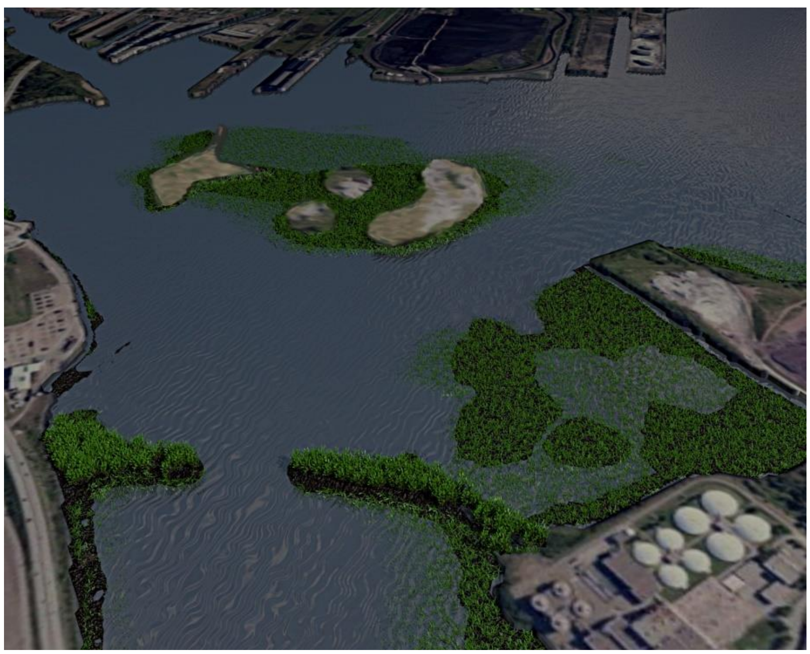
An Ecological Design for the 21st Avenue West Remediation-to-Restoration Project

George Host, Paul Meysembourg, Carol Reschke, Valerie Brady,
Gerald Niemi, Annie Bracey, and Lucinda Johnson
Natural Resources Research Institute, University of Minnesota Duluth

Matthew James and Jay Austin
Large Lakes Observatory, University of Minnesota Duluth

Elissa Buttermore
U.S. Fish and Wildlife Service



Contracted by

United States Fish and Wildlife Service
Cooperative Agreement F11AC00517

June 2013

NRRI/TR-2013/24

Full funding for this program is supported by a Cooperative Agreement from the U.S. Department of the Interior, Fish and Wildlife Service. Mention of trade names or commercial products does not constitute their endorsement by the U.S. Government.

Contents

Appendices

I. Background and Rationale

The lower 21 miles of the St. Louis River, the largest U.S. tributary to Lake Superior, form the 4856 ha St. Louis River estuary. Despite the effects of more than 100 years of industrialized and urban development as a major Great Lakes port, the estuary remains the most significant source of biological productivity for western Lake Superior, and provides important wetland, sand beach, forested, and aquatic habitat types for a wide variety of fish and wildlife communities.

The lower St. Louis River and surrounding watershed were designated an 'Area of Concern' (AOC) under the Great Lakes Water Quality Agreement in 1989, listing nine beneficial use impairments (BUIs), such as loss of fish and wildlife habitat, degraded fish and wildlife populations, degradation of benthos, and fish deformities. To address these BUIs, the St. Louis River Alliance (SLRA) completed the ***Lower St. Louis River Habitat Plan***, which identified ecosystems and sites with significant habitat limitations due to contaminated sediments and other unknown factors. The 21st Avenue West Habitat Complex is one of several priority sites for a 'Remediation-to-Restoration' (R-to-R) project. The intent of the R-to-R process is to implement remediation activities to address limiting factors such as sediment contamination while also implementing restoration projects that best complement the desired ecological vision.

This report documents the initial steps in the R-to-R process underway at 21st Avenue West, the development of an "Ecological Design" for the project area, and a preliminary evaluation of factors potentially limiting the realization of habitat and other land use goals. To establish the basis for this ecological design, researchers at the University of Minnesota Duluth's Natural Resources Research Institute (NRRI), in cooperation with U. S. Fish and Wildlife Service, the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, the Minnesota Pollution Control Agency, the Minnesota Department of Natural Resources and other partners, sampled the project area from late summer 2011 through fall 2012. The intent of field sampling was to establish baseline information on vegetation, benthos, birds, sediment contamination and types, and ecotoxicology. The subsequent ecological design effort will explore options to increase the overall footprint of quality aquatic vegetation beds and spawning habitat available, soften and extend shorelines, and remove or reduce the effect of industrially-influenced substrates. These options will be presented to adjacent landowners, as well as local and regional stakeholders, to contribute to the discussion on R-to-R options. The desired outcome of the project is to significantly increase the biological productivity of this complex of river flats and sheltered bays, in fulfillment of the SLRA Habitat Plan (SLRA 2002), while minimizing the risk of exposure of contaminants to fish and wildlife resources.

This project was funded under USFWS Cooperative Agreement Number F11AC00517, and is part of the USFWS Environmental Contaminants Program's goal to address contaminant-related needs of the St. Louis River Area of Concern as part of the Great Lakes Restoration Initiative.

II. Current Conditions at 21st Ave West

Bathymetry, Substrate and Stream Inputs

The 21st Ave West site is a complex of open water flats and shallow sheltered bay habitats that have been highly impaired by historical industrial activities (Figure 1). The project area covers approximately 526 acres and receives direct effluent from the Western Lake Superior Sanitary District (WLSSD) Treatment Plant. The site is heavily industrialized – it is bordered by the Canadian National Ore Docks and Rice's Point, a built landscape that houses numerous industries, as well as a popular public access boat launch and recreation area.

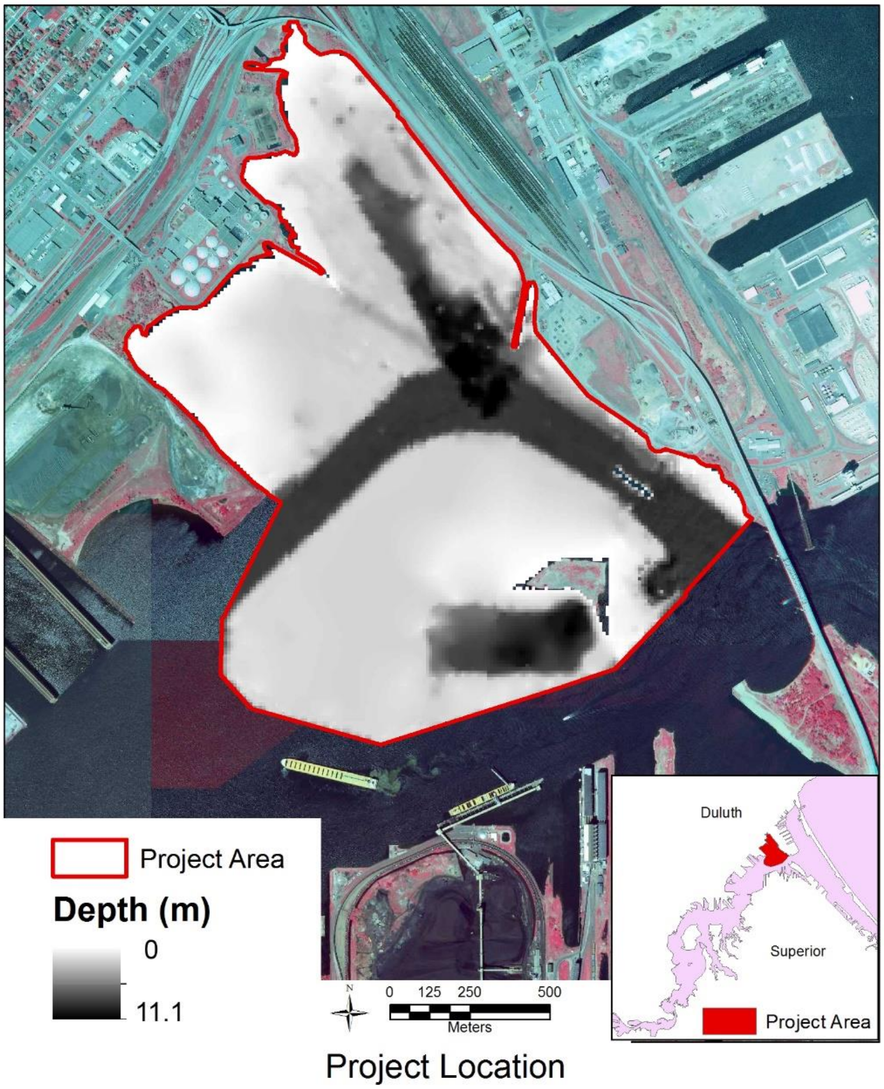


Figure 1. 21st Avenue West remediation-to-restoration project area in the St. Louis River estuary, Duluth, Minnesota. Black to white shading shows current bathymetry.

The 21st Ave West site has three important water inputs. Miller and Coffee Creeks drain into the northernmost bay in the project area. Both creeks receive runoff from highly urbanized watersheds, with the headwaters of Miller Creek draining Duluth's largest commercial shopping area. The streams contribute large amounts of sediment to this small bay, and the City of Duluth dredges the sediment on a regular basis to protect culverts under the I-35 freeway. The other significant input to the site is the outfall from WLSSD, where an average of 43 million gallons per day of waste water enters the bay from the City of Duluth and the surrounding communities of Cloquet, Esko, Carlton, and the Sappi Paper Mill. Potential issues associated with the effluent from WLSSD include increased temperatures, which result in year-around open water near the plant, as well as potential loading of nutrients and chemicals of emerging concern, such as personal care products and pharmaceuticals.

Important bathymetric features of the project area include the North Channel, a deepwater channel that bisects the site, with a connected deep channel that extends into Miller and Coffee Creek Bay. There is also a deep rectangular depression to the southwest of Interstate Island. Interstate Island itself is a Wildlife Management Area created from dredge waste and maintained free of woody vegetation. The island contains nesting pairs of common tern, a species of special concern (Coffin and Pfannmuller 1988), albeit with significant competition from ring-billed gulls.

The dominant substrate of the project area is primarily silt, with sand-textured sediments along the shorelines and scattered small pockets of muck throughout the site. Compared to reference locations in the St. Louis River estuary, 21st Avenue has proportionately less organic sediments in its shallow waters (Figure 2).

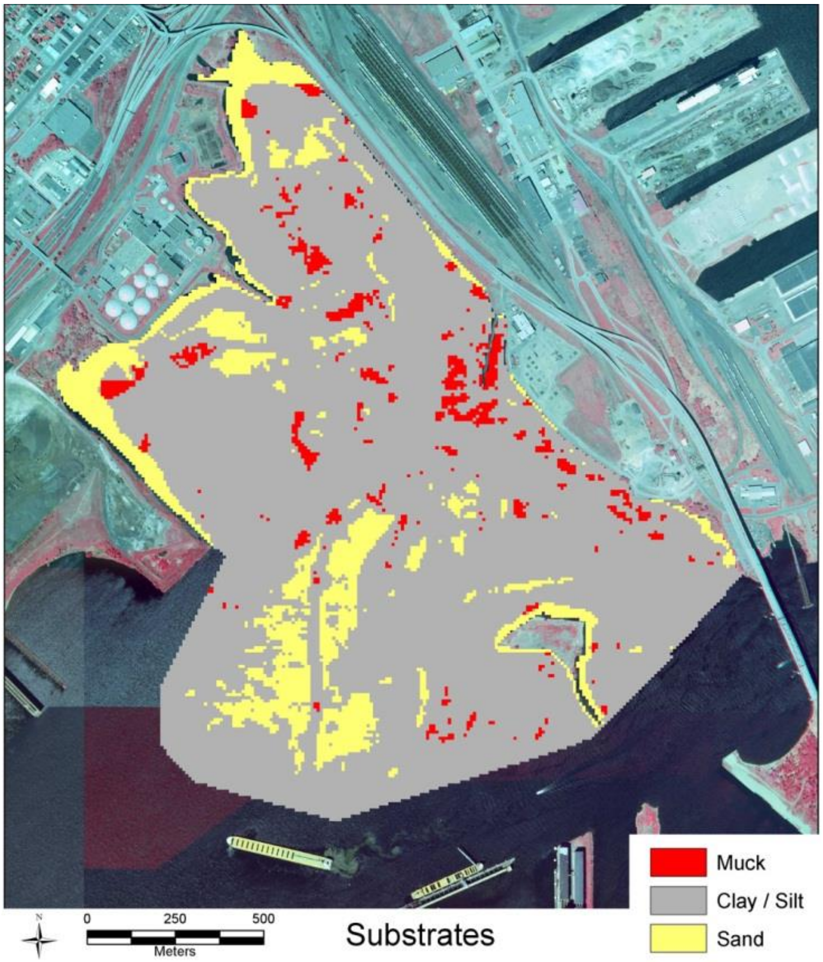


Figure 2. Interpolated substrate map for 21st Avenue West project area.

Aquatic Vegetation

The methods for aquatic vegetation surveys and plant community classification are described in Appendix 1. The aquatic vegetation present in the Project Area was very sparse and variable. In late summer of 2011 there were no aquatic plants visible at the water surface, but submerged aquatic plants were pulled up on the sampling rake. The total sample size was 64 points scattered through the Project Area; of those, 13 points were in water too deep (over 2 m) to be likely to support aquatic vegetation, and no plants were found at those points. Out of 51 points sampled in shallow water (under 2 m depth), 59% had some aquatic plants present, and 41% had no vegetation. The most abundant plants (those with the highest relative frequency) were water celery (*Vallisneria americana*), which was present at 29.4% of sample points, and algae (mostly filamentous) present at 15.7% of sample points. Each of the other aquatic plants present was found in fewer than 6% of the total sample points in shallow water. Three different portions of the bay had slightly different vegetation.

Near Interstate Island there were 24 shallow sample points and 13 points (54%) had Submerged Aquatic Vegetation (SAV) present. The only plants found near Interstate Island were scattered sparse patches of wild celery (*Vallisneria americana*), and some sparse algae. At three sample points near Interstate Island wild celery was gathered from water depths of 2.0-2.1 m, which is slightly deeper than the 1.8 m contour line for delineating shallow versus deep water. Average water depth at vegetated sample points was 1.41 m, and average Secchi depth was 0.67 m. Sediments near Interstate Island were mostly sand and silt, with some clay.

In the central and western parts of the bay near WLSSD there were 16 shallow sample points, and only 2 points (12%) had SAV present; plants identified were Nuttall's waterweed (*Elodea nuttallii*) and a narrow-leaved *Potamogeton* sp. The narrow-leaved *Potamogeton* was not fruiting and so was unable to be identified to species. Average water depth at vegetated sample points was 1.1 m, and average Secchi depth was 0.59 m. Sediments near WLSSD were mostly silt and detritus with a little clay. The water in this area stays ice-free longer than adjacent areas of the harbor due to effluent water from WLSSD; therefore it often has a large population of waterfowl, especially Canada geese. The abundant detritus at this part of the bay may be due to waterfowl concentrations, or from runoff or effluent from WLSSD.

Near the eastern shore of the bay, along Garfield Street, there were 11 shallow sample points, and 6 points (55%) had SAV present, although one of those had only algae. The plants along Garfield Street included water celery, two species of waterweed (*E. nuttallii* and *E. canadensis*), a narrow-leaved *Potamogeton* sp. (not fruiting), and algae. Average water depth at vegetated sample points was 0.75 m, and average Secchi depth was 0.62 m. Sediments near the Garfield Street shore were mostly sand and silt, with some detritus and gravel (note: at one point the "gravel" included taconite pellets).

Overall aquatic plant diversity was very low in the Project Area, especially when compared to other sites recently sampled for remediation to restoration projects. Even with a much higher number of sample points in the shallow portions of the Project Area, the number of aquatic plant taxa present was in the very low end of the range for open water sample points.

Wave Energy and Habitat Classes

Wind fetch, a surrogate for wave energy, is important for the establishment and maintenance of aquatic vegetation beds. A map of weighted wind fetch shows that the highest wind fetch values occur on the southern open water portion of the site. Rice's Point and the built land on the northern border of the site provide protection to the Miller and Coffee Creek bay, a factor that increases the chances of establishing aquatic beds in this area (Figure 3).

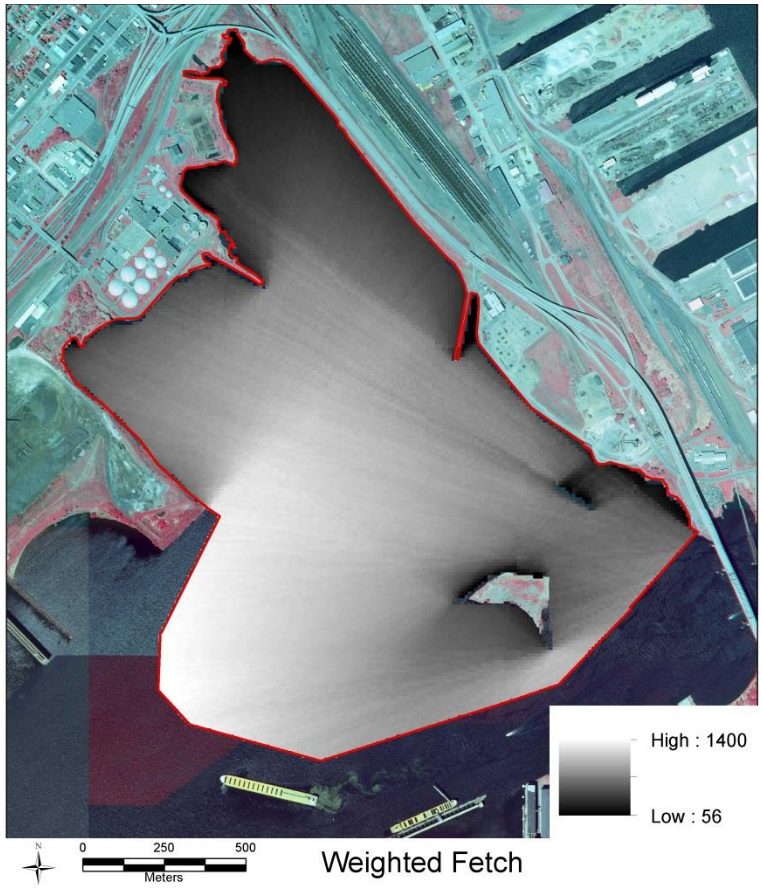


Figure 3. Weighted wind fetch for 21st Ave West project area.

The combination of depth and potential wave energy can be used to define potential and mappable habitat classes (Figure 4). Based on previous work, four depth classes were considered: shallow (<0.65 m), intermediate (0.65-1.60 m), deep (1.6-2.5 m) and disphotic (> 2.5). These are divided into high and low energy, based on a fetch distance of 250 m, which corresponded to an inflection point in the aquatic vegetation model. Note that there is not a sharp transition between low and high energy; these should be thought of as low vs. intermediate/high energy classes. While these are all inherently continuous variables, placing depth and energy into classes allows for the creation of simpler and more interpretable maps that show the type and amount of habitat, both in the current condition and in the scenarios.

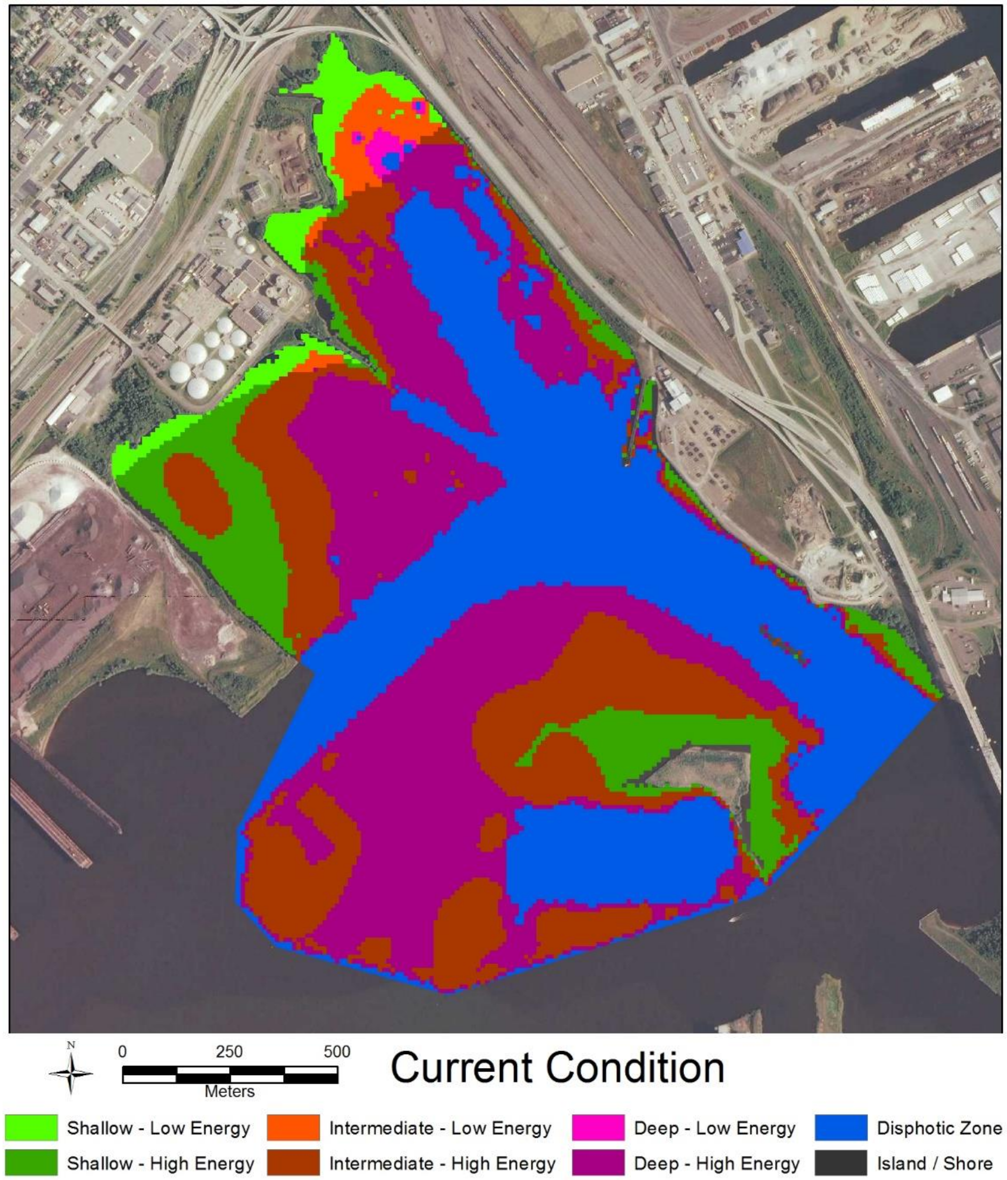


Figure 4. Distribution of habitat classes (depth x wave energy) under current conditions.

In general, the 21st Ave West site comprises primarily deep habitat, with 33% of the 526 ac in the disphotic (> 2.5 m) zone and 31% in the deep (1.6-2.5 m) category (Table 1). Only 62 ac or 12% of the area is classified as shallow, and most of this area is classified as intermediate/high energy. Low-energy habitats are relatively uncommon at the site in its current condition.

Ecotoxicological Characterization

MPCA Site Evaluations

The MPCA remediation staff evaluated recent and historical sediment chemistry data for the 21st Ave West Project Area by examining contaminant concentration data and comparing to guidelines that are an indication of potential risk to ecological receptors (MPCA 2013). Depth-integrated sediment samples collected in 2010 in cooperation with USACE were used as the primary dataset for contaminant assessment. Other historical studies were used to inform the conclusions and recommended management practices (RMPs). Historical studies that were evaluated are maintained in MPCA's Phase IV database: (*http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/contaminated-sediments/regional-sediment-databases.html*).

Risks evaluated included potential toxicity to sediment-dwelling organisms, a determination based primarily on comparison of bulk sediment contaminant concentrations to sediment screening values that are predictive of toxicity to benthic invertebrates. Sediment contaminant concentrations were compared to sediment quality targets (SQTs). SQTs are chemical benchmarks for the St. Louis River AOC for the protection of benthic invertebrates (Crane and Hennes 2007). Level I SQTs represent contaminant concentrations below which there are unlikely to be negative impacts on benthic organisms. Level II SQTs represent contaminant concentrations above which there are likely to be negative impacts to benthic invertebrates. Contaminant concentrations between Levels I and II have an unknown impact to benthic organisms because site-specific characteristics will affect toxicity, including temperature, pH, chemical interactions, etc. Mean PEC-Q (probable effect concentration quotient) has also been calculated for areas where sediment contaminants were tested. This metric has been shown to be a reliable basis for classifying sediments as toxic or nontoxic to benthic invertebrates in the St. Louis River (Crane and Hennes 2007). Mean PEC-Qs are a sediment assessment tool that condenses data from a select suite of contaminants [certain metals, total PAHs (polycyclic aromatic hydrocarbons), and total PCBs (polychlorinated biphenyls)] into a single unitless index. Mean PEC-Qs are used to compare sediment quality over time and space (Crane and Hennes 2007).

MPCA evaluations noted that the greatest concentrations of **mercury** (above the Level II SQT) occur in sediments near the WLSSD outfall at the 50-100 cm depth interval and within the bioactive zone. MPCA considers the bioactive zone to be from the sediment surface to 1 meter into the sediment for shallow waters (less than 8 ft water depth) and in deeper waters (greater than 8 ft water depth), from the sediment surface to 0.5 m into the sediment. **PAH** concentrations are documented at elevated levels in the central portion of the bay west of the WLSSD outfall that occasionally exceeded the Level I SQT, and one sample (deeper interval; 50-100 cm; within the bioactive zone) above the Level II SQT. Another area with greater PAH levels is in the Miller/Coffee Creek Delta. **PCBs** are documented in sediments throughout the Project Area, with most concentrations between the Level I and II SQTs, with the greatest concentration exceeding the Level II SQT at a deeper interval (50-100 cm; below the bioactive zone) in the deeper water area of the former navigational channel. **Dioxin/furans** are documented in sediments on both sides of the WLSSD outfall with surficial sediment concentrations between the Level I and II SQTs. The deeper interval (50-100 cm), near WLSSD, had the greatest dioxin/furans concentration (exceeding the Level II SQT). **Metals** (zinc, copper, lead, and nickel) are documented in sediments at concentrations often exceeding Level I SQTs, but not Level II SQTs, with concentrations that were generally greater in the surficial sediments. Areas with the greatest frequency of contamination were the western-side of the bay (west of WLSSD outfall), the Miller and Coffee Creek Delta area, and the former channel.

MPCA **recommended remedial practices** for the 21st Ave W Area (MPCA 2013) include the following:

- The default bioactive zone should be considered during remediation and restoration processes.
- Consult with an experienced risk manager when disturbing sediment.
- If possible, avoid disturbing sediment during restoration.
- More assessment and evaluation is recommended if disturbing sediment.
- Additional data collection may be required in areas where historical and/or recent data have indicated elevated contaminant concentrations.

USFWS Evaluations of Sediment Chemistry, Toxicity, and Bioaccumulation

The U.S. Fish and Wildlife Service initiated limited sampling and testing of sediments and fish in the 21st Ave West Complex in 2011-12 to complement the 2010 sediment sampling noted above. The primary objective of this investigation was to evaluate the toxicity and bioaccumulation of contaminants in surficial sediments obtained from the project area. Results of these sediment tests provide additional information to help evaluate trends in contaminant bioavailability at the 21st Ave West Complex Remediation-to-Restoration Project site and have helped to determine actions necessary to meet ecological goals while minimizing potential for contaminated sediments to limit the development of high quality aquatic habitat.

USFWS 2012 Methods

Sample collection

Bulk sediment was collected from fifteen locations in the 21st Avenue West Complex on May 7 and 8, 2012 and transferred to U.S. Geological Survey, Columbia Environmental Research Center in Columbia, MO (USGS-CERC) for toxicity and bioaccumulation testing. White suckers (*Catostomus commersonii*; N = 15) were collected from the project area by seining in the spring of 2011 to provide an additional indication of contaminant exposure.

Toxicity and bioaccumulation tests

Relationships between sediment chemistry, toxicity and bioaccumulation were evaluated using the amphipod *Hyalella azteca* (28-day whole-sediment exposures measuring effects on survival, growth, and biomass) and the midge *Chironomus dilutus* (10-day whole sediment exposures measuring effects on survival, growth, and biomass) and bioaccumulation of contaminants of concern by the oligochaete *Lumbriculus variegatus* (28-day whole-sediment exposures). Contaminants of potential concern in the sediments include both metals and organic contaminants (including PAHs, PCBs, and chlorinated pesticides).

Sediment, oligochaete, and fish chemistry

Physical (total organic carbon) and chemical characterization of the test sediment, oligochaetes (composited), and fish (whole-body) were performed by the Geochemical and Environmental Research Group in College Station, Texas (for organic contaminants: organochlorines, aliphatics, and aromatics) and Alpha Woods Hole Laboratory in Mansfield, Massachusettes (for metals). Because of limited sample mass, worm analyses were confined to inorganic contaminants. A rigorous QA/QC protocol was followed.

Results

Sediment chemistry and guideline exceedances

Contaminant concentrations were compared to sediment quality guidelines to assess risk to the aquatic community. Individual contaminant concentrations in sediment samples frequently exceeded the Level I SQT, and occasionally exceeded the Level II SQT. Sediment from 9 of the 15 locations included contaminant mixtures exceeding the Level 1 Mean PEC-Q. The site near WLSSD had the greatest sediment mean PEC-Q, and was between the Level I and Level II PEC-Qs. Contaminants of concern included: PAHs, PCBs, and mercury. **PAHs** were detected at high levels with 2-methylnaphthalene, and naphthalene exceeding Level II SQT near WLSSD and near the state-line across from Half Moon Bay. **Mercury** in sediment was also found at greatest concentrations near WLSSD (Figure 5). Total **PCB** concentrations were greatest in the area near WLSSD (Figure 5, subareas B and C). In general, **chlorinated pesticide** concentrations were low. **Toxaphene** was not detected in any sediment samples, although the detection limits were greater than the Level I SQT.

Sediment toxicity

One sediment sample (near the state-line and east of Interstate Island) demonstrated toxicity to both amphipod (lower survival) and midge (reduced growth) test organisms relative to the control sediment. Sediment from the site, near the state-line and south of Half Moon Bay, was toxic to the midge test organism (reduced growth) relative to the control sediment. Although sediment samples from the area near the state-line and east of Interstate Island were classified as the most toxic, this area had low contaminant concentrations, and similar water quality characteristics when compared to other sites, which suggests that perhaps some other contaminant that was not tested for is causing these adverse effects to these invertebrates.

Bioaccumulation

Sufficient tissue mass for chemical analyses of oligochaetes was obtained from all of the 15 treatments at the end of the exposures except for the location near WLSSD, from which very few oligochaetes survived, suggesting anecdotal evidence of toxicity. The worms did not accumulate significant concentrations of inorganic contaminants; organics contaminants were not tested for due to low tissue mass.

Other Bioindicators

Contaminant concentrations in white suckers (whole-body) generally reflected those contaminants of concern found in sediment. 1987 guidelines were created for contaminants (mercury, total DDT, PCBs) in fish for the Great Lakes Water Quality Agreement (GLWQA). **PAHs** are rapidly metabolized in vertebrates, and therefore, if they are measured in fish tissue, it is indicative of recent exposure to elevated levels of PAHs. Several **PAHs** were detected in white sucker samples. **PAHs** that were found at the greatest concentrations in sediment were also detected at the greatest concentrations in fish. All fish samples exceeded a Canadian **mercury** guideline for the protection of wildlife consumers of aquatic biota (CCME 2001), but were all below the GLWQA guideline. **PCBs** were detected at average concentrations of 193.2 ppb-wet, and ranged from 57.9 to 323.3 ppb-wet and 93% of the fish samples exceeded the GLWQA for PCBs (100 ppb-wet). Total **DDT** concentrations in white suckers (mean = 13 ppb-wet; range = 4.3 to 23.1 ppb-wet) sometimes exceeded the guideline for the protection of wildlife consumers of aquatic biota of 14 ppb-wet (CCME 2001), but all samples were below the GLWQA (1000 ppb-wet). Most **chlorinated pesticides** were detected at low levels or not detected at all in fish samples in this study.

Summary of ecotoxicological analyses

Recent (FWS 2012) data are generally consistent with previous results (as presented in MPCA 2013). Most individual contaminant concentrations were below the Level II SQT for both data evaluations. However, nearly all sample locations (some locations included multiple depths) exceeded the Level I SQT, and a majority of the sample sites also exceeded the Level II SQT, for at least one contaminant. Datasets (Phase IV and 2012) indicate toxic effects to benthic invertebrates throughout the 21st Ave West Project Area. The area near the WLSSD outfall generally had the greatest contaminant concentrations (when considering all recent and historical data). For example, **mercury** and **PCBs** in sediment was found at greatest concentrations near WLSSD (Figure 5, B; Figure 6). Data also suggest that **PAHs** were elevated in this area (see Figure 5, A and B subareas). In general, chlorinated pesticide concentrations were low. **Toxaphene** was not detected in any recent (2008-2012) sediment samples, although the detection limits were greater than the Level I SQT. Historical data indicate that the area was contaminated by **toxaphene**, thus, it may be important to consider this chemical during future sampling efforts. According to the recent sediment chemistry data (2010) described in the MPCA Remedial Review and Determination Memorandum, Remedial Assessment Area 57, **dioxin/furans** were also detected at elevated levels on both sides of the WLSSD outfall (Figure 5, B), with a majority of these concentrations in between the Level I and II SQTs, and with one sample from a deeper interval exceeding the Level II SQT. **Dioxin/furans** were not tested in the most recent (2012) study. Historical data indicate more contaminated sediment near the surface, but recent data (2008, 2010) suggest that greater contaminant levels are in the deeper sediments. These data may indicate that contaminated sediment has been buried over time. Disturbance of these contaminated sediments could increase bioavailability of contaminants, and thus increase the toxic effects to fish and wildlife.

In summary, available data indicate that the most contaminated areas (mercury, PAHs, and PCBs) are near WLSSD (Figure 5 B and C), the delta area of Miller and Coffee creeks (Figure 5, A), and near the state line in the river (Figure 5, D). Data are also more limited towards the state line section of the project area (Figure 5, D), and toxicity data indicate adverse effects on invertebrates. Intensive sampling in these areas would better inform the necessary remedial evaluations. Additional monitoring post-restoration will also help inform remedial decisions and is recommended because restoration activities are likely to disturb sediment and have the potential to increase contaminant bioavailability (especially if restoration will alter the geochemical conditions of the area).

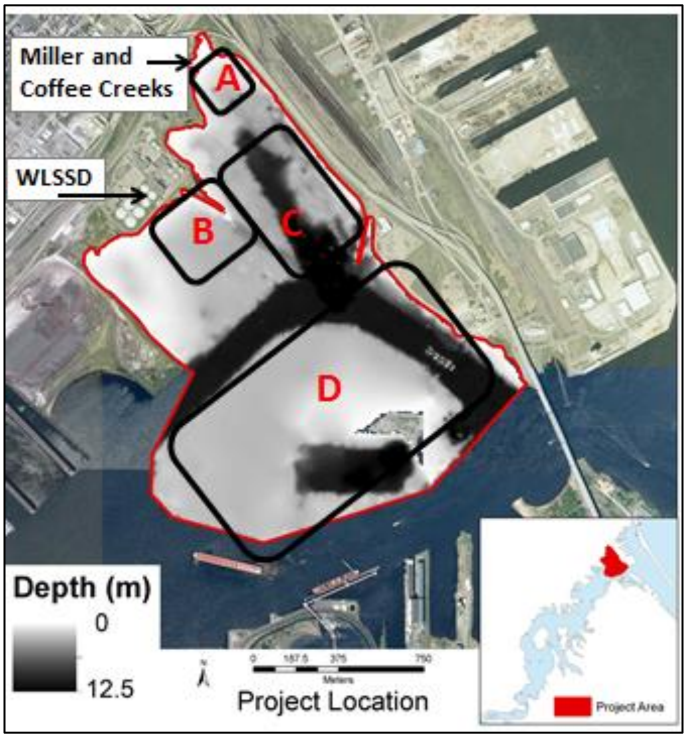


Figure 5. General areas of potential toxic contamination within the 21st Ave W Project Area. A) Miller and Coffee Creeks delta area; B) WLSSD outfall area; C) Former channel; D) Near the state-line of the St. Louis River.

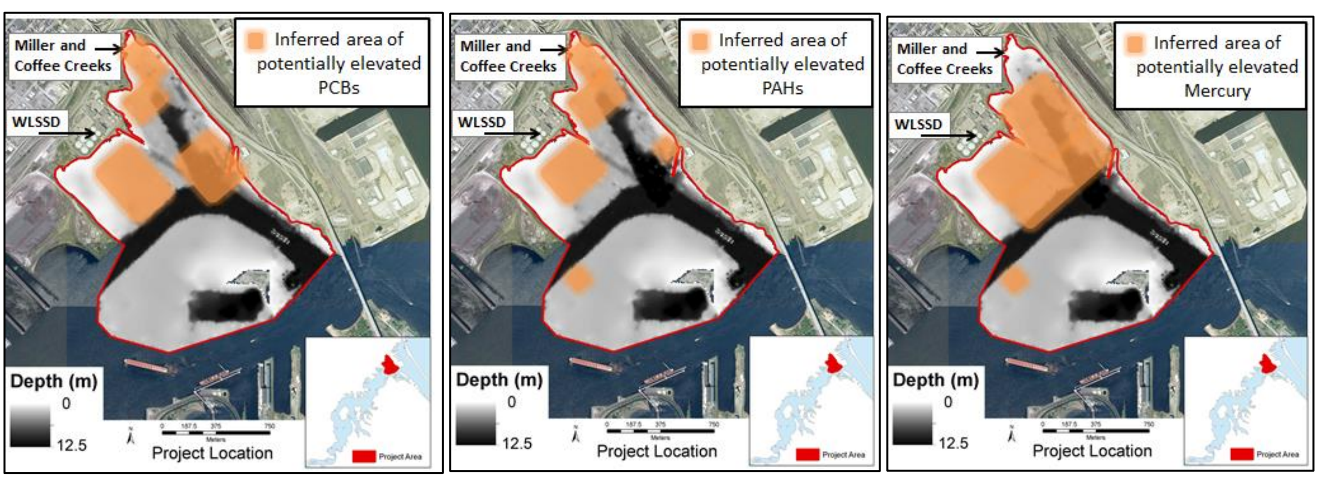


Figure 6. Inferred areas of potentially elevated PCBs, PAHs and mercury (Hg).

Invertebrate Community

Deep and shallow water macroinvertebrate assemblages were expected to differ from each other because of the expected difference in vegetation coverage between these depths, based on experiences elsewhere in the estuary. Thus, 21st Ave. sample points were divided into shallow (≤ 3 m) and deep (>3 m) depths and analyzed separately.

The shallow water benthic macroinvertebrate assemblage (21st Shallow) contained 31 taxa, while the deep water assemblage (21st Deep) contained only 21 taxa. In comparison, 38 taxa were collected from the reference areas (Ref), and 32 taxa from the 40th Avenue West site (40th Ave). It is well-documented that numbers of taxa should increase with increased sampling effort. Since twice as many samples were collected from 21st Shallow as from the other sites, the low taxonomic richness at 21st Shallow is the first of several indications that the current macroinvertebrate assemblage at 21st Ave overall exhibits signs of impairment.

Comparing macroinvertebrate assemblage composition (Figure 7) among sites shows that while the taxa found among sites were similar, the proportions differed, often significantly (Table 2), at 21st Ave relative to the other sites. Both Shallow and Deep areas of 21st were significantly more dominated by aquatic earthworms (Oligochaeta), tube worms (Polychaeta), and non-insects than the other sites. On the other hand, mayfly and caddisfly (Ephemeroptera and Trichoptera) taxa richness was significantly lower at 21st relative to the Reference and 40th Ave sites (Table 2, Figure 8). While this might be expected at the greater depths of many of the Deep points, Shallow points were expected to have an assemblage somewhat similar to that of 40th Ave. In addition, the overall mean density of invertebrates was significantly greater at 21st Shallow and Deep than the other sites.

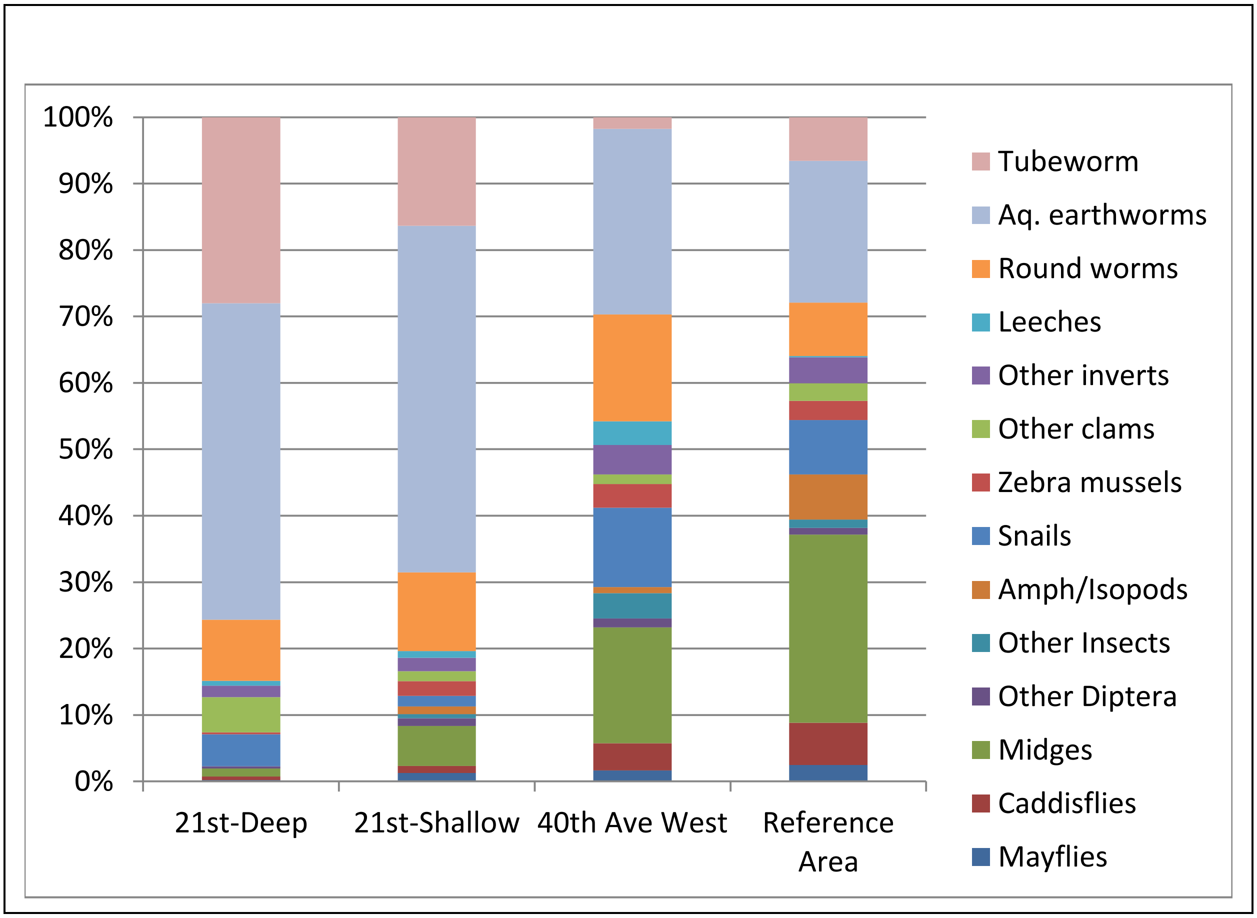


Figure 7. Benthic macroinvertebrate assemblages from four sites in the St. Louis River estuary. Common names of invertebrates are used for ease of interpretation.

Sites also had invertebrates unique to them and found at none of the other three sites (Host et al. 2012). For the 21st Deep site, this was a single taxon of leech. At 21st Shallow, 6 unique taxa were collected. This compares to 15 unique taxa for the Reference sites and 9 for 40th Ave W. Again, since sampling densities were higher for 21st than 40th, the lesser number of unique taxa is an indication of probable impairment.

In conclusion, the 21st Avenue West macroinvertebrate assemblage is highly dominated by aquatic earthworms (Oligochaeta) and contains fewer aquatic insects, both in abundance and as representative taxa, than the Reference Area. Lower taxa richness, despite greater sampling effort at 21st Shallow, also indicates an assemblage that is impaired compared to other areas in the estuary, particularly the Reference Area. While part of the cause of this impairment may be due to lack of aquatic vegetation, it is not clear that physical habitat characteristics are the sole cause. The high density and dominance of aquatic earthworms (Oligochaeta), suggests the possibility of a fertilization effect. Recent toxicity and contaminant work suggest that toxic contaminants may be reducing or eliminating intolerant and sensitive taxa, while nutrient enrichment may be fostering greater numbers of tolerant organisms (e.g., Oligochaeta).

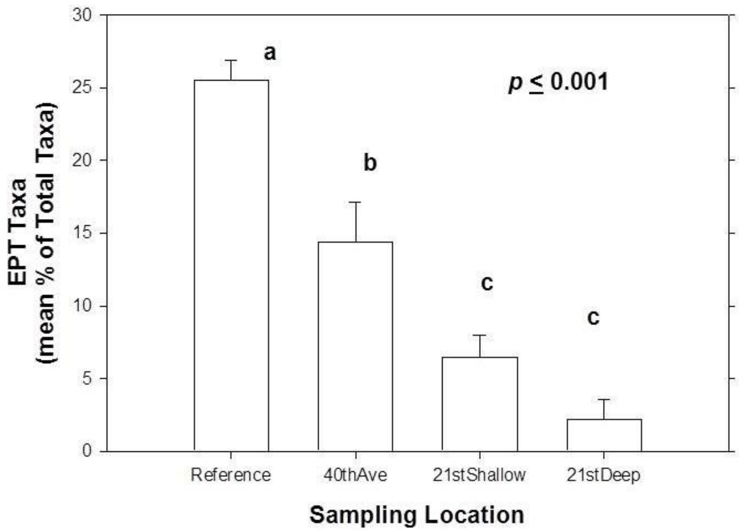


Figure 8. Percent abundance of Ephemeroptera and Trichoptera (no Plecoptera were found) per sample collected at four St. Louis River Estuary sampling locations. Values represent mean numbers + 1 standard error. p value if from the overall ANOVA. Columns with different letters are significantly different.

One favorable observation from this sampling is that the large burrowing mayfly *Hexagenia* was found within the 21st Shallow area (and also found at Reference and 40th Ave. West). (Note also that the family was found within 21st Deep, but could not be identified to genus). However, large shallow areas at the 21st site are void of *Hexagenia* even though habitat conditions (e.g., depositional mudflats) would appear to provide suitable habitat. One hypothesis would be that these areas receive too much wind and wave action for these burrowing mayflies. This mayfly is also particularly sensitive to dissolved oxygen, and its presence indicates that dissolved oxygen is not a limiting factor in areas where it occurs. Scientists and managers are interested in *Hexagenia* because it may serve as a bioaccumulation link in the estuary food web; it is large-bodied, long-lived, and resides with the sediment, and thus is in potentially close proximity to legacy toxins throughout most of its lifecycle.

Avian Communities

Avian communities showed characteristic habitat associations, with shorebird observations most abundant in shallow, low energy environments. Waterbird and waterfowl were most abundant in shallow nearshore and intermediate/high energy environments. Songbirds were confined to shoreline edges with shrubs and trees, while shorebirds and waterbirds were also associated with isolated, shoreline habitats (Table 3). Deep and disphotic habitat (> 1.6 m) had relatively few bird observations. Note that any islands or sand or cobble shorelines created will provide loafing areas or potential breeding sites for the large Ring-billed Gull population in the area. This species, as well as Herring Gulls, American Crows, and several exotic species such as European

Starlings, House Sparrows, and Rock Pigeons are already creating management problems for WLSSD because of their foraging at the site. Any restoration scenarios should discourage additional attractions to the area for these species. Similar concerns are relevant to Canada Geese; however, they are not necessarily foraging at the WLSSD site, but are prominently using the area as a protected site for resting and nesting. The high population levels of gulls and Canada geese may also be restricting the revegetation process at the site. For detailed summaries of avian use, see Host et al 2012.

III. Modeling Approach

Aquatic Vegetation Model

As a part of the ecological design for the 40th Avenue West R-to- R, NRRI developed a model to predict the probability of aquatic communities under particular combinations of depth, wave energy, and substrate (Host et al. 2012). The model was based on an assessment of vegetation, sediment types, benthic macroinvertebrates, and bird usage at the 21st and 40th Avenue West habitat complex areas, along with reference locations at other sites (Brady et al. 2010). These data were integrated with existing aquatic vegetation data, bathymetry, wind fetch, and other environmental variables. Classification and regression tree (CART) and logistic regression approaches were used to develop predictive models for dominant aquatic vegetation communities based on environmental factors. These relationships were then incorporated into a GIS modeling framework to map the predicted distribution of aquatic vegetation across these restoration sites. A full description of the technical details of the model can be found in Appendices A-C.

The primary outputs of the aquatic vegetation model are probability maps of the distribution of three aquatic plant communities: Emergent marsh (EM), Floating-leaf aquatic bed (FL), and Submerged aquatic bed (SAV). The probability maps were converted to aquatic plant community patches by identifying the p-values that best fit the sample data (Figure 9). Because there was no significant model for SAV, we subtracted the EM and FL communities from the vegetation presence model; the remaining grid cells were classified as SAV.

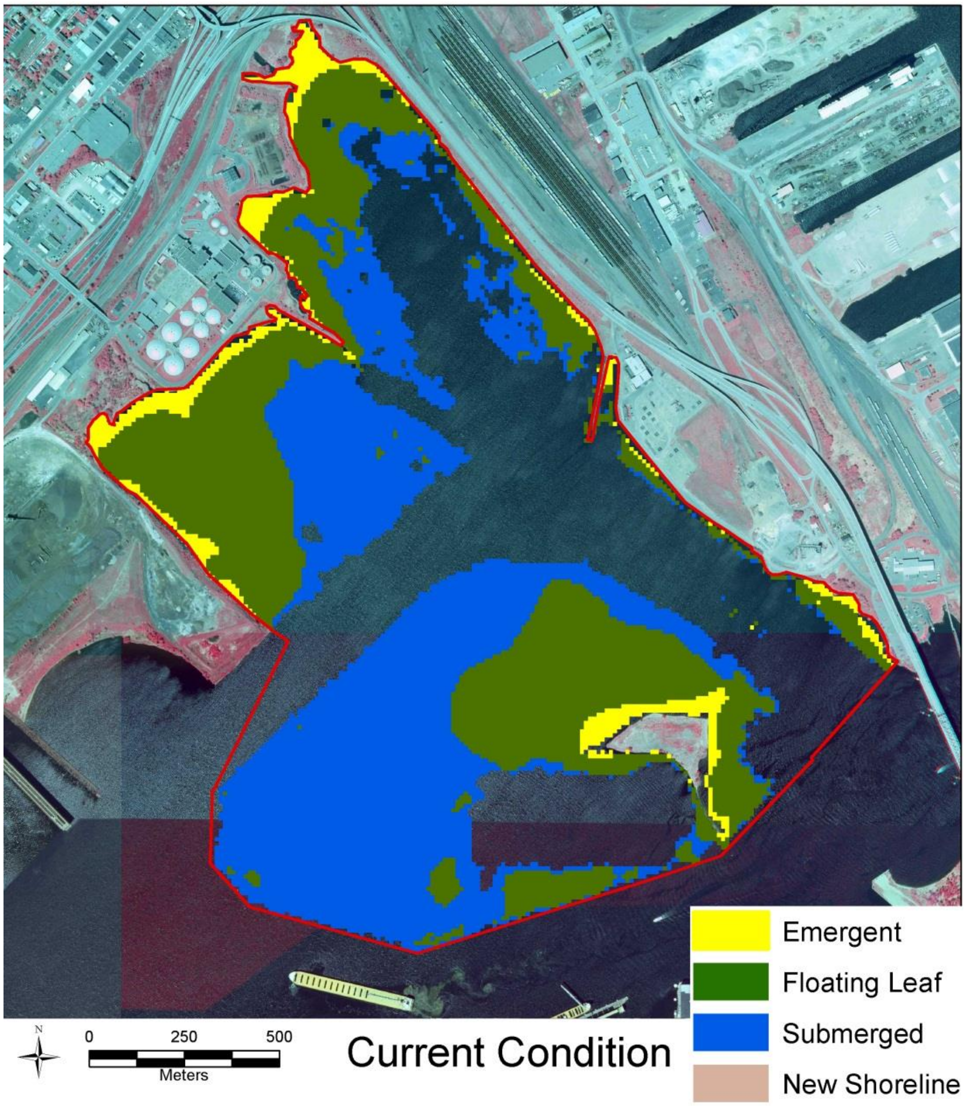


Figure 9. Model predictions of aquatic vegetation beds under current conditions.

At the 21st Avenue site there is a significant disparity between model predicted vegetation and field observations. The model predicts over half of the site supporting aquatic vegetation, with approximately 140 and 170 ac of floating leaf and submerged aquatic beds, respectively (Table 4). Emergent beds were predicted to comprise 22 ac or 3.5% of the project area. In the 2011 vegetation survey, the aquatic vegetation present in the project area was sparse and variable (Host et al 2012). In late summer, approximately 40% of sites in shallow water that seem favorable to aquatic plant growth had no vegetation present. The most abundant plant (based on highest relative frequency) was water celery (*Vallisneria americana*), which was present at 30% of the sample points. These beds were often quite sparse, however. Filamentous algae were present at 16% of sample points, but other aquatic plants present were found in fewer than 6% of the shallow water sample points. There are no significant beds of emergent or floating leaf vegetation observed in 2011.

The aquatic vegetation model was based on 850+ data points collected across the entire estuary. There are numerous potential reasons for the disparity between the model predictions and lack of vegetation found in the summer 2011 field sampling. Among these are issues related to the sediment composition, either in terms of presence of contaminants that might limit vegetation growth, or simply the influx of large amounts of sediment from Miller and Coffee creeks during rain events. Another might be bird herbivory on aquatic plants – the outfall from WLSSD is warm and maintains open water over the winter, resulting in large and persistent bird populations remaining at the site over the winter and present when spring growth begins. An informal EPA exclosure study showed that some vegetation became established in bird exclosures set up in the Miller Creek Bay in summer 2012 (T. Hollenhorst, *pers comm*). Plans are underway for more directed experiments on the sediments and other factors that may limit the growth of aquatic vegetation at 21st Ave West.

Hydrodynamic Modeling

To investigate the effect of bathymetry and coastline changes on flow within the project area and in particular the dispersal of effluent from WLSSD, a hydrodynamic model was developed. The model was based on the open source, finite-volume coastal ocean model (FVCOM), which was jointly developed by the University of Massachusetts-Dartmouth and Woods Hole Oceanographic Institution (Chen et al., 2007). The model solves the equations of momentum, heat transfer and continuity as they pertain to fluid flow on an unstructured grid.

Due to the large number of simulations required, computing resources available at the Minnesota Supercomputing Institute were used. Each simulation was carried out using up to 32 processors working in parallel.

Separate grids reflecting changes in coastline and bathymetry were generated for the current condition and the ecological design scenarios described below. Grids were generated using coastline and bathymetry data provided by UMD's NRRI and the National Geophysical Data Center. The domain included the whole of Lake Superior as far east as the St. Mary's River and as far west as the St. Louis River's Oliver Bridge. Grid resolution ranged from about 15km in the open lake (Figure 10) to less than 50 m in the harbor around WLSSD (Figure 11). The entire lake was modeled because of the importance of processes such as lake seiches to harbor circulation.

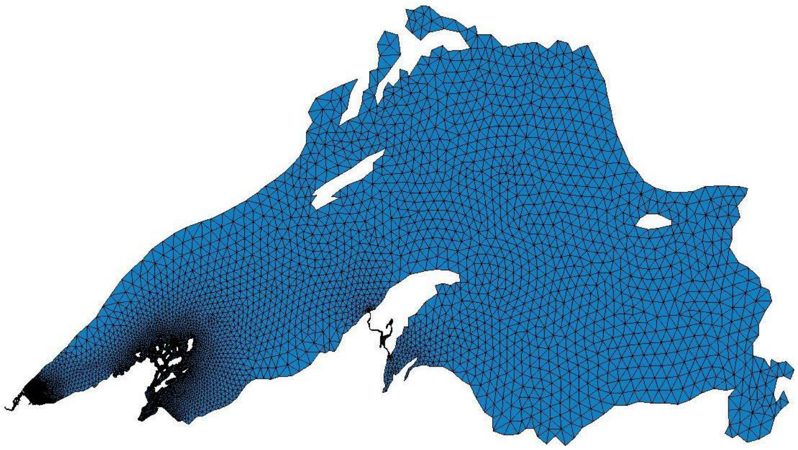


Figure 10. The finite-volume grid for the entire model.

