI-impacted sediment in previously clean areas.
- Management and disposal of sediment is necessary; requiring dewatering, a disposal site and transportation, which add complexity, cost, and duration to a project compared to in-situ treatments such as NR or capping. Hydraulic dredging can generate a large quantity of water that may create a bottleneck in the on-shore processes (depending on the availability of drying and staging areas) that can cause significant delays and require permitting and treatment prior to discharge.
- Disruption to the site is significantly greater than for in-situ technologies because of sediment removal, handling and disposal requirements.
- Disruption of the wetland or stream environment is unavoidable during excavation.
- A residual sediment cover is generally required because it is not technically feasible to remove all sediment without some quantity of residual remaining.

4.2.4.1 Applicability to the Former Operations Area Site

Complete or partial excavation could be one component of the remedial alternatives for the Former Operations Area. It may also be combined with capping, where sediment is removed to a set elevation to achieve a specified barrier thickness, topographic slope or other physical need.

Selection of the most appropriate excavation method would depend on the size of the area to be excavated, the final disposal method of removed sediments, and geotechnical considerations for the final stream channel or wetland. A residual cover may be needed in some areas to manage residuals that may remain after excavation.

4.2.4.2 Applicability to the Estuary Site

Sediment removal could be one component of the remedy used for the Estuary Site sediments. Removal would also allow for adequate depths for capping to meet the required potential BAZ thicknesses in some areas of the Estuary Site (MPCA, 2014b).

Sediment resuspension control measures would be needed to control mobilization of COIs during dredging, based on dredging elutriate testing results (EA, 2014). Mechanical dredges typically limit resuspension of fines and contaminants from sandy sediments, while hydraulic (cutterhead and plain suction dredges) limit resuspension of very soft, fluid sediments (ITRC, 2014). Estuary Site sediments are soft, so proper selection of dredging equipment and control measures would be needed (EPA, 1994 and 2005).

Selection of the most appropriate sediment removal method for the Site will require further assessment of site-specific conditions, including the physical characteristics of the sediment bed, time and space available for sediment and water management, the volume of sediments that would be removed and the feasible disposal options. Based on these aspects, mechanical removal, under wet or dry conditions, may be more applicable for sediment removal from the Estuary Site for the following reasons:

- Large debris in areas of the Wire Mill Delta, and cemented non-native sediment layers in Unnamed Creek Delta may require removal using mechanical methods. If hydraulic dredging is used at the Estuary Site, it would likely require removal of debris prior to dredging and would only be implementable to areas that do not have cemented sediments.
- Mechanical removal may require less water management than hydraulic dredging, reducing the water treatment costs and space required for sediment management and disposal.
- Efficiencies gained from hydraulic methods versus mechanical methods may not be realized for this Site because of the moderate volume of sediments anticipated for removal. However, the dredging type applicable for the Site will be evaluated during design.
- Hydraulic dredging is generally beneficial over mechanical methods when sediments are transported a large distance through a pipeline to the disposal site, since there is less material handling and transportation required. This is not the case for this Site, because the potential dredged sediment disposal areas being considered are relatively close to the removal areas.
- Mechanical removal in dry conditions may be implementable in some areas of the Site, including the Unnamed Creek Delta, where the geometry and shallow depth of the delta allows for construction of a containment barrier and diversion of water.
- Sediment resuspension control measures will likely be needed to control mobilization of COIs during dredging, based on dredging elutriate testing results (EA, 2014).
- A residual cover may be needed in some sediment removal areas to manage dredge residuals that may remain after dredging.

4.2.4.3 Screening

Effectiveness: Excavation and removal is considered a proven and effective method for removing impacted soil from Former Operations areas and sediment from wetland, stream channels areas, and the estuary for subsequent management and disposal. Removal will achieve the Former Operations Area and Estuary RAOs.

Implementability: Excavation and removal can be implemented in both the Former Operations Area and Estuary Sites. Excavation at the Site is implementable using standard civil engineering methods and controls. Contractors are available with the equipment and expertise to work with the types of materials expected in the Site. However, excavation in wetland areas would require permitting. Dry removal of sediments may be feasible in portions of the Unnamed Creek Delta, where the construction of a containment barrier and water diversion could be implemented. In open water portions of the Estuary, dredging in wet conditions is considered to be implementable at the Site. This work would require specialized equipment and skilled dredge operators. Significant permitting would be necessary to implement sediment removal. Soil and sediment removal could cause significant short-term disruption to the Site and would require erosion control measures in Former Operations areas, resuspension control management, sediment handling, and dewatering activities. Hydraulic dredging alone is not considered feasible at the Site due to the presence of debris and cemented non-native sediments. Overall, excavation and removal are more difficult to implement than all other non-invasive technologies.

Relative Cost. In general, excavation and removal costs are significantly higher than response actions where soil or sediment is managed in place due to the subsequent costs associated with sediment management and dewatering, water treatment, transportation, and disposal. At this Site, costs for mechanical dredging would likely be less than hydraulic dredging because mechanical methods would also need to be employed to remove debris and cemented sediment, and the disposal space and water treatment requirements are less with mechanical means compared to hydraulic dredging.

4.2.4.4 Screening Results

Excavation and removal, including mechanical and hydraulic removal of sediments under both wet and dry conditions, is retained for assembly of alternatives for the Site, as these methods would be effective at meeting Site RAOs.

Management and disposal of sediment and water is necessary following removal of sediments from wet areas. These steps generally include dewatering, transport to a disposal site, material handling and placement at the final disposal site. The sequence and methods used for sediment management will depend highly on the removal method and the disposal site location and design.

4.2.5 Sediment Containment and Disposal

Containment of soils and sediments may occur at an offsite location such as an existing permitted landfill or at a facility constructed onsite.

Off-site containment (i.e., disposal) involves transporting soil or sediment to an existing off-site disposal location. Removal, dewatering, and applying reagents to bind any free-liquids, as necessary, are generally the only actions required before transport and disposal at most landfills. Truck traffic volume at the Site and surrounding community may be disruptive, and could create noise and emission concerns or damage to existing roads. Temporary roadways are often constructed onsite specifically for sediment transport.

On-site disposal can be accomplished in different areas relative to the water body—in upland or near-shore area or sub-aqueously in the estuary. An on-site containment area may have different engineering requirements based on the choice of location and the nature of the material that is placed, and ultimately managed, in the containment system.

Consolidation with a simple cap may be used for materials that are relatively immobile and where direct contact is the primary mode for potential exposure. More complex engineered structures may be needed where water management is likely to be required over a longer duration or where slope stability needs to be considered, due to the height of the consolidation material. For example, consolidation of removed materials along the upland portion of the existing spit-of-land could take advantage of the existing geography and shallow depths to reduce construction and water management needed.

Confined Disposal Facilities (CDFs) are a widely used disposal technology for impacted sediments from both navigation dredging and remediation projects (EPA, 1994). The goal of confined disposal is to physically isolate and contain excavated sediments. Because of the nature of excavated sediment, a CDF must be designed to provide for placement of sediments and treatment of the effluent water. For example, hydraulically dredged material has higher water content than mechanically dredged material, and may take much longer to dewater before a CDF can be covered and closed. Design of a CDF requires detailed knowledge of the characteristics and quantity of impacted sediments. The CDF design must result in a stable structure, considering the geotechnical properties of the sediment. Effluent from sediment placement often requires treatment. Leachate and runoff must also be assessed and potentially managed.

Confined aquatic disposal facilities (CADs) are used to place and cap materials in a natural or excavated depression under the water, providing containment of the material. Design of a CAD facility requires detailed knowledge of the quantity and type of impacted sediments as well as hydraulic conditions. CAD areas may require a monitoring program to ensure COIs are effectively immobilized and have similar limitations as conventional sediment caps (Section 4.3.3). Materials used for construction should also prevent lateral migration.

4.2.5.1 Applicability to the Former Operations Area of the Site

Areas are available at the Site to accommodate a CDF for the estimated volumes of sediment being considered for removal from the Former Operations Site areas and the estuary. The CDF could be a repository located solely in an Former Operations area, or may cover both Former Operations are and near-shore shallow estuary zones.

4.2.5.2 Applicability to the Estuary Site

Areas are available in the Estuary Site to accommodate a CAD for a portion of the estimated volumes of sediment being considered for removal. These locations include the water intake hole in the Wire Mill Delta and the dredged channel in the Unnamed Creek Delta habitat.

4.2.5.3 Screening

Effectiveness. On-site or off-site disposal of Site sediments would be effective at achieving remediation goals since the sediments would be removed. An on-site CDF located in an Former Operations Area or near-shore area could effectively mitigate human and ecological exposure to COIs if designed to appropriately contain COIs. Wastewater created during the dewatering process would likely require treatment.

Implementability. Construction of a CDF would cause short-term disruption at the Site and would create permanent structures that would require long-term maintenance and monitoring. Although subaqueous disposal in a CAD in a natural depression would create less Site disruption and would have lower relative costs than a CDF, an existing, suitable location for a CAD that could accommodate the anticipated removal volumes without impacting fish habitat is not available in the estuary. Dredging to form a CAD is also not considered to be cost effective. Off-site disposal is implementable, given the Site is generally accessible for off-site transportation of sediments, but truck traffic would cause disruption to the Site and surrounding community and additional dewatering would be required prior to off-site transport. A potential benefit to locating a CDF on-site and in a near shore area would be the ability to place it over impacted sediments, thereby reducing the volume of sediments and water required to be removed, managed, and transported to another location. A preliminary evaluation of geotechnical and treatability considerations associated with construction of an on-site CDF was also conducted (AECOM, 2014 and Barr, 2014c). Both studies supported the conclusion that CDF construction was implementable as a remedial technology. Placement of a CDF in a near-shore area may require additional consideration of storm water controls.

Relative Cost. Relative costs for containment and disposal depend highly on the volume of sediment to be managed as well as the proximity of the disposal site relative to the removal area. In general, off-site disposal is more costly than on-site due to the cost of transportation, disposal fees, and significant material dewatering and handling. However, landfill costs may be off-set by construction costs for on-site disposal areas depending on site constraints. Cost for components of an onsite CDF/containment area, or repository can be substantial, and may include design, sediment dewatering, construction equipment, construction materials, containment structures (berms), and operation of a water treatment system for the effluent from sediment dewatering.

4.2.5.4 Screening Results

On-site disposal in a CDF is retained for the assembly of alternatives for the Site. Feasible disposal site locations could include an upland repository in the Former Operations Area, or areas above existing sediments, provided storm water can be properly managed.

On-site disposal in a CAD is not retained for the assembly of alternatives for the Site because of the limited volume available for disposal underwater and the loss of fish habitat that would result from placing a CAD in water intake hole in the Wire Mill Delta and the dredged channel in the Unnamed Creek Delta.

With the exception of elevated lead levels in dredge spoils within OU-Q, off-site disposal is not retained for the assembly of alternatives for the Site because of the additional handling, transportation and disposal costs and Site and community disruption.

4.2.6 In-Situ Treatment

In-situ treatment of sediments currently is less common than in-situ treatment of soils because these methods are much more difficult to implement and monitor in subaqueous environments. However, recently the effectiveness and implementability of some subaqueous in-situ remedies (especially use of activated carbon) have been demonstrated. In-situ treatments typically result in less disruption to the site when compared to excavation or removal and may be completed within a shorter time frame in comparison to natural recovery. The following in-situ treatment technologies were reviewed for consideration in the assembly of alternatives for the Site:

- Immobilization
- Enhanced Bioremediation
- Oxidation/Reduction
- Chemical Oxidation
- Phytoremediation
- Adsorption

Immobilization: In-situ immobilization treatments involve the addition of chemicals and/or solidification products to bind with impacted materials and reduce the leachability of COIs. Immobilization can be achieved by two mechanisms: solidification or stabilization. Solidification encapsulates impacted sediments to form a solid material restricting COI migration by decreasing the amount of surface area available for leaching. Stabilization is a process which involves chemical or adsorbtive reactions to convert COIs into less soluble, less mobile, and less toxic forms and may change the physical characteristics of the COIs.

Enhanced bioremediation uses microorganisms, either native to the site or introduced, to degrade organic contaminants. Nutrients, oxygen, or other amendments may be added to accelerate the process.

Oxidation/reduction is the addition of chemicals capable of serving as an oxidant or electron acceptor to facilitate aerobic decomposition.

Chemical oxidation involves the use of chemical additives to transform, degrade, or immobilize organic contaminants. Common oxidizing agents include ozone, hydrogen peroxide and permanganate.

Phytoremediation uses trees, grasses, or high-biomass crop species to remove, transfer, stabilize, or destroy COIs.

Adsorption. As with ex situ treatment of water, adsorbents can also be used as sediment amendments for in-situ treatment of COIs. It is possible for sorption of metals and organics to take place simultaneously with a suitable combination of sorbents, such as adding ion exchange materials to activated carbon. However, it is unknown if amendments would affect activated carbon’s sorption capacity.

4.2.6.1 Applicability to the Former Operations Area of the Site

As a requirement of the MPCA ROD for the Site, research into innovative and alternative treatment methods for Former Operations Area (and estuary) sediments was conducted and submitted to the MPCA (Barr, 1990). The results of this work showed that in situ treatments, especially bioremediation, had limited potential for success at the Site given the concentrations of the COIs and the physical nature and subaqueous setting of the materials.

Physical in-situ treatment, solidification and stabilization, was used to treat Former Operations Area sediments within the Unnamed Creek channel (Geraghty & Miller, 1996). The soil and sediment within a portion of the channel (referred to as Operable Unit J) was successfully stabilized in-situ and subsequent monitoring of this area suggests that this work was effective at immobilizing the COIs present within this former operable unit. While this work was effective, completing this remedial effort required overcoming several challenges including the restrictions to storm water and the consistency of the stabilized mixture. The stabilized material met both structural and hydraulic conductivity specifications.

4.2.6.2 Applicability to the Estuary Site

Until recently, in-situ treatment options had been considered less proven in the estuary environment but recent advancements in the use of activated carbon at sediment sites have shown promise. In-situ technologies tend to work best in well-controlled areas, where the treatment materials can be introduced to the impacted sediment in doses sufficient to cause the desired effect. Challenges to implementing in-situ treatments at the Estuary Site based on site-specific conditions include:

- Uncertainty due to difficulty with delivering the appropriate quantity and distribution of chemicals or amendments to the treatment zones.
- Addition of chemicals may alter the habitat or be toxic to benthic and aquatic organisms in the estuary.
- The physical characteristics of the sediments not supporting biological technologies.

4.2.6.3 Screening

Effectiveness: Site-specific treatability testing would be needed to determine whether in situ treatment could be feasible at locations on the site other than those where this technology has already been implemented. The previously completed in-situ treatment in the Former Operations Area of the Site resulted in a modification of the surface water system in the Unnamed Creek and therefore, evaluation of the potential effects would need to be evaluated. There are limited areas in the Estuary Site where physical conditions would allow enough control of the in-situ treatment material application to effectively remediate impacted sediment

Implementability: In-situ treatment has been successful implemented on the Former Operations Area Site and could be used with additional evaluation and treatment testing of the proposed soil or sediment. The implementability of in-situ treatment options for Estuary Site sediments is considered low because adequate distribution of the treatment media to the appropriate location is difficult in a dynamic estuarine environment.

Relative Cost: The cost for in-situ treatment options may be higher than those for conventional capping or removal, depending on the type and quantity of chemicals or amendments required for treatment and possibility of reapplication(s). While in-situ treatment could be less costly than removal in some applications, the lower certainty regarding effectiveness and implementability of application and the possibility that additional technologies may be needed to meet RAOs, reduces the feasibility of this technology, especially for the Estuary Site.

4.2.6.4 Screening Results

Given the uncertainty of application success and the potentially greater cost compared to capping or removal and consolidation, in-situ treatment was not considered for further evaluation in the Estuary Site. In-situ treatment may be further evaluated for application in the Former Operations Area of the Site.

4.3 Water Management Technologies

Water will need to be managed with both the Former Operations Area and estuary sediment management activities. Technologies for management of water that are considered in this screening evaluation include:

- Surface Water Engineering
- Water Management

The technology and process screening results for water management technologies are summarized in Table 4-2. Technologies and process options deemed most favorable were retained for assembling the alternatives described in Section 5.

4.3.1 Surface Water Engineering

Surface water engineering comprises a broad group of approaches to manage the flow of surface water. Surface water engineering would be combined with one or more remedial technologies as part of an overall remedy to either remove or physically stabilize impacted sediments. Due to the relatively wide range of storm water flows, particularly in the Unnamed Creek, some manner of surface water engineering is necessary for a successful Project. The surface water engineering technologies that could be used include:

- Stream Channelization: This would include regrading the Unnamed Creek stream channel to direct flow away from contaminated areas, and to control sediment transport; using features similar to a natural stream channel. Stream channelization may also include liner materials and geotextiles for sediment control;
- Stream Culverting: This engineering approach would include installing a culvert pipe or other engineered structure to carry water over or through a contaminated area; and

- Stream Diversion: This approach would include relocating all or a portion of the stream channel away from a contaminated area.

Surface water engineering offers the following advantages compared to the current Site conditions:

- Allows for a range of consolidation and capping remedies to be considered;
- Can minimize dewatering during excavation;
- Allows for potential future habitat/scenic value improvement (betterment); and
- May be used to improve site hydraulics and minimize erosion.

The main limitations of surface water engineering in Former Operations areas include the following:

- Former Operations Area water courses are subject to wide variations in flow due to storm events requiring potentially larger structures which result in more effort for work sequencing and contingency during construction;
- A high level of short term disturbance is required to the flow system during construction; and
- The methods require modifications to existing flow patterns and habitat.

While it is not possible to move the entire watershed, it may be possible to consider up-gradient diversions that could limit the volume of water that would need to be conveyed through the Unnamed Creek channel over the long-term. An up-stream approach to managing water could minimize the potential for scour or erosion during future storm events and would provide a more stable remedy for the long-term.

4.3.1.1 Applicability to the Site

Due to the presence of active stream courses at the Site, some degree of surface water engineering will be necessary for all but the no action alternative.

4.3.1.2 Screening

Effectiveness: Channels, culverts and diversions are well established tools of civil engineering and are highly effective in managing surface water flow and erosion.

Implementability. Channels, culverts and diversions are well established tools of civil engineering and are implementable using standard methods for both design and construction. Permitting is necessary for disturbing wetlands and modifying storm water flows.

Relative Cost. Costs are highly design specific for any type of surface water engineering.

4.3.1.3 Screening Results

Surface water engineering is retained for assembly of alternatives based on the likely effectiveness, implementability, and cost of this technology.

4.3.2 Water Management

Dewatering technologies are typically needed to prepare excavated or dredged sediments for disposal. Dewatering simplifies handling and transportation and reduces the volume and weight of sediments, reducing disposal costs. Dewatering is expected to be a more significant requirement for the estuary sediments due to the setting and volume. Dewatering sediments reduces the capacity and area needed for an on-site disposal facility and improves material handling, stability and strength.

Dewatering processes applicable to excavated sediments include passive dewatering, reworking sediments, hygroscopic amendment addition, and mechanical dewatering methods. Passive dewatering relies on natural evaporation and drainage and requires construction of a staging area and time to implement the drying process. Due to the generally fine-grained nature of the sediments in both estuaries, passive dewatering would likely require supplementation with another dewatering process option. Preliminary testing of potential drying methods including Calciment and Portland cement have been completed and are described in more detail in Section 5 (EA, 2014).

Sediment reworking with mechanical equipment is often employed to promote drainage and enhance passive dewatering methods. Dewatering can also be enhanced by mixing dredged sediments with hygroscopic amendments to absorb the water and remove moisture. Use of amendments can also provide geotechnical benefits to a disposal area, for example, increasing strength and stability of the sediment. Mechanical equipment containing presses and plate filters can also be used to press or squeeze water from dredged sediments. Mechanical dewatering generally works best with a homogeneous waste stream and constant flow rate, so temporary storage in a tank, lagoon, or CDF would be necessary to equalize flows and concentrations prior to further dewatering by one of the mechanical processes (EPA, 1994). Use of mechanical dewatering methods would decrease the amount of time and size for a CDF, but involve additional costs for equipment, infrastructure and energy use.

Other dewatering methods are typically employed for sediments that are hydraulically dredged. These include rapid dewatering systems that use mechanical and polymer treatment, geotextile tubes with polymer treatment and gravity separation and dewatering. Because these processes are specifically applicable for hydraulic and not mechanical dredging methods, they will be considered further during design if hydraulic dredging is identified as a potential sediment removal method.

Water removed during sediment management and disposal processes typically require treatment prior to discharge to remove COIs in the wastewater stream and to meet other National Pollutant Discharge Effluent Standards (NPDES). Water treatment technologies can range from filtration to remove solids and use of absorptive media to remove dissolved phase contaminants to methods designed to target specific COIs such as bioreactors and advanced oxidation.

4.3.2.1 Applicability to the Site

Passive dewatering methods would be appropriate to use at an on-site disposal facility, but would likely require sediment mixing, reworking and/or hygroscopic amendment addition to facilitate timely and adequate dewatering given the fine-grained Estuary Site sediments. The specific dewatering method and type and amount (if any) of amendments required would be identified during a detailed design or refined during implementation.

Dewatering effluent will likely require treatment prior to discharge based on effluent elutriate test results (EA, 2014). Wastewater treatment processes applicable for the Site COIs may include use of flocculants or filtration to remove COIs sorbed on suspended solids, and/or liquid adsorption which uses an absorbent media to adsorb dissolved phase COIs from the wastewater stream. Bioreactors and advanced oxidation can be used to treat organics, but are not effective at removing metals.

4.3.2.2 Screening

Effectiveness: Passive dewatering methods, combined with sediment reworking are deemed effective processes and applicable to the on-site disposal options being considered. Effective water treatment options are available to remove COIs from effluent water. The need for a water treatment system would be identified and the appropriate treatment equipment and media would be selected during detailed disposal facility design.

Implementability: The required dewatering and water treatment processes are highly implementable at the Site and could be performed within the space available, near or within an on-site disposal facility. Standard filtration and adsorption methods could be used for water treatment of the site COIs, requiring technical knowledge, but no highly specialized equipment.

Relative Cost: Costs for dewatering for on-site disposal are moderate relative to dewatering requirements for off-site disposal, as passive methods can be employed at the final disposal site and fluid reduction requirements are less stringent than for sediments that would be transported off-site. Costs for water treatment are relatively high, but depend on the treatment train and level of treatment required to meet discharge requirements.

4.3.2.3 Screening Results

Process components for water management during on-site disposal that are retained for consideration include passive dewatering, sediment reworking and hygroscopic amendment addition, as well as treatment of wastewater.

5.0 Alternatives Evaluation

This section presents the assembled alternatives stemming from the technology screening and multiple discussions and input from various groups. The common remedial elements of the assembled alternatives are described along with habitat/recreational enhancement elements that have been incorporated into the alternatives. The habitat enhancement elements are based on the AOC habitat goals, and resource managers input, including an AOC habitat work group (SLR-CAC, 2002; LimnoTech, 2012), and GLNPO program expertise. In Fall 2014 eleven alternatives were assembled and taken through a screening evaluation that resulted in a score for each alternative. Based on the score of each alternative and additional Project considerations, four alternatives were retained for detailed evaluation. The detailed evaluation of the four alternatives resulted in the identification of a preferred alternative. The Draft FS was completed and submitted to resource managers and the MPCA in November 2014. U.S. EPA began tribal consultations under Section 106 of the National Historic Preservation Act (NHPA) in March 2015 during which the draft FS was discussed. In light of the tribal consultations and discussions with MPCA, a twelfth alternative was assembled and included in an updated alternatives screening and detailed analysis. The following sections further describe the updated alternatives evaluation process.

5.1 Development of Alternatives

Based on the technology screening discussed in Section 4.0 and the PRGs provided by the MPCA in its March 5, 2014 letter, preliminary alternatives were developed. These alternatives were further refined through discussions with the Project partners (GLNPO, MPCA and U. S. Steel) and through a series of meetings and discussions that are briefly summarized below.

5.1.1 Review and Input on Alternatives Development

The MPCA presented early descriptions of potential alternatives or remedial elements to the resource managers and the AOC habitat work group over the course of multiple briefings. The initial briefings included discussions of much of the information presented in Sections 4.0 and 5.0. A meeting of the members of the AOC habitat work group and resource managers was convened in March 2014 at the Duluth MPCA office. MPCA facilitated a day-long discussion of Site conditions and remedial elements, and the Project partners were given specific input on preferences regarding remedial strategies and habitat goals for the Spirit Lake estuary area from estuary habitat management stakeholders (LimnoTech, 2012). During the subsequent months, the MPCA Project staff also met with resource managers, tribal representatives, City of Duluth staff and neighborhood representatives. Through these additional interactions, further feedback was provided on elements of Former Operations Area and estuary sediment remediation to help develop a selection of remedial options for evaluation in the draft FS (Barr, 2014d).

As noted above, the draft FS was produced in November 2014 (Barr, 2014d). A meeting of resource managers, tribal resource management staff, USS, MPCA and U.S. EPA occurred on November 18, 2014. Comments were received from the MPCA, resource managers, City of Duluth, St Louis River Alliance representative, and the Fond du Lac band staff. The Tribal Consultation with U.S. EPA began in March 2015 and in late May these consultations, together with discussions with MPCA resulted in development of a twelfth alternative, which is included in the screening and detailed alternatives evaluation that follows in this updated FS.

Based on the input received and taking into account MPCA and GLNPO programmatic requirements, a range of twelve alternatives were developed.

5.2 Common Remedy Elements

The following subsections describe common remedy elements for the Site that are included in many of the alternatives described in Section 5.4. Appendix I provides schematic illustrations of the remedy elements discussed throughout this Section.

5.2.1 Institutional Controls

Institutional controls layered over engineering controls will address the future threat of disturbance to protective measures associated with Site remedies. Institutional controls will be specific to a given remedial alternative and will consider potential long- and short-term controls. Institutional controls may include an environmental restrictive covenant for portions of the Site with private property ownership. For areas that are not private property, other institutional controls by the various local, state and federal permitting agencies could be implemented to restrict various activities (e.g., dredging) as conditions of future permits.

5.2.2 Natural Recovery

Natural deposition of new sediment layers over impacted sediments has been observed in the near shore and off shore zones of the Estuary Site. Areas that are within the PRG footprint, but do not have a remedy element shown are natural recovery (NR) zones. These areas have sufficient cover material and meet the RAOs and based on hydrodynamic modeling, site observations, geologic stratigraphy, and multiple bathymetric surveys, are expected to be stable and will therefore be protective over time. The NR areas will be monitored to confirm the sediment cover layers remain in place.

5.2.3 ENR Thin Cover

The enhanced natural recovery (ENR) thin cover will be placed in areas where the water depth is greater than 3 feet and the non-native sediments exhibit COI concentrations that exceed the PRGs, but are thin deposits (generally 15 cm/6 inches or less) with COI concentrations generally less than the level II SQT for the respective COIs. This element is applied where the setting and hydrodynamic conditions are shown to be stable similar to the factors noted in Section 5.2.2. Appendix I, Figure I-1 shows a schematic of the ENR thin cover concept.

5.2.4 Remedial Capping

5.2.4.1 Former Operations Area

Remedial capping of non-native Former Operations Area sediments involves placing a two-foot soil cover over areas where non-native soil or sediments will be managed in place. The bottom 1.5 feet will be comprised of a borrow layer and the top 6 inches will be topsoil. The capped areas will be vegetated with shallow rooted grasses, and woody vegetation and animals will be managed to maintain the cap integrity and maintain protectiveness. The CDA cap will include a geomembrane layer overlain by the two-foot soil cover. Several of the remediation alternatives include remedial capping of OU-I sediments similar to the estuary capping and is comprised of a 0.5 m (1.64 ft) cap with root barrier and possibly rip-rap. This setting requires the use of root barrier, where woody vegetation such as willows may colonize shallow water areas and the potential exists for burrowing animals to be present. In such settings, the barrier layer design may need to consider less deep burial to help prevent excessive colonization by burrowing vertebrates or deep rooting plants that may result in excessive disturbance of the overlying cap material. This aspect will be evaluated further during remedial design. Appendix I, Figures I-2 and I-3 shows schematic cap cross sections.

5.2.4.2 Estuary

Remedial capping in the estuary areas involves placing granular materials to meet the specified thickness requirements. As detailed in the MPCA letter, the remedial cap thickness would be based upon the post remedy habitat type. To develop these alternatives, post remedy habitat type was defined based on water depth and proximity to shore. The water depths that have been selected for each remedial cap thickness are listed below. If present, the existing sediments that have COI concentrations less than the MPCA PRGs are considered as part of the overall remedial cap thickness. The overall cap thickness would consist of the potentially BAZ thickness presented in the MPCA letter and an isolation zone (IZ), if necessary, which would be determined during design of the selected alternative. Appendix I, Figures I-4 through I-6 show schematic cross sections illustrating the remedial cap with potentially BAZ thickness and underlying isolation zone for the different settings or configurations listed below.

Estuary remedial cap thicknesses

- In estuary shoreline zone (as defined in Section 2.0): 1.2 meter (m) (3.93 ft) cap thickness
- 0 to 3 feet water depth that is adjacent to shoreline: 1.0 m (3.28 ft) cap thickness, or
- 0 to 3 feet water depth that is adjacent to shoreline: 0.5 m (1.64 ft) cap with root barrier, where necessary, to preserve water depth for armoring, to prevent deep rooting by plants, or to prevent animal burrowing.
- >3 feet water depth or <3 feet water depth and not adjacent to shoreline with low potential to shoal or transition to emergent habitat: 0.5 m (1.64 ft) cap

5.2.5 Removal to a Set Elevation and Cap Placement

An approach involving removal to a set elevation will be used in areas where the extent of removal does not encompass the full vertical extent of sediment with concentrations greater than the PRGs. A remedial cap will be placed following removal to a set elevation. Appendix I, Figure I-7, shows a schematic of the removal to a set elevation and remedial cap material placement to the required potentially BAZ thickness with underlying isolation zone for areas of the Site where this is the selected remedy element.

5.2.6 Removal to PRGs

An approach involving removal to the PRGs will be used in areas in which the extent of removal encompasses the full vertical extent of sediment with concentrations greater than the PRGs. A dredge residual cover will be placed following the removal to manage dredge residuals. Appendix I, Figure I-7 shows a schematic of this removal and residual cover placement remedy element.

5.2.7 Dredge Residual Cover

A dredge residual cover will be placed over areas where removal thickness targets the entire vertical extent of sediment with concentrations greater than the PRGs. The residual cover layer will be placed after dredging is completed to manage dredge residuals and will be constructed with characteristics such as grain size to account for the energy regime, habitat type and other conditions affecting the setting of the location within the selected alternative. As noted above, placement of a dredge residual cover is illustrated schematically in Appendix I, Figure I-7.

5.2.8 CDF

Confined disposal facilities (CDFs) are part of several alternatives and include several elements, such as perimeter berms, internal drainage systems, perimeter toe drains, storm water management of the cap, and the CDF cover system. The cover system will consist of a two-foot soil cap in which the bottom foot of this cover will consist of a low permeability barrier layer and the top foot will be comprised of 6 inches of borrow cover overlain by 6 inches of topsoil. While conceptually considered as part of the alternatives analysis, a CDF operations and maintenance plan and associated costs will be developed during the remedial design phase. Appendix I, Figure I-8 shows a schematic of the CDF cap and I-9 shows a schematic of the CDF perimeter berm. The height and configuration of CDF perimeter berms varies depending on many site factors as well as the design capacity; general information about likely berm height is discussed as an element of the assembled alternatives in Section 5.4.

5.2.9 Former Operations Area (Upland) CDF

A CDF that will be placed in an upland location is part of three alternative remedies. The upland CDF will have similar elements as the estuary/Unnamed Creek area CDFs, with the addition of a three-foot base liner system. The bottom 2-feet of the base liner system will be comprised of a two-foot low permeability barrier layer. The top foot will consist of a sand drainage layer. A geomembrane will be placed on top of the low permeability barrier layer and below the sand drainage layer. The upland CDF cover system will be comprised of a two-foot soil cap, similar to the estuary CDF cover system. While conceptually considered as part of the alternatives analysis, an upland CDF operations and maintenance plan and costs will be developed during the remedial design phase if necessary. Appendix I, Figure I-8 shows a schematic of the upland CDF cap and Figure I-10 shows a schematic of the upland CDF liner system.

5.2.10 Storm Water Conveyance – Unnamed Creek

Storm water conveyance through the Unnamed Creek channel, Unnamed Pond and Wire Mill pond areas presents a design challenge common to all active remediation alternatives, except for Alternative 11 where sediment removal provides added volume for storm water conveyance. Consolidation of non-native industrial sediment within the Unnamed Creek conveyance system will require rerouting and armoring of the current flow channel and reconstructing a flow management structure and embankment to manage storm water entering this Site feature from the larger upstream watershed. Unnamed Creek has two primary means of managing the storm water associated with all active remediation alternatives: (1) is to discharge to the OU-M delta; and (2) is to discharge to the depressed area of the estuary known as the Wire Mill Intake Area, east of the Spit of Land. Discharging to the OU-M delta will be comprised of open channel flow routed through the Unnamed Creek. Discharge to the Wire Mill Intake Area would only occur in alternatives where capping only of Former Operations Area sediment occurs or a CDF covers the OU-M delta. Discharge under these scenarios will consist of a combination of open channel flow and pipe flow. The storm water piping system will convey flow from the open channel underneath the existing railroad grade and discharge into the Wire Mill Intake Area below the water surface elevation. A rip-rap lined conveyance channel is common in many of the alternative remedies to route flow through the Unnamed Creek. The channel section will be sized to convey flows up to the 25-year 24-hour storm event. With the exception of Alternative 7, the existing weir structure at the downstream end of OU-I will remain in place or be replaced with a structure with similar hydraulics. This will allow flow to closely mimic existing conditions. Due to consolidation of impacted materials within the Unnamed Creek corridor under Alternative 7, ponding/retainage of storm flows will not be possible and storm water conveyance will consist of open channel flow along the entire Unnamed Creek course. Where used, the existing weir structure will be evaluated for structural integrity during the remedial design phase.

5.2.11 Storm Water Conveyance – Wire Mill Pond and Unnamed Pond

Though less complex, the need to accommodate storm water through the smaller Wire Mill Pond sub-watershed is a primary driver for choosing to excavate and remove the industrial sediments from this area and allow the landscape and storm water to revert to historic patterns. The Wire Mill Pond will receive overland flows from the west and convey the flow into the Estuary. Pond banks and slopes will be protected to minimize erosion.

