REMEDIAL ACTION PLAN UPDATE

for the

MILWAUKEE ESTUARY AREA OF CONCERN

AUGUST 2020

Wisconsin Department of Natural Resources
Office of Great Waters

Remedial Action Plan Update for the Milwaukee Estuary Area of Concern

This Remedial Action Plan includes updates from January 2018 through April 2020.

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Cover Photo: Taken by Stacy Hron, WDNR Lake Michigan Program Coordinator, along the Milwaukee River where the Estabrook Dam was removed as part of an Area of Concern management action in 2018.

Disclaimer

The Great Lakes Water Quality Agreement (GLWQA) is a non-regulatory agreement between the U.S. and Canada, and criteria developed under its auspices are non-regulatory. The actions identified in this document as needed to meet beneficial use impairment (BUI) delisting targets are not subject to enforcement or regulatory actions. The actions identified in this Remedial Action Plan (RAP) Update do not constitute a list of preapproved projects, nor is it a list of projects simply related to BUIs or generally to improve the environment. Actions identified in this document are directly related to removing a BUI and are needed to delist the Area of Concern (AOC).

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PURPOSE STATEMENT

This Remedial Action Plan (RAP), which serves as an update to the 2017 RAP, documents and communicates progress made in the Milwaukee Estuary Area of Concern (AOC) (Figure 1) over the last two years. This RAP also documents target revisions completed for nine of the eleven beneficial use impairments (BUIs) in 2020, which are also found in Appendix G: *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern*. The RAP shares the path forward with our partners and stakeholders. The RAP includes a concise summary of BUI status and tracks progress on specific actions that are important for reaching BUI removal targets. These "actions" include on-the-ground restoration projects, monitoring and assessment projects, and stakeholder engagement processes. As the primary agency with the responsibility to develop and implement the RAP, the Wisconsin Department of Natural Resources (WDNR) Office of Great Waters (OGW) and other WDNR programs are committed to making progress in remediating and restoring Wisconsin's Areas of Concern. In order to be lasting and effective, the RAP must be a program of continuous improvement, evaluating its course as new information and technology become available. Subsequent RAP updates will be produced as needed to incorporate new information.

Remedial Action Plans are required by Annex 1 of the Great Lakes Water Quality Protocol of 2012 (which replaced the 1987 Protocol amending the Revised Great Lakes Water Quality Agreement of 1978). The 2012 Protocol indicates that RAPs must include the following elements:

1. Identification of beneficial use impairments (BUIs) and causes;
2. Criteria for the restoration of beneficial uses that take into account local conditions and established in consultation with the local community;
3. Remedial measures to be taken, including identification of entities responsible for implementing these measures;
4. A summary of the implementation of remedial measures taken and the status of the beneficial use; and
5. A description of surveillance and monitoring processes to track the effectiveness of remedial measures and confirm restoration of beneficial uses.

Figure 1. The boundaries of the Milwaukee Estuary Area of Concern. For additional information about the history of the AOC and a narrative description of the AOC boundary, please refer to previous RAP documents which are available online: http://WDNR.wi.gov *Search "Milwaukee Estuary AOC"; RAP documents are stored on the "AOC Plans" tab.*

PROGRESS SUMMARY

The WDNR and partners are working to improve conditions in the Milwaukee Estuary AOC. During the past two years significant progress has been made, advancing sediment projects towards remediation, completing assessments to gather information on BUI status and support decision making to revise targets, forming and organizing work groups to further AOC progress, and continuing to make progress on habitat restoration management actions. A summary of progress is detailed below, with information on the status of each BUI included in the following chapters. Details about projects in the AOC are included in Appendix C.

Sediment

Contaminated sediments contribute to seven out of the eleven BUIs in the Milwaukee Estuary AOC (Table 1) and remediating contaminated sediment sites is necessary to address these impairments. A map illustrating contaminated sediment progress in the AOC is included in Figure 2. Since the last RAP Update, the following sediment related actions occurred. See the Restrictions on Dredging Activities BUI section for more detailed information.