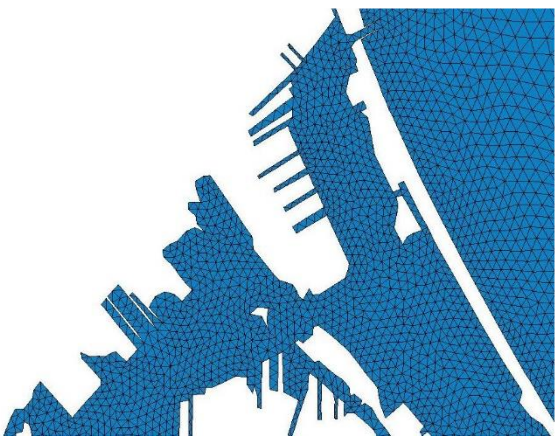


Figure 11. The finite-volume grid in the vicinity of the study area, demonstrating the much higher horizontal resolution of the grid at 21st Avenue West.

Five cases were modeled for the current condition and design scenarios, including average and strong wind conditions, from both east and west. River discharges were modeled as point volume sources, were temporally constant and included the St. Louis River, the WLSSD outfall, Miller Creek and the Nemadji River. Mean annual flow data was provided by the USEPA Mid-Continent Ecology Division. Consistent with WLSSD data, the WLSSD input water was put in at 29C, a much higher temperature than the ambient harbor water, resulting in significant thermal stratification.

The model was started from rest, with temperature structure of 7°C at depths of 1 through 20 m to 4°C at the bottom. Rivers were allowed to flow with their mean quantities (Appendix 4). The model was allowed to run for 8 weeks, which was sufficient time for currents due to river flows in the estuary to reach steady-state (Figure 12). Following this, a constant wind was applied to the domain to stimulate a typical Lake Superior seiche response. The model was considered to have an acceptable initial condition once a water level spectrum derived from the NOAA water level gauge in the Duluth Harbor (DULM5) records bore good agreement with modeled water level.

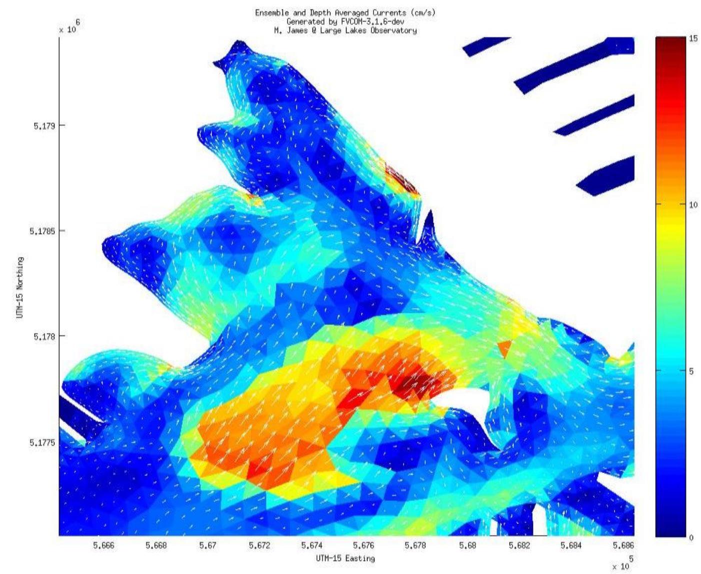


Figure 12. Depth-averaged currents under spun-up river forcing conditions. Colors represent velocity magnitudes, arrows indicate current direction.

To track the dispersal of WLSSD effluent water, modeled discharge water was tagged with a conservative, passive tracer, henceforth referred to as “dye”. The area in which a dye concentration of at least 10% was found was the primary metric used to compare different scenarios. In addition to this measure of dye-affected area, the time required for a dye concentration of 1% to reach stations in the Superior Entry and Duluth Ship Canal was measured. For the control case as well as each of the scenarios, we will present the steady state dye distribution. In Figure 13 and following figures, the color represents the log of the vertically-averaged WLSSD effluent concentration

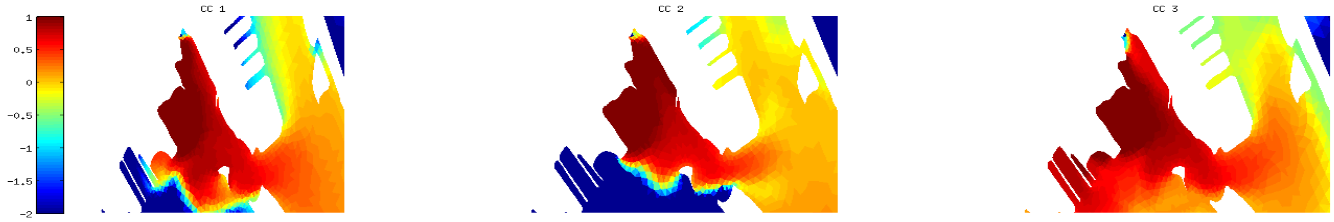


Figure 13. Steady-state dye distribution in the harbor in the control case under three scenarios: (a) Steady river forcing, no wind; (b) steady river forcing, wind from the west; (c) steady river forcing, wind from the east.

Five cases were modeled for the current condition and design scenarios, including average and strong wind conditions, from both east and west directions. River discharges were modeled as a point volume source, were temporally constant and included the St. Louis River, the WLSSD outfall, Miller Creek and the Nemadji River. Mean annual flow data was provided by the USEPA Mid-Continent Ecology Division.

IV. Ecological Design Scenarios

We considered five ecological design scenarios, developed by the SLRA Habitat Committee in conjunction with the USACOE. These scenarios were designed to represent a range of potential restoration scenarios that follow remediation at the site. Scenarios include alterations to substrate or bathymetry to provide more suitable habitat for emergent, floating-leaf or submerged aquatic vegetation beds and fish and wildlife resources, creation of islands or breakwalls to disrupt wind fetch and dissipate wave energy, and expansion of existing shoreline to increase land-based habitat. The scenarios vary in intensity, extent, amounts of materials required, and, consequently time, energy and expense. The results presented here are intended to be a guide toward balancing the costs and benefits of restoration activities.

For each scenario (labeled A-E), new input maps of bathymetry, substrate, and weighted wind fetch (the product of 12 separate wind grids) were calculated. The models for the three aquatic plant communities were then applied to the new set of grids, resulting in new probability maps. As a final step, the three plant community maps were integrated into a final predictive map of discrete communities, and areas of each aquatic plant type were calculated and compared with current condition. Finally, for each scenario, inferences on the macroinvertebrate and avian responses to the restoration treatments were made based on the habitat class and vegetation maps, as well as Ecological Risk Management issues to be considered.

Scenario A

Scenario A is a variation of a restoration activity proposed by the Army Corps of Engineers in 1999 and modified after discussions with the SLRA and other partners in September 2012. The restoration is focused primarily on the small bay formed by Miller and Coffee creeks, and treats 105 acres or 16% of the 636 acre site.

The intent of this design was to restore 75 acres of habitat by placing dredged materials that would encapsulate sediments at the site (Long 2012). There are two prominent features to the design. One is a 2400 ft underwater wave barrier that sweeps in an arc from the north across the bay to the peninsula that includes the WLSSD site (Figure 14). The barrier consists of riprap stone, with a 10' buffer of fill materials covering the soft sediments adjacent to the barrier. The design also includes an island, four pools, an access channel, and additional fill to create 75 acres of wetland. Note that, while locally intensive, Scenario A only covers a small portion of the overall project area.

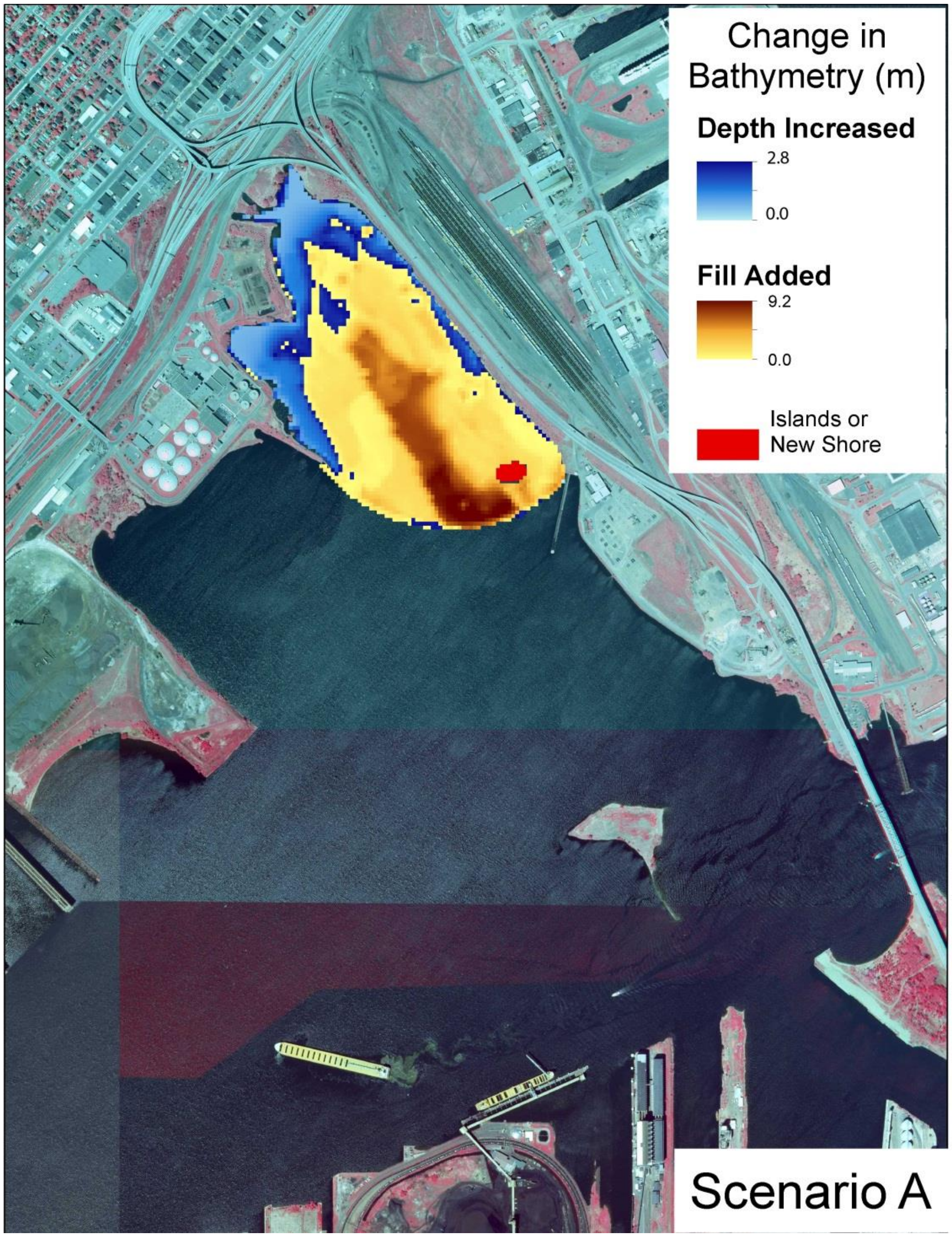


Figure 14. Bathymetric changes and island development for Scenario A.

Habitat and biotic response

Since Scenario A modifies only a small portion of the overall project area, it does not result in significant changes in habitat areas. Shallow and intermediate high-energy areas were each increased by 4 acres, with similar reductions in low energy environments. (Figure 15; Table 5).

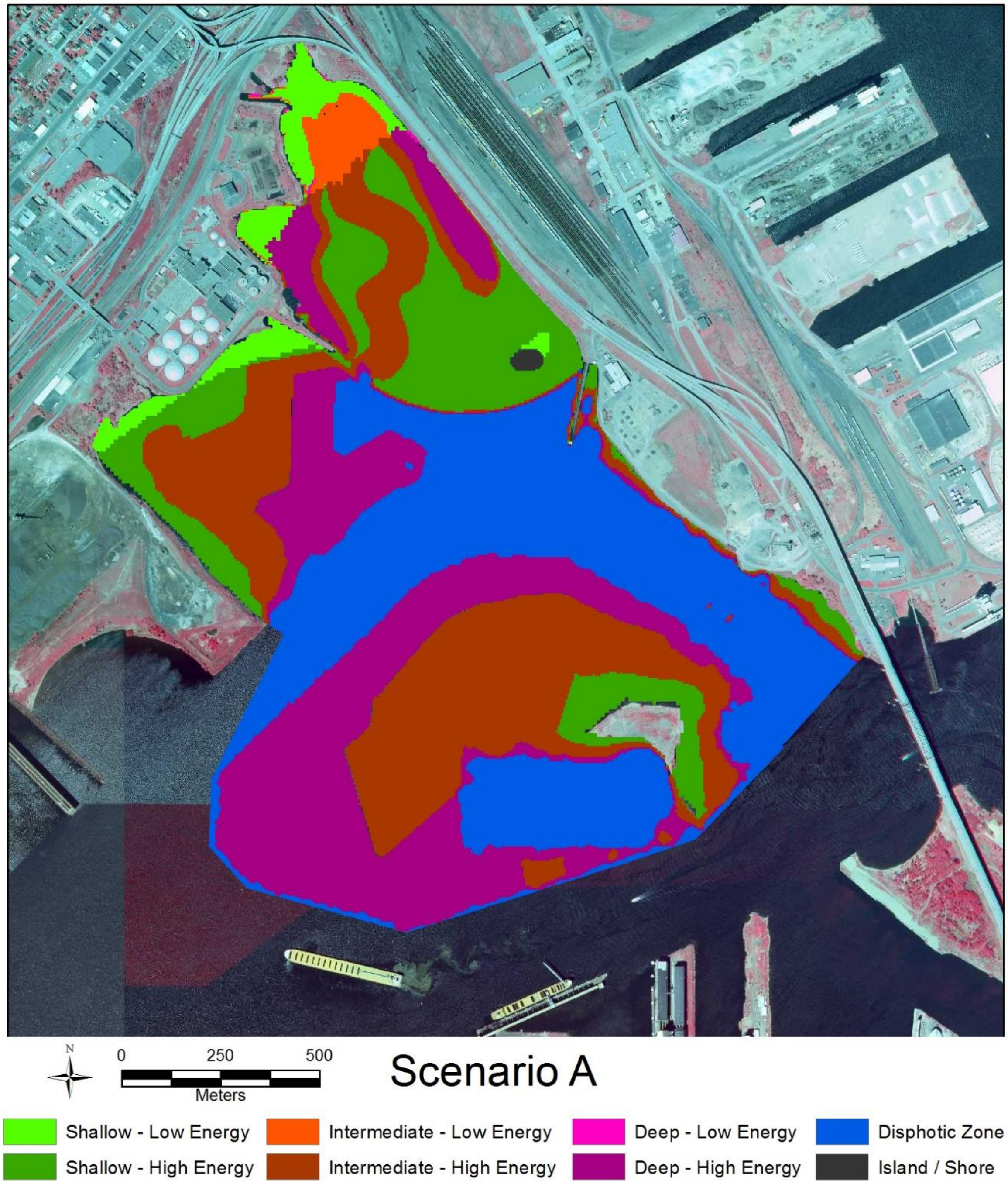


Figure 15. Habitat classes based on depth/energy environments for Scenario A.

Correspondingly, the response of vegetation, macroinvertebrates and birds is also relatively small with respect to the overall site. In terms of vegetation, the restoration increased the amount of submerged leaf aquatic bed by 29 ac, and reduced the acreages of floating leaf and emergent marsh by 24 and 14 acres, respectively (Table 6, Figure 16).

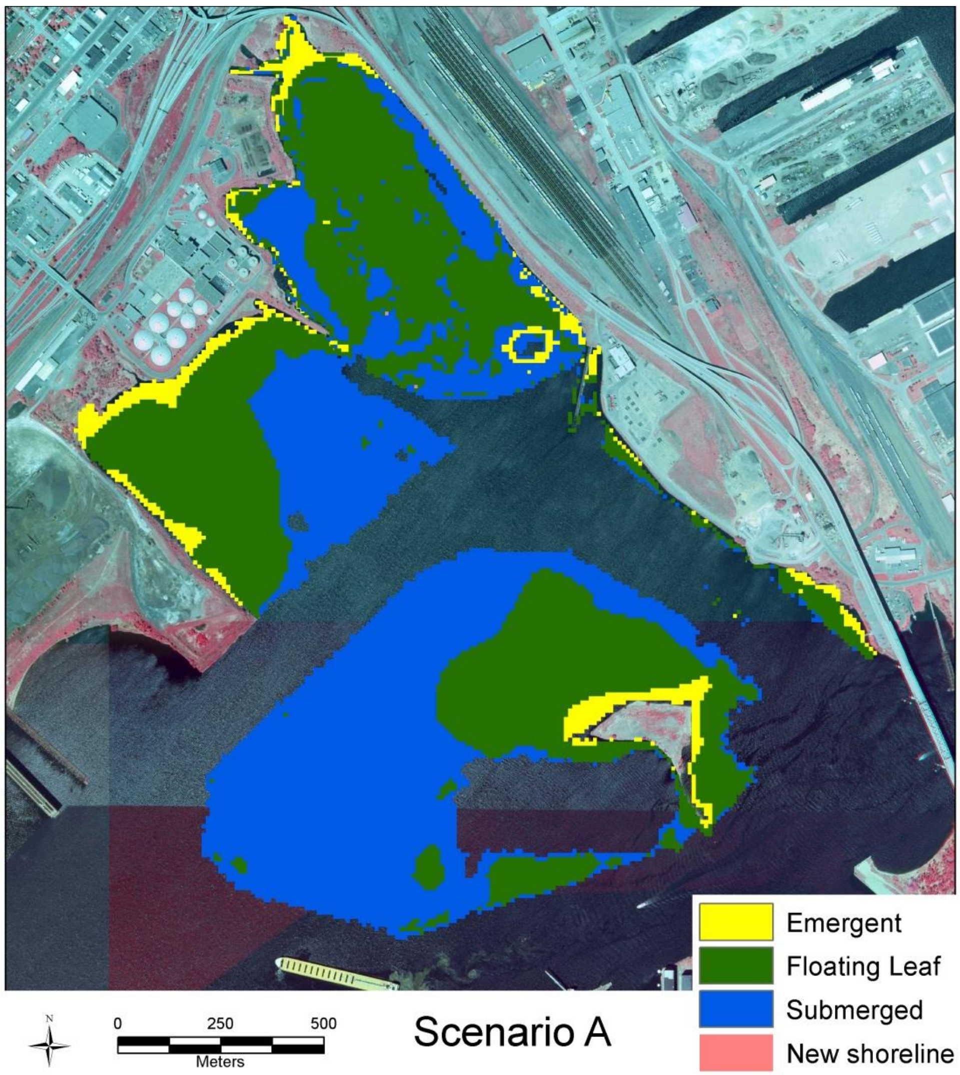


Figure 16. Predicted aquatic vegetation beds for Scenario A.

The invertebrate assemblage responses are predicted to be correspondingly small. Re-establishment of floating leaf vegetation in this small bay would increase aquatic invertebrate assemblage richness. However, if much of this bay receives high sediment loads from Miller and Coffee creeks, and has to be dredged routinely because of this, the vegetation and macroinvertebrates will be negatively affected and will not respond in the predicted manner. In addition, if this scenario increases the retention time of WLSSD effluent within this small bay, this is likely to be detrimental to the macroinvertebrate assemblage.

The creation of additional aquatic beds would benefit many species of birds including waterbirds such as grebes, herons, bitterns, and potentially rails; waterfowl, especially puddle ducks, and would create a potential foraging areas for terns. The small island may also benefit shorebirds, waterbirds, and songbirds, depending on the size, vegetative structure, and competition for use by other birds already present (e.g. Ring-billed gull). The reduction of shallow-low energy environments in this scenario could discourage use by some shorebird and waterfowl species, particularly shorebirds that rely almost exclusively on the presence of these environments that offer open sandy or cobble shorelines.

Physical Changes and Ecological Risk Considerations

Ecotoxicology

Scenario A would include burying an area that has potentially elevated PCBs and mercury. Available data does not indicate issues with increasing depth in the proposed areas.

Hydrodynamics

In terms of hydrodynamics, Scenario A has relatively minor differences from the current condition, with somewhat greater circulation near the mouth of Miller Creek bay (Figure 17).

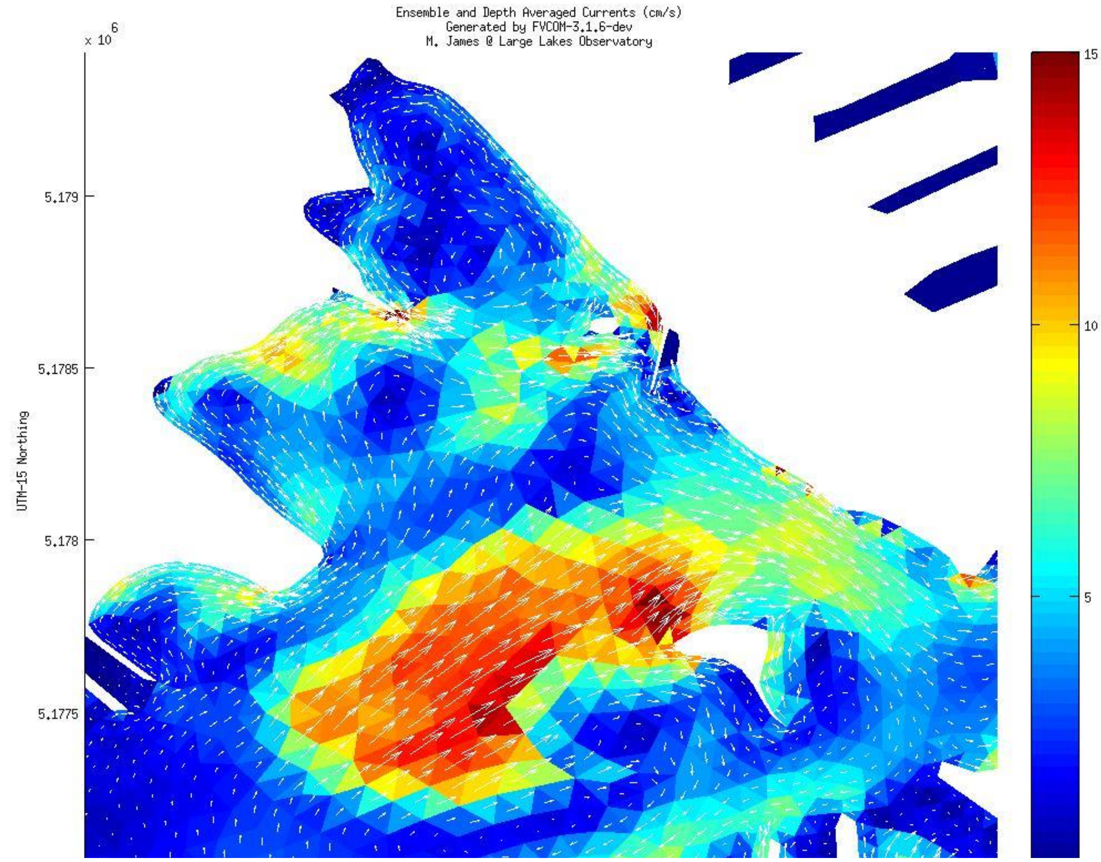


Figure 17. Modeled depth averaged currents for Scenario A. Color contours represent velocity magnitudes.

More of the WLSSD effluent appears to be retained in the bay under scenario A than in the control case (Figure 18).

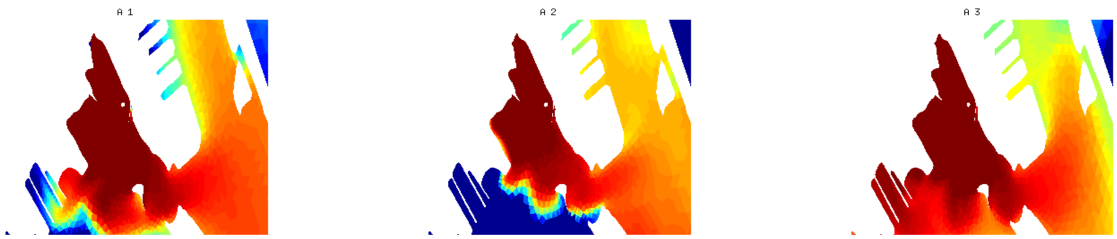


Figure 18. Steady-state dye distribution in the harbor in scenario A under three scenarios: (a) Steady river forcing, no wind; (b) steady river forcing, wind from the west; (c) steady river forcing, wind from the east.

Scenario B

Scenario B extends the restoration area to the southeast. The most prominent feature of Scenario B is the creation of new shoreland along a 0.6 mi stretch of land parallel to Hwy 53, from the mouth of Coffee Creek to the existing pier (Figure 19). The new land extends approximately 250 ft into the current bay. The design also adds additional deep channel habitat and two large areas of fill to promote aquatic vegetation. This restoration treats 131 ac or 25% of the 21st Ave project area.

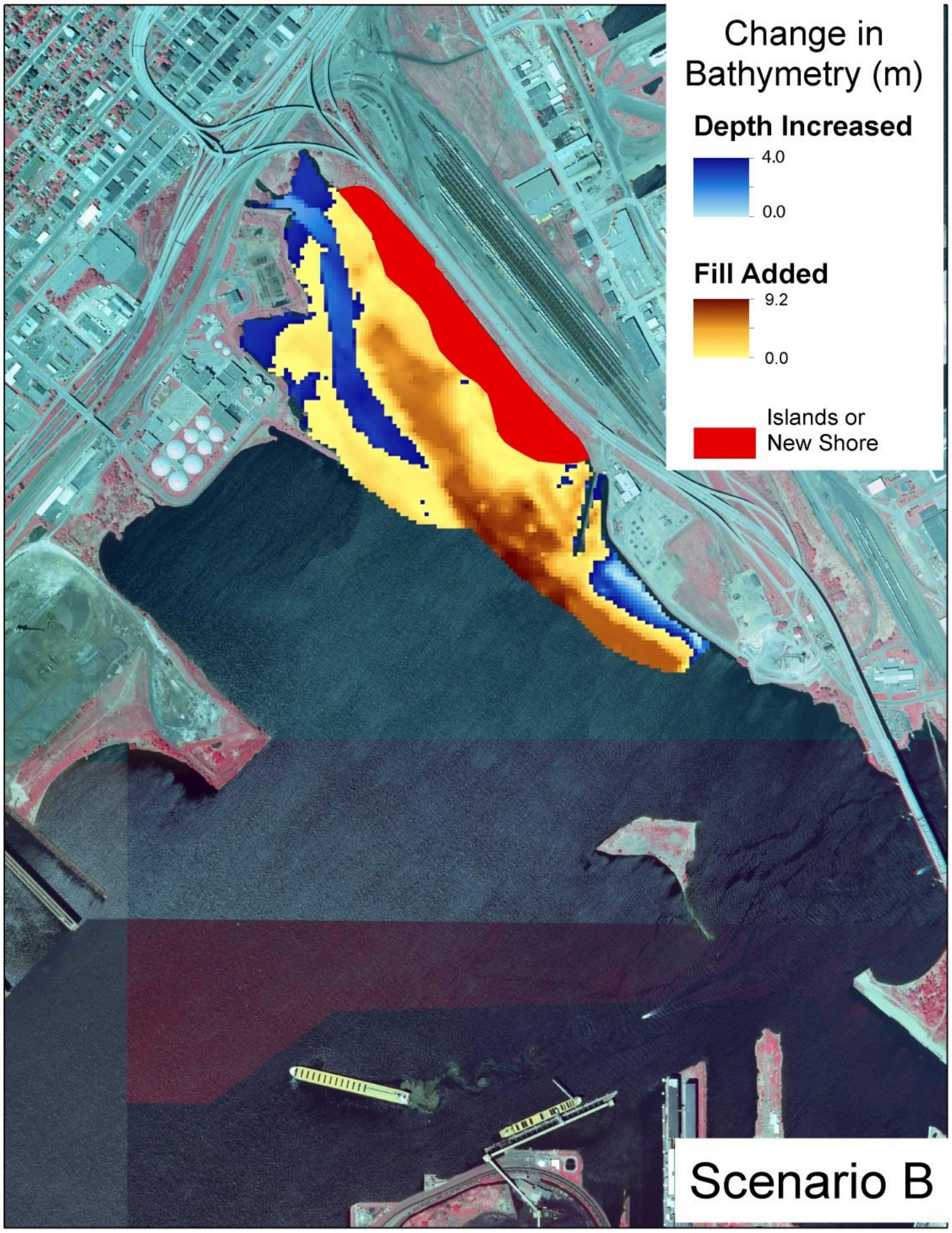


Figure 19. Bathymetric changes and shoreline expansion for Scenario B.

Habitat and biotic response

The Scenario B restoration treats a slightly larger area than Scenario A, and most significantly, expands the amount of shoreland, at the expense of some of the existing habitat for floating leaf and emergent aquatic vegetation (Figure 20). It also differs in that it creates proportionately more Intermediate Depth High Energy habitat, 55 acres total, along with a 78 acre decrease in disphotic habitat (Table 7). The creation of a deeper channel beginning at the mouths of Miller and Coffee creeks resulted in replacement of emergent marsh along the shoreline with floating-leaf aquatic beds, increasing habitat for SAV-dependent fish. It also creates a sparsely vegetated deepwater channel extending into the bay, creating continuity for channel and deep-water fish. In terms of vegetation, this restoration decreased the amount of floating leaf and emergent aquatic beds by 32 and 18 ac respectively; creating 77 additional acres of submerged aquatic beds. (Figure 21; Table 8).

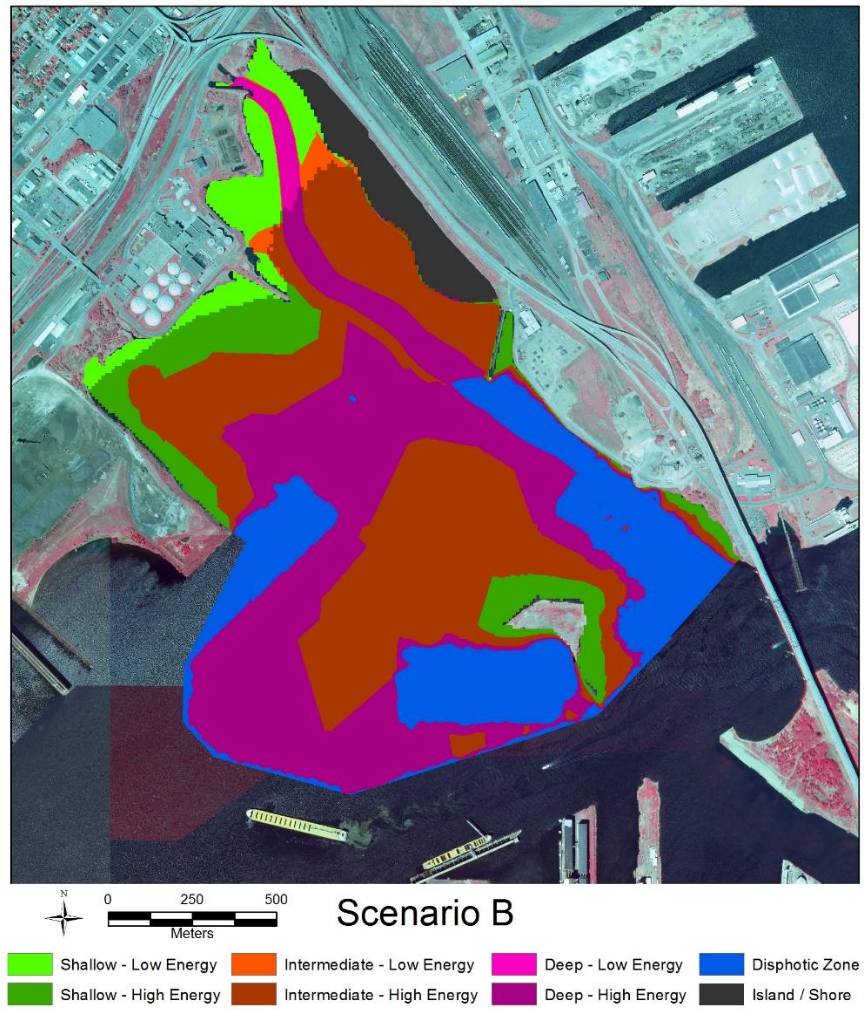


Figure 20. Depth-energy environments for Scenario B.

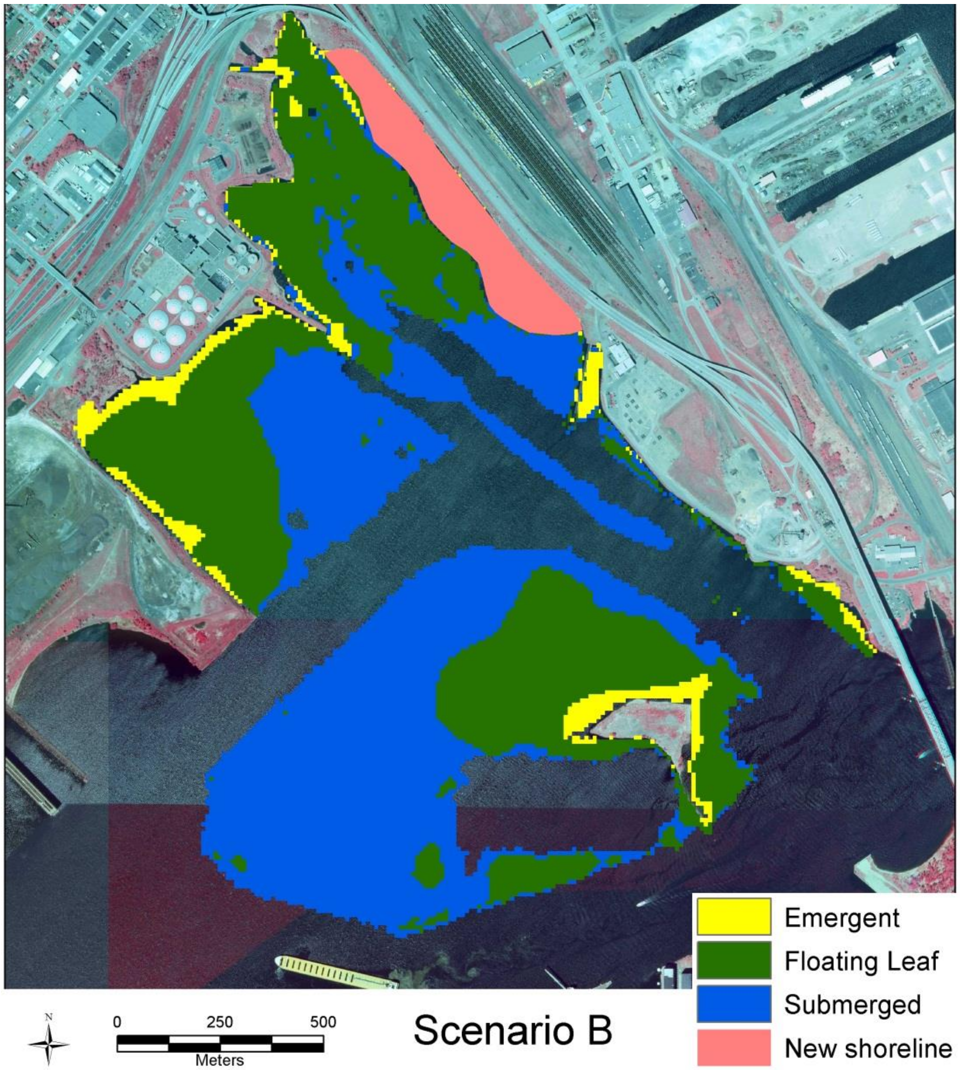


Figure 21. Predicted aquatic vegetation beds for Scenario B.

Again, because this scenario treats only a small portion of the 21st Avenue West site, its ability to affect aquatic macroinvertebrates across the entire site is somewhat limited. In fact, this scenario reduces the amounts of emergent vegetation, which would likely have a negative effect on certain macroinvertebrate species. As in Scenario A, the potential for increased amounts of floating leaf vegetation would increase overall macroinvertebrate richness, provided other issues related to sediment inputs to this bay are resolved. The increase in intermediate depths experiencing high energy is predicted to negatively affect both macroinvertebrate richness and *Hexagenia* abundance.

Because Scenario B creates new shoreland, a positive response from migratory and breeding shorebirds is expected. However, a potentially negative for the creation of this shoreland habitat may be the attraction for resting gulls and Canada geese. The promotion of aquatic vegetation expected to be created by filling two large areas within the site will also enhance the quality and extent of habitat used by several species of waterbirds and waterfowl. The latter especially for surface-feeding, puddle ducks like Mallard and Blue-winged Teal. These areas may also provide foraging habitat for terns and swallows as well as selected songbirds such as Common Yellowthroat, Red-winged Blackbird, and Swamp Sparrow.

Physical Changes and Ecological Risk Considerations

Ecotoxicology

Because of a lack of contaminant data in the newly expanded project area (Figure 5, D), it is difficult to consider contaminant impacts within this area for Scenario B. Data suggest that the area to be dredged may be contaminated. Additional testing is recommended for these sediments before reusing sediment as fill in the 21st restoration area. Data suggest that elevated levels of mercury and PCBs will be covered in this design scenario.

In terms of hydrodynamics, Scenario B resulted in increased current activity between Interstate Island and the southern shore of Rice's Point (Figure 22). The primary difference in WLSSD effluent distribution is the heightened effect of the fresh, St. Louis estuary water in the west wind scenario, where less of the study area is affected by the WLSSD effluent.

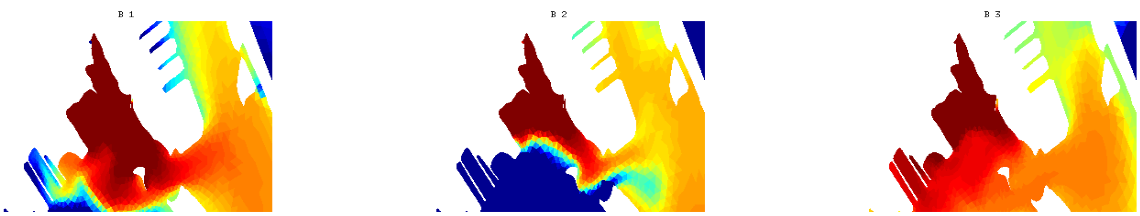


Figure 22. Steady-state dye distribution in the harbor in scenario B under three scenarios: (a) Steady river forcing, no wind; (b) steady river forcing, wind from the west; (c) steady river forcing, wind from the east.

Scenario C

Scenario C treats a larger area than the previous two scenarios. It adds a significant amount of new shoreline adjacent to Hwy 53, and adds additional fill to the Miller and Coffee Creek Bays, with some dredging to create deeper habitat. It also treats a significant portion of the southwest side of the project area, adding a more complex bathymetry that increases the amount of submerged aquatic vegetation near shore, and grades into floating leaf aquatic beds further out in the bay (Figure 23).

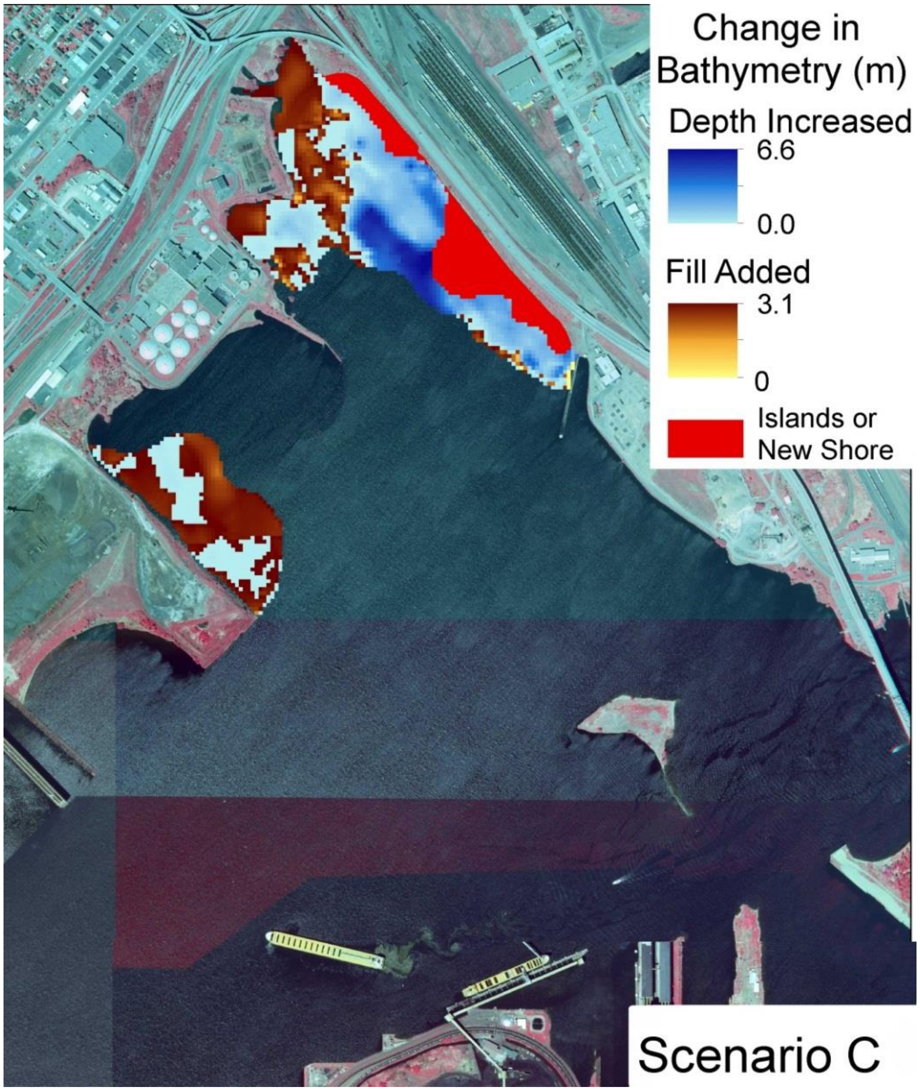


Figure 23. Changes in bathymetry and shoreland additions for Scenario C.

Habitat and biotic response

The predominant effect of the restoration, in addition to the expanded shoreline, is to reduce the amounts of deep and disphotic zone habitat (Figure 24; Table 9), converting most of this 70 ac to intermediate depth environments (0.65-1.6m). This resulted in 50 and 13 ac reductions in floating leaf and emergent beds, respectively, and a 60 ac increase in submerged aquatic beds. (Figure 25; Table 10).

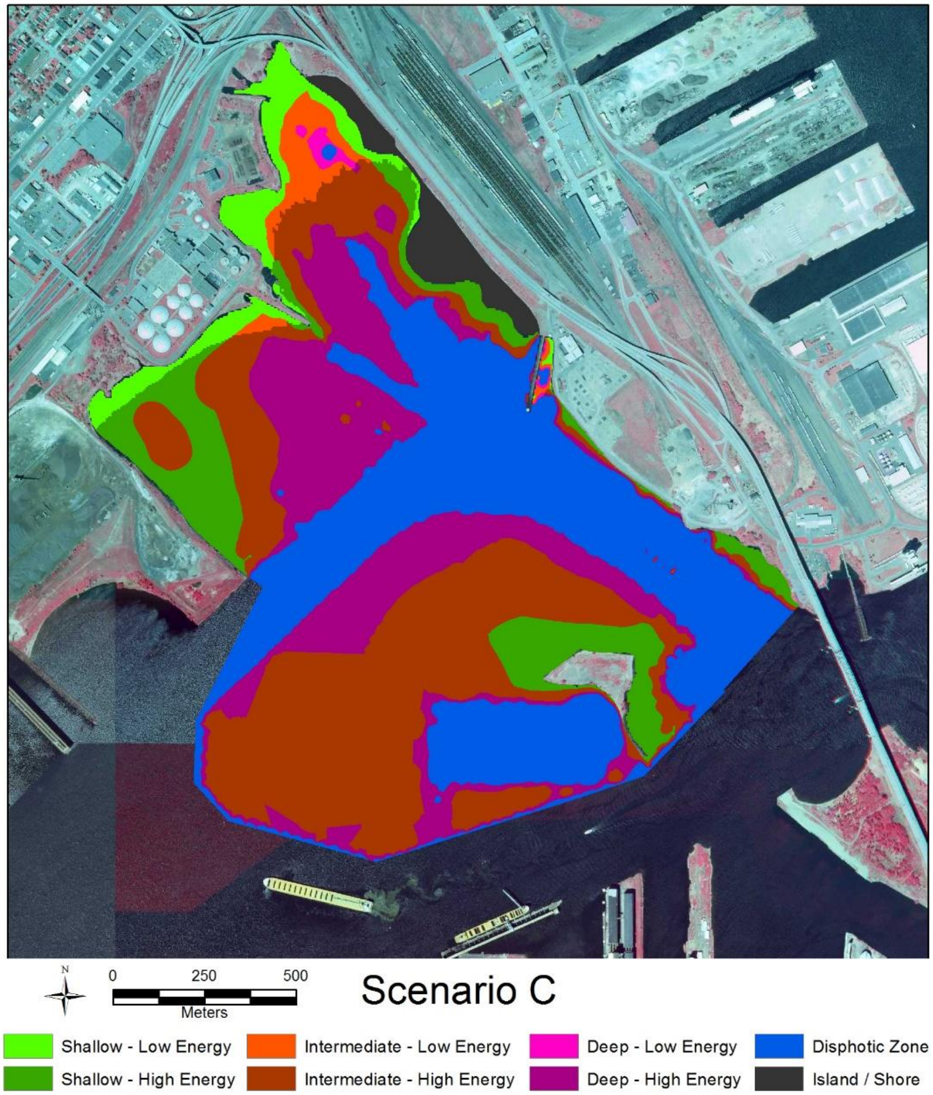


Figure 24. Depth-energy environments for Scenario C.

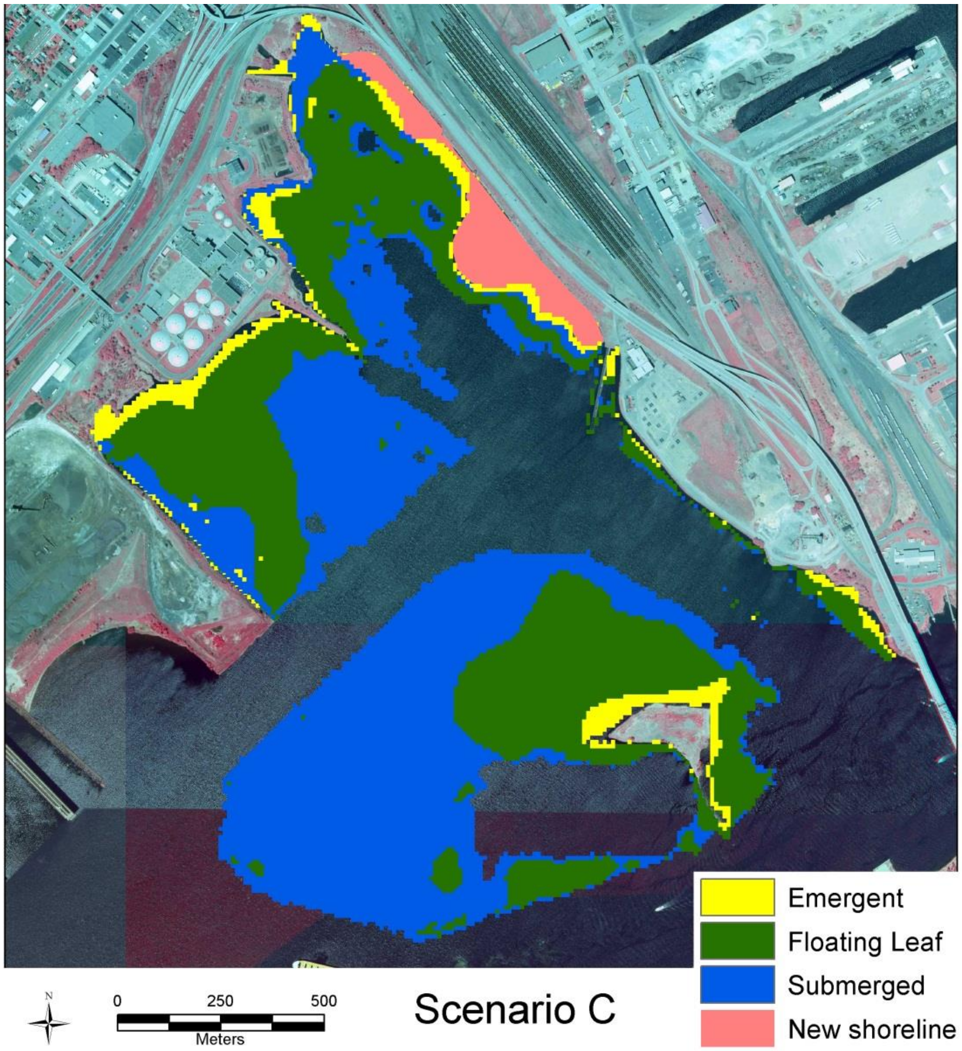


Figure 25. Predicted aquatic vegetation beds for Scenario C.

In this scenario, deep high energy areas are traded for intermediate depth high energy areas, which are unlikely to be good habitat for either wetland-type aquatic invertebrates, or *Hexagenia* mayflies. *Hexagenia* require relatively stable, finer sediments to support their burrows. Loss of potential areas of emergent marsh will have a negative effect on vegetation-associated aquatic invertebrate richness. Thus, although this scenario treats quite a large area, it probably will have a limited, potentially negative effect on aquatic macroinvertebrates. There is also an increased structural complexity component of this scenario that is not reflected in the area data – the gradients of depth and creation of more bottom structure will likely provide better SAV-dependent fish communities if SAV becomes established.

The expanded shoreline in this scenario could benefit shorebirds and songbirds. In addition, the increased shallow-depth habitats are also beneficial to shorebirds. However, as stated above, concerns remain with the attraction of this shoreland habitat for resting gulls and Canada Geese.

This scenario also increases the intermediate-depth habitats used by both waterbirds, such as herons and mergansers, and waterfowl, primarily puddle ducks. The increased vegetation expected to result from filling several areas within the study site should increase the quality and extent of habitat used by waterbirds and waterfowl, assuming these areas will become vegetated.

Physical Changes and Ecological Risk Considerations

Ecotoxicology

Scenario C proposes filling in an area with elevated PAHs and PCBs, and increasing water depth in areas containing elevated PCBs (testing these sediments for contaminants is recommended before reusing as fill in the 21st restoration area). In addition, it would be best to remove these sediments using a method that would only minimally disturb the sediment.

Hydrodynamic Model

In scenario C, while more effluent is retained, the differences from the control case are very minor (Figure 26).

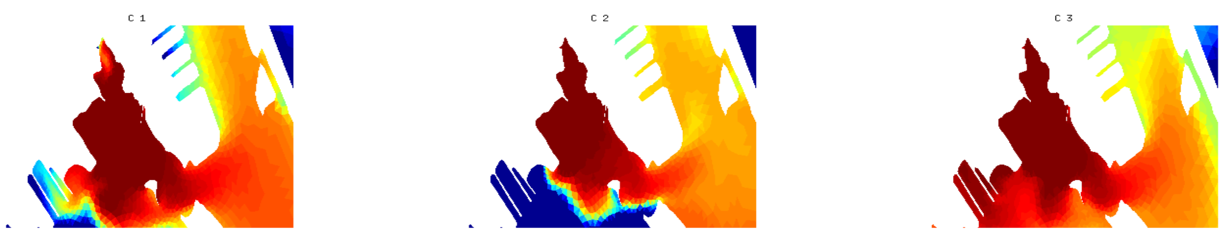


Figure 26. Steady-state dye distribution in the harbor in scenario C under three scenarios: (a) Steady river forcing, no wind; (b) steady river forcing, wind from the west; (c) steady river forcing, wind from the east.

Scenario D

Scenario D is a much more expansive restoration effort than the previous three. In the northern portion of the site, it expands shoreline and increases littoral habitat, including filling in the old channel that extends into the Miller/Coffee Creek Bay. It also adds new land area along the southwestern shoreline, and creates a more complex bathymetry in the ~80 ac site south of WLSSD. Additionally, the restoration design doubles the size of Interstate Island and adds a large new island 0.4 mi west of Interstate Island (Figure 27). This new island is surrounded by an extensive shallow zone. The restoration affects 320 ac, approximately 60% of the 21st Ave W site.

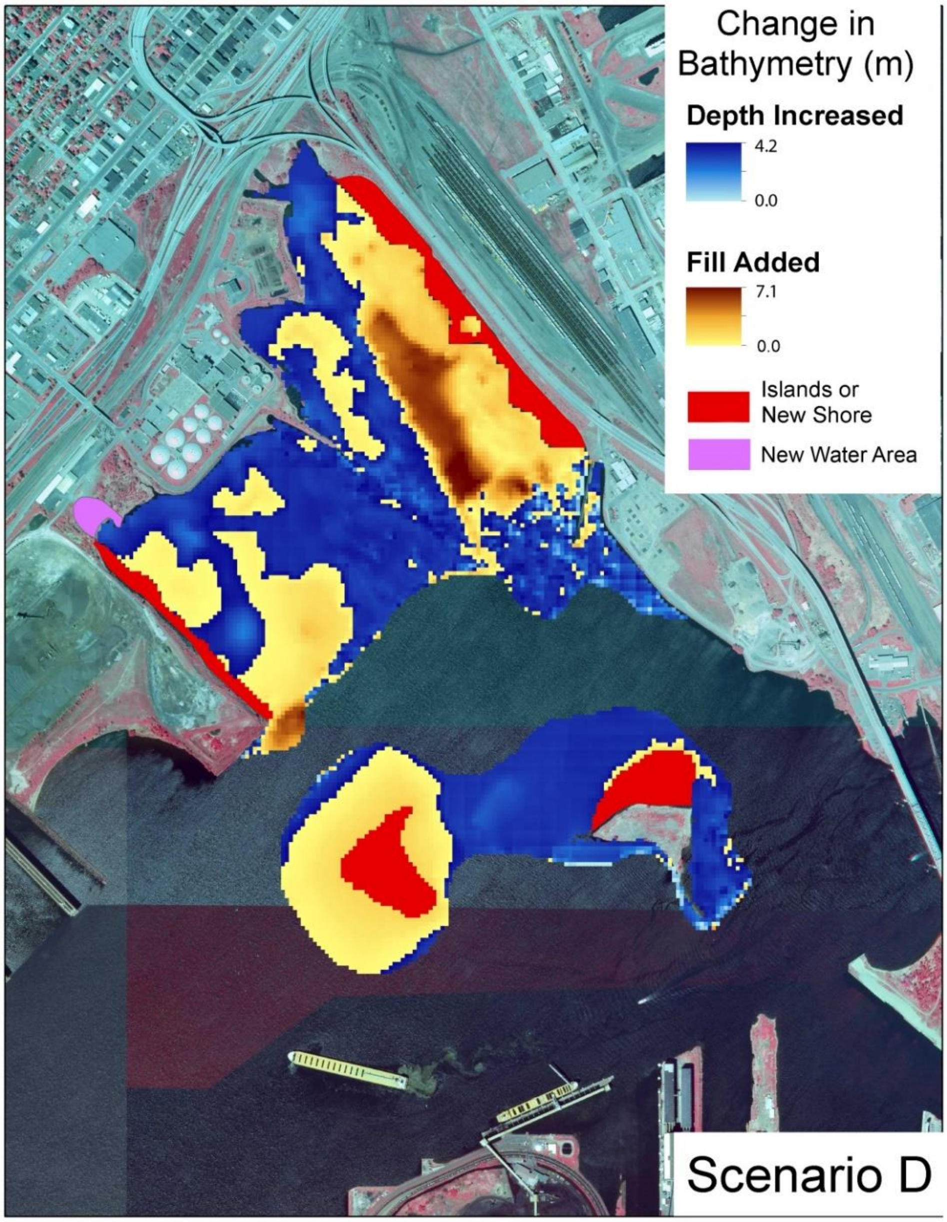


Figure 27. Bathymetric changes, shoreline expansion, and islands created in Scenario D.

Habitat and biotic response

Scenario D creates 38 ac of shallow habitat and 31 ac of intermediate habitat. By filling in the abandoned channel in the Miller Creek bay, it reduces the amount of disphotic and deep habitat by 98 ac. (Figure 28; Table 11). Much of this new habitat is created in the previously deep areas adjacent to the ship canal in the southernmost portion of the project area. This is accomplished through the expansion of Interstate Island and the creation of a new island with gradually sloping shoreline to the west.