The Unnamed Pond receives storm water from a small 14-acre sub-watershed. With the exception of Alternatives 1 and 2, remedial excavation will occur within this basin to remove COIs that exceed established PRGs. Final grading and turf establishment will follow excavation of impacted material.

Appendix I, Figures I-11 and I-12 provides schematic illustrations of the proposed storm water conveyances.

5.2.12 Surface Water Quality

As stated in FS Section 2.2.2, U. S. Steel has been engaged in an on-going effort to monitor surface water quality within and adjacent to the Site. The data generated through this on-going effort has revealed surface water impacts that are isolated in occurrence, limited in magnitude and contained within the terrestrial portions of the Site. Impacted sediment isolation and/or removal actions described above will also have the beneficial outcome of improving surface water quality in the limited areas of impairment. As such, remedial actions that specifically target surface water quality are not considered in this FS. Long term surface water quality monitoring will continue after construction of the final remedy.

5.2.13 Lead-Impacted Soil

Portions of the lead-impacted soil identified within OU-Q dredge spoils and OU-P during subsurface investigation activities were identified as being characteristically hazardous. On-site chemical stabilization followed by off-site disposal will be conducted to address these soils in the OU-P/OU-Q area.

5.3 Common Habitat Elements

Alternatives 5 through 8 and 12 include creation of new or deeper open water at the OU-M Delta/Unnamed Creek Delta area, which are consistent with the conceptual habitat plans for the lower St. Louis River (SLR-CAC, 2002) and Spirit Lake (LimnoTech, 2012). One primary difference between these four alternatives involves the restoration of open water in the OU-M delta where currently there is none. The depth of water in the resulting bay differs between some of these alternatives. To simplify descriptions of the alternatives, the definitions of two types of bays that may be envisioned are presented below. Details of each alternative are then presented in the following subsections.

5.3.1 Open Water Bay

The open water bay water depths in the Unnamed Creek delta would be similar to the existing open water areas and would be approximately 1 to 2 feet deep. The bay will be created by removing sediment to a set elevation and remedial capping. Appendix I, Figure I-13 shows a schematic of the proposed open water bay and submerged shoal.

5.3.2 Shallow Sheltered Bay

The open water depths created in the shallow sheltered bay of the Unnamed Creek delta will have average water depths ranging from 3 to 5 feet throughout most of the area. The bay will be created by removing sediment to a set elevation and remedial capping. Appendix I, Figure I-14 shows a schematic of the proposed shallow sheltered bay and submerged shoal.

5.3.3 Other Habitat/Recreational Elements

While not explicitly shown, remedies could provide the substrate or starting point for other ecological or recreational goals and do not preclude implementation of the majority of habitat elements described in the conceptual habitat plans for the lower St. Louis River (SLR-CAC, 2002) and Spirit Lake (LimnoTech, 2012).

5.4 Assembled Alternatives for Screening-Level Evaluation

The following twelve alternatives were assembled based on discussions with, and input from the MPCA, GLNPO, resource managers, and tribal representatives. Figures 5-1 through 5-12 illustrate these alternatives. The destinations for onsite management of removed sediments are shown by arrows on the figures.

The remedial footprints addressed by the alternatives are illustrated on Figure 5-1. The Former Operations areas exceeding RAOs are outlined in green and the estuary areas exceeding sediment PRGs are shown in purple. Approximate removal volumes, capping areas, CDF heights and change in open water areas for each alternative is summarized in Table 5-1.

5.4.1 Alternative 1 – Natural Recovery

Alternative 1 involves no action beyond restricting public access to the site. The alternative is included as a baseline for the evaluation of alternatives. Figure 5-1 shows the areas evaluated in this FS and to which this alternative would apply. No material would be removed or actively capped and there would be no change to the area of open water.

5.4.2 Alternative 2 – Remedial Capping

Alternative 2 includes placement of a 2-foot thick soil cap over the Former Operations sediment/soil impact areas and placement of varying thicknesses of capping material in the estuary to provide a remedial cap over the areas identified as "Remedial Cap" on Figure 5-2. No material would be removed as part of Alternative 2. Due to placement of the remedial cap, the shoreline shifts to the east in shallow capping areas, identified as "New Shoreline" on Figure 5-2, resulting in a loss of open water. Storm water flow within the Unnamed Creek would be channelized and diverted to the Wire Mill Intake Area of the estuary to preserve the integrity of the capped areas. Limited storm water ponding capacity would be retained upstream of the weir at OU-I to mitigate peak flows; however, ponding capacity would be reduced due to cap placement without removal of impacted sediment.

The conceptual layout illustrates the general effects of capping near shore; however, details of new shoreline shaping and grading to match existing bathymetry are not conceptualized on the preliminary illustration. Additional details regarding matching capped areas to site bathymetry and shoreline shape would need to be developed.

5.4.3 Alternative 3 – Delta/Estuary CDF (Confined Disposal Facility)

Alternative 3 includes excavation of impacted Former Operations area soil and sediments and placement of a 2-foot thick soil cap over OU-I, the CDA and the OU-M area west of the railroad tracks. Alternative 3 also includes removal of estuary sediments that exceed PRGs from near the shoreline in the southern portion of the Wire Mill Delta and the northern portion of the Unnamed Creek Delta (identified as "Remove" on Figure 5-3). Removal of sediments to a set elevation and remedial capping is proposed on the northeast edge of the confined disposal facility (CDF) (identified as "Remove to Set Elevation and Cap" on Figure 5-3). This alternative also includes placement of a remedial cap or ENR thin cover over portions of the estuary area. Storm water flow upstream of the weir would be compatible with current conditions and would include similar ponding capacity of peak flows. Storm water would be diverted to the Wire Mill Intake Area downstream of the weir to deflect flow away from a CDF placed within the OU-M delta. Figure 5-3 shows a map view of this alternative.

Removed/Excavated Material Management – Materials will be consolidated in a single CDF that extends over the OU-M delta into the estuary. The CDF berm will be 4 feet high.

Change in Open Water – Open water is created as a result of excavating sediment from the OU-P and OU-Q areas; however, because a portion of the CDF is within the estuary there is a net loss of open water (Table 5-1).

5.4.4 Alternative 4 – CDF on OU-M Delta (within Shoreline)

Alternative 4 includes excavation of impacted Former Operations Area soil and sediment and placement of a 2-foot thick soil cap over OU-I, the CDA and the OU-M area west of the railroad tracks. Alternative 4 also includes removal of estuary sediments that exceed PRGs from near the shoreline in the southern portion of the Wire Mill Delta and the northern portion of the Unnamed Creek Delta (identified as "Remove" on Figure 5-4). Removal of sediments to a set elevation and remedial capping is proposed in the Unnamed Creek Delta (identified as "Remove to Set Elevation and Cap" on Figure 5-4). The alternative also includes placement of a remedial cap or ENR thin cover over portions of the estuary area. Storm water flow upstream of the weir would be similar to current conditions and would include similar ponding capacity of peak flows because OU-I sediment would be removed to a set elevation and then covered with a remedial cap. Storm water management features would be included as discussed in Section 5.2.10. Storm water would be diverted to the Wire Mill Intake Area downstream of the weir to deflect flow away from a CDF placed within the OU-M delta. Figure 5-4 illustrates the alternative.

Removed/Excavated Material Management – Materials will be consolidated in a single CDF within the OU-M delta area. The CDF berm will be 8 feet high. Contrasting with Alternative 3, the proposed CDF foot-print would be contained entirely within OU-M delta.

Change in Open Water – Open water is created as a result of excavating sediment from areas near the shoreline, resulting in a net gain of open water.

5.4.5 Alternative 5 – CDF with Open Water Bay

Shown on Figure 5-5, Alternative 5 includes excavation of impacted Former Operations Area soil and sediments and placement of a 2-foot thick soil cap over OU-I, the CDA and the OU-M area west of the railroad tracks. Additionally, restored estuary will be created where impacted material excavated from the northern and western sides of the OU-M delta creates an open water bay similar in depth to the off shore portion of the existing Unnamed Creek delta area.

Alternative 5 also includes removal of sediments that exceed PRGs from near the shoreline in the southern portion of the Wire Mill Delta and the northern portion of the Unnamed Creek Delta (identified as "Remove" on Figure 5-5). Additional sediment will be dredged from the northern portion of the Unnamed Creek estuary delta (the shelf area), where sediments will be removed to a target elevation and a remedial cap will be placed (identified as "Remove to Set Elevation and Cap" on Figure 5-5). The alternative also includes placement of a remedial cap or ENR thin cover over portions of the estuary area. A submerged shoal would be constructed at the mouth of the bay to serve as an energy dissipation barrier between the bay and the greater estuary and as a remedial cap, if the shoal is constructed over remaining sediment exceeding PRGs.

Storm water flow upstream of the weir would be similar to current conditions and would include similar ponding capacity of peak flows. Downstream of the weir, storm water flow would be directed to the shallow open water bay created in the OU-M delta. This alternative provides additional storm water ponding in the OU-M area west of the railroad tracks/OU-L area of Unnamed Creek.

Removed/Excavated Material Management – Materials will be consolidated in two locations under Alternative 5. The primary consolidation area will be a CDF that is located in the southern portion of the OU-M delta and extends into the estuary. A secondary consolidation area, comprised of impacted sediment removed from the Area Between OU-I and OU-J and OU-I, will be placed behind OU-J over the T-10 and T-11 SAs. CDF berm heights range from 9 to 25 feet.

Change in Open Water – A portion of the OU-M CDF extends into the estuary; however, an overall net gain of open water is created as a result of excavating sediment from areas near the shoreline (at OU-P and OU-Q) and from creating the open water bay.

5.4.6 Alternative 6 – Shallow Sheltered Bay with CDF

Alternative 6 includes excavation of impacted soil and sediments and placement of a 2-foot thick soil cap over OU-I, the CDA and the OU-M west of the railroad tracks, as shown on Figure 5-6. Restored estuary will be created where impacted material excavated from the northern portion of the OU-M delta and placed along the spit-of land, creating a shallow (3 to 5 feet water depth) sheltered bay.

Alternative 6 also includes removal of sediments that exceed PRGs from near the shoreline in the southern portion of the Wire Mill Delta and the northern portion of the Unnamed Creek Delta (identified as “Remove” on Figure 5-6). Additional sediment will be dredged from the northern portion of the Unnamed Creek estuary delta (the shelf area), where sediments will be removed to a target elevation and a remedial cap will be placed (identified as “Remove to Set Elevation and Cap” on Figure 5-6). As noted above, the shallow sheltered bay will have an average water depth of 3 to 5 feet. The alternative also includes placement of a remedial cap or ENR thin cover over portions of the estuary area. A submerged shoal would be constructed at the mouth of the shallow sheltered bay to serve as an energy dissipation barrier between the bay and the greater estuary and as a remedial cap.

Storm water flow upstream of the weir would be similar to current conditions and would include similar ponding capacity of peak flows. Downstream of the weir, storm water flow would be directed to the shallow sheltered bay created in the OU-M delta.

Removed/Excavated Material Management – Materials will be primarily consolidated in a linear CDF of varying-height that is located in the southern portion of the OU-M delta and extends both westward and into the estuary. The CDF topographic contours would be sloped such that areas bordering open water would be low and increase in height to the south (near the spit of land) and west (on the west side of OU-M). Only estuary sediments will be managed within the footprint of the low CDF that is east of the railroad tracks. A secondary consolidation area, comprised of impacted sediment removed from the Area Between OU-I and OU-J and OU-I, will be placed behind OU-J over the T-10 and T-11 SAs. CDF berm heights range from 6 to 25 feet.

Change in Open Water – A portion of the OU-M CDF extends into the estuary; however, an overall net gain of open water is created as a result of excavating sediment from areas near the shoreline (at OU-P and OU-Q) and from creating the shallow sheltered bay.

5.4.7 Alternative 7 – Shallow Sheltered Bay and Delta Cap Area with Upland CDFs

Alternative 7 is illustrated on Figure 5-7. Alternative 7 includes excavation of impacted soil and sediment and placement of a 2-foot thick soil cap over the CDA. Additionally, restored estuary will be created where impacted material will be excavated from the northern portion of the OU-M delta, creating a shallow sheltered bay (average water depth of 3 to 5 feet).

Alternative 7 also includes removal of sediments that exceed PRGs from near the shoreline in the southern portion of the Wire Mill Delta and the northern portion of the Unnamed Creek Delta (identified as "Remove" on Figure 5-7). Additional sediment will be dredged from the northern portion of the Unnamed Creek estuary delta (the shelf area), where sediments will be removed to a target elevation and a remedial cap will be placed (identified as "Remove to Set Elevation and Cap" on Figure 5-7). As noted above, the shallow sheltered bay will have an average water depth of 3 to 5 feet. The alternative also includes placement of a remedial cap or ENR thin cover over a portion of the estuary area. A submerged shoal would be constructed at the mouth of the bay to serve as an energy dissipation barrier between the bay and the greater estuary and as a remedial cap.

Storm water flow under Alternative 7 is constrained by consolidation of impacted material within the Unnamed Creek corridor. Flow would be channelized along the entire Unnamed Creek segment until it discharges to the shallow sheltered bay created in the OU-M delta. The capacity to pond storm water during major precipitation and run-off events would largely be eliminated as the existing weir would be removed for consolidation of impacted materials.

Removed/Excavated Material Management – Materials will be consolidated under Alternative 7 in three CDFs located entirely within the Former Operations portion of the Site west of the existing railroad grade. The OU-J CDF, comprised of material excavated from OU-P, OU-Q and storm water channel construction, would be placed behind OU-J (covering the T-10 and T-11 SAs) in a manner similar to previously discussed alternatives and would extend eastward to OU-I. Additional material removed from OU-P, OU-Q and storm water channel construction would be placed in a second CDF over OU-I and extend from the OU-J CDF east to the current location of the Site access road. The OU-L/western OU-M CDF would serve as a consolidation area for material excavated from Unnamed Pond, OU-M delta, as well as material dredged from the estuary. Because of the large volume of sediment in the OU-L/OU-M CDF, containment berms will be constructed with steeper side slopes and geotechnically reinforced to effectively confine the sediments. Both the OU-I and OU-L/OU-M CDFs will be bounded on the north/northwest by the Unnamed Creek storm water conveyance channel and will extend to the top of a natural bench located to the southeast. The CDF berm height will range from 13 to 25 feet.

Change in Open Water – An overall net gain of open water is created as a result of excavating sediment from areas near the shoreline (at OU-P and OU-Q) and from creating the shallow sheltered bay.

5.4.8 Alternative 8 – Shallow Sheltered Bay with Delta Sediment CDF and Former Operations Area CDFs

Figure 5-8 illustrates this alternative. Alternative 8 includes excavation of impacted soils and sediment and placement of a 2-foot thick soil cap over OU-I and the CDA. Additionally, restored estuary will be created where impacted material will be excavated from the northern portion of the OU-M delta, creating a shallow sheltered bay (average water depth of 3 to 5 feet).

Alternative 8 also includes removal of sediments that exceed PRGs from near the shoreline in the southern portion of the Wire Mill Delta and the northern portion of the Unnamed Creek Delta (identified as "Remove" on Figure 5-8). Additional sediment will be dredged from the northern portion of the Unnamed Creek estuary delta (the shelf area), where sediments will be removed to a target elevation and a remedial cap will be placed (identified as "Remove to Set Elevation and Cap" on Figure 5-8). As noted above, the shallow sheltered bay will have an average water depth of 3 to 5 feet. In this alternative those sediments removed to the target elevation from the northern OU-M delta would be consolidated in a single source, estuary sediment CDF in the southern portion of the OU-M Delta and extending into the estuary. Only sediments removed from the adjoining estuary area will be consolidated in this location. The alternative also includes placement of a remedial cap or ENR thin cover over portions of the estuary area.

Storm water flow upstream of the weir would be similar to current conditions and would include similar ponding capacity of peak flows. Downstream of the weir, storm water flow would be directed to the shallow sheltered bay created in the OU-M delta.

Removed/Excavated Material Management – The majority of the materials will be consolidated in the CDF located in the OU-L/OU-M area. The OU-L/OUM CDF would maintain the same foot-print as described above in Alternative 7 but consolidate less material due to the absence of OU-M delta sediment; resulting in minimized view-shed impacts and less complicated construction. A smaller amount of excavated soil/sediment will be consolidated in the OU-J area in a manner previously described in this report section. As described above, a third estuary only CDF would be constructed within OU-M delta extending along the spit of land. The CDF berm heights will range from 6 to 25 feet. A submerged shoal would be constructed at the mouth of the bay to serve as an energy dissipation barrier between the bay and the greater estuary and as a remedial cap.

Change in Open Water – An overall net gain of open water is created as a result of excavating sediment from areas near the shoreline (at OU-P and OU-Q) and from creating the shallow sheltered bay.

5.4.9 Alternative 9 – Delta Cover and Upland CDFs

Alternative 9 is illustrated on Figure 5-9. Alternative 9 includes excavation of impacted soil and sediment and placement of a 2-foot thick soil cover over the CDA, OU-I and western OU-M. Alternative 9 also includes removal of sediments that exceed PRGs from near the shoreline in the southern portion of the Wire Mill Delta and the northern portion of the Unnamed Creek Delta (identified as "Remove" on

Figure 5-9). The alternative also includes removal of non-native sediments to a set elevation near the OU-M delta (identified as “Remove to Set Elevation and Cap” on Figure 5-9). Placement of a remedial cap or ENR thin cover over an expanded area is included as part of the alternative.

Storm water flow upstream of the weir would be similar to current conditions and would include similar ponding capacity of peak flows. Flow would be channelized downstream of the weir along the northern margins of a CDF placed within the OU-L/OU-M area until it discharges to a drainage feature along the toe of the OU-M delta bluff line.

Removed/Excavated Material Management – Materials will primarily be consolidated in an upland CDF that is located in the OU-L/OU-M area. A secondary consolidation area, comprised of impacted sediment removed from the Area Between OU-I and OU-J and OU-I, will be placed behind OU-J over the T-10 and T-11 SAs. CDF berm heights will range from 14 to 25 feet.

Change in Open Water – Open water is created as a result of excavating sediment from areas near the shoreline at OU-P and OU-Q.

5.4.10 Alternative 10 – Targeted Removal with Coke Plant Area CDF

Alternative 10 is illustrated on Figure 5-10. Alternative 10 involves removal of impacted soils and sediment from the T-10/T-11 SA, the tar between OU-I and OU-J area, OU-I, OU-L, western OU-M, OU-M delta (to a target elevation), OU-P and OU-Q and the Unnamed Pond SA followed by placement of a remedial cap over the OU-I and the OU-M delta. The CDA will receive a remedial cap similar to that described in Alternative 9. The removed sediments would be placed into an upland CDF as described in Section 5.2.9. The consolidation location was selected based on proximity and accessibility to receive the removed materials and in a location of former foundations with the objective of minimizing loss of upland development area. However, development area would be lost on the upland property.

Alternative 10 also includes removal of sediments that exceed PRGs from near the shoreline in the southern portion of the Wire Mill Delta and the northern portion of the Unnamed Creek Delta (identified as “Remove” on Figure 5-10). Placement of a remedial cap or ENR thin cover over portions of the estuary area is included as part of the alternative.

Removed/Excavated Material Management – All removed materials would be placed over the former coke battery area within a CDF. The CDF would compass 34 acres with a berm height of 26 feet. The upland CDF is shown conceptually as a rectilinear feature for FS evaluation purposes, but the shape of this feature could be softened to mimic similar slopes nearby- this would be evaluated and addressed during the design phase.

Change in Open Water – Open water is created as a result of excavating sediment from areas near the shoreline at OU-P, OU-Q, OU-M, and OU-L areas.

5.4.11 Alternative 11 – Removal with Large Coke Plant Area CDF

Alternative 11 is illustrated on Figure 5-11. Alternative 11 involves removal of all impacted soils and sediment encompassed by the feasibility study. Alternative 11 also includes removal of sediments that exceed PRGs throughout both the Wire Mill and Unnamed Creed Deltas (identified as “Remove” on Figure 5-11). No remedial cap is included as part of the alternative.

Removed/Excavated Material Management – All removed materials would be placed over the former coke battery within a CDF. The CDF would encompass 76 acres and will have a berm height of 26 feet. The upland CDF is shown conceptually as a rectilinear feature for FS evaluation purposes, but the shape of this feature could be softened to mimic similar slopes nearby- this would be evaluated and addressed during the design phase.

Change in Open Water – Open water is created as a result of excavating sediment from areas near the shoreline, denoted “New Open Water” on Figure 5-11.

5.4.12 Alternative 12 – Open Water Bay with Upland CDFs

Figure 5-12 illustrates this alternative. Alternative 12 includes excavation of impacted soils and sediment and placement of a 2-foot thick soil cap over OU-I and the CDA. Additionally, restored estuary will be created where impacted material will be excavated from the OU-M delta, creating an open water bay (average water depth of 1 to 3 feet).

Alternative 12 also includes removal of sediments that exceed PRGs from near the shoreline in the southern portion of the Wire Mill Delta and the northern portion of the Unnamed Creek Delta (identified as “Remove” on Figure 5-12). Additional sediment will be dredged from the Unnamed Creek estuary delta (the shelf area), where sediments will be removed to a target elevation and a remedial cap will be placed (identified as “Remove to Set Elevation and Cap” on Figure 5-12). As noted above, the open water bay will have an average water depth of 1 to 3 feet. A submerged shoal would be constructed at the mouth of the bay to serve as an energy dissipation barrier between the bay and the greater estuary and as a remedial cap. In this alternative those sediments removed to the target elevation from the northern OU-M delta would be removed from the estuary and consolidated in one of several upland CDFs. The alternative also includes placement of a remedial cap or ENR thin cover over portions of the estuary area.

Storm water flow upstream of the weir would be similar to current conditions and would include similar ponding capacity of peak flows. Downstream of the weir, storm water flow would be directed to the shallow sheltered bay created in the OU-M delta.

Removed/Excavated Material Management – The majority of the materials will be consolidated in two locations – a CDF located in the OU-L/western OU-M area and an upland CDF located south of the OU-P/OU-Q area in an area referred to as the Borrow Site. The OU-L/western OU-M CDF would maintain the same foot-print as in Alternative 7 and 8 but the available storage capacity would be maximized, resulting in potential view-shed impacts. Except for the small amount of material consolidated in the OU-J area (as previously described in this report), all soil/sediment that does not fit into the CDF at the OU-

L/OU-M area would be consolidated in the Borrow Site upland CDF. The upland CDFs are shown conceptually as a rectilinear features for FS evaluation purposes, but the shapes of these features could be softened to mimic similar slopes nearby- this would be evaluated and addressed during the design phase.

Change in Open Water – There is an overall net gain of open water as a result of excavating sediment from areas near the shoreline (at OU-P and OU-Q) and from creating the open water bay (OU-M Delta).

5.5 Screening-Level Evaluation of Alternatives

This section discusses the screening-level evaluation of the eleven assembled alternatives described in Section 5.4. In performing this screening-level evaluation, the eleven alternatives were given a relative score with respect to three comparative screening categories and compared to one another.

The screening-level criteria used to evaluate the 11 alternatives include:

- Effectiveness at achieving remedial action objectives (RAOs)
- Implementability
- Relative cost

Table 5-2 presents the relative evaluation of the alternatives. The first two columns of the table list the eleven alternatives and provide a description of each. Figures 5-1 through 5-11 provide schematic maps showing the layout and key elements of each alternative.

The effectiveness with which an alternative would achieve the RAOs is ranked as high, with a score of 1, to low, with a score of 5. The numeric effectiveness scoring of 1 to 5 is described in the key provided at the bottom of Table 5-2. A similar scoring range for implementability uses the highest score of 1 and the lowest implementability score of 5. Relative costs are compared between the alternatives and a relative cost score is assigned with the lowest cost alternatives assigned 1 and the highest relative cost alternatives assigned scores of 5. Cost-ranking was based on engineering judgment, experience with similar Projects, and preliminary development of site-specific cost estimates, which were carried forward for use in detailed evaluation of retained alternatives as described in Section 5.7. The sum of the scores for the three relative evaluation categories for each alternative is provided as the screening level score included in Table 5-2 and are used to rank the alternatives. Additional factors for consideration are also noted and used to identify the alternatives that were selected for detailed evaluation.

To aid in screening the alternatives, the table cells are shaded with colors according to the key at the bottom of Table 5-2. The best performing alternatives are shaded light gray. The poorest performing alternatives are shaded red. In this scheme of scoring and color-coding, individual criteria can be visualized for their contributions to the lowest overall scoring alternatives.

In summary, the alternatives fell into three groups, ranging from most favorable to least favorable:

- Alternatives 4, 5, 6 and 8 had the lowest screening level score (7)
- Alternatives 2, 3, 7, 9, and 12 had a moderate screening level score (ranging from 9 to 10)
- Alternatives 10 and 11 had the greatest screening level scores (12 and 13, respectively)

Additional factors for consideration were also included in Table 5-2 and were used in conjunction with the screening level score to identify alternatives that would be evaluated in detail. These additional factors included whether habitat goals are met by one approach versus another, whether aquatic habitat would be lost, and how stormwater was managed.

5.5.1 Alternatives Retained for Detailed Evaluation

Based on multiple meetings, discussions and reviews by the Project Partners, consultation with resource managers, and the screening evaluation included in Table 5-2; the following proposed focused list of alternatives was identified for detailed evaluation in the FS.

- Alternative 4 – CDF on OU-M Delta (within Shoreline)
- Alternative 6 – Shallow Sheltered Bay with Low CDF
- Alternative 7 – Shallow Sheltered Bay and Delta Cap Area with Upland CDFs
- Alternative 8 – Shallow Sheltered Bay with Delta Sediment CDF and Upland CDFs
- Alternative 12 – Open Water Bay with Upland CDFs

Alternative 4 is retained as it represents an efficient approach to managing impacted estuary sediments by consolidating impacted material on top of impacted sediments on OU-M Delta. Alternative 4 is a modification of, and scores better than, Alternative 3 which was determined to have more wetland permitting requirements along with a net loss of open water habitat. Alternative 5 was one of the lowest scoring alternatives, but was not retained for detailed evaluation because it was similar to Alternative 6 and had less water depth in the open water bay (average of 1 to 2 ft water depths) than the shallow sheltered bay (average of 3 to 5 ft water depths) in Alternative 6.

Alternative 7 was not one of the lowest scoring alternatives, but was retained to provide a comparison with Alternative 8. Both of these alternatives provide habitat enhancement elements in the Unnamed Creek Delta area, but differ in how storm water is managed and location and type of CDFs constructed. Alternative 8 manages some estuary sediments in a CDF beside the spit of land which allows upland CDFs to be placed in a manner that provides for stormwater retention in the Unnamed Creek drainage way (a ponding area in the OU-I area). In contrast, Alternative 7 manages all Site sediments in 3 upland CDFs with taller berms than Alternative 8, but also restricts storm water flow, thereby increasing water velocities of stormwater and doesn't provide ponding from storms. These aspects were determined by the Project partners to be important comparison points and therefore Alternative 7 was retained for detailed evaluation with three selected low-scoring alternatives (4, 6, and 8).

Alternative 12 was also not one of the lowest scoring alternatives, but was retained as an option that did not involve consolidation of any impacted material east of the railroad tracks, based on feedback from Project partners. Alternative 12 manages all Site sediments in three upland CDFs, two of which would have taller berms than Alternative 8 and one which would require longer haul distances for removed sediments. Because the Project partners indicated that it was important to evaluate an alternative that managed material removed from the unnamed creek delta in locations west of the railroad tracks, Alternative 12 was retained for detailed evaluation along with the three selected low-scoring alternatives (4,6, and 8) and with Alternative 7 (retained for comparison with Alternative 8).

5.6 Detailed Evaluation of Retained Alternatives

The detailed evaluation of retained alternatives involves evaluating each of the five alternatives with respect to the USEPA's National Contingency Plan (NCP) remedy evaluation criteria (40 CFR §300.430). The seven evaluation criteria are summarized in Table 5-3; two additional modifying criteria, State/Tribal and Community Acceptance, are evaluated after the public comment period. In addition, the detailed evaluation considered the USEPA Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites (EPA, 2002). These eleven principles are summarized in Table 5-4. Other factors that were also considered include the USEPA Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (EPA, 2005) and the Minnesota Environmental Response and Liability Act (MERLA, Minn. Stat. § 115B). Tables 5-5 through 5-9 provide detailed evaluations with respect to the Seven Criteria for each retained alternative. Table 5-10summarizes the results of the detailed evaluation and compares each of the five alternatives to one another. In Table 5-10 a new scoring of 1 to 5, is applied for each criterion according to the key at the bottom of the page. A low score value is most desirable.

The estimated costs of the alternatives retained for detailed evaluation are summarized in Table 5-11. These costs were developed in detail using unit quantities for the remedial alternatives described in Section 5.5.1 and unit costs that were developed based on bid tabs for similar recent projects, R. S. Means, supplier quotes, and professional judgment. Estimated operation and maintenance costs were developed for the five detailed alternatives to be considered with the estimated remediation implementation cost for each and are listed in Table 5-11. It should be noted that the level of design detail is low at the FS stage of evaluation. Therefore, both estimated implementation costs as well as post-construction operation and maintenance costs are based on a set of assumptions and information that are limited in nature due to the conceptual level of detail. The cost information is developed for the purposes of general comparison and evaluation of feasibility and it is normal for the cost estimate ranges used for evaluating feasibility, to vary from the actual costs. The objective of developing general ranges of operation and maintenance cost for each of the detailed alternatives is to evaluate whether any of the alternatives may have a significantly higher operation and maintenance level of effort needed once the remedy is constructed. Specific details and requirements of operation and maintenance will be developed during the design phase and may also be subject to modification or updating once the construction is completed and the remedy has been monitored for a period of time. For all these reasons, the operation and monitoring costs provided in Table 5-11 are given as ranges.

The total scores for each of the five alternatives indicate that Alternative 7, with a score of 20, has the highest score (least favorable) primarily due to high scores for short-term effectiveness, implementability and cost. Alternative 12 has the second highest score of 17 (less favorable) mainly due to implementability and cost- this alternative requires three upland CDFs, one of which is located a significant distance from the removal area and requires a significant excavation to construct along with a liner system. Alternative 6 has the third highest (less favorable) score of 15 due to implementability and cost. Alternative 4 is the lowest cost of the four alternatives, but its score of 13 is the same as Alternative 8, which has significant advantages in habitat creation. Alternative 8 is indicated to be the best-performing alternative based on the criteria, principles, and Project goals (Table 5-10).

5.7 Recommended Alternative

Based on the screening evaluation and the detailed analysis, **Alternative 8-Shallow Sheltered Bay with Delta Sediment CDF and Upland CDFs** compares most favorably to the remedy evaluation criteria, principles and additional habitat considerations. It scored in the best performing group in the screening evaluation (Table 5-2) and has the best ranking in the detailed evaluation (Table 5-10).

Alternative 8 embodies numerous key elements of the remediation goals and habitat goals for the Former Operations and estuary areas of the site. It is reflective of important priorities identified by stakeholder input such as the creation of two shallow sheltered bay habitat areas; features which are currently absent in Spirit Lake. The need for shallow sheltered bay habitat is discussed in the Lower St. Louis River Habitat Plan (SLR-CAC, 2002) and Lower St. Louis River Habitat Plan Strategies Implementation Planning Worksheet: Project 2.7: Sheltered Bays/Shallow Wetlands- Spirit Lake (LimnoTech, 2012). In addition, the recommended alternative includes important stormwater retention elements in the Unnamed creek drainage way. This Alternative incorporates a mixture of remedial technologies and was developed out of an iterative, risk-based decision-making process that sought, and included input from various groups throughout the FS development process.

6.0 Recommendations and Path Forward

This FS has evaluated Site conditions and developed a series of Conceptual Site Models to provide a detailed understanding of the nature, extent, and magnitude of COIs across the Former Operations and Estuary portions of the Site. Using the process outlined in this FS, potential Project alternatives have been identified, screened, and evaluated in detail to identify a preferred alternative. Input was received at multiple stages as outlined in the preceding sections of the FS. Most recently the U.S. EPA has entered into formal tribal consultations under Section 106 of the National Historic Preservation Act (NHPA). As noted in Sections 1.0 and 5.0 an additional alternative was identified as a result of those consultations and that alternative was evaluated with four other alternatives, the results of that evaluation are set forth in Section 5.0.

This section of the FS includes a discussion of the recommended Project alternative and outlines the path forward for implementation of a Project in the Former Operations and the Estuary areas.

6.1 Recommended Project Alternative

Using the FS process, which was initiated with technology screening and the assembly of potential Project alternatives, a total of twelve Project alternatives were identified for screening. After the initial screening, which included input from both the MPCA and GLNPO, five alternatives were selected for detailed evaluation. During the draft FS review, tribal consultation was begun and the number 12 alternative was developed. As a result of the screening evaluation, Alternative 12 was carried forward through the detailed evaluation described in Section 5.6.

Alternative 8-Shallow Sheltered Bay with Delta Sediment CDF and Upland CDFs was identified in Section 5.7 as the best overall Project alternative because it compares most favorably with the threshold criteria while providing the most consistent balance of considerations for the balancing criteria, providing betterment of the St. Louis River AOC through key habitat benefits such as the creation of two shallow sheltered bay areas, creation of more locations with water depth transitions from shallow to deeper water and shoal areas that can provide future sites for emergent vegetation establishment, key habitat goals are met for the estuary site. Alternative 8 provides these features in accordance with the conceptual goals of the AOC habitat objectives set forth in the Lower St. Louis River Habitat Plan (SLR-CAC, 2002) and the Lower St. Louis River Habitat Plan Strategies Implementation Planning Worksheet: Project 2.7: Sheltered Bays/Shallow Wetlands- Spirit Lake (LimnoTech, 2012).

Alternative 8 reflects a balance of factors with respect to how it manages sediment in separate areas- Former Operations area sediments and some estuary sediments are consolidated in upland CDFs within the UC ravine where the CDF facilities have lower visual impact and can take some advantage of the valley side to help contain the material. A trade-off is required, however, due to space limitations and stormwater flow needs within the upper UC; which means that some estuary sediments, removed to create a shallow sheltered bay in the OU-M Delta area, are consolidated along with the remainder of the in-place OU-M Delta material in a low CDF constructed against the northern side of the Spit of Land. This will result in a broadened peninsula beside what will be a longer and deeper embayment on the north.