- Since 2017, WDNR and the U.S. Geological Survey (USGS), along with Milwaukee Metropolitan Sewerage District (MMSD), have been working on a project to evaluate non-point source polycyclic aromatic hydrocarbon (PAH) loading to the Milwaukee Estuary. This information is valuable for AOC related sediment management action planning. The assessment is being piloted in the Kinnickinnic River portion of the AOC. The project consists of a few key components: 1) Construction of a PAH assessment Source Loading and Management Model for Windows (WinSLAMM); 2) Collection of stormwater samples for model calibration and verification; 3) Model prediction of PAH loading to the project area; and 4) A mass balance approach to assess the significance of urban nonpoint source contribution. As a result, sources can be identified as whether urban runoff or others (i.e. spills) are more of concern for management purposes. USGS collected stormwater runoff and combined sewer samples for analyses of PAHs and total suspended solids (TSS). Model calibration is underway.
- In June 2018, a Sediment Work Group was formed by the partners involved in sediment remediation in the Milwaukee Estuary AOC, which is facilitated by the City of Milwaukee. The group includes the WDNR, United States Environmental Protection Agency (USEPA) Great Lakes National Program Office (GLNPO), City of Milwaukee, Milwaukee County Parks, MMSD, We Energies, Milwaukee Riverkeeper, Harbor District, Inc., Menomonee Valley Partners, and U.S. Army Corps of Engineers (USACE).
- In 2019, a focused feasibility study (FFS) for the Milwaukee and Menomonee (M&M) River area was completed, and a preferred alternative was selected for remediation. As

part of the cost analysis for this preferred alternative, an option was to transport the material to a new material management facility adjacent to an existing facility.

- An *Analysis of Dredged Material Management Alternatives for the Milwaukee Estuary AOC Great Lakes Legacy Act Project(s)* (Appendix H) was completed to evaluate the cost of remediating the extent of known contamination in the AOC based on the preferred alternative from the M&M FFS. In November 2019, this analysis underwent a 45-day public comment period. All feedback was in support of the preferred alternative for constructing a new facility to manage dredged material.
- In 2019, the WDNR, the City of Milwaukee, including Port Milwaukee, and We Energies formed a Design Technical Work Group to work on the pre-design investigation, design, funding, and construction of the Dredged Material Management Facility (DMMF) in a collaborative, efficient, and expedient manner.
- Sediment characterization continued in the Milwaukee Estuary AOC with the completion of the report for the Milwaukee River Downstream (MRD) area in 2019.
- In 2018, USEPA GLNPO awarded the WDNR a multi-year grant to continue investigation and characterization of areas in the Milwaukee Estuary and St. Louis River AOCs. The first characterization project covered under this grant started in the South Menomonee Canal (SMC) in Fall 2019. As part of the characterization, WDNR performed a special study of Per- and polyfluoroalkyl substances (PFAS) in sediment and surface water in the AOC. The news release and results from the work can be found online on DNR's website.
- Starting in 2019, the USEPA GLNPO tasked the USACE with providing technical assistance and to perform an investigation of the navigation channel area of the Kinnickinnic River. The USACE is currently working on the Field Sampling Plan (FSP) and Quality Assurance Project Plan (QAPP) and expect to collect 50 cores, advancing to native materials. Sampling is expected to start in Fall 2020.
- In January 2020, a $29.2 million Milwaukee Estuary AOC-wide project agreement was signed between USEPA GLNPO, WDNR, City of Milwaukee, Milwaukee County Parks, MMSD, and We Energies to cover FFS, pre-design investigation (PDI) and remedial design (RD) of impacted sediments in the Estuary.
- In 2020, MMSD, the City of Milwaukee, and We Energies all began working on their in-kind contributions to the project agreement, such as the Basin H PCB remediation project, locating as-builts for sheet pile walls, and design of the 3rd Ward manufactured gas plant (MGP) and Solvay Car Ferry Area, respectively.
- Superfund sites (Burnham Canal, Solvay Coke and Gas, Cedar Creek) are all underway with different portions of the cleanups started or finished since the last RAP update.