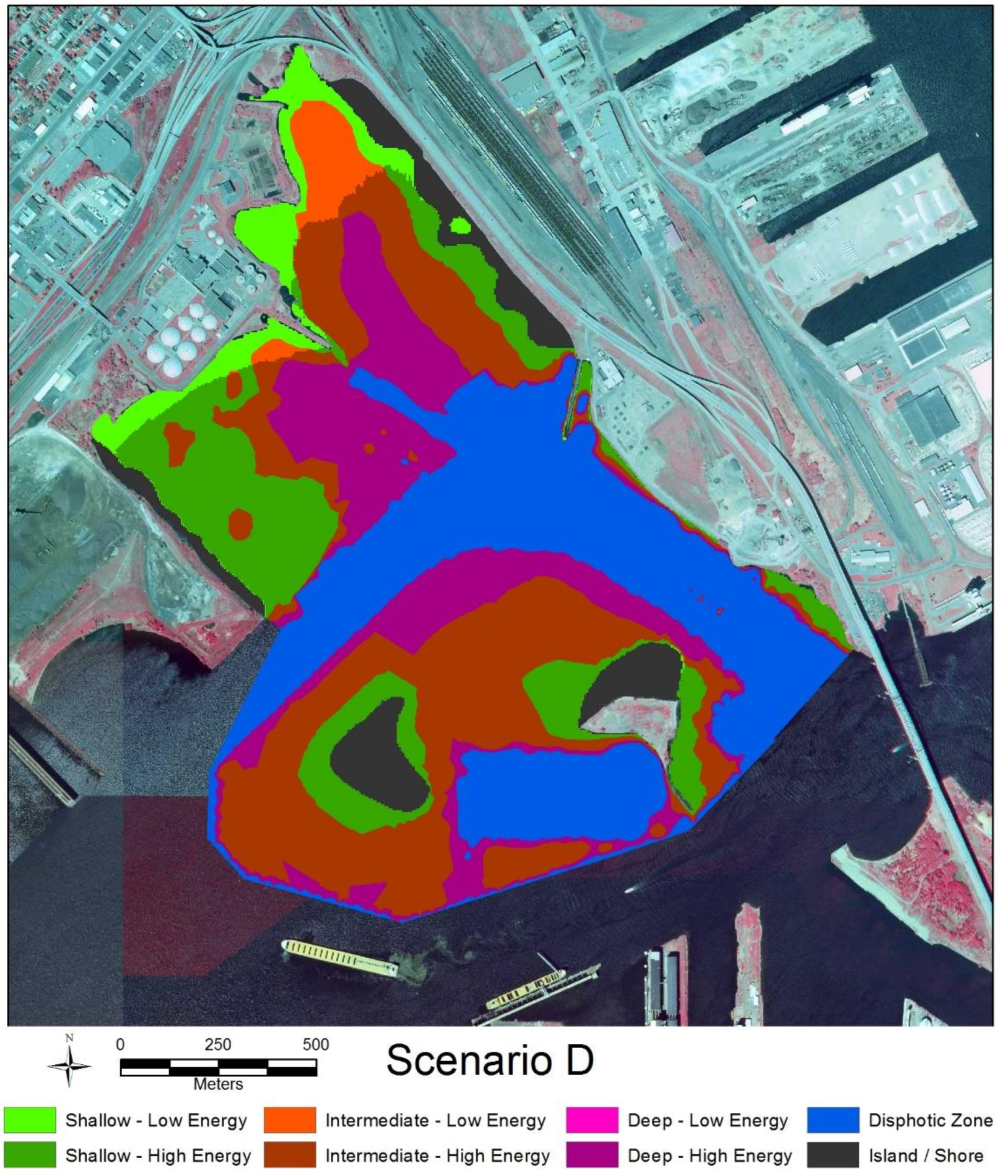


Figure 28. Depth-energy environments produced in Scenario D.

Whereas the previous scenarios had reduced the area of emergent marsh, Scenario D adds 10 acres of this wetland community, most notably in the southwestern portion of the site (Figure 29; Table 12). Bathymetric changes further to the northeast result in a complex of aquatic vegetation that creates a patchwork of emergent marsh grading into floating leaf communities and submerged aquatic beds. An additional 27 ac of floating leaf beds are added in this scenario, replacing the submerged aquatic beds under current conditions, both in the nearshore and open water areas.

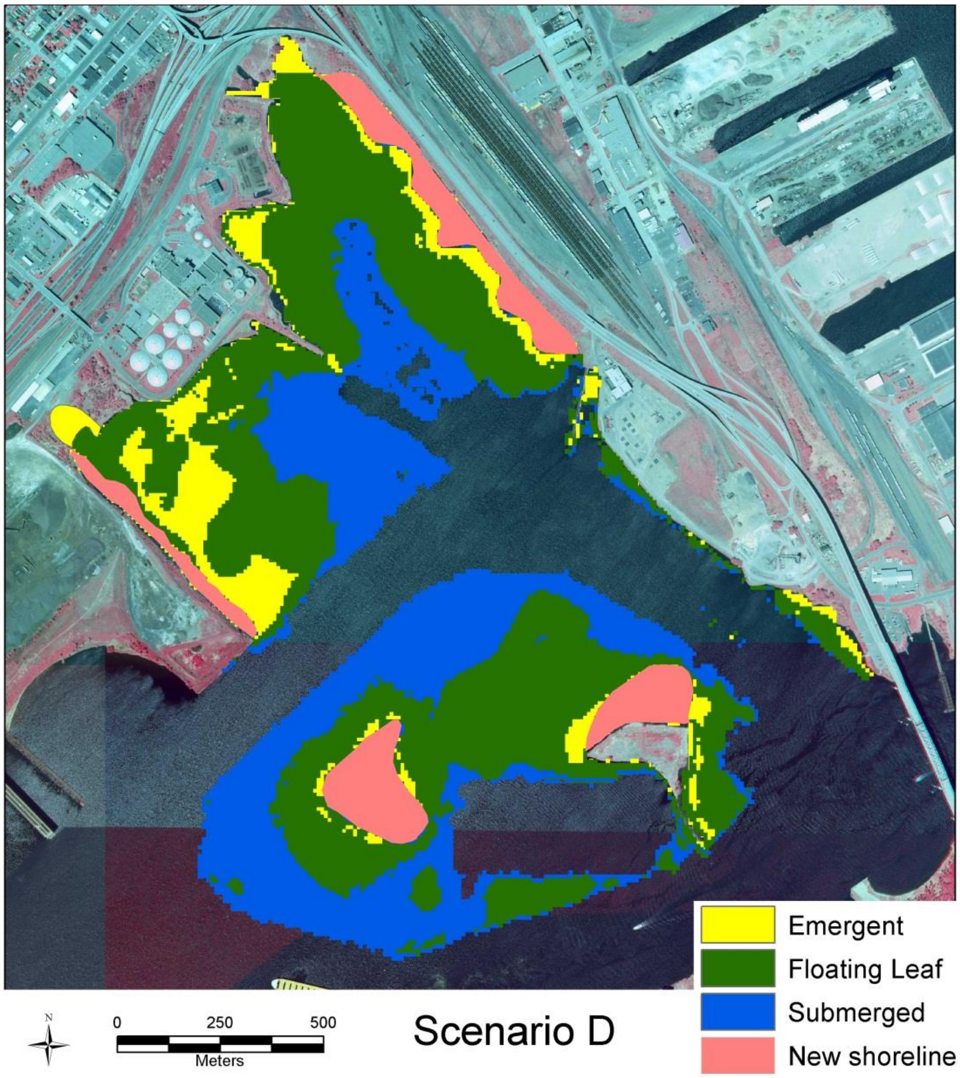


Figure 29. Predicted aquatic vegetation beds for Scenario D.

Scenario D also treats enough of the 21st Avenue West site to potentially have a significant effect on aquatic macroinvertebrates. This scenario should be the best for development of a diverse wetland macroinvertebrate assemblage because the predicted vegetation is for increased amounts of emergent and floating leaf vegetation than what should be found at the depths that occur under present conditions. However, these vegetation beds (if they develop) are likely to have relatively sparse stem densities because many of these shallow areas are predicted to have high wind and wave energy exposure. Elsewhere in the estuary, floating leaf vegetation only occurs in quite protected locations. Emergent vegetation can be somewhat hardier, but still typically needs some protection to develop dense diverse stands. Thus, the macroinvertebrate response may not be as strong as could potentially occur if these shallow regions could be provided with more wind and wave protection. If this scenario has any effect on *Hexagenia* mayflies, it is likely to be negative because deep water (disphotic) area is reduced, while the increased shallower areas are predicted to be high energy. In summary, while reducing disphotic and deep areas should increase macroinvertebrate richness, the increase is in locations subjected to high energy areas. High energy areas are unlikely to develop the diverse aquatic macrophyte assemblage that would in turn support the development of diverse wetland invertebrate assemblages.

The proposed addition of new land, increase of littoral habitat, and expansion of shoreline included in Scenario D would greatly benefit shorebirds, waterbirds, waterfowl, and songbirds. The proposed alterations would increase both low and high energy, shallow environments and intermediate-high energy environments as well as land. Increasing the size of Interstate Island in addition to creating of a new island makes this scenario particularly appealing because it would increase the potential nesting area for common terns and shorebirds already nesting on Interstate Island. Again, this is interpreted with the caveat that unless populations of Ring-billed Gull and Canada Goose are managed, they could limit the success of other species.

Physical Changes and Ecological Risk Considerations

Ecotoxicology

It is uncertain what contaminant issues may exist with the new creation of these two islands, but the data suggests that sediment in this area is toxic to benthic organisms. Contaminant data is limited in the newly expanded project area (more southern portion of project area) and additional testing would help inform remedial management. Sediments dredged in the western portion are likely contaminated and may require confined disposal. Additional testing would be required if an objective was to reuse these sediments as fill in the 21st restoration area. Filling areas particularly near the WLSSD outfall would cover contaminated sediment, which could potentially increase the bioavailability of methylmercury. Dredged material removed from near the mouths of Miller and Coffee creek (hotspots for PAH and PCBs) may require disposal; more testing would need to be conducted if plans include to use these sediments as fill in the 21st restoration area.

Scenario E

Scenario E is the most extensive of the five scenarios. It adds a significant amount of new land, in terms of expanded shorelines, a large breakwall of land extending into Miller Bay from WLSSD, and creation of several new islands (Figure 30). It adds a large amount of fill in Miller Bay, including filling in the abandoned deep channel. In the open water areas in the southern portion of the project area, the plan fills in another deep channel. It also creates a complex of islands and shallow water habitat west of Interstate Island, which is also expanded. The restoration also calls for removing land to create a small bay at the extreme western edge of the project area. The restoration treats a total of 382 ac, or 72% of the site.

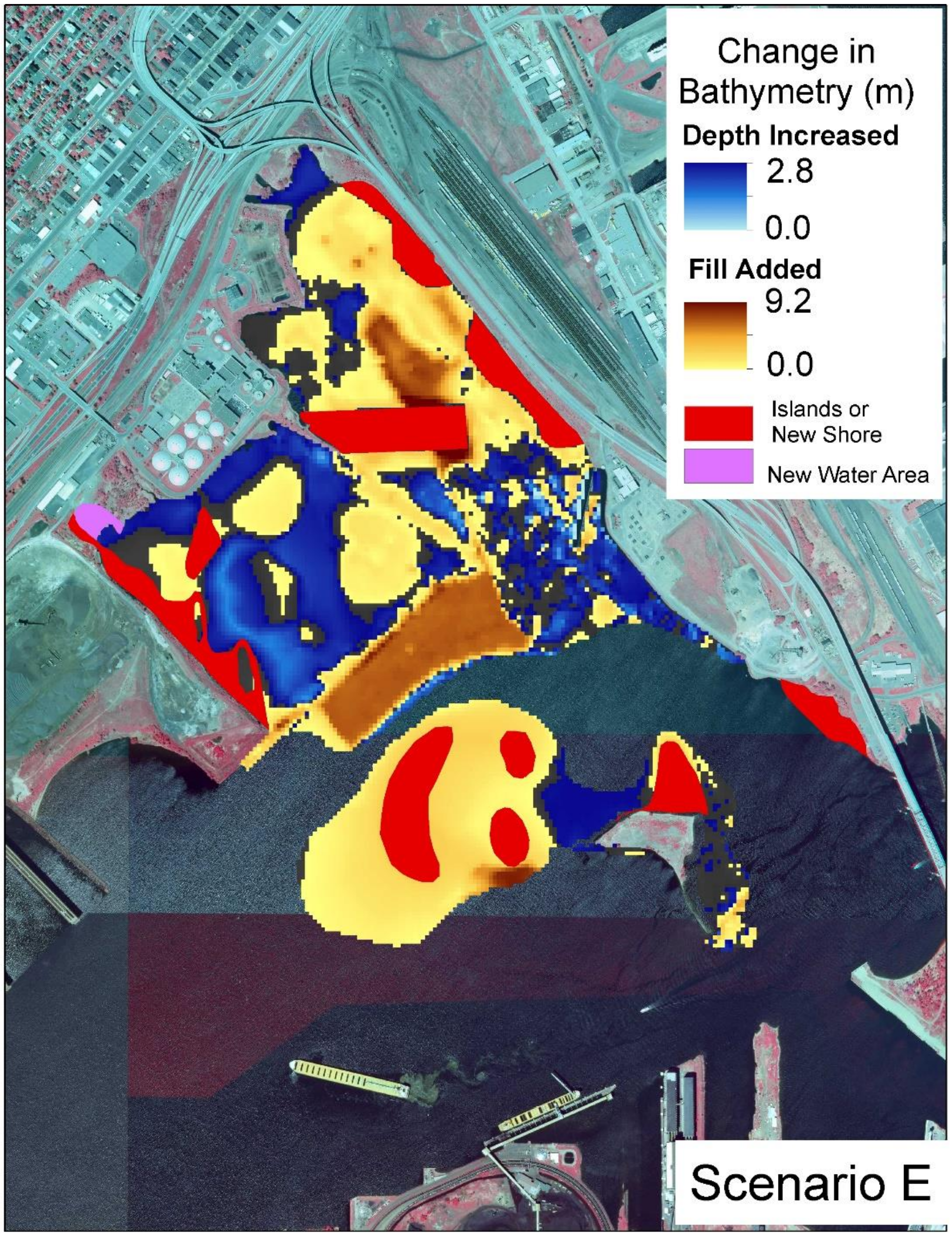


Figure 30. Bathymetric change, shoreline and breakwall development and islands created in Scenario E.

Habitat and Biotic Response

Effects on the depth-energy environments are similar to those of Scenario D but more extreme, creating 51 acres of shallow habitat and 49 acres of intermediate depth habitat (Figure 31; Table 13). Deep habitat is reduced by 71 acres and disphotic habitat is reduced by 56 ac. In addition 22 acres of new land are added to the project area, both as expanded shoreline and islands or island expansion.

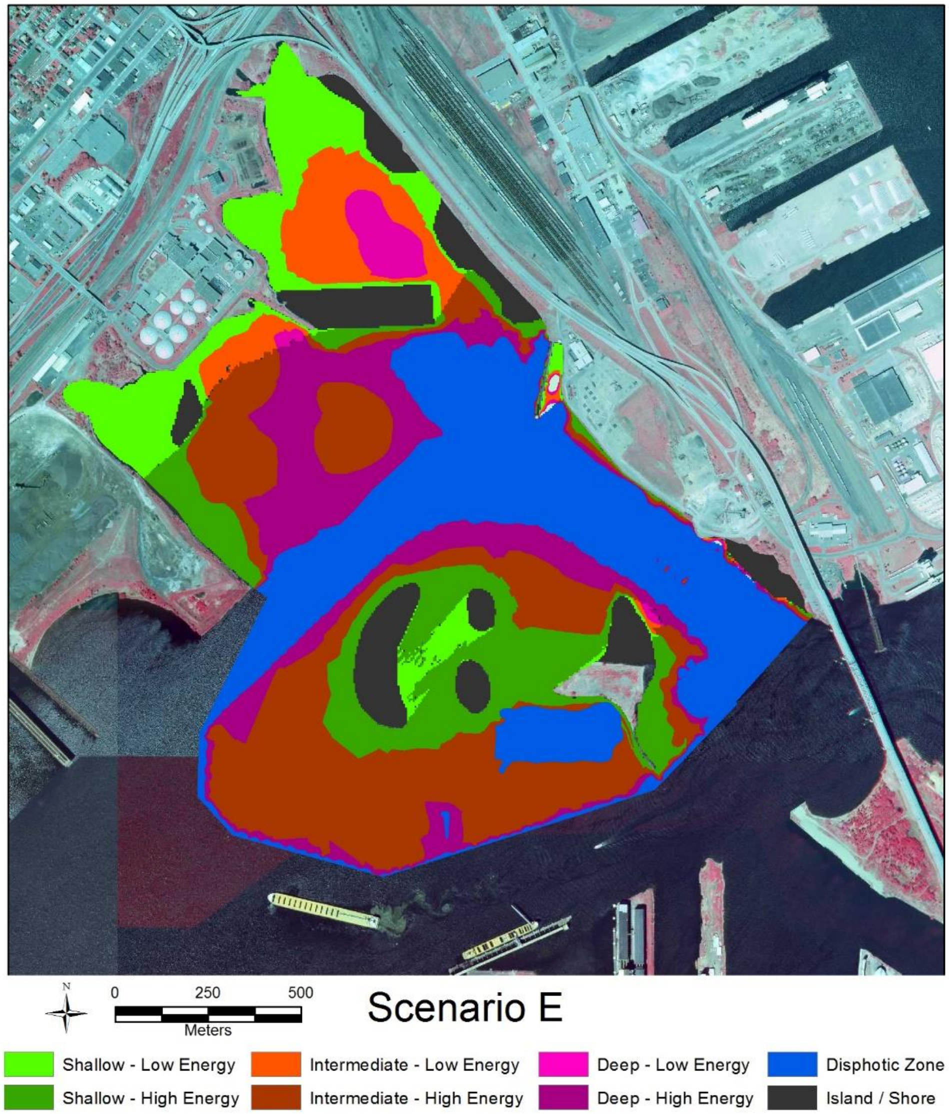


Figure 31. Depth-energy environments produced in Scenario E.

As expected, Scenario E produces quite a bit of new habitat, and in particular creates 24 ac of emergent marsh (Table 14). The majority of this new wetland occurs in the former deep-water sites to the west of Interstate Island (Figure 32). There are also extensive emergent beds along the new shoreline and back in Miller Creek Bay. There is a loss of 31 ac of submerged aquatic beds, due to both a shift toward shallower conditions overall throughout the study area as well as the creation of new land masses (Table 14).

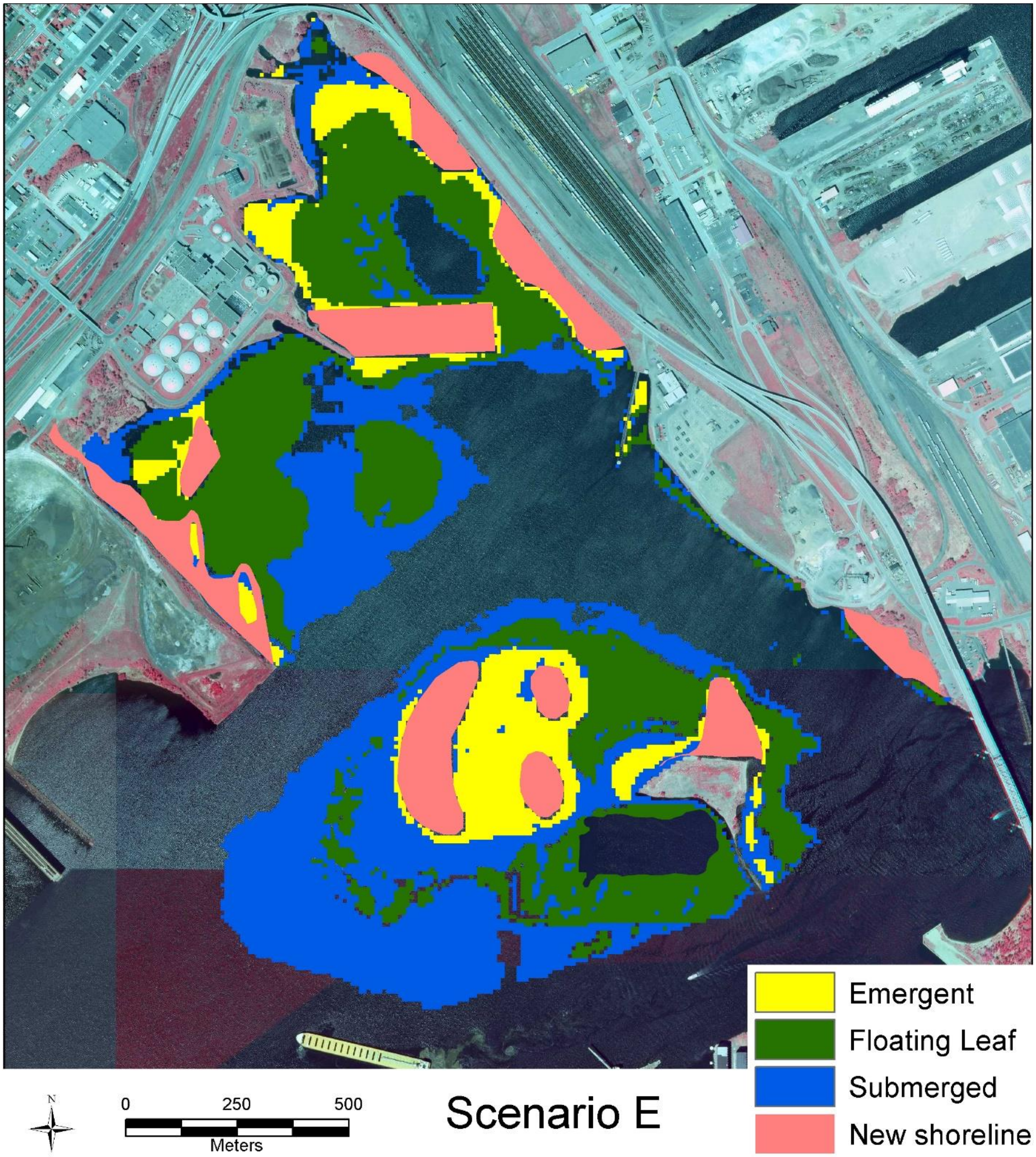


Figure 32. Predicted aquatic vegetation beds for Scenario E

Scenario E should be the second-best scenario for a wetland-type macroinvertebrate assemblage with high taxonomic richness because it should greatly increase habitat diversity by trading areas with submergent vegetation for areas with emergent and floating leaf vegetation. However, as observed for Scenario D, it is uncertain whether the large emergent vegetation beds will actually develop to any significant amount because so much of this shallow area is predicted to be high energy rather than protected, as is also the case with Scenario D. If this scenario has any effect on *Hexagenia* mayflies, it is likely to be negative because the disphotic area is reduced, while the intermediate depth areas that increase are predicted to be high energy. While reducing disphotic and deep area should increase macroinvertebrate richness, as in Scenario D, the increase is in high energy areas (with the exception of 5 ac of shallow low energy area). These shallow high energy areas probably will not develop diverse emergent macrophyte beds, which are needed to produce diverse wetland invertebrate assemblages.

Scenario E is the most extensive and structurally diverse. The addition of new shoreline, the large extension of land, and the expansion of Interstate Island, benefit bird communities in the same manner as scenario D. However, the degree of expansion of both low and high-energy shallow environments is greatest in this scenario as is the increase in land area. . The same cautions mentioned for Scenario D apply to this scenario.

Physical Changes and Ecological Risk Considerations

Ecotoxicology

Sediment dredged in the western portion of the project area is likely contaminated and may require confined disposal. Additional contaminant testing would need to be conducted if these sediments are to be used as fill in the 21st Avenue area. When increasing the depths in areas near the creek delta (a hotspot for PAH and PCBs), it would be best to use a method that would prevent significant amounts of sediment mixing in the water column. In addition, the dredged sediments from this area and from the area near the newly created islands may require disposal and more contaminant testing would be needed if these sediments were to be used as fill in the 21st restoration area. Contaminant data are limited in the newly expanded project area (more southern portion of project area) and additional testing would help inform remedial management. It is uncertain what contaminant issues may exist with the new creation of these two islands, but our data suggest that sediment in this area is toxic to benthic organisms.

Hydrodynamic Model

In scenario E, the most extensive of the scenarios, the northern breakwater clearly reduces the WLSSD effluent load north of it near the mouth of Miller Creek (Figure 33). There is more retention of WLSSD effluent in the vicinity of the island complex west of Interstate Island in the no-wind case, but less of a difference in both the east and west wind scenarios.

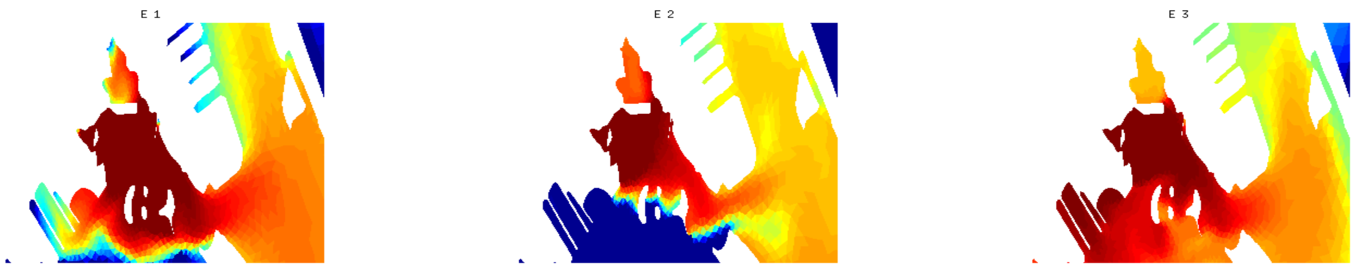


Figure 33. Steady-state dye distribution in the harbor in scenario E under three scenarios: (a) Steady river forcing, no wind; (b) steady river forcing, wind from the west; (c) steady river forcing, wind from the east.

V. Ecological Concept Plan

AOC Coordinators Recommendations

On March 15, 2013, the ecological design scenarios A-E were presented to the AOC Coordinators from MPCA, MNDNR and Fond du Lac. Given the overall goals were to increase habitat diversity and complexity, expand the littoral zone, and reduce wave energy, a number of modifications to Scenario E were made (Figure 34). The depth of the Miller/Coffee Creek bay was increased and the abandoned slip extending into the bay was partially filled, producing a thalweg for the main flows from these streams. The modified scenario, hereafter referred to as the Ecological Concept Plan, also extended two fingers of land that result in a narrow outlet from the bay, making this a much more protected habitat compared with the current condition. WLSSD Bay also received extensive fill, with the intent of increasing the acreage in emergent marsh. In addition, the new design uses shoals – underwater features approximately 12” below the surface – rather than islands to break wind fetch into the bay. Under lower water conditions, these shoals might replicate the mud flats that were extensive features in the bay in presettlement times. The North Channel also received a significant amount of fill.

In the new scenario, Interstate Island is approximately doubled in size, and the area between Interstate Island and the new islands to the west was made shallower. These recommendations were incorporated into the Ecological Concept Plan and the model re-run to predict effects on aquatic vegetation beds and biotic response variables.

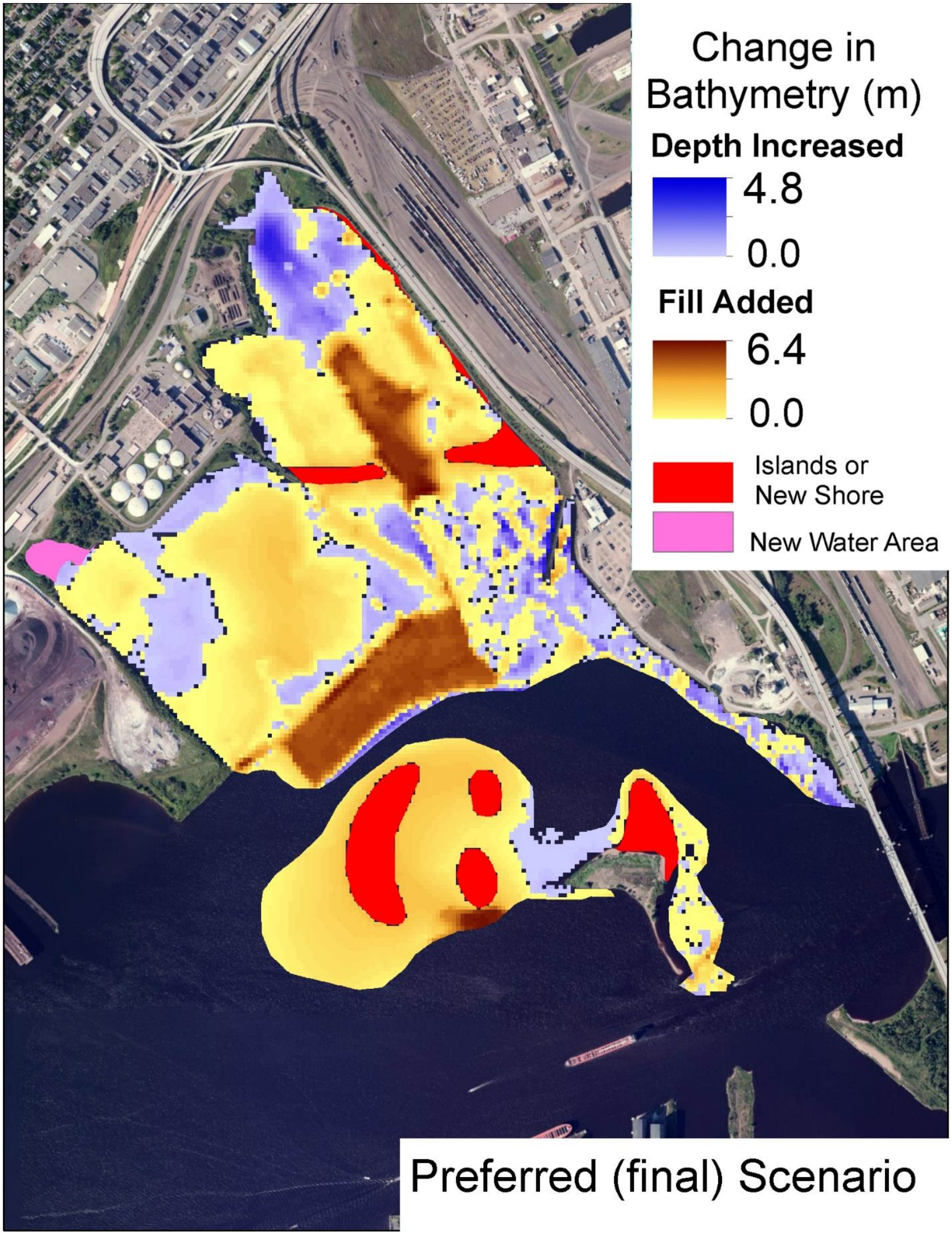


Figure 34. Bathymetric change, shoreline and breakwall development and islands created in AOC preferred scenario.

Habitat and Biotic Response

The Ecological Concept Plan significantly increases the area in shallow-low energy habitat (Figure 35; Table 15), by approximately 30 ac. It also increased shallow high energy habitat from 48 to 87 ac. These increases are attained primarily by reduction of deep-high energy habitat (161 to 68 ac). Deep habitat is reduced by 85 acres and disphotic habitat is reduced by 50 ac. In addition 22 acres of new land are added to the project area, both as expanded shoreline, islands or island expansion.

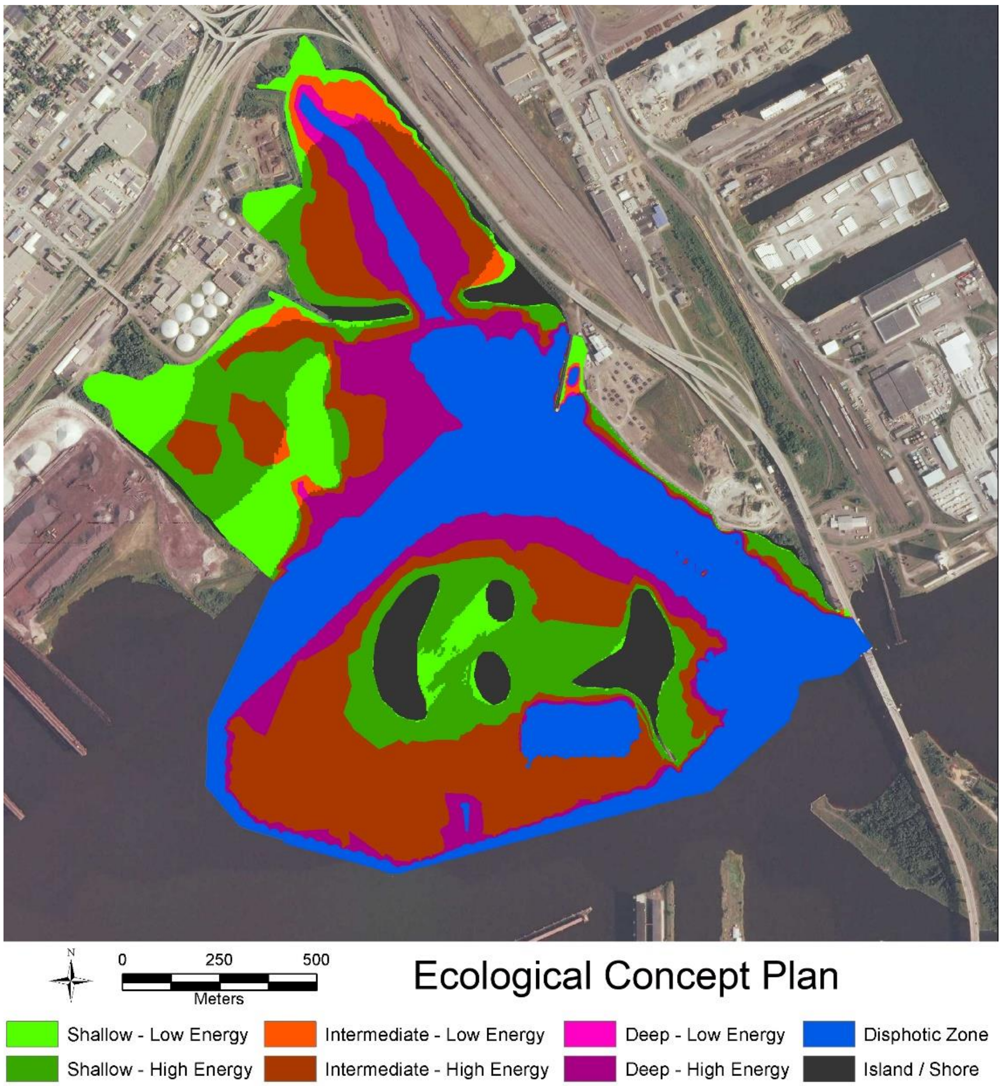


Figure 35. Depth-energy environments from ecological concept plan.

The increase in shallow low energy habitat resulting in an increase of 30 ac of emergent wetland, more than any of the previous scenarios (Table 16). Moreover, the Ecological Concept Plan creates a spatially dispersed distribution of vegetation beds, occupying areas of WLSSD bay, Miller Bay and an extensive complex west of Interstate Island (Figure 36). The design creates a reduction in the areas of floating leaf and submerged aquatic beds, 22 and 13%, respectively. Compared with the current condition, the Ecological Concept Plan produces a much more heterogeneous distribution of aquatic beds, with extensive patches of emergent marsh in the outer portions of WLSSD bay interlaces with floating leaf beds.

The Ecological Concept Plan improves upon Scenarios D and E by creating more protection from wave energy for shallow and intermediate depth areas, giving these areas a much greater likelihood of actually developing dense, diverse beds of aquatic vegetation. And because this scenario treats a significant amount of the site, it has the potential to have a significant effect on aquatic macroinvertebrates. This plan is the best of the 6 developed so far for improvement of the aquatic macroinvertebrate community. In addition, the interspersion should help create diverse and heterogenous vegetative habitats, which are likely to lead to diverse and heterogeneous fish and macroinvertebrate assemblages. On the other hand, there may be a negative effect on H*exagenia* mayflies because disphotic and deep water areas are reduced. Hexagenia typically prefer stable, relatively soft, sparsely vegetated substrate, which likely translates to disphotic depths in areas either deep enough to be beneath the wave zone influence, or protected from wave energy.

Increasing emergent wetland habitat will benefit both waterfowl and waterbirds by offering protection from human disturbance and potentially increasing the number and diversity of nesting species in the area. Terns and shorebirds will benefit from the creation of island habitat and the expansion of land and shallow low energy habitat along the shoreline. Deterring Ring-billed Gull and Canada Goose occupancy of these newly created habitats will be crucial to promoting habitation by more sensitive target species. Rare migrating shorebirds and gulls observed in the St. Louis River estuary, including the 21st Avenue West complex, will benefit from the expansion and maintenance of shallow low energy habitats.

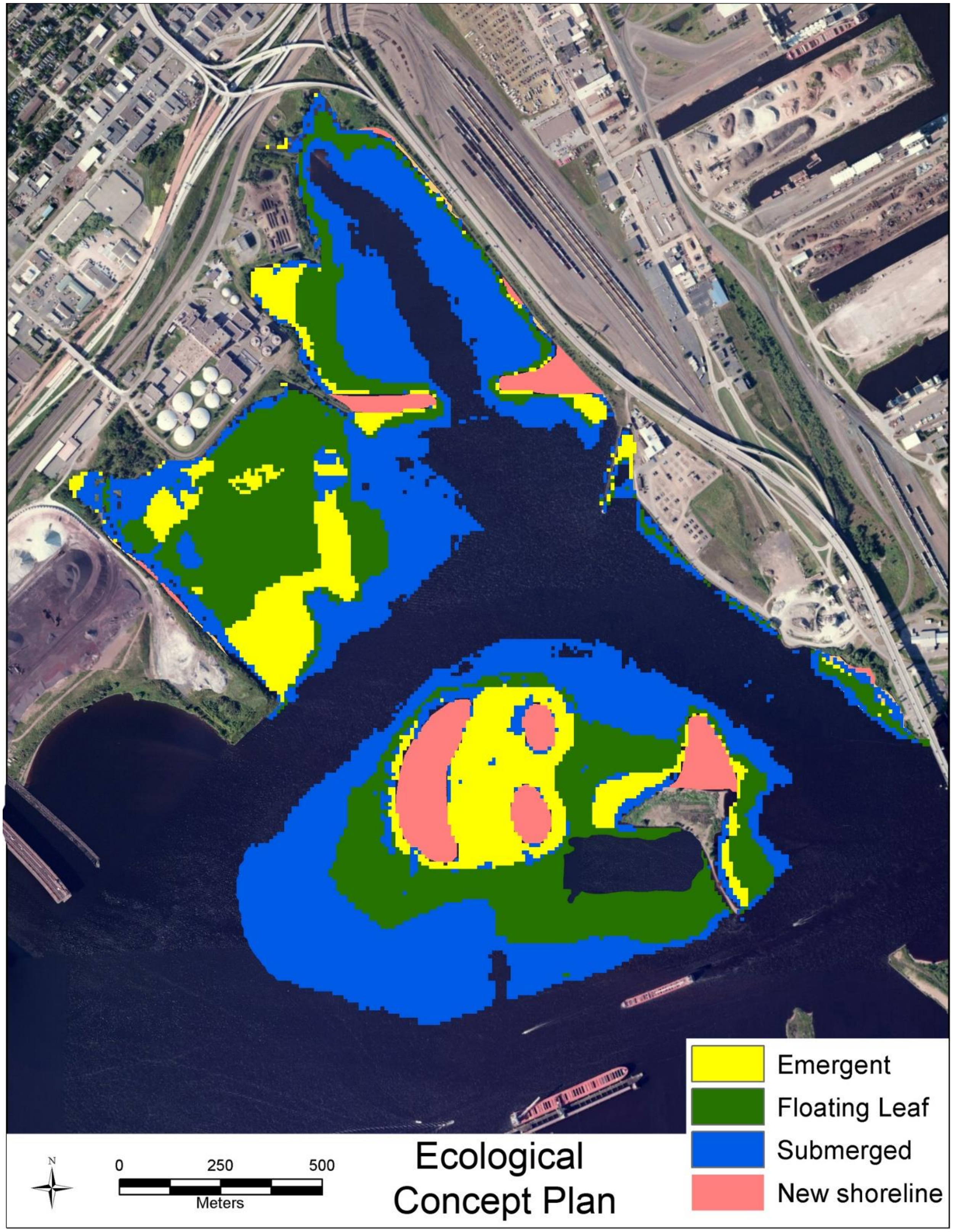


Figure 36. Distribution of aquatic vegetation beds in the Ecological Concept Plan.

Ecotoxicology

It would be best to use a method that would prevent significant amounts of sediment mixing in the water column when increasing water depths in the Project Area. Sediment dredged in the western portion of the project area and in areas near the creek delta (a hotspot for PAH and PCBs) is likely contaminated and may require confined disposal. Additional contaminant testing would need to be conducted if these sediments are to be used as fill in the 21st area. In addition, the dredged sediments from this area and from the area near the newly created islands may require disposal and more contaminant testing would be needed if these sediments were to be used as fill in the 21st restoration area. Contaminant data are limited in the newly expanded project area (more southern portion of project area) and additional testing would help inform remedial management. It is uncertain what contaminant issues may exist with the new creation of these two islands, but data suggest that sediment in this area is toxic to benthic organisms.

Hydrodynamics

In the Ecological Concept Plan, the influence of the northern 'finger' breakwaters is clearly seen, resulting in a large volume of water on the western side of this new sub-bay which is unaffected by the WLSSD outflow, though WLSSD effluent impacts the eastern portion of this bay in each case (Figure 37).

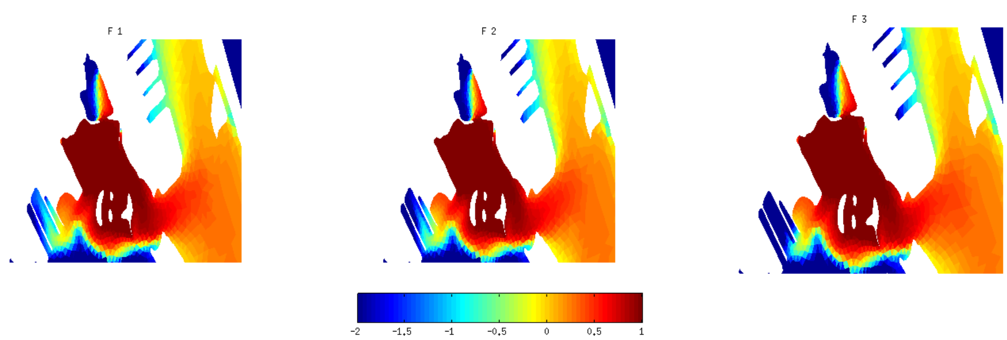


Figure 37. Steady-state dye distribution in the harbor in the ecological concept plan under three conditions: (a) Steady river forcing, no wind; (b) steady river forcing, wind from the west; (c) steady river forcing, wind from the east.

In nearly all simulations of altered bathymetry, the bulk dispersal of WLSSD effluent was enhanced as compared to the natural case. This enhancement is hypothesized to be due to the decreased volume of water surrounding the WLSSD outfall resulting from deposition of materials to reduce wave energy. Having less volume in the WLSSD embayment, dye may be more quickly transported to and entrained in the main course of St. Louis River water, where it is carried to the harbor and ultimately the lake via connections at the Superior Entry and Duluth Canal. Locally, the most significant difference between natural and altered scenarios occurs in Scenario E, and to the same extent in the Ecological Concept Plan, where the embayment of Miller Creek creates an area less affected by effluent.

In analysis of time-to-lake measures, there is little difference between the natural and altered cases. This suggests that while modification of WLSSD-area bathymetry and coastline enhances intra-estuary dispersion of WLSSD effluent, lake-estuary exchange remains unaffected and, unsurprisingly, changes in dispersive currents are local to the area of bathymetric modification. Very little if any differences in the distribution of WLSSD outflow can be seen between the control case and the various scenarios outside the immediate vicinity of the bay.

VI. Conclusions

Overview of the Project

These restoration scenarios provide guidance toward understanding how plant and animal communities might change with the changes to bathymetry, expansion of existing shoreland, and the creation of islands and additional shallow habitat to promote aquatic vegetation and reduce wind energy. The most pronounced effects are predicted to result from scenarios that create new shallow and intermediate depth habitat, especially when this can be done in areas provided protection from wave and wind energy. These areas would, in turn, support development of emergent marsh and floating leaf plant communities. Shallow and, ideally, low energy environments provide increased habitat for macroinvertebrates, wetland-affiliated fish and birds – effects that would be further amplified by the trophic relationships among these communities.

The Ecological Concept Plan incorporates the best elements of the original scenarios, along with new modifications that provide increased emergent habitat, a high degree of habitat heterogeneity, and altered flow patterns (Figure 38). While the specific presettlement conditions for the site are unknown, evidence from the Hearding map and early photos of the harbor imply extensive vegetation beds, numerous shallows, and exposed mud flats. The use of shoals and creation of shallower habitat, particularly in WLSSD bay, should restore this site to a more original representation of plants, fish and bird habitat.

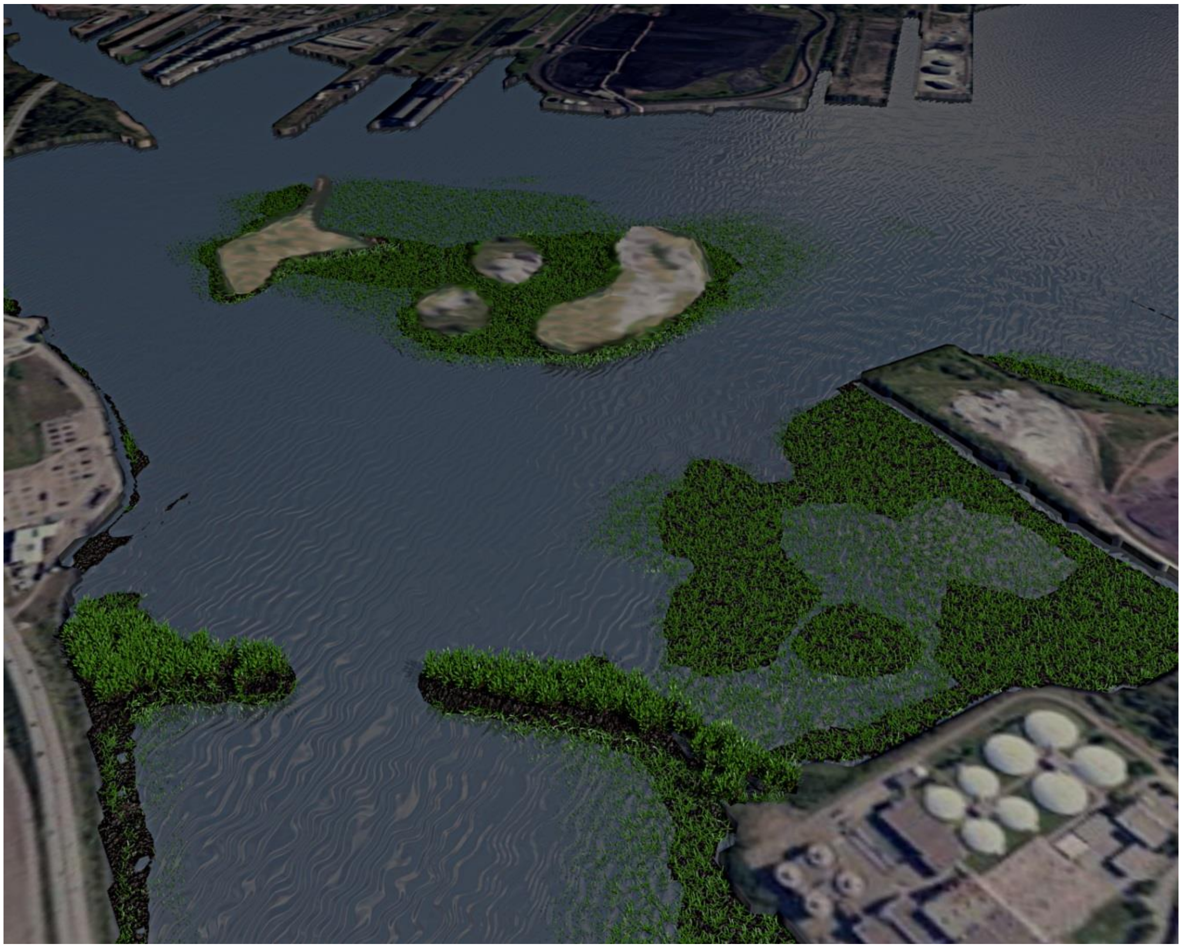


Figure 38. Digital rendering of future restoration site following implementation of ecological design. ***[T. Brown]***

Biological Effects and Considerations

Aquatic Plant Community Considerations

Since marsh vegetation is a good natural filter for many sewage effluent contaminants, there may be additional benefits to increasing emergent marsh and adjacent floating-leaf marsh vegetation, especially near WLSSD outfall areas. In that respect, the Ecological Concept Plan may be the most beneficial for long-term water quality conditions in the harbor because of the substantial increases in both emergent marsh and submerged aquatic bed vegetation.

Overall aquatic plant diversity was very low at 21st Ave West when sampled in 2011, especially when compared to other sites recently sampled for remediation to restoration projects. Even with a much higher number of sample points in the shallow portions of the Project Area), the number of aquatic plant taxa present was in the very low end of the range for open water sample points.

The low diversity of plant taxa in the shallow portions of the Project Area is not explained by water clarity as expressed by average Secchi depth, nor by water depths, nor even by the combination of depth and energy environment. The range of water depths and Secchi depths are similar to the reference areas. The low diversity of the deep portions of the Project Area may be due to much deeper water depths in the dredged channels, since they have depths much greater than in the comparable reference areas.

Macroinvertebrate Community Considerations

The 21st Avenue West site is highly dominated by aquatic earthworms (Oligochaeta) and contains fewer aquatic insects, both in abundance and as representative taxa, than the Reference Area. Lower taxa richness, despite greater sampling effort at 21st Shallow, also indicates an assemblage that is not as good as it could be compared to other areas in the estuary. While part of the cause of this impairment may be due to lack of aquatic vegetation, it is not clear that physical habitat characteristics are the sole reason causing impairment. The finding of sediment toxicity to benthic invertebrates around Interstate Island, and the presence of toxic contaminants at other locations within the project area, suggests that toxicity has a role in explaining the differences in aquatic macroinvertebrates at 21st relative to Reference and other areas in the estuary. Nutrient enrichment from the WLSSD outfall may be another component of the explanation, since the high densities of aquatic oligochaetes and other “hardy” invertebrates suggests nutrient enrichment.

Thus, improvement of the aquatic macroinvertebrate community may depend on more than altering depth and energy environments and coaxing a diverse aquatic macrophyte community to grow. It may also be necessary to remediate legacy toxins and to monitor for contaminants of emerging concern that could affect invertebrates (and fish). The WLSSD outfall will be a source of nutrient enrichment into the future unless tertiary treatment becomes affordable. There may be additional ways to mitigate effects of the enrichment, however, by ensuring that WLSSD outflow mixes quickly with St. Louis River flow.

One favorable observation from this sampling is that the large burrowing mayfly *Hexagenia* was found within the 21st Shallow location (and also found at Reference and 40th Avenue West). (Note also that the family was found within 21st Deep, but could not be identified to genus). However, large shallow areas further into the bay are void of *Hexagenia* even though habitat conditions (e.g., depositional mudflats) would appear to provide suitable refuge. These may be areas where either legacy toxins are causing a problem, or where wave energies are too high for *Hexagenia* to maintain stable burrows. This mayfly is particularly sensitive to dissolved oxygen, and its presence indicates that dissolved oxygen is not a limiting factor in areas where it occurs. *Hexagenia* are of particular interest to sport fishermen, who often like to fish the “Hex hatch” when the mayfly emerges to become a winged adult. Scientists and managers are interested in *Hexagenia* because it may also serve as a bioaccumulation link in the estuary food web; it is large-bodied, long-lived, and resides with the sediment, and thus in potentially close proximity to legacy toxins, throughout most of its lifecycle.

Avian Community Considerations

The recommendations for 21st Avenue West are nearly identical to those for the 40th Avenue West site, as described in Niemi et al. (2011). Recommendations have been altered where necessary to reflect needs specific to 21st Avenue West. The greatest potential for restoration includes creating wetlands, sandy/cobble shorelines, and a variety of habitat conditions for migratory songbirds. However, this area has a severe ornithological problem due to the attraction to the site of Ring-billed Gulls, Canada Goose, American Crow, and European Starling. The former three are native species of the region, while the European Starling is a non-native, invasive species introduced to the United States in the late 1800's. Any restoration that could create additional open sandy or cobble habitat will be an attraction to gulls. Restoration that increases wetland habitat in the region will also likely benefit the Canada Goose. The high populations of American Crow and European Starling are due to the food sources available at WLSSD. If these populations are left unmanaged, then it is possible that restoration efforts may make the problems with these species even worse.

Specific remediation of the site should consider the following with respect to bird use of the area:

1) *Development of Sandy/Cobble Habitat* - The greatest potential for positive benefit for remediation at the site includes considerations for creation of habitat for the endangered Piping Plover and threatened Common Tern. Both of these species require open and protected sandy or cobble beaches. Restoration of open sandy or beach habitat and colonization of subsequent sites by either species would face significant challenges from the presence of gulls and other predators.

2) *Enhancement of Emergent Wetlands* -Waterfowl and other wetland bird species would greatly benefit by improvement in the quality and expansion of wetland habitats in the area. Each of these species groups were largely confined to shallow water habitats within the study area. The current diversity of waterfowl and waterbird species use of the area would be enhanced further with improvement in wetlands. There were several wetland-associated species that were not observed in the area that may also colonize these areas in the future if the wetland habitats were improved or expanded. These include the American Bittern, Forster's Tern, Black Tern, Marsh Wren, and Virginia Rail. However, emergent wetlands may also prove attractive to more Canada Geese; the interactions of this species with other species of interest are unclear.

3) *Public Access* – Due to landownership and the industrialized nature of the location, the area is currently inaccessible to the public. There is no public viewing area for bird watching or

other recreational activities, with the exception of the Port Terminal Road beneath the Blatnik Bridge (US Hwy 53), which does not provide an ideal environment for bird watching due to noise pollution created by the high level of use by humans. Improving public exposure and opportunities for wildlife viewing with public access would be beneficial and access to selected portions of the site should be developed. Considerations at this site include safety issues with the railroad tracks and property ownership. The area east of WLSSD is a popular bird watching area already and this could be enhanced; however, there are also sensitive issues regarding the successful operation of WLSSD such as deterring the use of the site by birds. Signage would be important to explain to the public about safety issues to not enter WLSSD property, plus health reasons on why bird use of the compost area is discouraged.

4) *Management Coordination* – There are several wildlife conflicts that exist in this area such as the presence of prolific species such as Ring-billed Gull and Canada Goose. Encouragement of Common Tern or Piping Plover nesting habitat within the site by the creation of open, protected sandy and cobble areas would also be attractive to Ring-billed and Herring Gulls. There would be little justification for further encouragement of nesting for either of these species in the Duluth-Superior Harbor if these species are not managed. Restoration of the site requires extensive discussion among management agencies, non-government organizations, and the public to achieve an optimum result for the area.

Ecological Risk Management Considerations

Available data suggest that there are moderate remedial considerations for the 21st Ave W restoration area. While recent sediment chemistry data (MPCA 2013) suggest that the greatest concentrations are often found in deeper sediment layers (50-100 cm), including the exceedance of Level II SQTs, these data also show that contaminant concentrations exceed the Level I SQTs in the surficial sediments. Additional recent results (FWS 2012) indicate that surficial sediment, in a few areas, exhibit toxic effects on invertebrates. Therefore, the project area presents a significant risk to the aquatic community even if the sediment is left undisturbed in these particular locations (particularly near the State Lines and WLSSD).

Recommended remedial practices:

- Ensure that sediments being used as fill in the 21st Ave Project Area are clean and meet state standards.
- Consult with an experienced risk manager during the remediation and restoration processes.
- Consider bioactive zones for the selected project design.
- When restoring habitat, avoid disturbing sediment in areas with greater contaminant concentrations (Figure 6). Disturbance of these contaminated sediments could increase bioavailability of contaminants, and thus increase the toxic effects to fish and wildlife.