The full thickness of sediments exceeding the PRGs will be removed from the WM Delta shore area and OU-P and -Q. This results in partially recreating the topography of the embayment that existed in this location prior to the Duluth Works site development. This results in an increase in open water and creation of a second shallow sheltered bay habitat area. Alternative 8 increases open water area by 20 acres, which is another important goal of the AOC delisting effort for the lower St. Louis River (SLR-CAC, 2002 and LimnoTech, 2012).

Comparison of the LimnoTech (2012) Spirit Lake Conceptual (Habitat) Restoration Plan with the preferred alternative, identified that although the spit of land will remain with a broad low CDF on its northern side, the majority of the project area will be available for implementing the conceptual plan for habitat improvements in Spirit Lake. Overall the preferred remedy is consistent with the conservation goals set forth in the Restoration Concept Plan. All four of the general habitat types identified in the plan would not be precluded by Alternative 8. Open water – shallow, mid- and deep-water areas either already exist or would not be precluded over most areas of Spirit Lake. Shallow and deep marsh area could be expanded and would not be precluded by Alternative 8. Saturated islands could be developed as broadly outlined in the Restoration Concept Plan. A technical memorandum was submitted to the MPCA and EPA in March 2015 (Barr, 2015). Hydrodynamic conditions should be taken into consideration when planning any habitat restoration work that might affect water flows and sediment transport.

The sustainability of Alternative 8 is also consistent with the overall Vision for this Project (Section 3). This alternative is consistent with the USEPA's National Contingency Plan (NCP) remedy evaluation criteria (40 CFR §300.430), the Minnesota Environmental Response and Liability Act (MERLA, Minn. Stat. § 115B), the USEPA Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites (EPA, 2002), and the USEPA Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (EPA, 2005).

The 11 risk management principles outlined in the EPA guidance (EPA, 2002) are summarized below with a brief discussion of how each principle has been applied throughout the RI/FS process and how Recommended Alternative 8 is fully consistent with the Sediment Management Principles.

Principle 1 – Control Sources Early

The sources of COIs identified in site sediments were primarily wastewater discharges from facilities formerly located on the site and urban runoff/stormwater that flows across the site. The majority of the site operations ceased in 1979, with most of the buildings and other structures razed by the late 1980s, thereby eliminating the wastewater discharges. Several control measures including in situ stabilization, excavation, dredging, capping and covering were implemented in the late 1980s and 1990s to limit the amount of COI-impacted material in the stormwater drainage system that discharges to Spirit Lake. Urban runoff and atmospheric fallout and the river's wash load continue, but are not likely sources to impact site sediments at concentrations above the PRGs for the Site or require additional remedial or restoration activities. Alternative 8 includes restoration elements that control stormwater conveyance on the site to limit the potential for COI-impacted sediment from causing recontamination of site sediments.

Principle 2 – Involve the Community Early and Often

The Morgan Park, West Duluth and greater Duluth community have been involved throughout the RI/FS process, including numerous community meetings to solicit community input and discuss remediation and restoration project goals and progress. Future land use has been the subject of significant discussion with the City of Duluth, the Port Authority and other interested stakeholders during the RI/FS process and is one of the elements considered during remedial alternative evaluation. In addition to remediation elements, Alternative 8 also includes restoration elements that address discussions from the community and stakeholder meetings.

Principle 3 – Coordinate with States, Local Governments, Tribes and Natural Resource Trustees

The RI/FS process has involved a significant coordination among U. S. Steel, the federal government (EPA Region 5 and GLNPO), state government (MPCA and MDNR), local government (City of Duluth and Port Authority), tribes (Fond du Lac and 1854 Treaty Authority) and the natural resource trustees (USF&W, NOAA, and St. Louis River Alliance). The MPCA and EPA (Region 5 and GLNPO) were involved in extensive discussions with U. S. Steel to develop the remediation alternatives evaluated in this FS over several years, including, most recently, a presentation of the draft FS conclusions to a group of St. Louis River estuary resource managers. Alternative 8 includes remediation and restoration elements suggested by stakeholders during the many discussion.

Principle 4 – Develop and Refine a Conceptual Site Model that Considers Sediment Stability

The CSMs developed for the site and presented in Section 2 of this FS summarize the interrelationships of soil, surface and groundwater, sediment and ecological and human receptors. The CSMs are iterative and the results of the site investigations completed at the site to date, including sediment coring, geotechnical drilling and hydrodynamic/sediment transport modeling have been incorporated to assess the temporal, physical and chemical forces that affect the sediment stability at the site. Alternative 8 addresses the interrelationships evaluated in the CSMs and evaluates and factors the sediment stability in Spirit Lake and potential effects on ecological and human receptors.

Principle 5 – Use an Iterative Approach in a Risk-Based Framework

As described in Principle 4, above, iterative CSMs have been used to compile site data, interrelationships, observations and model results to evaluate potential risks presented by sediment impacted by COIs at the site. The CSMs have been updated as new information became available (and will continue to be used during the permitting and design phase) and used to evaluate the potential risks to ecological and human receptors represented by different remedial alternatives. Alternative 8 successfully incorporates remediation components that reduce the potential risks to receptors, including potential recontamination of site sediments.

Principle 6 – Carefully Evaluate the Assumptions and Uncertainties Associated with Site Characterization Data and Site Models

Iterative use of the CSMs to evaluate remedial options has included identification of assumptions and potential uncertainties in site data, observations and model results. Subsequent investigations, observations and modeling have been completed to verify or refute assumptions and refine and inform uncertainties. The investigation, observations and models used during the RI/FS process have been completed in accordance with work plans reviewed by the MPCA and EPA (Region 5 and GLNPO). Hydrodynamic modeling completed for Spirit Lake involved consultation and recommendations from Deltares, the developer of the Delft3D model used for the site and one of the leading coastal process research institutes in the world, during model set up, data collection, and results review. The major 2012 storm and flood provided corroboration of model results predicting areas of sediment erosion and deposition and confirmed the very positive information that substantial deposition of clean sediment occurred in the Estuary as a result of the storm. Site characterization and modeling results have been used to develop appropriate remediation alternatives included in Alternative 8.

Principle 7 – Select Site-Specific, Project Specific, and Sediment-Specific Risk Management Approaches that will Achieve Risk based Goals

The FS includes a detailed evaluation of 12 remedial alternatives developed in consultation with the MPCA and EPA (Region 5 and GLNPO) that incorporate different combinations of the numerous remediation and restoration elements considered. No presumptive remedy was identified prior to the evaluation included in Section 5. Recommended Alternative 8 includes an excellent balance of remediation and restoration elements that manage potential risks by addressing a broad set of environmental, natural resources, property use and other stakeholder interests and goals.

Principle 8 – Ensure that Sediment Cleanup Levels are Clearly Tied to Risk Management Goals

As discussed in the context of Principle 5, an iterative approach has been used to evaluate risk, and the uncertainty of those risks has been addressed via discussion of RI/FS results and potential remediation and restoration alternatives with stakeholders. Attainment of the sediment cleanup levels (designated as PRGs at this site) through the appropriate application of dredging and capping technologies is expected to control ecological and human health risks from the COIs at the site. Site-specific sediment PRGs, identified by the MPCA and presented in Section 2, have been used to determine areas of the site requiring remediation, appropriate remediation alternatives to control and limit potential receptor pathways, and to evaluate the effectiveness of the potential remediation alternatives in achieving protection of human health and the environment. Alternative 8 is expected to meet appropriate risk-management goals, including attainment of the site's sediment PRGs.

Principle 9 – Maximize the Effectiveness of Institutional Controls and Recognize their Limitations

Institutional controls may be used to enhance and support active remediation measures such as dredging, containment and capping, which will be the primary means of limiting exposure to COIs at the site. Institutional controls that may be used at the site are summarized in Section 5.2.1.

Principle 10 – Design Remedies to Minimize Short-term Risks while Achieving Long-term Protection

Evaluation of short-term risks and long-term protection for each of the remediation alternatives is included in Section 5, which demonstrates that the short-term risks during remedy implementation are minimal and that the recommended remedy will be protective on a long-term basis.

Principle 11 – Monitor During and After Sediment Remediation to Assess and Document Remedy Effectiveness

Construction quality assurance and environmental monitoring will be completed during site remediation and restoration activities to ensure compliance with project RAOs, PRGs and other goals. The details of the monitoring program, including but not limited to, media, sample location and frequency, laboratory analysis methods, data quality objectives, compliance standards, and approval or rejection criteria, will be detailed in the quality assurance project plan (QAPP), construction quality assurance plan (CQAP), and sampling and analysis plan (SAP) that will be completed during the permitting and design phase. A long-term monitoring plan will be implemented after completion of the remediation activities to monitor remedy effectiveness.

Added benefits to the recommended alternative are the improvements that could occur to the shoreline and shallow water areas of the Site once the remedial work is completed. Opportunities will exist for incorporating further habitat enhancements along the reconstructed shoreline. Previously prohibited shoreline and shallow water uses such as recreational access could be improved. The post-remedy configuration of shore features will be planned in consultation with the current land owners and neighboring stakeholders during Project design.

In addition, upland areas (Former Operations area) of the site are maintained for future redevelopment opportunities.

6.2 Path Forward

U. S. Steel, GLNPO and MPCA are following an aggressive path forward for the remaining pre-implementation activities described in Section 6.2.1 in order to meet the goal of beginning construction of the preferred alternative during 2016.

6.2.1 Pre-Implementation Activities

To meet this desired Project implementation schedule, several tasks will need to occur in parallel. Below is a summary of the primary pre-implementation tasks that need to occur prior to Project implementation.

- FS review
- Public comment on, and final approval of, the proposed remedy
- Secure Legacy Act funding for the Project implementation phase
- EAW preparation, public comment, and expeditious EIS decision (Appendix G)
- Design development
    - Habitat elements included in design
    - Coordination with resource managers

- Collect supplemental sediment data to refine PRG extent and determine remedy element boundaries to support design, including areas with adjacent remedy elements – in progress

- Conduct supplemental geotechnical sampling and testing to support design for Alternative 8 – in progress

- Negotiate and implement property access agreements and agreements regarding reconstruction of areas disturbed by the remedy construction, including replacement or new infrastructure

- Permitting coordination, application preparation, and agency review (Appendix G)

- Preparation of contractor bid documents, review contractor bids and select contractor

The MPCA will assist with the EAW and the permit review process to help meet the Project schedule.

6.2.2 Project Implementation

The recommended alternative is anticipated to require two full construction seasons to complete. Specific Project implementation schedules will be included as part of the design and will be determined based on input from the selected response action contractor.

Implementation of the recommended alternative, or any of the other alternatives retained for detailed analysis, may require full-time (24 hours per day/7 days per week) project operations at some areas of the Site. The remedial design and associated documents, including the construction quality assurance plan, response action contractor implementation plan, Site-specific health and safety plan, and applicable permits or other regulatory requirements will determine the methods and frequency of monitoring to ensure compliance with applicable standards and guidelines, including noise, air emission quality, surface water quality and turbidity.

7.0 References

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Tables

Table 3-1
TERRESTRIAL CRITERIA BY ANTICIPATED FUTURE LAND USE
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Element/Compound	Recreational SRV*	Industrial SRV*
Arsenic	11	20
Copper	100	9,000
Lead	300	700
Mercury	1.2	1.5
Naphthalene	24	28
BaP Equivalents	2	3

* SRVs are currently under review

Table 3-2
FORMER OPERATIONS AREA BASELINE ECOLOGICAL RISK ASSESSMENT
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Assessment Endpoint	Risk Potential
Terrestrial Areas – CDA, T-10/T-11 and OU-Q Dredge Spoils	
Survival, Growth and Reproduction of Herbivorous Bird Populations Exposed to Soil	Low potential for risk.
Survival, Growth and Reproduction of Invertivorous Bird Populations Exposed to Soil	Potential for risk to invertivorous birds associated with exposure to high molecular weight (HMW) PAHs and lead.
Survival, Growth and Reproduction of Carnivorous Vertebrates Exposed to Soil	Low potential for risk.
Aquatic (Open Water) Areas - Unnamed Pond, OU-I, OU-L, OU-M, OU-Q Wetland, and OU-P (Wire Mill Pond)	
Viability and Function of Aquatic Plant and Benthic Invertebrate Communities	Potential for risk to benthic invertebrates from exposure to PAHs in sediment. Toxicity reference values (TRVs) are unavailable for aquatic plants.
Viability and Function of Aquatic Communities in the water column (fish, plankton, invertebrates)	Potential risks to aquatic biota due to HMW PAHs in surface water.
Survival, Reproduction and Growth of Birds and Mammals	Low potential for risk.
Scrub-Shrub/Forested Wetland Areas - Tar Between I & J, OU-M, OU-L, and OU-Q	
Evaluated as Terrestrial Habitat	
Viability and Function of Plant and Invertebrate Communities	Potential for risk to plant and invertebrate communities exposed to PAHs, lead and zinc.
Survival, Reproduction and Growth of Birds and Mammals	Potential risks to invertivorous birds and mammals exposed to HMW PAHs, lead and zinc.
Evaluated as Aquatic Habitat	

Table 3-2
FORMER OPERATIONS AREA BASELINE ECOLOGICAL RISK ASSESSMENT
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Assessment Endpoint	**Risk Potential**
Viability and Function of Aquatic Plant and Benthic Invertebrate Communities	Potential risks to benthic invertebrates exposed to PAHs and lead. TRVs are unavailable for aquatic plants.
Survival, Reproduction and Growth of Birds and Mammals	Low potential for risk to birds and mammals.

Table 3-3
EXTENT OF IMPACTS
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Area	**Comparison Criteria**	**Horizontal Extent**	**Vertical Extent**
Tar Impacted Soil (Areas T-10 and T-11)	MPCA Tier 2 ISRVs (exceedances noted for arsenic, lead and select PAHs) and ecological SRVs (exceedances included metals and PAHs).	A test pit investigation identified a lateral zone of impact of approximately 0.5 acres at T-10 and approximately 2,000 square feet at T-11.	The full thinkness of non-native material at T-10 in cosidered impacted above PRGs. Test pits in the vicinity of T-11 identified tar within the uppermost two feet.
Non-native Material in the Settling Basin (OU-I)	Level I and Level II SQTs. Level I SQT exceedances were noted for both metals and PAH constituents. Level II exceedances were limited to select metals.	The horizontal extent of impacted upland sediment at OU-I (approximately 6.78 acres) is constrained by topographic features associated with the historic coke plant settling basin and adjacent Ous.	The full thickness of non-native sediment within OU-I is considered impacted above PRGs. The base of the upland sediment extends to approximately 606 feet amsl.
Tar and Tar-Impacted Soil in the Coke Plant Settling Basin (Tar between I & J)	Level I and Level II SQTs. Level I and Level II SQT exceedances were noted for both metals and PAHs.	The 1.2 acre area of impacted upland sediment is constrained by topographic features associated with the historic coke plant settling basin and adjacent OUs.	The full thickness of non-native sediment within the area between OU-I and OU J is considered impacted above PRGs.
Stream Channel (OU-L)	Level I and Level II SQTs. Level I and Level II SQT exceedances were noted for both metals and PAHs.	The horizontal extent of OU-L, approximately 3.2 acres, is impacted upland sediment	The full thickness of non-native sediment within OU-L is considered impacted above PRGs. The base of the upland sediment extends to approximately 598 feet AMSL.
Delta and Stream Channel (OU-M)	Level I and Level II SQTs. Level I and Level II SQT exceedances were noted for both metals and PAHs.	The horizontal extent of impacted upland sediment is approximately 46 acres, constrained by topographic features.	The full thickness of non-native sediment within OU-M is considered impacted above PRGs.
Wire Mill Pond (OU-P)	MPCA Tier 2 ISRVs (exceedances noted for lead), ecological SRVs (exceedances included metals and PAHs) and Level I and Level II SQTs (exceedances were noted for both metals and PAHs).	The horizontal extent of impacted upland sediment is constrained by topographic features associated with the Wire Mill settling basin (approximately 1.1 acres).	The full thickness of non-native sediment within OU-P is considered impacted above PRGs. The base of the upland sediment extends to approximately 587 feet AMSL.
Non-native Material and Dredge Spoils in Wire Mill Settling Basin (OU-Q)	MPCA Tier 2 ISRVs (exceedances noted for arsenic, lead and benzo(a) pyrene equivalents). Further evaluation of OU-Q dredge spoils was performed in order to develop disposal options for elevated levels of lead in soil. Soil was found to exceed the toxicity characteristic for lead.	The horizontal extent of sediment impacts at OU Q encompasses an area of approximately 6.4 acres. The lateral extent of an area exhibiting elevated lead in dredge spoils on the periphery of OU-Q has not been defined.	The full thickness of non-native sediment within the wetland portion of OU-Q is considered impacted above PRGs. Dredge spoils along the periphery of OU-Q extend up to 8 feet below grade.
Concrete Disposal Area (CDA)	MPCA Tier 2 ISRVs (exceedances noted for arsenic and select PAHs) and ecological SRVs (exceedances included metals, PAHs, VOCs and PCBs). Alkaline soils also are present.	The horizontal extent of chemical impacts and non-native fill encompasses 13 acres, as determined by test pit and soil boring investigations.	The vertical extent of chemical impacts and non-native fill were observed to a maximum depth of 32 feet below grade.

Table 3-3
EXTENT OF IMPACTS
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Area	**Comparison Criteria**	**Horizontal Extent**	**Vertical Extent**
Unnamed Pond	Level I and Level II SQTs. Level I and Level II SQT exceedances were noted for both metals and PAHs.	The horizontal extent of impacted upland sediment is assumed to extend across the 0.2 acre foot-print of the Unnamed Pond.	Impacted upland sediments were encountered vertically within the four feet deep investigation zone. Native material was not encountered.
Wire Mill Delta	Level I and Level II SQTs. Level I and Level II SQT exceedances were noted for both metals and PAHs.	The horizontal extent of impacted sediment is assumed to extend across approximately 90 acres of the Wire Mill Delta.	The impacted sediments in the Wire Mill Delta ranges from up to 4 ft thick near shore to less than 0.5 ft thick offshore.
Unnamed Creek Delta	Level I and Level II SQTs. Level I and Level II SQT exceedances were noted for both metals and PAHs.	The horizontal extent of impacted sediment is assumed to extend across approximately 90 acres of the Unnamed Creek Delta.	The impacted sediments in the Unnamed Creek Delta ranges from more than 10 ft thick near shoreline to less than 0.5 ft offshore.

Table 3-4
SUMMARY CHEMICALS OF INTEREST (COIs)
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

	Operable Unit or Study Area							
Sediment COI	OU-N and OU-R	OU-I	SA Tar Btwn I &J	OU-L	OU-M	OU-P	OU-Q	SA Unnamed Pond
Arsenic	●	●	●	●	●	●	●	●
Cadmium	---	---	●	●	●	●	●	●
Copper	●	●	●	●	●	●	●	●
Chromium	●	---	●	---	●	●	●	●
Lead	●	●	●	●	●	●	●	●
Mercury	---	●	●	●	●	---	●	●
Nickel	●	●	●	---	●	●	●	---
Zinc	●	●	●	●	●	●	●	●
PAH (13)	●	●	●	●	●	●	●	---

	Operable Unit or Study Area		
Soil COI	OU-Q	SA T-10 and T-11	SA-CDA
Arsenic	●	●	●
Cadmium	---	---	---
Copper	---	---	---
Chromium	---	---	---
Lead	●	●	---
Mercury	---	---	---
Nickel	---	---	---
Zinc	●	---	---
Naphthalene	---	●	●
BaP Equiv.	---	●	●
pH	---	---	●

Table 3-5
FORMER OPERATIONS AREA STORMWATER CONVEYANCE GOALS
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

GOAL	OBJECTIVE	CRITERIA
Stormwater Conveyance	Contain flowing stormwater within the structures (including ponds), box culverts, channels, and embankments of the stormwater conveyance system to limit erosion and routine maintenance requirements	Base flow and frequent events (10-year, 24-hour design storm) Caps: 10-year, 24-hour design storm
Flood Management	Avoid increasing the flood level downstream of the project and avoid adverse on-site impacts from flooding	100-year, 24-hour design storm
Containment	Design conveyances and caps to protect sediments that are capped in place from susceptibility to further transport; limit potential for erosion and scour by specifying materials, and designing conveyances and caps, to remain stable under a range of anticipated velocities and flow characteristics	Base flow 10-year, 24-hour design storm 100-year, 24-hour design storm

Table 3-6
PRELIMINARY REMEDIATION GOALS FOR SEDIMENT
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Element/Compound	Bulk Sediment Preliminary Remediation Goal[1] (mg/kg)
Total $PAH_{(13)}$	12.3
Lead	83
Copper	91
Zinc	290

1 – Preliminary Remediation Goals were provided by MPCA (MPCA, 2014b) and set at the midpoint between Level I and Level II MPCA Sediment Quality Targets (MPCA, 2007)

Table 3-7
POTENTIAL RECEPTORS DRIVING HABITAT ZONE THICKNESS
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Habitat Zone	Thickness (cm)	Applicable Areas	Potential Receptors
Backshore / Foreshore	120	• Shoreline/beach areas • Sediment flats • Open water/transition	• Deep rooted herbaceous and/or woody plants • Deep burrowing mammals
Emergent Aquatic Vegetation	100	• Wetlands and areas of emergent aquatic vegetation • Potential for emergent aquatic vegetation	• Emergent aquatic vegetation • Deep burrowing amphibians, reptiles, or crustaceans
Submerged Aquatic Vegetation and Deep Water	50	• No potential to transition to wetland • Deep water • Armored areas or areas with root barriers	• Benthic organisms • Submerged aquatic vegetation

Reference: MPCA Letter dated March 2014 (MPCA, 2014b)

Table 4-1
SOIL AND SEDIMENT TECHNOLOGY SCREENING RANKING
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
St. Louis River
Duluth, Minnesota

General Category	Technology	Description	Site	Applicability to Site	Ranking: Effectiveness	Ranking: Implementability	Ranking: Relative Cost	Retained for Consideration	Rationale
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.	**Estuary**	May include fish consumption advisories, commercial fishing bans, waterway use restrictions, and deed restrictions.(1)	Effective at meeting remediation goals when combined with other remedies.	Easily implemented with little disruption to the site at any stage of the remedial process.	$ Minimal but there are long term costs associated with initiating and maintaining institutional controls.	Yes	Institutional controls are expected to be a required component of any remedy.
			Upland	May include restrictions on excavation or types of development.					
Natural Recovery (NR)	Natural Recovery (NR)	NR leaves impacted sediment in place and relies on ongoing, naturally occurring processes to isolate, destroy, or reduce exposure or toxicity of impacted sediment.	**Estuary**	Already occurring at the site in some areas through deposition of new sediment layers.	Highly effective in some estuary locations, when combined with other technologies and institutional controls.	Highly implementable. No construction, infrastructure, or heavy equipment is required.	$ The main cost of NR is associated with monitoring, if required.	Yes	Effective at some locations when combined with other remedies.
			Upland	NR is occurring in some upland areas, though rate is slow.	Marginally effective due to thickness of impacts.			No	Limited effectiveness for deep impacts.
	Enhanced Natural Recovery (ENR)	ENR adds amendments to the soil or 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).	**Estuary**	May enhance NR that is already occurring in some areas.	Would accelerate the NR process, reducing time to meet SMGs.	Implementable. Placement requires Site access, standard sediment remediation equipment and resuspension controls.	$$ Greater cost than NR due to thin cover or amendment placement, but low compared to sediment removal and capping.	Yes	Effective at some locations when combined with other remedies.
			Upland	May enhance NR in surficial soils.	Marginally effective due to thickness of impacts.	Technically challenging in areas of deep impacts.	$$ Costly to address deep impacts with ENR.	No	Limited effectiveness for deep impacts.
Capping	Capping	Capping provides a physical barrier and chemical isolation from COIs. Caps may be constructed from clean sediment, sand, gravel, geotextiles, liners, reactive or absorptive material and may consist of multiple layers (5). Granular sediment caps can provide erosion protection and limit bioturbation (1).	**Estuary**	Cap thickness depends on bioactive zone (BAZ) thickness requirements, which vary by habitat, substrate and water depth. A cap may alter hydrologic and habitat conditions in the estuary.	Highly effective and proven method. Site COIs have low solubility and mobility, so capping would be an effective containment method. Hydrodynamic modeling suggests that potential scouring by wave action is not a significant concern. Short term movement of COIs in porewater is possible during consolidation.	Dredging may be required in shallow areas to accommodate cap thickness. Multiple layered caps may require specialized equipment. Additional study is needed if reactive or absorptive materials are used. Maintenance is manageable given the stable hydrodynamic conditions.	$$$ Costs are generally less than sediment removal, and depend on cap thickness, material, lateral extent and surface water engineering factors. Material costs for a synthetic cap are generally higher than a granular cap.	Yes	Proven effective method to control exposure and erosion.
			Upland	Capping would control direct exposure to impacted material and prevent erosion.	Highly effective and proven method.	Readily implemented in upland areas.		Yes	Proven effective method to control exposure and erosion.
Excavation and Removal	Mechanical Dredging	Sediment is lifted to the surface using a mechanical excavator or crane and placed on a barge for transport. Removed sediment has a similar moisture content as the in situ material, requiring dewatering prior to disposal (3). Residual cover is typically needed to manage remaining impacts.	**Estuary**	Mechanical methods are required to remove debris in the Wire Mill sediments and the cemented non-native sediments in the Unnamed Creek Delta. Resuspension controls expected to be needed.	Highly effective proven method for remediating impacted sediment. Controlling resuspension and limiting redeposition and transport of impacted sediment is needed to achieve short and long term SMGs.	Requires dredging equipment and infrastructure for treatment, transport, and/or disposal of dredged sediment. Less water is produced compared to hydraulic dredging, so less space is needed for sediment/water management.	$$$ Main capital costs include equipment mobilization, equipment operation, residual cover materials, and construction and operation of a containment area for dredged material.	Yes	Proven method. Required for removal of debris and hardened sediments.
	Hydraulic Dredging	Hydraulic dredging adds water to the sediment and removes it by pumping it in the form of a 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.	**Estuary**	Hydraulic methods are not suitable to remove debris in the Wire Mill Delta or cemented non-native sediments in the Unnamed Creek Delta.	Proven method for remediating impacted sediment, but not effective at removing debris or hardened sediments. Mechanical methods would also be reqiuired.	Requires hydraulic dredging equipment and infrastructure similar to mechanical dredging. More water treatment and space for sediment management needed than with mechanical dredging due to high water content of slurry.	$$$ Higher costs than mechanical dredging due to the need for mechanical equipment to remove debris, and the additional treatment and disposal costs due to greater water content of the slurried sediment.	Yes	Suitable for dredging soft sediments. Not suitable for removing debris or hardened sediments.

Table 4-1
SOIL AND SEDIMENT TECHNOLOGY SCREENING RANKING
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
St. Louis River
Duluth, Minnesota

General Category	Technology	Description	Site	Applicability to Site	Ranking			Retained for Consideration	Rationale
					Effectiveness	Implementability	Relative Cost		
Excavation and Removal	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.(1)	**Estuary**	Well suited for areas in the Unnamed Creek Delta with shallow water depths and geometry that allows for construction of a containment barrier and water diversion.	● Removal of sediment in dry conditions allows for visual inspection and is typically more complete than with dredging. Very little potential for resuspension, mobilization and redeposition of impacted sediment.	⊙ Not feasible for all estuary areas due to the large removal areas and large amount of water to divert. Site preparation complicated and lengthy due to water management. Implementable in shallow areas where containment is feasible.	$$$ Costs are similar to mechanical dredging costs, with the added cost to construct diversion or containment structures.	Yes	May be suitable for select areas of estuary with shallow water and favorable geometry for containment.
		Soil is removed with conventional excavation equipment. Commonly combined with capping.	**Upland**	Either complete excavation or partial excavation combined with capping may meet RAOs.	● Highly effective and proven method.	● Readily implemented in upland areas with conventional earthwork equipment.	$$ Costs depend highly on excavation extent and volume. Cost can be less when combined with capping to minimize volume of excavated soil and backfill.	Yes	Proven effective method.
Disposal	Offsite - Sanitary/ Hazardous Waste Landfill	Removed soil or sediment is transported to an offsite disposal location that will accept the waste. Dewatering of sediments is generally required before transport.	**Estuary/ Upland**	Transportation of large volumes of soil and sediment would create significant truck traffic through the surrounding community for a long duration.	● Very effective at meeting SMGs and RAOs, as the sediment would be removed from the site. Some risk of release during transportation.	⊙ Thorough dewatering is required to meet landfill liquid restrictions. The site is accessible for haul trucks, but truck traffic would cause significant disruption, damage to roads and noise concerns. Risk of off-site release during transportation.	$$$$ Costs for offsite disposal include dewatering, water treatment, loading and transportation costs and landfill disposal fees. Transportation costs depend on distance to the landfill.	No - for large estuary or OU-I, OU-M areas. *However, retained for localized upland soil impact area on hillside beside OU-P/Q area.*	High cost and community disruption relative to other disposal options. Risk of off-site release during transport.
	Onsite - Confined Disposal Facilities (CDFs)	CDFs are engineered structures enclosed by dikes and specifically designed to contain sediment. CDFs may be located either upland (above the water table), near-shore (partially in the water), or completely in the water (island CDFs).	**Estuary/ Upland**	Land is available for a CDF. Placement of a CDF near shore in the Unnamed Creek Delta could utilize existing geometry for containment while covering impacted sediments in this area.	● CDFs are the most widely used method for disposal of impacted sediments and have demonstrated effectiveness for containment.	⊙ CDF design requires detailed knowledge of the dredging plans, sediment properties and predicted effluent quality. A CDF would be a permanent structure occupying a large area. Treatment of the dewatering discharge is likely required.	$$$ Costs for a CDF include engineering and design costs, materials for dikes and suspended solids control, and construction equipment and labor.	Yes	Feasible consolidation areas are available. Community disruption is limited.
	Onsite - Contained Aquatic Disposal (CAD)	Dredged or excavated sediment is disposed within a natural or excavated depression elsewhere in the water body.	**Estuary**	A suitable location to accommodate all sediment volumes is not available due to shallow water depths. The water intake hole in the Wire Mill Delta and the dredged channel in the Unnamed Creek Delta could hold some volume, but these are desirable fish habitat areas.	⊙ A CAD may be effective at containing PAHs and metals due to their low mobility and solubility. Monitoring may be needed to verify effectiveness. Materials used for construction need to prevent lateral migration. Wave effects at the CAD site would need to be evaluated.	⊘ An existing depression large enough for a CAD is not available. Dredging to accommodate required disposal volumes would not be cost effective. CAD design requires knowledge of sediment and hydraulic conditions.	$$$ Specialized equipment for a CAD may be required, especially if the disposal site is in deep water. Dredging to create a CAD would add cost.	No	A suitable location is not available in the estuary to accommodate the required disposal volume.
In Situ Treatments	Immobilization	Immobilization treatments add chemicals or cements to reduce the leachability of COIs. Mechanisms include solidification (encapsulation) or stabilization (chemical or absorptive reactions that convert COIs to less toxic or mobile forms). (2)	**Estuary**	Implementation at a sediment site is difficult, due to work below the water and concerns with temporary pH effects and volatilization of COIs.	⊙ Not widely used at sediment sites. Effectiveness for PAHs demonstrated at some sites, but not widely accepted. Proven effective for metals in soils. May create toxic conditions for benthic organisms.	⊘ Can be difficult to inject and adequately mix reagents in situ. The solidified material increases in volume and could limit future site uses, and future site dredging.	$$$ 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.
			Upland	Used successfully at OU-J, with some challenges; modifications to storm water system were required.	● The effectiveness for PAHs has been demonstrated at some sites, but is not widely accepted. Proven effective methods for metals in soils.	⊙ Pilot studies and evaluation of effects on surface waters required. The solidified material results in a permanent solid structure below ground.	$$$ Large volumes are costly to treat.	Yes	Requires treatability testing and further evolution.

Table 4-1
SOIL AND SEDIMENT TECHNOLOGY SCREENING RANKING
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
St. Louis River
Duluth, Minnesota

General Category	Technology	Description	Site	Applicability to Site	Ranking: Effectiveness		Ranking: Implementability		Ranking: Relative Cost		Retained for Consideration	Rationale
In Situ Treatments	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 or soil.	**Estuary**	Can be effective for PAHs, but not likely effective for metals.	∅	Metals are not easily removed by bioremediation. Success depends on temperature, pH, oxygen, nutrient availability, bioavailability, and toxicity of end products, which vary by site and are difficult to control insitu. Time frame difficult to predict.	◉	Bioremediation is easily implemented with shallow impacts, but becomes more difficult with deep impacts.	$$	Costs of enhanced bioremediation are relatively low, but several treatments and extensive monitoring may be required.	No	Difficult to implement subaqueously.
			Upland								No	Effectiveness for metals is uncertain.
	Oxidation/ Reduction	Chemicals are injected into sediment to act as an oxidant/electron acceptor to facilitate aerobic decomposition of organic matter.	**Estuary**	Effectiveness is uncertain for metals. Chemical addition may create toxic conditions.	∅	Not proven safe and effective for sediment sites.	⊙	Bench-scale and pilot-scale testing required to determine the type, concentration and quantities of oxidant and amendments needed. Specialized equipment is likely required for injection of chemicals.	$$$	Costs include bench- or pilot-scale tests. Monitoring may be required.	No	Not proven safe for subaqueous conditions. Effectiveness for metals is uncertain.
			Upland	Would require treatment of large areas.	⊙	PAH degradation can occur under both denitrifying and sulfate-reducing anaerobic conditions. Effectiveness for metals is highly dependent on site conditions.					No	Effectiveness for metals is uncertain.
	Chemical Oxidation	The addition of chemical oxidizers to sediment can cause the rapid and complete chemical destruction of many toxic organic chemicals	**Estuary**	Limited effectiveness for Site COIs.	∅	Addition of chemicals may form toxic conditions for benthic or aquatic organisms.	⊙	Pilot studies would be required to determine the effectiveness of specific oxidants for Site COIs.	$$$	Costs include bench- or pilot-scale tests to determine effectiveness, oxidants for injection, and a delivery system. Monitoring may also be required.	No	Limited effectiveness. Chemical addition may create toxic conditions.
			Upland		⊙	Chemical oxidation has limited demonstrated effectiveness for PAHs. Effectiveness for treating site metals is not known, but depends on the specific constituent.					No	Effectiveness for PAHs and metals is uncertain.
	Phyto-remediation	Phytoremediation uses plant species to remove, transfer, stabilize, and destroy COIs in soil and sediment. Generally limited to sediments in shallow water zones and low concentrations.	**Estuary/ Upland**	Planting restoration measures to restore habitat may contribute to natural recovery.	⊙	Only effective where COIs are near the surface at residual concentrations. Remediation time frame is long.	●	Implementation involves planting and in some cases harvesting, with little disruption to the site.	$$	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 COIs. Sorption of metals and organics can take place simultaneously with a suitable combination of sorbents.	**Estuary**	May be useful as a capping or ENR amendment in the areas of the delta where impacted sediment is at the surface and would be in direct contact with amendments.	◉	Activated carbon is not effective for metals, but may be impregnated with ion exchange materials to enhance metal adsorption. However, this could affect the carbon's capacity for organics absorption.	◉	Sorbent amendments can be delivered to the sediment in the form of pellets that are dense enough to sink through the water column and are resistant to re-suspension while being worked into the sediments.	$$	The main costs include the adsorbent material, and a method for depositing it on the surface sediment. Monitoring may also be required.	No	Not retained as sole remedy, but may be useful as capping or ENR amendment.