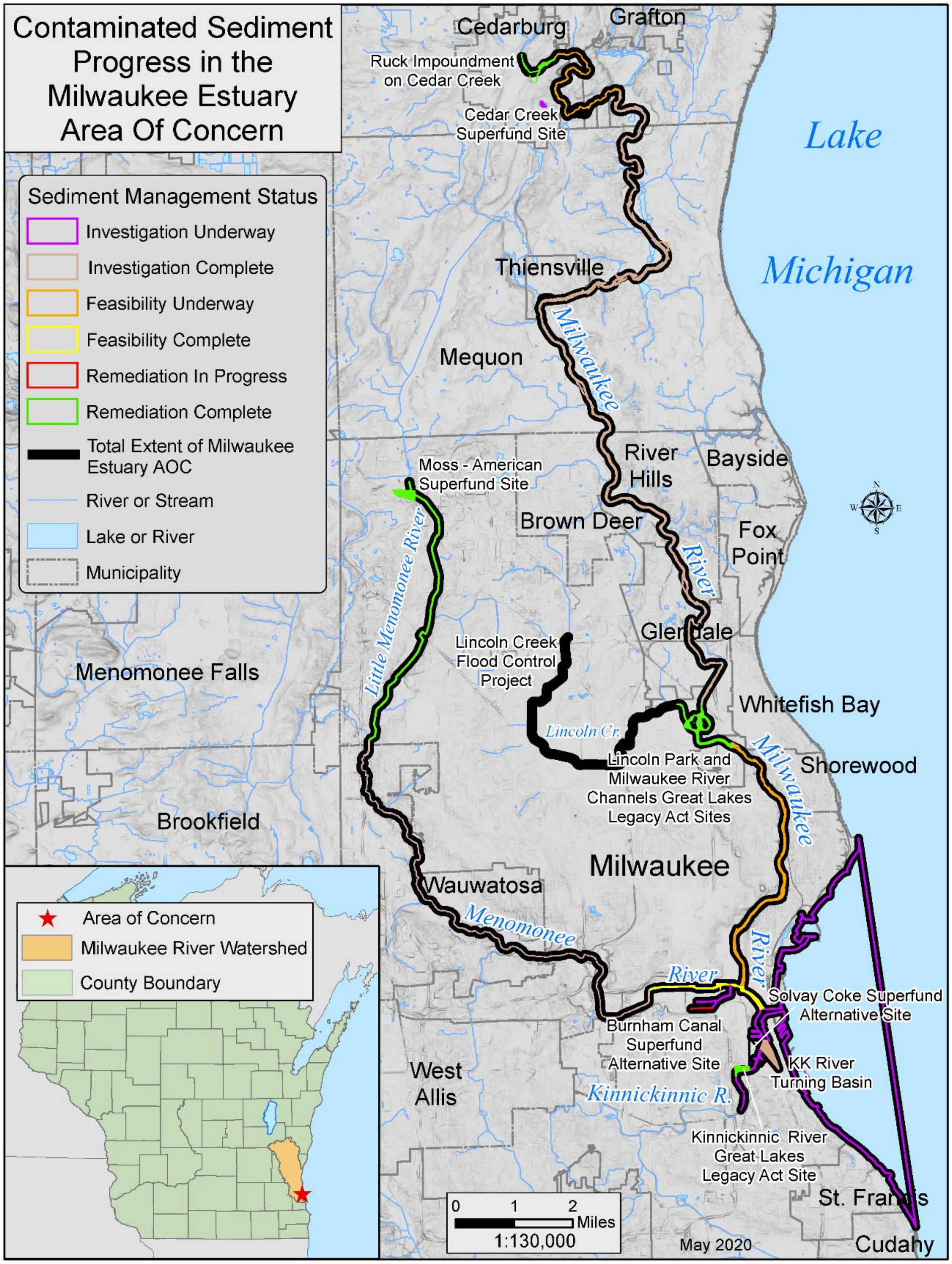

Figure 2. Contaminated Sediment Progress in the Milwaukee Estuary AOC.

Management Action Implementation

In 2018 and 2019, major strides were made to determine the status of the Degradation of Fish and Wildlife Populations BUI and develop a list of management actions to address the impairment. More information about this extensive work can be found in the Degradation of Fish and Wildlife Populations BUI section of this RAP. In addition, throughout the past two years, progress has been made on planning and implementing the remaining management actions to address the Loss of Fish and Wildlife Habitat BUI. The following is a summary of these projects.

Grand Trunk Wetland Restoration

Contaminated sediment issues in the channel adjacent to the wetland delayed work to complete the engineering and design for this project. As a result, WDNR and the Redevelopment Authority of the City of Milwaukee (RACM) have been working with the design consultant team to solve material disposal issues. The final design for the wetland restoration is on track to be completed by summer 2020. The goal is to put the project out for bid in Fall 2020.