Additional Information Needs

Contaminant risks in the project area are still somewhat poorly understood because of some data issues and uncertainties which may affect risk determinations. It would be helpful to have more data with depth profiles and acceptable detection limits (below Level I SQTs) to help inform remedial management. For example, data collected in 2008 and 2010 had poor detection limits for select contaminants, such as PCBs and chlorinated pesticides, and were not useable. These data were not considered in this remedial assessment, and therefore it is difficult to quantify risk for these contaminants. Invertebrates for the toxicity and bioaccumulation bioassay exposures were limited to surficial sediments for the 2012 USFWS study. In addition, bioaccumulation data are limited because the oligochaetes from the bioassay were only tested for metals due to low tissue mass. For future studies, it would be beneficial to focus analyses on PAHs, PCBs, toxaphene, dioxin/furans, and mercury for bioaccumulation assays.

However, there are a number of factors that make the 21st Avenue West site different from the previous ecological design study at 40th Ave West (Host et al 2012). In our aquatic plant survey from summer 2011, the aquatic vegetation, especially the floating leaf and submerged aquatic plants, were quite sparse. Approximately 40% of points where we would expect vegetation, and where the model predicts vegetation, substrates were essentially devoid of plant life. Other locations that should support healthy aquatic beds had limited numbers of individuals. The macroinvertebrate community, perhaps partly in response, was also not as expected, with a lack of typical macroinvertebrates for the site and a dominance by oligochaete worms. There are a number of potential causes for these disparities:

- Excessive sediment loading from Miller and Coffee Creeks physically disrupting establishing aquatic plants
- Herbivory by persistent bird populations attracted to the site by year-around open water
- Increased loading of dissolved organic carbon (as evidenced by macroinvertebrate indicators), potentially from WLSSD
- Presence of contaminants in sediments that inhibit plant growth

It will be critical that the causal factors limiting growth of aquatic macrophytes and creating the anomalous responses of vegetation and biota be understood and resolved before the predicted results of restoration activities can be interpreted with confidence. Several of these factors – contaminants for example-lie in the realm of remediation, the necessary first step in the R-to-R process.

The *Hexagenia* mayfly is an important species in the food chain that often uses deep habitat as refugia. Increased deep habitat could lead to increases in *Hexagenia* as well as walleye and other fish. However, the scenarios presented here promote shallow habitat, none increases the amount of disphotic or deep, low energy area that is predicted to benefit *Hexagenia*.

Recommendations for Future Steps

Vegetation Studies

In order to address the question of what is limiting growth of aquatic plants (sediment quality, water quality, or both), we recommend conducting two experiments, one in a controlled mesocosm setting and one at the 21st Avenue West site, to attempt to identify causal factors for the depauparate vegetation at the site:

1) Mesocosm experiments

These experiments will be controlled experiments on growth of aquatic plants in sediments collected from both clean and contaminated sites within the St. Louis River estuary, initially using untreated water from Lake Superior. The experiment will be run in in mesocosm tanks consisting of 50 gallon plastic barrels, with aquatic plants set in 6" diameter sediment core tubes that will serve as planting "pots" for the aquatic plants. The tanks will hold about 20 to 22" of water depth above the tops of sediment tubes placed in the bottom of the tanks. The first year (summer 2013) will be a trial of two mesocosm tanks using clean sediments, to test and refine the mesocosm tank design and confirm that aquatic plants can be successfully grown in the tanks. The second year (summer 2014) will be a comparison of growth of aquatic plants in sediments from clean and contaminated sites: four mesocosm tanks will have "clean" sediments from reference sites within the St. Louis River estuary, and four tanks will have sediments from contaminated sites (e.g. 21st Avenue West and 40th Avenue West). Aquatic plants (e.g. *Vallisneria americana*) will be grown from buds planted in the tubes of sediment for 12 weeks; plants will be dried and weighed to compare biomass between treatments.   This experiment should help determine if contaminated sediments are limiting growth of aquatic plants. Depending on the outcome of the first year's experiment, the treatments can be modified in the second year (2015) to either compare different water sources, or to amend clean sediments with suspected sources of contamination.

2) Reciprocal Transplant experiments

These experiments are similar to a common garden experiment; however in this case the common garden sites will be reference and remediation sites within the St. Louis River estuary. Submerged aquatic plants will be found growing near shore in a “clean” reference site, and a few individual plants will be transplanted to pots filled with sediments from two sources: the same clean reference site (e.g. east of Clough Island) and a contaminated site (21st Ave West). The pots filled with clean sediment will be transplanted to a location in the reference site near where plants were collected, and the pots filled with 21st Ave West sediment will be transplanted to a similar water depth at the 21st Ave West site. A few submerged aquatic plants growing near shore at the 21st Ave West site will also be located, and transplanted into pots with sediments from both sites. Pots with 21st Ave West sediment will be planted near where they were collected, and the pots with reference site sediments will be planted at similar water depths near where the sediment was collected at the reference site. In each case the transplanted plants will be covered with a wire mesh cage to reduce herbivory by waterfowl. Then after a set period of time (e.g. 12 weeks) the transplants will be collected, dried and weighed to compare biomass.

VII. Literature Cited

Blouin, M., P. Hudson, and M. Chriscinske. 2004. Habitat selection by two species of burrowing mayfly nymphs in the Les Cheneaux Islands region of northern Lake Huron. J. Freshw. Ecol. 19 (3): 607-514.

Brady, V., C. Reschke, D. Breneman, G. E. Host, and L. B. Johnson. 2010. 40th Avenue West remediation to restoration project: biological survey results. Natural Resources Research Institute. NRRI/TR-2010/24 23 pp.

Canadian Council of Ministers of the Environment. 2001. Canadian tissue residue guidelines for the protection of wildlife consumers of aquatic biota: summary table. Updated. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Coffin, B and L. Pfanmuller. 1988. Minnesota's endangered flora and fauna. University of Minnesota Press, Minneapolis, MN 465 p.

Crane, J.L. 2006. Phase IV GIS-Based Sediment Quality Database for the St. Louis River Area of Concern- Wisconsin Focus: Overview of sediment quality conditions in the St. Louis River Area of Concern. Environmental Analysis and Outcomes Division, Minnesota Pollution Control Agency.

Crane, J.L. and D.D. MacDonald. 2003. Applications of numerical sediment quality targets for assessing sediment quality conditions in a US Great Lakes Area of Concern. Environ.Manage. 32:128-140.

Crane, J.L., D.D. MacDonald, C.G. Ingersoll, D.E. Smorong, R.A. Lindskoog, C.G. Severn, T.A.Berger, and L.J. Field. 2000. Development of a framework for evaluating numerical sediment quality targets and sediment contamination in the St. Louis River Area of Concern. Great Lakes National Program Office, United States Environmental Protection Agency, Chicago, IL. EPA 905-R-00-008.

Crane, J.L., D.D. MacDonald, C.G. Ingersoll, D.E. Smorong, R.A. Lindskoog, C.G. Severn, T.A.Berger, and L.J. Field. 2002. Evaluation of numerical sediment quality targets for the St. Louis River Area of Concern. Arch. Environ. Contam. Toxicol. 43:1-10.

Hoffman, J.C., J.R. Kelly, A.S. Trebitz, G.S. Peterson, and C.W. West. 2011. Effort and potential efficiencies for aquatic non-native species early detection. Canadian Journal of Fisheries and Aquatic Sciences 68:2064-2079.

Host, G. E., P. Meysembourg, C. Reschke, V. Brady, G. Niemi, A. Bracey and L. Johnson. 2012. An ecological design for the 40th Avenue West Remediation-to-Restoration Project. Natural Resources Research Institute. NRRI/TR-2012/27 57 p.

Host, G.E., C. Reschke, V. Brady, D. Breneman, J. Dumke, G. Niemi, J. Austin, M. James, and L. Johnson. 2012. 21st Avenue West Remediation-to-Restoration Project: Biological Survey Results. Report to US Fish and Wildlife Service, 29 p.

Krieger K.A. 1999. Ecosystem change in western Lake Erie: Cause and effect of burrowing mayfly recolonization. Final Report, Ohio Lake Erie Commission, Toledo, OH.

MPCA. 2013. Remedial Review and Determination Memorandum. Remedial Assessment Area 57

Niemi, G. J., J. Lind, A. Bracey, C. Lapin, and P. Meysembourg. Avian Survey Results, 40th Avenue West Remediation to Restoration Project. Addendum to Brady, V., C. Reschke, D. Breneman, G. E. Host and L. B. Johnson. 2010. 40th Avenue West remediation to restoration project: biological survey results. Natural Resources Research Institute. NRRI/TR-2010/24

Peterson, G.S., J.C. Hoffman, A.S. Trebitz, C.W. West, and J.R. Kelly. 2011. Establishment patterns of non-native fishes: lessons from the Duluth-Superior harbor and lower St. Louis River, an invasion-prone Great Lakes coastal ecosystem. Journal of Great Lakes Research 37:349-358.

Rohweder, J., J.T. Rogala, B.L. Johnson, D. Anderson, S. Clark, F. Chamberlin, and K. Runyon. 2008. Application of wind fetch and wave models for habitat rehabilitation and enhancement projects. Open-File Report 2008–1200, U.S. Geological Survey, Reston, Virginia.

Yin Y., J. Rogala, J. Sullivan, and J. Rohweder. 2008. Submersed aquatic vegetation modeling output online. USGS Upper Midwest Environmental Science Center. http://umesc-gisdb03.er.usgs.gov/sav_model_p8/viewer.aspx (accessed 6/13/11).

Table 1. Habitat Class (depth x exposure) summaries for current condition at 21st Avenue West.

Habitat Classes		Current Condition (acres)	% of Total Area
Shallow (< 0.65 m) - Low Energy		15.0	2.9
Shallow (< 0.65 m) - High Energy		47.6	9.0
Intermediate (< 0.65 - 1.6 m) - Low Energy		8.1	1.5
Intermediate (< 0.65 - 1.6 m) - High Energy		112.0	21.3
Deep (1.6 - 2.5) - Low Energy		1.8	0.3
Deep (1.6 - 2.5) - High Energy		161.4	30.7
Disphotic zone (> 2.5 m)		174.6	33.2
Island		5.7	1.1
	Total Acres	526.2	

Table 2. Benthic macroinvertebrate trait comparisons between sampling locations within the St. Louis River Estuary. Total number and total taxa represent mean values ± 1 standard error per sample. Trait characteristics are expressed as a percent of total. Metrics were compared using a one-way ANOVA and are significant at the α= 0.05 level. Metric values with the same letter are not significantly different based on Duncan's Multiple Range Test. Dominance (%) is a proportion of the total numbers represented by a single taxa. ET taxa are those identified as Ephemeroptera or Trichoptera.

Invertebrate metric	Reference	40th Ave W	21st Shallow	21st Deep
Sample n	n=20	n=20	n=48	n=22
Total Abundance (m^2)	15,921±134[b]	20,360±4126 [b]	34,857±4579 [a]	44,587±5754 [a]
% Dominance	44±2.6 [c]	49±2.9 [bc]	63±2.3 [a]	57±2.1 [ab]
% Chironomidae	36±3.6 [a]	22±2.8 [b]	9±1.3 [c]	2±0.3 [d]
% Oligochaeta	29±3.1 [b]	39±3.8 [b]	55±3.6 [a]	55±2.6 [a]
% Non-Insects	57±3.6 [d]	75±3.1 [c]	91±1.3 [b]	98±0.4 [a]
Total Taxa	15±0.9 [a]	9±1.1 [b]	9±0.3 [b]	8±0.3 [b]
% Collect-Gather Taxa	40±2.5 [b]	53±4.7 [a]	44±1.3 [a]	37±1.8 [c]
% Grazer-Scraper Taxa	10±1.5 [a]	8±2.2 [ab]	8±1.1 [b]	13±1.6 [a]
% ET Taxa	25±1.3[a]	14±2.7 [b]	6±1.5 [c]	2±1.3 [c]

Table 3. Percent of total observations among bird communities by Depth-Exposure categories at the 21st Avenue East study site.

	shallow-low	shallow-high	intermediate-low	intermediate-high	deep-low	deep-high	disphotic	land
Corvid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Gull	0.31	0.02	0.00	0.66	0.00	0.00	0.00	0.00
Shorebird	0.84	0.03	0.00	0.00	0.00	0.00	0.00	0.13
Songbird	0.12	0.03	0.00	0.00	0.00	0.01	0.00	0.83
Waterbird	0.05	0.41	0.01	0.14	0.00	0.10	0.03	0.26
Waterfowl	0.34	0.24	0.01	0.24	0.00	0.10	0.01	0.06

Table 4. Area summaries from aquatic vegetation model runs under current conditions.

Aquatic Vegetation Beds (predicted)	Current Condition (acres)	% of Total Area
Emergent Marsh	22.1	3.5
Floating Leaf Aquatic Beds	139.3	21.9
Submerged Aquatic Beds	171.3	26.9
Total Acres	332.7	

Table 5. Summary of Habitat Class (depth x exposure) area and biotic response for Scenario A.

Habitat Classes	Current Condition (acres)	Scenario A (ac)	Change (ac)	% Change over site	Macroinv. Richness	Hexagenia Habitat	Waterbird Waterfowl Habitat	Songbird Corvid Habitat	SAV-affiliated fish	Channel or Deepwater Fish
Shallow (< 0.65 m) - Low Energy	15.0	11.9	-3.1	-0.6						
Shallow (< 0.65 m) - High Energy	47.6	51.5	3.9	0.7						
Intermediate (< 0.65 - 1.6 m) - Low Energy	8.1	4.2	-3.9	-0.7						
Intermediate (< 0.65 - 1.6 m) - High Energy	112.0	115.8	3.8	0.7						
Deep (1.6 - 2.5) - Low Energy	1.8	0.5	-1.3	-0.2						
Deep (1.6 - 2.5) - High Energy	161.4	162.4	1.0	0.2						
Disphotic zone (> 2.5 m)	174.6	173.8	-0.8	-0.2						
Island	5.7	6.6	0.9	0.2						
Total Acres	526.2	526.7								

Table 7. Summary of Habitat Class (depth x exposure) areas and biotic response for Scenario B.

Habitat Classes	Current Condition (acres)	Scenario B	Change (ac)	% Change	Macroinv. Richness	Hexagenia Habitat	Waterbird Waterfowl Habitat	Songbird Corvid Habitat	SAV-affiliated fish	Channel or Deepwater Fish
Shallow (< 0.65 m) - Low Energy	15.0	25.8	10.8	2.1	++					
Shallow (< 0.65 m) - High Energy	47.6	44.7	-3.0	-0.6						
Intermediate (< 0.65 - 1.6 m) - Low Energy	8.1	3.9	-4.2	-0.8						
Intermediate (< 0.65 - 1.6 m) - High Energy	112.0	167.0	55.0	10.8					+++	
Deep (1.6 - 2.5) - Low Energy	1.8	5.6	3.8	0.7						
Deep (1.6 - 2.5) - High Energy	161.4	160.8	-0.6	-0.1						
Disphotic zone (> 2.5 m)	174.6	96.3	-78.3	-15.4						---
Island	5.7	5.7	0.0	0.0						
Total Acres	526.2	509.7	-16.5							

Table 9. Summary of Habitat Class (depth x exposure) areas and biotic response for Scenario C.

Habitat Classes	Current Condition (acres)	Scenario C	Change (ac)	% Change	Macroinv. Richness	Hexagenia Habitat	Waterbird Waterfowl Habitat	Songbird Corvid Habitat	SAV-affiliated fish	Channel or Deepwater Fish
Shallow (< 0.65 m) - Low Energy	15.0	21.5	6.5	1.2	+					
Shallow (< 0.65 m) - High Energy	47.6	50.5	2.9	0.6						
Intermediate (< 0.65 - 1.6 m) - Low Energy	8.1	10.5	2.4	0.5						
Intermediate (< 0.65 - 1.6 m) - High Energy	112.0	158.5	46.5	8.8					+++	
Deep (1.6 - 2.5) - Low Energy	1.8	2.0	0.2	0.0						
Deep (1.6 - 2.5) - High Energy	161.4	104.3	-57.1	-10.9		---				---
Disphotic zone (> 2.5 m)	174.6	161.1	-13.5	-2.6						
Island	5.7	5.7	0.0	0.0						
Total Acres	526.2	514.1	-12.1							

Table 11. Summary of Habitat Class (depth x exposure) areas and biotic response for Scenario D.

Habitat Classes	Current Condition (acres)	Scenario D	Change (ac)	% Change	Macroinv. Richness	Hexagenia Habitat	Waterbird Waterfowl Habitat	Songbird Corvid Habitat	SAV-affiliated fish	Channel or Deepwater Fish
Shallow (< 0.65 m) - Low Energy	15.0	22.7	7.7	1.5						
Shallow (< 0.65 m) - High Energy	47.6	77.5	29.9	5.7			++		+++	
Intermediate (< 0.65 - 1.6 m) - Low Energy	8.1	11.8	3.7	0.7						
Intermediate (< 0.65 - 1.6 m) - High Energy	112.0	139.2	27.2	5.2						
Deep (1.6 - 2.5) - Low Energy	1.8	0.0	-1.8	-0.3						
Deep (1.6 - 2.5) - High Energy	161.4	89.8	-71.6	-13.6		---				---
Disphotic zone (> 2.5 m)	174.6	149.3	-25.3	-4.8						--
Island	5.7	24.1	18.4	3.5				+		
Total Acres	526.2	514.4	-11.8							

Table 13. Summary of Habitat Class (depth x exposure) areas and biotic response for Scenario E.

Habitat Classes	Current Condition (acres)	Scenario E	Change (ac)	% Change	Macroinv. Richness	Hexagenia Habitat	Waterbird Waterfowl Habitat	Songbird Corvid Habitat	SAV-affiliated fish	Channel or Deepwater Fish
Shallow (< 0.65 m) - Low Energy	15.0	51.7	36.7	7.0	+					
Shallow (< 0.65 m) - High Energy	47.6	62.0	14.4	2.7			+++		+++	
Intermediate (< 0.65 - 1.6 m) - Low Energy	8.1	27.9	19.8	3.8						
Intermediate (< 0.65 - 1.6 m) - High Energy	112.0	140.8	28.8	5.5						
Deep (1.6 - 2.5) - Low Energy	1.8	9.4	7.6	1.4						
Deep (1.6 - 2.5) - High Energy	161.4	68.0	-93.4	-17.8						---
Disphotic zone (> 2.5 m)	174.6	124.1	-50.5	-9.6		---				---
Island	5.7	27.9	22.2	4.2				++		
Total Acres	526.2	511.8	-14.4							

Table 15. Summary of Habitat Class (depth x exposure) areas and biotic response for Ecological Concept Plan.

Habitat Classes	Current Condition (acres)	Preferred Scenario	Change (ac)	% Change	Macroinv. Richness	Hexagenia Habitat	Waterbird Waterfowl Habitat	Songbird Corvid Habitat	SAV-affiliated fish	Channel or Deepwater Fish
Shallow (< 0.65 m) - Low Energy	15.0	43.9	28.9	5.5	+++		+++		+++	
Shallow (< 0.65 m) - High Energy	47.6	86.9	39.3	7.5	++		++		++	
Intermediate (< 0.65 - 1.6 m) - Low Energy	8.1	9.0	0.9	0.2						
Intermediate (< 0.65 - 1.6 m) - High Energy	112.0	152.9	40.9	7.8					++	
Deep (1.6 - 2.5) - Low Energy	1.8	2.5	0.7	0.1						
Deep (1.6 - 2.5) - High Energy	161.4	75.2	-86.2	-16.4						---
Disphotic zone (> 2.5 m)	174.6	133.7	-40.9	-7.8		---				---
Island	5.7	27.9	22.2	4.2				+		
Total Acres	526.2	532.0	5.8							

Appendix 1: Introduction and Vegetation Sampling (G. Host, C. Reschke)

Introduction

The lower 21 miles of the St. Louis River, the largest U.S. tributary to Lake Superior, form the 4,856 ha St. Louis River estuary. Despite the effects of more than 100 years of industrialized and urban development as a major Great Lakes port, the estuary remains the most significant source of biological productivity for western Lake Superior, and provides important wetland, sand beach, forested, and aquatic habitat types for a wide variety of fish and wildlife communities.

The lower St. Louis River and surrounding watershed were designated an area of concern (AOC) under the Great Lakes Water Quality Agreement in 1989 because of the presence of chemical contaminants, poor water quality, reduced fish and wildlife populations, and habitat loss. Nine beneficial use impairments (BUIs) have been identified in the AOC including: Loss of Fish and Wildlife Habitat, Degraded Fish and Wildlife Populations, Degradation of Benthos, and Fish Tumors and Deformities. The St. Louis River Citizens Action Committee, now the St. Louis River Alliance, was formed in 1996 to facilitate meeting the needs of the AOC. Following the recommendations of the St. Louis River AOC Stage II Remedial Action Plan, the St. Louis River Alliance completed the Lower St. Louis River Habitat Plan (Habitat Plan) in 2002 as "an estuary-wide guide for resource management and conservation that would lead to adequate representation, function, and protection of ecological systems in the St. Louis River, so as to sustain biological productivity, native biodiversity, and ecological integrity." The St. Louis River Alliance also facilitated development of "delisting targets" for each BUI in the St. Louis River AOC in December 2008.

The Habitat Plan identified several sites within the AOC with significant habitat limitations. One of these sites, the "21st Avenue West habitat complex" (approximately 215 ha; Map 1.1), was identified by a focus group within the St. Louis River Alliance Habitat Workgroup as a priority for a "remediation-to-restoration" project. The focus group subsequently developed a general description of desired future ecological conditions at the 21st Avenue West Habitat Complex, hereafter referred to as the Project Area, including known present conditions and limiting factors of the area. In addition, the focus group recommended a process to develop specific plans and actions to achieve the desired outcomes at the site.

As the next step toward the creation of an "ecological design" for the Project Area, Natural Resource Research Institute researchers, in cooperation with USFWS, USEPA, MPCA, MNDNR, and other partners sampled the Project Area from late summer of 2011 until early fall of 2012 to establish baseline information on vegetation, sediment types, benthic macroinvertebrates, sediment contamination and toxicity, and bird usage of the area. This work will inform the development of an ecological design that will allow the assessment of restoration scenarios in the Project Area. The project will build on the 40th Avenue West Remediation to Restoration effort, which developed an aquatic vegetation model based on depth, energy environment (predicted from a wind fetch model), water clarity, and other environmental factors. The model allows the evaluation of restoration scenarios involving changes in bathymetry, remediation or enhancement of substrate, reduction in wave energy, and other strategies.

In this study we also incorporate a hydrodynamic model of the estuary to inform the ecological design process. Relationships between vegetation and the macroinvertebrate and avian communities will provide information on the efficacy of these strategies in remediating and restoring overall habitat and biological productivity in the Project Area. This project was funded under USFWS Cooperative Agreement Number F11AC00517; full details of the project can be found in Attachment 1 of that Agreement.

Map 1.1. Twenty-first Avenue West remediation-to-restoration Project Area in the St. Louis River estuary, Duluth, Minnesota.

Aquatic Vegetation Survey Methods

Field survey methods for sampling the aquatic vegetation in the Project Area followed the sampling protocol used in 2010 in the 40th Avenue West project area. A wetland survey following the meander methodology described by Millar (1973) was completed, and an assessment of wetland functions was completed following the Minnesota Routine Assessment Method for Wetlands (MN BWSR 2009). Since all portions of the Project Area were open water, we used a variation of the point-intercept method described in Chapter 2 (MNDNR 2009) for sampling the aquatic plants. When we surveyed the area in late August and early September 2011, there were no aquatic plants visible at the water surface in the entire project area. There were no apparent beds of aquatic plants visible from the boat. We were unable at that point to map aquatic plant community boundaries for vegetation sampling. So instead we used a grid of points that were evenly spaced across the Project Area for vegetation sampling, and when we started finding aquatic plants, we added intermediate points to increase the density of sampling in areas that had some aquatic vegetation underwater (Map 2). The grid of evenly spaced points included the points where benthic macroinvertebrates were being sampled. We navigated the boat to each sampling point using GPS location measurements (accuracy ± 3 m). At each sampling point we recorded any submerged aquatic plants pulled up by a rake tossed into the water and allowed to float down until it hit bottom. All plants were identified to the level of genus and species when practicable. For plants such as narrow-leaved pondweeds, which are difficult to identify to species, genus-level categories were used. Plant nomenclature followed the Minnesota DNR county checklist (MNDNR 2010). Any algae collected by the rake were noted, but not identified to species. Vegetation sampling was completed by September 9, 2011.

In addition to plant species identification, we also recorded the following environmental conditions at each sampling point: (1) water depth, (2) Secchi disk depth, and (3) substrate type (muck, detritus, silt, sand, clay, gravel, rubble, boulder). A combination of up to three substrate types was reported to describe the conditions at each sampling point, with one type rated as dominant and the others as second or third most prominent. Bulk samples for substrate characterization were collected from the upper 8 cm of the bottom.

In order to produce a map of submerged aquatic vegetation (SAV) present in the Project Area, we relied on bathymetric data produced during recent surveys by the Fond du Lac Natural Resources staff using a hydroacoustic sensor. They used a BioSonics Digital Echosounder System in combination with BioSonics visual bottom typer data processing software to provide bathymetric measurements and sediment textures. For the vegetation study we used only the bathymetric data. In ArcView GIS we followed the 1.8 m depth contours to delineate shallow water polygons in the Project Area. This “shallow water” area represents the area where SAV beds are most likely to occur. Within this shallow water area in Map 1.2, the sample points where SAV occurred are indicated with green symbols.

Map 1.2. Vegetation sample points, 21st Avenue West remediation-to-restoration Project Area in the St. Louis River estuary, Duluth, Minnesota.

A single qualitative field assessment of wetland functions was completed for the entire shallow water area (or "Assessment Area") within the Project Area (Map 12) following the Minnesota Routine Assessment Method for Wetlands, Version 3.4 beta (Microsoft Access Database version). Fieldwork for the wetland assessment was completed at the same time as the vegetation surveys in the Project Area.

Narrative Description of Project Area and Plant Community Classification

The aquatic vegetation present in the Project Area was very sparse and variable. In late summer of 2011 there were no aquatic plants visible at the water surface, but we did pull up submerged aquatic plants on the sampling rake. The total sample size was 64 points scattered through the Project Area; of those 13 points were in water too deep (over 2 m) to be likely to support aquatic vegetation, and no plants were found at those points. Out of 51 points sampled in shallow water (under 2 m depth), 59% had some aquatic plants present, and 41% had no vegetation. The most abundant plants (those with the highest relative frequency) were water celery (*Vallisneria americana*), which was present at 29.4% of sample points, and algae (mostly filamentous) present at 15.7% of sample points. Each of the other aquatic plants present was found in fewer than 6% of the total sample points in shallow water. Three different portions of the bay had slightly different vegetation.

Near Interstate Island there were 24 shallow sample points and 13 points (54%) had SAV present. The only plants found near Interstate Island were scattered sparse patches of wild celery (*Vallisneria americana*), and some sparse algae. At three sample points near Interstate Island we gathered wild celery from water depths of 2.0-2.1 m, which is slightly deeper than our 1.8 m contour line for delineating shallow versus deep water. Average water depth at vegetated sample points was 1.41 m, and average Secchi depth was 0.67 m. Sediments near Interstate Island were mostly sand and silt, with some clay.

In the central and western parts of the bay near the Western Lake Superior Sanitary District (WLSSD) there were 16 shallow sample points, and only 2 points (12%) had SAV present; plants identified were Nuttall's waterweed (*Elodea nuttallii*) and a narrow-leaved *Potamogeton* sp. The narrow-leaved *Potamogeton* was not fruiting and so we were unable to identify the species. Average water depth at vegetated sample points was 1.1 m, and average Secchi depth was 0.59 m. Sediments near WLSSD were mostly silt and detritus with a little clay. The water in this area stays ice-free longer than adjacent areas of the harbor due to effluent water from WLSSD; therefore it often has a large population of waterfowl, especially Canada geese. The abundant detritus at this part of the bay may be due to waterfowl concentrations, or from runoff or effluent from WLSSD.

Near the eastern shore of the bay along the Garfield Street point of land there were 11 shallow sample points, and 6 points (55%) had SAV present, although one of those had only algae. The plants along the

Garfield Street point of land included water celery, two species of waterweed (*E. nuttallii* and *E. canadensis*), a narrow-leaved *Potamogeton* sp. (not fruiting), and algae. Average water depth at vegetated sample points was 0.75 m, and average Secchi depth was 0.62 m. Sediments near the Garfield Street shore were mostly sand and silt, with some detritus and gravel; at one point the "gravel" included taconite pellets.

Overall aquatic plant diversity was very low in the Project Area, especially when compared to other sites recently sampled for remediation to restoration projects. A comparison of number of aquatic plant taxa and sampling intensity is shown in Figure 1.1. Even with a much higher number of sample points in the shallow portions of the Project Area (21stSH), the number of aquatic plant taxa present was in the very low end of the range for open water sample points.

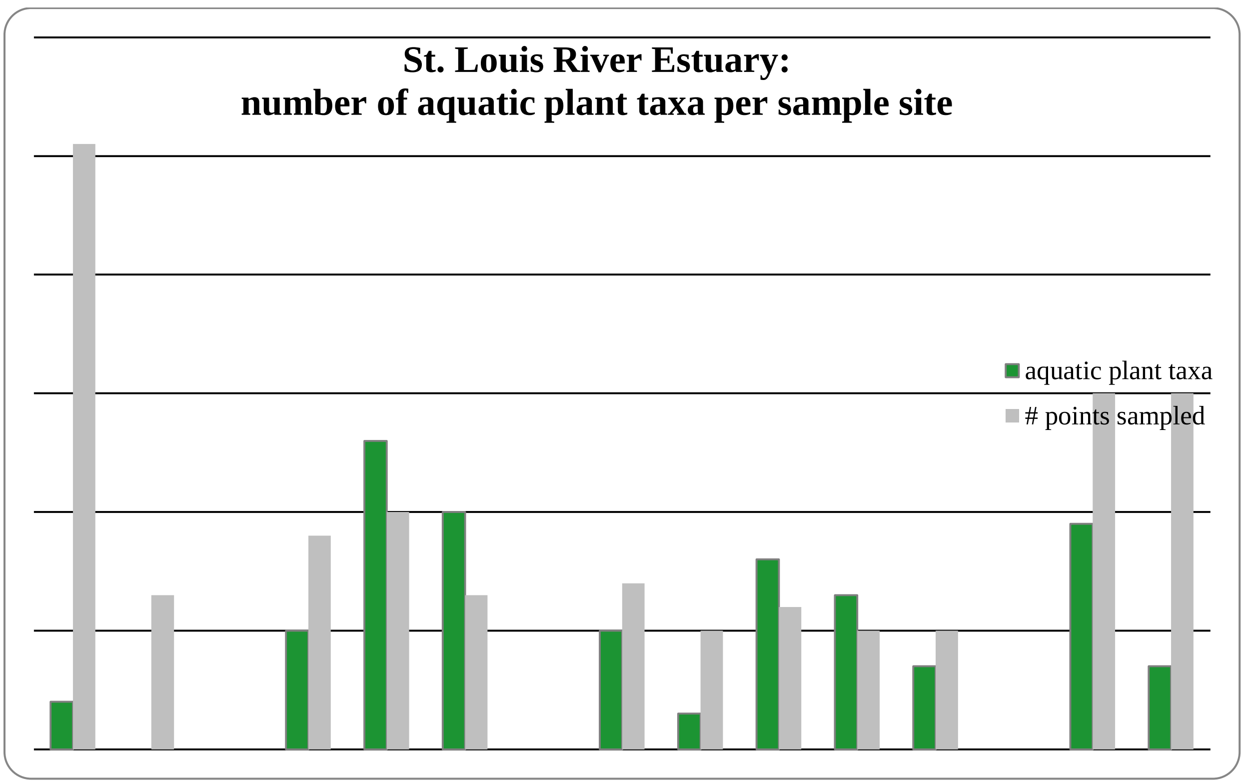


Figure 1.1. Comparison of number of aquatic plant taxa found in 2011 at 21st Avenue West shallow and deep sample points, to 2010 samples from 40th Avenue West (AA, AB, AC), open water reference areas (N of Dwight's Point, NE of Clough Island, Between Clough Island and Dwight's Point, W of Kilchlis Meadow Island, and near Spirit Island), and near shore reference areas (NSA: E of Clough Island, and NSB: N of Clough Island).

The low diversity of plant taxa in the shallow portions of the Project Area is not explained by water clarity as expressed by average Secchi depth, nor by water depths. The range of water depths and Secchi depths are similar to the reference areas. The low diversity of the deep portions of the Project Area may be due to much deeper water depths in the dredged channels, since they have depths much greater than in the comparable reference areas. A comparison of aquatic plant diversity with average Secchi depths and average water depths for the same set of sample sites is shown in Figure 1.2.

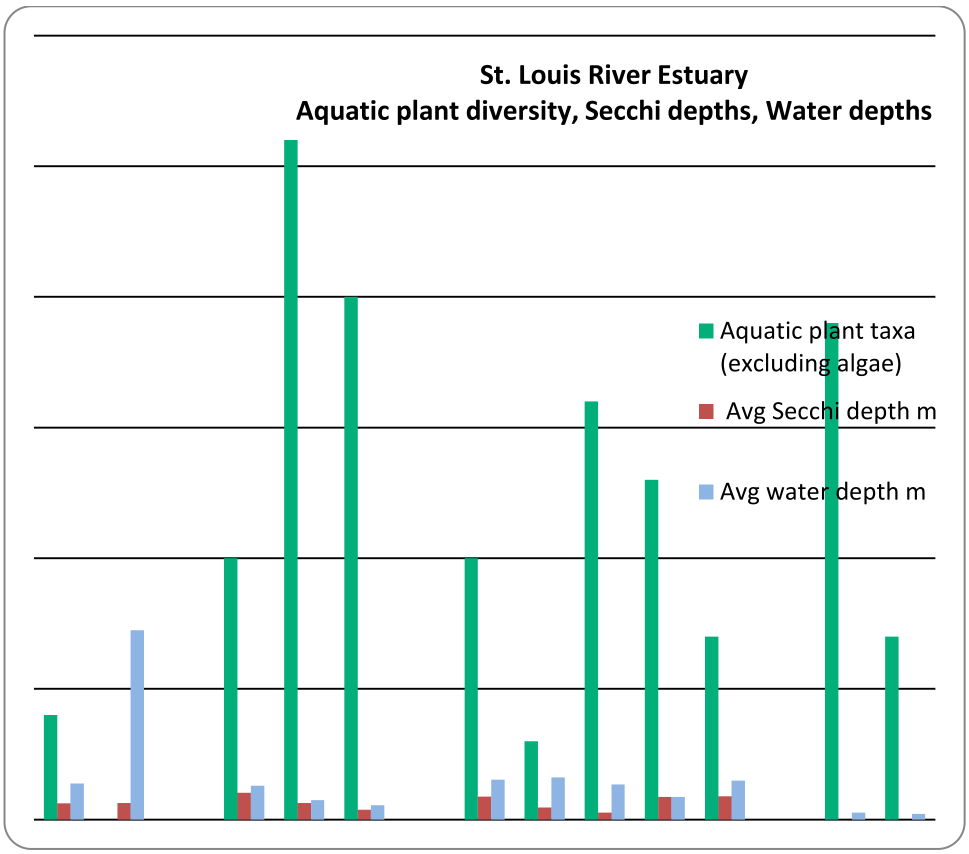


Figure 1.2. Comparison of aquatic plant diversity with average Secchi and water depths. Samples from 2011 at 21st Avenue West shallow and deep sample points, and from 2010 at 40th Avenue West (AA, AB, AC), open water reference areas (N of Dwight's Point, NE of Clough Island, Between Clough Island and Dwight's Point, W of Kilchlis Meadow Island, and near Spirit Island), and near shore reference areas (NSA: E of Clough Island, and NSB: N of Clough Island).

For this very sparse aquatic vegetation, the closest community class in the Minnesota DNR Ecological Land Classification System (MNDNR 2003) is the Lake Superior Coastal Marsh community class (MRu94). This class is described as emergent marshes that occur in estuaries and embayments near river mouths along the shore of Lake Superior, in settings influenced by fluctuating water levels caused by lake seiches. This class is present in tributaries of Lake Superior upstream as far as water levels are influenced by seiche-mediated Lake Superior water level fluctuations. Seiches, which are wind-driven changes in local water levels in Lake Superior, have significant influence on the vegetation of MRu94. These changes in local water level, which occur regularly as water levels oscillate back and forth, normally range between 1-10 in (3-25 cm) and can reverse the flow of tributary rivers of Lake Superior and flush sediments and nutrients back upstream. Water levels in coastal marshes are also influenced by river flooding from runoff following snowmelt or heavy precipitation.

The plant community Estuary Marsh (Lake Superior) with the code MRu94a is the only Minnesota DNR native plant community type currently recognized in the Lake Superior Coastal Marsh class, and there are no subtypes recognized (MNDNR 2003). Estuary Marsh (Lake Superior) is broadly defined to include a variable mixture of species, typically with a dense layer of submerged plants under and between floating-leaved and emergent aquatic plants. So portions of that plant community may include open water areas with submerged aquatic plants (lacking emergent and floating-leaf plants) similar to the sparse aquatic beds found in the Project Area. But the MNDNR classification does not currently include a classification of strictly aquatic vegetation types, so Estuary Marsh plant community type is the closest plant community type available. In past MNDNR maps of the St. Louis River estuary, the Project Area was not mapped as an example of the Estuary Marsh (Lake Superior) type.

Wetland Type/Characterization in Assessment Area

In the Eggers and Reed classification (1997) the shallow wetlands in the Project Area are all classified as “shallow, open water communities," which are described as follows:

> Shallow, open water plant communities generally have water depths of less than 6.6 feet (2 meters). Submergent, floating and floating-leaved aquatic vegetation including pondweeds, water-lilies, water milfoil, coontail, and duckweeds characterize this wetland type. Size can vary from a one-quarter acre pond, to a long oxbow of a river or shallow bay of a lake. Floating vegetation may or may not be present depending upon the effects of the season, wind, availability of nutrients, and aquatic weed control efforts.
>
> Shallow, open water communities differ from deep and shallow marshes in that they are seldom, if ever, drawn down. As a result, emergent aquatic vegetation cannot become established.

> Shallow, open water communities provide important habitat for waterfowl, terns, furbearers, fish, frogs, turtles, and aquatic invertebrates. For example, the submergent plants and aquatic invertebrates provide food for waterfowl, which is especially important during migration. The permanent to semi-permanent water regime of these deep-water wetlands results in their being especially important for waterfowl production in drought years when other wetlands have become dry. Also provided is habitat for spawning beds and nursery areas for both game and nongame fish. Finally, these areas of open water provide a valuable aesthetic resource important to municipalities and landowners.

In the Cowardin et al. (1979) classification of wetlands, the wetlands in the Project Area consist of two classes in the Riverine system, Lower Perennial subsystem; described as follows:

> The Riverine System is bounded on the landward side by upland, by the channel bank (including natural and man-made levees), or by wetland dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens. The Riverine System terminates at the downstream end where the concentration of ocean-derived salts in the water exceeds 0.5 ‰ during the period of annual average low flow, or where the channel enters a lake. It terminates at the upstream end where tributary streams originate, or where the channel leaves a lake. Springs discharging into a channel are considered part of the Riverine System.

> The Lower Perennial subsystem has a low gradient, and water velocity is slow. There is no tidal influence, and some water flows throughout the year. The substrate consists mainly of sand and mud. The gradient is lower than that of the Upper Perennial Subsystem and the floodplain is well developed.

Applying the Cowardin et al. classification, there are two classes present in the Project Area: “unconsolidated bottom” and “aquatic bed.” The shallow areas that have submerged aquatic plants are classified as “aquatic bed," and the unvegetated shallow areas are classified as “unconsolidated bottom.”

Assessment of Wetland Functions in Assessment Area (from MnRAM reports)

The shallow water portions of the Project Area are estimated to cover 295 acres. Site conditions in June 2011 were cooler than usual, so the growing season for aquatic plants may have been shorter than usual. This may partly explain the lack of aquatic vegetation visible at the water surface: it may have been too short a growing season in 2011 for the water celery (*Vallisneria americana*) to reach the water surface in this site. Patches of this plant have been reported near Interstate Island in previous years. At other sites further upstream in the estuary, including 40th Avenue West, Radio Tower Bay, and Pokegama River, water celery was visible at the surface in 2011. So conditions for water celery to reach the water surface existed in other parts of the estuary in 2011, but it may not have been as dense in 2011 as it was in 2010. The very sparse aquatic vegetation at 21st Avenue West seems unusual for the estuary, and may be due to some other environmental factor specific to the Project Area such as water pollution or sediment contamination.

Hydrogeomorphology

The maximum water depth in the shallow water portions of the Project Area is 86 inches (2.18 m), with 100% inundated. With an immediate drainage area of approximately 125 acres, it is doubtful that the current wetland is sustainable given its small catchment area. As a Riverine wetland, this site is within the river or stream banks. As such, its vegetation may serve to protect the banks from erosion, and may harbor fish, amphibian, bird, and mammal species. As a Lacustrine Fringe wetland, this site is located at the edge of deepwater areas and may be considered shoreland. As such, it protects from possible erosive wave effects and may be used as a spawning area for fish. This wetland has the unique characteristics of a freshwater estuarine wetland; it is subject to the irregular water level fluctuations and currents caused by seiches on Lake Superior. This wetland has been altered approximately 45% from its historical size of 534 acres.

Soils

The soils in the immediate wetland area are primarily under water. The adjacent upland, to about 500 feet is Urban land-Udorthents-Aquents complex, with 0 to 8% slopes.

Vegetation and upland buffer

The extent of vegetation in this wetland is about 33% and the naturalized buffer width averages 60 feet. Vegetated buffers around wetlands provide multiple benefits including wildlife habitat, erosion protection, and a reduction in surface water runoff. This buffer not only provides a good buffer for wetland water quality, it also serves as an important resource for wildlife habitat.

As a shoreline wetland, this site has the potential to protect from erosion and provide spawning and nursery habitat for fish and wildlife. Wetlands located in areas with strong currents and wave action, have the greatest potential for protecting shoreline. Shorelines composed of sandy or erodible soils will benefit the most from shoreline wetland protection.

Special features

The tributaries flowing into this wetland are designated trout streams; so the fish habitat rating is exceptional. This wetland is part of a high priority wetland complex and environmental corridor identified in a local water management plan (Lower St. Louis River Habitat Plan). This area is a local shoreland management plan area; and it is part of a federally identified special area management plan (the St. Louis River AOC).

Vegetative communities

The only plant community observed was "Shallow, Ow Communities, Type 5." This community had a vegetative index of low, and comprised 33% of the entire area; it was rated at 1. The vegetative diversity and integrity of this wetland is low. The majority of vegetation at this site, such as it is, does not contribute to wetland function beyond water retention and flow resistance.

Summary of functional ratings

Function	Rating
Vegetative diversity	low
Additional stormwater treatment needs	low
Maintenance of hydrologic regime	low
Provision of flood/stormwater attenuation	moderate
Downstream water quality	moderate
Maintenance of wetland water quality	low
Shoreline protection	moderate
Maintenance of characteristic wildlife habitat structure	low
Maintenance of characteristic fish habitat	exceptional
Maintenance of characteristic amphibian habitat	low
Aesthetics/recreation/education/cultural	moderate
Wetland restoration potential	moderate
Wetland sensitivity to stormwater and urban development	moderate

Sediment summary

Sediment samples were collected by the macroinvertebrate survey crew August 24-26 and by the vegetation crew Sept 8-9, 2011. The bug crew collected three samples at each point, and the majority of these were identical, occasionally with one exception. The vegetation crew collected one sample at each point. For the following summary, we used only one of the three bug crew samples, and avoided using the odd sample when there was one different from the other two. The combined group of sediment samples from both sample crews was 100 sediment samples, including sediments from 28 deep sample points, and 72 shallow sample points.

Sediment data were converted to approximate proportions or percentages as follows. The three variables on the field form: sediment 1, sediment 2, and sediment 3 represent the most prominent sediment texture, the second most prominent texture, and the third most prominent texture, respectively. These three variables were converted into 9 variables, one for each sediment texture class. For each sample, a proportion was entered for each texture reported at a sample. If three sediment types were reported for a sample point or plot, then the sediment type entered for sediment 1 was assigned an estimated proportion of 0.55, sediment 2 was assigned a proportion of 0.30, and sediment 3 was assigned a proportion of 0.15, so that the total of the three proportions would add to 1. If only two sediment types were reported for a sample point or plot, then sediment 1 was assigned an estimated proportion of 0.65, and sediment 2 was assigned a proportion of 0.35. If only one sediment type was reported for a sample point or plot, then that type was assigned a proportion of 1 (or 100%). These estimated sediment proportions were then summarized across all the samples for each of the 12 sample sites: AA, AB, and AC in the 40th Avenue West project site, BETW, CLIS, DWPT, KILM, SPIS are open water reference areas, NSA and NSB near-shore reference areas, 21-SH and 21-DP are the shallow and deep portions of the 21st Avenue West Project Area. In general, sediments at the shallow sample points in the Project Area were primarily silt and sand, with lesser amounts of clay and detritus. Sediments at the deep sample points were primarily silt, with lesser amounts of muck, detritus, and clay. The relative proportions of the different sediment types in each sample site are presented in Figure 1.3.

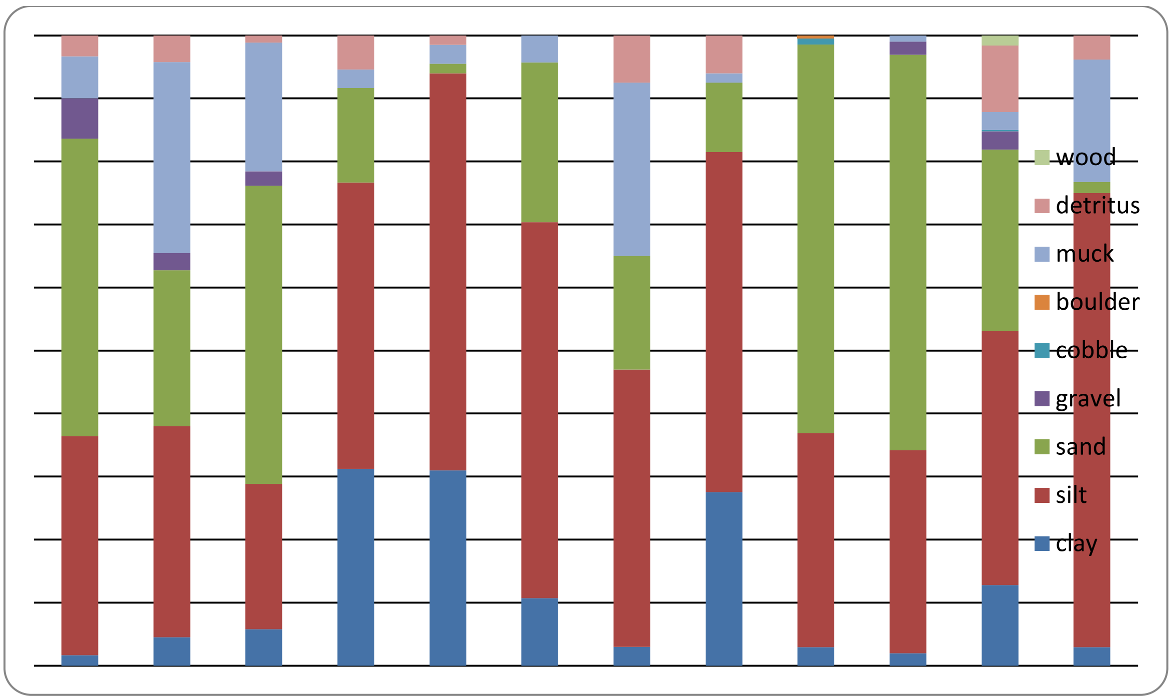


Figure 1.3. Summary of approximate proportions of sediment classes in each sample area.

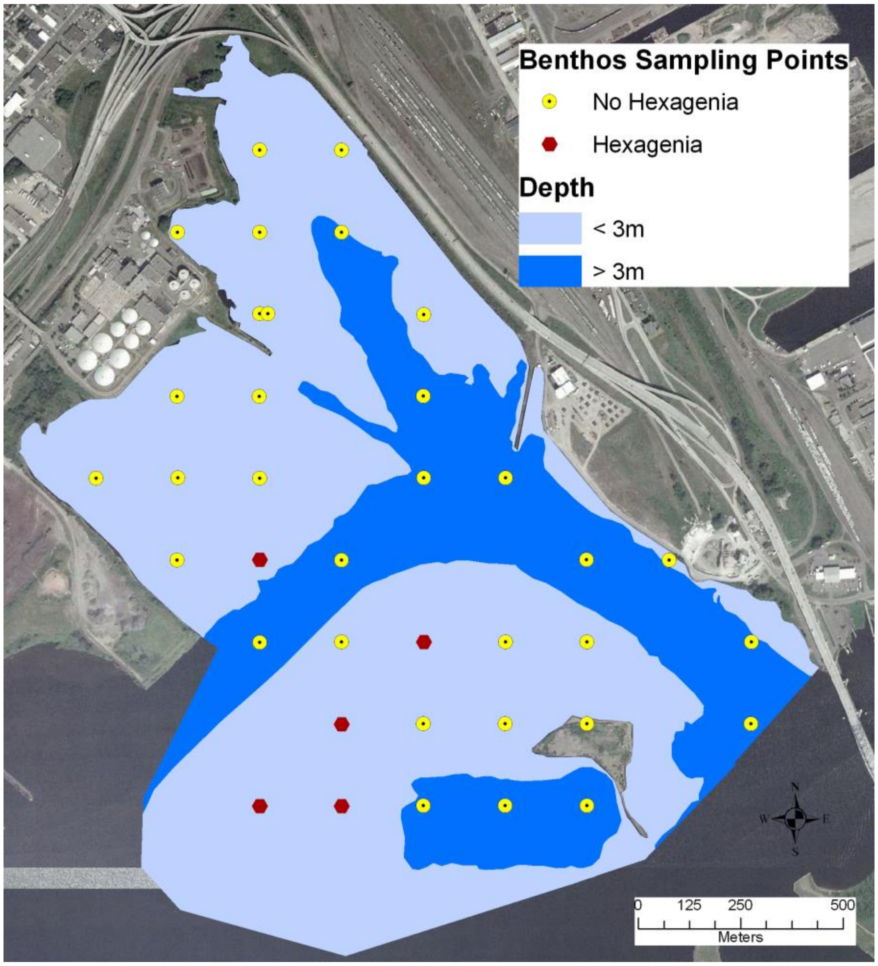
Acknowledgements

Pat Collins of the USFWS provided field assistance and use of a USFWS boat for field surveys. Paul Meysembourg provided assistance with GIS datasets.

Appendix 2. Benthic Macroinvertebrate Surveys (V. Brady)

Macroinvertebrate Sampling

The benthic macroinvertebrate community was sampled within the Project Area between August 24 and 26, 2011 (Map 2.1). Coordinates for 35 sample points were stratified by depth contours with 11 points ('deep,' > 3 m) targeting the abandoned shipping channel, and 24 in 'shallow' (≤ 3m) habitats (Appendix 2.1). Sampling points were recorded on-site using a hand-held GPS (NAD 83 UTM, accuracy ± 3 m) and downloaded to a project file at NRRI's GIS laboratory. Field crews double-anchored the boat after obtaining the coordinate, adjusting the boat position in order to establish appropriate sampling depths, obtain optimal sediment content, or to avoid debris interfering with proper sample retrieval.



Map 2.1. Benthic macroinvertebrate sampling locations within the Project Area. Background coloring shows the 3 m depth contour. Dark red hexagons show where the mayfly genus *Hexagenia* was found.

Samples were collected in triplicate using a Petite Ponar dredge. Dredge samples were hand-washed through a 250 µm mesh according to methods outlined in NRRI Microscopy Laboratory's standard operating procedures (Breneman 1999) and subsequent Great Lakes Environmental Indicators (GLEI) project reports (USEPA 2003). Procedures were adapted specifically for the 21st Avenue West project in accordance with USFWS recommendations, and as outlined in the 40th Avenue West project report (Brady et al. 2011). Those recommendations outside the standard procedures briefly describe that 1) ponar samples brought on-board be considered representative, and subsequently retained, only if the device content was at least 25 percent of full capacity, 2) primary laboratory processing to physically separate invertebrates from sample detritus would conclude within an 8-hour duration, and 3) macroinvertebrate identifications could be limited to family-level rather than the typical genus-level for most aquatic insects.

Invertebrate samples were preserved in the field using Kahle's solution and labeled both internally and externally with unique identification. Additional site information including water and Secchi disc depth, substrate type, vegetation presence, and sample quantity were recorded in field books. Sample information was recorded on site and transferred to a chain-of-custody document as samples were archived after being returned to NRRI.

Sample processing

Benthic samples were processed at NRRI following standard protocols. Invertebrates were identified to an appropriate level by a qualified NRRI invertebrate taxonomist using standard identification guides (e.g., Merritt et al. 2008, Thorp and Covich 1991, 2010). Although the protocol specified family-level identification of Class:Insecta, many organisms were identified to genus without adding additional time to the identification process. Chironimidae:Diptera were the exception, and this group was identified to sub-family. However, data were summed at the family-level for statistical analyses to better compare with the reference site and 40th Avenue West data. Remaining invertebrates, such as Oligochaeta and Nematoda, typically remained at a phylum or class-level because of the difficulty and cost of further identification. Macroinvertebrate and point data were entered into electronic spreadsheets and incorporated into an Access database in accordance with USFWS guidelines.

Quality control

NRRI laboratory personnel re-checked every sample, with 34 of 106 (over 30%) samples from this project randomly selected to evaluate processing efficiency. On average, 95% of the organisms from each sample were extracted during the primary processing effort, ranging from 82 to 100% complete, depending on sample conditions and individual staff performance. Representative individuals from each taxa were retained during identification procedures to complete a project-specific voucher collection. No organisms remained unidentified following laboratory processing, and no samples were subject to outside expert identification.

Data entry was double-checked for all field and laboratory data sheets. Suspicious and missing values were double-checked against field and laboratory data sheets. Taxonomic information was merged by taxonomic number with the Integrated Taxonomic Information System database to ensure current information.

Biotic metrics

Respective counts of each taxonomic category per sample were merged with a trait characteristic database to organize individuals by functional feeding behaviors, trophic status, and mechanistic processes. A host of metrics were then generated and compared among sample locations. These metrics were used to help uncover differences among sites that are less apparent when looking solely at the taxonomy and raw population numbers.

Analysis

Individual taxa counts and raw abundances for each sample were log transformed, with metrics expressed as proportions undergoing an arcsin square root transformation prior to analysis. Trait categories among the Project Area sites were grouped by deep and shallow habitats as separate locations, and compared with 40th Avenue West and the Reference location near Clough Island (see Brady et al. 2011). Data were analyzed with location as the class variable using a general linear model procedure in SAS (PROC GLM, SAS, 1988). Mean comparisons by locations was performed using Duncan's Multiple Range Test.

Results and Discussion

Benthic Habitat

Benthic macroinvertebrates respond strongly to their habitat, particularly substrate type and composition, presence and type of aquatic macrophytes, and water quality. Substrate at sampling points was predominantly silt, with some sand, clay, organic matter, and wood thrown in (Appendix 2.1). Aquatic vegetation was quite scarce in this area and rarely noted in ponar samples. Water depths at 21st Shallow sites averaged 1.6 m, with the average depth increasing to 7.7 m for 21st Deep (Appendix 2.1).

Water quality measurements were collected in conjunction with a separate project and are only available for the 21st and 40th Avenue West sites (Table 2.1). This project focused on shallow-water sites, so water quality represents only the shallow portion of 21st. Secchi disc depths are quite shallow (average 0.6 m, Appendix 2.1) and turbidity is relatively high (Table 2.1), as is typical in the estuary. This may be one factor that limits aquatic vegetative growth in the Project Area. Another factor may be burial due to sedimentation of fine materials entering from tributaries, but we do not have sedimentation rates available to evaluate this possibility. Finally, it is also possible that sediments may still contain toxic substances that affect both vegetation and aquatic invertebrates

Table 2.1. Water quality data collected as part of a separate project from the general vicinity of the 21st and 40th Avenue West sites.