Key:

	Effectiveness	Implementability
●	Demonstrated effective technology	Readily implemented
◉	Effective under certain conditions	Implementable, requires technical knowledge
⊙	Partially effective for some COIs or Site areas	Difficult to implement
∅	Not effective at reaching SMGs or PRGs	Not implementable at the site

	Relative Cost
$	Low
$$	Moderate
$$$	Medium-High
$$$$	High

References:

(1) USEPA. 2005. *"Contaminated Sediment Remediation Guidance for Hazardous Waste Sites,"* EPA-540-R-05-012, OSWER 9355.0-85, Washington, DC.

(2) USEPA. 2000. *"Solidification/Stabilization Use at Superfund Sites,"* EPA-542-R-00-010, OSWER 5102G, Washington, DC.

(3) USEPA. 1994. *"ARCS Remediation Guidance Document,"* EPA 905-B94-003. Chicago, Ill.: Great Lakes National Program Office.

(4) Federal Remediation Technologies Roundtable. 2002. *"Remediation Technologies Screening Matrix and Reference Guide, 4th Edition,"* Available online at: http://www.frtr.gov/matrix2/top_page.html

(5) ASCE. 2007. *In Situ Capping of Contaminated Sediments with Reactive Materials. J.T. Olsata. Proceedings of Ports 2007: 30 Years of Sharing Ideas 1977-2007".* American Society of Civil Engineers (ASCE). March 25-28, 2007.

Table 4-2
WATER MANAGEMENT TECHNOLOGY SCREENING RANKING
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
St. Louis River
Duluth, Minnesota

General Category	Technology	Description	Applicability to Site	Ranking			Retained for Use in Alternatives?	Rationale
				Effectiveness	Implementability	Relative Cost		
Surface Water Engineering	Stream Channelization	Regrading the Unnamed Creek stream channel to direct flow away from impacted areas and to control sediment transport using features similar to a natural stream channel. May include liner materials and geotextiles for sediment control.	Some degree of surface water engineering will be necessary for any alternative except for no action.	● Highly effective, well established methods for managing surface water flow and diversion	● Highly implementable using standard design and construction methods. Permitting may be necessary for disturbing wetlands and altering storm water flow.	$$ Depends highly on the design.	Yes	Some surface water engineering will be necessary.
	Stream Culverting	Install a culvert pipe or other structure to carry water over or through a impacted area.					Yes	
	Stream Diversion	Relocate all or part of the channel away from impacted area.					Yes	
Dewatering	Passive Dewatering	Passive dewatering relies on natural evaporation and drainage to remove moisture from the sediment. Drainage may be driven by gravity or assisted with a vacuum pump. Passive dewatering may occur in CDFs, lagoons, tanks, or temporary holding/rehandling facilities.	Upland areas are available at the site that could serve as a passive dewatering area.	⊙ Passively dewatered sediments may not have low enough water content for landfill disposal, so supplemental technologies may be required. CDF volume must be designed to account for passive dewatering residence time.	⊙ Significant footprint required for construction of lagoons or a CDF. Time frames for passive dewatering likely longer than for mechanical dewatering. With a proper CDF design passive methods may be easily supplemented with other dewatering technologies.	$$ Costs to consider include construction of a dewatering facility or adequately sized CDF.	Yes	Appropriate for onsite CDF.
	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.	◉ Sediment mixing and reworking would facilitate a timelier and more complete dewatering.	◉ Mixing and reworking sediments would decrease time needed to dewater with passive methods. Reworking and mixing could be done with standard excavation equipment already required for the project.	$$ Cost savings are expected over passive dewatering alone due to time saved.	Yes	Supplement to passive methods.
	Hygroscopic Amendment Addition	Dredged sediments are mixed with amendments such as slags or cementitious materials to remove moisture and improve strength and stability.	Could be used to enhance dewatering in conjunction with sediment reworking.	◉ Effectiveness of amendments depend on the moisture content of removed sediment. Pre-treatment dewatering may be needed for maximum effectiveness and to achieve desired geotechnical properties.	◉ Would require staging, mixing, and curing areas. However, the process can be completed in a relatively short time frame. Amendment addition creates a greater volume and mass, which needs to be considered in disposal options.	$$ Costs include amendment materials and mixing equipment. Costs increase with increased moisture content. Both the addition rate and the bulking factor of treated material should be considered when evaluating costs of amendment material.	Yes	Supplement to passive methods.
	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 hydraulic dredging, which is not retained for alternatives for the Site.	◉ Applicable to hydraulic dredging. For fine grained sediment (silt and peat from Spirit Lake), polymer addition is usually needed to facilitate dewatering. Treatability tests indicate filtrate would need treatment to meet water quality criteria.	◉ Would require a staging location if transported to landfill. Dewatering duration likely to be shorter than for passive dewatering but longer than mechanical.	$$$ Costs include flocculent and coagulant materials, cost of geotextile tubes and construction of staging area.	Yes	For use with hydraulic dredging.
	Mechanical Dewatering	Mechanical dewatering technologies include use of plate filters, presses, centrifuges or other equipment to squeeze, press, or draw water from dredged sediment.	Difficult to produce required homogeneous waste stream with mechanical dredging methods and site sediments.	◉ Generally works best with a homogeneous waste stream, so temporary storage in a lagoon or tank would be required (3). Selection of specific mechanical dewatering equipment depends on treatment or disposal methods that follow.	◉ Faster than passive dewatering and requires less space. Production rates depend on size and quality of the dewatering device and on the solids content of the input stream.	$$$$ Costs of mechanical dewatering are generally higher than passive dewatering due to the energy and equipment requirement.	No	Not cost effective. Waste stream not homogeneous.
	Rapid Dewatering Systems (e.g. Genesis)	A system that continuously processes the slurry from a hydraulic dredge and separates solids into piles of debris; shells; and gravel, sand, and fines. Includes polymer addition and flocculation, which may remove some COIs.	Only suitable for hydraulic dredging methods, which are not retained.	◉ Applicable to hydraulic dredging methods. Pilot scale testing may be needed to evaluate effectiveness for site specific conditions.	◉ The complete system is mobile and has a relatively small footprint.	$$$ Exact cost would depend on site-specific treatment needs.	Yes	For use with hydraulic dredging.
Treatment of Wastewater	Bioreactors	Bioreactors use microbial activity to degrade organic constituents in water.	Not effective at removing metals.	∅ Bioreactors have often been used to effectively treat PAHs, but would not be effective for metals.	∅ This is a long-term technology that can take several years to bring concentrations of COIs to acceptable levels (4). Residuals from the sludge process also require treatment or disposal.	$$ Costs include equipment, energy for pumping and agitation, and sludge material. Cost is affected by COD of the water and the need for pH adjustment.	No	Not effective for metals. Time frame too long.

Table 4-2
WATER MANAGEMENT TECHNOLOGY SCREENING RANKING
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
St. Louis River
Duluth, Minnesota

General Category	Technology	Description	Applicability to Site	Ranking			Retained for Use in Alternatives?	Rationale
				Effectiveness	Implementability	Relative Cost		
Treatment of Wastewater	Filtration	Filters remove solids and sediments from wastewater, also removing absorbed COIs 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 COIs sorbed to suspended sediments in the waste stream.	● Filters can be selected based on the required particulate size. Treatability study indicated COIs in CDF effluent likely associated with suspended sediment, so filtration may be effective at reducing the COI concentration.	⊙ Filtration is a widely used method for water treatment. Selection of the filtration methods and type requires engineering design and site specific knowledge of the waste stream.	$$$ Costs depend on change out frequency of filtration material.	Yes	Effective for COI removal.
	Liquid Absorption	Involves pumping water through a vessel containing granular activated carbon (GAC), organoclay, or another adsorbent material; dissolved compounds to adsorb to its surface.	Conventional absorptive materials would remove PAHs.	◉ Activated carbon vessels are appropriate for treating PAHs. Activated alumina, forage sponges, lignin adsorption/sorptive clays are more effective for the removal of inorganics and heavy metals (4). The presence of multiple constituents can impact the performance of activated carbon systems.	◉ Liquid adsorption systems are widely available, have a relatively small footprint, and require a relatively short timeframe for treatment.	$$$ Costs include activated carbon, or other adsorbent vessels. The adsorbent must be recharged or replaced periodically. Power is required for pumping.	Yes	Effective for COI removal.
	Advanced Oxidation	Advanced oxidation uses UV light and the addition of strong oxidizers to destroy organic constituents in water.	Not effective at removing metals.	⊙ Advanced oxidation is applicable for treating most organics, including PAHs, but may not be effective for the treatment of metals.	◉ Advanced oxidation systems are widely available, have a relatively small footprint, and require a relatively short timeframe for treatment. Handling and storage of oxidizers would require special safety precautions.	$$$$ Costs may be higher because of energy requirements to power UV lights.	No	Not effective for metals. High cost.

Key:

	Effectiveness	Implementability
●	Demonstrated effective technology	Readily implemented
◉	Effective under certain conditions	Implementable, requires technical knowledge
⊙	Partially effective for some COIs or Site areas	Difficult to implement
∅	Not effective at reaching SMGs or PRGs	Not implementable at the site

	Relative Cost
$	Low
$$	Moderate
$$$	Medium-High
$$$$	High

References:
(1) USEPA. 2005. *"Contaminated Sediment Remediation Guidance for Hazardous Waste Sites,"* EPA-540-R-05-012, OSWER 9355.0-85, Washington, DC.
(2) USEPA. 2000. *"Solidification/Stabilization Use at Superfund Sites,"* EPA-542-R-00-010, OSWER 5102G, Washington, DC.
(3) USEPA. 1994. *"ARCS Remediation Guidance Document,"* EPA 905-B94-003. Chicago, Ill.: Great Lakes National Program Office.
(4) Federal Remediation Technologies Roundtable. 2002. *"Remediation Technologies Screening Matrix and Reference Guide, 4th Edition,"* Available online at: http://www.frtr.gov/matrix2/top_page.html
(5) ASCE. 2007. *In Situ Capping of Contaminated Sediments with Reactive Materials. J.T. Olsata. Proceedings of Ports 2007: 30 Years of Sharing Ideas 1977-2007".* American Society of Civil Engineers (ASCE). March 25-28, 2007.

Table 5-1
Quantities Summary
U. S. Steel Former Duluth Works

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9	Alternative 10	Alternative 11	Alternative 12
Removal Total Volume (cubic yards)	0	0	287,000	354,000	454,000	648,000	616,000	648,000	327,000	1,139,000	3,008,000	716,000

Capping Area (acres)	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9	Alternative 10	Alternative 11	Alternative 12
Estuary Remedial Cap	--	172	57	77	78	91	91	91	121	121	--	114
Estuary ENR Thin Cover	--	--	30	30	30	30	30	30	30	30	--	30
Upland Remedial Cap	--	47	37	37	37	28	14	22	22	22	--	22
CDF/Landfill Cap	--	--	57	36	42	46	31	23	23	34	76	40
Unnamed Creek Estuary Sediment CDF Cap	--	--	--	--	--	--	--	29	--	--	--	--
Delta Cap (Alternative 7)	--	--	--	--	--	--	29	--	--	--	--	--
Total Area (acres)	**0**	**219**	**181**	**181**	**187**	**196**	**196**	**196**	**196**	**207**	**76**	**207**

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9	Alternative 10	Alternative 11	Alternative 12
Net Change in Open Water (acres)	0	-48	-11	9	10	20	20	20	7	56	56	44

CDF Berm Height (feet)	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9	Alternative 10	Alternative 11	Alternative 12
OU-M Delta/Estuary CDF	--	--	4	8	9	19	--	6	--	--	--	--
OU-M Upland	--	--	--	--	--	6	20	9	14	--	--	20
OU-I	--	--	--	--	--	--	13	--	--	--	--	--
Behind OU-J	--	--	--	--	25	25	25	25	25	--	--	25
Borrow Site	--	--	--	--	--	--	--	--	--	--	--	20
Upland Coke Plant Area	--	--	--	--	--	--	--	--	--	26	26	--

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Table 5-2
SCREENING LEVEL EVALUATION OF ALTERNATIVES
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Alternative	Description	Effectiveness of Achieving RAOs and Considerations: Upland RAOs and Considerations • Protect human health and the environment • Provide a stable water course for stormwater conveyance and discharge • Preserve areas for economic development	Effectiveness of Achieving RAOs and Considerations: Estuary RAOs and Considerations • Protect human health and the environment • Reduce beneficial use impairments for St. Louis River Area of Concern • Improve habitat (betterment)	Implementability	Relative Cost Relative Rankings: #1 = lowest cost; #12 = highest cost	Screening Level Score (sum of Effectiveness, Implementability, and Cost scores)	Additional Factors for Consideration	Retained for Detailed Evaluation?
Alternative 1 No Action	No Action.	NA - current conditions		NA	NA	NA	NA	
Alternative 2 Remedial Capping	Alternative 2 is the "cap-only" option and involves placement of a remedial cap over portions of the Upland Site and the Estuary Site. Unnamed Creek would be re-routed to discharge into the former water intake area in the northern portion of Wire Mill Delta.	Low-Medium - 4 - Would be effective at protection of human health and environment as a result of physical barrier, but would not remove any impacted material. - Would be effective at achieving RAOs and Considerations, with the exception that it would result in the loss of open water habitat.		Medium - 3 - Large volume of capping material is necessary; however, traditional earthwork and subaqueous capping equipment could be used. -Construction of the Wire Mill discharge structure would be possible, but challenging.	Low-Medium - 2 Relative Cost Ranking: #2	9	As a result of cap placement, approximately 48 acres of open water would be lost.	**No,** because results in a net loss of aquatic habitat.
Alternative 3 Delta/Estuary CDF	Alternative 3 involves removal of impacted sediments from the Upland Site and Estuary Site with placement in a CDF that extends from the OU-M Delta into the estuary. The alternative also involves placing a remedial cap over three areas on the Upland Site and placement of a remedial cap or ENR thin cover over a portion of the Estuary Site. Unnamed Creek would be allowed to pond in OU-I and would be re-routed to discharge into the former water intake area in the northern portion of Wire Mill Delta. Stormwater management in Alternative 3 would include construction of a small base-flow channel through OU-I (allowing OU-I to flood during high flow conditions).	Low-Medium - 4 - Would be effective at protection of human health and environment as a result of cap placement and impacted material removal, - Would be effective at achieving RAOs and Considerations, with the exception that it would result in the loss of open water habitat.		Medium - 3 - Dredging, subaqueous capping and traditional earthwork equipment would be necessary. -Construction of the Wire Mill discharge structure would be possible, but challenging.	Low-Medium - 2 Relative Cost Ranking: #3	9	CDF located in OU-M Delta and estuary. CDF is placed on top of existing OU. Net loss of approximately 11 acres of open water.	**No**, because results in a net loss of aquatic habitat and both upland and estuary sediments are consolidated in a Delta/Estuary CDF.
Alternative 4 CDF on OU-M Delta	Alternative 4 involves the same actions as Alternative 3 except that the extent of the CDF is entirely within OU-M Delta. Additional material would be removed from the estuary in the area that was covered by CDF in Alternative 3. Capping would involve three areas on the Upland Site and placement of a remedial cap or ENR thin cover over a portion of the Estuary Site. Stormwater management in Alternative 4 would include construction of a small base-flow channel through OU-I (allowing OU-I to flood during high flow conditions).	Medium-High - 2 - Would be effective at protection of human health and environment as a result of cap placement and impacted material removal. - Would be effective at achieving all RAOs and Considerations. - Results in a net gain of open water as a result of removal from the Wire Mill pond; however, significant habitat improvement is not a major component.		Medium - 3 - Dredging, subaqueous capping and traditional earthwork equipment would be necessary. -Construction of the Wire Mill discharge structure would be possible, but challenging.	Low-Medium - 2 Relative Cost Ranking: #4	7	CDF is placed on top of existing OU.	**Yes**
Alternative 5 CDF with Open Water Bay	Alternative 5 involves removal of impacted sediments from the Upland Site and Estuary Site with placement in a CDF that extends throughout a portion of OU-M Delta into the Estuary Site. The shape of the OU-M Delta/Estuary CDF creates an open water bay. A small CDF would also be constructed at OU-J. Capping would involve three areas on the Upland Site and placement of a remedial cap or ENR thin cover over a portion of the Estuary Site. Stormwater management in Alternative 5 would include construction of a small base-flow channel through OU-I (allowing OU-I to flood during high flow conditions) and discharge of Unnamed Creek into the open water bay.	High - 1 - Would be effective at protection of human health and environment as a result of cap placement and impacted material removal. - Would be effective at achieving all RAOs and Considerations. - Significant habitat betterment would be achieved through creation of the open water bay.		Medium - 3 - Dredging, subaqueous capping and traditional earthwork equipment would be necessary.	Medium - 3 Relative Cost Ranking: #6	7	Placement of excavated and dredged sediments in a CDF that extends into the estuary. CDFs are placed on top of existing OU's. Open water bay (1 ft avg. depth) has less water depth than shallow sheltered bay (3 to 5 ft avg. depth). Less open water and shallower average water depth than Alternative 6.	**No**, because although similar to Alternative 6, this alternative does not provide a Shallow Sheltered Bay habitat improvement element.
Alternative 6 Shallow Sheltered Bay with CDF	Alternative 6 involves removal of impacted sediments from the Upland Site and Estuary Site with placement in a CDF that extends throughout a portion of OU-M Upland and OU-M Delta and into the Estuary Site. Material removed from the Estuary Site would be placed in the Estuary portion of the CDF and material from the Upland Site would be placed in the Upland portion of the CDF. The shape of the CDF creates a shallow sheltered bay in OU-M and the estuary. Because the footprint is larger, the CDF height is lower than in Alternative 5. Capping and stormwater management are generally the same as in Alternative 5.	High - 1 - Would be effective at protection of human health and environment as a result of cap placement and impacted material removal. - Would be effective at achieving all RAOs and Considerations. - Significant habitat betterment would be achieved through creation of a shallow sheltered bay.		Medium - 3 - Dredging, subaqueous capping and traditional earthwork equipment would be necessary.	Medium - 3 Relative Cost Ranking: #8	7	Creation of shallow sheltered bay. Placement of dredged sediments in a CDF constructed within the OU-M Delta and estuary. CDFs are placed on top of existing OU's.	**Yes**, because this alternative follows the AOC habitat plan more closely than Alternative 5.
Alternative 7 Shallow Sheltered Bay and Delta Cap Area with Upland CDFs	Alternative 7 involves removal of impacted sediments from the Upland Site and Estuary Site with placement in several CDFs that are located entirely within the Upland site. A remedial cap would be placed over impacted materials on the spit-side of the OU-M Delta. Removal of impacted material from the landward side of the OU-M Delta would create a shallow sheltered bay. Construction of a CDF in OU-I would present stormwater challenges that would require additional permitting effort, and construction will require extensive soil stabilization, riprap channel, root barrier, and erosion protection against a large flood event that will impact the OU-I CDF and OU-J CDFs. Capping of the CDA in the Upland Site and capping of impacted sediments in portions of the Estuary Site would also be completed.	High - 1 - Would be effective at protection of human health and environment as a result of cap placement and impacted material removal. - Would be effective at achieving all RAOs and Considerations. - Significant habitat betterment would be achieved through creation of a shallow sheltered bay.		Low-Medium - 4 - Dredging and traditional earthwork equipment would be necessary. - Construction of CDF in OU-I creates added stormwater management and engineering challenges - tall, steep berms and does not allow for stormwater ponding. -High flow stormwater discharge events would be difficult to accommodate in this alternative.	Medium-High - 4 Relative Cost Ranking: #10	9	Creation of shallow sheltered bay, with no placement of dredged sediments in OU-M Delta or the estuary. CDFs are placed on top of existing OU's. Does not allow for stormwater detention in OU-I area, creating challenges for erosion-control and bank stability on a short-term and long-term basis.	**Yes**, retained for comparison with Alternative 8 which differs mainly in location of one CDF and stormwater management capabilities.

Table 5-2
SCREENING LEVEL EVALUATION OF ALTERNATIVES
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Alternative	Description	Effectiveness of Achieving RAOs and Considerations		Implementability	Relative Cost	Screening Level Score	Additional Factors for Consideration	Retained for Detailed Evaluation?
		Upland RAOs and Considerations **• Protect human health and the environment** **• Provide a stable water course for stormwater conveyance and discharge** **• Preserve areas for economic development**	**Estuary RAOs and Considerations** **• Protect human health and the environment** **• Reduce beneficial use impairments for St. Louis River Area of Concern** **• Improve habitat (betterment)**		**Relative Rankings:** **#1 = lowest cost;** **#12 = highest cost**	**(sum of Effectiveness, Implementability, and Cost scores)**		
Alternative 8 Shallow Sheltered Bay with Delta Sediment CDF and Upland CDFs	Alternative 8 is similar to Alternative 7 except that material that is removed from OU-M Delta and the Estuary Site to create the shallow sheltered bay would be consolidated on the spit-side of OU-M Delta in a delta sediment CDF. All other material would be placed in CDFs located within OU-M Upland and at OU-J. Additional stormwater management actions would be required; however, they would likely be more readily constructed and permitted than those in Alternative 7. Stormwater management along Unnamed Creek, from OU-J to OU-M Upland would be similar to the described for Alternative 5. Capping of two areas in the Upland Site and capping of impacted sediments in portions of the Estuary Site would also be completed.	High - 1 - Would be effective at protection of human health and environment as a result of cap placement and impacted material removal. - Would be effective at achieving all RAOs and Considerations. - Significant habitat betterment would be achieved through creation of a shallow sheltered bay.		Medium - 3 - Dredging, subaqueous capping and traditional earthwork equipment would be necessary.	Medium - 3 Relative Cost Ranking: #7	7	Only material that is removed to create the shallow sheltered bay is consolidated within the OU-M Delta and estuary (same material is consolidated together). CDFs are placed on top of existing OU's.	**Yes**
Alternative 9 Upland CDF and Delta Cover	Alternative 9 is similar to Alternative 7 in that all material is consolidated in an upland CDF. However, in Alternative 9, there is not a CDF in OU-I, since less total sediment is being removed. Another difference is that a remedial cap is placed throughout the OU-M Delta, eliminating the creation of a shallow sheltered bay. Capping of two areas in the Upland Site and capping of impacted sediments in portions of the Estuary Site would also be completed.	Medium-High - 2 - Would be effective at protection of human health and environment as a result of cap placement and impacted material removal. - Would be effective at achieving all RAOs and Considerations. - Results in a net gain of open water as a result of Upland sediment removal from the Wire Mill Delta; however, significant habitat improvement is not a major component.		Low-Medium - 4 - Dredging, subaqueous capping and traditional earthwork equipment would be necessary.	Medium - 3 Relative Cost Ranking: #5	9	Placement of impacted sediments in upland CDFs. CDFs are placed on top of existing OU's. Significant habitat improvement is not a major component. Capping OU-M Delta may require wetland mitigation. Stormwater conveyance a challenge at outer OU-M Delta.	**No,** lacks significant habitat betterment at Unnamed Creek Delta.
Alternative 10 Targeted Removal with Coke Plant Area CDF	Alternative 10 involves removal of impacted sediments from the Upland Site and Estuary Site and placement in an approximately 35 acre CDF located in the potentially developable area of the Upland Site. Capping of the two areas in the Upland site and capping of impacted sediments in portions of the Estuary Site would also be completed.	Medium - 3 - Would be effective at protection of human health and environment as a result of cap placement and impacted material removal. - Would be effective at achieving all RAOs and Considerations except for preserving areas for economic benefit (construction of large CDF in Upland Site would eliminate possibility for development). - Results in a net gain of open water as a result of Upland Site removal; however, significant habitat improvement is not a major component.		Low-Medium - 4 - Dredging, subaqueous capping and traditional earthwork equipment would be necessary. - Large volume of sediment to remove and transport to Upland CDF. - Would cause a high degree of disruption to the Site. -Large volume of water to be treated.	High - 5 Relative Cost Ranking: #11	12	Significant habitat improvement is not a major component. Developable upland area lost due to the construction of an upland consolidation area.	**No**
Alternative 11 Removal with Large Coke Plant Area CDF	Alternative 11 is the "remove all" option and involves removal of all sediments that exceed criteria in the Estuary Site and Upland Site. Removed materials would be deposited in a nearly 80 acre CDF located in the potentially developable area of the Upland Site. Capping is not included in this Alternative, though the CDF will include a final cover.	Medium - 3 - Would be effective at protection of human health and environment as a result of cap placement and impacted material removal. - Would be effective at achieving all RAOs and Considerations except for preserving areas for economic benefit (construction of large CDF in Upland Site would eliminate possibility for development).		Low - 5 - Dredging and traditional earthwork equipment would be necessary. - Very large volume of sediment to remove and transport. - Would cause a high degree of disruption to the Site. -Very large volume of water to be treated.	High - 5 Relative Cost Ranking: #12	13	Developable upland area lost due to the construction of an upland consolidation area.	**No**
Alternative 12 Open Water Bay with Upland CDFs	Alternative 12 involves removal of impacted sediments from the Upland Site and the Estuary Site and placement in several Upland CDFs. Alternative 12 is unique from other alternatives for several reasons: (1) no material is placed in the OU-M Delta. (2) Some removed material will be placed in a CDF that will be constructed in an area referred to as the "Borrow Site." (3) Removal of material from the OU-M Delta will create an open water bay that is larger than other alternatives with a similar feature. Capping of two areas in the Upland Site and capping of impacted sediments in portions of the Estuary Site would also be completed.	Medium-High - 2 - Would be effective at protection of human health and environment as a result of cap placement and impacted material removal. - Significant habitat betterment would be achieved through creation of the shallow sheltered bay. - Would be effective at achieving all RAOs and Considerations except for preserving areas for economic benefit (construction of large CDF in Upland Site would eliminate possibility for development).		Low-Medium - 4 - Dredging, subaqueous capping and traditional earthwork equipment would be necessary. - Sediment would be transported greater distances than in all alternatives except for Alternatives 10 and 11. - Consolidation of large volume of sediment in OU-M Upland CDF results in high berms.	Medium-High - 4 Relative Cost Ranking: #9	10	More area of open water generated but shallower average water depth than shallow sheltered bays in other alternatives. No placement of removed material in OU-M Delta. CDF constructed in non-impacted portion of site.	**Yes,** retained for comparison based on feedback from project partners.

Screening Key:

Effectiveness	Implementability	Cost	Overall Score
Highest Effectiveness - 1 point	Highest Implementability - 1 point	Lowest Cost - 1 point	<4
Medium-High Effectiveness - 2 points	Medium-High Implementability - 2 points	Low-Medium Cost - 2 points	5-7 points
Medium Effectiveness - 3 points	Medium Implementability - 3 points	Medium Cost - 3 points	8-10 points
Low-Medium Effectiveness - 4 points	Low-Medium Implementability - 4 points	Medium-High Cost - 4 points	11-13 points
Lowest Effectiveness - 5 points	Lowest Implementability - 5 points	Highest Cost - 5 points	>13 points

Lowest score is the most desirable

Table 5-3
EVALUATION CRITERIA
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Category	Criteria	Description	Factors Considered
Threshold Criteria	Overall Protection of Human Health and the Environment	How does the alternative achieve and maintain protection of human health and the environment?	Elimination, reduction, or control of current and potential/future risks from direct or indirect exposure to COIs by representative individuals and targeted environmental species based on site specific exposure scenarios and site specific understanding of COI fate and transport.
	Compliance with Regulatory Requirements (ARARs)	How does the alternative comply with applicable regulatory requirements and ARARs?	- Review and undertanding of the requirements for compliance with action-specific, location-specific and chemical specific ARARs. - Compliance with other criteria, advisories and guidance.
Balancing Criteria	Long Term Effectiveness and Permanence	The functional ability of the completed activities to maintain protection of human health and the environment after response actions have been implemented by removal or destruction of materials containing COIs or engineered barriers to prohibit contact with materials containing COIs.	- Magnitude of residual risk. - Adequacy and reliability of containment or control systems including: safety factors for engineered barriers; operation, maintenance, and monitoring of programs for containment systems; and institutional measures to maintain and report on long-term activities, as necessary.
	Reduction of Toxicity and Mobility (Overall Risk)	Quantitiative assessment of the mass and/or volume of material that is transformed, removed from the site, or contained in a manner that prohibits future migration of COIs or direct or indirect exposures.	- Process used and materials mitigated. - Expected reductions in toxicity, mobility and volume. - Degree to which the remedy reduces principal threats.
	Short-Term Effectiveness	Consideration of the effect of secondary impacts associated with the implementation of an alternative and their related impacts on human health and the environment near the site during construction and implementation of a remedy and continuing until the response objectives have been achieved.	- Protection of the local community during remedial actions from potential environmental impacts including dust, noise, erosion, increased traffic, or other factors. - Environmental impacts of remedial actions. - Duration of remedial actions.
	Implementability	Evaluation of the technical and administrative feasibility of completing an alternative including the availability of services, materials, equipment and skilled manpower and other resources needed to successfully complete the Project.	- Ability to construct and operate the technology. - Reliability of the technology. - Coordination with other stakeholders and agencies. - Capacity and availability of necessary equipment and specialists.
	Cost	An engineering estimate of the likely capital and O&M cost of each alternative, with appropriate contingencies to match the preliminary nature of the design work completed and the design work that will remain prior to implementing the Project.	- Capital costs. - Operating and maintenance costs. - Performance period/duration of construction. - Proportionality between the risk reduction and cost of the remedy.

Table 5-4
PRINCIPLES FOR MANAGING CONTAMINATED SEDIMENT RISKS
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Risk Management Principle[1]	Summary
1. Control Sources Early.	-Identify direct and indirect sources of significant contamination to the sediments under investigation. -Assess which continuing sources can be controlled and by what mechanisms. -Evaluate the potential for future recontamination of sediments when selecting a response action.
2. Involve the Community Early and Often.	-Ensure early and meaningful community involvement by providing community members with necessary technical information for their informed participation. -Provide affected parties with the same information used by the decision makers. -Include all affected parties in the entire decision-making process to the extent possible. -Allow adequate time for evaluation and comment on the information by all parties.
3. Coordinate with States, Local Governments, Tribes, and Natural Resource Trustees.	-Communicate and coordinate early to ensure the most relevant information is considered and that these viewpoints are considered in the remedy selection process.
4. Develop and Refine a Conceptual Site Model that Considers Sediment Stability.	-A conceptual site model should identify all known and suspected sources of contamination. The types of contaminants and affected media, existing and potential pathways, and the known or potential human and ecological receptors that may be threatened. -Prepare the conceptual site model early and use it to guide site investigations and decision making. -Update conceptual site model when new information becomes available and understanding of the site increases. -Conceptual site model is especially important at sediment sites for understanding the complex interrelationships and potential for changing conditions.
5. Use an Iterative Approach in a Risk-Based Framework.	-Use a risk-based framework or strategy for remedy evaluation and selecting response actions appropriate for the site. -Use an iterative approach that incorporates testing of hypotheses/conclusions and fosters re-evaluation of site assumptions as new information is gathered. -Consider the benefits of phasing remediation especially when early action is needed to quickly reduce risks or control the spread of contamination. -This framework should not be used to delay a decision at a site if sufficient information is available to make an informed decision.
6. Carefully Evaluate the Assumptions and Uncertainties Associated with Site Characterization Data and Site Models.	-The amount of site specific data required and complexity of models used to support site decisions should depend on the complexity of the site and significance of the decision. -Clearly describe the basis for all models used and their uncertainties when using the predicted results to make a site decision.
7. Select Site-Specific, Project-Specific, and Sediment-Specific Risk Management Approaches that will Achieve Risk-Based Goals.	-There is no presumptive remedy for any contaminated sediment sites, regardless of the contaminant or level of risk. -Evaluate all remedies that may potentially meet the project goals/objectives prior to selecting the site remedy. -Remedies should be evaluated on a comparative basis, considering all components of the remedies, temporal and spatial aspects of the site and the overall risk reduction potentially achieved. -At many sites, a combination of options will be the most effective to manage risk.
8. Ensure that Sediment Cleanup Levels are Clearly Tied to Risk Management Goals.	-While it is generally more practical to use measures such as contaminant concentrations in sediment to identify areas to be remediated, other measures can be used to ensure human health and/or ecological risk reduction goals are being met.
9. Maximize the Effectiveness of Institutional Controls and Recognize their Limitations.	-Institutional controls are often used as a component of the remedial decisions at sediment sites to limit human exposures and to prevent further contaminant redistribution until remedial action objectives are met. -Institutional controls may not be effective in eliminating or significantly reducing all exposures.
10. Design Remedies to Minimize Short-term Risks while Achieving Long-term Protection.	-Consider the advantages and disadvantages of available options and balance the risks, costs and benefits of each option. -Identify and consider short-term and long-term impacts of each alternative on societal and cultural practices, as appropriate.
11. Monitor During and After Sediment Remediation to Assess and Document Remedy Effectiveness.	-Establish a physical, chemical and/or biological monitoring program to determine if risks are being mitigated and to evaluate remedy effectiveness. -Collect baseline data for use in comparing and long-term remedy effectiveness. -Identify long term monitoring indicators that are used to determine the success of a remedy in meeting broader remedial objectives.

[1] Based on "Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites." EPA OSWER. 12 February 2002.

Table 5-5
DETAILED ANALYSIS OF ALTERNATIVES SUMMARY
Alternative 4 – CDF on OU-M Delta (within Shoreline)
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Criteria and Applicable Factors	**Detailed Analysis Summary**
Overall Protection of Human Health and the Environment Human Health Protection • Mitigate the potential for direct contact with and/or incidental ingestion of, impacted soils and sediment. • Addresses potential recreational and trespass user risks. Environmental Protection • Reduce the potential for unacceptable risk to ecological receptors.	Implementation of Alternative 4 is anticipated to be protective of human health and the environment. The actions of excavating and dredging impacted soils/sediment and consolidating these materials within an OU-M delta CDF will partially cover the greatest thickness of non-native sediment and reduce the footprint of impacted materials across the Site. The complimentary actions of remedial capping and placement of an ENR thin cover will eliminate direct human health exposure pathways and control the risk to ecological receptors.
Compliance with Regulatory Requirements (ARARs) Compliance with Applicable Regulatory Guidance • Meets the regulatory requirements of governing agencies. Compliance with ARARs • Actions are permit-able by stakeholder agencies	Execution of Alternative 4 will address regulatory requirements by achieving Upland RAOs and Estuary SMGs.
Long-Term Effectiveness and Permanence Magnitude of Residual Risk • Remedy addresses residual risk to human health and the environment. Adequacy and Reliability of Containment or Controls • Remedy is permanent and effective in the long-term.	The combination of removal, consolidation and capping of impacted soil and sediment will effectively mitigate residual risk by eliminating human health and ecological exposure pathways in the FS areas of concern. The remedy is permanent, but will require long-term monitoring and O&M to maintain effectiveness of engineering controls. Institutional controls layered over engineering controls will address the future threat of disturbance to protective measures associated with this remedy. Diversion of storm water to the former plant water intake area will require engineered energy dissipation and armoring structures that will require on-going maintenance.
Reduction of Toxicity and Mobility (Overall Risk) Process Used and Materials Mitigated Expected Reductions in Toxicity, Mobility and Volume Type and Quantity of Materials Remaining After Implementation Degree to which the Remedy Reduces Principal Threats	Alternative 4 will be effective in reducing the overall risk posed by COIs present in the Upland and Estuary areas of the Site. This alternative utilizes industry-proven methods for removal, consolidation and capping of impacted soil and sediment. The volume of impacted material will be reduced through off-site disposal of characteristic hazardous lead-impacted soil from OU-Q. However, the future mobility of COI will be eliminated through implementation of proposed engineering controls.
Short-Term Effectiveness Protection of Community during Remedial Actions Environmental Impacts of Remedial Actions Duration of Remedial Actions	Implementation of Alternative 4 is not anticipated to have a significant adverse effect on the community or environment while construction is underway. Construction-related traffic will be moderate and proper protective measures will be implemented to eliminate exposure risk to the community. Best management practices will be implemented during construction to minimize environmental impacts. The duration of Alternative 4 is consistent with Alternatives 6 and 8 and is expected to encompass two years.
Implementability Ability to Construct and Operate the Technology Reliability of the Technology Coordination with Other Stakeholders and Agencies Capacity and Availability of Equipment and Specialists	Alternative 4 is implementable and will provide a reliable remedy to address risks posed by COCs present in the Upland and Estuary areas of the Site. The technology associated with this alternative is proven and there are no perceived capacity or availability issues with earth moving and dredging contractors who will perform the work. Placement of a CDF within the OU-M delta presents slightly increased logistical challenges associated with longer haul routes from some removal areas.
Cost Capital Costs Long-Term O&M Costs Performance Period	Alternative 4 is identified as the lowest cost alternative advancing to detailed analysis. Long-term O&M is projected to be slightly higher than Alternatives 6 and 8 because of maintenance of the concrete stormwater structures. The O&M costs are projected to be similar to Alternative 12, but less than Alternative 7. The estimated two year duration of Alternative 4 construction is also consistent with Alternatives 6 and 8.

Table 5-6
DETAILED ANALYSIS OF ALTERNATIVES SUMMARY
Alternative 6 – Shallow Sheltered Bay with CDF
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

<u>Criteria and Applicable Factors</u>	<u>Detailed Analysis Summary</u>
Overall Protection of Human Health and the Environment <u>Human Health Protection</u> • Mitigate the potential for direct contact with and/or incidental ingestion of impacted soils and sediment. • Addresses potential recreational and trespass user risks. <u>Environmental Protection</u> • Reduce the potential for unacceptable risk to ecological receptors.	Implementation of Alternative 6 is anticipated to be protective of human health and the environment. The actions of excavating and dredging impacted soils/sediment and consolidating these materials within OU-M (delta and upland) CDF will partially cover the greatest thickness of non-native sediment and reduce the footprint of impacted materials across the Site. The complimentary actions of remedial capping and placement of an ENR thin cover will eliminate direct human health exposure pathways and control the risk to ecological receptors.
Compliance with Regulatory Requirements (ARARs) <u>Compliance with Applicable Regulatory Guidance</u> • Meets the regulatory requirements of governing agencies. <u>Compliance with ARARs</u> • Actions are permit-able by stakeholder agencies	Execution of Alternative 6 will address regulatory requirements by achieving Upland RAOs and Estuary SMGs. The portion of the CDF residing in the OU-M delta extends along the Spit of Land eastward beyond the OHWL. The open water element north of the CDF creates additional layers of permitting and compliance with ARARs will be more complicated in comparison to Alternatives 4 and 7.
Long-Term Effectiveness and Permanence <u>Magnitude of Residual Risk</u> • Remedy addresses residual risk to human health and the environment. <u>Reliability of Controls</u> • Remedy is permanent and effective in the long-term.	The combination of removal, consolidation and capping of impacted soil and sediment will effectively mitigate residual risk by eliminating human health and ecological exposure pathways in the FS areas of concern. The remedy is permanent, but will require long-term monitoring and O&M to maintain effectiveness of engineering controls. Institutional controls layered over engineering controls will address the future threat of disturbance to protective measures associated with this remedy. Future storm water conveyance will generally follow the current Unnamed Creek alignment and discharge to the shallow sheltered bay created north of the CDF. This alignment, in tandem with storm water retention and ponding components within OU-I, provides the lowest risk option for managing storm water in the future consolidation/capping areas.
Reduction of Toxicity and Mobility (Overall Risk) <u>Process Used and Materials Mitigated</u> <u>Expected Reductions in Toxicity, Mobility and Volume</u> <u>Type and Quantity of Materials Remaining After Implementation</u> <u>Degree to which the Remedy Reduces Principal Threats</u>	Alternative 6 will be effective in reducing the overall risk posed by COCs present in the Upland and Estuary areas of the Site. This alternative utilizes industry-proven methods for removal, consolidation and capping of impacted soil and sediment. The volume of impacted material will be reduced through off-site disposal of characteristic hazardous lead-impacted soil from OU-Q. However, the future mobility of COCs will be eliminated through implementation of proposed engineering controls.
Short-Term Effectiveness <u>Protection of Community during Remedial Actions</u> <u>Environmental Impacts of Remedial Actions</u> <u>Duration of Remedial Actions</u>	Implementation of Alternative 6 is not anticipated to have a significant adverse effect on the community or environment while construction is underway. Construction-related traffic will be moderate and proper protective measures will be implemented to eliminate exposure risk to the community. Best management practices will be implemented during construction to minimize environmental impacts. The duration of Alternative 6 is consistent with Alternatives 4 and 8 and is expected to encompass a term of two years.
Implementability <u>Ability to Construct and Operate the Alternative</u> <u>Reliability of the Alternative</u> <u>Coordination with Other Stakeholders and Agencies</u> <u>Capacity and Availability of Equipment and Specialists</u>	Alternative 6 is implementable and will provide a reliable remedy to address risks posed by COCs present in the Upland and Estuary areas of the Site. The technology associated with this alternative is proven and there are no perceived capacity or availability issues with earth moving and dredging contractors who will perform the work. To reduce haul routes and consolidate finer grained industrial sediment close to the area of original deposition, dredge material from the OU-M delta, the Unnamed Creek delta and the Wire Mill delta will be placed within a comparatively narrow CDF along the Spit of Land. Consolidation of these materials within a restricted foot-print will create potential sight-line impairments with a peak height of 29 feet above the estuary. Loading of soft sediment and long term berm/slope stability are unique design and construction challenges for this structure. Material derived from shallow storm water-related improvements in OU-I will be contained within a small valley-fill CDF south of OU-J.
Cost <u>Capital Costs</u> <u>Long-Term O&M Costs</u> <u>Performance Period</u>	Alternative 6 is comparatively higher in cost than Alternatives 4 and 8, because of a larger OU-M delta CDF with more significant berms and material handling requirements, but less than Alternative 7 and Alternative 12. Long-term O&M is projected to be similar to Alternative 8 and less than Alternatives 4 and 7 because of fewer stormwater management requirements. The approximate two year duration of Alternative 6 construction is also consistent with Alternatives 4 and 8.

Table 5-7
DETAILED ANALYSIS OF ALTERNATIVES SUMMARY
Alternative 7 – Shallow Sheltered Bay and Delta Cap Area with Upland CDFs
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Criteria and Applicable Factors	Detailed Analysis Summary
Overall Protection of Human Health and the Environment Human Health Protection • Mitigate the potential for direct contact with and/or incidental ingestion of impacted soils and sediment. • Addresses potential recreational and trespass user risks. Environmental Protection • Reduce the potential for unacceptable risk to ecological receptors.	Implementation of Alternative 7 is anticipated to be protective of human health and the environment. The actions of excavating and dredging impacted soils/sediment and consolidating these materials within the Unnamed Creek corridor will reduce the footprint of impacted materials across the Site. The complimentary actions of remedial capping and placement of an ENR thin cover will eliminate direct human health exposure pathways and control the risk to ecological receptors.
Compliance with Regulatory Requirements (ARARs) Compliance with Applicable Regulatory Guidance • Meets the regulatory requirements of governing agencies. Compliance with ARARs • Actions are permit-able by stakeholder agencies.	Implementation of Alternative 7 will address regulatory requirements by achieving Upland RAOs and Estuary SMGs. This alternative simplifies permitting and compliance with ARARs by eliminating placement of a CDF east of the railway tracks.
Long-Term Effectiveness and Permanence Magnitude of Residual Risk • Remedy addresses residual risk to human health and the environment. Reliability of Controls • Remedy is permanent and effective in the long-term.	The combination of removal, consolidation and capping of impacted soil and sediment will effectively mitigate residual risk by eliminating human health and ecological exposure pathways in the FS areas of concern. The remedy is permanent, but will require long-term monitoring and O&M to maintain effectiveness of engineering controls. The level of effort associated with long-term O&M is anticipated to be higher comparative to other alternatives as this alternative involves construction of three challenging CDFs. Institutional controls layered over engineering controls will address the future threat of disturbance to protective measures associated with this remedy. Future storm water conveyance presents the greatest challenge and risk among the alternatives advancing to detailed analysis. Consolidation of impacted media within the Unnamed Creek corridor will eliminate storm water retention and ponding within OU-I and create a constricted channel for managing peak flows. Enhanced armoring of the creek channel will be necessary to mitigate CDF berm and slope failure risks. Enhanced stabilization of CDF berms along the Unnamed Creek stream channel will be necessary to prevent CDF berm and slope failure issues.
Reduction of Toxicity and Mobility (Overall Risk) Process Used and Materials Mitigated Expected Reductions in Toxicity, Mobility and Volume Type and Quantity of Materials Remaining After Implementation Degree to which the Remedy Reduces Principal Threats	Alternative 7 will be effective in reducing the overall risk posed by COIs present in the Upland and Estuary areas of the Site. This alternative utilizes industry-proven methods for removal, consolidation and capping of impacted soil and sediment. The volume of impacted material will be reduced through off-site disposal of characteristic hazardous lead-impacted soil from OU-Q. However, the future mobility of COCs will be eliminated through implementation of proposed engineering controls.
Short-Term Effectiveness Protection of Community during Remedial Actions Environmental Impacts of Remedial Actions Duration of Remedial Actions	Implementation of Alternative 7 is not anticipated to have a significant adverse effect on the community or environment while construction is underway. However, this alternative presents the greatest challenge for temporary storm water management during construction due to extensive filling and construction activity within the Unnamed Creek corridor. Construction-related traffic will be moderate and proper protective measures will be implemented to eliminate exposure risk to the community. Best management practices will be implemented during construction to minimize environmental impacts. The duration of Alternative 7 is the longest among the alternatives advancing to detailed analysis and is expected to encompass a term of three years.
Implementability Ability to Construct and Operate the Technology Reliability of the Technology Coordination with Other Stakeholders and Agencies Capacity and Availability of Equipment and Specialists	Alternative 7, while the most challenging, is implementable and will provide a reliable remedy to address risks posed by COIs present in the Upland and Estuary areas of the Site. The technology associated with this alternative is proven and there are no perceived capacity or availability issues with earth moving and dredging contractors who will perform the work. Alternative 7 will entail consolidation of all removed soil and sediment into a CDF located west of the railway tracks. Consolidation of these materials within the space constraints of Unnamed Creek corridor results in three high CDF structures with peak heights ranging from 25 feet above grade (within the OU-I area to 29 feet above grade (within the OU-M upland area). Loading of soft sediment and long term berm/slope stability are unique design and construction challenges for these structures. The long-term risk of failure is also increased given the concerns cited for storm water conveyance.
Cost Capital Costs Long-Term O&M Costs Performance Period	Alternative 7 is the highest construction cost alternative because of the need to construct 3 CDFs and implement more robust stormwater management features. It will yield the highest annual O&M costs due to the requirement of maintaining three CDF structures and potentially less stable storm water conveyance features. The duration of Alternative 7 construction is expected to encompass a term of three years.

Table 5-8
DETAILED ANALYSIS OF ALTERNATIVES SUMMARY
Alternative 8 – Shallow Sheltered Bay with Delta Sediment CDF and Upland CDFs
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Criteria and Applicable Factors	Detailed Analysis Summary
Overall Protection of Human Health and the Environment Human Health Protection • Mitigate the potential for direct contact with and/or incidental ingestion of impacted soils and sediment. • Addresses potential recreational and trespass user risks. Environmental Protection • Reduce the potential for unacceptable risk to ecological receptors.	Implementation of Alternative 8 is anticipated to be protective of human health and the environment. Similar to other alternatives, the actions of excavating and dredging impacted soils/sediment and consolidating these materials within CDF structures will partially cover residual non-native sediment and reduce the footprint of impacted materials across the Site. The complimentary actions of remedial capping and placement of an ENR thin cover will eliminate direct human health exposure pathways and control the risk to ecological receptors.
Compliance with Regulatory Requirements (ARARs) Compliance with Applicable Regulatory Guidance • Meets the regulatory requirements of governing agencies. Compliance with ARARs • Actions are permit-able by stakeholder agencies	Execution of Alternative 8 will address regulatory requirements by achieving Upland RAOs and Estuary SMGs. To create a shallow sheltered bay habitat betterment in the OU-M delta, non-native sediment excavated during this process will be consolidated within a low profile, single source CDF extending along the Spit of Land eastward beyond the OHWL. This open water element creates additional layers of permitting and compliance with ARARs in comparison to Alternatives 4 and 7.
Long-Term Effectiveness and Permanence Magnitude of Residual Risk • Remedy addresses residual risk to human health and the environment. Reliability of Controls • Remedy is permanent and effective in the long-term.	The combination of removal, consolidation and capping of impacted soil and sediment will effectively mitigate residual risk by eliminating human health and ecological exposure pathways in the FS areas of concern. The remedy is permanent, but will require long-term monitoring and O&M to maintain effectiveness of engineering controls. The level of effort associated with long-term O&M for the three CDFs is anticipated to be similar to Alternative 6 but less than Alternative 7. Institutional controls layered over engineering controls will address the future threat of disturbance to protective measures associated with this remedy. Future storm water conveyance will generally follow the current Unnamed Creek alignment and discharge to the shallow sheltered bay created north of the CDF. This alignment, in tandem with storm water retention and ponding components within OU-I, provides the lowest risk option for managing storm water in the future consolidation/capping areas.
Reduction of Toxicity and Mobility (Overall Risk) Process Used and Materials Mitigated Expected Reductions in Toxicity, Mobility and Volume Type and Quantity of Materials Remaining After Implementation Degree to which the Remedy Reduces Principal Threats	Alternative 8 will be effective in reducing the overall risk posed by COIs present in the Upland and Estuary areas of the Site. This alternative utilizes industry-proven methods for removal, consolidation and capping of impacted soil and sediment. The volume of impacted material will be reduced through off-site disposal of characteristic hazardous lead-impacted soil from OU-Q. However, the future mobility of COCs will be eliminated through implementation of proposed engineering controls.
Short-Term Effectiveness Protection of Community during Remedial Actions Environmental Impacts of Remedial Actions Duration of Remedial Actions	Implementation of Alternative 8 is not anticipated to have a significant adverse effect on the community or environment while construction is underway. Construction-related traffic will be moderate and proper protective measures will be implemented to eliminate exposure risk to the community. Best management practices will be implemented during construction to minimize environmental impacts. The duration of Alternative 8 is consistent with Alternatives 4 and 6 and is expected to encompass a term of two years.
Implementability Ability to Construct and Operate the Alternative Reliability of the Alternative Coordination with Other Stakeholders and Agencies Capacity and Availability of Equipment and Specialists	Alternative 8 is implementable and will provide a reliable remedy to address risks posed by COIs present in the Upland and Estuary areas of the Site. The technology associated with this alternative is proven and there are no perceived capacity or availability issues with earth moving and dredging contractors who will perform the work. Consolidation of non-native sediment will largely be proximal to its source area, improving construction efficiencies and simplifying staging. Material derived from the OU-M delta shallow sheltered bay removal area will be contained in the same area within the delta sediment CDF. Material derived from the estuary dredge areas, as well as OU-P and Q and the Unnamed Pond will be contained within the OU-M upland area CDF. Material derived from shallow storm water-related improvements in OU-I will be contained within a small valley-fill CDF south of OU-J.
Cost Capital Costs Long-Term O&M Costs Performance Period	Alternative 8 is comparatively higher in cost than Alternative 4, but is exceeded by Alternatives 6, 7, and 12 among the options advancing to detailed analysis. Long-term O&M is projected to be in alignment with Alternatives 6, but less than Alternatives 4 and 7 because of fewer stormwater management requirements. The approximate two year duration of Alternative 8 construction is also consistent with Alternatives 4 and 6.

Table 5-9
DETAILED ANALYSIS OF ALTERNATIVES SUMMARY
Alternative 12 – Open Water Bay with Upland CDFs
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Criteria and Applicable Factors	Detailed Analysis Summary
Overall Protection of Human Health and the Environment Human Health Protection • Mitigate the potential for direct contact with and/or incidental ingestion of impacted soils and sediment. • Addresses potential recreational and trespass user risks. Environmental Protection • Reduce the potential for unacceptable risk to ecological receptors.	Implementation of Alternative 12 is anticipated to be protective of human health and the environment. Similar to other alternatives, the actions of excavating and dredging impacted soils/sediment and consolidating these materials within CDF structures will partially cover residual non-native sediment and reduce the footprint of impacted materials across the Site. The complimentary actions of remedial capping and placement of an ENR thin cover will eliminate direct human health exposure pathways and control the risk to ecological receptors.
Compliance with Regulatory Requirements (ARARs) Compliance with Applicable Regulatory Guidance • Meets the regulatory requirements of governing agencies. Compliance with ARARs • Actions are permit-able by stakeholder agencies	Execution of Alternative 12 will address regulatory requirements by achieving Upland RAOs and Estuary SMGs. To create an open water bay habitat betterment in the OU-M delta, non-native sediment excavated during this process will be removed from the delta and placed in several upland CDFs. This alternative simplifies permitting by eliminating placement of a CDF east of the railway tracks but retains a third CDF location that requires other permitting considerations.
Long-Term Effectiveness and Permanence Magnitude of Residual Risk • Remedy addresses residual risk to human health and the environment. Reliability of Controls • Remedy is permanent and effective in the long-term.	The combination of removal, consolidation and capping of impacted soil and sediment will effectively mitigate residual risk by eliminating human health and ecological exposure pathways in the FS areas of concern. The remedy is permanent, but will require long-term monitoring and O&M to maintain effectiveness of engineering controls. The level of effort associated with long-term O&M for the three CDFs is anticipated to be more than Alternatives 6 and 8 because the third CDF is located a significant distance away from the other two CDFs. However, the level of effort is anticipated to be less than Alternative 7. Institutional controls layered over engineering controls will address the future threat of disturbance to protective measures associated with this remedy. Future storm water conveyance will generally follow the current Unnamed Creek alignment and discharge to the open water bay created north of the spit. This alignment, in tandem with storm water retention and ponding components within OU-I, provides the lowest risk option for managing storm water in the future consolidation/capping areas.
Reduction of Toxicity and Mobility (Overall Risk) Process Used and Materials Mitigated Expected Reductions in Toxicity, Mobility and Volume Type and Quantity of Materials Remaining After Implementation Degree to which the Remedy Reduces Principal Threats	Alternative 12 will be effective in reducing the overall risk posed by COIs present in the Upland and Estuary areas of the Site. This alternative utilizes industry-proven methods for removal, consolidation and capping of impacted soil and sediment. The volume of impacted material will be reduced through off-site disposal of characteristic hazardous lead-impacted soil from OU-Q. However, the future mobility of COCs will be eliminated through implementation of proposed engineering controls.
Short-Term Effectiveness Protection of Community during Remedial Actions Environmental Impacts of Remedial Actions Duration of Remedial Actions	Implementation of Alternative 12 is not anticipated to have a significant adverse effect on the community or environment while construction is underway. Construction-related traffic will be moderate but likely less than the other options advancing to detailed analysis because material generated from excavation of the borrow site CDF will be utilized for earthwork, reducing the volume of imported material required. However, more on-site transportation will be required because of the haul distance to the CDFs. Proper protective measures will be implemented to eliminate exposure risk to the community. Best management practices will be implemented during construction to minimize environmental impacts. Because of the additional volume removed from the OU-M Delta, construction of tall berms at the OU-M Upland CDF, and excavation of the Borrow Site CDF, the construction duration is expected to encompass a term of three years, which is longer than Alternatives 4, 6, and 8 and consistent with Alternative 7.
Implementability Ability to Construct and Operate the Alternative Reliability of the Alternative Coordination with Other Stakeholders and Agencies Capacity and Availability of Equipment and Specialists	Alternative 12 is implementable and will provide a reliable remedy to address risks posed by COIs present in the Upland and Estuary areas of the Site. The technology associated with this alternative is proven and there are no perceived capacity or availability issues with earth moving and dredging contractors who will perform the work. Although consolidation of non-native material will be proximal to its source area where feasible, on average it will require greater travel distances than Alternative 8, reducing construction efficiencies and complicating staging. The OU-M Upland CDF will be filled with material generated from the Unnamed Creek dredge area and the open water bay removal area. The berms at the OU-M Upland CDF will be much higher than in Alternatives 4, 6, and 8, and similar to those in Alternative 7. Additionally, because of the limited capacity of the OU-M Upland CDF, a significant volume of material from the open water bay removal area will be transported to the borrow site CDF. Material derived from the Wire Mill Delta dredge area, from OU-P and Q, and from the Unnamed Pond will be contained within the Borrow Site CDF. Material derived from shallow storm water-related improvements in OU-I will be contained within a small valley-fill CDF south of OU-J.
Cost Capital Costs Long-Term O&M Costs Performance Period	Alternative 12 is comparatively higher in cost, exceeded only by Alternative 7 among the options advancing to detailed analysis. Long-term O&M is projected to be slightly higher than Alternatives 6 and 8 but less than Alternatives 4 and 7. The approximate three year duration of Alternative 12 construction is consistent with Alternative 7 but one year longer than Alternatives 4, 6, and 8.

Table 5-10
ALTERNATIVES COMPARISON
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

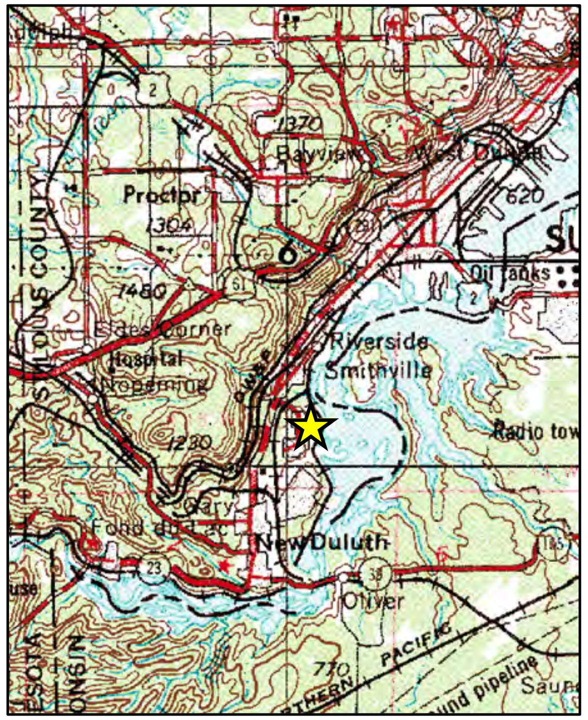
	Alternative 4 **CDF on OU-M Delta (within shoreline)**	**Alternative 6** **Shallow Sheltered Bay with CDF**	**Alternative 7** **Shallow Sheltered Bay and Delta Cap Area with Upland CDFs**	**Alternative 8** **Shallow Sheltered Bay with Delta Sediment CDF and Upland CDFs**	**Alternative 12** **Open Water Bay with Upland CDFs**
Overall protection of human health and the environment	Score: 1 Protective	Score: 1 Protective	Score: 1 Protective	Score: 1 Protective	Score: 1 Protective
Compliance with regulatory requirements (ARARs)	Score: 1 Compliant	Score: 2 Compliant. Requires additional permit considerations as part of CDF is located within the assumed OHWL.	Score: 1 Compliant	Score: 2 Compliant. Requires additional permit considerations as part of CDF is located within the assumed OHWL.	Score: 1 Compliant
Long-term effectiveness and permanence	Score: 2 More stormwater structures to maintain.	Score: 1 Effective	Score: 3 Stormwater management and three CDFs would require more O&M than other alternatives and would be more likely to result in greater potential risk of short and long-term failure than the other alternatives.	Score: 2 Effective. Three CDFs would require more O&M than other alternatives.	Score: 2 Effective. Three CDFs would require more O&M than other alternatives.
Reduction of toxicity, mobility (overall risk)	Score: 1 Effective at reducing overall risk	Score: 1 Effective at reducing overall risk	Score: 1 Effective at reducing overall risk	Score: 1 Effective at reducing overall risk	Score: 1 Effective at reducing overall risk
Short-term effectiveness	Score: 2 Effective. Stormwater diversion south of spit.	Score: 1 Effective.	Score: 3 Stormwater management presents risks during construction. Less effective than other alternatives because of longer construction duration.	Score: 1 Effective	Score: 2 Less effective than other alternatives because of longer construction duration.
Implementability	Score: 3 Implementable; however, Upland material must be moved longer distance to CDF.	Score: 5 Implementable; however, height of delta CDF creates potential sight-line impairments and geotechnical loading concerns. In addition, elimination of the LS&M Railroad is required.	Score: 5 Implementable; however, has the most uncertainty because of the complications of stormwater management in a confined channel, and CDF construction, which includes steeper berms and requires soil stabilization, is more complicated than other alternatives. Height of OU-M Delta CDF has potential to create view-shed impacts. Longer construction schedule than other alternatives.	Score: 2 Implementable. Consolidation areas are proximal to source removal areas.	Score: 5 Implementable; however, removed material must be moved greater distance than other alternatives retained for detailed analysis. Height of OU-M Upland CDF berms requires soil stabilization and has the potential to create view-shed impacts. Longer construction schedule than other alternatives.
Cost	Score: 2 Lowest cost of the alternatives retained for detailed analysis	Score: 3 Moderate cost, more than Alternatives 4 and 8, but less than Alternatives 7 and 12	Score: 5 Most expensive of the alternatives retained for detailed analysis	Score: 3 Moderate cost	Score: 4 Second highest among the alternatives retained for detailed analysis
Compliance with 11 Sediment Principles/Sediment Guidance	Score: 1 Compliant	Score: 1 Compliant	Score: 1 Compliant	Score: 1 Compliant	Score: 1 Compliant
Total Score	**13**	**15**	**20**	**13**	**17**

Scoring Key: 1 through 5, lowest score is the most desirable

Table 5-11
Cost Estimate Summary
U. S. Steel Former Duluth Works

Construction Costs	Alternative 4	Alternative 6	Alternative 7	Alternative 8	Alternative 12
Estuary/OU-M Delta	**$21,400,000**	**$26,000,000**	**$29,800,000**	**$26,100,000**	**$31,100,000**
Dredge and Transport - Subaqeuous	$4,790,000	$4,790,000	$4,790,000	$4,790,000	$4,790,000
Dredge and Transport - Dry	$3,080,000	$5,080,000	$5,590,000	$5,080,000	$6,570,000
Capping - Subaqeuous	$11,200,000	$10,830,000	$10,830,000	$10,830,000	$10,830,000
Capping and Shoal Construction - Dry	$2,310,000	$5,250,000	$8,480,000	$5,300,000	$8,870,000
Shoreline Stabilization	$70,000	$70,000	$70,000	$70,000	$70,000
Former Operations Area	**$10,000,000**	**$5,500,000**	**$10,700,000**	**$5,100,000**	**$5,100,000**
Excavation and Transport	$910,000	$750,000	$500,000	$750,000	$750,000
Stormwater Features	$5,850,000	$2,000,000	$8,680,000	$2,000,000	$2,000,000
Capping and Restoration	$3,270,000	$2,770,000	$1,560,000	$2,380,000	$2,380,000
CDF	**$9,100,000**	**$14,300,000**	**$16,000,000**	**$12,500,000**	**$16,300,000**
Construction, Capping, and Operation	$9,150,000	$14,290,000	$15,980,000	$12,480,000	$16,270,000
OU-P/OU-Q	**$5,000,000**	**$5,000,000**	**$5,000,000**	**$5,000,000**	**$4,800,000**
Dredging, Transport, and Restoration	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$4,830,000
Water Management and Treatment	**$2,600,000**	**$3,400,000**	**$5,240,000**	**$3,650,000**	**$4,180,000**
Mobilization and Demobilization	$1,110,000	$1,110,000	$1,110,000	$1,110,000	$1,110,000
WTP Operation	$1,490,000	$2,290,000	$4,130,000	$2,540,000	$3,070,000
Engineering and Administration	**$6,200,000**	**$6,800,000**	**$8,400,000**	**$6,600,000**	**$7,800,000**
Design, CQA, and Reporting	$6,150,000	$6,840,000	$8,410,000	$6,580,000	$7,750,000
Contractor Preparation, Mobilization, and Demobilization	**$6,900,000**	**$7,200,000**	**$8,500,000**	**$6,600,000**	**$7,500,000**
Contractor Preparation, Mobilization, Demobilization	$6,860,000	$7,160,000	$8,500,000	$6,600,000	$7,550,000
Project Total	**$61,000,000**	**$68,000,000**	**$84,000,000**	**$66,000,000**	**$77,000,000**

Operation and Maintenance - 30 Year Life Cycle Costs Range	Alternative 4			Alternative 6			Alternative 7			Alternative 8			Alternative 12		
	Low	-	High	Low	-	High	Low	-	High	Low	-	High	Low	-	High
Estuary Subtotal	$1,400,000	-	$3,300,000	$1,400,000	-	$3,300,000	$1,600,000	-	$3,600,000	$1,600,000	-	$3,600,000	$1,800,000	-	$4,200,000
Former Operations Area Subtotal	$6,200,000	-	$9,600,000	$3,400,000	-	$7,000,000	$9,300,000	-	$13,400,000	$4,100,000	-	$8,000,000	$4,200,000	-	$7,900,000
Total	**$7,600,000**	**-**	**$12,900,000**	**$4,800,000**	**-**	**$10,300,000**	**$10,900,000**	**-**	**$17,000,000**	**$5,700,000**	**-**	**$11,600,000**	**$6,000,000**	**-**	**$12,100,000**



Approximate U. S. Steel Operations Area (URS, 2008)

State Boundary

0 2,000 4,000

Feet

1 Inch = 2,000 Feet

Figure 1-1

SITE LOCATION
Former U. S. Steel Duluth Works -
Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Figure 1-2

SITE LAYOUT
Former U. S. Steel Duluth Works -
Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Human Exposure Pathways

Source Area: Former Duluth Works → Source Media: Soil → Release Mechanisms: (direct), Runoff, Leaching

Exposure Media	Exposure Routes	Future Industrial Worker	Future Construction Worker*	Future Maintenance/ Utility Worker*	Trespasser
Food Chain	Game/ Fish Ingestion	○	○	○	○
Surface Soil (0-1 Feet)	Ingestion	○	●	●	●
	Dermal Contact	○	●	●	●
	Inhalation (dust)**	○	●	●	●
	Inhalation (vapor)	○	●	●	●
Subsurface Soil (>1 Feet)	Ingestion	○	●	●	○
	Dermal Contact	○	●	●	○
	Inhalation (vapor)	○	●	●	○
Surface Water/Sediment (Runoff)	Ingestion	○	○	○	○
	Dermal Contact	○	○	○	○
Groundwater (Leaching)	Ingestion	○	○	○	○
	Dermal Contact	○	○	○	○
	Inhalation (Vapor)	○	○	○	○

● Potentially Complete Pathway
○ Incomplete Pathway
◐ Potentially Complete but Insignificant

* Applicable to CDA only
** Applicable to upland soils only (CDA, T-10 and T-11, and OU-Q soils).