	21st Ave W	21st Ave W	40th Ave W	40th Ave W	40th Ave W
Habitat	Open water 1	Open water 2	Open water 3	Submergent veg	Typha
Date	8/25/2011	8/25/2011	8/29/2011	8/29/2011	8/30/2011
Mean depth (cm)	46.0	62.7	84.0	89.0	11.0
Alkalinity (as $CaCO_3$ mg/L)	86.226	77.568	64.880	67.105	119.418
Chlorophyll a (ppb)	0.9	5.9	3.0	5.2	8.0
Phaeophytin (ppb)	1.9	2.9	5.5	4.9	13.7
Total phosphorus (mg/L)	0.075	0.072	0.07	0.052	0.07
Ortho phosphorus (mg/L)	0.031	0.031	0.028	0.015	0.011
Total nitrogen (mg/L)	1.686	1.531	1.16	1.029	1.037
Ammonium (mg/L)	0.6	0.472	0.053	0.036	0.02
Nitrate-nitrite (mg/L)	0.263	0.274	0.227	0.08	0.003
Color (pt-co)	227	237	274	271	174
Turbidity (NTU)	7.2	8.0	7.7	7.4	12.6
Chloride (mg/L)	34.6	21.0	10.5	22.5	36.0
Trans. tube (cm)	62.0	55.8	51.0	56.0	54.0
DO (mg/L)	11.8	12.1	6.5	9.1	4.7
DO (%)	146.2	143.9	74.5	108.6	55.6
Temperature (C)	23.4	21.7	19.8	21.2	20.1
pH	7.1	7.1	6.9	7.5	6.8
Specific cond. (µS cm-1)	314.3	269.6	154.6	175.3	342.8

Invertebrate Community

The shallow water benthic macroinvertebrate assemblage contained 31 taxa, while the deep water assemblage contained only 21 taxa (Appendix 2.2). In comparison, 38 taxa were collected from the reference site, and 32 taxa from the 40th Avenue West site. It is important to note that twice as many ponar samples were collected from the Project Area shallow water area, and it is well documented that numbers of taxa increase with increased sampling effort. Thus, the taxonomic richness of 21st Shallow should be compared to the other sites with caution.

Comparing macroinvertebrate assemblage composition (Table 2.2, Figure 2.1) reveals that the most abundant invertebrate at all sites, except Reference sites was aquatic earthworms (Oligochaeta). Non-biting midges (Chironomidae) were the dominant group at Reference, with aquatic earthworms the subdominant group. Tube worms (Polychaeta) were the subdominant group at both the shallow and deep 21st locations. A perusal of the top ten most abundant invertebrates at all sites shows that most taxa are non-insects such as various types of worms (Oligochaeta, Polychaeta, Turbellaria, and Nematoda), mussels (Sphaeriidae, Dreissena), snails (Hydrobiidae, Gastropoda, Lymnaeidae, Planorbidae, Ferrissia), leeches (Glossiphoniidae), aquatic sowbugs and scuds (Caecidotea, Gammarus), and mites (Acari). Insects in the top ten list are non-biting midges (Chironomidae), mayflies (Ephemeridae), and caddisflies (Phylocentropus, Oectis). These results are not atypical of soft-sediment benthic assemblages.

Table 2.2. Top ten most abundant benthic macroinvertebrates found in samples at each location sampled by NRRI in the St. Louis River estuary. Values are sample mean abundances ± one standard deviation.

Reference Area		]		21st-Shallow		40th Ave W	
Chironomidae	138±124	Oligochaeta	522±286	Oligochaeta	494±503	Oligochaeta	189±197
Oligochaeta	104±71	Polychaeta	307±301	Polychaeta	155±441	Chironomidae	118±151
Nematoda	39±24	Nematoda	101±66	Nematoda	112±113	Nematoda	109±126
Polychaeta	32±29	Sphaeriidae	58±50	Chironomidae	57±65	Ferrissia	29±57
Caecidotea	18±2	Hydrobiidae	42±39	Dreissena	21±324	Glossiphoniidae	24
Hydrobiidae	14±21	Chironomidae	13±12	Sphaeriidae	13±18	Dreissena	24±43
Dreissena	14±19	Turbellaria	11±11	Acari	10±9	Lymnaeidae	13±13
Sphaeriidae	12±18	Gastropoda	8	Glossiphoniidae	6±5	Oecetis	13±10
Phylocentropus	9±9	Acari	4±2	Hydrobiidae	6±6	Polychaeta	12±18
Gammarus	9±9	Phylocentropus	4±4	Ephemeridae	5±2	Planorbidae	12±6

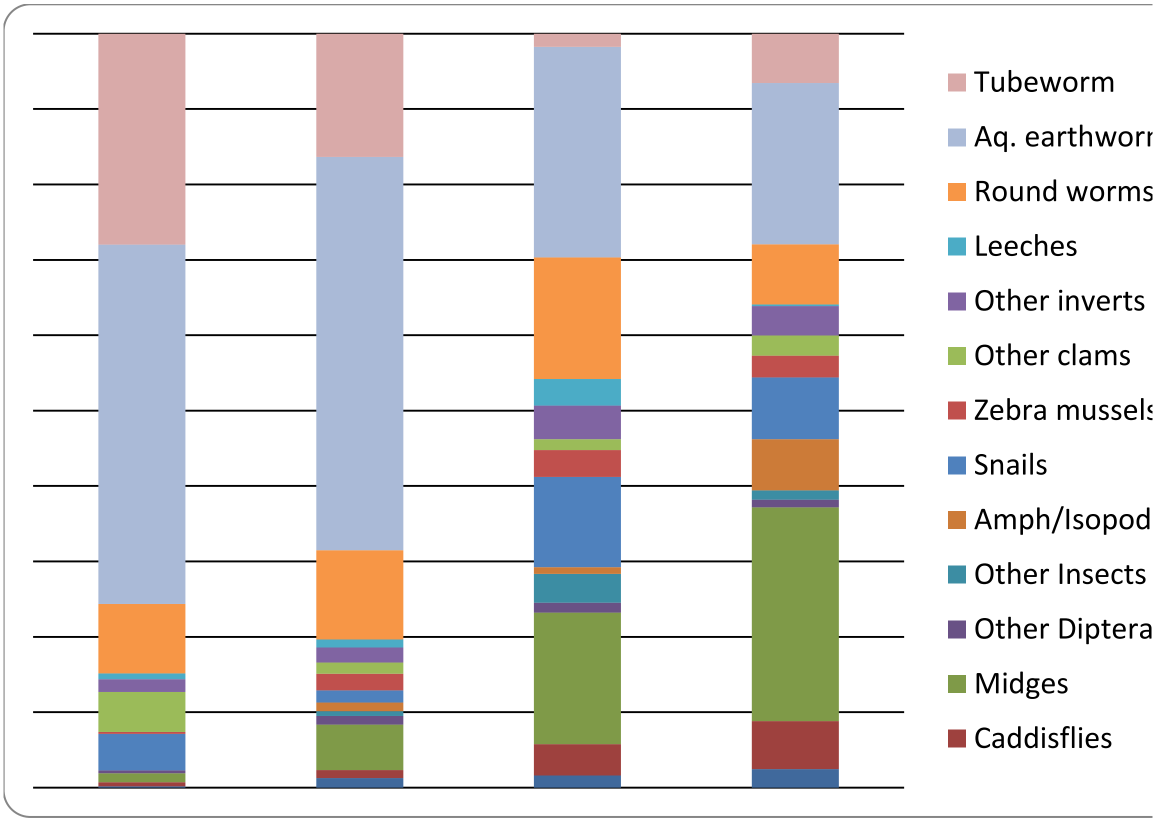


Figure 2.1. Benthic macroinvertebrate assemblages from the four sites NRRI sampled in the St. Louis River estuary. Common names of invertebrates are used for ease of interpretation.

Table 2.3. List of unique taxa for the sites NRRI has sampled in the St. Louis River estuary as part of the overall remediation-to-restoration work. "Unique" thus means found at only that location of the 4 separate locations sampled. Note that the Project Area site was separated into shallow (≤ 3 m) and deep (> 3 m) sampling points.

Location	Taxa	Class	Order	Family
21st-Shallow	Corbicula	Bivalvia	Veneroida	Corbiculidae
21st-Shallow	Dubiraphia	Insecta	Coleoptera	Elmidae
21st-Shallow	Hyalella	Malacostraca	Amphipoda	Hyalellidae
21st-Shallow	Hydra	Hydrozoa	Anthoathecatae	Hydridae
21st-Shallow	Polycentropus	Insecta	Trichoptera	Polycentropodidae
21st-Shallow	Probezzia	Insecta	Diptera	Ceratopogonidae
21st-Deep	Piscicolidae	Clitellata	Rhynchobdellida	Piscicolidae
40th Ave W.	Bezzia	Insecta	Diptera	Ceratopogonidae
40th Ave W.	Coenagrionidae	Insecta	Odonata	Coenagrionidae
40th Ave W.	Dytiscidae	Insecta	Coleoptera	Dytiscidae
40th Ave W.	Empididae	Insecta	Diptera	Empididae
40th Ave W.	Gyraulus	Gastropoda	Basommatophora	Planorbidae
40th Ave W.	Haliplus	Insecta	Coleoptera	Haliplidae
40th Ave W.	Lymnaeidae	Gastropoda	Basommatophora	Lymnaeidae
40th Ave W.	Pseudosuccinea	Gastropoda	Basommatophora	Lymnaeidae
40th Ave W.	Trichocorixa	Insecta	Hemiptera	Corixidae
Reference	Baetidae	Insecta	Ephemeroptera	Baetidae
Reference	Brachycercus	Insecta	Ephemeroptera	Caenidae
Reference	Gyrinus	Insecta	Coleoptera	Gyrinidae
Reference	Helisoma	Gastropoda	Basommatophora	Planorbidae
Reference	Hydroptilidae	Insecta	Trichoptera	Hydroptilidae
Reference	Molanna	Insecta	Trichoptera	Molannidae
Reference	Nectopsyche	Insecta	Trichoptera	Leptoceridae
Reference	Paraponyx	Insecta	Lepidoptera	Crambidae
Reference	Planorbella	Gastropoda	Basommatophora	Planorbidae
Reference	Potamoprygus	Gastropoda	Mesogastropoda	Hydrobiidae
Reference	Serromyia	Insecta	Diptera	Ceratopogonidae
Reference	Sialis	Insecta	Megaloptera	Sialidae
Reference	Somatochlora	Insecta	Odonata	Corduliidae
Reference	Unionidae	Bivalvia	Unionoida	Unionidae
Reference	Viviparidae	Gastropoda	Architaenioglossa	Viviparidae

Invertebrate Metrics

Several metrics indicate a difference in communities associated with each location, and a representative set are provided in Table 2.4. A suite of metrics often helps describe community structure and function more appropriately than a single indicator. Total abundance and taxa richness are two common metrics, and in this survey greater numbers of macroinvertebrates occurred in samples from the Project Area. Abundances at both shallow and deep habitats at the Project Area were significantly greater compared to either 40th Avenue West or Reference. There was not a significant difference within the Project Area when samples were stratified by depth. Mean number of taxa per sample was also different between locations, with the Project Area and 40th Avenue locations containing significantly fewer taxa compared to Reference. Again, taxa richness in 21st Avenue Deep and Shallow habitats was not significantly different.

Table 2.4. Benthic macroinvertebrate trait comparisons between sampling locations within the St. Louis River estuary. Total number and total taxa represent mean values ± 1 standard error per sample. Trait characteristics are expressed as a percent of total. Metrics were compared using a one-way ANOVA and are significant at the α= 0.05 level. Metric values with the same letter are not significantly different based on Duncan's Multiple Range Test. Dominance (%) is a proportion of the total numbers represented by a single taxa. ET taxa are those identified as Ephemeroptera or Trichoptera.

	Reference	**40th Ave W**	**21st Shallow**	**21st Deep**
Sample n	n=20	n=20	n=48	n=22
Total Abundance (m^2)	15,921±134[b]	20,360±4126[b]	34,857±4579[a]	44,587±5754[a]
% Dominance	44±2.6	49±2.9[bc]	63±2.3[a]	57±2.1[ab]
% Chironomidae	36±3.6[a]	22±2.8[b]	9±1.3[c]	2±0.3[d]
% Oligochaeta	29±3.1[b]	39±3.8[b]	55±3.6[a]	55±2.6[a]
% Non-Insects	57±3.6[d]	75±3.1[c]	91±1.3[b]	98±0.4[a]
Total Taxa	15±0.9[a]	9±1.1[b]	9±0.3[b]	8±0.3[b]
% Collect-Gather Taxa	40±2.5[b]	53±4.7[a]	44±1.3[a]	37±1.8[c]
% Grazer-Scraper Taxa	10±1.5[a]	8±2.2[ab]	8±1.1[b]	13±1.6[a]
% ET Taxa	25±1.3	14±2.7[b]	6±1.5[c]	2±1.3[c]

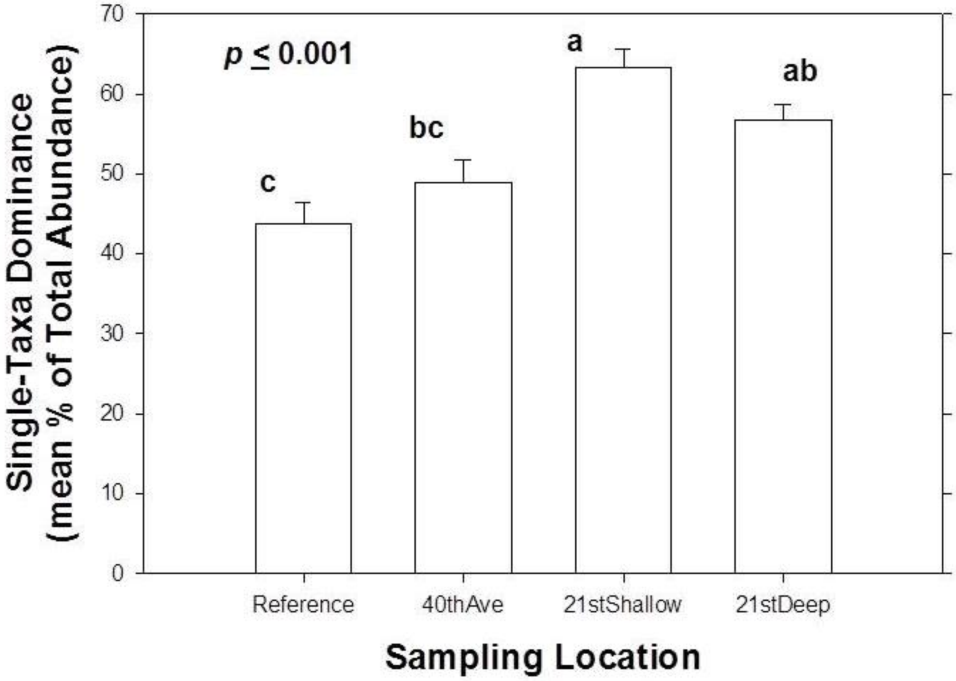


Figure 2.2. Percent dominance by a single macroinvertebrate taxon at St. Louis River Estuary sampling locations. Values represent mean numbers + 1 standard error. *p* value if from the overall ANOVA. Columns with the same letter are not significantly different (α= 0.05) based on Duncan's Multiple Range Test.

The greater abundances but lower taxa richness at the 21st Avenue locations indicates that the assemblages at 21st Avenue may be dominated by a few taxa. This is confirmed by the percent dominance metric, which shows that the 21st Shallow site was significantly more dominated by a single taxon than Reference and 40th Avenue West (Table 2.4, Figures 2.1 and 2.2). Aquatic earthworms (Oligochaeta) comprised 55% of the 21st Shallow and 21st Deep and 40th Avenue West assemblages, which was significantly higher than the percentage of aquatic earthworms at 40th Avenue West (39%) and Reference (29%). All three study locations consisted of significantly greater percentages of non-insects than occurred at Reference, and this percentage was greater than 90% of the total abundance at the 21st Avenue sites. The high percentages of aquatic earthworms and other non-insects suggests habitat conditions that are homogenous and unsuitable to a variety of the taxa observed at Reference, where submergent aquatic vegetation was abundant (Brady et al. 2011).

Midge larvae (Chironomidae:Diptera) found at high abundances are often associated with impacted conditions or depositional sediments (Rosenberg and Resh 1993). In this survey, the Reference Area contained a large proportion of midge larvae (~ 35% of total), which was significantly greater than the other study locations (Table 2.4, Figure 2.3). A large midge population in the Reference Area may be an indication of habitats dominated by fine sediments, rather than anthropogenic disturbance. This supposition is further supported by the higher dominance of aquatic earthworms at the study sites, and the greater occurrence of the more sensitive groups such as mayflies (Ephemeroptera) and caddisflies (Trichoptera) at Reference sites (Table 2.4, Figures 2.1 and 2.4). In contrast, the 21st Deep location contained the fewest midge (Chironomidae) larvae, mayfly, and caddisfly taxa of the four locations (< 2% of total). EPT taxa results are provided for this comparison; this is a common metric identifying all three taxonomic orders, but it should be noted that Plecoptera were not found at any of the four sampling locations in the estuary. This is consistent with Plecoptera primarily occurring in flowing stream habitats, rather than estuarine depositional zones.

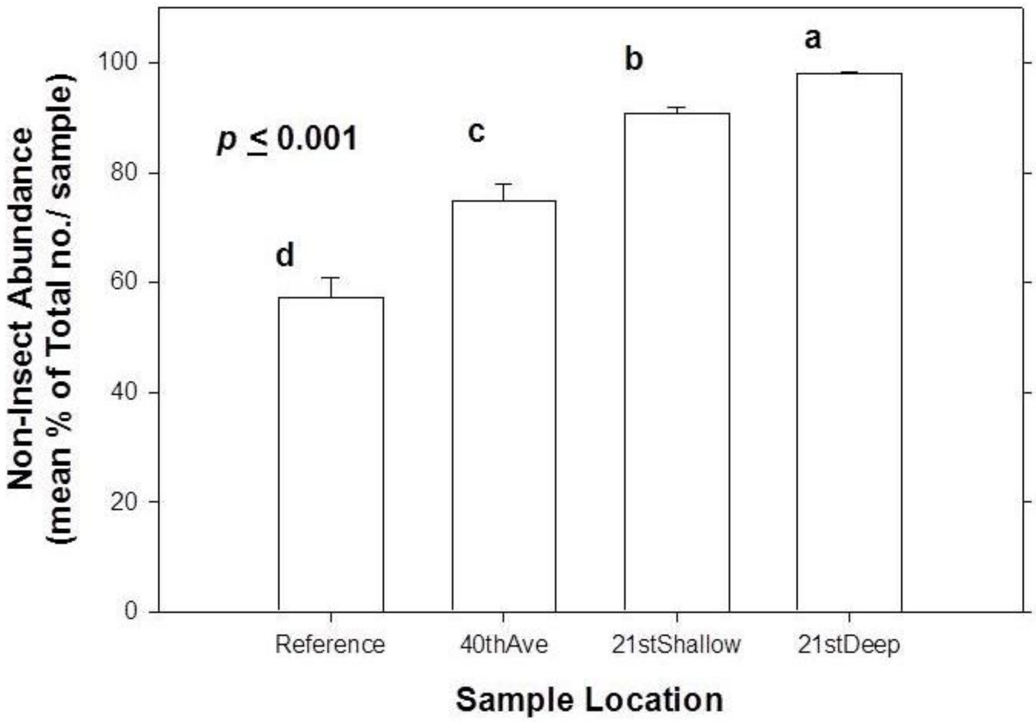


Figure 2.3. Percent non-insect abundance at St. Louis River Estuary sampling locations. Values represent mean numbers + 1 standard error. *p* value if from the overall ANOVA. Columns with the same letter are not significantly different (α= 0.05) based on Duncan's Multiple Range Test.

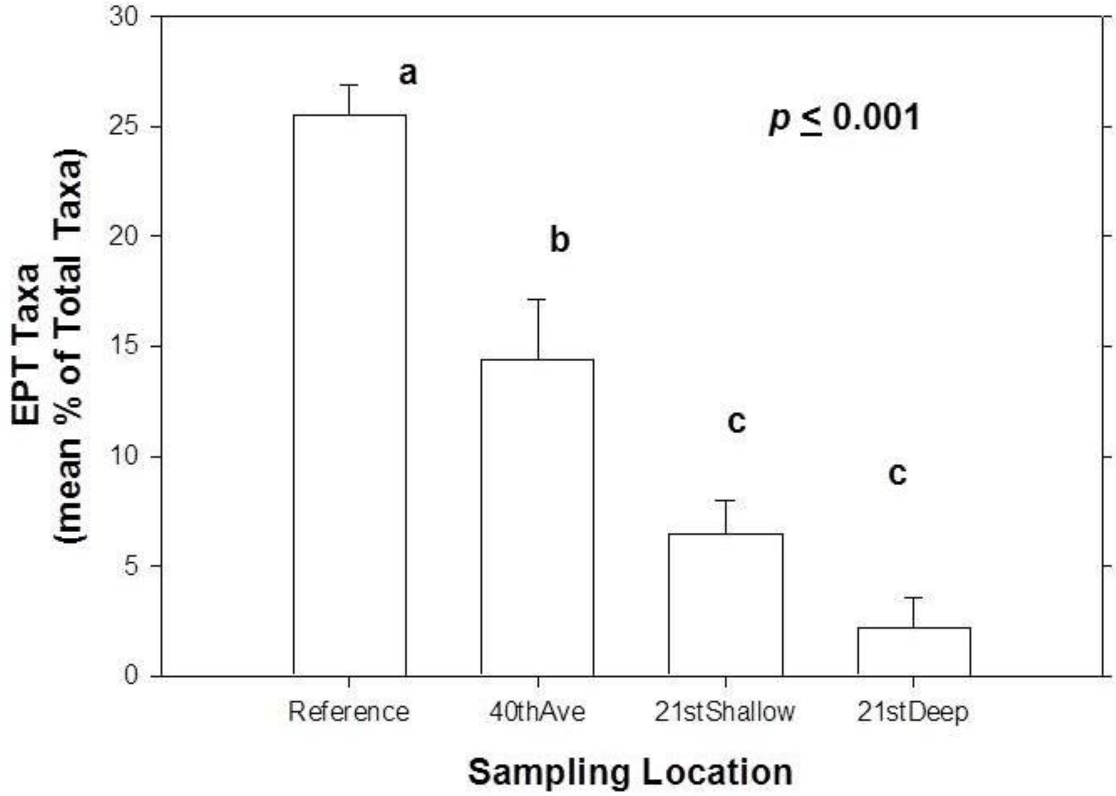


Figure 2.4. Percent abundance of Ephemeroptera and Trichoptera (no Plecoptera were found) per sample collected at four St. Louis River estuary sampling locations. Values represent mean numbers + 1 standard error. *p* value if from the overall ANOVA. Columns with the same letter are not significantly different (α= 0.05) based on Duncan's Multiple Range Test.

Summary and Conclusions

The Project Area macroinvertebrate assemblage is highly dominated by aquatic earthworms (Oligochaeta) and contains fewer aquatic insects, both in abundance and as representative taxa, than the Reference Area. Lower taxa richness, despite greater sampling effort at 21st Shallow, also indicates an assemblage that is not as good as it could be compared to other areas in the estuary. While part of the cause of this impairment may be due to lack of aquatic vegetation, it is not clear that physical habitat characteristics are the sole reason causing impairment. Ruling out legacy toxins in the substrate as a potential source of the problem may be possible when recent sediment contamination analyses become available (MPCA in progress) and sample points are compared to the results provided here.

One favorable observation from this sampling is that the large burrowing mayfly *Hexagenia* was found within the 21st Shallow location (and also found at Reference and 40th Avenue West). (Note also that the family was found within 21st Deep, but could not be identified to genus). However, large shallow areas further into the bay are void of *Hexagenia* even though habitat conditions (e.g., depositional mudflats) would appear to provide suitable refuge (Map 2.1). This mayfly is particularly sensitive to dissolved oxygen, and its presence indicates that dissolved oxygen is not a limiting factor in areas where it occurs. *Hexagenia* are of particular interest to sport fishermen, who often like to fish the “Hex hatch” when the mayfly emerges to become a winged adult. Scientists and managers are interested in *Hexagenia* because it may also serve as a bioaccumulation link in the estuary food web; it is large-bodied, long-lived, and resides with the sediment, and thus in potentially close proximity to legacy toxins, throughout most of its lifecycle.

Appendix 2.1. Depths and substrate types at benthic sampling locations.

Location	Site type	Depth (m)	Secchi Depth (m)	Substrate	Longitude (DD)	Latitude (DD)
D-01	Shallow	3.1	0.8	silt	-92.117757	46.76067233
D-02	Deep	8.8	0.55	silt/sand/organic	-92.11520042	46.75705623
D-03	Deep	7.4	0.5	silt/organic	-92.11521585	46.75525136
D-04	Deep	8.8	0.57	silt/organic	-92.11260066	46.75523111
D-05	Deep	7.5	0.55	silt	-92.12052525	46.75168426
D-06	Deep	7.5	0.65	silt	-92.11787002	46.75346998
D-07	Deep	7.5	0.6	silt/organic	-92.11003367	46.75341669
D-08	Deep	5.6	0.65	silt/organic	-92.10480276	46.75156889
D-09	Deep	7.5	0.72	silt/organic	-92.10484209	46.74976792
D-10	Deep	5.8	0.69	silt/organic	-92.11534646	46.74805775
D-11	Deep	7.9	0.66	silt/organic	-92.11272664	46.74803189
D-12	Deep	10.1	0.69	silt/organic	-92.11011445	46.74801032
S-01	Shallow	0.7	0.7	silt/detritus/SAV	-92.12034471	46.76249289
S-02	Shallow	1.8	0.61	silt/organic	-92.11772777	46.76247274
S-03	Shallow	0.7	0.57	sand/pebble	-92.12299766	46.76070551
S-04	Shallow	1.5	0.6	silt/zebra mussels	-92.12036739	46.76068869
S-05a	Shallow	2	0.7	silt/muck	-92.12014121	46.75889496
S-06	Shallow	1.3	0.68	silt/organic	-92.12306766	46.75710525
S-07	Shallow	1.7	0.52	organic/silt	-92.12044739	46.75708729
S-08	Shallow	0.7	0.58	silt/sand/wood	-92.12569558	46.75532773
S-10	Shallow	1.5	0.55	organic/silt	-92.12046687	46.75528766
S-11	Shallow	0.5	0.5	sand/silt	-92.12312601	46.75350828
S-12	Shallow	2.9	0.6	silt	-92.12048272	46.75349259
S-13	Shallow	2.6	0.52	silt/organic	-92.11515966	46.75884539
S-14	Shallow	1.6	0.6	silt	-92.11790328	46.75166902
S-15	Shallow	1.7	0.58	silt	-92.11527596	46.75165301
S-16	Shallow	1.6	0.65	silt	-92.11266375	46.75163278
S-17	Shallow	1.6	0.6	silt	-92.11005161	46.75160822
S-18	Shallow	1.8	0.6	silt/organic	-92.11792687	46.74986416
S-19	Shallow	0.9	0.61	sand/clay	-92.11531668	46.74985075
S-20	Shallow	0.6	0.58	sand/silt	-92.11270348	46.74983052
S-21	Shallow	0.5	0.68	sand	-92.11008868	46.74980677
S-22	Shallow	1.7	0.6	silt/organic	-92.12058088	46.74808695
S-23	Shallow	1.9	0.66	silt/organic	-92.11795619	46.74806675
S-24	Shallow	3	0.6	silt/organic/zebra mussels	-92.10739942	46.75338884

Appendix 2.2. Taxa lists for each site sampled by NRRI, shown in alignment for easier comparison. Taxa richness for each site is at the bottom of the table.

Ref	21st-Shall	21st-Deep	40th Ave	Taxa	Class	Order	Family
X	X	X	X	Nematoda			
	X	X		Erpobdellidae	Clitellata	Arhynchobdellida	Erpobdellidae
	X	X		Hirudinea	Clitellata	Hirudinea	
X	X	X	X	Oligochaeta	Clitellata	Oligochaeta	
X	X		X	Glossiphoniidae	Clitellata	Rhynchobdellida	Glossiphoniidae
		X		Piscicolidae	Clitellata	Rhynchobdellida	Piscicolidae
X	X	X	X	Polychaeta	Polychaeta		
X	X	X	X	Acari	Arachnida	Acari	
X	X			Caecidotea	Crustacea	Isopoda	Asellidae
X			X	Physella	Gastropoda	Basommatophora	Physidae
			X	Dytiscidae	Insecta	Coleoptera	Dytiscidae
	X			Dubiraphia	Insecta	Coleoptera	Elmidae
X				Gyrinus	Insecta	Coleoptera	Gyrinidae
			X	Haliplus	Insecta	Coleoptera	Haliplidae
			X	Bezzia	Insecta	Diptera	Ceratopogonidae
X	X	X	X	Probezzia	Insecta	Diptera	Ceratopogonidae
X				Serromyia	Insecta	Diptera	Ceratopogonidae
	X	X	X	Chaoborus	Insecta	Diptera	Chaoboridae
X			X	Chironomidae	Insecta	Diptera	Chironomidae
	X	X		Chironominae	Insecta	Diptera	Chironomidae
	X	X		Orthocladiinae	Insecta	Diptera	Chironomidae
	X	X		Tanypodinae	Insecta	Diptera	Chironomidae
			X	Empididae	Insecta	Diptera	Empididae
X				Baetidae	Insecta	Ephemeroptera	Baetidae
X				Brachycercus	Insecta	Ephemeroptera	Caenidae
X	X		X	Caenis	Insecta	Ephemeroptera	Caenidae
		X		Ephemeridae	Insecta	Ephemeroptera	Ephemeridae
X	X		X	Hexagenia	Insecta	Ephemeroptera	Ephemeridae
	X	X		Phylocentropus	Insecta	Hemiptera	Corixidae

			X	Trichocorixa	Insecta	Lepidoptera	
X				Paraponyx	Insecta	Lepidoptera	Pyralidae
			X	Lepidoptera	Insecta	Lepidoptera	
X				Sialis	Insecta	Megaloptera	Sialidae
X	X		X	Coenagrionidae	Insecta	Odonata	Coenagrionidae
X				Somatochlora	Insecta	Odonata	Corduliidae
X			X	Phylocentropus	Insecta	Trichoptera	Dipseudopsidae
X			X	Hydroptila	Insecta	Trichoptera	Hydroptilidae
X				Nectopsyche	Insecta	Trichoptera	Leptoceridae
X	X	X	X	Oecetis	Insecta	Trichoptera	Leptoceridae
X				Molanna	Insecta	Trichoptera	Molannidae
X	X			Polycentropus	Insecta	Trichoptera	Polycentropodidae
X	X		X	Gammarus	Malacostraca	Amphipoda	Gammaridae
X	X		X	Hyalella	Malacostraca	Amphipoda	Hyalellidae
X	X			Hydra	Hydrozoa	Hydroida	Hydridae
	X			Corbicula	Bivalvia	Veneroida	Corbiculidae
X	X	X	X	Dreissena	Bivalvia	Veneroida	Dreissenidae
X	X	X	X	Sphaeriidae	Bivalvia	Veneroida	Sphaeriidae
X				Viviparidae	Gastropoda		Viviparidae
	X			Planorbidae	Gastropoda	Basommatophora	Lymnaeidae
X				Planorbella	Gastropoda	Basommatophora	Planorbidae
			X	Pseudosuccinea	Gastropoda	Basommatophora	Planorbidae
X			X	Ferrissia	Gastropoda	Gastropoda	
			X	Gyraulus	Gastropoda	Limnophila	Ancylidae
X				Helisoma	Gastropoda	Limnophila	Planorbidae
	X	X	X	Hydrobiidae	Gastropoda	Mesogastropoda	Hydrobiidae
X				Potamopyrgus	Gastropoda	Mesogastropoda	Hydrobiidae
X	X	X	X	Valvata	Gastropoda	Mesogastropoda	Valvatidae
X				Unionidae	Pelecypoda	Unionoida	Unionidae
X	X	X	X	Turbellaria	Turbellaria		
	X	X	X	Tardigrada			
38	**31**	**21**	**32**		**Taxa Richness**		

Literature Cited

Brady, Valerie, Carol Reschke, Dan Breneman, George Host and Lucinda Johnson. 2011. 40th Avenue West Remediation Project: Biological Survey Results. Natural Resources Research Institute, University of Minnesota Duluth, Technical Report- NRRI/TR-2010/24. 21 pp.

Breneman, Dan. 1999. Standard Operating Procedures (SOP): Aquatic Field Collection Guidelines, Habitat Characterization, Benthic Sample Processing. Natural Resources Research Institute, University of Minnesota Duluth, Technical Report, NRRI/TR-99/37, 17 p.

Cowardin, L. M., V. Carter, F. C. Golet, E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/wetlands/classwet/index.htm (Version 04DEC1998).

Eggers, Steve D., and D. M. Reed. 1997. Wetland plants and communities of Minnesota and Wisconsin. U.S. Army Corps of Engineers, St. Paul District. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/plants/mnplant/index.htm (Version 03SEP1998).

Merritt, R.W., K.W. Cummins, and M.B. Berg. 2008. An introduction to the aquatic insects of North America, fourth ed. Kendall/Hunt Publishing Co., Dubuque, IA. 1158 pp.

Millar, J. B. 1973. Vegetation changes in shallow marsh wetlands under improving moisture regime. Canadian Journal of Botany 51: 1443-1457.

MnBWSR. 2010. Comprehensive Guidance for Minnesota Routine Assessment Method (MnRAM) Evaluating Wetland Function, Version 3.4 (beta). The report is available for download at: http://www.bwsr.state.mn.us/wetlands/mnram/index.html .

MnDNR. 2003. Field Guide to the Native Plant Communities of Minnesota: the Laurentian Mixed Forest Province: http://www.dnr.state.mn.us/npc/classification.html .

MnDNR. 2010. Minnesota Department of Natural Resources County Record Checklist 2010. The report is available for download at: http://www.dnr.state.mn.us/eco/mcbs/plant_lists.html .

NRRI (Natural Resources Research Institute). 2010. Great Lake Environmental Indicators (GLEI) Standard Operating Procedures: Fish and Invertebrate Community Sampling. NRRI/TR-2010/15, 24 p.

Rosenberg, D.M. and V.H. Resh. 1993. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall, London. 488 p.

SAS, 1988. Statistical Anaylsis Software (SAS/STAT), SAS Institute Inc., Cary, NC.

Thorp, J.H., and A.P. Covich. 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, San Diego, CA. 911 pp.

Thorp, J.H., and A.P. Covich. 2010. Ecology and classification of North American freshwater invertebrates. 3rd Edition. Academic Press, San Diego, CA. 1021 pp.

USEPA (U.S. Environmental Protection Agency). 2003. Standard operating procedures (SOP): collection of benthic macroinvertebrate samples and sediment samples using a Ponar sampler. MED-D-SOP-PONAR, FIE-0044, Revision No. 1.

Appendix 3. Avian Community Surveys (G. Niemi, A. Bracey)

Introduction

This report presents information on bird surveys gathered during the spring migration, breeding season, and fall migration 2012 at the Project Area site in the St. Louis River estuary, Duluth, Minnesota (Map 3.1). The St. Louis River estuary and Minnesota Point were recently nominated and jointly accepted as a Minnesota Important Bird area by Minnesota Audubon (Green and Niemi 2011). Details on the use, distribution, and abundance of birds in the St. Louis River estuary and Minnesota Point can be found in that document. A thorough inventory of bird use in the St. Louis River estuary was last completed in 1979 (Niemi et al. 1979) and breeding bird species were briefly inventoried in 1999 (Niemi et al. 2000). The 40th Avenue West area, an area just southwest of the Project Area site, was surveyed in 2010 and 2011 for both breeding and migrating birds to estimate the number of species and individuals utilizing the area. The resulting distribution and abundance of species observed at this area can be found in Niemi et al. (2011). Our objectives, consistent with those of the 40th Avenue West project, were to 1) complete an inventory of the birds using the Project Area site during spring and fall (migration) and summer (breeding), 2) summarize this information, especially the spatial use of the area by species that require water such as waterfowl, waterbirds, and shorebirds, as well and use by raptors, gulls, and songbirds, and 3) recommend considerations for restoration activities at the site relative to bird use.

Methods

Accessing the Project Area project location to conduct bird surveys was difficult primarily due to accessibility issues such as private land ownership. We were granted permission from WLSSD, located on 26th Avenue West, to access several of our survey sites from their facilities. The locations within WLSSD provided a nearly complete view of the project area and long distance visibility. Survey techniques used at the 40th Avenue West site proved to be an effective way of inventorying bird use in the area and was therefore also used for surveys at the Project Area site. Weekly surveys were conducted during spring migration (March-May), breeding season (June-July), and fall migration season (August-November) in 2012. A total of 5 survey locations were established within the Project Area study area (Figure 3.1). Weekly counts were conducted at each survey point to determine species identity and spatial location (habitat use) of individuals in the area. Niemi et al. (1979; 2011) found that these survey techniques are most effective for species associated with water and the shoreline such as for waterfowl, waterbirds, and shorebirds, but less so for songbirds, raptors, and gulls that are making frequent movements through the area, especially during migration.

Surveys were completed by individuals experienced in conducting avian field surveys, during early morning hours when weather conditions were suitable (e.g., minimal wind or precipitation). All data collected during the spring surveys in 2012 were simultaneously collected by Josh Bednar, Edmund Zlonis, and Annie Bracey. Breeding season data were collected by Gerald Niemi, and fall data was collected by Josh Bednar and Annie Bracey. Surveys were completed by systematic reconnaissance at each of the five survey locations using binoculars and a spotting scope. All bird observations were identified to specific locations on aerial photo field sheets; accuracy was approximately 25 m in open water and 10 m near or on shore. All individual birds or groups of birds observed were digitized into a geographic information system to represent the spatial distribution and habitat use of species observed within the site. Flyover observations of migrating birds obviously not using the study area were not included. Birds were grouped into seven species guilds (corvid, gull, raptor, shorebird, songbird, waterbird, and waterfowl) to simplify mapping and habitat use characterizations. Waterbirds included a diverse group of bird species associated with water: grebes, rails, cormorants, herons, egrets, mergansers, and kingfisher. Waterfowl were restricted to ducks and geese, while mergansers were included in the waterbird group primarily because mergansers are not frequently hunted.

Figure 3.39. Distribution of observation points in the Project Area study area in the St. Louis River estuary, Duluth, MN.

Results

A total of 81,522 bird observations were made during the weekly sampling periods during spring migration, breeding season, and fall migration 2012 in the Project Area study area. The majority of these observations were of American Crow, Ring-billed Gull, Herring Gull, European Starling, and Canada Goose. These species accounted for 75,451 observations (Table 3.5), most of which represent counts of the same individuals during multiple visits. The results for these species will be discussed below, but they represent a major ornithological problem in the area that will need to be seriously considered in any restoration of the area.

We focus the majority of this report on the remaining 6,071 bird observations of the other species identified within the study area (Table 3.1, Figure 3.2). Observations of individuals are color-coded by bird group (Figure 3.2) to show the distribution pattern of different species over the course of the survey period. The majority of observations for species within all groups were in shallow near shore habitats, whereas the more open water areas of the bay were only lightly used by waterfowl and waterbirds. Fewer individual waterfowl were counted in spring 2012 compared to fall 2012 surveys. Because surveys were conducted from the same observation points weekly, some bias exists due to the probability that many of the same individuals were counted on multiple occasions, particularly gulls and certain species of waterfowl (e.g. Canada goose). Therefore, results are presented using the average number of individuals observed per guild per season within the study area. The highest average concentrations include 1) two shallower bays in the area northeast of WLSSD (sites1 and 4, Figure 3.1), 2) the shallow discharge site along the peninsula within the WLSSD complex (site 2, Figure 3.1), and 3) the shallow bay to the west of WLSSD (site 3, Figure 3.1). In addition, there were several species using Interstate Island (See Section VII).

The species that we decided to exclude from the guild analysis were chosen because we assumed that their distributions would add little to this report. They included many flyovers and species with highly variable movement patterns. However, because these species are prolific in the area, their presence could influence the extent to which other target species are able to utilize the area. Therefore, a summary of the distribution and abundance of each of these species is provided at the end of the report (Tables 5; Figures 18-21).

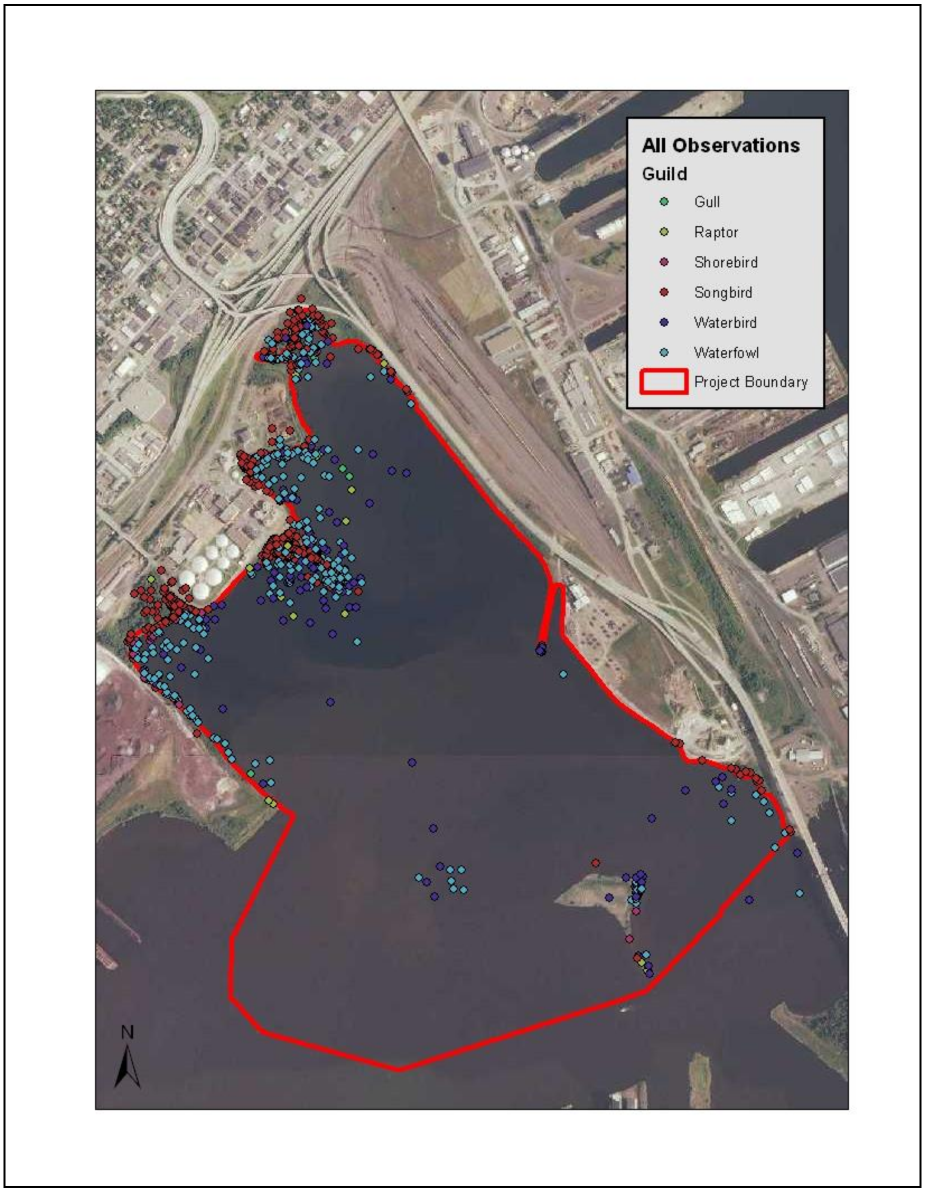


Figure 3.40. Distribution of all bird observations included in analysis at the Project Area remediation site in the St. Louis River estuary in Duluth, Minnesota during spring, summer, and autumn 2012 surveys.

Spring Migration 2012

There were a total of 2,654 individual birds recorded during the spring migration season, between 7 March and 26 May, 2012 (Table 3.1). The total number of individuals observed within each guild and the species that comprised the largest number of observations within each guild included; 334 gulls (100 Bonaparte's Gull), 7 raptors (6 Bald Eagle), 44 shorebirds (35 Willet), 309 songbirds (88 Song Sparrow), 356 waterbirds (240 Double-crested Cormorant), and 1,604 waterfowl (955 Mallard). This total represented 51 bird species, of which there was one species of corvid, 3 gull species, 2 raptor species, 3 shorebird species, 18 songbird species, 9 waterbird species, and 12 waterfowl species (Table 2). The highest number of total observations was recorded on 4 April 2012 (512 birds). The species with the highest number of observations was the Mallard with 463 total observations. The maximum one-day count of Mallard was 469 birds on 7 March 2012.

Waterfowl Observations

The highest average concentrations in the study area include 1) the shallow discharge site along the peninsula within the WLSSD complex (site 2, Figure 3.1), and 2) intermediate to deep water habitat in the southwest portion of the study area (just northwest of Interstate Island; Figure 3.3).Waterfowl were also present in the bay west of WLSSD (site 3, Figure 3.1), and in the bay northeast of WLSSD (site 4, Figure 3.1). Primary species found in these areas were puddle ducks such as Green-winged Teal and Mallard. Diving ducks such as Bufflehead, Ring-necked duck, and Common Goldeneye were also observed throughout much of the shallow nearshore areas. Waterfowl use of the deeper water areas was relatively limited, we observed Lesser Scaup and Redhead (albeit in low abundance) in deeper off shore waters. In addition, there were several species using the area on and around Interstate Island (primarily Mallards).

Waterbird, Shorebird, and Gull Observations:

Waterbird use in spring 2012 was similar to use of the area by waterfowl though overall density was lower. The greatest concentration was near the shallow discharge site along the peninsula within the WLSSD complex (site 2, Figure 3.1) and near Interstate Island (primarily Double-crested Cormorant; Figure 4). Waterbird species of interest included; Common Merganser, Hooded Merganser, Common Tern, Caspian Tern, Pied-billed Grebe, and Great Blue Heron. Shorebird species included Killdeer, Spotted Sandpiper, and Willet. The largest observation of shorebirds was on 2 May 2012, when 35 Willet were observed on the shallow sand flats northeast of WLSSD near site 4 (Figure 3.1). The remaining observations were scattered among the shorelines within sites 1-3 (Figure 3.5). Excluding Ring-billed Gulls and the Herring Gulls which were seen in large numbers, there were several gull species of interest including Bonaparte’s Gulls, Glaucous Gulls, and a Lesser Black-backed Gull, most of which were observed near site 4 in the bay northeast of WLSSD (Figure 3.6).

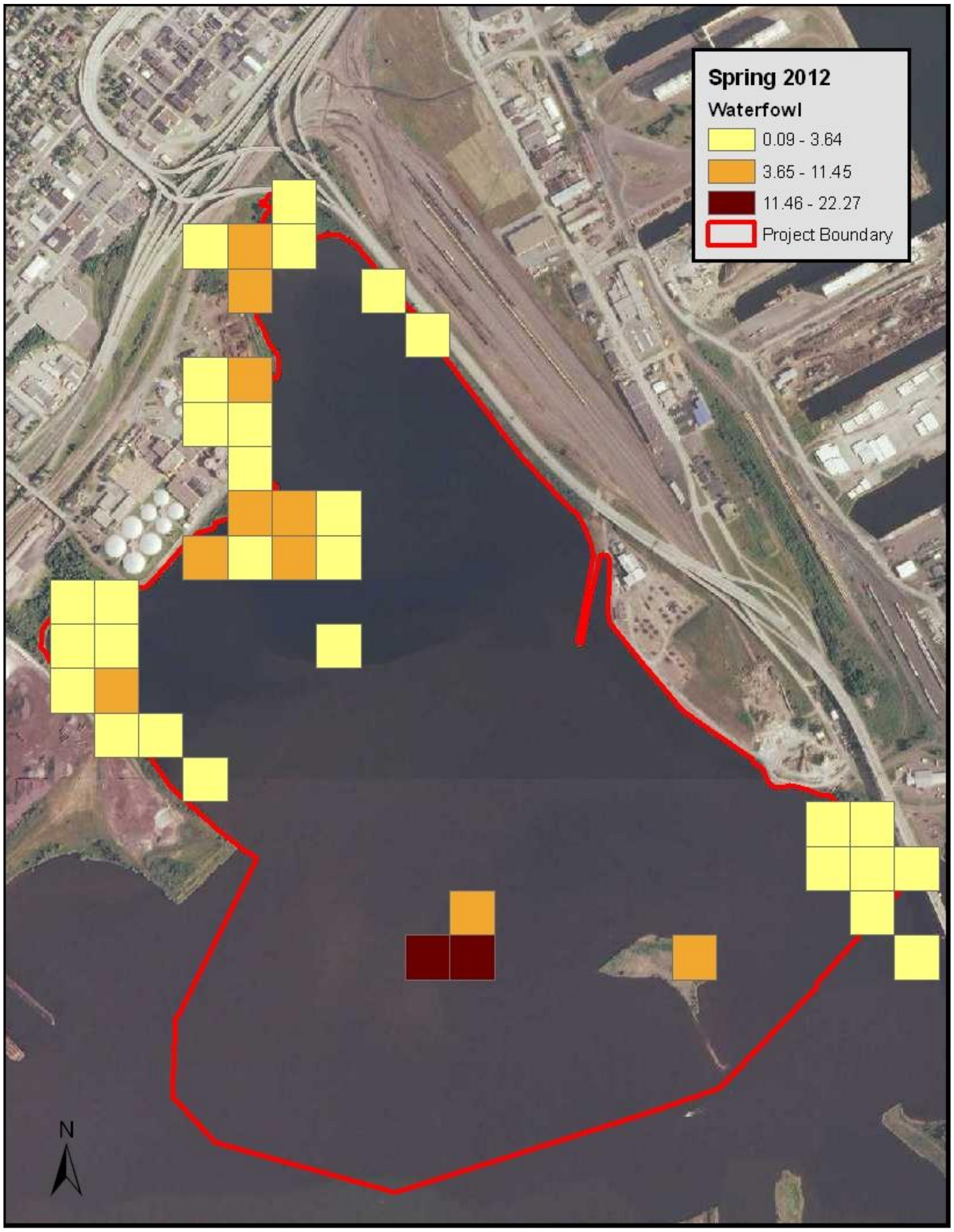


Figure 3.3. Average number of waterfowl observations per 10,000m^2 during spring migration 2012 at the Project Area remediation site in the St. Louis River estuary, Duluth, Minnesota.

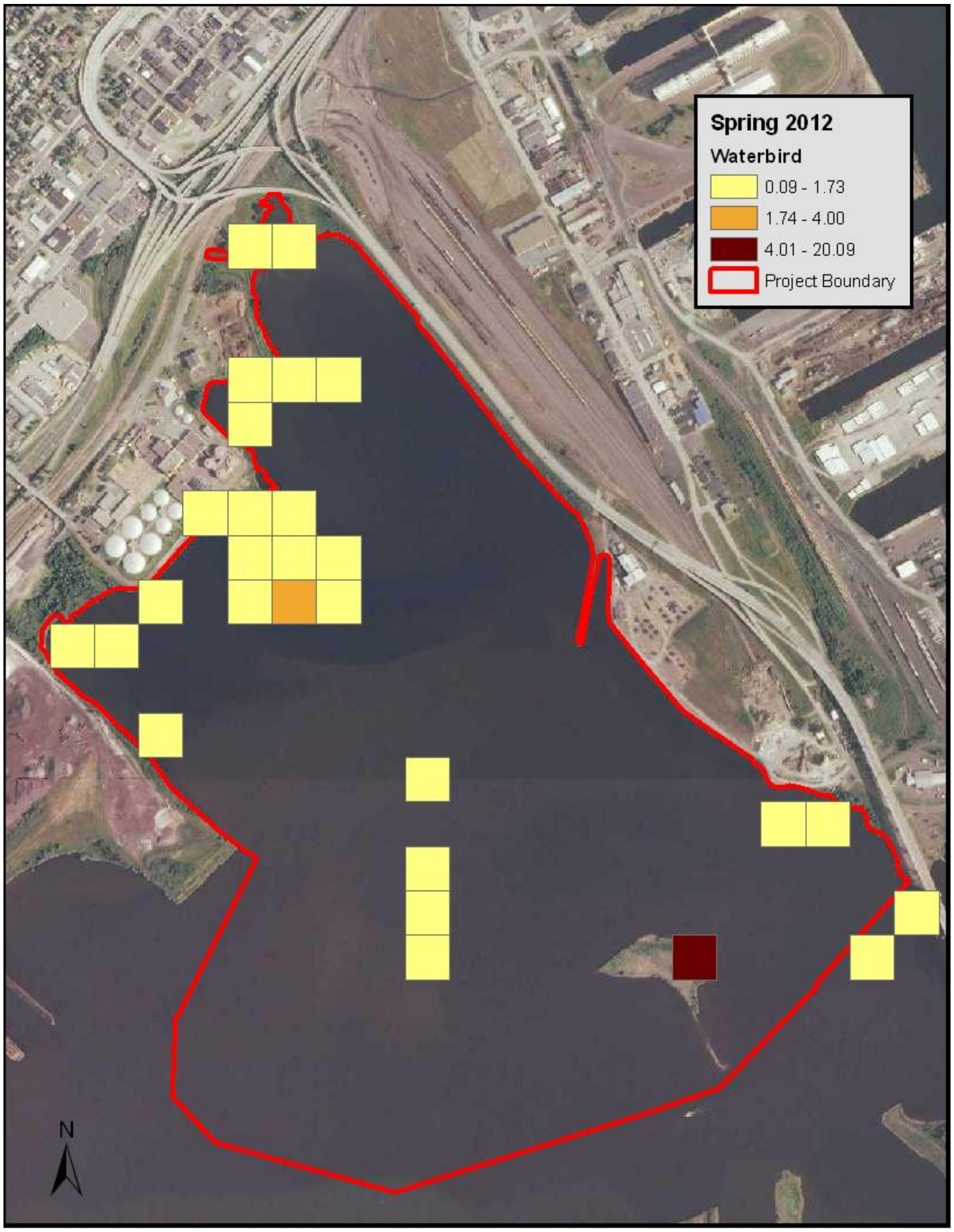


Figure 3.4. Average number of waterbird observations per 10,000m^2 during spring migration 2012 at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota.

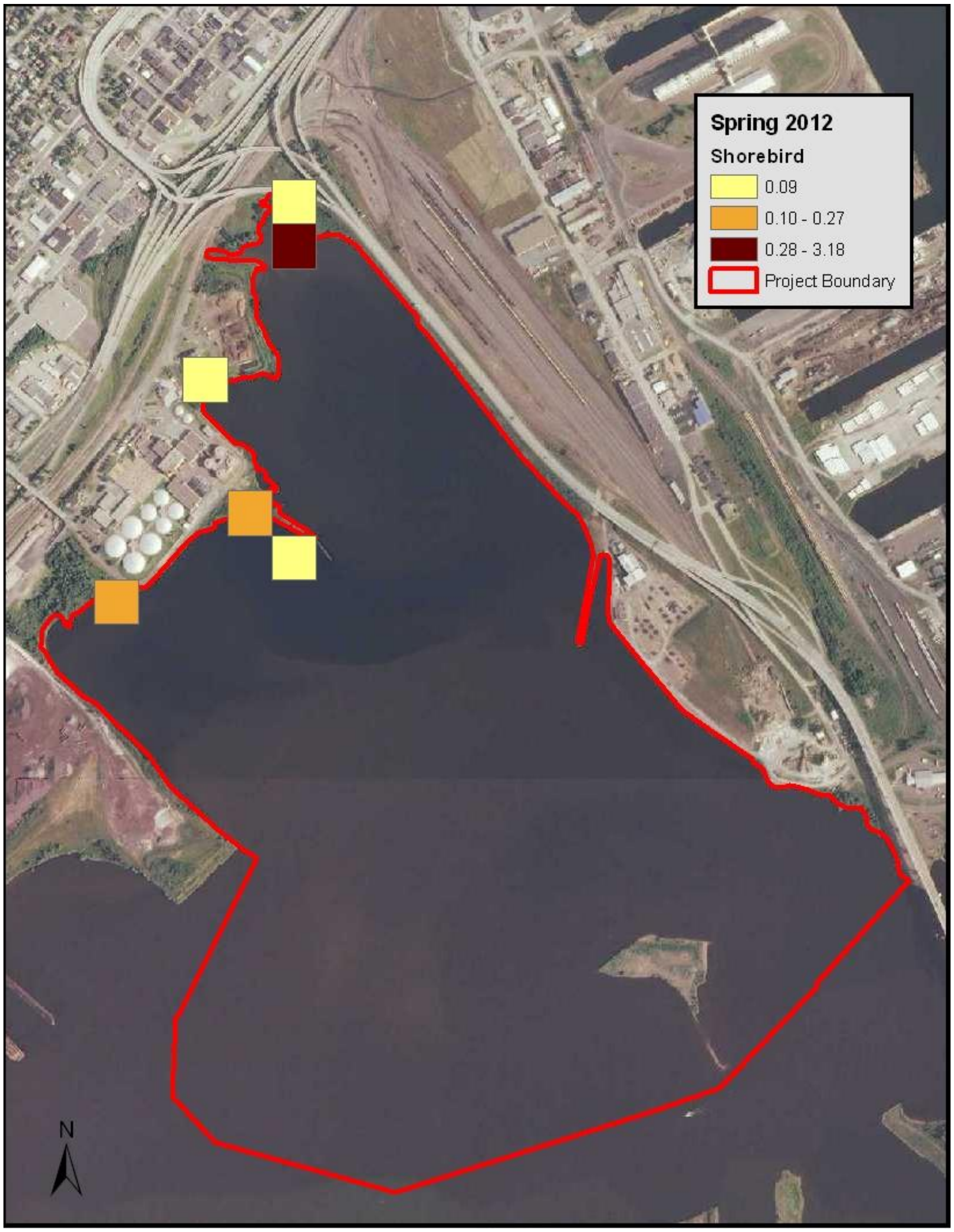


Figure 3.5. Average number of shorebird observations per 10,000m^2 during spring migration 2012 at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota.