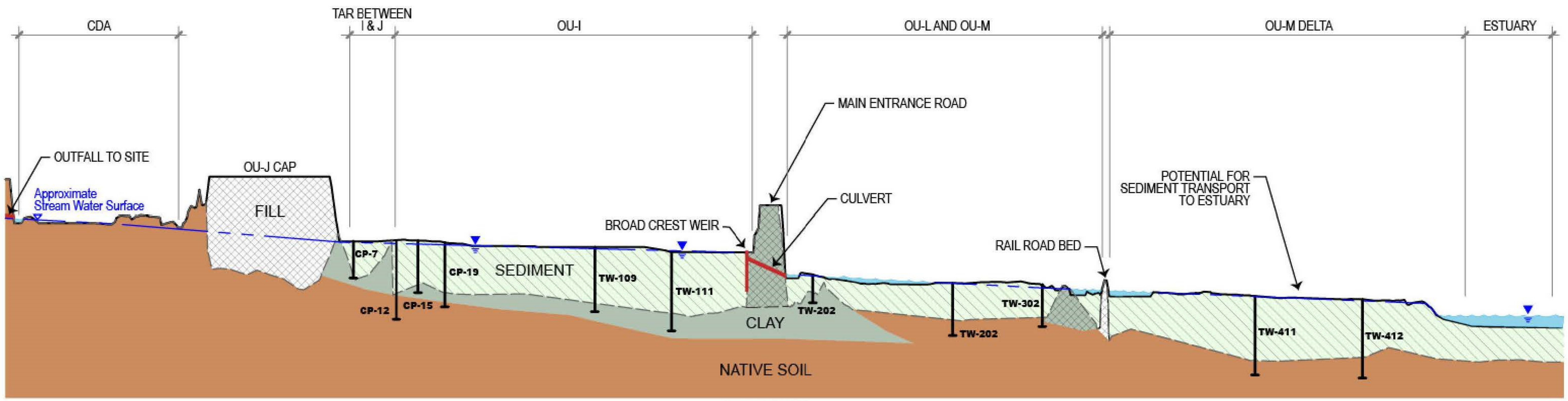
Ecological Exposure Pathways

Source Area: Former Duluth Works → Source Media: Soil, Direct Dicharge → Release Mechanisms: (direct), Runoff/ Discharge, Leaching

Exposure Media	Exposure Routes	Upland Terrestrial Areas: Plants and Invertebrates	Upland Terrestrial Areas: Terrestrial Birds and Mammals[1]	Wetlands/Aquatic Habitats: Plants and Invertebrates	Wetlands/Aquatic Habitats: Aquatic Biota[2] (fish, plankton, invertebrates)	Wetlands/Aquatic Habitats: Aquatic and Terrestrial Birds and Mammals
Food Chain	Forage/ Prey Ingestion	○	●	○	◐	●
Surface Soil (0-1 Feet)	Ingestion	○	●	○	○	●
	Dermal Contact	◐	◐	○	○	◐
	Inhalation (dust)	○	◐	○	○	◐
Subsurface Soil (>1 Feet)	Ingestion	○	○	○	○	○
	Dermal Contact	○	○	○	○	○
	Inhalation (vapor)	○	○	○	○	○
Surface Water/Sediment	Ingestion	○	○	●	◐	●
	Dermal Contact	○	○	●	●	◐
Groundwater	Ingestion	○	○	○	○	○
	Dermal Contact	○	○	○	○	○
	Inhalation (Vapor)	○	○	○	○	○

● Complete Pathway
○ Incomplete Pathway
◐ Potentially Complete but Insignificant, or Not Quanitified

[1] Only receptors whose range extends beyond the investigation Area boundaries will be evaluated.
[2] Open surface water areas



NOT TO SCALE

LEGEND

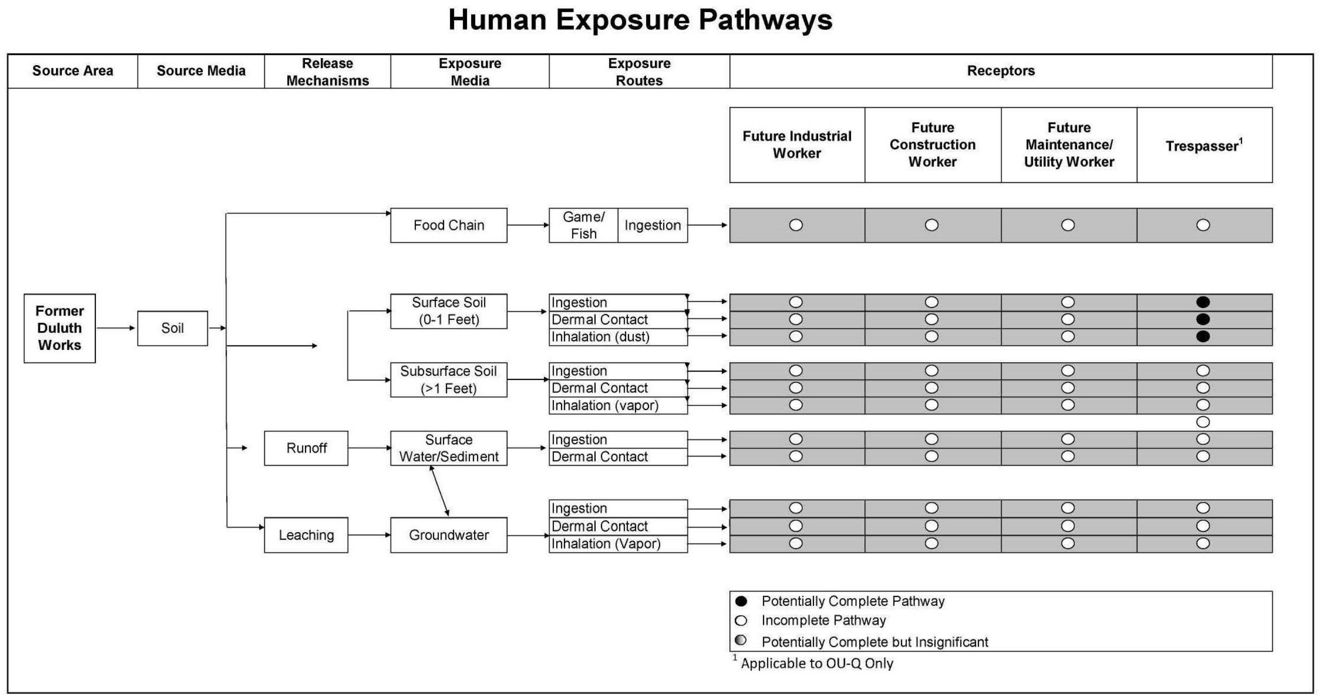
EXISTING GROUND
UPLAND SEDIMENTS
FILL
CLAY
NATIVE MATERIAL

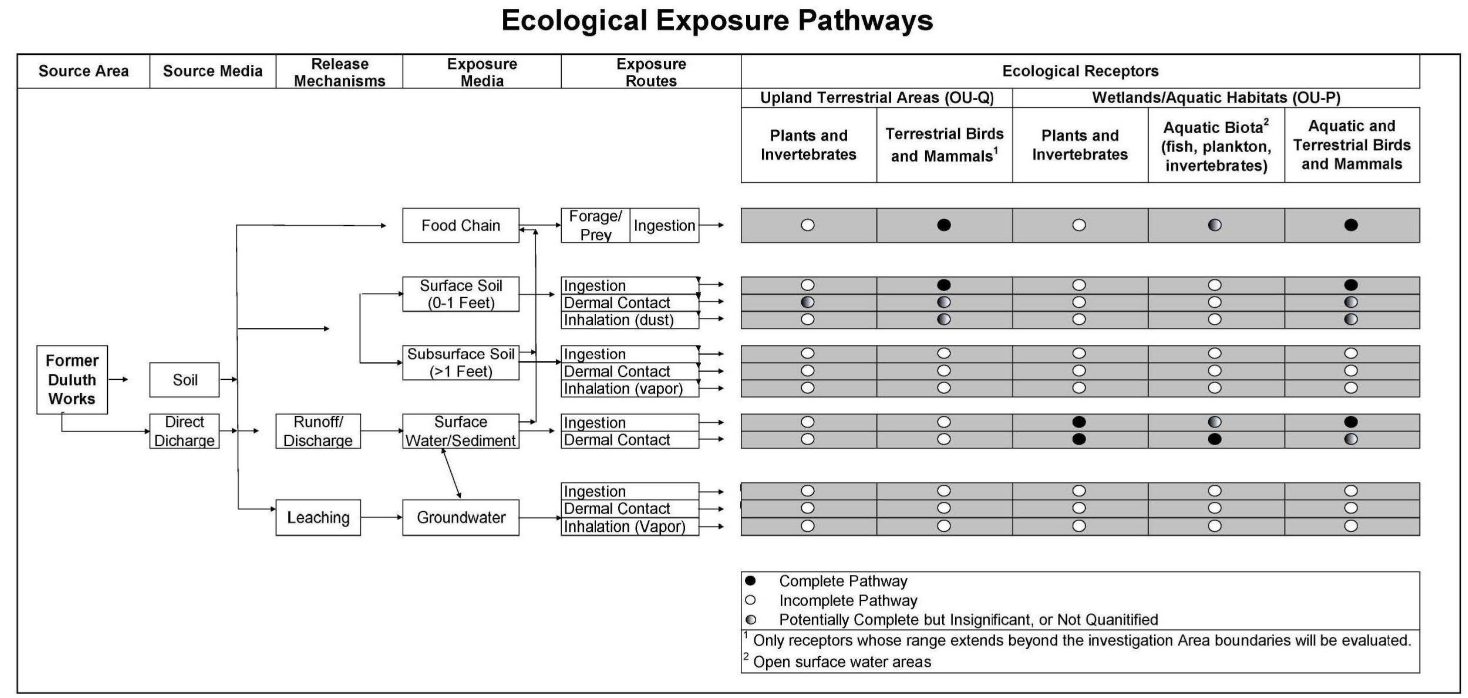
Notes:
* - Estuary evaluated separately

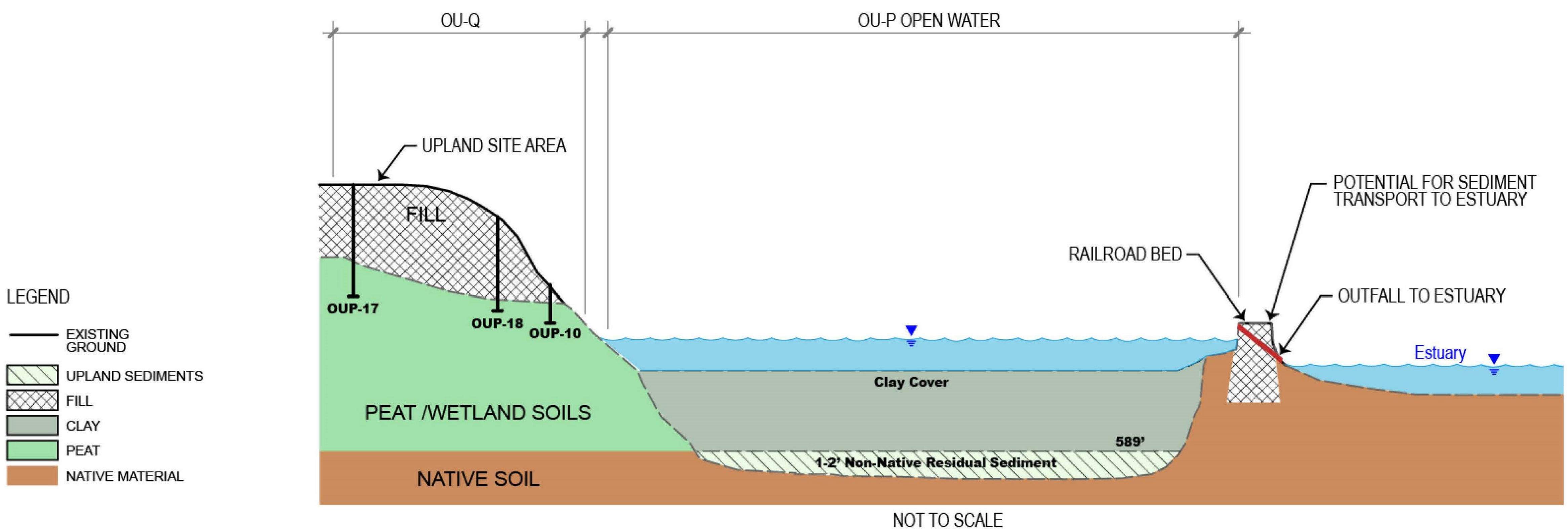
Figure 2-1

CONCEPTUAL MODEL CDA TO OU-M
Former U. S. Steel Duluth Works – Sprit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

DRN BY: CP	DATE: 5/13/2013	PROJECT NO. 31811152	FIG NO. 2-1
CHK'D BY: DS	DATE: 5/13/2013		







Notes:
*** - Estuary evaluated separately**

Figure 2-2

CONCEPTUAL MODEL OU-P TO OU-Q
Former U. S. Steel Duluth Works – Sprit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

DRN BY: CP	DATE: 5/13/2013	PROJECT NO. 31811152	FIG NO. 2-2
CHK'D BY: DS	DATE: 5/13/2013		

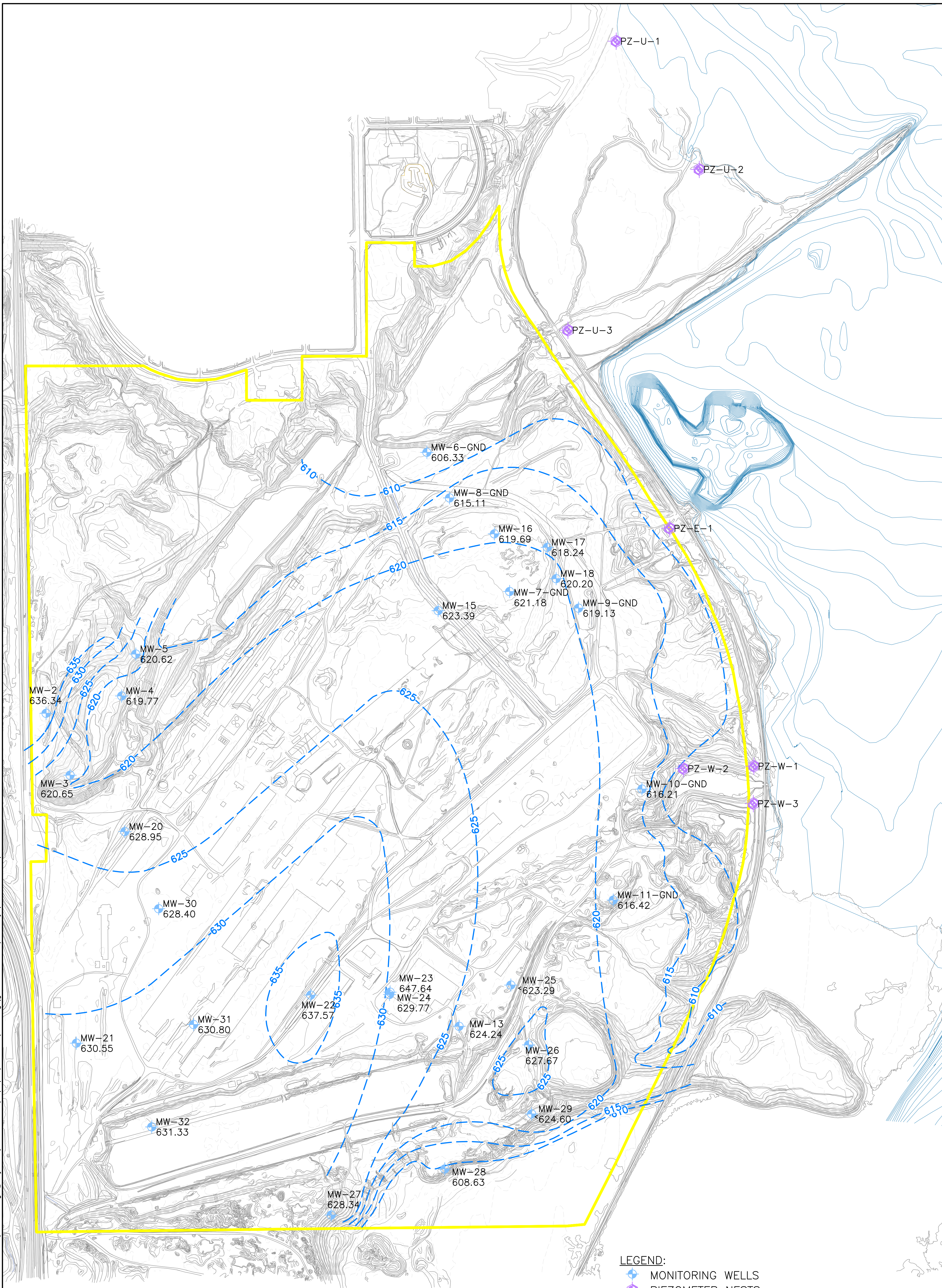


Figure 2-3

GROUNDWATER CONTOURS 2013 4TH QUARTER
Former U. S. Steel Duluth Works – Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

DRW: PJA	DATE: 11/11/14	PROJECT NO.	FIG NO.
CHK: MC	DATE: 11/11/14	31811532	2-3

DATE: 11/11/14 TIME: 4:59:48 PM FILENAME: v:\envir mngt\projects\uss duluth\hsp prep-cadd\existing\groundwater quarterly\2013-4th-quarter

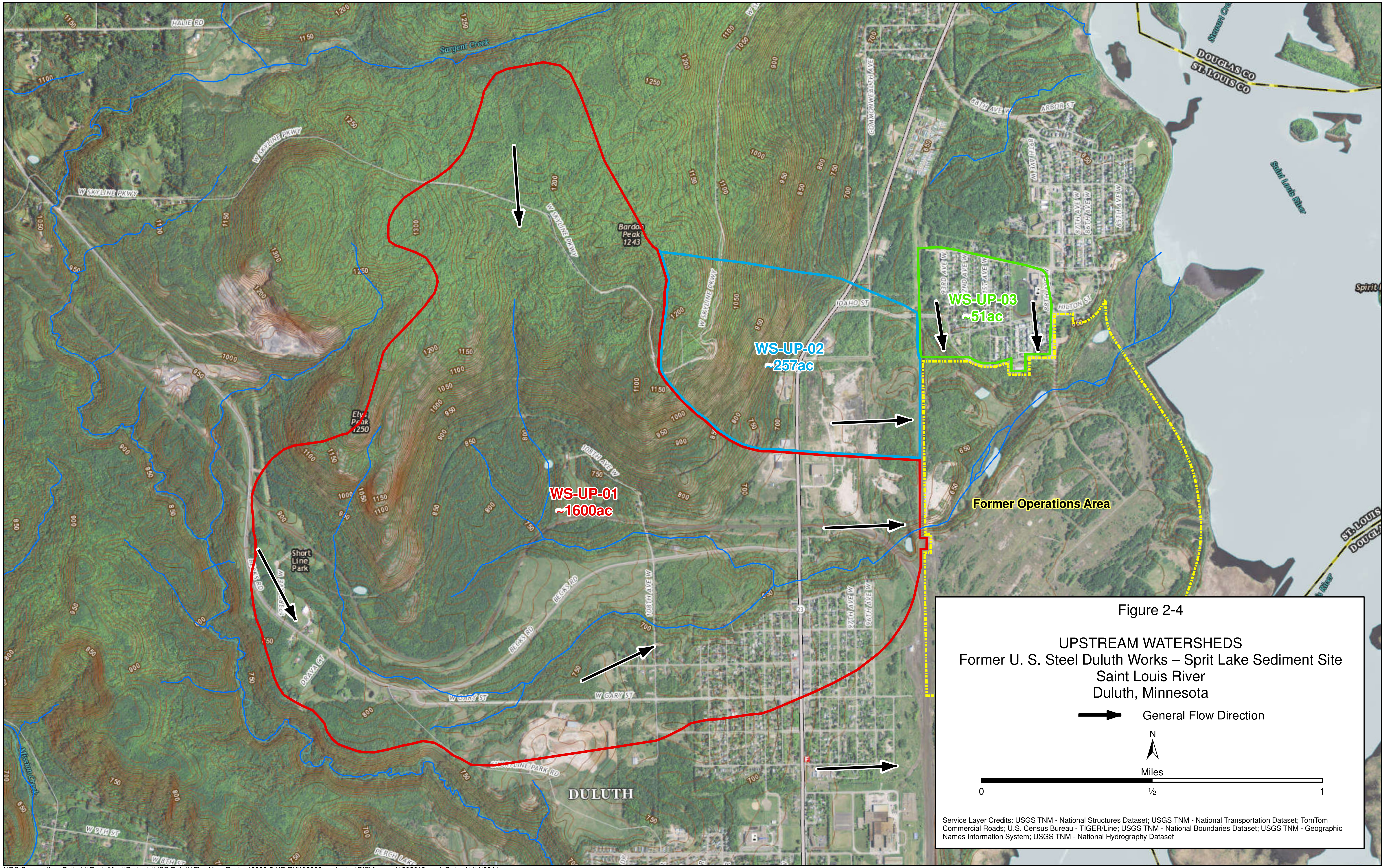


Figure 2-4

UPSTREAM WATERSHEDS
Former U. S. Steel Duluth Works – Sprit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

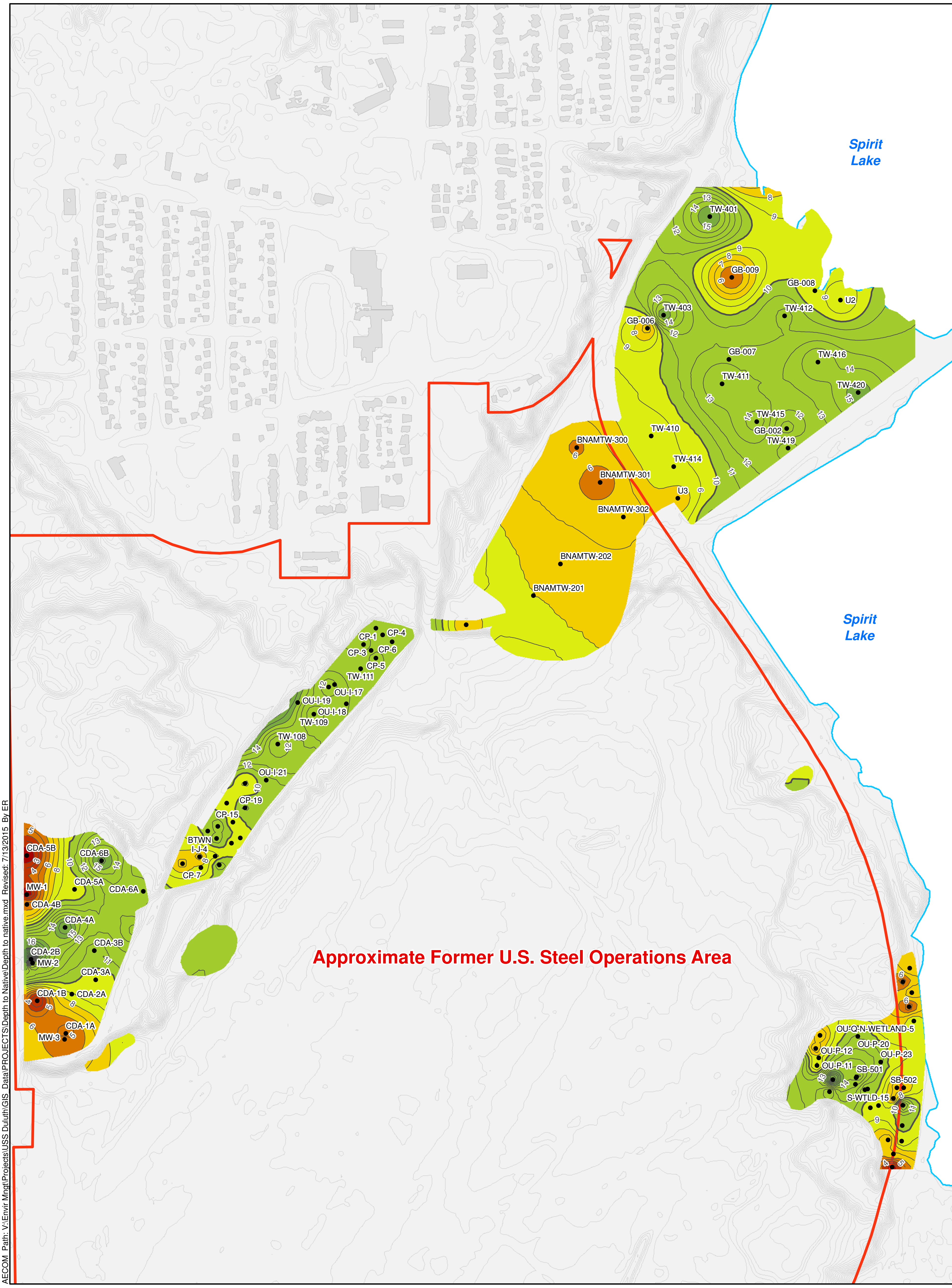
General Flow Direction

N

Miles
0 ½ 1

Service Layer Credits: USGS TNM - National Structures Dataset; USGS TNM - National Transportation Dataset; TomTom Commercial Roads; U.S. Census Bureau - TIGER/Line; USGS TNM - National Boundaries Dataset; USGS TNM - Geographic Names Information System; USGS TNM - National Hydrography Dataset

URS Corporation Path: V:\Envir Mngt\Projects\USS Duluth\Five Year Review\2008 5-YR RVW\2008 work plan\GIS\Areas_11202013.mxd Date: 11/11/2014



AECOM Path: V:\Envir Mngt\Projects\USS Duluth\GIS_Data\PROJECTS\Depth to Native\Depth to native.mxd Revised: 7/13/2015 By ER

- Core Location
- 10 ft contour
- 1 ft Contour
- Former U.S. Steel Operational Area

Fill Thickness (feet)

- Less than 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 15
- 15 - 20
- More than 20

N

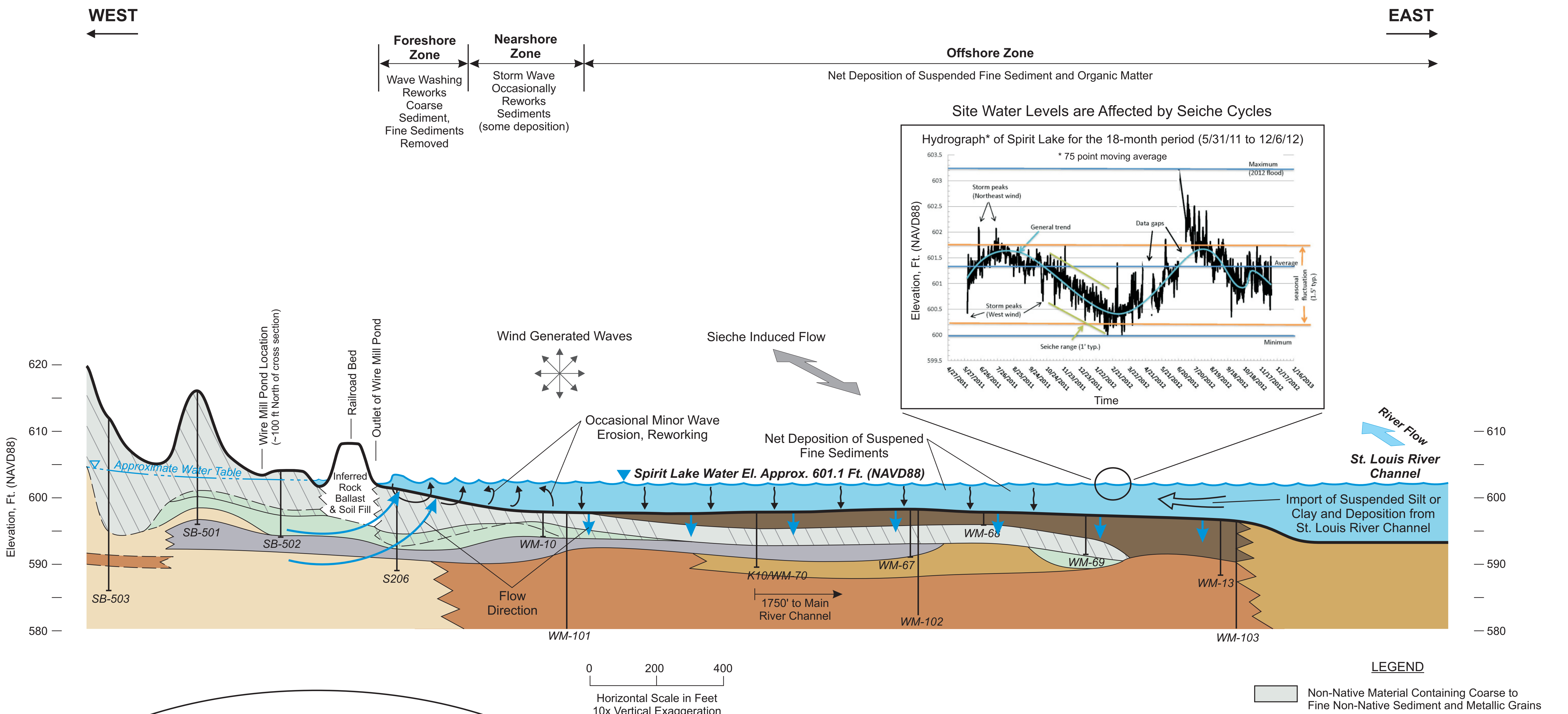
Feet

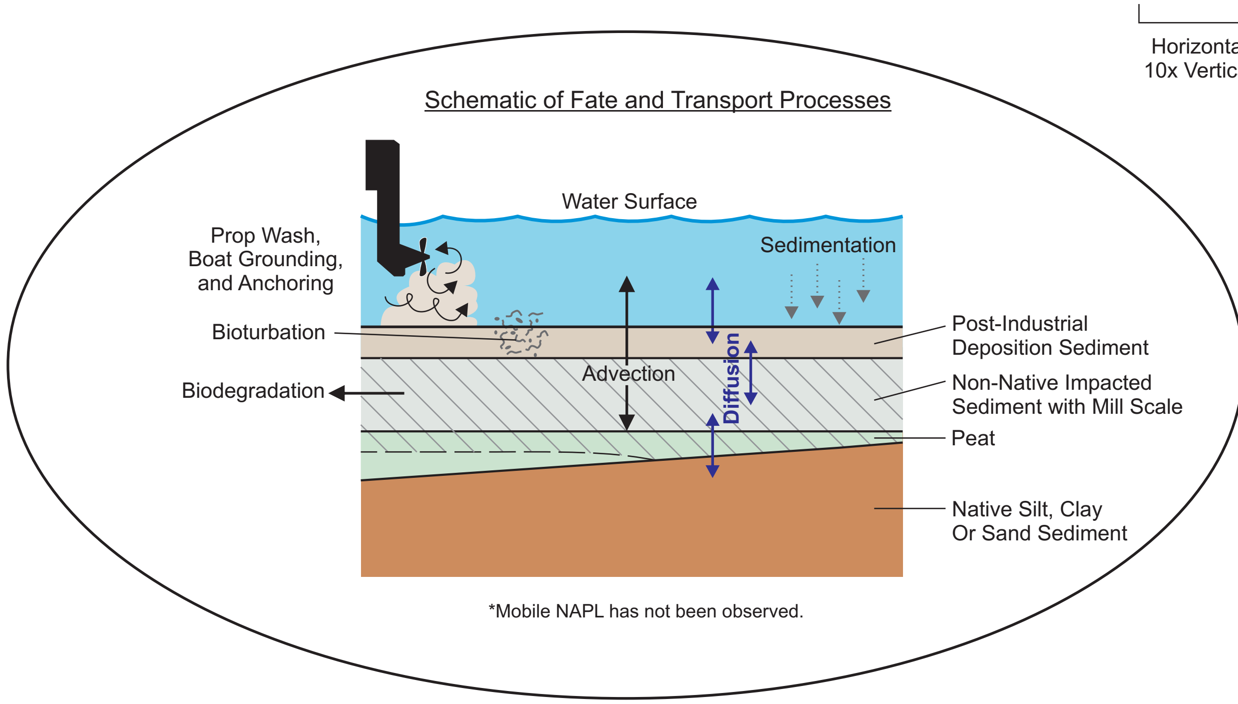
0 250 500 1,000

Figure 2-5

DEPTH TO NATIVE MATERIAL

Former U.S. Steel Duluth Works - Morgan Park, Minnesota





LEGEND

- Non-Native Material Containing Coarse to Fine Non-Native Sediment and Metallic Grains
- Organic Silt
- Silt
- Silty Sand
- Sand
- Clay
- Fiberous Peat
- Potentially Impacted Sediments

Figure 2-6

WIRE MILL POND DELTA
CONCEPTUAL MODEL
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

P:\Mpls\23 MN\69\23691125\WorkFiles\Wire Mill Pond Delta Conceptual Model.CDR RLG 07-14-15

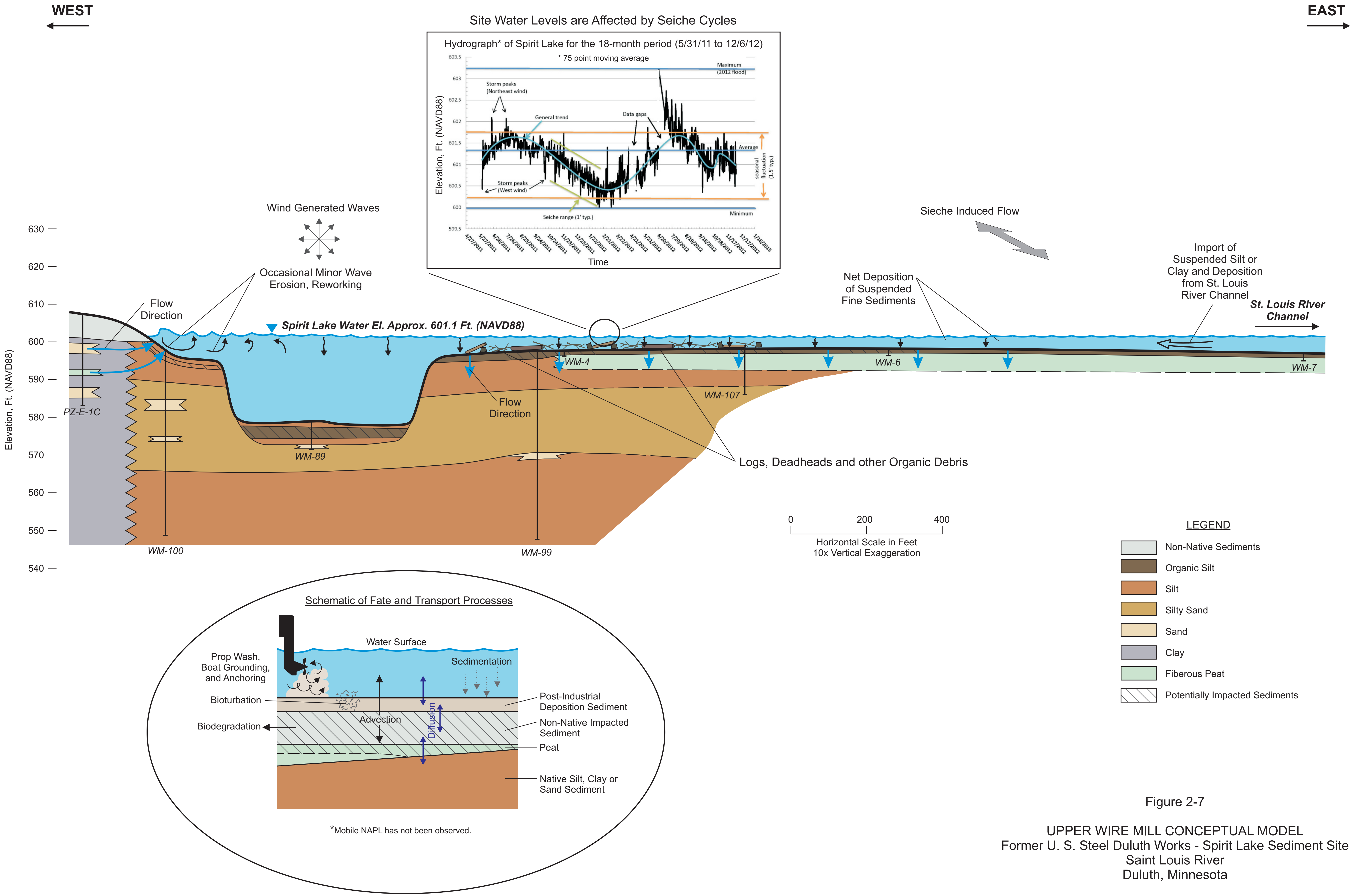


Figure 2-7

UPPER WIRE MILL CONCEPTUAL MODEL
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