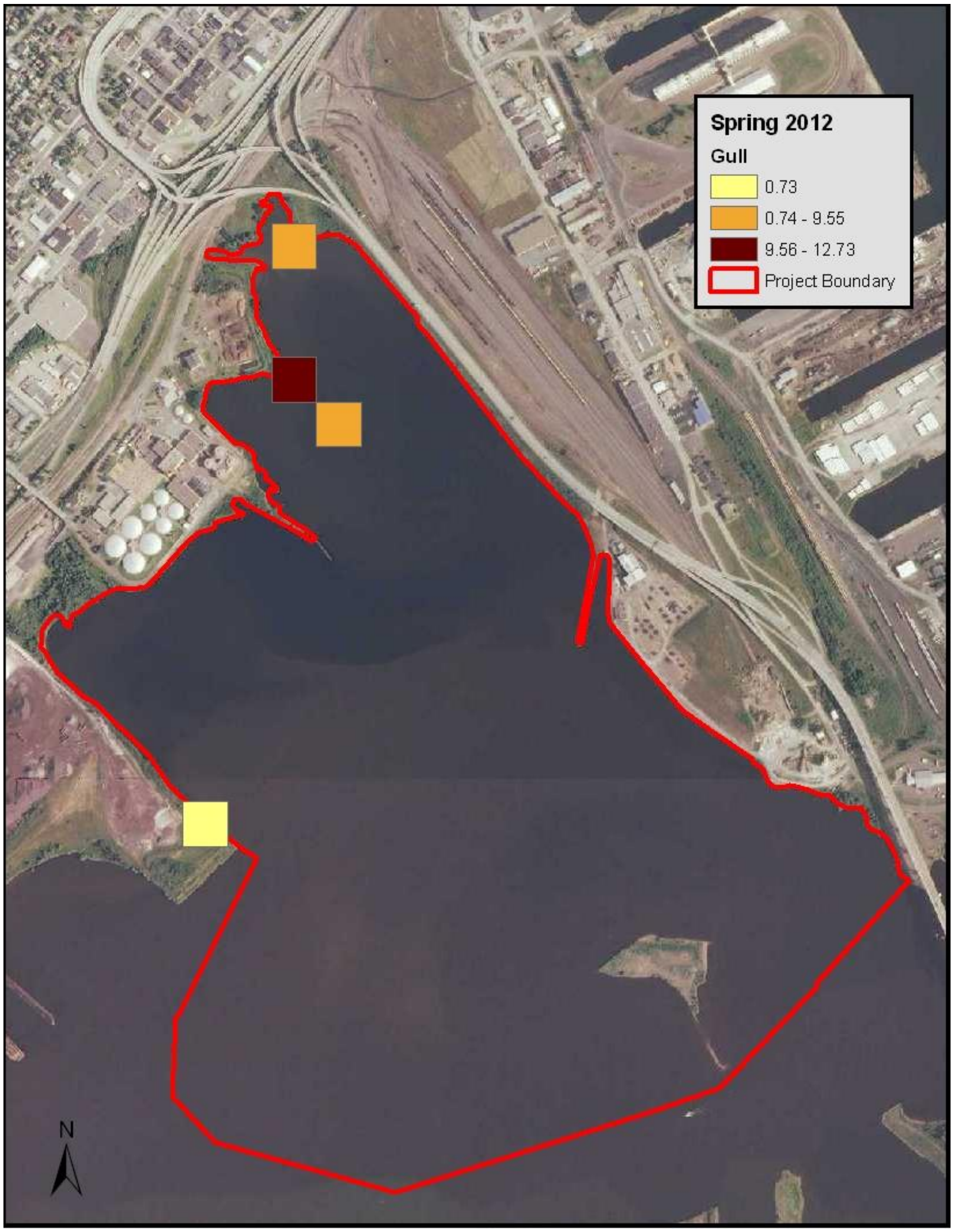


Figure 3.6. Average number of gull observations per 10,000m^2 during spring migration at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota. These observations exclude both Ring-billed Gull and Herring Gull observations.

Summer Breeding Season 2012

Excluding the aforementioned species (e.g., Canada Geese and Ring-billed Gulls), a total of 333 individual birds were recorded during the breeding season, between 4 June and 8 July, 2012 (Table 1). The total number of individuals observed within each guild and the species that comprised the largest number of observations within each guild included; 5 shorebirds (4 Spotted

Sandpiper), 59 waterbirds (32 Common Tern), 72 songbirds (22 Song Sparrow), and 197 waterfowl (192 Mallard). This total represented 17 bird species, of which there was one shorebird species (and one unidentified individual), 5 waterbird species, and 4 waterfowl species (Table 3.1). The highest number of total observations was recorded on 13 June, 2012 (194 birds). The species with the highest number of observations was the Mallard with 137 total observations, which was the maximum one-day count for Mallard during the breeding season.

Waterfowl Observations

The highest average concentrations of summer waterfowl in the study area were found in 1) the shallow bay northeast of WLSSD (site 4, Figure 3.1), and 2) in the bay and near the shoreline along the western boundary of the study site (across from site 3; Figure 3.7). There were also observations near the shallow discharge site along the peninsula within the WLSSD complex (site 2, Figure 3.1). Mallard was the dominant species found in these areas. Other observed species included Northern Shoveler, Wood Duck, and Lesser Scaup. Of these species, Mallard were nesting in the area while Wood Duck (a hole-nesting species) and Northern Shoveler may be nesting within the study area or in the surrounding area; however, no nest searches were conducted. There were a large number of Canada Geese pairs observed during the spring surveys, particularly along the peninsula (site 2, Figure 3.1) and along the shoreline in tall grass near sites 1 and 4 (Figure 3.1). Multiple nests were observed along the narrow peninsula protruding from the WLSSD site, several with eggs present.

Waterbird and Shorebird Observations

Waterbird use in the study area during the 2012 breeding season followed the patterns of use observed in the area during spring 2012 surveys. The largest concentration was that of Double-crested Cormorant and Common Tern on Interstate Island. The majority of Interstate Island is inhabited by nesting gulls, primarily Ring-billed Gulls. In spring and summer of 2012 there were 14,383 nesting pairs of Ring-billed Gulls and 30 nesting pairs of Herring Gulls on Interstate Island; both are record highs on the island since 2000 (Fred Strand, Wisconsin DNR, pers. comm). Common Terns also exclusively have been nesting on Interstate Island in the entire St.

Louis River Estuary in recent years. Typically around 200 nests have been found counted on Interstate Island and around 300 in 2011, but this year all nesting failed due to predation by an unknown predator or predators (Fred Strand, WDNR, pers. comm.). Mortality was also high in 2011 but primarily due to prolonged cold and wet weather at the peak of hatching in mid-June (Fred Strand, WDNR, pers. comm.). Common Terns were observed foraging in the area near the shallower bays northeast of WLSSD and near the shallow discharge site along the peninsula within the WLSSD complex (site 2; Figure 8). The three most abundant species of waterbird observed were Common Tern, Double-crested Cormorant, and Red-breasted Merganser. Other documented species include Common Loon and Great Blue Heron. One shorebird species, the Spotted Sandpiper, was observed during the breeding season surveys and is likely a nesting species within the study area and throughout the St. Louis River (Figure 9). There was also one unknown shorebird observed on Interstate Island during the summer breeding survey.

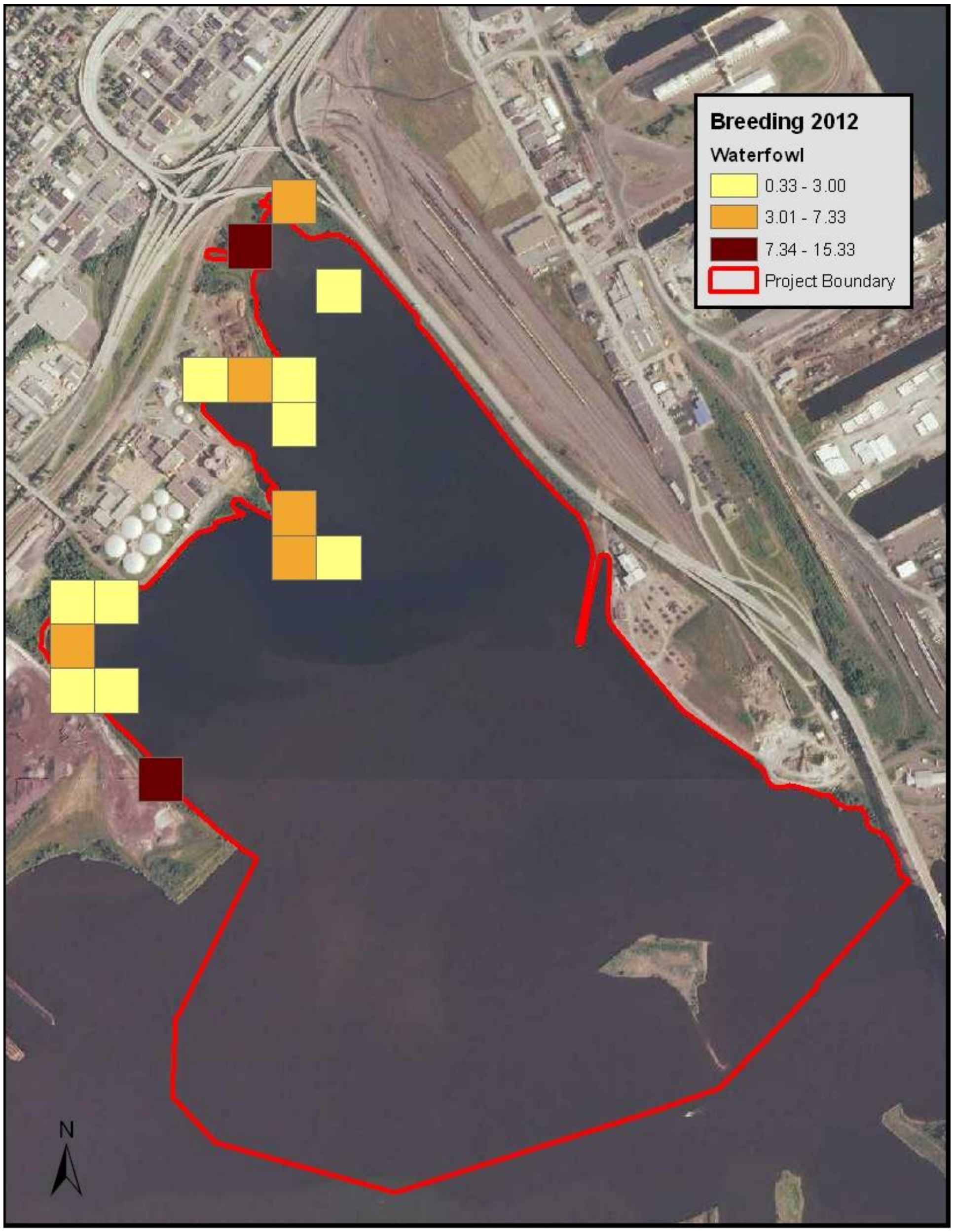


Figure 3.7. Average number of waterfowl observations per 10,000m^2 during the breeding season 2012 at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota.

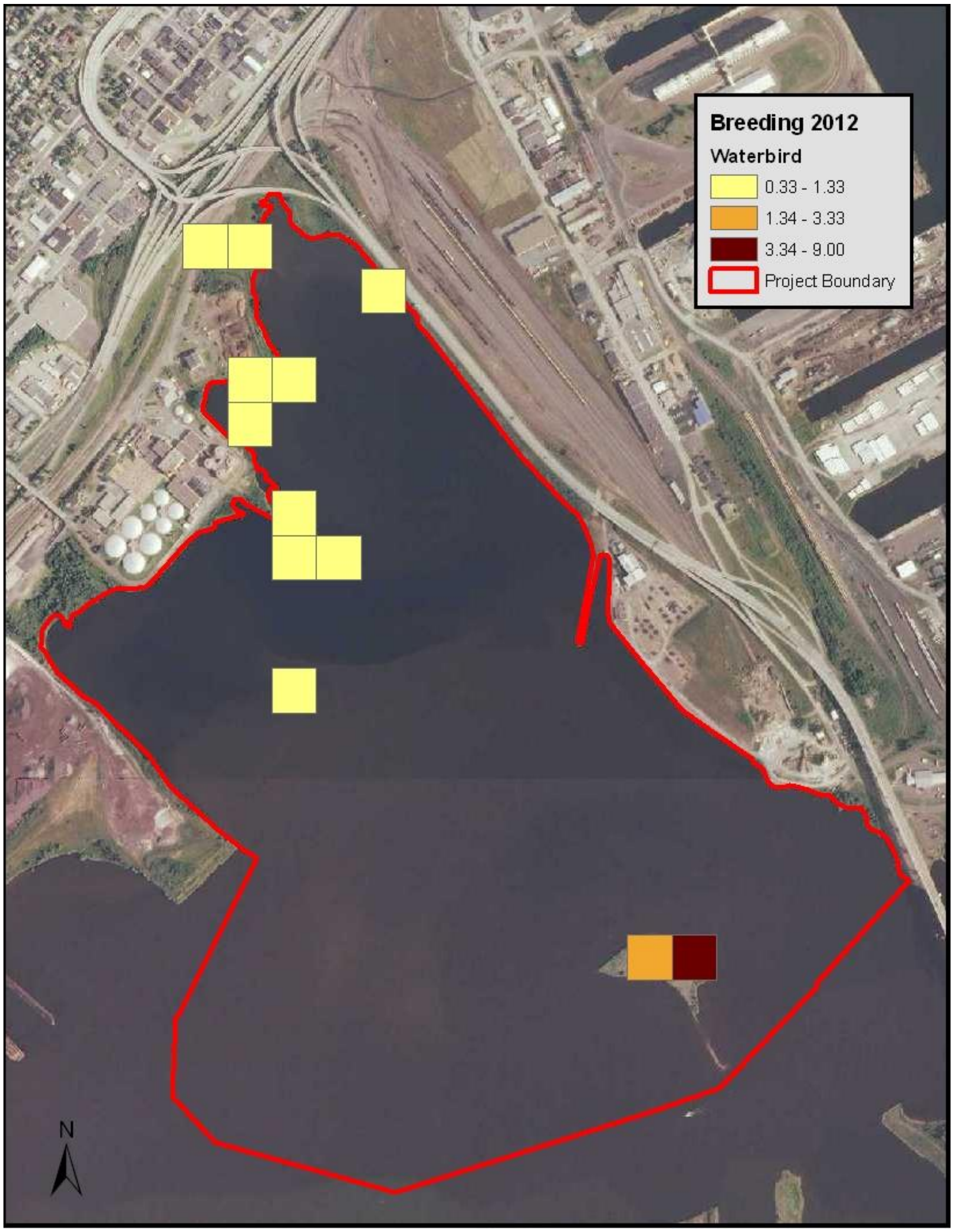


Figure 3.8. Average number of waterbird observations per 10,000m^2 during the breeding season 2012 at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota.

Figure 3.9. Average number of shorebird observations per 10,000m^2 during the breeding season 2012 at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota.

Fall Migration 2012

A total of 3,084 individual birds were recorded during the fall migration season between 28 August and 8 November, 2012 (Table 3.1). The total number of individuals observed within each guild and the species that comprised the largest number of observations within each guild included; 14 raptors (10 Bald Eagle), 21 shorebirds (13 Spotted Sandpiper), 235 waterbirds (175

Double-crested Cormorant), 612 songbirds (128 White-throated Sparrow), and 2,202 waterfowl (2,217 Mallard). This total represented 22 bird species, of which there was one species of corvid, 4 raptors, 3 shorebirds, 9 waterbirds, and 5 waterfowl (Table 4). The highest number of total observations was recorded on 31 October 2012 (417 birds). The species with the highest number of observations was Mallard with 378 total observations which was also the maximum one-day count for Mallard.

Waterfowl Observations

The highest average concentrations of fall waterfowl in the study area were found in 1) the shallow discharge site along the peninsula within the WLSSD complex (site 2, Figure 3.1), 2) the bay west of WLSSD (site 3, Figure 3.1), and 3) the bay northeast of WLSSD (site 4; Figure 3.10). Primary species found in these areas were Green-winged Teal and Mallard. There were also singular observations of Northern Shoveler and Lesser Scaup scattered throughout the nearshore areas of the study site. Waterfowl use of the deeper water areas was very limited.

Waterbird and Shorebird Observations

The greatest concentration of waterbirds in the study area during the fall 2012 surveys was by Double-crested Cormorants on Interstate Island and on a dock located along the eastern shoreline (Figure 3.11). The remaining waterbird observations were primarily near the shallow discharge site along the peninsula within the WLSSD complex (site 2, Figure 3.1) and scattered among the shallower bays along the northern shoreline of the study area (Figure 3.11). Waterbird species of interest included; Red-breasted Merganser, Hooded Merganser, Common Merganser, Great Blue Heron, Pied-billed Grebe, American Coot, Belted Kingfisher, and one American White Pelican. The three shorebird species observed during the surveys were Lesser Yellowlegs, Spotted Sandpiper, and Semipalmated Sandpiper. With the exception of one observation (unidentified shorebird) on Interstate Island, all other shorebirds were observed within the shallow bay southwest of WLSSD near site 3 (Figure 3.12).

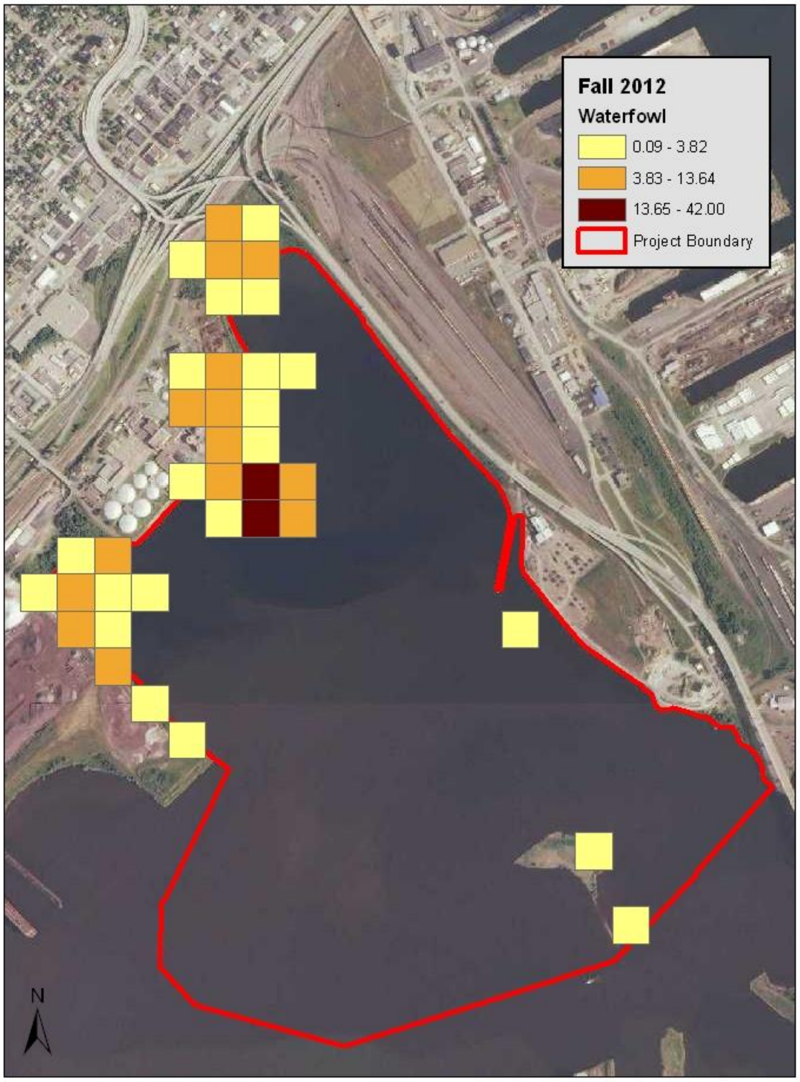


Figure 3.10. Average number of waterfowl observations per 10,000m^2 during the fall season 2012 at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota.

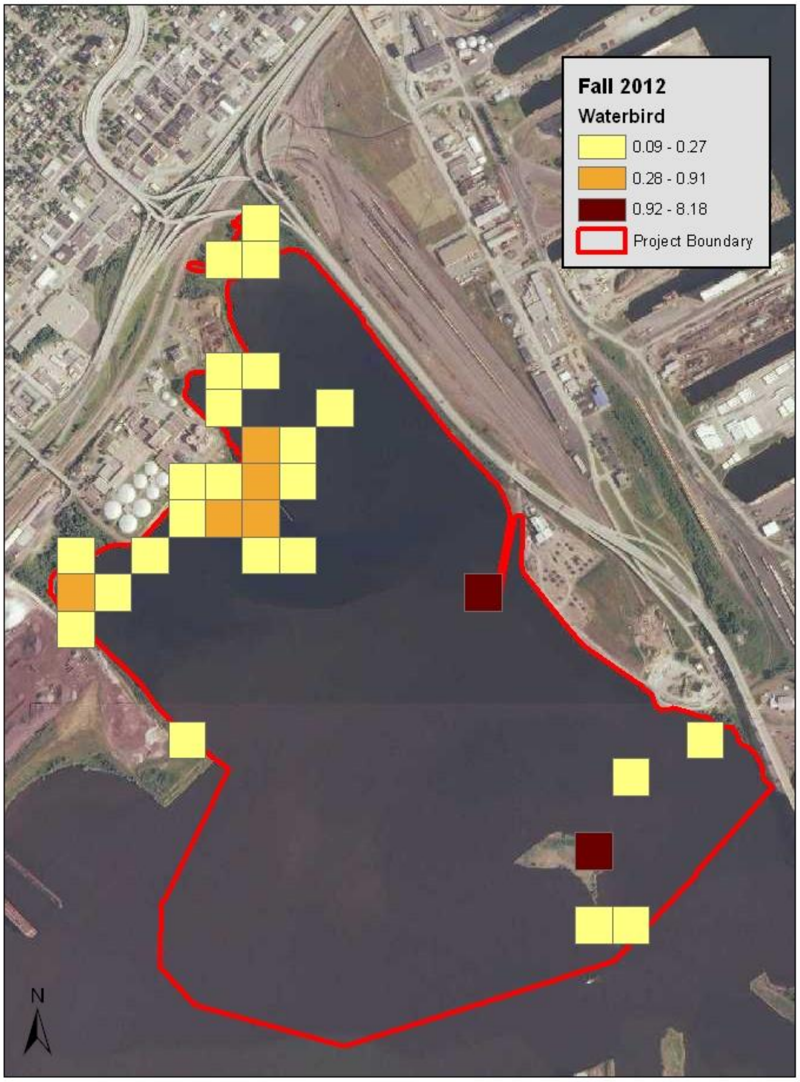


Figure 3.11. Average number of waterbird observations per 10,000m^2 during the fall season 2012 at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota.

Figure 3.12. Average number of shorebird observations per 10,000m^2 during the fall season 2012 at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota.

Raptors

The distribution of raptors during the 2012 surveys is shown in Figure 3.13. There were a total of 5 species observed and 21 individual birds. The majority of individuals were Bald Eagles (16), of which many were likely the same individuals observed on successive visits. The majority of the Bald Eagle observations were of individuals using habitat along the peninsula within the WLSSD complex (primarily Site 2, Figure 3.1). On 6 September 2012, 4 Bald Eagles (2 adult and 2 juvenile) were observed communally roosting in trees on the peninsula near site 2. Other raptor species observed included singular observations of Merlin, Sharp-shinned Hawk, Red-tailed Hawk, and Broad-winged Hawk. The majority of raptors observed were using habitat along or within the study area. Raptors soaring within the study area or sitting on the ice were also included, and appear as being observed on the water (Figure 3.13).

Songbirds

A distributional map for songbird observations in 2012 is presented in Figure 3.14. Species observations and specific information regarding numbers of individual birds can be found within the attached tables 3.2-3.4. There were a total of 35 species and 995 individual songbirds observed in the 21st avenue west study area. Due to the highly industrialized landscape there is minimal available shoreline habitat for songbirds. The habitat that does exist along the shoreline was used by songbirds both during migration and during the breeding season. There were several migrant species observed in the wooded habitat along the shallow bay west of WLSSD near site 3 and along the peninsula near site 2 (Figure 3.1). During migration many of these migrants were observed moving along the entire shoreline (the northern border of the study site) and foraging throughout, including in grass areas and along roadsides. Notable observations include 30 American Pipit, 5 Rusty Blackbirds, and use by migrant songbirds associated with forests (e.g., Magnolia Warbler, Mourning Warbler, Yellow-rumped Warbler, and Palm Warbler) , wetlands (Common Yellowthroat, Yellow Warbler, Song Sparrow, and Swamp Sparrow), and open areas (American Pipit, Northern Rough-winged Swallow, and Rusty Blackbird). There were also Tree Swallows present in the study area, nesting in nest boxes along the peninsula (site 2) and along the eastern shoreline. Other species likely nesting in the area (particularly in the small reedy area along the western part of the peninsula) included Red-winged Blackbird, Song Sparrow, Swamp Sparrow and Common Yellowthroat. Woodpecker species observed included; Downy Woodpecker and Northern Flicker.

Figure 3.13. Location of individual raptor observations (*n*=21) during the 2012 surveys at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota. Several observations occurred at the same location and overlap on the map.

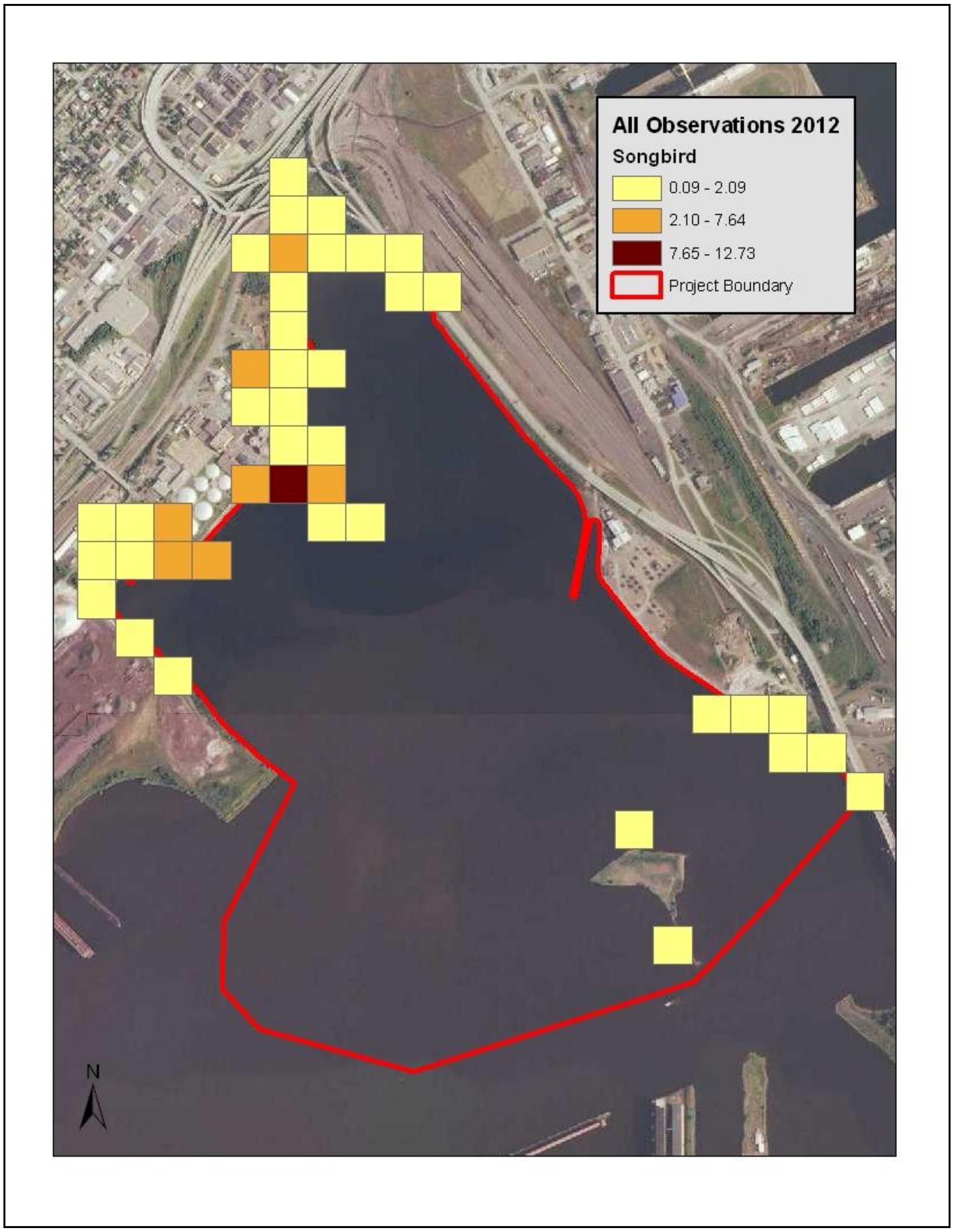


Figure 3.14. Average number of songbird observations per 10,000m² during all 2012 surveys (spring, breeding, fall) at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota.

Discussion

Despite the extensive industrial activity within the study area, including substantial on-going activity at WLSSD, the BNSF railway company, and its proximity to a major roadway system, there were many bird species utilizing the area during both migratory and breeding periods. There were a total of 81 species observed using the area over the study period. Of these, 76 were included in this analysis. The compilation by Green and Niemi (2011) reports 238 species using the St. Louis River estuary regularly (yearly) and an overall list of 302 species that have been identified (1991-2010) within the estuary. Therefore, the use of the study area by 81 species within this area of the estuary is notable, despite the heavy industrial activity.

The distribution of waterfowl and waterbirds were likely influenced by two major factors: 1) the shallow water habitat, plus associated plant species, and 2) isolation from both human and industrial disturbance. Many species were found within the shallow bays or along the shoreline and although isolation from human disturbance was difficult given the location, individuals tended to gather in more sheltered locations.

Removal or reduction of the influence of debris and industrially influenced substrates at the 21st Avenue West site is important. Currently, there is a significant disparity between model predicted vegetation and field observations, which could reflect issues related to the sediment composition, either in terms of presence of contaminants that might limit vegetation growth, or simply influx of large amounts of sediment from Miller and Coffee creek during rain event. It has also been suggested that bird herbivory on aquatic plants may be limiting growth. Currently plans are underway at NRRI for more directed experiments on the sediments and other factors that may limit aquatic vegetation bed development at 21st Avenue West. For instance, it would be unwise to restore appropriate physical habitat for bird species if the chemical environment is detrimental to their ultimate survival. Because it is unlikely that human and industrial disturbance will be reduced in the area, restoration efforts that produce quality shallow water and wetland habitat will be beneficial to the diverse avifauna of waterfowl and waterbirds as long as the chemical environment is also harmless.

Raptors

Bald Eagles, a Minnesota species of special concern, nest in various locations within the St. Louis River ecosystem, but not within the current study area. They were observed frequently, especially using the trees along the peninsula within the WLSSD complex (site 2, Figure 3.1), for resting. Although there were no raptors observed nesting within the study area, several may use the area for foraging such as the Bald Eagle and Peregrine Falcon.

Shorebirds

Collectively among the three seasons of sampling, five species of shorebird were found using the study area. Two of which were likely nesting in the area, Spotted Sandpiper (shorelines), and Killdeer (open areas such as along railroad grade). Restoration activities that encourage shoreline habitat, shallow water, and mudflats will encourage use by a variety of shorebird species for both breeding and as migration stopover locations.

Gulls

Five species of gull were found in the study area, Ring-billed Gull, Herring Gull, Bonaparte's Gull, Glaucous Gull, and Lesser Black-backed Gull. The Ring-billed Gull is an abundant species in the St. Louis River estuary with breeding population in 2012 of over 14,000 pairs (Strand, pers.comm.). The area is heavily used by Ring-billed Gull. With a safe location for a large population to breed on Interstate Island and the WLSSD site as a potential foraging location, it is likely that this species will continue to be attracted to the area. The Herring Gull is also a common breeding and migrant species in the estuary. It also nests on Interstate Island, though in much lower numbers than the Ring-billed Gull. **Management and control of the gull populations in the study area will be essential if a goal of restoration is to enhance habitat for Piping Plover and Common Tern because gulls may quickly colonize available habitat created for either species.** The Bonaparte's Gull is a common migrant in the St. Louis River estuary that was observed using the shallow sand flats near the northeastern bay (near site 4, Figure 3.1). Use of the area by several Glaucous Gulls and a Lesser Black-backed Gull during spring migration was also notable, especially because of their interest to bird watchers.

Songbirds

Thirty-four songbird species were identified within the study area. Species of particular interest and numbers that are unusual for the area include species of open areas such as the American Pipit, Northern Rough-winged Swallow and Rusty Blackbird. Maintaining or to the extent possible, expanding habitat (trees and shrubbery) within the study site, will enhance songbird use within the area for migratory species. Stopover habitat will benefit many songbird species and render the area attractive to bird watchers, photographers, and other wildlife enthusiasts.

Comparison to 40th Avenue West

Overall there were fewer species observed at the 21st Avenue West study area as compared with the 40th Avenue West study area, with 81 and 132 species observed respectively. The number of species identified per guild as well as the weighted average number of observations per guild (for species included) is shown in Figures 15 and 16. There were fewer shorebirds observed at the Project area study site as compared with the 40th Avenue West area. This may be because 21st Avenue is smaller in area and because of the lack of secluded habitat. The variety of available habitats in the area is substantially less than that of 40th Avenue West which may also have contributed to the lower number of songbird species found in the area relative to 40th Avenue West. There were substantially more American Crow, Ring-billed and Herring Gull, European Starling, and Canada Goose at the 21st Avenue West study area (Figure 3.17).

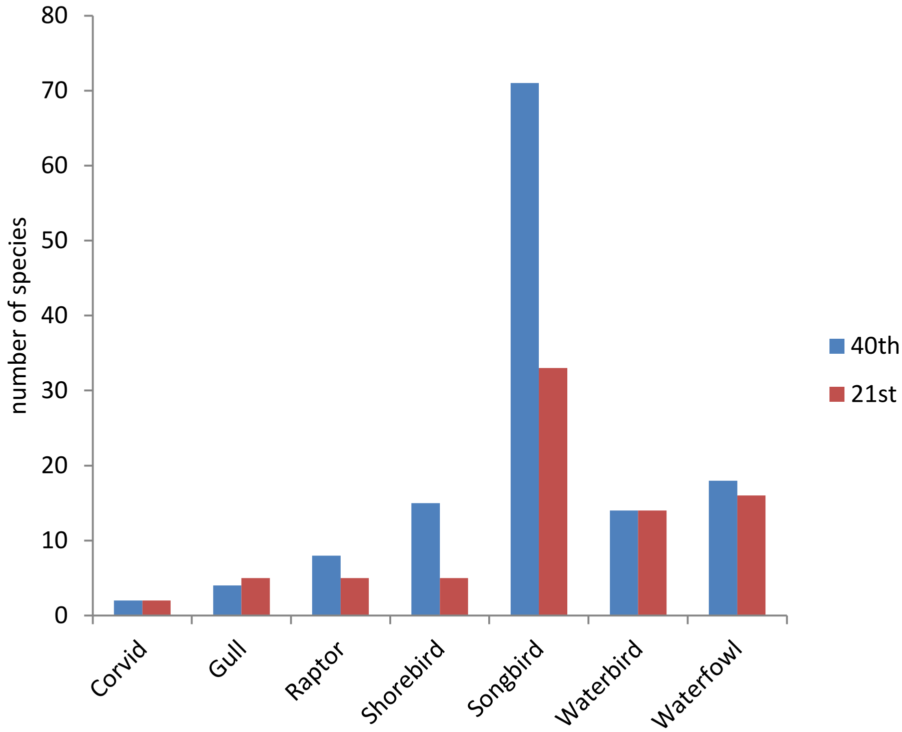
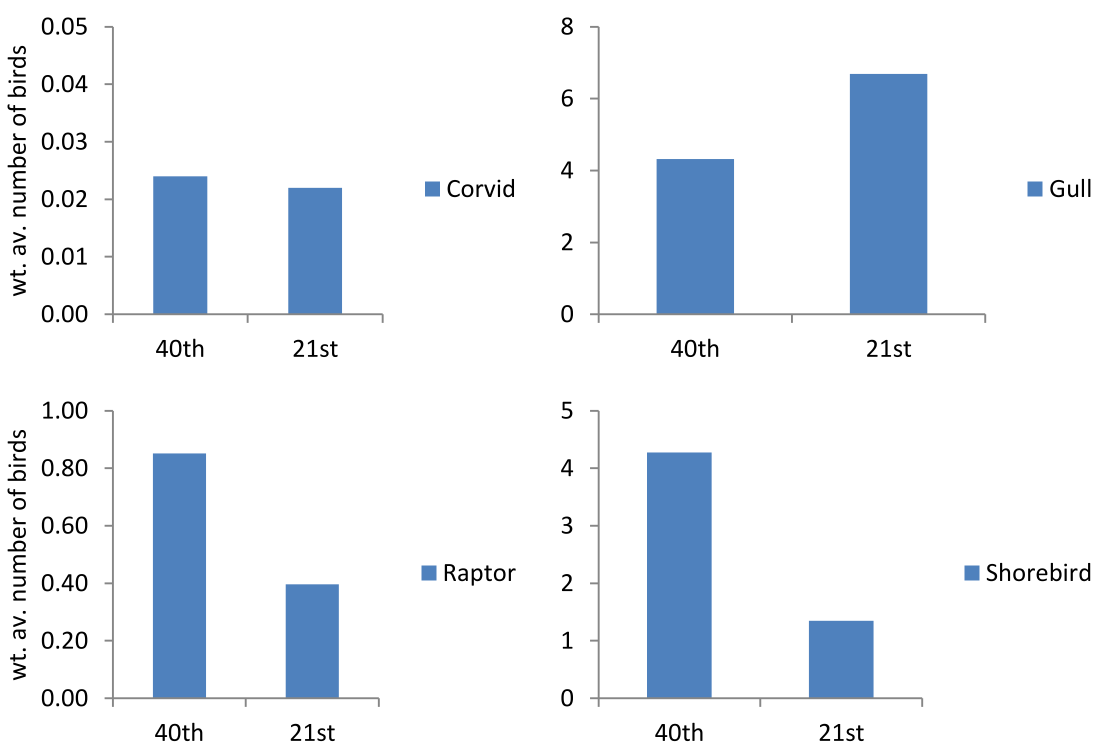


Figure 3.15. The number of species observed per guild at the 40th and 21st Avenue West study areas.



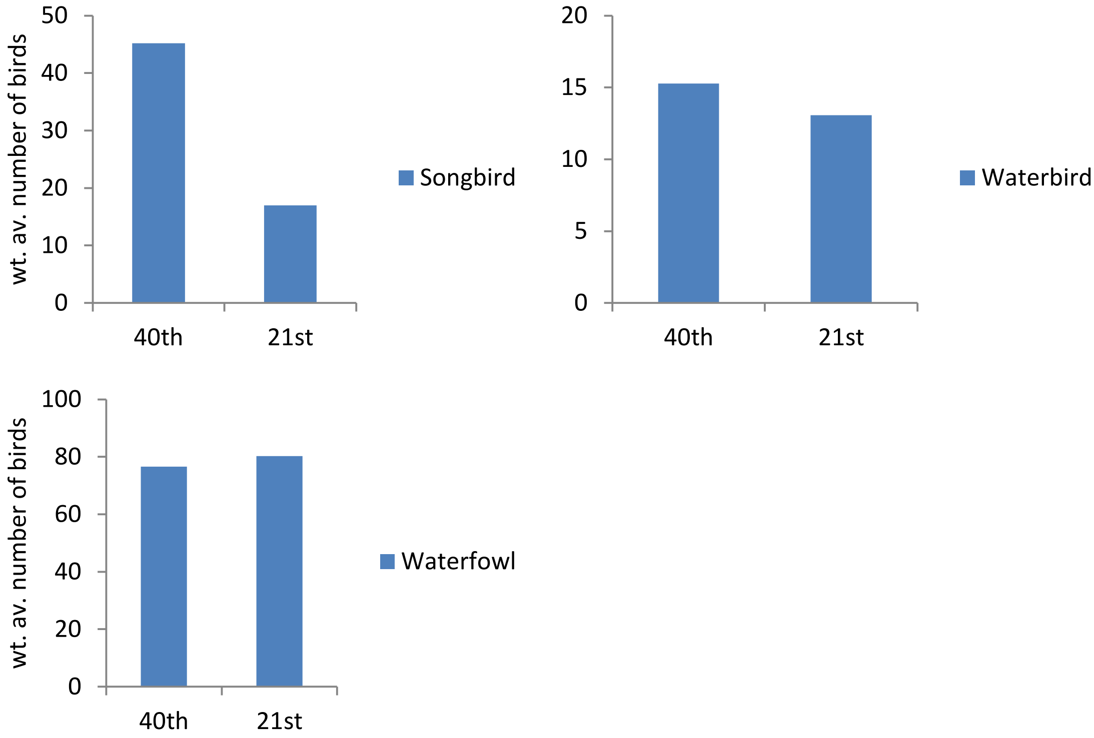


Figure 3.16. Weighted average number of birds observed per guild at the 40th and 21st Avenue West study sites.

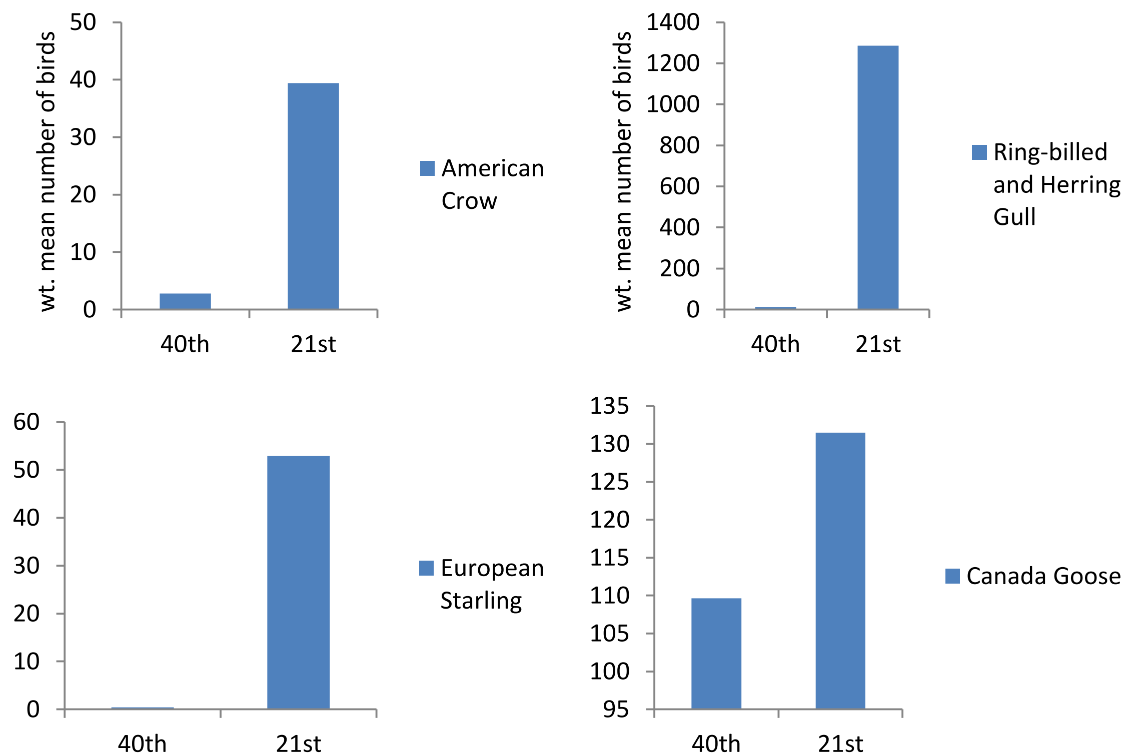


Figure 3.17. Weighted average number of birds excluded from the analysis at the 40th and 21st Avenue West study sites.

Species Excluded from the Summary

Several species were not included in our guild analysis for one of the following reasons; 1) they are widely distributed in the area and not highly associated with aquatic habitats, or 2) they are widely distributed with highly variable movement patterns in the study area. The species excluded were American Crow, Ring-billed Gull, Herring Gull, European Starling, and Canada Goose. These species were observed in large numbers because the same individuals were being counted on successive visits, therefore, it is unrealistic to accumulate total numbers for these species because they are represented by some of the same individuals. Moreover, species such as Ring-billed Gulls, European Starlings, and American Crows were so abundant that counting them was impossible. Counts of the Ring-billed Gull were best estimated by counts of nests at Interstate Island, but this is also likely a conservative number.

The numbers presented on the distribution maps are given as averages so they provide a reasonable approximation on the numbers of individuals present. Each of these species were observed in large concentrations along the bays northeast of WLSSD at sites 1 and 4 (Figure 3.1) and foraging at the WLSSD compost site. Corvids, primarily the American Crow, were widely distributed in the area and not highly associated with aquatic habitats. The average number of daily observations and the maximum number of individuals observed in one day of sampling are provided for each species. The daily average for American Crow was 64 with a daily maximum of 235 (Figure 3.18). Gulls, primarily Ring-billed Gulls and to a lesser extent Herring Gulls, were also widely distributed and highly variable in the study area. The daily average for Ring-billed Gull was 2,220 with a daily maximum of 15,675 (Figure 3.19). Herring Gull averaged 93 daily observations with a daily maximum of 600 (Figure 3.19). Gull distributions consisted of a combination of feeding and resting areas. A great number of these observations were made on Interstate Island during the spring and breeding seasons, where large numbers of Ring-billed Gulls are known to nest, in addition to observations near site 1. The daily average for European Starling was 88 observations with a daily maximum of 339. This species was scattered along the northern shoreline of the study area particularly near site 1 (Figure 20). Canada Goose was the most widely spread species observed within the study area, with a daily average of 267 observations and a daily maximum of 735 (Figure 21).

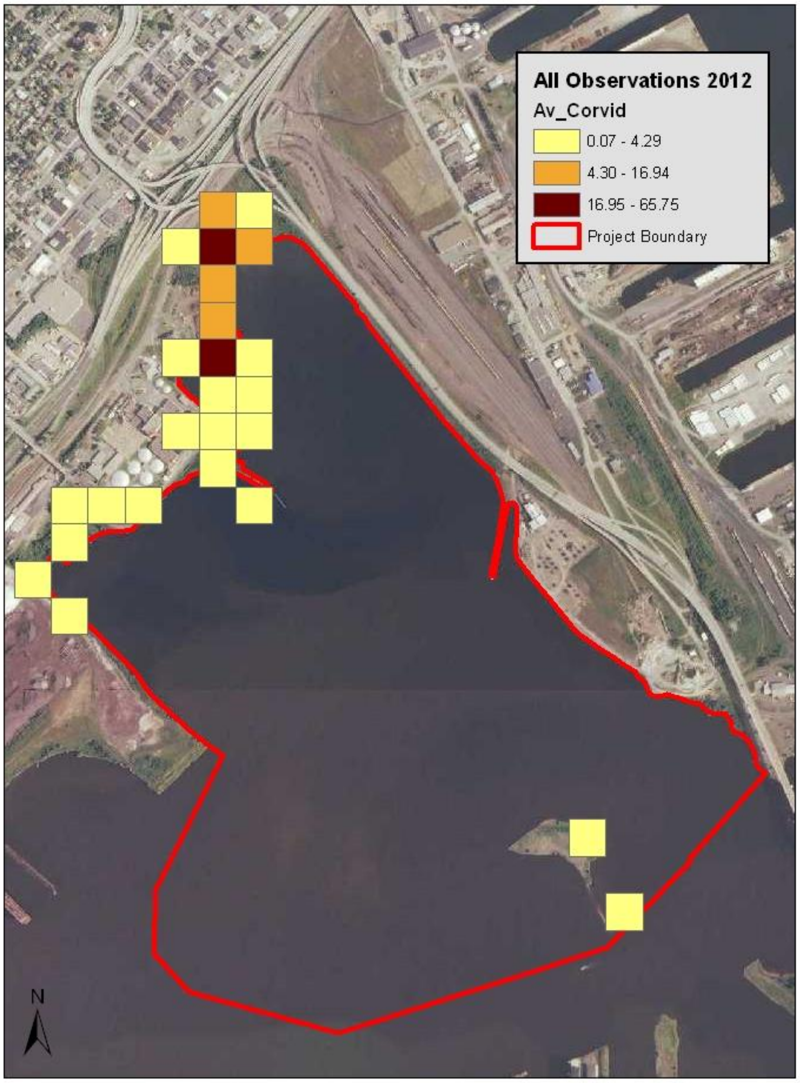


Figure 3.18. Average number of Corvid (American Crow) observations per 10,000m^2 during the 2012 survey at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota.

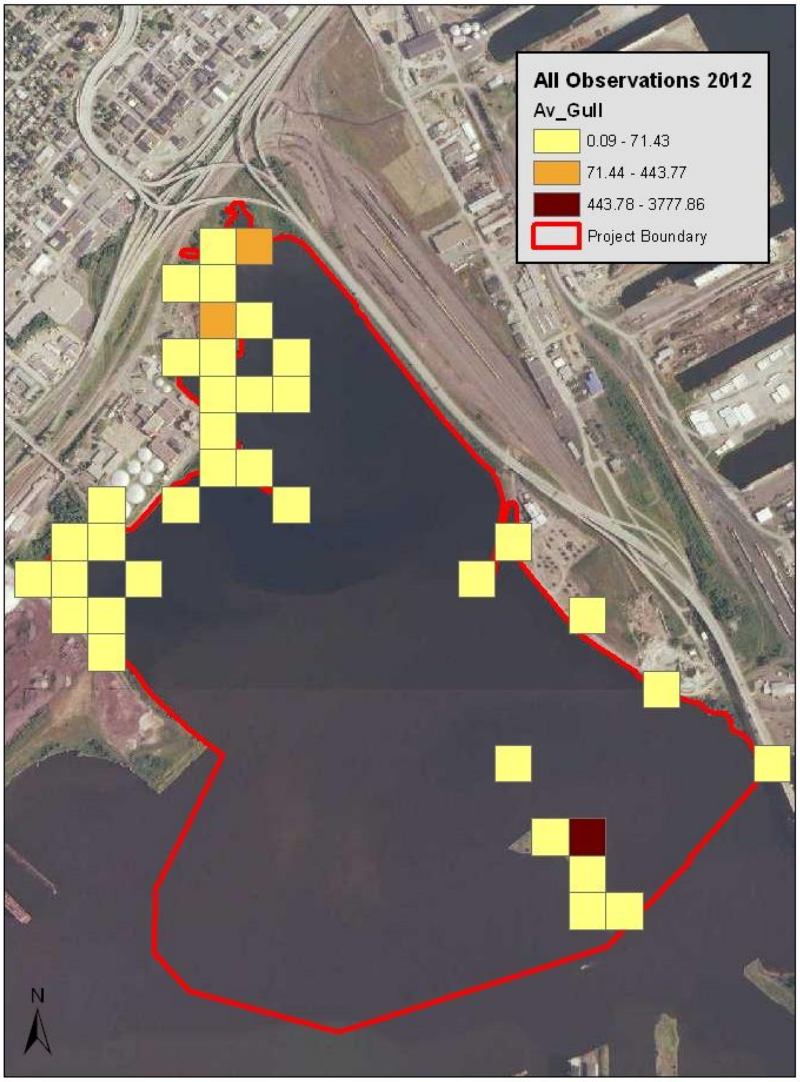


Figure 3.19. Average number of Gull (Ring-billed and Herring) observations per $10{,}000m^2$ during the 2012 survey at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota.

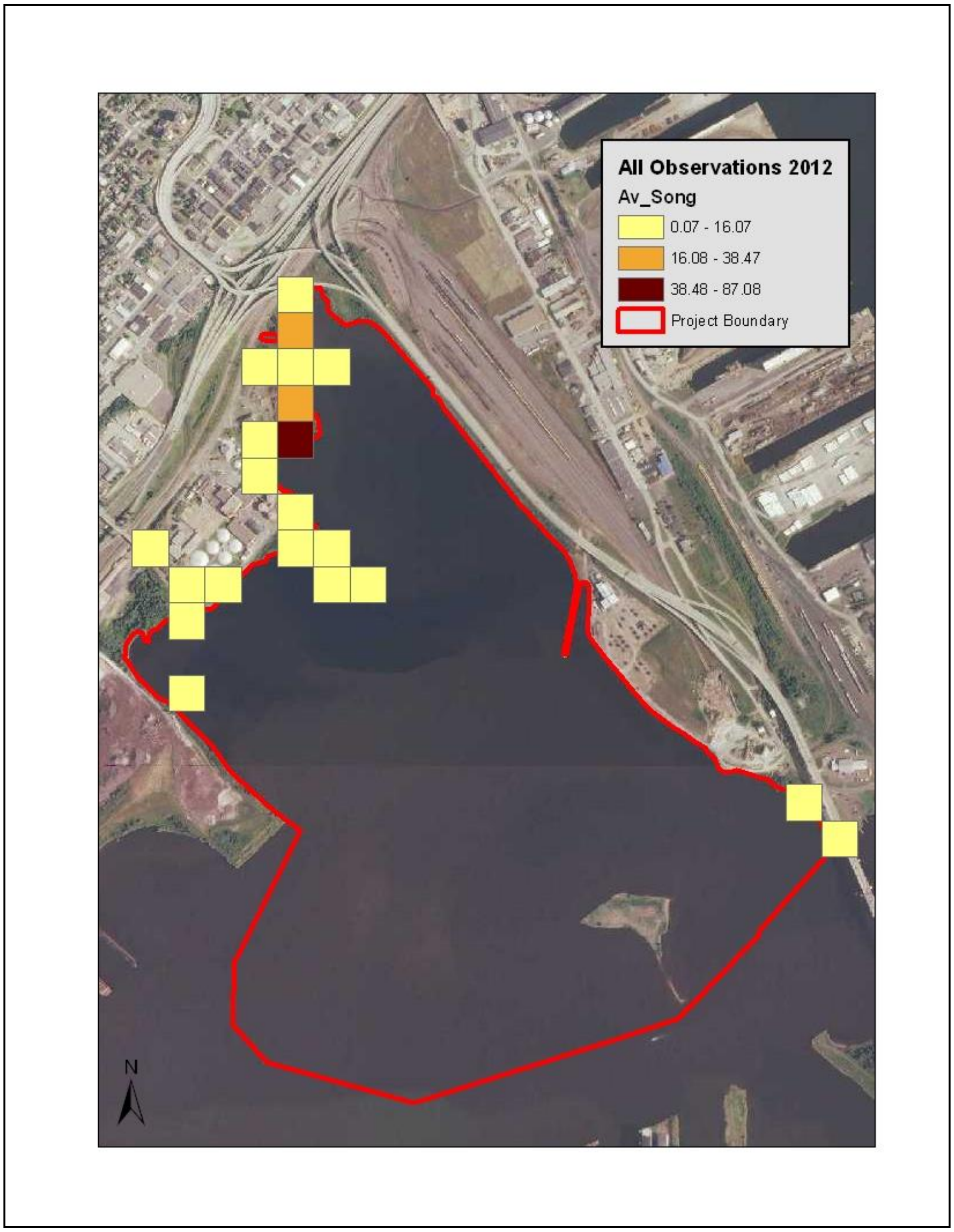


Figure 3.20. Average number of songbird (European Starling) observations per 10,000m^2 during the 2012 survey at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota.