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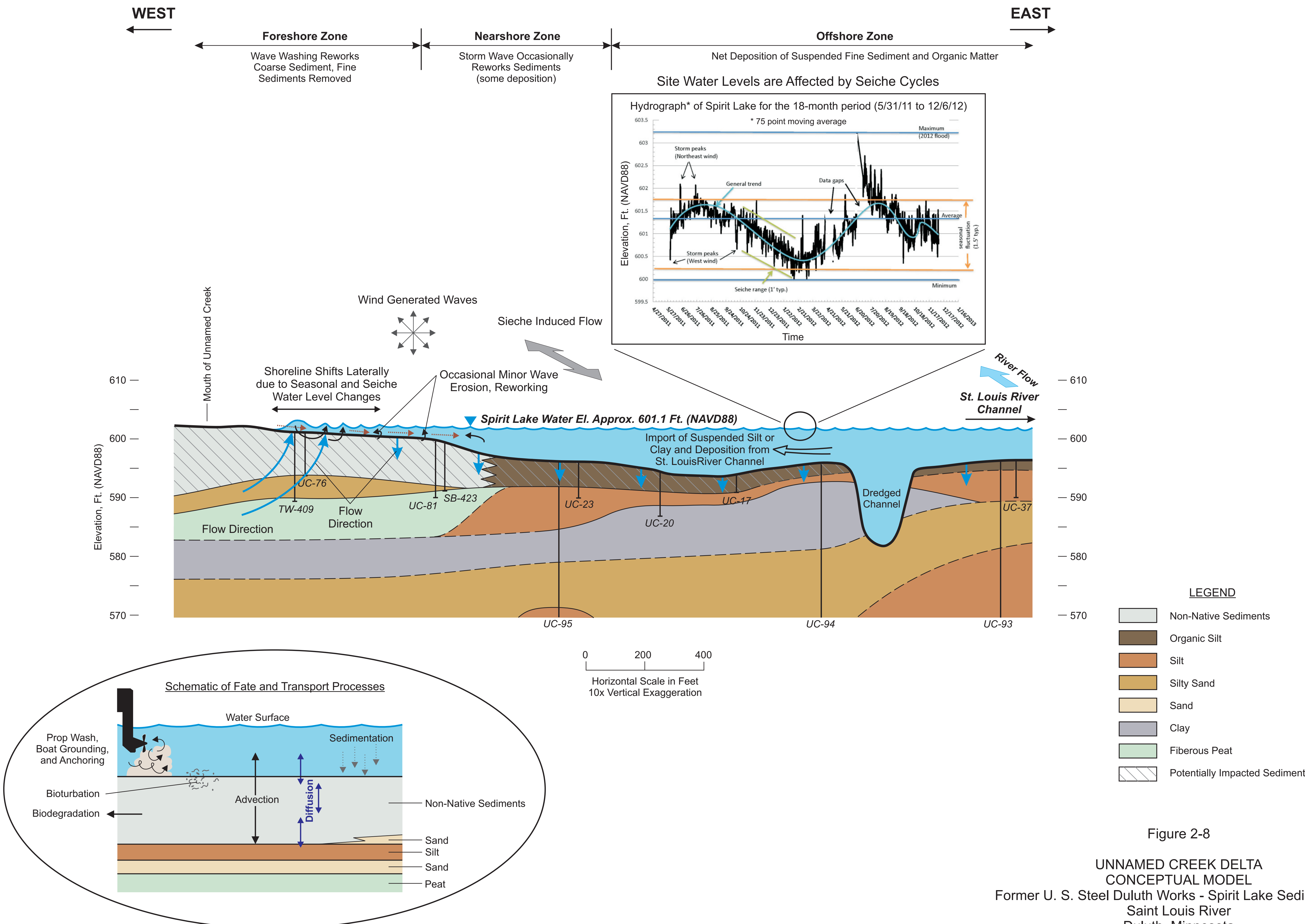
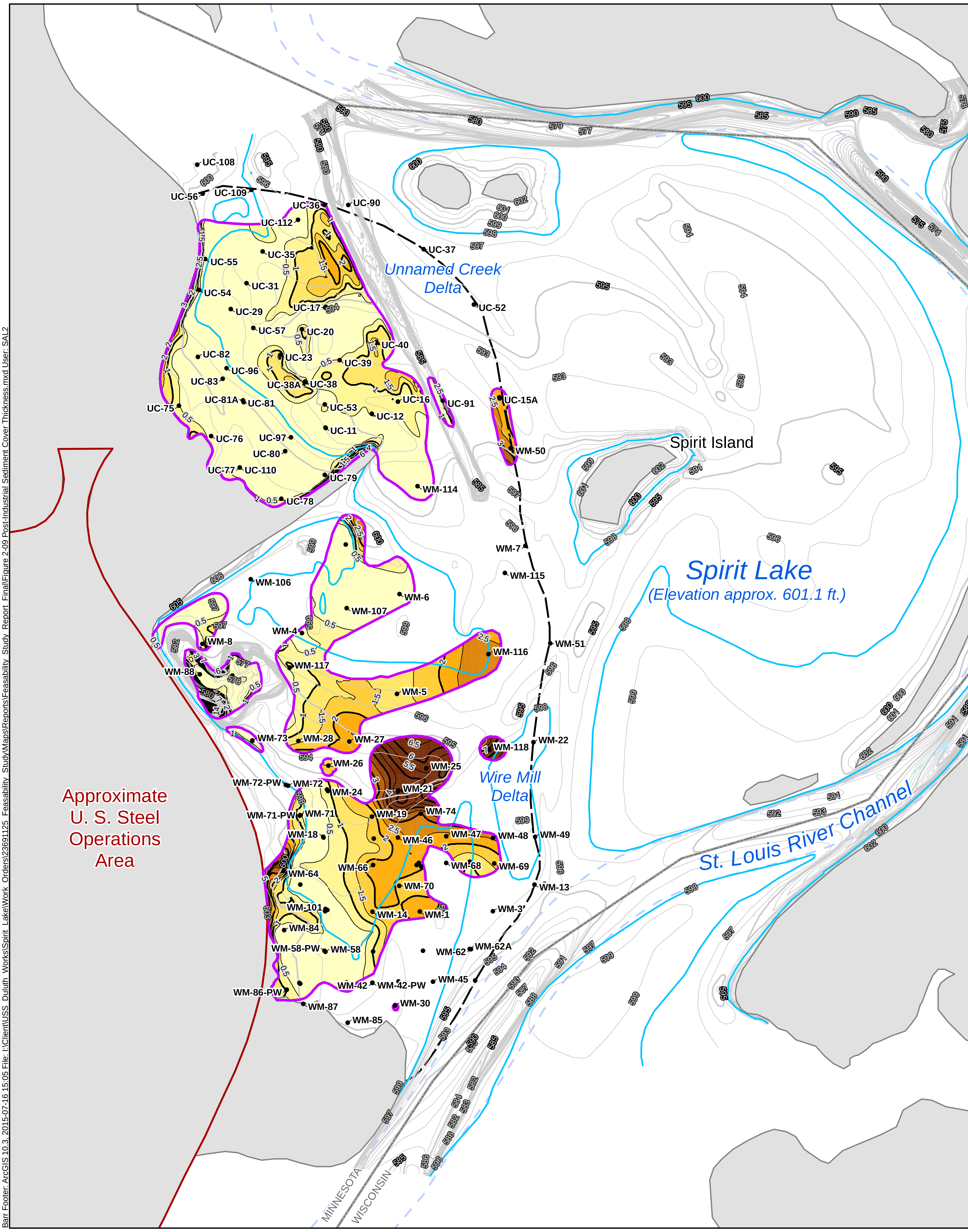


Figure 2-8

UNNAMED CREEK DELTA
CONCEPTUAL MODEL
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota



- Sediment Core Location
- PRG Footprint {Total PAH(13), Lead, Zinc, Copper; MPCA - March 5, 2014}
- State Boundary
- Approximate U. S. Steel Operations Area (URS, 2008)
- 2012 Bathymetry Contours (5-Foot)
- 2012 Bathymetry Contours (1-Foot)
- 598 Feet Bathymetry Contour
- Approximate Outer Study Area Limit
- Approximate Location of St. Louis River Channel, Based on Orthophoto Interpretation
- Post-Industrial Sediment Cover Thickness Contours (1-Foot)
- Post-Industrial Sediment Cover Thickness Contours (0.5-Foot)

Post-Industrial Sediment Cover Thickness (Feet)

- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- > 4

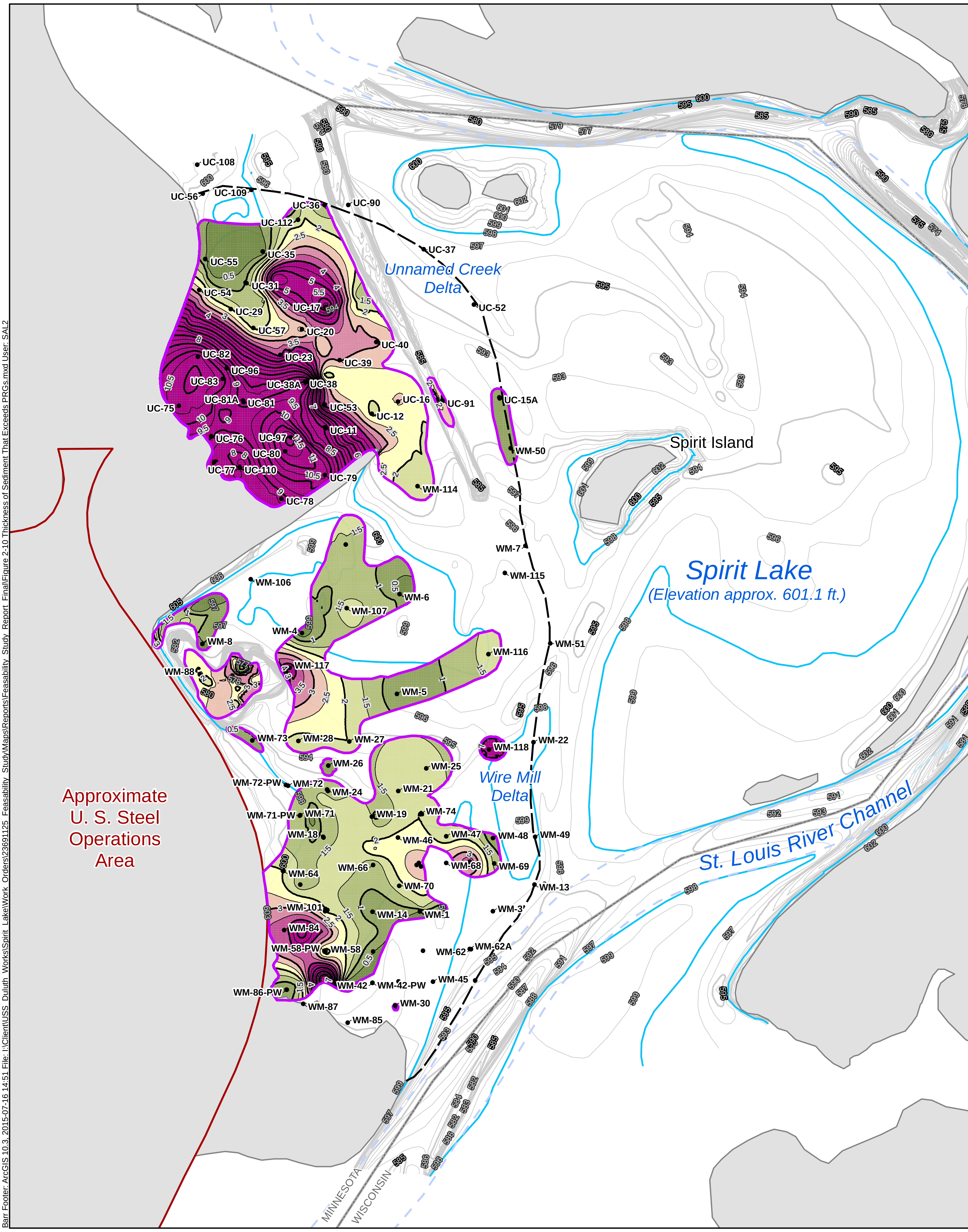
N

0 800 1,600
Feet

Figure 2-9

POST-INDUSTRIAL SEDIMENT COVER THICKNESS - ESTUARY AREA

Former U. S. Steel Duluth Works -
Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota



- Sediment Core Location
- PRG Footprint {Total PAH(13), Lead, Zinc, Copper; MPCA - March 5, 2014}
- State Boundary
- Approximate U. S. Steel Operations Area (URS, 2008)
- Approximate Outer Study Area Limit
- Approximate Location of St. Louis River Channel, Based on Orthophoto Interpretation
- PRG Thickness Contours (1-Foot)
- PRG Thickness Contours (0.5-Foot)
- 2012 Bathymetry Contours (5-Foot)
- 2012 Bathymetry Contours (1-Foot)
- 598 Feet Bathymetry Contour

PRG Thickness (Feet) *

- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- > 4

* Excludes post-industrial cover thickness

N

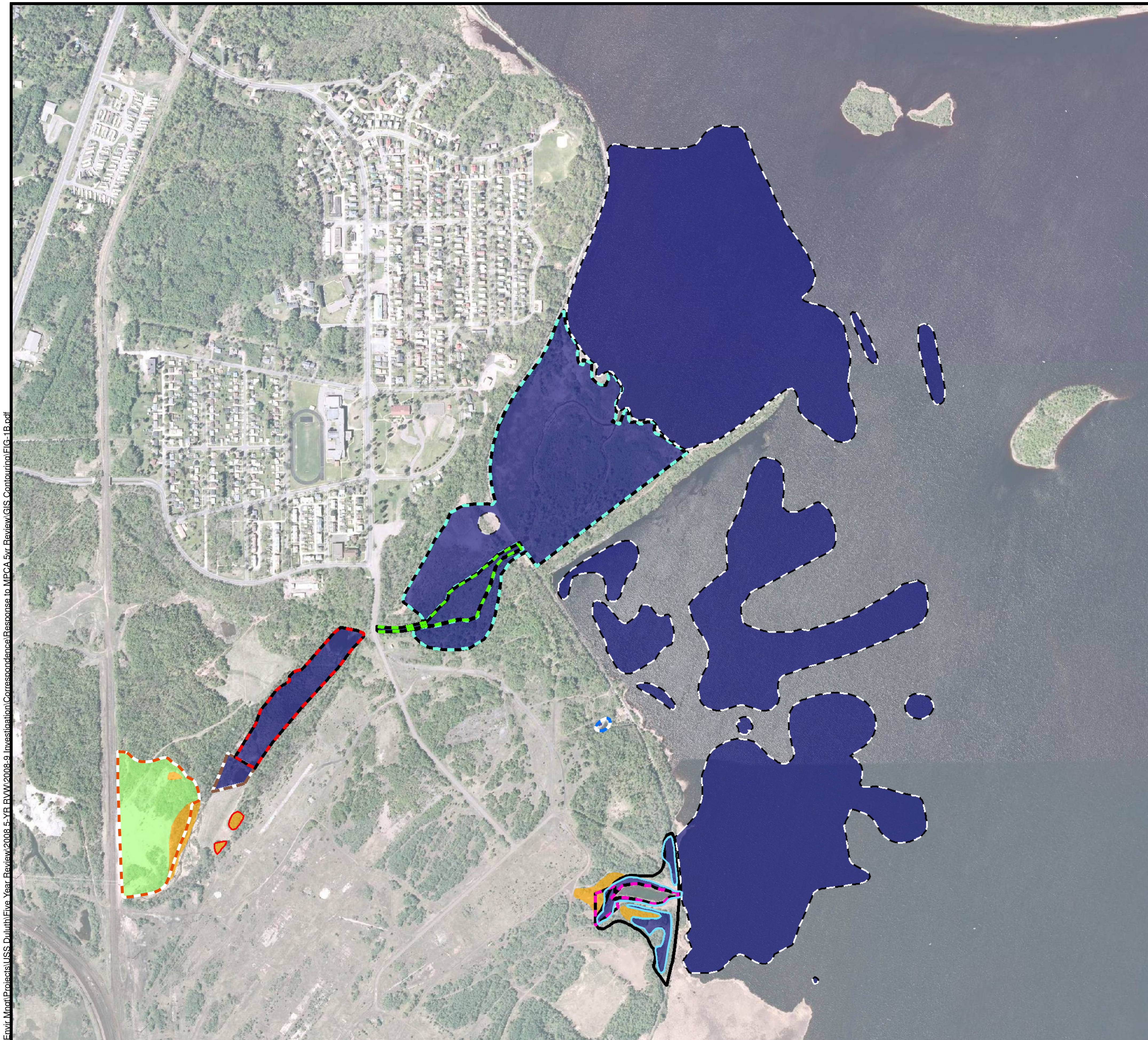
0 800 1,600

Feet

Figure 2-10

THICKNESS OF SEDIMENT THAT EXCEEDS PRGs - ESTUARY AREAS

Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota



Legend

- Concrete Disposal Area
- Area Between OU-I and OU-J
- Investigation Area OU-I
- Investigation Area OU-L
- Investigation Area OU-M
- Investigation Area OU-P
- Investigation Area OU-Q
- Unnamed Pond Investigation Area
- Investigation Areas T-10 and T-11
- OU-Q Wetland Areas
- Off Shore Sediment Concentrations
- Soil concentrations are above corresponding ISRVs
- Sediment concentrations are above an applicable PRG
- Other Soil Exceeding Physical Criterion (pH)

0 250 500

Meters

1 inch = 800 feet

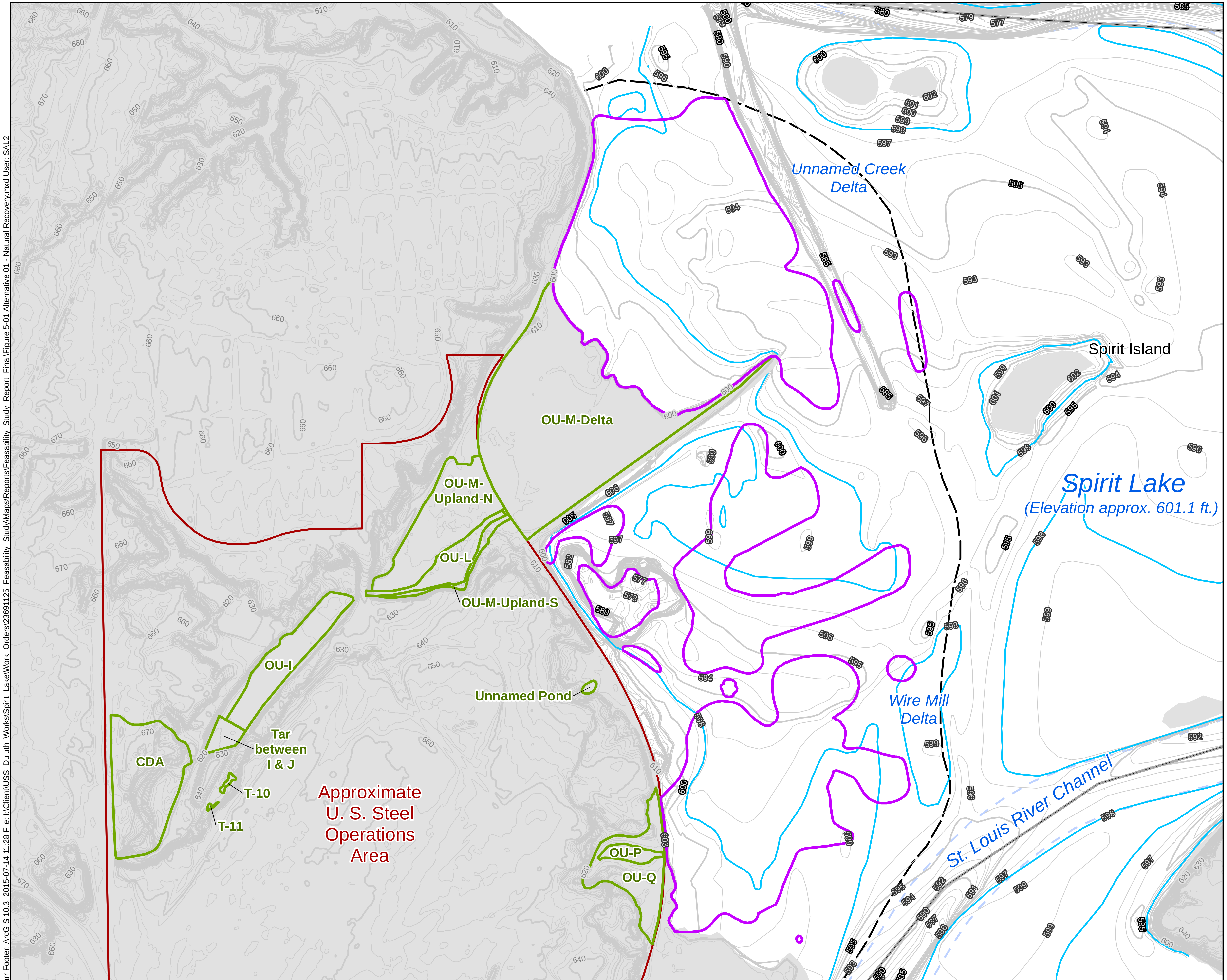
Figure 3-1

EXTENT OF IMPACTED SITE MEDIA
Former U. S. Steel Duluth Works – Sprit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

Drawn by:	Date:	Project No.	Figure No.
ER	7/16/2015	31811532	3-1
Checked by:	Date:	Ref. File:	
MC	7/16/2015	...\GISQuery_2152011\Figures\MPCAReview\Sitewide Mean PEC-Q Rev.mxd	

Aerial Source: MnGeo WMS 2009 DNR Aerials

V:\Envir Mngt\Projects\USS Duluth\Five Year Review\2008 5-YR RVW\2008-9 Investigation\Correspondence\Response to MPCA 5yr Review\GIS Contouring\FIG-1B.pdf



Upland Operable Units (OUs)
Estuary PRG Footprint {Total PAH(13), Lead, Zinc, Copper; MPCA - March 5, 2014}
2011 Upland Elevation Contours (10-Foot) *
2011 Upland Elevation Contours (2-Foot) *
2012 Bathymetry Contours (5-Foot)
2012 Bathymetry Contours (1-Foot)
598 Feet Bathymetry Contour
Approximate Outer Study Area Limit
Approximate Location of St. Louis River Channel, Based on Orthophoto Interpretation
Approximate U. S. Steel Operations Area (URS, 2008)
State Boundary

* Source: Minnesota Department of Natural Resources LiDAR Elevation, Arrowhead Region, NE Minnesota, 2011

N

800 0 800
Feet

Figure 5-1

ALTERNATIVE 1
NATURAL RECOVERY
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

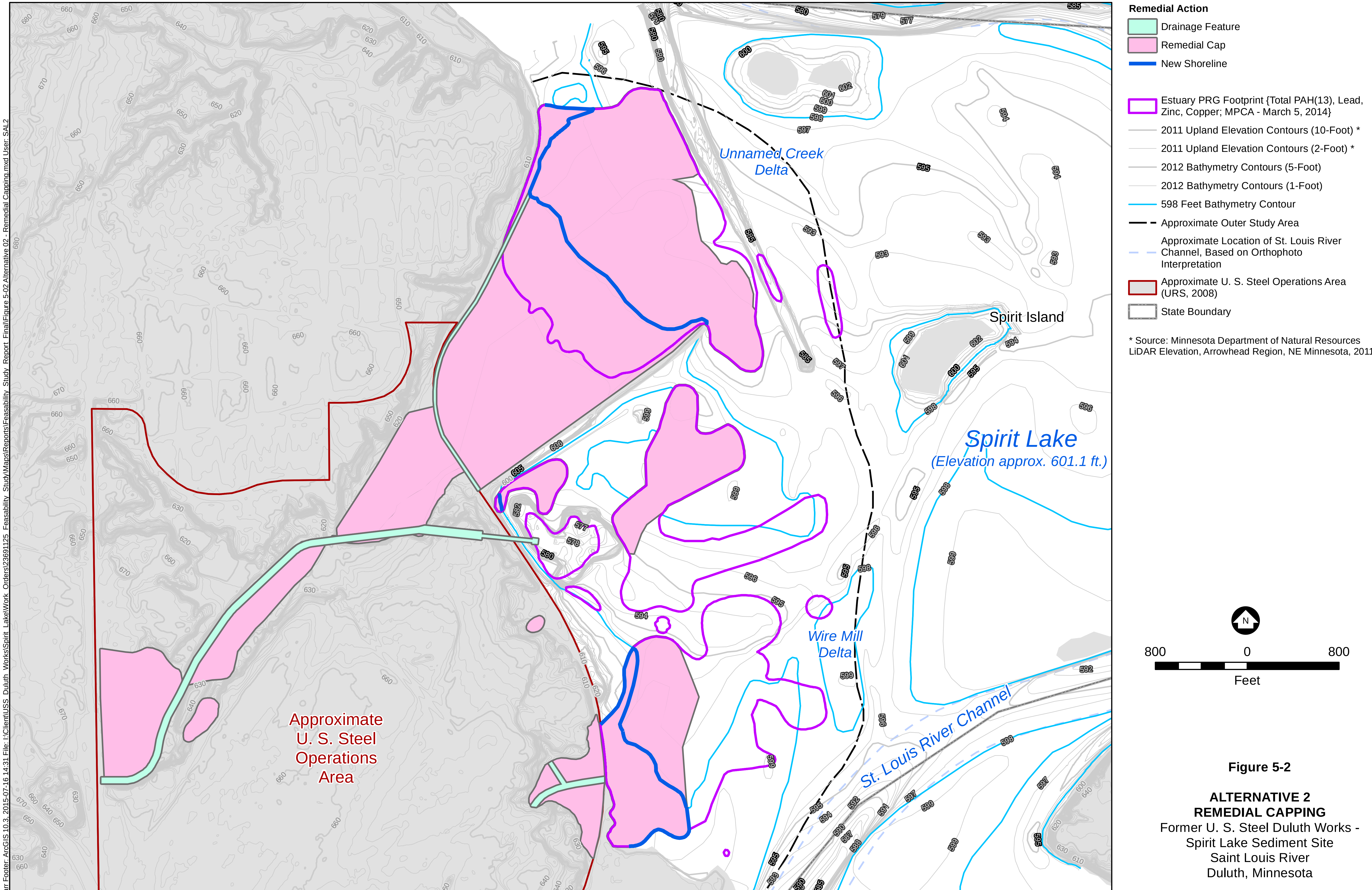
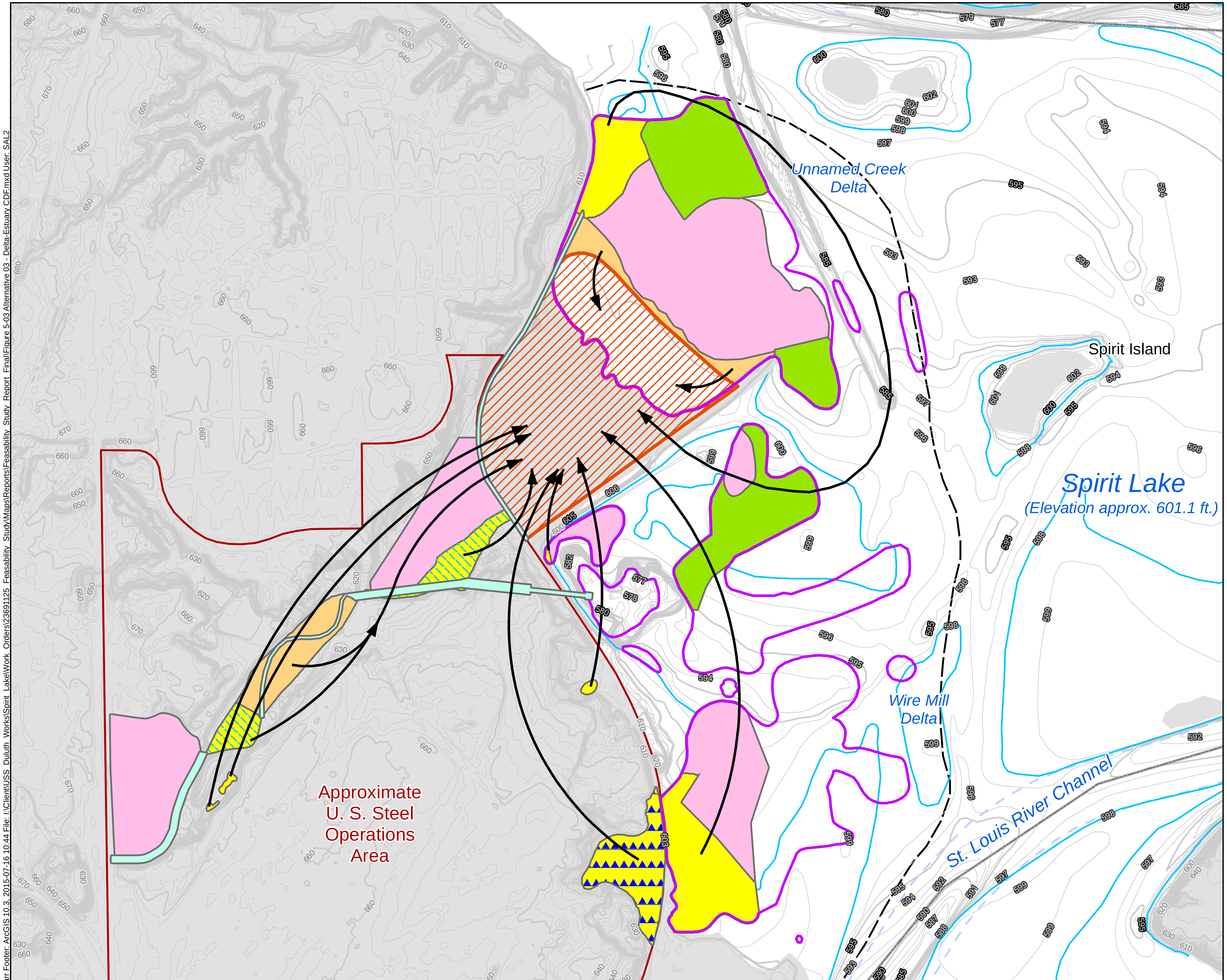


Figure 5-2

ALTERNATIVE 2
REMEDIAL CAPPING
Former U. S. Steel Duluth Works -
Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota



Remedial Action

- CDF
- Drainage Feature
- Remove
- ENR Thin Cover
- Remedial Cap
- Remove to Set Elevation and Remedial Cap
- Stormwater Ponding Area
- New Open Water
- Movement and Destination of Removed Material

- Estuary PRG Footprint {Total PAH(13), Lead, Zinc, Copper; MPCA - March 5, 2014}
- 2011 Upland Elevation Contours (10-Foot) *
- 2011 Upland Elevation Contours (2-Foot) *
- 2012 Bathymetry Contours (5-Foot)
- 2012 Bathymetry Contours (1-Foot)
- 598 Feet Bathymetry Contour
- Approximate Outer Study Area
- Approximate Location of St. Louis River Channel, Based on Orthophoto Interpretation
- Approximate U. S. Steel Operations Area (URS, 2008)
- State Boundary

* Source: Minnesota Department of Natural Resources LiDAR Elevation, Arrowhead Region, NE Minnesota, 2011

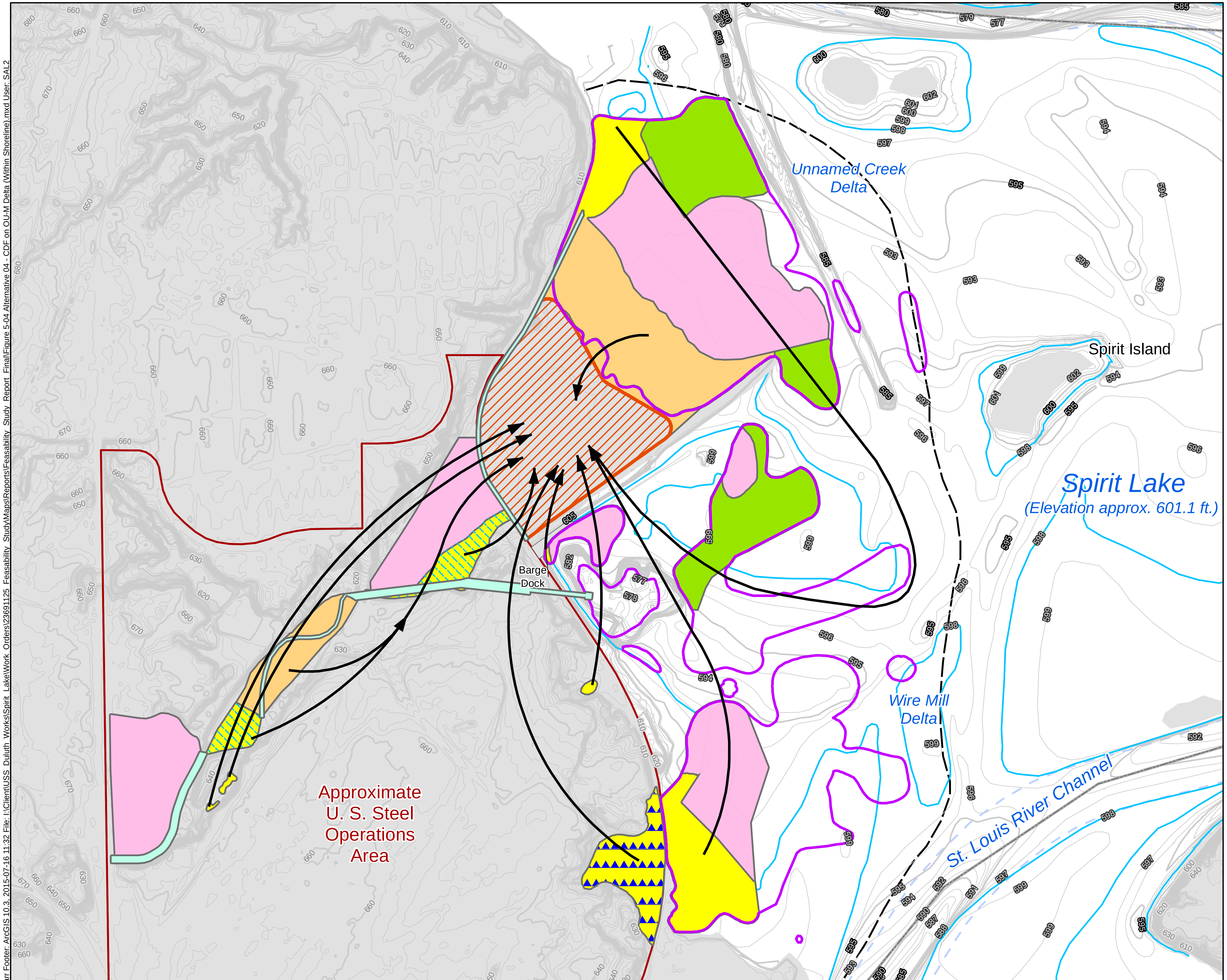
N

800 0 800

Feet

Figure 5-3

ALTERNATIVE 3
DELTA/ESTUARY CDF
Former U. S. Steel Duluth Works -
Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota