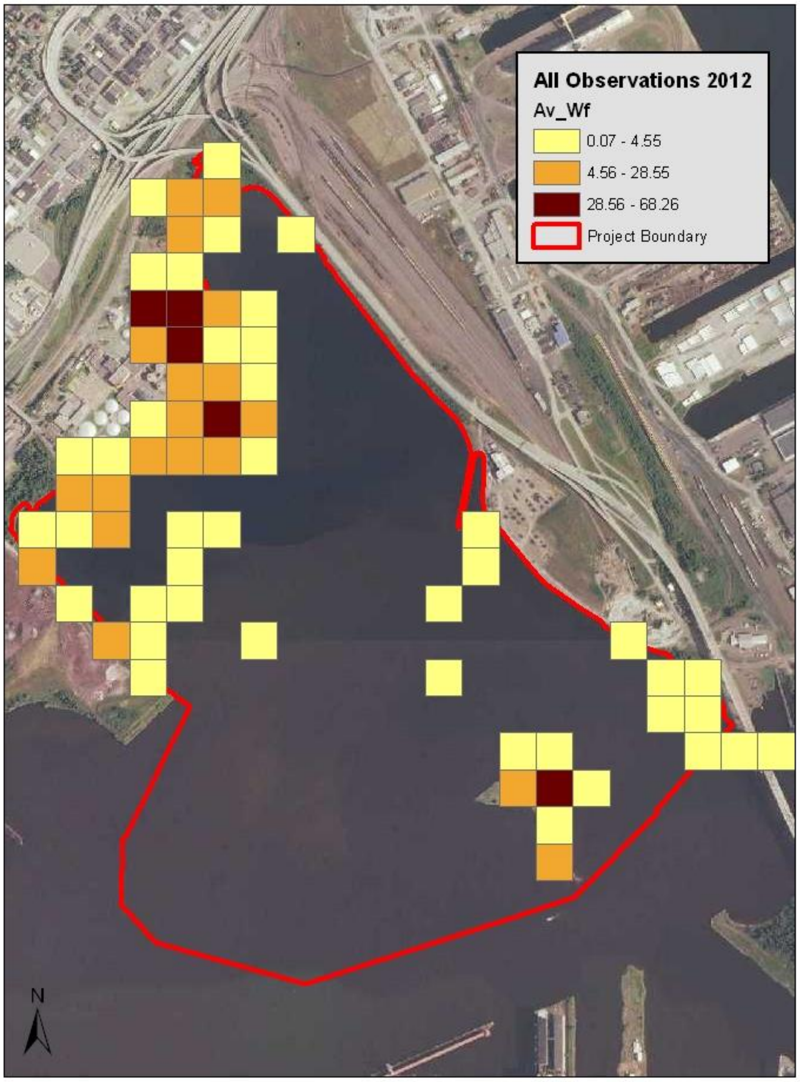


Figure 3.21. Average number of waterfowl (Canada Goose) observations per 10,000m^2 during 2012 surveys at the 21st Avenue West project remediation site in the St. Louis River estuary, Duluth, Minnesota.

Interstate Island

Created from dredged materials in the 1930's, Interstate Island (~ 3.2 hectares) located in the Duluth-Superior Harbor, near the Hwy 53 Blatnik Bridge overpass, provides suitable habitat for colonial water birds (MNDNRa., 2012). As previously mentioned, the majority of the island is inhabited by nesting gulls, primarily Ring-billed Gulls, although a small population of Common

Terns nest on the island and are managed for by the Department of Natural Resources (MNDNRb., 2012). The island, at one time, was proposed as potential critical habitat of the Piping Plover, but was removed from the final designation, because it lacked proper features required to sustain the species (USFWS, 2012). Bird use of Interstate Island was included in the 2012 survey of the 21st Avenue West remediation site. Surveys were conducted from site 5 (Figure 3.1) using a spotting scope and binoculars. Due to the distance, it is likely that observations of smaller birds such as songbirds and shorebirds were missed or listed as unidentified. However, this method was sufficient for documenting use of the island by larger species such as waterfowl and waterbirds. The average number of daily observations and the maximum number of individuals observed in one day of sampling are provided for each species. The average number of daily observations for corvid (American Crow) was 5 with a daily maximum of 8. For gulls (primarily Ring-billed and Herring Gull) the daily averages were 2,930 and 221 with daily maximums of 15,000 and 500 respectively. The daily waterbird (primarily Double-crested Cormorant) average was 22 with a daily maximum of 55. The daily waterfowl (primarily Canada Goose) was 36 with a daily maximum of 150. There were also 2 raptors (Bald Eagle) observed and 16 songbirds (primarily unidentified).

Endangered and Threatened Species

Two species of particular interest in this area from the perspective of restoration activities include the Piping Plover, a federal and state listed endangered species, and the Common Tern, a threatened species in the state of Minnesota. The Piping Plover was never observed in the study area. At the current time there is no suitable habitat for the Piping Plover within this study site, except for the possibility of Interstate Island. Little suitable nesting habitat for the Common Tern currently exists within the St. Louis River estuary. However, Common Terns were observed foraging within the study area and nesting on Interstate Island. Active management efforts by habitat creation and protection within the study area could potentially restore Common Tern breeding populations to this area.

Even though there are no documented nesting records of Piping Plover, a federally endangered species, in this region of the estuary, if suitable habitat was created, then it is possible that Piping Plovers could colonize these areas. The lack of historical nesting records for the Piping Plover may be due to the following: 1) past heavy industrial activity, 2) the lack in availability of sandy or cobble habitat most of which is confined to Minnesota and Wisconsin Points or to dredge-created islands, 3) the lack of anyone looking for the species or reporting its presence in this area over the past 100 + years of human settlement, or 4) their lack of use in this area. Predator issues would be an important consideration for any recovery effort for either the Piping Plover or Common Tern in this region. For instance, the production of young for the Common Tern in 2012 on Interstate Island was zero because of predation by as yet unknown species or multiple species. In addition, the Peregrine Falcon has nested or attempted to nest in several nearby locations: the Greysolon Building in downtown Duluth, the Hibbard Steam Plant in the 47th Avenue West area, the Bong Bridge, and the Blatnik Bridge.

Recommendations

The recommendations provided by Niemi et al. (2011) for the 40th avenue west remediation site are provided below, as they are nearly identical. Recommendations have been altered where necessary to reflect needs specific to 21st avenue west. The greatest potential for restoration includes creating wetlands, sandy/cobble shorelines, and a variety of habitat conditions for migratory songbirds. However, this area has a severe ornithological problem due to the attraction to the site by Ring-billed Gulls, Canada Geese, American Crow, and European Starling. The former three are native species of the region, while the European Starling is an exotic, invasive species introduced to the United States in the late 1800’s. Any restoration that could create additional open sandy or cobble habitat will be an attraction to gulls. Restoration that increases wetland habitat in the region will also likely benefit the Canada Goose. The high populations of American Crow and European Starling are due to the food sources available at the WLSSD site. If these populations are left unmanaged, then it is possible that restoration efforts may make the problems with these species even worse.

Specific remediation of the site should consider the following with respect to bird use of the area:

5) ***Development of Sandy/Cobble Habitat* -** The greatest potential for positive benefit for remediation at the site includes considerations for creation of habitat for the endangered Piping Plover and threatened Common Tern. Both of these species require open and protected sandy or cobble beaches. Restoration of open sandy or beach habitat and colonization of subsequent sites by either species would face significant challenges from the presence of gulls and other predators.

6) ***Enhancement of Emergent Wetlands* -**Waterfowl and other wetland bird species would greatly benefit by improvement in the quality and expansion of wetland habitats in the area. Each of these species groups were largely confined to shallow water habitats within the study area. The current diversity of waterfowl and waterbird species use of the area would be enhanced further with improvement in wetlands. There were several wetland-associated species that were not observed in the area that may also colonize these areas in the future if the wetland habitats were improved or expanded. These include the American Bittern, Forster's Tern, Black Tern, Marsh Wren, and Virginia Rail. However, emergent wetlands may also prove attractive to more Canada Geese; the interactions of this species with other species of interest are unclear.

7) ***Public Access*** – Due to landownership and the industrialized nature of the location, the area is currently inaccessible to the public. There is no public viewing area for bird watching or other recreational activities, with the exception of the Port Terminal Road beneath the Blatnik Bridge (US Hwy 53), which does not provide an ideal environment for bird watching due to noise pollution created by the high level of use by humans. Improving public exposure and opportunities for wildlife viewing with public access would be beneficial and access to selected portions of the site should be developed. Considerations at this site include safety issues with the railroad tracks and property ownership. The area east of the WLSSD operation is a popular bird watching area already and this could be enhanced; however, there are also sensitive issues regarding the successful operation of the WLSSD such as deterring the use of the site by birds. Signage would be important to explain to the public about safety issues to not enter the WLSSD site, plus health reasons on why bird use of the compost area is discouraged.

8) ***Management Coordination*** – There are several wildlife conflicts that exist in this area such as the presence of prolific species such as Ring-billed Gull and Canada Goose. Encouragement of Common Tern or Piping Plover nesting habitat within the site by the creation of open, protected sandy and cobble areas would also be attractive to Ring-billed and Herring Gulls. There would be little justification for further encouragement of nesting for either of these species in the Duluth-Superior Harbor if these species are not managed. Restoration of the site requires extensive discussion among management agencies, non-government organizations, and the public to achieve an optimum result for the area.

Table 3.1. Number of birds observed per guild per day during spring migration, breeding season, and fall migration (2012) at the 21st Avenue West Remediation site in the St. Louis River estuary, Duluth, MN.

Date	Gulls	Raptors	Shorebirds	Songbirds	Waterbirds	Waterfowl	Total
Spring migration (2012)							
7-Mar	0	3	0	15	6	469	493
14-Mar	228	2	0	12	4	146	392
22-Mar	6	0	0	18	7	48	79
28-Mar	0	0	0	20	16	205	241
4-Apr	0	1	0	27	21	463	512
11-Apr	0	0	0	24	57	53	134
19-Apr	0	0	0	30	110	18	158
27-Apr	0	1	0	27	40	16	84
2-May	0	0	35	43	22	106	206
16-May	0	0	3	49	54	52	158
26-May	100	0	6	44	19	28	197
Total	334	7	44	309	356	1604	2654
Breeding season (2012)							
4-Jun	0	0	0	26	29	21	76
13-Jun	0	0	4	33	20	137	194
8-Jul	0	0	1	13	10	39	63
Total	0	0	5	72	59	197	333
Fall migration (2012)							
28-Aug	0	2	0	49	30	133	214
6-Sep	0	4	0	38	39	161	242
13-Sep	0	1	5	86	28	178	298
19-Sep	0	1	2	82	16	125	226
26-Sep	0	0	9	95	10	150	264
3-Oct	0	1	5	49	65	105	225
10-Oct	0	2	0	142	19	128	291
19-Oct	0	0	0	25	2	156	183
26-Oct	0	1	0	34	14	317	366
31-Oct	0	1	0	10	10	396	417
8-Nov	0	1	0	2	2	353	358
Total	0	14	21	612	235	2202	3084

Table 3.2. Summary of species observed during spring migration (2012) at the 21st Avenue West Remediation site in the St. Louis River estuary, Duluth, MN.

Guild	Species	Total	Av. Obs.[a]	Max Obs. in one day
Corvid	American Crow (*Corvus brachyrhynchos*)	530	48.2	142
Gull	Bonaparte's Gull (*Chroicocephalus Philadelphia*)	100	9.1	100
Gull	Glaucous Gull (*Larus hyperboreus*)	5	0.5	5
Gull	Herring Gull (*Larus argentatus*)	2696	245.1	600
Gull	Lesser Black-backed Gull (*Larus fuscus*)	1	0.1	1
Gull	Ring-billed Gull (*Larus delawarensis*)	53397	4854.3	15675
Gull	Unidentified Gull	228	20.7	228
Raptor	Bald Eagle (*Haliaeetus leucocephalus*)	6	0.5	3
Raptor	Red-tailed Hawk (*Buteo jamaicensis*)	1	0.1	1
Shorebird	Killdeer (*Charadrius vociferous*)	4	0.4	3
Shorebird	Spotted Sandpiper (*Actitis macularius*)	5	0.5	3
Shorebird	Willet (*Tringa semipalmata*)	35	3.2	35
Songbird	American Goldfinch (*Spinus tristis*)	3	0.3	2
Songbird	American Robin (*Turdus migratorius*)	10	0.9	3
Songbird	Black-capped Chickadee (*Poecile atricapillus*)	4	0.4	2
Songbird	Brown-headed Cowbird (*Molothrus ater*)	9	0.8	4
Songbird	Cedar Waxwing (*Bombycilla cedrorum*)	1	0.1	1
Songbird	Chipping Sparrow (*Spizella passerine*)	2	0.2	2
Songbird	Dark-eyed Junco (*Junco hyemalis*)	7	0.6	5
Songbird	European Starling (*Sturnus vulgaris*)	838	76.2	339
Songbird	Nashville Warbler (*Oreothlypis ruficapilla*)	1	0.1	1
Songbird	Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)	5	0.5	5
Songbird	Rock Pigeon (*Columba livia*)	35	3.2	12
Songbird	Red-winged Blackbird (*Agelaius phoeniceus*)	51	4.6	11
Songbird	Song Sparrow (*Melospiza melodia*)	88	8	13
Songbird	Swamp Sparrow (*Melospiza Georgiana*)	2	0.2	2
Songbird	Tree Swallow (*Tachycineta bicolor*)	74	6.7	24
Songbird	Unidentified Swallow	3	0.3	3
Songbird	White-throated Sparrow (*Zonotrichia albicollis*)	4	0.4	2

Songbird	Yellow Warbler (*Setophaga petechia*)	8	0.7	5
Waterbird	Belted Kingfisher (*Megaceryle alcyon*)	2	0.2	1
Waterbird	Caspian Tern (*Hydroprogne caspia*)	3	0.3	3
Waterbird	Common Merganser (*Mergus merganser*)	44	4	12
Waterbird	Common Tern (*Sterna hirundo*)	32	2.9	32
Waterbird	Double-crested Cormorant (*Phalacrocorax auritus*)	240	21.8	91
Waterbird	Great Blue Heron (*Ardea Herodias*)	2	0.2	1
Waterbird	Hooded Merganser (*Lophodytes cucullatus*)	9	0.8	3
Waterbird	Pied-billed Grebe (*Podilymbus podiceps*)	2	0.2	2
Waterbird	Red-breasted Merganser (*Mergus serrator*)	21	1.9	6
Waterbird	Unidentified Grebe	1	0.1	1
Waterfowl	Green-winged Teal (*Anas crecca*)	7	0.6	4
Waterfowl	American Black Duck (*Anas rubripes*)	35	3.2	26
Waterfowl	Bufflehead (*Bucephala albeola*)	3	0.3	2
Waterfowl	Blue-winged Teal (*Anas discors*)	5	0.5	3
Waterfowl	Canada Goose (*Branta Canadensis*)	1142	103.8	202
Waterfowl	Canvasback (*Aythya valisineria*)	2	0.2	2
Waterfowl	Common Goldeneye (*Bucephala clangula*)	58	5.3	25
Waterfowl	Lesser Scaup (*Aythya affinis*)	278	25.3	100
Waterfowl	Mallard (*Anas platyrhynchos*)	955	86.8	418
Waterfowl	Northern Shoveler (*Anas clypeata*)	12	1.1	12
Waterfowl	Redhead (*Aythya Americana*)	246	22.4	200
Waterfowl	Ring-necked Duck (*Aythya collaris*)	2	0.2	2
Waterfowl	Wood Duck (*Aix sponsa*)	1	0.1	1

[a] Average number of birds observed for 11 days of effort

Table 3.3. Summary of species observed during the breeding season (2012) at the 21st Avenue West Remediation site in the St. Louis River estuary, Duluth, MN.

Guild	Species	Total	Av. Obs.[a]	Max. Obs. in one day
Corvid	American Crow (*Corvus brachyrhynchos*)	58	19.3	31
Gull	Herring Gull (*Larus argentatus*)	10	3.3	10
Gull	Ring-billed Gull (*Larus delawarensis*)	4520	1506.7	2220
Shorebird	Spotted Sandpiper (*Actitis macularius*)	4	1.3	3
Shorebird	Unidentified Shorebird	1	0.3	1
Songbird	Brown-headed Cowbird (*Molothrus ater*)	1	0.3	1
Songbird	Common Grackle (*Quiscalus quiscula*)	4	1.3	3
Songbird	European Starling (*Sturnus vulgaris*)	97	32.3	39
Songbird	Rock Pigeon(*Columba livia*)	10	3.3	6
Songbird	Red-winged Blackbird (*Agelaius phoeniceus*)	17	5.7	7
Songbird	Song Sparrow (*Melospiza melodia*)	22	7.3	11
Songbird	Tree Swallow (*Tachycineta bicolor*)	14	4.7	12
Songbird	Yellow Warbler (*Setophaga petechia*)	4	1.3	2
Waterbird	Common Loon (*Gavia immer*)	2	0.7	2
Waterbird	Common Tern (*Sterna hirundo*)	32	10.7	22
Waterbird	Double-crested Cormorant (*Phalacrocorax auritus*)	14	4.7	7
Waterbird	Great Blue Heron (*Ardea Herodias*)	2	0.7	1
Waterbird	Red-breasted Merganser (*Mergus serrator*)	9	3	7
Waterfowl	Canada Goose (*Branta Canadensis*)	835	278.3	416
Waterfowl	Lesser Scaup (*Aythya affinis*)	1	0.3	1
Waterfowl	Mallard (*Anas platyrhynchos*)	192	64	137
Waterfowl	Northern Shoveler (*Anas clypeata*)	3	1	3
Waterfowl	Wood Duck (*Aix sponsa*)	1	0.3	1

[a] Average number of birds observed for 3 days of effort

Table 3.4. Summary of species observed during the breeding season (2012) at the 21st Avenue West Remediation site in the St. Louis River estuary, Duluth, MN.

Guild	Species	Total	Av. Obs.	Max. obs. in one day
Corvid	American Crow (*Corvus brachyrhynchos*)	1383	125.7	235
Corvid	Blue Jay (*Cyanocitta cristata*)	1	0.1	1
Gull	Herring Gull (*Larus argentatus*)	339	30.8	61
Gull	Ring-billed Gull (*Larus delawarensis*)	3303	300.3	481
Raptor	Bald Eagle (*Haliaeetus leucocephalus*)	10	0.9	4
Raptor	Merlin (*Falco columbarius*)	1	0.1	1
Raptor	Broad-winged Hawk (*Buteo platypterus*)	1	0.1	1
Raptor	Sharp-shinned Hawk (*Accipiter striatus*)	1	0.1	1
Shorebird	Lesser Yellowlegs (*Tringa flavipes*)	1	0.1	1
Shorebird	Spotted Sandpiper (*Actitis macularius*)	13	1.2	5
Shorebird	Semipalmated Sandpiper (*Calidris pusilla*)	3	0.3	3
Songbird	American Goldfinch (*Spinus tristis*)	2	0.2	1
Songbird	American Pipit (*Anthus rubescens*)	30	2.7	30
Songbird	American Tree Sparrow (*Spizella arborea*)	4	0.4	4
Songbird	Chipping Sparrow (*Spizella passerine*)	12	1.1	8
Songbird	Black-capped Chickadee (*Poecile atricapillus*)	15	1.4	10
Songbird	Cedar Waxwing (*Bombycilla cedrorum*)	3	0.3	3
Songbird	Common Yellowthroat (*Geothlypis trichas*)	26	2.4	14
Songbird	Downy Woodpecker (*Picoides pubescens*)	2	0.2	1
Songbird	Eastern Kingbird (*Tyrannus tyrannus*)	1	0.1	1
Songbird	Least Flycatcher (*Empidonax minimus*)	1	0.1	1
Songbird	Eastern Phoebe (*Sayornis phoebe*)	2	0.2	2
Songbird	European Starling (*Sturnus vulgaris*)	1709	155.4	335
Songbird	Palm Warbler (*Setophaga palmarum*)	6	0.5	5
Songbird	Yellow-rumped Warbler (*Setophaga coronate*)	54	4.9	29
Songbird	Nashville Warbler (*Oreothlypis ruficapilla*)	4	0.4	3
Songbird	Northern Waterthrush (*Parkesia noveboracensis*)	3	0.3	3
Songbird	Rock Pigeon (*Columba livia*)	2	0.2	2
Songbird	Rusty Blackbird (*Euphagus carolinus*)	5	0.5	3

Songbird	Red-winged Blackbird (*Agelaius phoeniceus*)	39	3.5	25
Songbird	Slate-colored Junco (*Junco hyemalis*)	47	4.3	25
Songbird	Song Sparrow (*Melospiza melodia*)	64	5.8	22
Songbird	Swamp Sparrow (*Melospiza Georgiana*)	5	0.5	2
Songbird	Swainson’s Thrush (*Catharus ustulatus*)	1	0.1	1
Songbird	White-throated Sparrow (*Zonotrichia albicollis*)	128	11.6	72
Songbird	Yellow-shafted Flicker (*Colaptes auratus*)	1	0.1	1
Songbird	Mourning Warbler (*Geothlypis Philadelphia*)	1	0.1	1
Songbird	Magnolia Warbler (*Setophaga magnolia*)	3	0.3	3
Songbird	Yellow Warbler (*Setophaga petechia*)	6	0.5	6
Waterbird	American Coot (*Fulica Americana*)	2	0.2	2
Waterbird	Belted Kingfisher (*Megaceryle alcyon*)	2	0.2	1
Waterbird	Common Merganser (*Mergus merganser*)	17	1.5	6
Waterbird	Double-crested Cormorant (*Phalacrocorax auritus*)	175	15.9	58
Waterbird	American White Pelican (*Pelecanus erythrorhynchos*)	1	0.1	1
Waterbird	Great Blue Heron (*Ardea Herodias*)	13	1.2	4
Waterbird	Hooded Merganser (*Lophodytes cucullatus*)	7	0.6	3
Waterbird	Pied-billed Grebe (*Podilymbus podiceps*)	4	0.4	2
Waterbird	Red-breasted Merganser (*Mergus serrator*)	16	1.5	6
Waterfowl	Canada Goose (*Branta Canadensis*)	4598	418	735
Waterfowl	Common Goldeneye (*Bucephala clangula*)	4	0.4	3
Waterfowl	Green-winged Teal (*Anas crecca*)	46	4.2	17
Waterfowl	Lesser Scaup (*Aythya affinis*)	1	0.1	1
Waterfowl	Mallard (*Anas platyrhynchos*)	2157	196.1	378
Waterfowl	Northern Shoveler (*Anas clypeata*)	3	0.3	3

[a] Average number of birds observed per day for 11 days of effort

Table 3.5. Species that were excluded from the analysis include; American Crow, Herring Gull, Ring-billed Gull, European Starling, and Canada Goose. For each of these species, the number of birds observed per day during the spring migration, breeding season, and fall migration (2012) at the 21st Avenue West Remediation site in the St. Louis River estuary, Duluth, MN are listed by guild.

Date	Corvids	Gulls	Songbirds	Waterfowl	Total
Spring migration (2012)					
7-Mar	92	302	339	27	760
14-Mar	142	2200	272	202	2816
22-Mar	64	3132	48	96	3340
28-Mar	52	3584	90	158	3884
4-Apr	19	3758	14	85	3876
11-Apr	29	2868	14	85	2996
19-Apr	32	3723	15	109	3879
27-Apr	47	3981	30	94	4152
2-May	23	3467	3	74	3567
16-May	16	15806	11	120	15953
26-May	14	13272	2	92	13380
Total	530	56093	838	1142	58603
Breeding season (2012)					
4-Jun	15	1100	27	278	1420
13-Jun	31	1210	31	416	1688
8-Jul	12	2220	39	141	2412
Total	58	4530	97	835	5520
Fall migration (2012)					
28-Aug	23	25	77	154	279
6-Sep	151	350	150	593	1244
13-Sep	120	457	140	334	1051
19-Sep	114	393	50	514	1071
26-Sep	124	521	25	549	1219
3-Oct	221	467	288	735	1711
10-Oct	235	310	245	252	1042
19-Oct	175	354	120	156	805
26-Oct	60	227	180	365	832
31-Oct	143	276	101	399	919
8-Nov	17	232	335	571	1155
Total	1383	3612	1711	4622	11328

Table 3.6. Summary of bird species group, brief explanation of benefit, and priority for potential restoration in the study area.

Bird Group	Desirable Habitat Features	Priority
Waterfowl	Wetland creation- intermix of open pools and wetland vegetation; protection from human disturbance; also provides benefit for many wetland species besides waterfowl .	High
Terns and shorebirds	Open sandy, cobble habitat islands and shorelines; emphasis on an intermix with wetland habitat; creation of habitat for Common Tern nesting needs consideration of competition by Ring-billed Gull.	High
Songbirds	Maintenance and expansion of vegetation cover - trees, shrubbery, and a variety of wetland types will be beneficial for many of the songbirds found in the area during migratory periods; available breeding habitat for most songbirds will be limited because of the limited forested area.	Moderate
Raptors	Increasing the amount of vegetated land surrounding the site could promote use of the area by raptors, particularly use by Bald Eagle. This species has been documented within the study area, using it as a resting site and potential foraging ground. An increase in land area could provide more resting locations for raptors using the area.	Moderate
\Shorebirds	Rare migrating shorebirds have been observed within the St. Louis River estuary as well as within the 21st Avenue West study area; to the extent possible the long-term maintenance of the site with shallow water pools and public access to the site are highly desirable particularly for bird watchers interested observing these migrant species.	Moderate

Literature Cited

Brady, V., C. Reschke, D. Breneman, G. Host, and L. Johnson. 2010. 40th Avenue West Remediation to Restoration project: biological survey results. Report to United States Fish and Wildlife Service, Cooperative Agreement 30181AJ68, November 2010, Natural Resources Research, University of Minnesota Duluth technical report number NRRI/TR-2010/24.

Davis, T. 1985. St. Louis River estuary colonial bird program. Report to Minnesota Department of Natural Resources. 21 pp.

Green, J.C., and G.J. Niemi. 2011. Minnesota important bird areas: nomination form for St. Louis River estuary and Minnesota Point. (Copies available from the authors – jgreen@d.umn.edu or gniemi@d.umn.edu)

MNDNR(a) (Minnesota Department of Natural Resources). 2012. Habitat preservation projects. http://www.dnr.state.mn.us/eco/nongame/land_preservation/projects.html. Accessed 10 October 2012.

MNDNR(b) (Minnesota Department of Natural Resources). 2012. Rare species guide-common tern. http://www.dnr.state.mn.us/rsg/profile.html?action=elementDetail&selectedElement=ABNNM08070 Accessed 10 October 2012.

Niemi, G.J., T. Davis, and P.B. Hofslund. 1979. Distribution and relationships of habitats and birds in the St. Louis River estuary. Report by University of Minnesota to U.S. Fish and Wildlife Service, St. Paul, Minnesota. 120 pp. and 6 appendices.

Niemi, G.J., J. Solin, D. Waters, and P. Wolter. 2000. Breeding bird inventory of the St. Louis River, Minnesota and Wisconsin, 1999. Natural Resources Research Institute, University of Minnesota Duluth technical report NRRI/TR-2000/34.

Niemi, G.J., J. Lind, A. Bracey, C. Lapin, and P. Meysembourg. 2011. Addendum 1. 40th Avenue West remediation to restoration project: biological survey results. Natural Resources Research Institute, University of Minnesota Duluth technical report NRRI/TR-2010/24.

USFW (United States Fish and Wildlife Services). Endangered Species-Piping Plover. http://www.fws.gov/midwest/endangered/pipingplover/summary.html. Accessed October 2012

Appendix 4. Hydrodynamic Modeling of the Project Area (J. Austin, M. James)

To investigate the effect of bathymetry and coastline changes on flow within the project area and in particular the dispersal of effluent from WLSSD, a hydrodynamic model was developed. The model was based on the open source, finite-volume coastal ocean model (FVCOM), which was jointly developed by the University of Massachusetts-Dartmouth and Woods Hole Oceanographic Institution (Chen et al., 2007). The model solves the equations of momentum, heat transfer and continuity as they pertain to fluid flow on an unstructured grid.

Due to the large number of simulations required, computing resources available at the Minnesota Supercomputing Institute were used. Each simulation was carried out using up to 32 processors working in parallel.

Separate grids reflecting changes in coastline and bathymetry were generated for the current condition and the ecological design scenarios described below. Grids were generated using coastline and bathymetry data provided by UMD's NRRI and the National Geophysical Data Center. The domain included the whole of Lake Superior as far east as the St. Mary's River and as far west as the St. Louis River's Oliver Bridge. Grid resolution ranged from about 15km in the open lake to less than 50 m in the harbor around WLSSD. The entire lake was modeled because of the importance of processes such as lake seiches to harbor circulation.

.

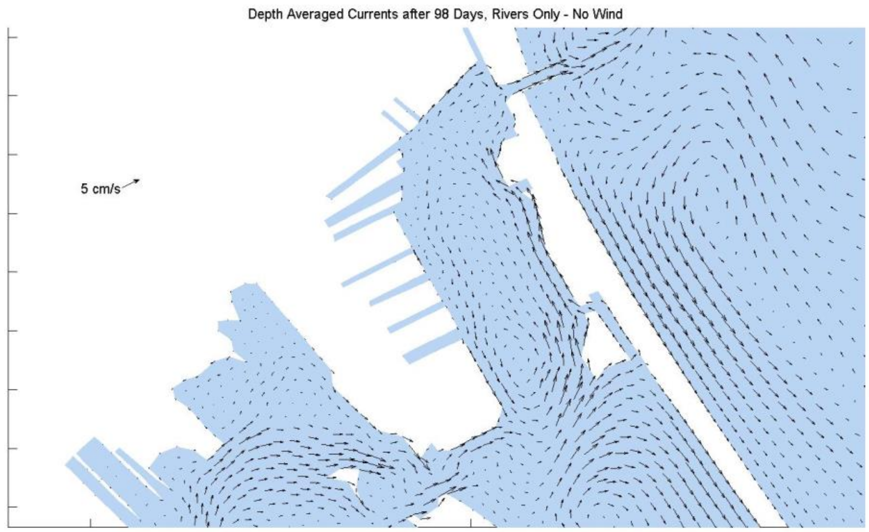


Figure 4. 1 Example of hydrodynamic model output under no wind conditions.

Five cases were modeled for the current condition and design scenarios, including average and strong wind conditions, from both east and west. River discharges were modeled as point volume sources, were temporally constant and included the St. Louis River, the WLSSD outfall, Miller Creek and the Nemadji River. Mean annual flow data was provided by the USEPA Mid-Continent Ecology Division. Consistent with WLSSD data, the WLSSD input water was put in at 29C, a much higher temperature than the ambient harbor water, resulting in significant thermal stratification.

The model was started from rest, with temperature structure of 7°C at depths of 1 through 20 m to 4°C at the bottom. Rivers were allowed to flow with their mean quantities (Appendix 4). The model was allowed to run for 8 weeks, which was sufficient time for currents due to river flows in the estuary to reach steady-state (Figure 12). Following this, a constant wind was applied to the domain to stimulate a typical Lake Superior seiche response. The model was considered to have an acceptable initial condition once a water level spectrum derived from the NOAA water level gauge in the Duluth Harbor (DULM5) records bore good agreement with modeled water level.

To track the dispersal of WLSSD effluent water, modeled discharge water was tagged with a conservative, passive tracer, henceforth referred to as “dye”. The area in which a dye concentration of at least 10% was found was the primary metric used to compare different scenarios. In addition to this measure of dye-affected area, the time required for a dye concentration of 1% to reach stations in the Superior Entry and Duluth Ship Canal was measured. For the control case as well as each of the scenarios, we will present the steady state dye distribution. In Figure 13 and following figures, the color represents the log of the vertically-averaged WLSSD effluent concentration

Selected models are posted to *www.d.umn.edu/~mdjames/modeling/*

Appendix 5. Ecotoxicological Characterization (E. Buttermore, Z. Jorgenson)

Fish and wildlife habitat in 21st Ave West Complex area of the St Louis River (Duluth, MN) has been identified as compromised by contaminated sediments. Complex chemical and physical interactions can affect contaminant transport and bioavailability; which can result in: tumors and other deformities in fish, degraded benthic communities, degraded fish and wildlife habitat, consumption advisories and other human health risks, aesthetic impairments, and restrictions on navigational dredging and beneficial re-use of dredged material (Crane and Hennes 2007). This "ecotoxicological characterization" presents a summary of existing information and some original site-specific data collected for the ecological design of the project area. The purpose of this information is to guide ecological risk management decisions necessary to ensure the implementation of remedial and restoration actions to result iUSn high quality aquatic habitat in the 21st Ave West Complex.

MPCA Site Evaluations

The MPCA remedial staff evaluated recent and historical sediment chemistry data for the 21st Ave W Project Area by examining contaminant concentration data and comparing to guidelines that are an indication of potential risk to ecological receptors (MPCA St. Louis River Sediment Assessment Remedial Review and Determination Memo 2013). Depth-integrated sediment samples collected in 2010 in cooperation with the USACOE and US EPA were used as the primary dataset used to make the PCA's determination, and the other historical studies were used to inform the conclusions and recommended management practices (RMPs). Historical studies that were evaluated are maintained in the Minnesota Pollution Control's Phase IV Database (*http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/contaminated-sediments/regional-sediment-databases.html*).

Risks evaluated included potential toxicity to sediment dwelling organisms based primarily on a comparison of bulk sediment contaminant concentrations to sediment screening values that are predictive of toxicity to benthic invertebrates. Sediment contaminant concentrations were compared to sediment quality targets (SQTs). SQTs are chemical benchmarks for the St. Louis

River AOC for the protection of benthic invertebrates (Crane and Hennes 2007). Level I SQTs represent contaminant concentrations below which are unlikely to negatively impact benthic organisms, and Level II SQTs represent contaminant concentrations above which are likely to negatively impact benthic invertebrates. Contaminant concentrations between Level I SQTs and Level II SQTs have an unknown impact to benthic organisms because site-specific characteristics will affect the toxicity, including temperature, pH, mixing of chemicals, etc. Another useful tool is the mean PEC-Q (probable effect concentration quotient), which has been shown to be a reliable basis for classifying sediments as toxic or not toxic to benthic invertebrates in the St. Louis River (Crane and Hennes 2007). Mean PEC-Qs are a sediment assessment tool that condenses data from a mixture of a select suite of contaminants [certain metals, total PAHs (polycyclic aromatic hydrocarbons), and total PCBs (polychlorinated biphenyls)] into one unitless index. Mean PEC-Qs are used to compare sediment quality over time and space (Crane and Hennes 2007).

MPCA evaluations noted that the greatest concentrations of **mercury** (above the Level II SQT) occur in sediments near the Western Lake Superior Sanitary District (WLSSD) Treatment Plant outfall at the 50-100 cm depth interval and within the bioactive zone. MPCA considers the bioactive zone to be from the sediment surface to 1 meter-deep into the sediment for shallow waters (less than 8 ft water depth) and in deeper waters (greater than 8 ft water depth), from the sediment surface to 0.5 m-deep into the sediment. For example, if a contaminated shallow-water area was to be covered with a 0.4-m layer of sediment, the bioactive zone would still include 0.6-m of the original, contaminated sediment. **PAH** concentrations are documented at elevated levels on the central portion of the bay west of the WLSSD outfall that occasionally exceeded the Level I SQT, and one sample (deeper interval; 50-100 cm; within the bioactive zone) above the Level II SQT. Another area with greater PAH levels is in the Miller/Coffee Creek Delta. **PCBs** are documented in sediments throughout the Project Area, with most of concentrations in between the Level I and II SQTs, with the greatest concentration exceeding the Level II SQT at a deeper interval (50-100 cm; below the bioactive zone) in the deeper water area of the former navigational channel. **Dioxin/furans** are documented in sediments on both sides of the WLSSD outfall with surficial sediment concentrations between the Level I and II SQTs. The deeper interval (50-100 cm), near WLSSD, had the greatest dioxin/furans concentration (exceeding the Level II SQT). **Metals** (zinc, copper, lead, and nickel) are documented in sediments at concentrations often exceeding the Level I SQTs, but not the Level II SQTs, with concentrations that are generally greater in the surficial sediments. Areas with the greatest frequency of contamination are the western-side of the bay (west of WLSSD outfall), the Miller and Coffee Creek Delta area and the former channel.

MPCA **recommended remedial practices** for the 21st Ave W Area (MPCA 2013) include the following:

- The default bioactive zone should be considered during remediation and restoration processes.
- Consult with an experienced risk manager when disturbing sediment.
- If possible, avoid disturbing sediment during restoration.
- More assessment and evaluation is recommended if disturbing sediment.
- Additional data collection may be required in areas where historical and/or recent data have indicated elevated contaminant concentrations.

The MPCA evaluations also noted some data issues and uncertainties which may affect risk determinations. For example, MPCA noted the following data quality exceptions: pesticides and some of the SVOC data were rejected because of quality control during analyses, which were out of compliance with the data quality goals. These data were not considered in this remedial assessment, and therefore it is difficult to quantify risk for these contaminants. Determination of total PCBs was especially problematic because the reporting limits were often above Level I SQTs, affecting the comparison with SQTs, and adding uncertainty to the assessment. For instance, when non-detects were treated as zero, 60% of samples were below the Level I SQT, but when ½ of the reporting limit was used for non-detected values, nearly 100% of the samples exceeded the Level I SQT. Another issue was that historical data are 20 years old, so there are uncertainties regarding the extent to which these data represent current conditions within the project area.

FWS Evaluations of Sediment Chemistry, Toxicity, and Bioaccumulation

The U.S. Fish and Wildlife Service initiated limited sampling and testing of sediments and fish in the 21st Ave West Complex in 2011-12 to complement the 2010 sediment sampling noted above. The primary objective of this investigation was to evaluate the toxicity and bioaccumulation of contaminants in surficial sediments obtained from the project area. Bulk sediments were collected for chemical analyses through U.S. Fish and Wildlife Service contract laboratories, and sediment toxicity tests were conducted by the U.S. Geological Survey, Columbia Environmental Research Center in Columbia, MO (USGS-CERC). Fish were also collected from the study area to provide an additional indication of contaminant exposure. Results of these sediment tests provide additional information to help evaluate trends in contaminant bioavailability at the 21st Ave West Complex Remediation to Restoration Project site and have helped to determine actions necessary to meet ecological goals while minimizing potential for contaminated sediments to limit the development of high quality aquatic habitat.

USFWS 2012 Methods

Sample collection

Sediment was collected from fifteen locations in the 21st Avenue West Complex on May 7 and 8, 2012 (Figure 5.1). Approximately 12 L of surficial sediment were obtained at each location through compositing multiple grab samples using a hand-held dredge and stainless steel bowls and scoops. Samples were stored on ice in a cooler, and transferred to USGS-Columbia, MO, where they were subsequently stored in the dark at 4°C until toxicity and bioaccumulation testing. White suckers (*Catostomus commersonii*; $N = 15$; total length range = 362 to 462 mm) were collected from the project area by seining in the spring of 2011.

Toxicity and Bioaccumulation Tests

Relationships between sediment chemistry, toxicity and bioaccumulation were evaluated using the amphipod *Hyalella azteca* (28-day whole-sediment exposures measuring effects on survival, growth, and biomass) and the midge *Chironomus dilutus* (10-day whole sediment exposures measuring effects on survival, growth, and biomass) and bioaccumulation of contaminants of concern by the oligochaete *Lumbriculus variegatus* (28-day whole-sediment exposures). Contaminants of potential concern in the sediments include both metals and organic contaminants (including PAHs, PCBs, and chlorinated pesticides).

The toxicity and bioaccumulation (metals only) tests met test acceptability requirements outlined in USEPA (2000) and in ASTM (2012a, b). Statistical analyses for toxicity tests were performed using SAS statistical software (SAS/STAT version 9.2; SAS Institute, Cary, NC). Differences in a toxicity endpoint among sites within a study area and within batch of sediments tested were determined by analysis of variance (ANOVA). Toxicity endpoint data were transformed before ANOVA to improve normality, as indicated by the Shapiro-Wilks test (USEPA 2000; ASTM 2012a). If transformations (arcsine square root for survival; square root or log for weight or total biomass) did not improve normality, data were rank-transformed before analysis (Conover and Iman 1981).

Whole sediment toxicity and bioaccumulation tests were conducted following methods outlined in USEPA (2000), ASTM (2012a, b), and Ingersoll (2008). Control sediment used in the toxicity tests was obtained from West Bearskin, MN (approximately 3% total organic carbon). No control sediment was used in the bioaccumulation test, although in future studies it would be recommended to help evaluate the data. Toxicity endpoints for midge included 10-d survival, ash-free-dry weight (AFDW), and total biomass. Total biomass was calculated as the sum AFDW for all surviving organisms in each replicate chamber. Toxicity endpoints for amphipods included 28-d survival, length, weight, and total biomass. Surviving amphipods were preserved in 8% sugar formalin for subsequent 28-d length measurement. The biomass of surviving amphipods from each replicate was estimated as the sum of individual amphipod weights calculated from the empirical relationship: Weight (mg) = $\{[0.177 * \text{Length (mm)}] - 0.0292\}^3$ (Ingersoll et al. 2008; Moran et al. 2012). Oligochaetes were held in clean test water following exposure for 8 hours to depurate their gut contents before samples were frozen at -20°C for subsequent tissue analyses. Test organisms at the end of the exposures (Day 10 for midge and Day 28 for amphipods, or oligochaetes) were isolated from sediment in each chamber. Overlying water quality (dissolved oxygen, pH, hardness, alkalinity, conductivity, and ammonia) was determined at the beginning and the end of each test in each treatment. Pore-water quality was measured at the start of the sediment exposures (Kemble et al. 1994).

Sediment, Oligochaete, and Fish chemistry

Physical (total organic carbon) and chemical characterization of the test sediment, oligochaetes (composited), and fish (whole-body) were performed by the Geochemical and Environmental Research Group in College Station, Texas (for organic contaminants: organochlorines, aliphatics, and aromatics) and Alpha Woods Hole Laboratory in Mansfield, Massachusettes (for metals). Because of limited sample mass, worm analyses were limited to inorganic contaminants. A rigorous QA/QC protocol was followed. Results were not corrected for recoveries, due to acceptable accuracy and precision revealed by QA/QC protocol and were reviewed by the Analytical Control Facility (U.S. Fish and Wildlife Service).

Results

<u>Sediment Chemistry and Guideline Exceedances</u>

Contaminant concentrations were compared to sediment quality guidelines to assess risk to the aquatic community. Individual contaminant concentrations in sediment samples frequently exceeded the Level I SQT, and occasionally exceeded the Level II SQT (Table 5.1). Sediment from 9 of the 15 locations included contaminant mixtures exceeding the Level 1 Mean PEC-Q. Site 4 had the greatest sediment mean PEC-Q (0.41), which is between the Level I and Level II PEC-Qs (Figure 5.2). Contaminants of concern included: PAHs (especially 2-methylnaphthalene and naphthalene), PCBs, and mercury. **PAHs** were detected at high levels with 2-methylnaphthalene, and naphthalene exceeding Level II SQT at sites 4 and 13 (Figure 5.1). **Mercury** in sediment was also found at greatest concentrations at site 4 near WLSSD (Figure 5.3; Figure 5.4, B subarea). Total **PCB** concentrations were greatest in WLSSD area (Figure 5.4, subareas B and C). In general, **chlorinated pesticide** concentrations were low. **Toxaphene** was not detected in any sediment samples, although the detection limits were greater than the Level I SQT.

Contaminants tend to sorb to organic carbon, total organic carbon (TOC) is an indicator of the capacity of sediments to hold contaminants. Total organic carbon was similar among sites (mean = 3.1%; range = 0.2-6.5%) with sediment collected from site 4 having the greatest TOC.

Sediment Toxicity

One sediment sample (Site 15) demonstrated toxicity to both amphipods (lower survival) and midge (reducd growth) test organisms relative to the control sediment. Sediment from Site 13 was toxic to midge test organism (reduced growth) relative to the control sediment. Although sediment samples from site 15 were classified as the most toxic, it had low contaminant concentrations (Table 5.1), and similar water quality characteristics when compared to other sites, which suggests that perhaps some other contaminant that was not tested for is causing these adverse effects to these invertebrates.

Bioaccumulation

Sufficient tissue mass for chemical analyses of oligochaetes were obtained from all of the 15 treatments at the end of the exposures except for the site 4 treatment (near WLSSD), of which very few oligochaetes survived, suggesting possible anecdotal evidence of toxicity. Because few worms survived in the site 4 treatment, there was less tissue mass, and thus greater detection limits. For example, mercury detection limits for worm tissue was 0.012 ppm wet weight for every treatment except for site 4, where the detection limits was 0.063 ppm wet weight. The worms did not accumulate significant concentrations of inorganic contaminants; organics contaminants were not tested for due to low tissue mass (Table 5.s 2, 3, 7).

Other Bioindicators

Contaminant concentrations in white suckers (whole-body) generally reflected those contaminants of concern found in sediment (Table 5.7 and 5.8). 1987 guidelines were created for contaminants (mercury, total DDT, PCBs) in fish for the Great Lakes Water Quality Agreement (GLWQA). **PAHs** are rapidly metabolized in vertebrates, and therefore, if they are measured in fish tissue, it is indicative of recent exposure to elevated levels of PAHs. Several **PAHs** were detected in white sucker samples (1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, biphenyl, C1-naphthalene, and naphthalene). **PAHs** that were found at the greatest concentrations in sediment were also detected at the greatest concentrations in fish (naphthalene: mean = 27.2 ppb-wet; range = 2.7 to 263.3 ppb-wet; 2-methylnapthalene: mean = 3.7 ppb-wet; range = undetected to 42.2 ppb-wet; Table 5.8). All fish samples (mean = 0.08 ppb-wet; range = 0.042 to 0.20 ppb-wet) exceeded a Canadian **mercury** guideline for the protection of wildlife consumers of aquatic biota (guideline = 0.033 ppb-wet; CCME 2001; Table 5.7), but were all below the GLWQA guideline of 0.5 ppm-wet.

PCBs were detected at average concentrations of 193.2 ppb-wet, and ranged from 57.9 to 323.3 ppb-wet and 93% of the fish samples exceeded the GLWQA for PCBs (100 ppb-wet; Table 5.8). Total **DDT** concentrations in white suckers (mean = 13 ppb-wet; range = 4.3 to 23.1 ppb-wet) sometimes exceeded the guideline for the protection of wildlife consumers of aquatic biota of 14 ppb-wet (CCME 2001), but all samples were below the GLWQA (1000 ppb-wet; Table 5.8). Most **chlorinated pesticides** were detected at low levels or not detected at all in fish samples in this study.

USGS Tree Swallow Data

Tree swallows (*Tachycineta bicolor*) serve as an indicator of contaminant exposure through a semi-aquatic foodchain because they feed on the aerial stage of benthic aquatic insects. In 2010 and 2011, the U.S. Geological Survey, deployed Tree swallow nest boxes throughout the United States, including one near the 21st Ave W Project Area. Two eggs were analyzed for organic contaminants (PCBs, PBDEs, and DDE). Blood plasma was analyzed for PFCs. Liver tissue was analyzed for cadmium, mercury, and bioindicator responses (EROD activity and genetic damage). PCBs egg concentrations (mean = 0.39 ppm-wet) were lower than the hatching effect level (20 ppm-wet) for the Project Area. EROD was induced above reference locations and the CV of DNA was wider than the reference site's values (T. and C. Custer p*ers. comm.*).

Discussion

Contaminant risks in the project area are still somewhat poorly understood because of some data issues and uncertainties which may affect risk determinations. It would be helpful to have more data with depth profiles and acceptable detection limits (below Level I SQTs) to help inform remedial management. For example, data collected in 2008 and 2010 had poor detection limits for select contaminants, such as PCBs and chlorinated pesticides and were not useable. These data were not considered in this remedial assessment, and therefore it is difficult to quantify risk for these contaminants. Invertebrates for the toxicity and bioaccumulation bioassay exposures were limited to surficial sediments for the 2012 FWS study. In addition, bioaccumulation data are limited because the oligochaetes from the bioassay were only tested for metals due to low tissue mass. For future studies, it would be beneficial to focus analyses on PAHs, PCBs, toxaphene, dioxin/furans, and mercury for bioaccumulation assays. Another consideration is that there are a number of life history characteristics of organisms that affect how they bioaccumulate contaminants (e.g., habitat affinities and trophic level). White suckers were used in this risk assessment because they are benthic feeders and consume worms, thus are directly exposed to sediment contaminants, such as PAHs, PCBs, and mercury. White suckers are low in lipid content (mean = 1.6%, range = 0.8 to 2.9%) and also low on the foodchain. Other fish species that are greater in lipid content and higher in trophic level may have greater contaminant concentrations (e.g., mercury and organochlorinated compounds).

Recent (FWS 2012) data are generally consistent with previous results (as presented in MPCA 2013). Most individual contaminant concentrations were below the Level II SQT for both data evaluations. However, nearly all sample locations (some locations included multiple depths) exceeded the Level I SQT, and a majority of the sample sites also exceeded the Level II SQT, for at least one contaminant (Figure 7). Datasets (Phase IV and 2012) indicate toxic effects to benthic invertebrates throughout the 21st Ave W Project Area (Figure 5.5). The area near the WLSSD generally had the greatest contaminant concentrations (when considering all recent and historical data). For example, **mercury** and **PCBs** in sediment was found at greatest concentrations near WLSSD (Figure 5.4, B subarea; Figure 5.s 8 and 10). Data also suggest that **PAHs** were elevated in this area (see Figure 5.4, A and B subareas; Figure 5.9). In general, chlorinated pesticide concentrations were low. **Toxaphene** was not detected in any recent (2008-2012) sediment samples, although the detection limits were greater than the Level I SQT. Historical data indicate that the area was contaminated by **toxaphene**, thus, it may be important to consider this chemical during future sampling efforts. According to the recent sediment chemistry data (2010) described in the MPCA Memo (MPCA 2013), **dioxin/furans** were also detected at elevated levels on both sides of the WLSSD outfall (Figure 5.4, subarea B), with a majority of these concentrations in between the Level I and II SQTs, and one sample from a deeper interval exceeding the Level II SQT. **Dioxin/furans** were not tested in the most recent (2012) study. Historical data indicate more contaminated sediment near the surface, but recent data (2008, 2010) suggest that greater contaminant levels are in the deeper sediments. These data may indicate that contaminated sediment has been buried over time. Disturbance of these contaminated sediments could increase bioavailability of contaminants, and thus increase the toxic effects to fish and wildlife.

There are a few remaining issues with available data and subsequent interpretations of those data. Previous studies were conducted with different objectives, and consequently different methods, which makes their results somewhat difficult to compare to each other. Recent risk assessments of the area concluded that "limited contamination is present, but the sediment in the remediation area does not present a significant risk to the aquatic community if the sediment is undisturbed". However, recently collected (FWS 2012) surficial sediment samples were toxic to benthic organisms. In addition, recent risk assessments have concluded that "The level of sampling conducted during this assessment is adequate to determine if significant areas of elevated contaminant concentrations are present and provide information regarding relative contamination levels within the assessment areas." However, this risk assessment did not include the entire project area, and there are limited data for the area that was not evaluated (area near the state-line). Another potential problem is the comparison of contaminant concentrations to the midpoint between the Level I and II SQTs. The midpoint between these two guidelines is an arbitrary number and does not necessarily reflect harm to the aquatic community. The relationship in between the Level I and Level II SQTs is unknown (i.e., the relationship may not be linear, or the midpoint value may be about equal in toxicity as the Level 2 PEC-Q). For example, a contaminant concentration near the Level I SQT may be severely harmful to an organism, or it may have a therapeutic effect at that concentration, depending on other site characteristics. Additional analyses would be beneficial to distinguish a more scientifically-based threshold for the protection of fish and wildlife resources

In summary, available data indicate that the most contaminated areas (mercury, PAHs, and PCBs) are near the WLSSD (Figure 5.4, B and C), the delta area of Miller and Coffee Creek (Figure 5.4, A), and near the state line in the river (Figure 5.4, D). Data are also more limited towards the state line of the project area (Figure 5.4, D), and toxicity data indicate adverse effects on invertebrates. Intensive sampling in these areas would better inform the necessary remedial evaluations. Additional monitoring post-restoration will also help inform remedial decisions and is recommended because restoration activities are likely to disturb sediment and have the potential to increase contaminant bioavailability (especially if restoration will alter the geochemical conditions of the area).

Ecological Risk Management Considerations

Available data suggest that there are moderate remedial considerations for the 21st Ave W restoration area. While recent sediment chemistry data (MPCA 2013) suggest that the greatest concentrations are often found in deeper sediment layers (50-100 cm), including the exceedance of Level II SQTs, these data also show that contaminant concentrations exceed the Level I SQTs in the surficial sediments. Additional recent results (FWS 2012) indicate that surficial sediment, in a few areas, exhibit toxic effects on invertebrates. Therefore, the project area presents a significant risk to the aquatic community even if the sediment is left undisturbed in these particular locations (particularly near the State Lines and WLSSD; FWS 2012 sites 4, 13, and 15; Figure 5.4, B and D).

<u>Recommended remedial practices</u>

- Ensure that sediments being used as fill in the 21st Ave Project Area are clean and meet state standards.

- Consult with an experienced risk manager during the remediation and restoration processes.

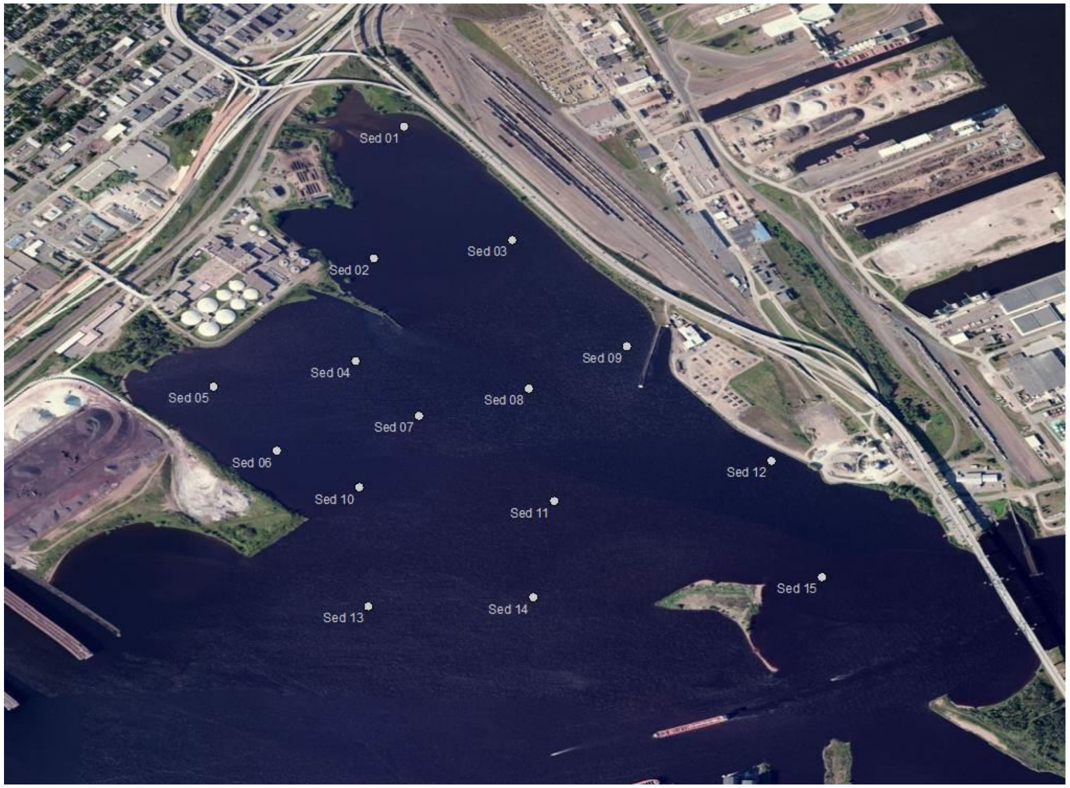
- Remedial actions should consider bioactive zones for the selected project design.

- When restoring habitat, it is important to avoid disturbing sediment in areas with greater contaminant concentrations (Figures 8-10). Disturbance of these contaminated sediments could increase bioavailability of contaminants, and thus increase the toxic effects to fish and wildlife.

In conclusion, results have provided information to evaluate trends in contaminant bioavailability at the 21st Ave West Complex Remediation to Restoration Project site and have guided actions necessary to meet ecological goals while limiting or removing the likelihood of exposure to contaminated sediments.