Remedial Action
- CDF
- Drainage Feature
- Remove
- ENR Thin Cover
- Remedial Cap
- Remove to Set Elevation and Remedial Cap
- New Open Water
- Stormwater Ponding
- Movement and Destination of Removed Material

- Estuary PRG Footprint {Total PAH(13), Lead, Zinc, Copper; MPCA - March 5, 2014}
- 2011 Upland Elevation Contours (10-Foot) *
- 2011 Upland Elevation Contours (2-Foot) *
- 2012 Bathymetry Contours (5-Foot)
- 2012 Bathymetry Contours (1-Foot)
- 598 Feet Bathymetry Contour
- Approximate Outer Study Area
- Approximate Location of St. Louis River Channel, Based on Orthophoto Interpretation
- Approximate U. S. Steel Operations Area (URS, 2008)
- State Boundary

* Source: Minnesota Department of Natural Resources LiDAR Elevation, Arrowhead Region, NE Minnesota, 2011

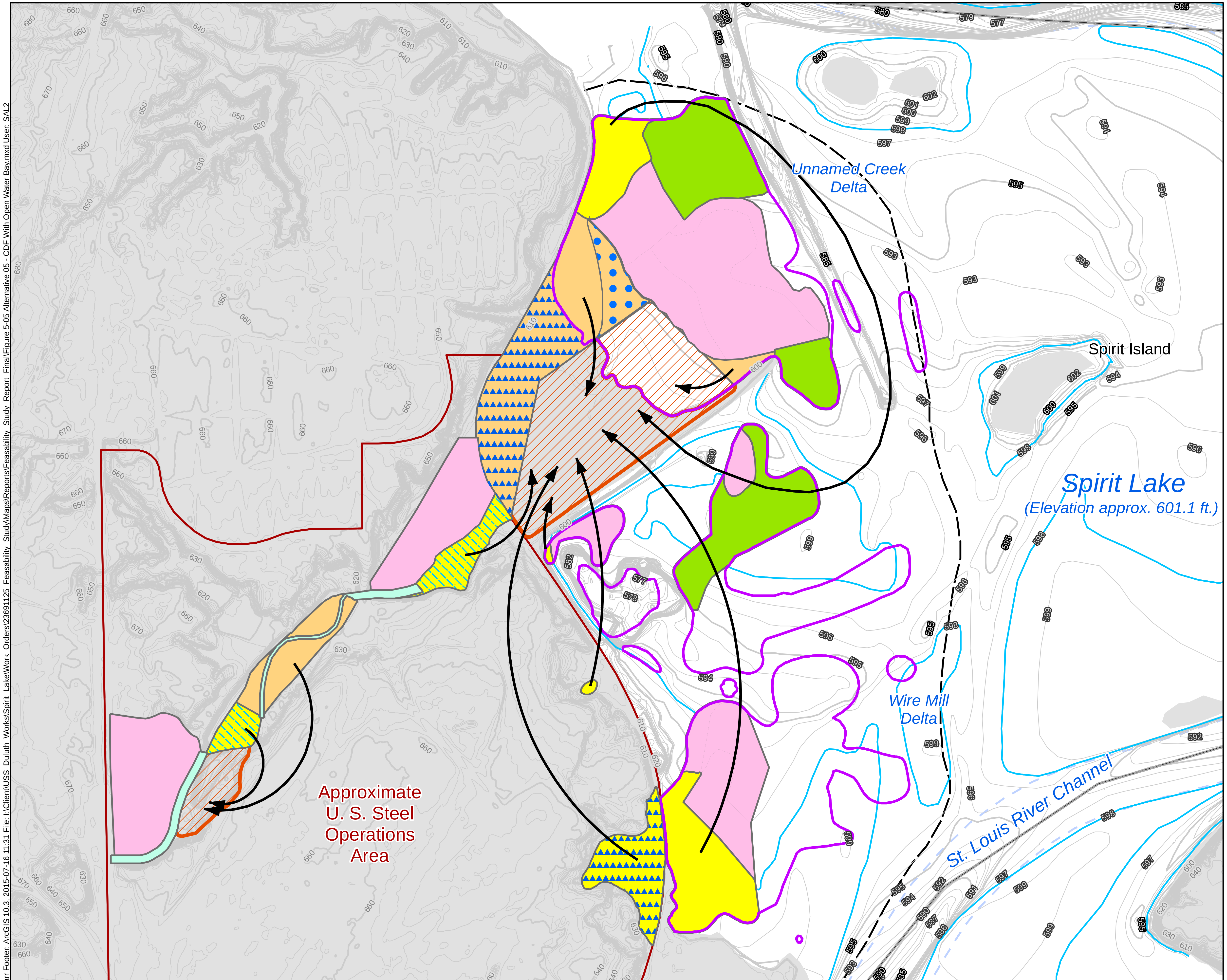
N

800 0 800

Feet

Figure 5-4

ALTERNATIVE 4
CDF ON OU-M DELTA
(WITHIN SHORELINE)
Former U. S. Steel Duluth Works -
Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota



Remedial Action

- Drainage Feature
- Remove
- ENR Thin Cover
- Remedial Cap
- Remove to Set Elevation and Remedial Cap
- CDF
- Open Water Bay Protection-Submerged Shoal Feature
- New Open Water
- Stormwater Ponding
- Movement and Destination of Removed Material
- Estuary PRG Footprint {Total PAH(13), Lead, Zinc, Copper; MPCA - March 5, 2014}
- 2011 Upland Elevation Contours (10-Foot) *
- 2011 Upland Elevation Contours (2-Foot) *
- 2012 Bathymetry Contours (5-Foot)
- 2012 Bathymetry Contours (1-Foot)
- 598 Feet Bathymetry Contour
- Approximate Outer Study Area Limit
- Approximate Location of St. Louis River Channel, Based on Orthophoto Interpretation
- Approximate U. S. Steel Operations Area (URS, 2008)
- State Boundary

* Source: Minnesota Department of Natural Resources LiDAR Elevation, Arrowhead Region, NE Minnesota, 2011

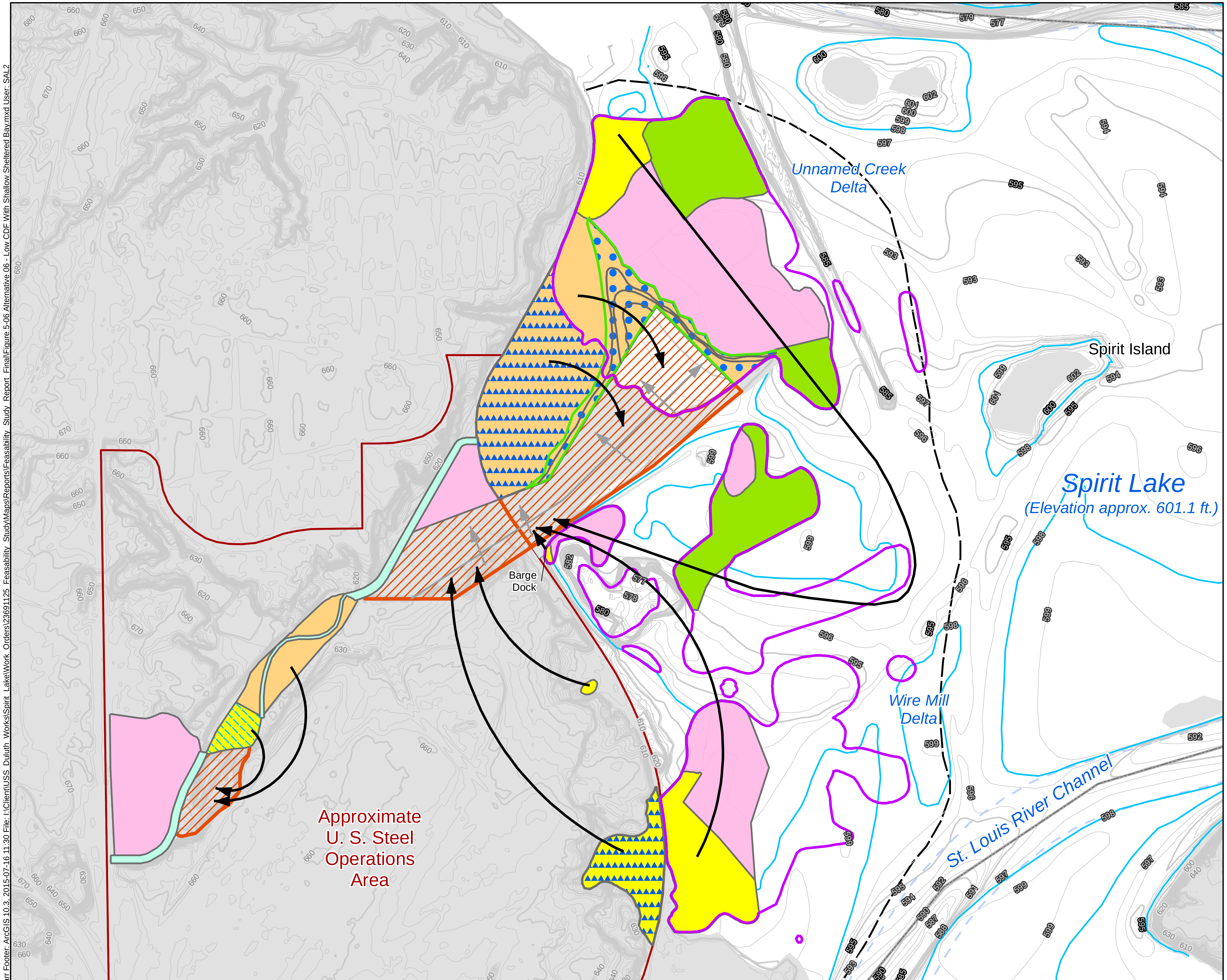
N

800 0 800

Feet

Figure 5-5

ALTERNATIVE 5
CDF WITH OPEN WATER BAY
Former U. S. Steel Duluth Works -
Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota



Remedial Action

- Drainage Feature
- Remove
- ENR Thin Cover
- Remedial Cap
- Remove to Set Elevation and Remedial Cap
- CDF
- Shallow Sheltered Bay Protection-Submerged Shoal Feature
- New Open Water
- Stormwater Ponding
- Movement and Destination of Removed Material
- CDF Cover Slope Direction
- Submerged Shoal Elevation Contours
- Estuary PRG Footprint {Total PAH(13), Lead, Zinc, Copper; MPCA - March 5, 2014}
- 2011 Upland Elevation Contours (10-Foot) *
- 2011 Upland Elevation Contours (2-Foot) *
- 2012 Bathymetry Contours (5-Foot)
- 2012 Bathymetry Contours (1-Foot)
- 598 Feet Bathymetry Contour
- Approximate Outer Study Area
- Approximate Location of St. Louis River Channel, Based on Orthophoto Interpretation
- Approximate U. S. Steel Operations Area (URS, 2008)
- State Boundary

* Source: Minnesota Department of Natural Resources LiDAR Elevation, Arrowhead Region, NE Minnesota, 2011

N

800 0 800
Feet

Figure 5-6

ALTERNATIVE 6
SHALLOW SHELTERED BAY WITH CDF
Former U. S. Steel Duluth Works -
Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

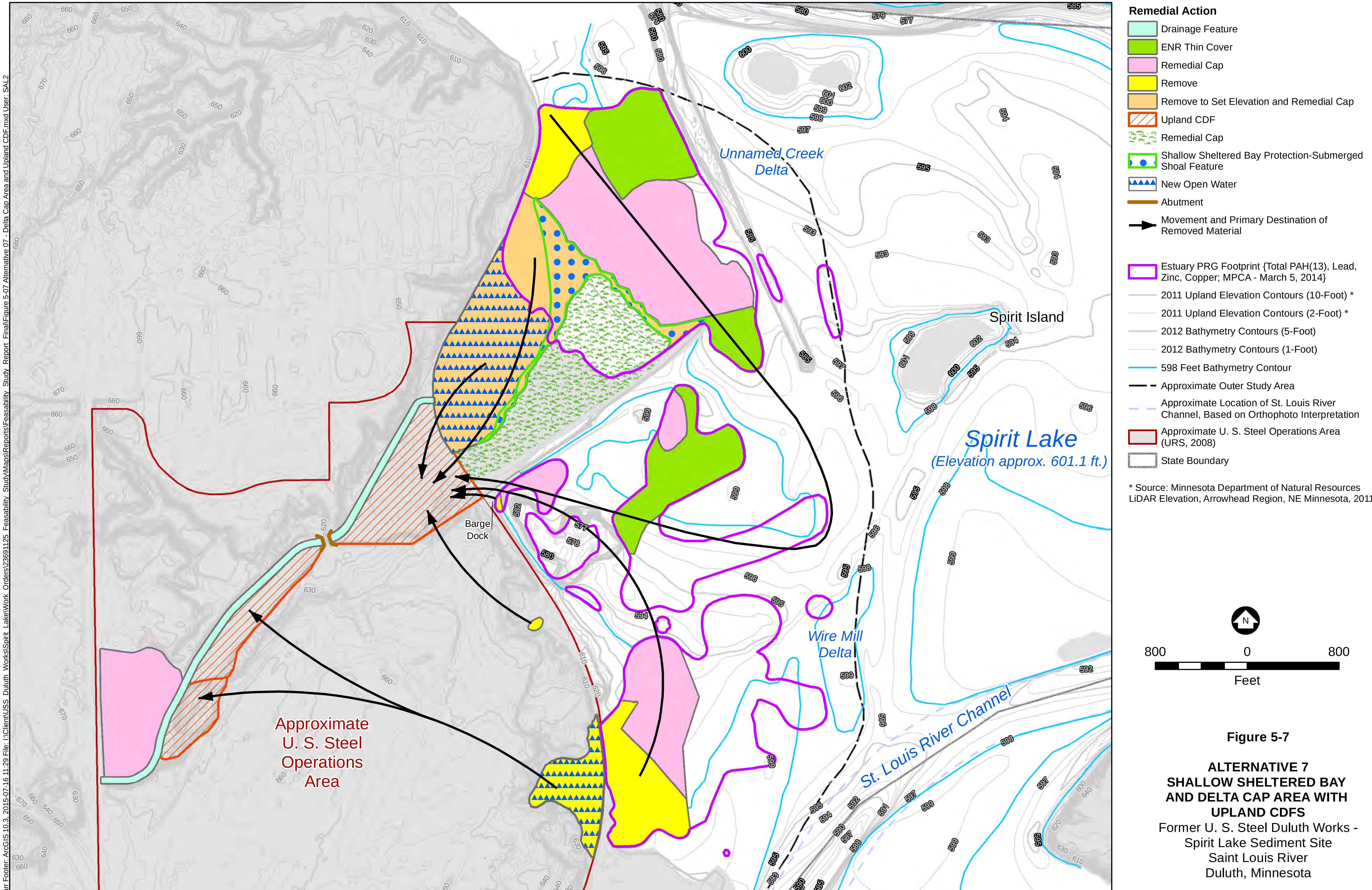


Figure 5-7

ALTERNATIVE 7
SHALLOW SHELTERED BAY AND DELTA CAP AREA WITH UPLAND CDFS
Former U. S. Steel Duluth Works -
Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

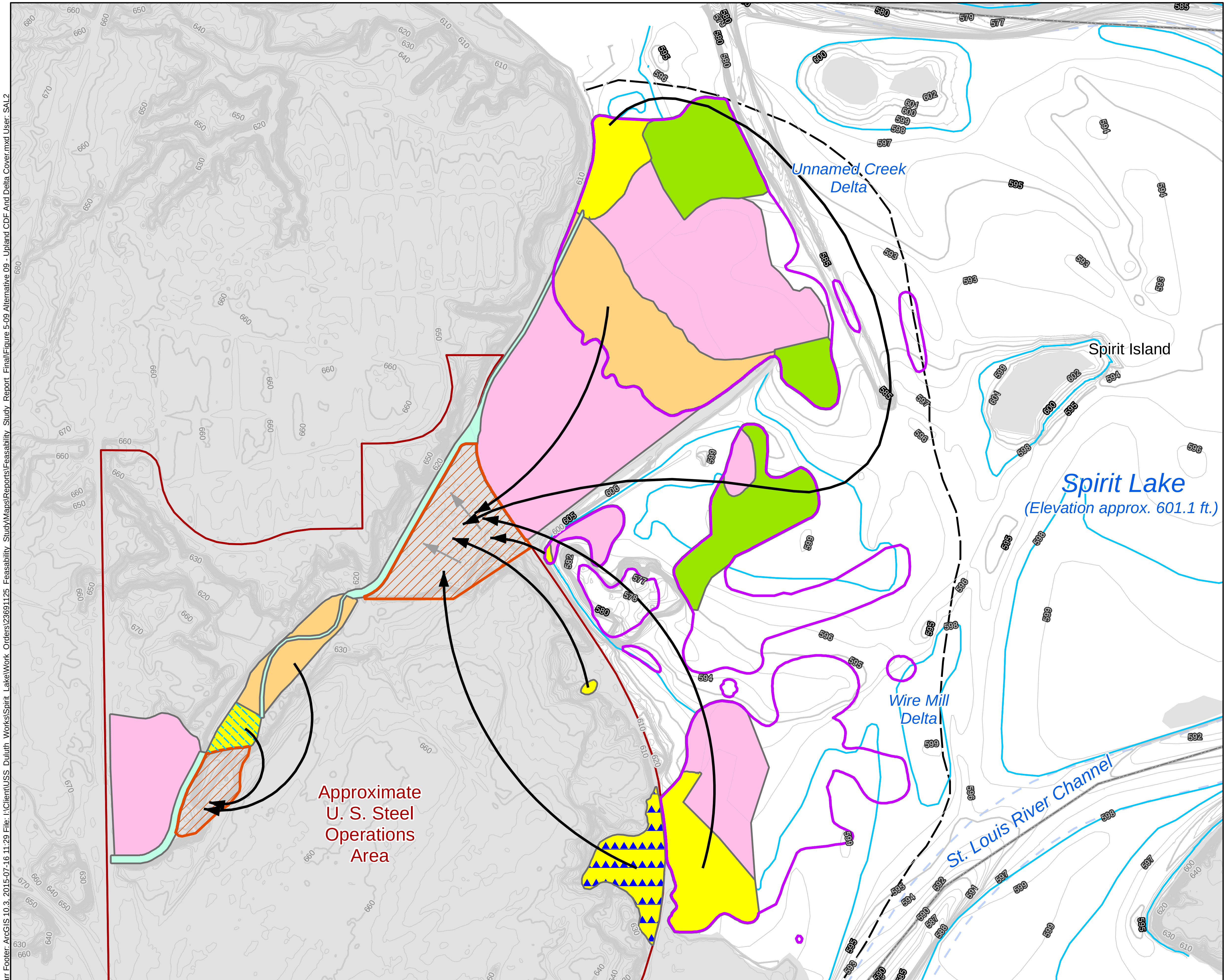


Figure 5-9

ALTERNATIVE 9
DELTA COVER AND UPLAND CDFS
Former U. S. Steel Duluth Works - Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota

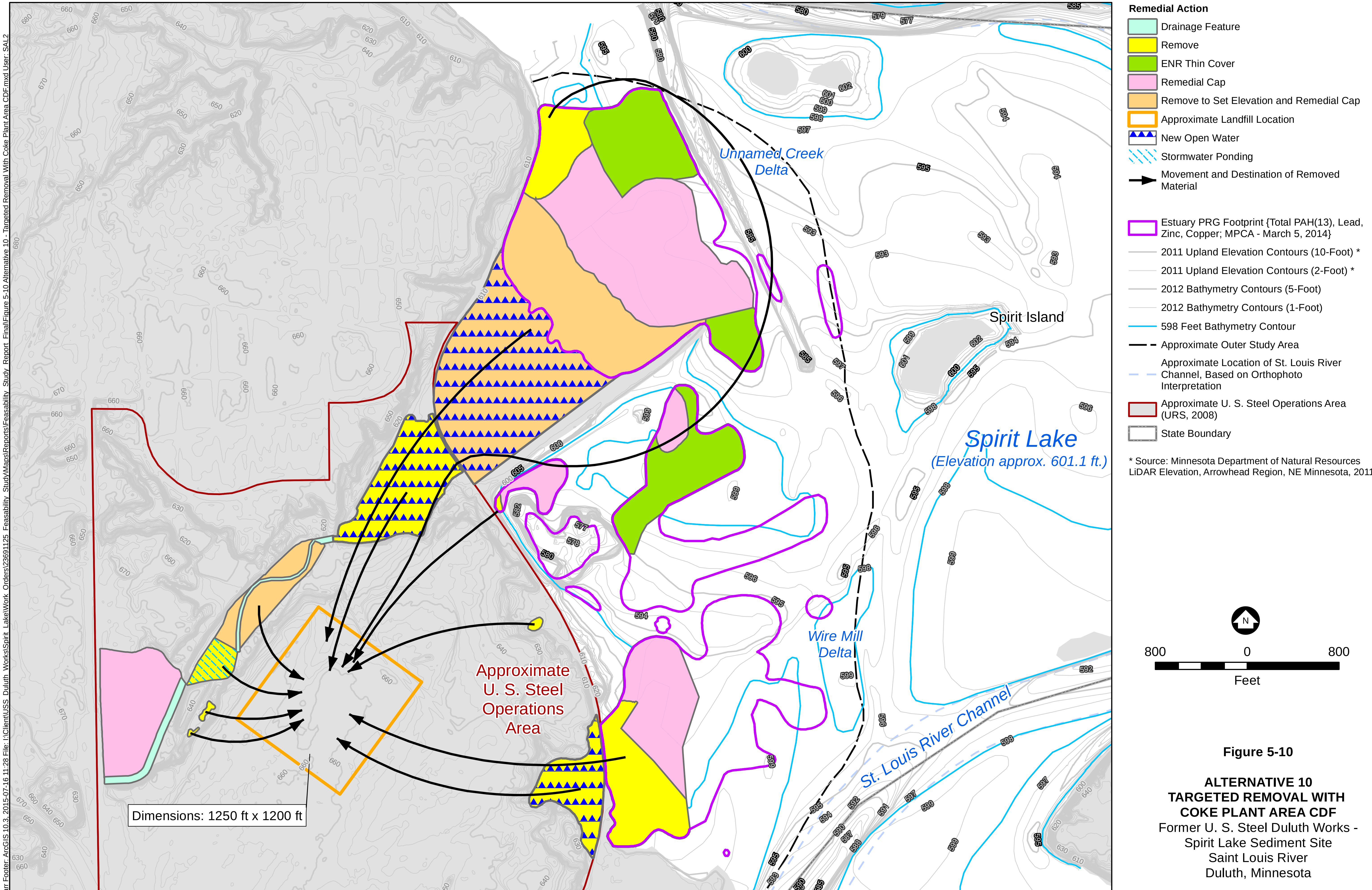
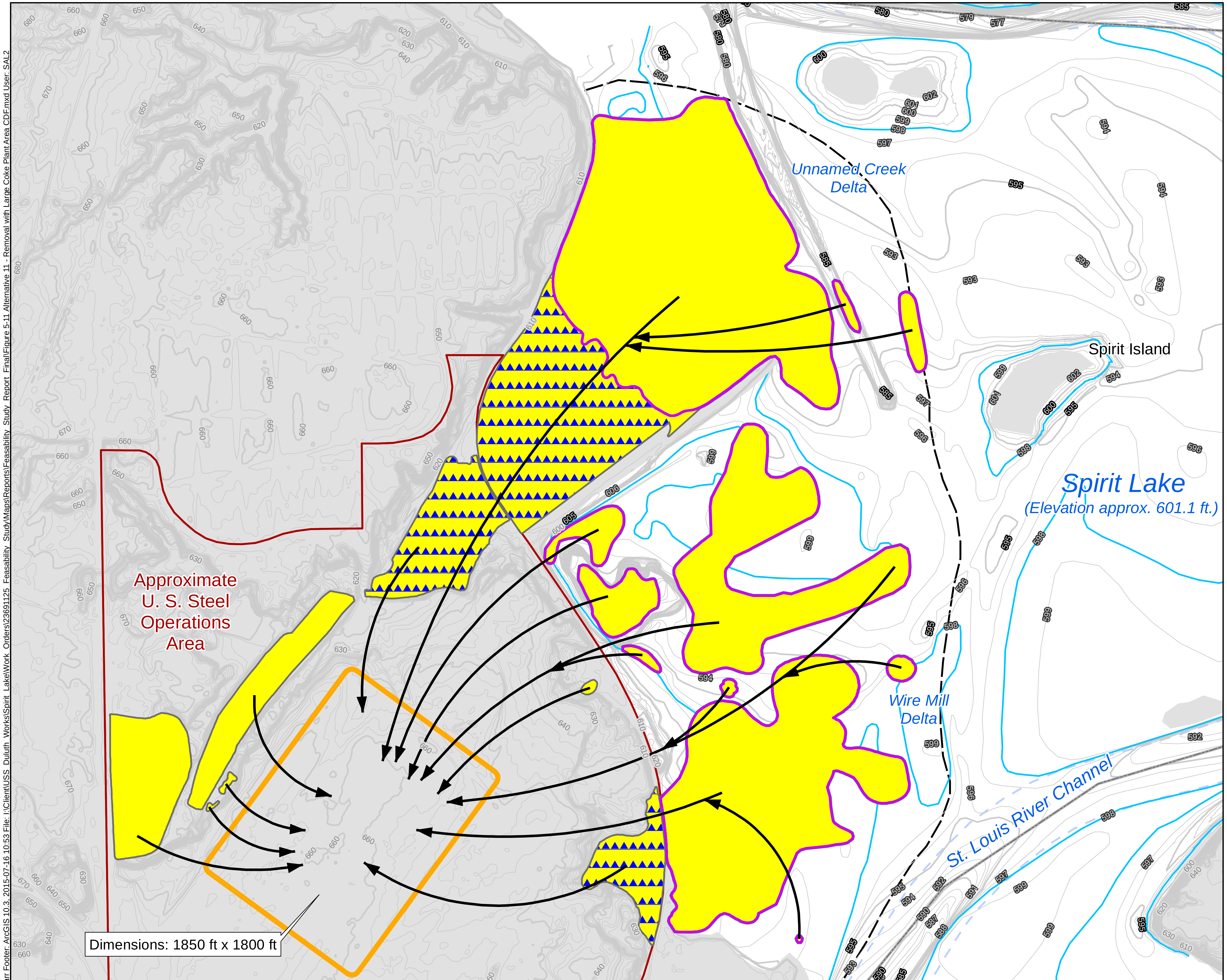


Figure 5-10

ALTERNATIVE 10
TARGETED REMOVAL WITH COKE PLANT AREA CDF
Former U. S. Steel Duluth Works -
Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota



Remedial Action

- Remove
- Approximate Landfill Location
- New Open Water
- Movement and Destination of Removed Material
- Estuary PRG Footprint {Total PAH(13), Lead, Zinc, Copper; MPCA - March 5, 2014}
- 2011 Upland Elevation Contours (10-Foot) *
- 2011 Upland Elevation Contours (2-Foot) *
- 2012 Bathymetry Contours (5-Foot)
- 2012 Bathymetry Contours (1-Foot)
- 598 Feet Bathymetry Contour
- Approximate Outer Study Area
- Approximate Location of St. Louis River Channel, Based on Orthophoto Interpretation
- Approximate U. S. Steel Operations Area (URS, 2008)
- State Boundary

* Source: Minnesota Department of Natural Resources LiDAR Elevation, Arrowhead Region, NE Minnesota, 2011

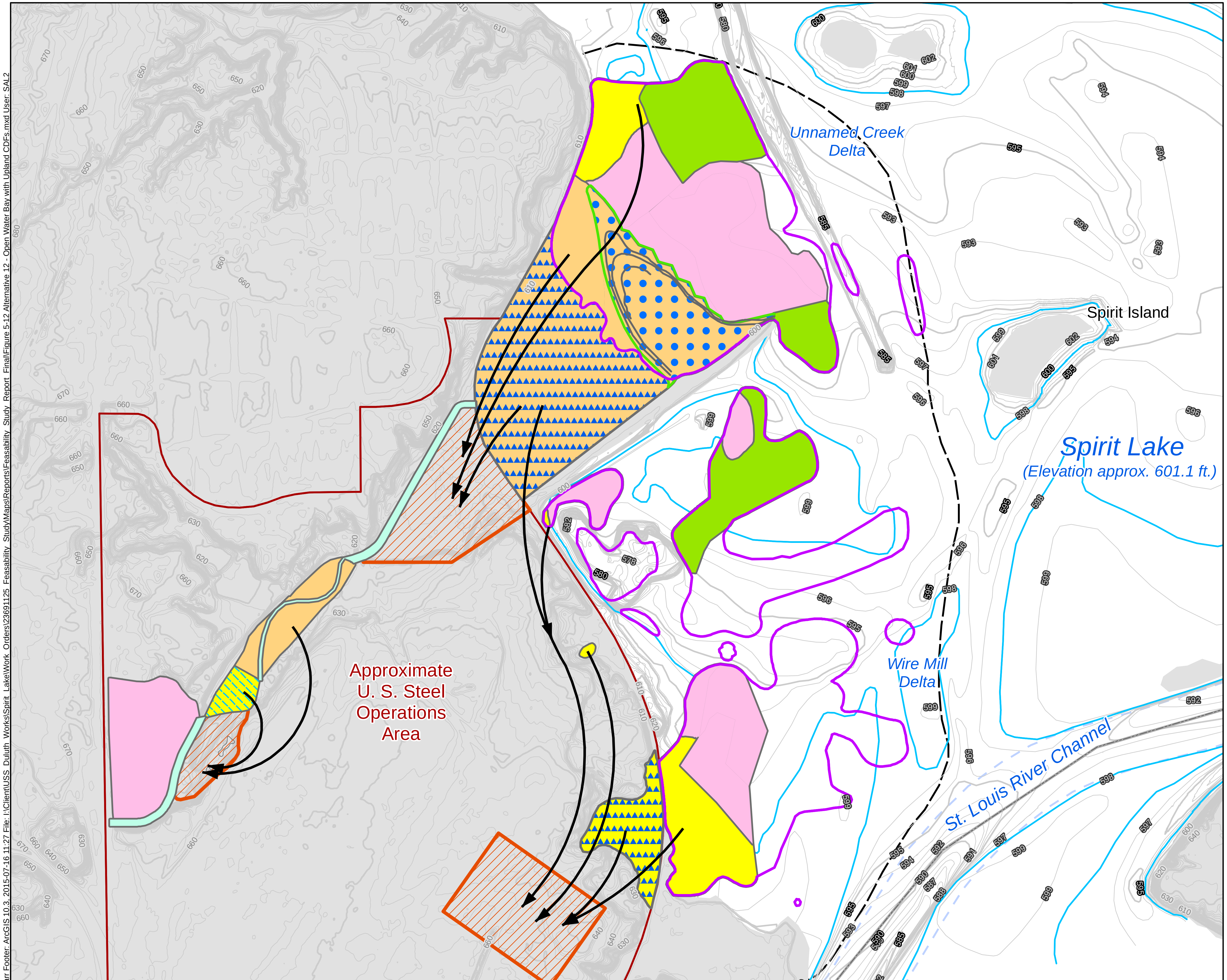
N

800 0 800

Feet

Figure 5-11

ALTERNATIVE 11
REMOVAL WITH LARGE COKE PLANT AREA CDF
Former U. S. Steel Duluth Works -
Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota



Remedial Action

- Drainage Feature
- ENR Thin Cover
- Remedial Cap
- Remove
- Remove to Set Elevation and Remedial Cap To Create/Maintain Open Water
- Upland CDF
- Shallow Sheltered Bay Protection-Shoal Feature
- New Open Water
- Stormwater Ponding
- Shoal Elevation Contours
- Movement and Primary Destination of Removed Material
- Estuary PRG Footprint {Total PAH(13), Lead, Zinc, Copper; MPCA - March 5, 2014}
- 2011 Upland Elevation Contours (10-Foot) *
- 2011 Upland Elevation Contours (2-Foot) *
- 2012 Bathymetry Contours (5-Foot)
- 2012 Bathymetry Contours (1-Foot)
- 598 Feet Bathymetry Contour
- Approximate Outer Study Area
- Approximate Location of St. Louis River Channel, Based on Orthophoto Interpretation
- Approximate U. S. Steel Operations Area (URS, 2008)
- State Boundary

* Source: Minnesota Department of Natural Resources LiDAR Elevation, Arrowhead Region, NE Minnesota, 2011

N

800 0 800

Feet

Figure 5-12

ALTERNATIVE 12
OPEN WATER BAY WITH UPLAND CDFS
Former U. S. Steel Duluth Works -
Spirit Lake Sediment Site
Saint Louis River
Duluth, Minnesota