Figure 5.1: Map of sediment sampling locations (FWS 2012)

Site	Latitude	Longitude
1	46° 45' 49.4"	92° 07' 10.0"
2	46° 45' 35.0"	92° 07' 13.4"
3	46° 45' 37.0"	92° 06' 58.3"
4	46° 45' 23.8"	92° 07' 15.4"
5	46° 45' 21.0"	92° 07' 30.9"
6	46° 45' 14.0"	92° 07' 24.0"
7	46° 45' 17.8"	92° 07' 08.5"
8	46° 45' 20.8"	92° 06' 56.5"
9	46° 45' 25.4"	92° 06' 45.8"
10	46° 45' 10.0"	92° 07' 15.0"
11	46° 45' 08.5"	92° 06' 53.7"
12	46° 45' 12.9"	92° 06' 30.0"
13	46° 44' 57.0"	92° 07' 14.0"
14	46° 44' 58.0"	92° 06' 56.0"
15	46° 45' 00.2"	92° 06' 24.5"



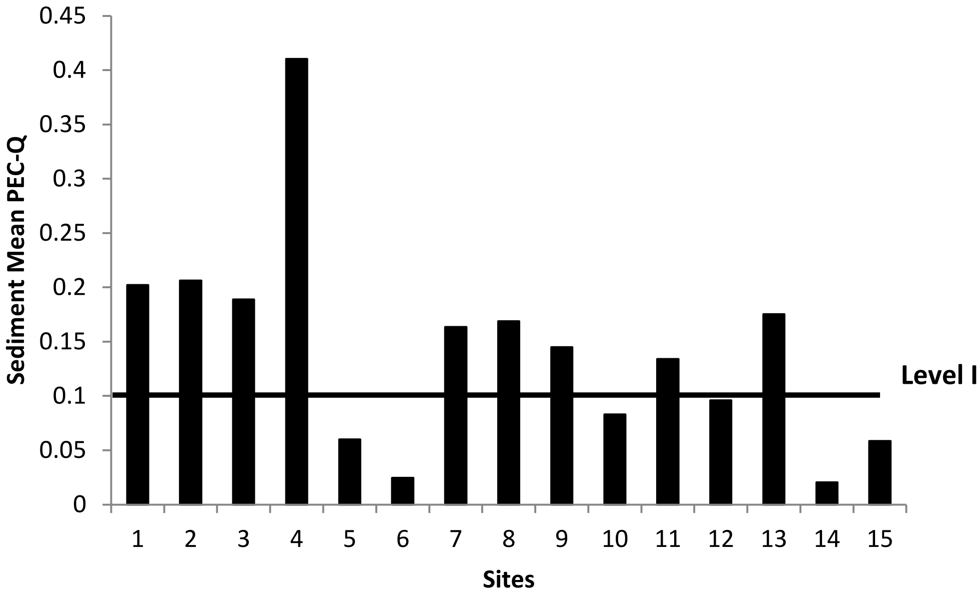


Figure 5.2. Mean sediment PEC-Q values for each site. The line indicates the Level 1 benchmark value, which suggests that sediment PEC-Qs below this benchmark provide a high level of protections for benthic organisms (FWS 2012). Mean PEC-Q: (mean probable effect concentration quotient). A screening tool used to compare sediment quality between sites. It only includes contaminant data that has available PEC values (7 metals, 13 PAHs, and PCBs). Mean PEC-Qs have been shown to provide a reliable basis for classifying sediments as toxic or not toxic in the St. Louis River of Concern (Crane and Hennes 2007). Mean PEC-Q Level 1 = 0.1; Mean PEC-Q Level 2 = 0.6.

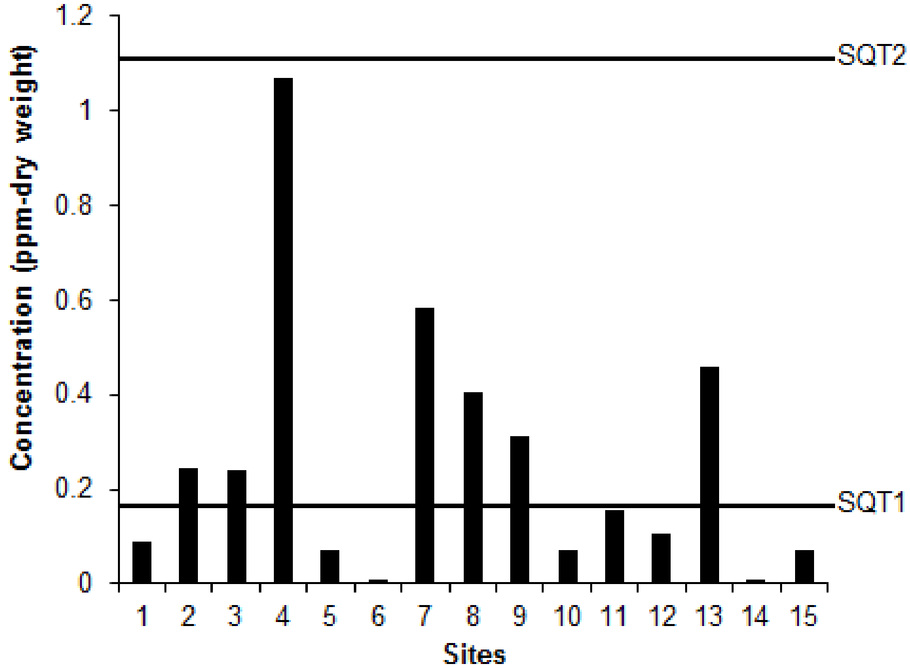


Figure 5.3. Mercury concentrations in sediment (ppm-dry weight). SQT I (Level 1 sediment quality targets): Chemical concentrations which will provide a high level of protection for benthic invertebrates. SQT 2 (Level 2 sediment quality targets): Chemical concentrations which will provide a moderate level of protection for benthic organisms.

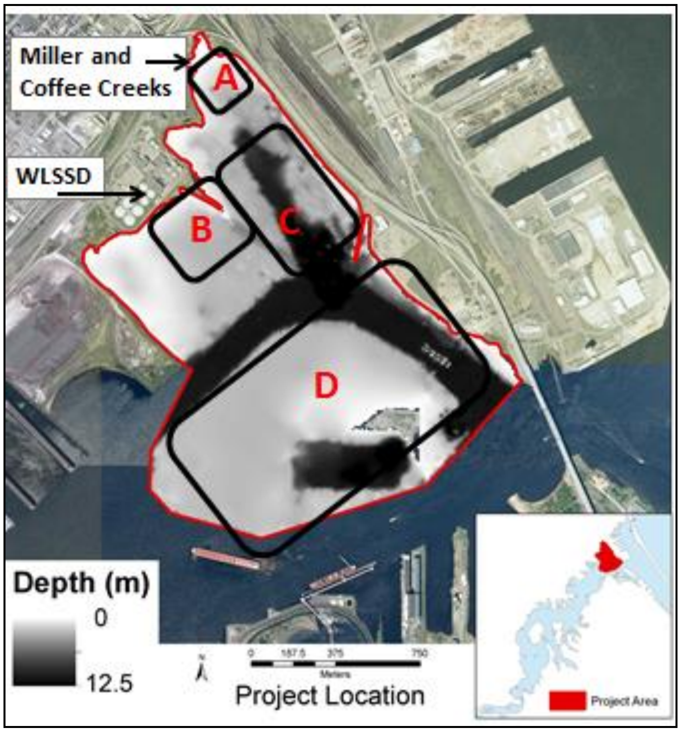


Figure 5.4. General areas requiring more in-depth characterization for toxicologywithin the 21st Ave W Project Area.

A: Miller and Coffee Creeks delta area
B: WLSSD outfall area
C: Former channel
D: Near the state-line of the St. Louis River

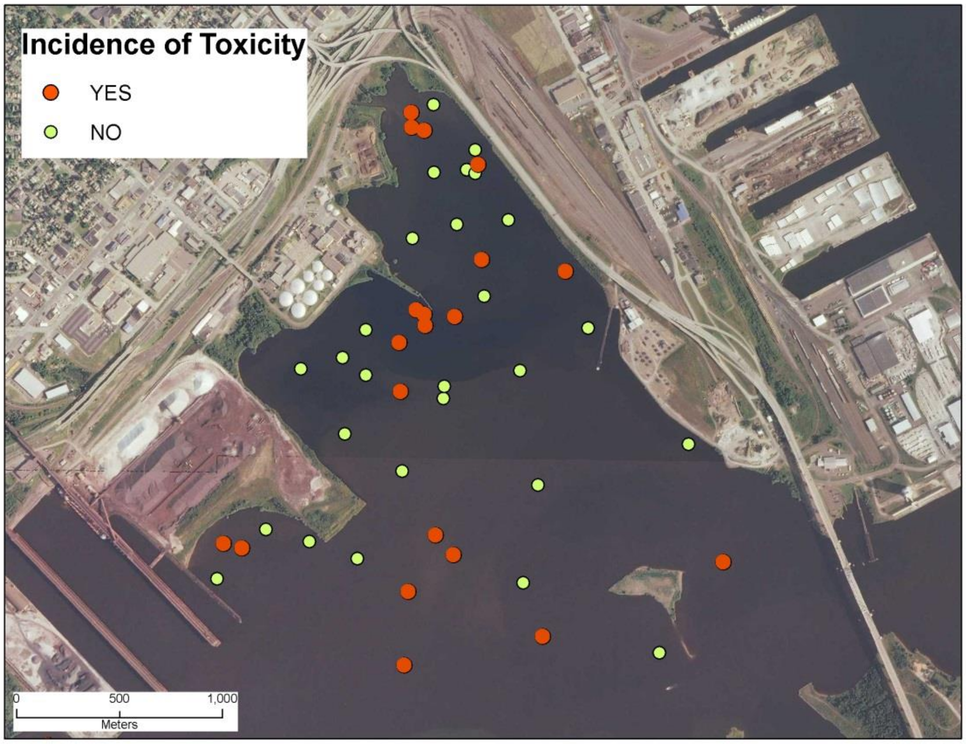


Figure 5.5. Invertebrate toxicity results from all available studies [MPCA Phase IV database (R-EMAP Study 1995, Hotspot Study 1994; R-EMAP Study 1996; Duluth-Superior Harbor Study 1993) FWS 2012].

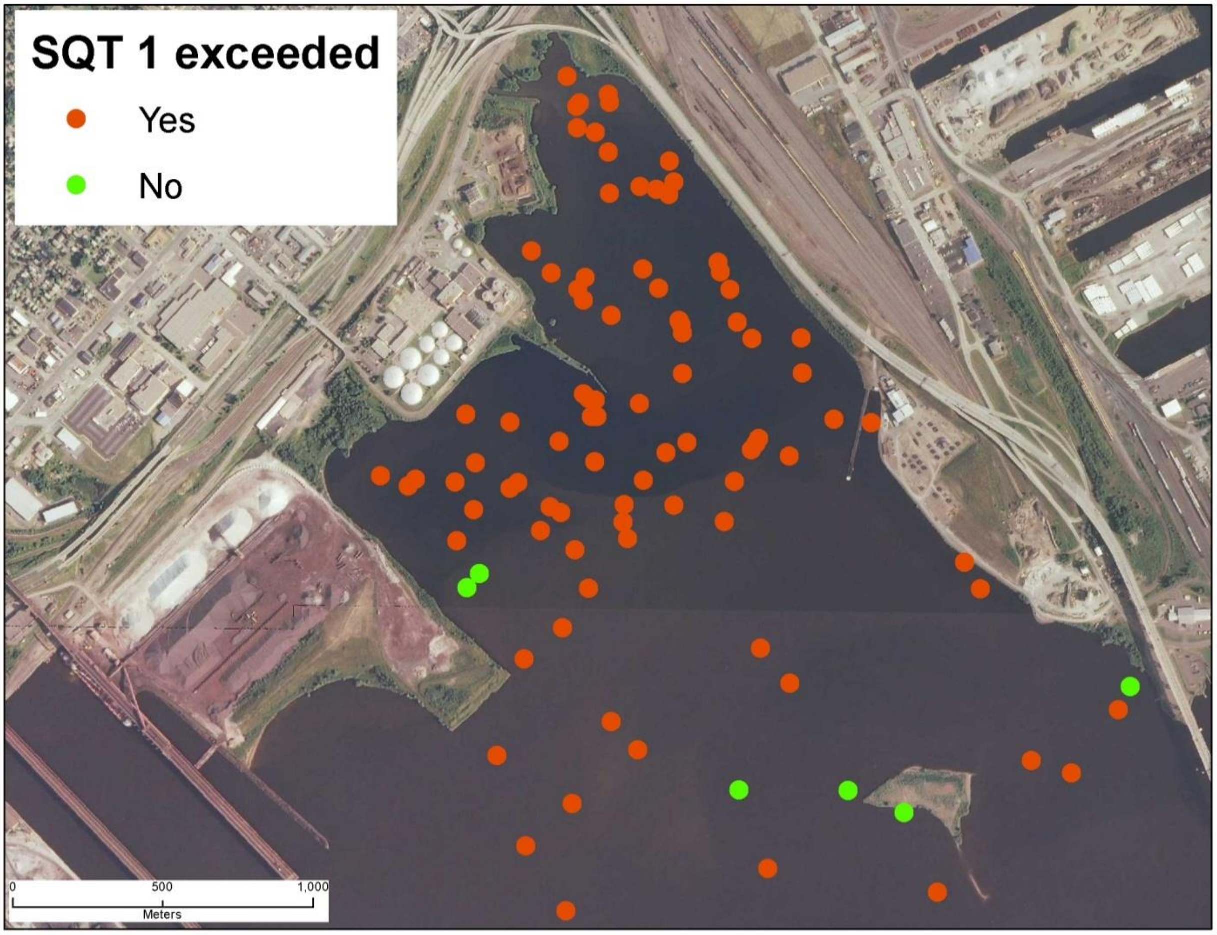


Figure 5.6. All contaminant concentrations exceeding Level I SQT [MPCA Phase IV database (R-EMAP Study 1995, Hotspot Study 1994, R-EMAP Study 1996, Duluth-Superior Harbor Study 1993, Toxaphene Study 1996, USACE DACW35-93-D0005 Delivery Order 29, USACE DACW35-91-D0005 Delivery Order 40, Superior Bay – 21st Ave 2008 & 2010, St. Louis bay 40th Ave. 2010) FWS 2012]

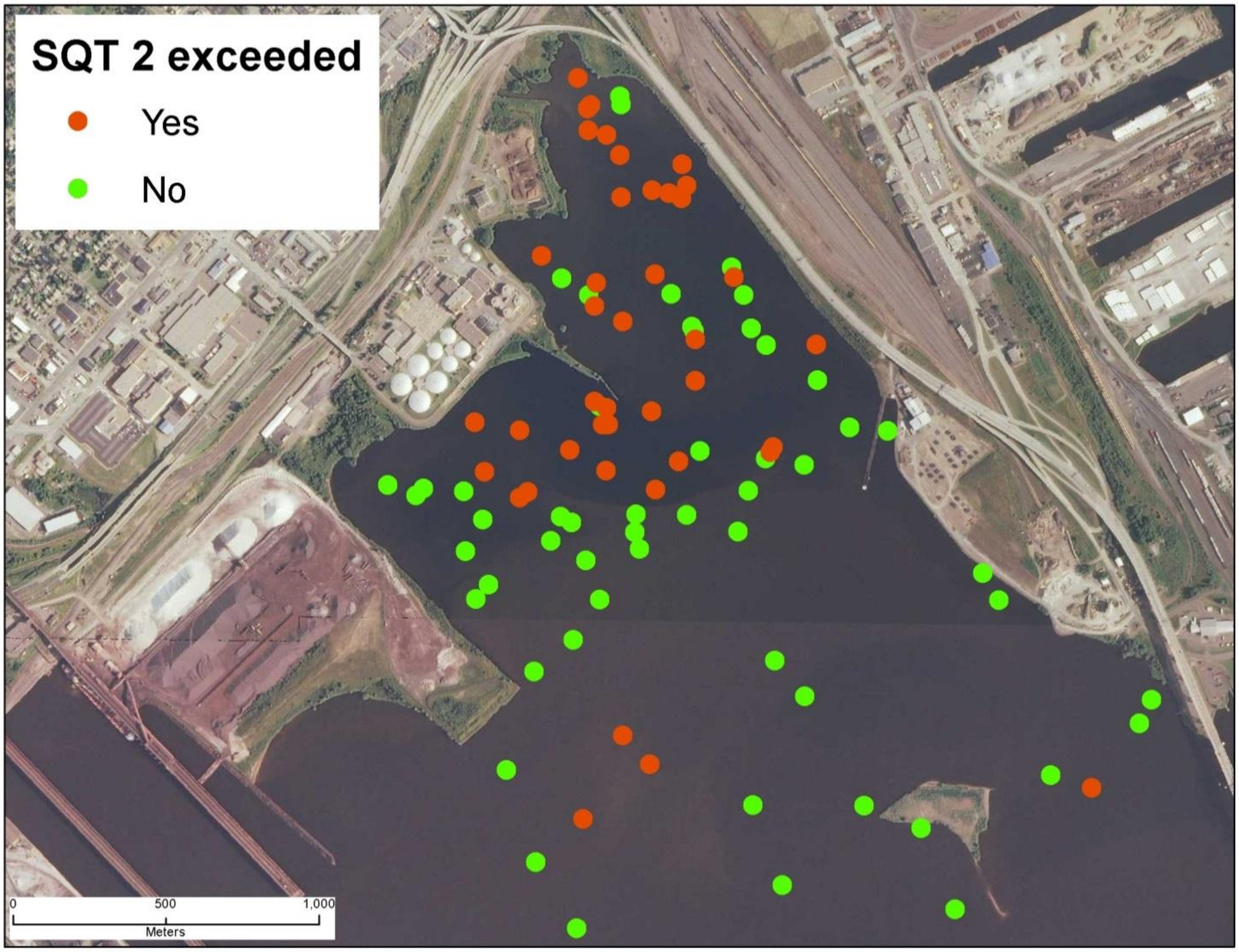


Figure 5.7. All available contaminant concentrations exceeding SQT 2 for all studies [MPCA Phase IV database (R-EMAP Study 1995, Hotspot Study 1994, R-EMAP Study 1996, Duluth-Superior Harbor Study 1993, Toxaphene Study 1996, USACE DACW35-93-D0005 Delivery Order 29, USACE DACW35-91-D0005 Delivery Order 40, Superior Bay – 21st Ave 2008 & 2010, St. Louis bay 40th Ave. 2010) FWS Study 2012].

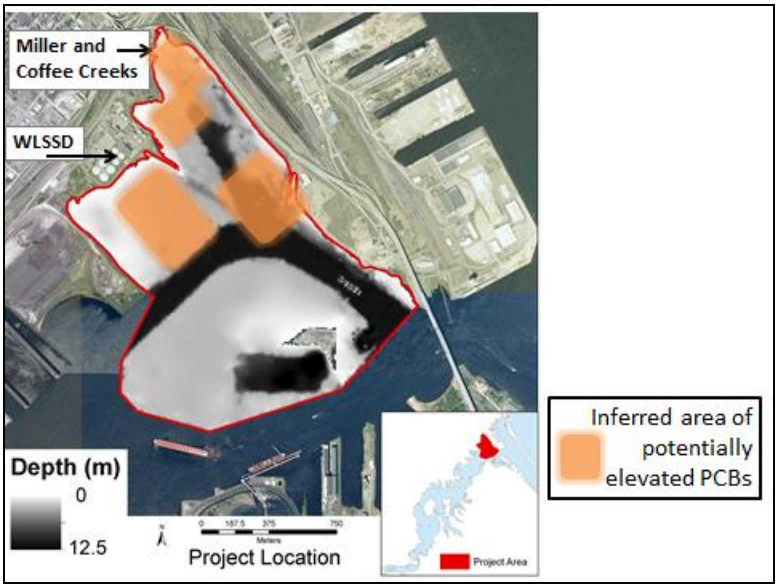


Figure 5.8. Inferred areas of potentially elevated PCBs.

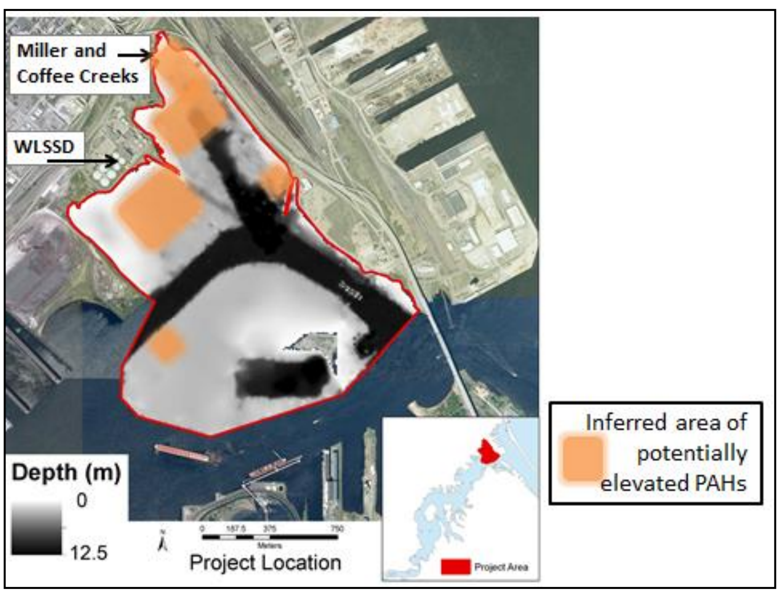


Figure 5.9. Inferred areas of potentially elevated PAHs.

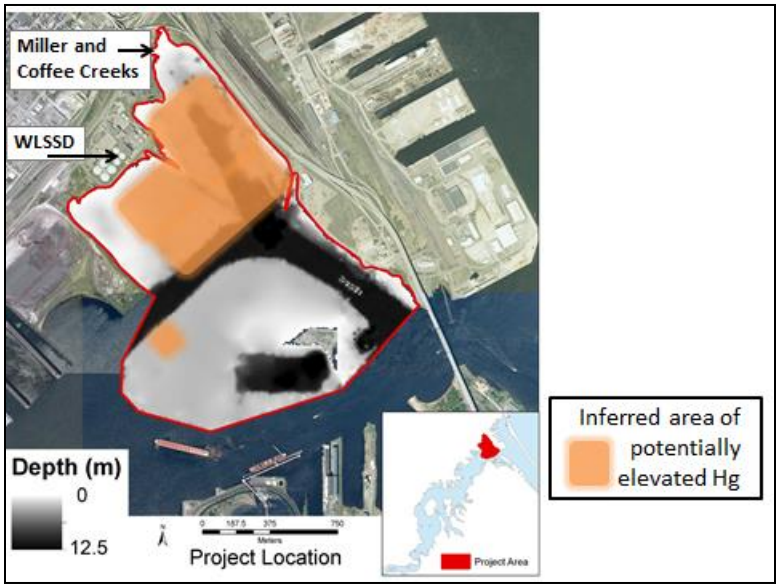


Figure 5.10. Inferred areas of potentially elevated mercury (Hg).

Table 5.1. Sediment contaminant concentrations for each FWS 2012 site, mean concentrations for the project area, and mean PEC-Q values. No asterisk indicates concentrations that are below Level I SQT. One asterisk indicates concentrations that are above Level I SQT, but are below Level II SQT. Two asterisks indicate concentrations that exceed Level II SQT. Toxaphene is italicized because it was below detection limits, but the detection limits exceeded the Level I SQT.

Analyte	**Site**															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Mean**
Chlorinated Pesticides (ppb)																
Dieldrin	0.11	0.07	0.07	0.07	0.03	0.11	0.05	0.20	0.05	0.04	0.06	0.05	0.04	0.03	0.04	**0.1**
Endrin	0.20	0.07	0.37	0.25	0.03	0.12	0.05	0.17	0.05	0.04	0.30	0.05	0.04	0.19	0.04	**0.1**
Gamma BHC	0.31	0.07	0.32	0.63	0.22	0.03	0.32	0.13	0.14	0.04	0.52	0.19	0.25	0.03	0.11	**0.2**
Heptachlor epoxide	0.08	0.07	0.17	0.07	0.03	0.07	0.05	0.06	0.05	0.04	0.06	0.05	0.04	0.08	0.04	**0.1**
Toxaphene (not detected)	*0.65*	*1.36*	*1.36*	*1.31*	*0.68*	*0.59*	*1.08*	*1.27*	*0.90*	*0.78*	*1.26*	*1.03*	*0.90*	*0.62*	*0.72*	***1.0***
Sum DDD	0.80	0.46	0.47	*8.21	0.98	0.09	1.19	0.41	1.63	0.23	0.34	0.38	1.95	0.06	0.33	**1.2**
Sum DDE	0.40	0.62	0.33	2.89	0.07	0.15	0.64	0.58	0.38	0.08	0.23	0.10	0.53	0.31	0.23	**0.5**
Sum DDT	0.45	0.43	0.14	0.37	0.07	0.09	0.11	0.13	0.09	0.17	0.13	0.19	0.09	0.06	0.11	**0.2**
Total DDT	1.64	1.50	0.94	*11.47	1.12	0.33	1.94	1.12	2.10	0.47	0.70	0.67	2.56	0.43	0.68	**1.8**
Total chlordanes	0.93	0.60	0.67	*6.87	0.25	0.18	0.96	0.56	0.77	0.30	0.32	0.39	0.54	0.16	0.18	**0.9**
PCBs (ppb)																
Total PCBs	*69.5	*72.6	51.8	*330.0	24.2	8.8	*85.3	56.4	*61.6	30.9	42.7	36.1	49.9	8.4	25.3	***63.6**
PAHs (ppb)																
2-methylnaphthalene	*36.1	*49.9	*46.3	****477.3**	*43.0	1.8	*172.0	*67.9	*123.0	*119.4	*61.3	*66.0	*138.0	1.9	*39.8	***96.2**
Acenaphthalene	*47.7	*30.8	*26.5	*124.2	*10.3	1.8	*43.2	*22.9	*42.2	*19.6	*25.2	*27.5	*49.0	1.9	*14.1	***32.5**
Acenaphthene	*35.6	*17.6	*14.5	*78.1	5.0	1.8	*23.8	*14.4	*24.4	*8.7	*11.3	*13.1	*18.2	1.9	*7.5	***18.4**
Anthracene	*271.3	*81.0	*72.7	*327.4	27.8	1.8	*104.6	*59.4	*95.3	49.0	*59.1	*63.0	*124.3	1.9	32.3	***91.4**
Benzo(a)anthracene	*722.9	*214.2	*168.5	*730.0	84.7	1.8	*292.5	*185.6	*252.6	85.9	87.1	90.6	*213.1	1.9	44.8	***211.7**
Benzo(a)pyrene	*548.5	138.6	71.0	*408.5	28.8	1.8	115.8	84.8	110.5	66.7	81.9	70.3	*154.5	1.9	36.3	**128.0**
Chrysene	*843.5	*269.0	*204.8	*879.7	94.8	4.6	*308.7	*217.3	*292.8	101.1	105.8	160.8	*258.7	1.9	52.1	***253.0**
Dibenz(a,h)anthracene	*79.8	26.7	16.6	*66.0	5.8	1.8	24.1	17.4	26.5	11.1	12.0	12.7	27.7	1.9	6.3	**22.4**
Fluoranthene	*1687.4	*501.9	401.1	*1655.1	101.0	8.3	*444.4	250.4	345.8	175.5	223.9	233.0	403.6	7.1	127.9	***437.8**
Fluorene	61.2	28.9	24.8	*159.5	15.0	1.8	59.2	31.2	53.5	32.1	29.4	32.4	62.1	1.9	19.7	**40.8**
Naphthalene	38.0	115.5	137.9	****943.5**	89.4	4.2	*402.3	*210.5	*297.7	151.2	*261.1	*193.4	****607.0**	4.4	91.3	***236.5**
Phenanthrene	*747.8	169.7	134.7	*851.0	55.2	1.8	*218.8	97.4	186.8	100.6	84.3	97.5	168.6	1.9	49.4	**197.7**
Pyrene	*1128.1	*412.0	*344.1	*1313.0	86.4	7.0	*380.5	*220.5	*294.4	151.1	179.8	193.9	*347.9	5.8	108.9	***344.9**

Total PAHs	*6248.0	*2055.8	*1663.4	*8013.3	647.3	40.2	2590.1	1479.7	*2145.7	1072.1	1222.2	1254.3	*2572.4	36.0	630.4	***2111.4**
Metals (ppm)																
Arsenic	2.4	5.0	5.2	5.9	1.9	1.0	4.2	5.2	3.8	2.7	3.8	3.3	4.5	1.1	1.9	**3.5**
Cadmium	0.4	1.0	*1.2	*2.2	0.3	0.0	0.9	*1.1	0.7	0.3	0.5	0.4	*1.0	0.0	0.2	**0.7**
Chromium	22.4	*50.4	*50.3	31.6	14.5	9.2	29.6	*47.1	27.0	21.3	41.9	23.8	37.2	6.8	14.3	**28.5**
Copper	*40.4	*58.8	*53.2	*57.7	15.3	5.3	30.0	*44.5	27.0	16.4	28.4	20.1	*32.9	4.6	10.9	**29.7**
Mercury	0.1	*0.2	*0.2	*1.1	0.1	0.0	*0.6	*0.4	*0.3	0.1	0.2	0.1	*0.5	0.0	0.1	***0.3**
Nickel	*23.0	*37.9	*39.9	22.2	13.8	9.4	21.9	*33.5	20.1	18.2	*33.1	19.3	*30.1	6.4	12.5	**22.8**
Lead	33.6	*58.3	*49.4	*57.8	8.3	2.1	31.0	35.7	*48.2	14.9	25.8	17.3	*47.4	2.7	10.6	**29.5**
Zinc	116.0	*238.0	*229.0	*250.0	54.8	20.9	*136.0	*206.0	*126.0	73.6	*152.0	93.2	*223.0	20.5	58.2	***133.1**
Overall Mean PEC-Q	***0.20**	***0.21**	***0.19**	***0.41**	**0.06**	**0.02**	***0.16**	***0.17**	***0.14**	**0.08**	***0.13**	***0.10**	***0.18**	**0.02**	**0.06**	***0.14**

Table 5.2. Comparison of our 2012 study data with a previous assessment (2004) indicating frequency of low, moderate, and high risk sediment samples from the St. Louis River (Crane and Hennes 2007)

Location description	N	Percentage of samples within ranges of mean PEC-Qs		
		<0.1 Low	0.1-0.6 Moderate	>0.6 High
Hog Island Inlet/Newton Creek	189	19	78	3
Howard's Bay	30	7	83	10
Lower St. Louis River	46	33	61	6
Minnesota Slip	62	2	11	87
Slip C	48	15	46	39
SLRIDT Superfund Site	214	4	25	71
Superior Bay	41	46	54	0
Thomson Reservoir	23	30	70	0
USS Superfund Site	36	30	42	28
WLSSD, Miller Creek, Coffee Creek Embayment	*42*	*24*	*55*	*21*
FWS 2012 Evaluation	*15*	*33*	*67*	*0*

Table 5.3. Bioaccumulation factors (treatment worm tissue concentrations after experiment divided by worm concentration at the beginning of the experiment) for the 28-day duration of the experiment. When calculating these values, non-detected values were assumed to be equal to half of the detection limit. B, Be, Hg, and V were excluded from these analyses. B, Be, and Hg were not detected in any samples. V was detected, but detection limits were unacceptably high for some samples.

	Site															
Metals	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Mean**
Al	2.37	3.92	6.36	1.88	4.63	1.68	2.95	4.72	5.51	2.99	18.41	2.90	4.95	0.99	5.79	**4.67**
As	1.66	1.77	3.43	0.54	1.56	1.60	2.52	5.49	2.36	2.16	5.70	8.46	2.11	1.36	9.46	**3.35**
Ba	1.81	1.67	2.05	1.39	2.06	2.11	2.02	2.38	2.04	1.55	2.67	2.35	1.98	2.27	2.16	**2.03**
Ca	1.01	0.87	1.09	2.56	1.18	0.87	1.08	1.31	1.23	0.89	1.58	0.95	1.11	0.88	1.23	**1.19**
Cd	1.05	1.00	1.05	5.26	1.00	1.05	1.05	1.05	3.79	1.00	1.05	1.00	3.79	2.63	1.05	**1.79**
Co	0.69	0.80	0.93	0.79	1.09	1.07	1.02	1.21	1.16	0.85	1.20	0.76	0.96	0.92	0.85	**0.95**
Cr	1.15	1.15	1.59	2.32	1.36	1.53	1.53	1.78	2.00	1.35	2.80	1.43	1.49	1.07	1.66	**1.61**
Cu	1.39	1.01	1.24	1.45	1.24	1.64	1.14	1.50	2.49	1.50	1.71	0.99	2.05	1.94	1.20	**1.50**
Fe	1.46	1.43	2.23	1.25	2.08	1.64	1.46	2.20	2.17	1.42	4.86	1.58	2.03	1.13	2.07	**1.93**
Mg	0.94	0.96	1.22	1.26	1.42	1.13	1.14	1.36	1.81	1.02	1.95	1.02	1.30	0.98	1.30	**1.25**
Mn	1.70	1.65	4.27	1.47	3.45	2.74	1.97	3.49	3.17	2.16	28.04	3.28	2.80	4.58	5.54	**4.69**
Mo	2.16	4.16	3.80	5.10	4.82	4.73	3.55	3.96	3.10	2.20	3.35	8.24	3.18	6.61	3.06	**4.14**
Na	0.99	1.00	1.08	1.68	0.90	0.84	1.09	1.13	0.99	0.84	1.13	1.06	0.88	0.89	1.02	**1.03**
Ni	1.25	1.32	1.75	3.46	1.68	1.92	1.28	1.83	2.39	1.23	3.75	1.27	1.77	1.41	1.87	**1.88**
Pb	2.11	1.85	2.23	1.70	1.52	0.95	1.39	1.90	3.33	1.06	3.13	1.10	2.08	0.79	1.56	**1.78**
Se	1.31	1.09	1.34	1.27	1.57	1.55	1.41	1.58	1.55	1.17	1.35	1.47	1.41	1.33	1.23	**1.38**
Tl	1.05	1.00	1.05	5.26	1.00	1.05	1.05	1.05	1.05	1.00	1.05	1.00	1.00	1.00	1.05	**1.31**
Zn	0.84	0.77	0.89	1.06	1.06	1.12	1.03	1.15	1.13	0.87	0.91	0.89	1.06	0.96	0.86	**0.97**
Mean	**1.39**	**1.52**	**2.09**	**2.21**	**1.87**	**1.62**	**1.59**	**2.17**	**2.29**	**1.40**	**4.70**	**2.21**	**2.00**	**1.76**	**2.39**	**2.08**

Table 5.4. Sediment bioaccumulation factors (BSAF; worm wet weight concentrations/sediment wet weight concentrations). Note: nondetected concentrations are assumed to be equal to ½ of the detection limit. Blank areas indicate sites where contaminant was not detected in neither sediment nor worms. Gray area indicates sites where contaminant was not detected in worms. No sites were only detected in worms.

	Site															
Metal	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Mean**
Al	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.06	0.01	0.02	0.01	0.03	**0.02**
As	0.48	0.50	0.90	0.13	0.53	0.90	0.63	1.25	0.51	0.63	1.76	2.29	0.45	0.70	3.49	**1.01**
B	0.09	0.08	0.08	0.42	0.09	0.22	0.09	0.07	0.09	0.10	0.08	0.10	0.07	0.33	0.14	**0.14**
Ba	0.68	0.44	0.45	0.42	0.99	2.43	0.63	0.50	0.58	0.57	0.51	0.62	0.44	2.33	0.98	**0.84**
Be	0.08	0.08	0.08	0.74	0.09	0.18	0.10	0.07	0.09	0.09	0.07	0.10	0.06	0.21	0.13	**0.14**
Ca	0.03	0.06	0.06	0.14	0.04	0.06	0.06	0.05	0.05	0.04	0.02	0.02	0.04	0.11	0.06	**0.06**
Cd	0.04	0.03	0.02	0.07	0.05	0.29	0.03	0.02	0.09	0.05	0.05	0.05	0.07	0.97	0.06	**0.13**
Co	0.05	0.07	0.08	0.09	0.12	0.16	0.10	0.10	0.11	0.08	0.10	0.08	0.07	0.18	0.10	**0.10**
Cr	0.03	0.03	0.04	0.09	0.05	0.08	0.05	0.04	0.05	0.04	0.07	0.05	0.03	0.08	0.07	**0.05**
Cu	0.03	0.03	0.03	0.04	0.06	0.20	0.04	0.04	0.08	0.08	0.08	0.05	0.07	0.27	0.08	**0.08**
Fe	0.02	0.02	0.03	0.04	0.05	0.05	0.03	0.03	0.04	0.03	0.06	0.03	0.03	0.04	0.05	**0.04**
Hg	0.11	0.08	0.07	0.09	0.12		0.02	0.04	0.03	0.14	0.10	0.11	0.03		0.14	**0.08**
Mg	0.04	0.04	0.05	0.09	0.05	0.08	0.05	0.04	0.08	0.04	0.07	0.05	0.03	0.10	0.06	**0.06**
Mn	0.01	0.01	0.02	0.03	0.04	0.05	0.02	0.02	0.03	0.01	0.09	0.02	0.02	0.04	0.03	**0.03**
Mo	0.14	0.26	0.31	0.20	0.61	1.50	0.24	0.25	0.30	0.36	0.54	1.17	0.39	2.35	0.56	**0.61**
Na	1.40	3.10	2.94	5.50	2.24	2.71	4.26	3.32	3.89	2.84	3.23	3.49	3.04	5.73	4.10	**3.45**
Ni	0.01	0.02	0.02	0.08	0.03	0.05	0.02	0.02	0.04	0.02	0.05	0.02	0.02	0.05	0.04	**0.03**
Pb	0.02	0.02	0.03	0.02	0.05	0.11	0.02	0.03	0.02	0.02	0.06	0.02	0.02	0.07	0.04	**0.04**
Se	2.80	1.87	2.46	1.82	3.43	7.02	2.68	2.61	3.09	2.48	2.42	2.86	2.18	6.03	3.58	**3.16**
Sr	0.12	0.18	0.20	0.29	0.24	0.35	0.25	0.23	0.22	0.18	0.11	0.13	0.20	0.50	0.23	**0.23**
Tl	0.10	0.03	0.12	0.35	0.11		0.10	0.10	0.12	0.11	0.13	0.14	0.07		0.17	**0.13**
V	0.01	0.01	0.02	0.03	0.02	0.01	0.01	0.01	0.02	0.01	0.06	0.01	0.01	0.01	0.03	**0.02**
Zn	0.37	0.35	0.40	0.44	0.96	2.38	0.59	0.50	0.56	0.69	0.53	0.65	0.35	2.10	0.78	**0.78**
Mean	**0.29**	**0.32**	**0.37**	**0.48**	**0.43**	**0.90**	**0.44**	**0.41**	**0.44**	**0.37**	**0.45**	**0.52**	**0.33**	**1.06**	**0.65**	0.49

Table 5.5. Mean responses of the amphipod *Hyalella azteca* in 28-d whole-sediment exposures conducted with samples from the St Louis River in 2012. Samples that are significantly reduced compared to the West Bearskin control sample are designated with an asterisk (*n* = 6). SEM=Standard error of the mean. Average starting size of amphipod was 1.51 mg (0.03 SEM).

Sample	Amphipod Survival (%)	Amphipod Survival (SEM)	Amphipod Survival (% of control)	Amphipod Length (mm)	Amphipod Length (SEM)	Amphipod Length (% of control)	Amphipod Weight (mg)	Amphipod Weight (SEM)	Amphipod Weight (% of control)	Amphipod biomass (mg)	Amphipod biomass (SEM)	Amphipod Biomass (% of control)
Control	87	6.15	100	4.80	0.05	100	0.56	0.02	100	4.87	0.51	100
1	92	6.54	106	5.30	0.06	110	0.77	0.03	138	7.02	0.48	144
2	92	4.77	106	5.00	0.05	104	0.63	0.02	113	5.71	0.28	117
3	97	2.11	111	4.58	0.08	95	0.50	0.02	89	4.85	0.60	100
4	95	3.42	109	5.17	0.04	108	0.70	0.02	125	6.32	0.39	130
5	97	2.11	111	4.94	0.04	103	0.61	0.02	109	5.91	0.28	121
6	100	0.00	115	5.16	0.05	108	0.70	0.02	125	5.93	0.63	122
7	98	1.67	113	4.66	0.09	97	0.54	0.02	96	5.12	0.75	105
8	88	6.54	101	4.64	0.04	97	0.50	0.01	89	4.75	0.46	98
9	93	2.11	107	4.60	0.08	96	0.51	0.03	91	4.68	0.65	96
10	88	4.77	101	4.47	0.07	93	0.46	0.02	82	3.99	0.34	82
11	97	2.11	111	5.19	0.05	108	0.71	0.02	127	6.88	0.28	141
12	85	9.57	98	4.84	0.07	101	0.59	0.03	105	4.99	0.79	102
13	100	0.00	115	4.58	0.06	95	0.49	0.02	88	4.93	0.51	101
14	98	1.67	113	5.08	0.06	106	0.68	0.02	121	6.64	0.38	136
15	57	20.28	**66***	4.87	0.06	101	0.59	0.02	105	3.44	1.26	71

Table 5.6. Mean responses of the midge *Chironomus dilutus* in 10-d whole-sediment exposures conducted with samples from the St Louis River in 2012. Samples significantly reduced compared to the West Bearskin control sample are designated with an asterisk (*n* = 6). SEM=Standard error of the mean. Average starting size of midge was 0.03 mg (0.00 SEM).

Sample	Midge Survival (%)	Midge Survival (SEM)	Midge Survival (% of control)	Midge Weight (mg)	Midge Weight (SEM)	Midge Weight (% of control)	Midge biomass (mg)	Midge biomass (SEM)	Midge Biomass (% of control)
Control	92	2.83	100	1.84	0.09	100	17.2	0.63	100
1	93	4.94	101	1.85	0.07	101	17.1	0.53	100
2	88	4.77	96	1.85	0.11	101	16.1	0.42	94
3	97	2.11	105	1.70	0.10	92	16.8	0.56	98
4	90	2.58	98	1.69	0.09	92	15.3	0.56	89
5	95	3.42	103	1.55	0.06	84	14.6	0.44	85
6	98	1.67	107	1.94	0.09	105	19.1	0.86	111
7	98	1.67	107	1.81	0.13	98	16.7	1.10	97
8	88	4.77	96	2.07	0.14	113	18.1	1.09	106
9	97	3.33	105	1.57	0.12	85	15.2	0.95	89
10	82	16.41	89	1.72	0.16	93	17.1	1.30	100
11	87	5.58	95	1.74	0.10	95	15.1	0.80	88
12	93	2.11	101	1.70	0.06	92	16.1	0.67	94
13	92	4.01	100	1.47	0.06	**80***	13.5	0.83	**79***
14	98	1.67	107	1.78	0.06	97	17.4	0.35	102
15	78	15.15	85	1.84	0.10	100	13.9	2.71	**81***

Table 5.7. Mean and range values for metal concentrations in sediment (ppm-dry), oligochaetes (ppm-wet), and fish (ppm-wet) samples collected in 2012.

	Sediment			Oligeochate			Fish		
Metal	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
Al	10435	2890	19000	95	21	394	3	2	7
As	3.47	1.04	5.88	1.47	0.25	4.36	0.05	0.04	0.05
B	5.63	0.94	9.40	0.31	0.24	1.25	0.23	0.19	0.25
Ba	95.01	14.60	178.00	26.00	13.20	35.30	0.96	0.39	1.91
Be	0.56	0.15	0.91	0.03	0.02	0.13	0.02	0.02	0.03
Ca	10149	1820	33900	219	162	477	12067	2527	18812
Cd	0.68	0.03	2.20	0.02	0.01	0.05	0.03	0.01	0.07
Co	9.57	2.94	15.70	0.43	0.31	0.54	0.02	0.02	0.03
Cr	28.49	6.77	50.40	0.63	0.40	1.12	0.77	0.39	2.10
Cu	29.70	4.61	58.80	0.74	0.50	1.25	0.86	0.69	1.28
Fe	20033	6160	36400	315	168	816	50	20	70
Hg	0.259	0.005	1.070	0.008	0.006	0.032	0.080	0.042	0.201
Mg	6177	1600	10200	155	117	244	420	242	583
Mn	572.7	133.0	1530.0	8.2	1.8	51.6	10.1	1.6	22.6
Mo	0.59	0.09	1.80	0.10	0.02	0.20	0.02	0.02	0.03
Na	407	121	663	628	512	1020	1020	792	1205
Ni	22.75	6.37	39.90	0.32	0.17	0.65	0.39	0.12	1.01
Pb	29.54	2.10	58.30	0.34	0.15	0.65	0.01	0.01	0.04
Se	0.46	0.12	0.89	0.58	0.43	0.68	0.51	0.37	0.66
Sr	24.12	5.34	55.50				6.56	0.97	10.35
Tl	0.22	0.04	0.85	0.01	0.01	0.05	0.01	0.01	0.01
V	31.21	10.90	52.30				0.11	0.04	0.20
Zn	133.1	20.5	250.0	34.0	26.8	40.1	14.8	11.0	18.0

Table 5.8. Organic contaminant concentrations in white suckers (ppb-wet). Non-detected values were assumed to be equal to ½ of the detection limit.

Category	Analyte	Mean	Min	Max	SD
Organochlorine	DDTs-Total	13.0	4.3	23.1	4.9
	PCB-total	193.2	57.9	323.3	77.9
Aromatics	1-methylnaphthalene	2.3		24.8	6.2
	2-methylnaphthalene	3.7		42.2	10.7
	acenaphthene	2.1		9.5	2.5
	biphenyl			18.6	
	C1-naphthalenes	6.2	1.2	67.0	16.8
	naphthalene	27.2	2.7	263.3	68.2
	% Lipid	1.6260	0.78	2.94	0.59

Appendix 6. Memo to AOC Coordinators

To: AOC Coordinators and other staff

From: Daryl Peterson, MLT

Re: 21st Ave West Ecological Design Report Minnesota AOC Coordinator Recommendations

Date: March 15, 2013

AOC Coordinators from MPCA, MDNR and Fond du Lac met with U.S. Fish and Wildlife Service, Minnesota Land Trust and UMD-NRRI on March 13, 2013 to review the restoration alternatives modeled as part of the 21st Ave West Ecological Design project and discuss recommendations.

The AOC coordinator site level priorities include increasing diversity and complexity of available habitats, reducing wave energy within the project area to foster aquatic plant growth and increasing the littoral zone area. Specific actions to consider included partial filling of the North Channel and 21st Ave channel, island creation on interstate island flats and enhanced use of shoaling in WLSSD Bay, sheltering Miller Creek Bay and enhancing the Miller/Coffee creek outfall.

The AOC Coordinators requested the following changes to the modeled scenario E: Increase the extent of shoaling to reduce wave energy in the southern portion of WLSSD Bay, reduce the width of riparian/floodplain buffers along CN Pier and Hwy 535 corridor, narrow the sheltering point east of the WLSSD outfall and include a submerged meandering channel through 21st Ave Bay to facilitate discharge from Miller and Coffee Creeks.

The AOC Coordinators recognized that model results over-predict the distribution of submersed aquatic vegetation under existing conditions, which indicates additional factors not included in the SAV model are influencing the ecological conditions within the project area. The factors most warranting additional investigation are: 1) water chemistry effects of WLSSD outfall, 2) urban water quality and sediment loads from Miller and Coffee Creek, 3) in-place historic chemical contaminants and anthropogenic substrates and 4) grazing and disturbance by artificially large population densities of geese and carp within the project area.

To address these potential unknowns the AOC Coordinators recommend the following:

- Advance understanding of phytotoxicity effects using laboratory and in situ testing to quantify effects of Ammonia, sulfate, pesticides (fungicides, herbicides, insecticides) water temperature, and conductivity on SAV germination and growth.

- Conduct in-situ and greenhouse experiments to understand factors limiting germination and growth of SAV species in the project area using extant soil, herbivore exclosures, etc.

- Implement pilot “restoration” actions and monitor biological, chemical and physical responses in advance of project area-wide actions

Appendix 7: 21st Avenue West R2R Ecological DesignReport on Public /Stakeholders Outreach Efforts

Public Outreach Committee: Andy McDonald, Metropolitan Interstate Council
Julene Boe, St. Louis River Alliance
Daryl Peterson**,** Minnesota Land Trust
Zachary Jorgenson, USFWS

Ecological Design Committee: Rick Gitar, Fond du Lac Band
Tracey Ledder, WI DNR
John Lindgren, MN DNR
Diane Desotelle, MPCA

Outreach Planning

The St. Louis River Alliance (SLRA) and the Metropolitan Interstate Council (MIC) together developed the plan for outreach activities. The MIC targeted commercial and industrial stakeholders and corporations and the SLRA handled general public outreach and agency engagement. The two organizations developed a power point presentation and handouts. These presentations were submitted to Zachary Jorgenson, USFWS and Daryl Peterson, Minnesota Land Trust for review and input. The MIC and the Alliance coordinated the scheduling of presentations to major stakeholders and public agencies. This also included coordinating with the Ecological Design Committee to make presentations to public entities and agencies with regulatory, jurisdictional, or operations affected by the proposed project.

Meetings with Stakeholders and public agencies

MIC and SLRA gave a project presentation at the following major stakeholder meetings between December 2012 and March 2013. Notes are provided, including the concerns and questions raised at the meetings.

MIC Harbor Technical Advisory Committee (HTAC) Meeting – December 5, 2012

Andy McDonald opened the discussion with Julene Boe, of the St. Louis River Alliance. They gave a little bit of history about the project area, citing a 1999 study by the U.S. Army Corps of Engineers for dredge material placement which ultimately was shelved due to a lack of adequate information about the nature and levels of contaminants and other issues..

McDonald said that several meetings were held over the summer where MPCA and MDNR determined to move ahead with a remediation to restoration project in the 21st Ave West area in support of AOC delisting objectives, and the result was that a feasibility study was undertaken. The study is now currently in the ecological design process. Julene Boe said goals for the project include: Remove or sequester contaminated sediments in support of habitat restoration and human health objectives, remove all marine debris and abandoned infrastructure to the extent practicable, incorporate appropriate bathymetry and substrate types in clean-up solutions to accomplish habitat restoration goals, and incorporate existing WLSSD outfall mixing zones and water quality standards. McDonald showed slides indicating the location of some areas currently indicated as "hot spots" (elevated chemical concentrations) and said that it's crucial these areas like these are considered during the design phase so they are properly handled.

Next steps for this project will be to complete the baseline assessment that is currently underway, do some restoration modeling and scenario testing, and then do ecological design concept development. They will also be carrying out the public outreach phase and seeking stakeholder involvement from land owners and industrial and commercial interests. Groups they are also planning to present to include city and county boards and city councils for both Minnesota and Wisconsin, MIC board and TAC committee, the Port Authority board and the WLSSD board. Other activities for stakeholder involvement will involve newsletters, social media and river tours.

Boe then explained that the Corps of Engineers was planning to do a Dredged Material Placement pilot study at 21st Ave W Channel Embayment, which will be a three year project placing and examining the results of dredged material placement. They have selected three areas in the 21st Ave study area and will place dredged material in one of them each year, monitoring plant growth and benthic invertebrates , as well as determining how the water currents may affect material placed in deeper areas, and whether or not that material stays in place.

McDonald said that this presentation was what they would be doing for much of the public outreach and wanted to approach the HTAC first for suggestions and feedback, which he welcomed at that time. Lisa Angelos noted that there was a thirty day period of public comment during which the DNR would be getting its thoughts down and thinking about how to meet regulatory requirements, so that would be coming but it was early yet. McDonald said that was fine since the public outreach wouldn't really begin until sometime in January. Boe added that essentially they would be presenting the ecological design and some of the modeling scenarios, which will be separate from the Corps' pilot project.

Western Lake Superior Sanitary District (WLSSD) Solid Waste Planning Committee – February 19, 2013

Andy McDonald from the Metropolitan Interstate Council and Julene Boe from the St. Louis River Alliance gave a brief presentation on the restoration initiative for the lower St. Louis River. The restoration initiative will plan to restore roughly 1,400 acres within the lower St. Louis River. The 21st Avenue West site is an area being evaluated as one of the first steps for the restoration initiative. This project will include removing contaminated sediments to restore habitats for fish and wildlife; and using dredge material within these sites to create viable habitats. There were 5 design scenarios for the 21st Avenue West Site at the time of this meeting; several presentations will be given to stakeholders to gain input and information regarding how this site should be restored. The WLSSD outfall is a major component to this project and the committee expressed only one concern that the outfall would not be adversely affected in any way by this project.

MIC-Transportation Advisory Committee (TAC) – February 19, 2013 and Metropolitan Interstate Council (MIC) Meeting – February 20, 2013

Information regarding the 21st Avenue West Ecological Design was presented on February 19, 2013 to the MIC-TAC and on February 20, 2013 at the MIC Meeting. Andy McDonald opened both presentations of the 21st Ave W Habitat Restoration Project by introducing Julene Boe, of the St. Louis River Alliance, a non-profit group that works with governmental and other agencies to promote the restoration of the St. Louis River Area of Concern (AOC). She explained that 21st Ave W is an R2R project area, which means Remediation to Restoration, and the primary goals are to restore and protect fish and wildlife and their habitat.

McDonald gave a brief history of the project area, citing the 1999 study by the U.S. Army Corps of Engineers for dredged material placement which ultimately was shelved due to a lack of adequate information about the nature and levels of contaminants and other issues. .

Boe described that the partners they are working with include the MPCA, MN DNR, WI DNR, NRRI, MN Land Trust, the Fond Du Lac Tribe of Lake Superior Chippewa, US Fish and Wildlife Service, and the US Army Corps of Engineers, and that the funding for the Ecological Design Report was being provided through the US Fish and Wildlife Service.

Boe explained that goals for the project include: Remove or sequester contaminated sediments in support of habitat restoration and human health objectives, remove all marine debris and abandoned infrastructure to the extent practicable, incorporate appropriate bathymetry and substrate types in clean-up solutions to accomplish habitat restoration goals, and incorporate existing WLSSD outfall mixing zones and water quality standards.

She said they are currently in the ecological design phase of the project. They are completing baseline assessments, identifying contamination as well as attempting to determine causes for the lack of aquatic, including examining wind and current patterns. NRRI has been working on restoration design modeling and scenario testing to get an idea of what kind of ecological effects the various restoration designs would have.

Boe also stated they are currently in a stakeholder engagement phase, engaging with and requesting input from stakeholders and the public, such as WLSSD. McDonald said they'll be showing these modeling scenarios to various groups to get their feedback, and that those comments would be part of the final Ecological Design Report. This presentation and the one for the MIC are part of the public involvement process as well.

Boe then explained that the Corps of Engineers was planning to do a Dredged Material Placement pilot study at 21st Ave W Channel Embayment, which will be a three year project examining the physical and biological effects of dredged material placement. They have selected three areas in the 21st Ave study area and will place dredged material in one of them each year, and monitor what kind of plant growth takes place. They will also determine how the water currents change in deeper areas, and whether or not the material stays in place.

She said the next step for 21st Ave W would be a feasibility study, and then the final design and implementation. The Ecological Design Report and the Dredged Material Placement Pilot Project will be very important first steps to feed into the next phase for Remediation and Restoration in the 21st Avenue West Complex.

At the MIC-TAC presentation, Dennis Jensen commented that he was concerned that the effects of Coffee Creek and Miller Creek runoff should not be underestimated, due to the snow melt and the chemicals that are transported in the runoff. McDonald said it was a good message for them to carry forward and discuss ways to filter and deal with those influences.

At the MIC Meeting, Broc Allen commented that he remembered a historical map of the shoreline being presented in the past, and wondered if they were trying to restore some of that. McDonald said they have an 1865 shoreline map, but they are not looking to replicate that, they are looking to replace the amount of wetlands in the harbor while still being very mindful of maintaining the working harbor.

David Montgomery asked what the overall timeline was for the project, and whether they would wait for the results of the three-year pilot study before doing any design work. McDonald said that they would continue with the ecological design work now, because nearly every single concept they consider will require that area to be made shallower by placing dredge material.

McDonald thought that it would likely take 20-25 years for the completion of all these projects throughout the St. Louis River, and they need to prioritize and start working immediately.

Nick Baker wanted to know what the MPCA was saying, since they had shut down work in the past in the 21st Avenue West Complex. McDonald said they are one of the groups pushing the project forward, and pointed out that in the past, they were concerned about work being performed in the area because they were unsure as to the extent of contamination.

Allen asked how much dredge material would be used. McDonald said they won't know until they get to the engineering design stage as part of future projects, which is when they determine that.

Other Public outreach activity

Besides the stakeholder meetings listed above, the SLRA also conducted public outreach efforts, providing the public with information about this project and other habitat restoration and remediation efforts estuary-wide. Julene Boe, SLRA, presented information about this project at the SLRA annual meeting on January 16, 2013, to the Twin Ports Freshwater Folks on May 1, 2013, and the Park Point Community Club on May 16, 2013.

The SLRA included information about this Remediation to Restoration project in the St Louis River Area of Concern 2013 Progress Report that was published in March 2013. The Progress Report has been distributed widely to the public since it was published. Additionally, a brief reference was included in the revised "On the Water" Guide for Paddlers and Boaters published and distributed in June 2013. 3000 copies of this free publication were distributed through various public outlets.