Kinnickinnic River Corridor Habitat Rehabilitation

In early 2018, the engineering services and design for Phase I of this work was completed. Phase I included limited habitat restoration work along the shoreline and in-river between I-94 and Chase Avenue. It also included invasive species removal and rapid response treatment for areas between Chase Avenue and W Becher Street. MMSD hired a consultant team to design this work and the project was implemented in summer 2018. As part of this project, a pilot aeration system and study were completed in late 2018. Phase II restoration work will be informed by results from the Kinnickinnic River Watershed floodplain study being led by MMSD and sediment characterization work in the Kinnickinnic River. In 2020, project partners will take steps toward selecting a preferred alternative for large-scale restoration in this stretch of the river.

Burnham Canal Wetland Restoration

WDNR is working with MMSD to complete a wetland restoration in Burnham Canal, which is also the location of a Superfund alternative site. MMSD previously partnered with USACE to develop design plans for the wetland restoration project throughout the canal. WDNR obtained funding to work with MMSD on implementing this project in two phases: wetland base construction on the east side of the canal and wetland restoration construction. Wetland base construction on the west side of the canal will be performed along with the Superfund Alternative remedy construction by Miller Compressing. Specifications for the wetland base construction began in 2018. MMSD hired an engineering consultant to complete a bid package for this first phase, based on the USACE design plans. The goal is to bid out the wetland base construction in late 2020.

Estabrook Dam Fish Passage

Deconstruction of Estabrook Dam was successfully completed over the course of one construction season in 2018. As part of the construction contract, vegetation maintenance will continue through 2021 for disturbed areas. A conservation easement was placed at the site, ensuring the area will be protected for the future. Final project closeout is expected in 2021.

Kletzsch Dam Fish Passage

In 2015, after consulting with Milwaukee County, the dam owner, WDNR applied for and received funding to implement fish passage at Kletzsch Dam which was coordinated with other public access improvements that Milwaukee County was pursuing in the park with funding from the Nelson-Knowles Stewardship Program. In Fall 2017, the County hired a consultant team to develop concept designs for a fish passage structure to provide aquatic connectivity at this site. As these concept designs were developed, specific alternatives were selected to pursue more in-depth design possibilities to address project limitations that were encountered. After many alternatives were explored a nature-like fishway design was found to meet all project requirements and was shared with the public during an informational meeting in January 2019. Based on feedback from this meeting, the design team revisited the concept plan to address the comments and concerns from the public. Through weekly project team meetings and consultation with dam experts in southeast Wisconsin, the design team developed a second alternative, an in-river fishway, that met all project requirements. In September 2019, a second informational meeting was held. Feedback from this public meeting was incorporated into the design plans. Approval of this concept plan was sought from the Milwaukee County Board of Supervisor Parks, Energy & Environment Committee (PEEC). The item was tabled, and no approval has been received as of this time. Project partners and community members will be continuing discussions about the options for fish passage and site access improvements while also working through the National Historic Preservation Act Section 106 process.

Little Menomonee River Corridor Restoration

In 2017, planning began for restoration throughout the Little Menomonee River Corridor/former Moss-American Superfund Site, in coordination with Milwaukee County Parks. In 2019, the Little Menomonee River Parkway Ecological Restoration and Management Plan (covering Sections 2-6) was completed and will guide restoration efforts in this 6.5-mile-long riparian green space. Restoration efforts for the first implementation phase of this project, from Fond du Lac Avenue to Appleton Avenue (Section 5) and Good Hope Road to Fond du Lac Avenue (Section 4), are to begin in 2020.

South Shore Beach Rehabilitation

WDNR, working with Milwaukee County Parks, received Great Lakes Restoration Initiative (GLRI) funding in late 2017 to develop design alternatives to address water quality and beach closure issues at South Shore Beach. Concept designs for several alternatives were developed and after input from stakeholders and the design team, a preferred design was selected. Design plans and specifications were completed in December of 2019. Upon completion of a study, being led by the University of Wisconsin – Milwaukee (UWM) School of Freshwater Sciences (SFS), to identify management action recommendations for the other AOC beaches (Bradford Beach, McKinley Beach, and Bayview Beach), WDNR and Milwaukee County Parks will seek funding for implementing the selected alternative at South Shore Beach.

Assessments

In 2018 and 2019, multiple assessment projects were finished and final reporting completed. Results from these assessments and proposed recommendations for future work informed revisions for nine of the eleven BUIs in 2020 (Appendix G: *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern)*. A summary of each assessment is included in the list below with additional information found in relevant BUI chapters of this RAP update.

- USGS published the interpretive report for the 2012 and 2014 plankton and benthos sampling (Appendix I). More information can be found in the Degradation of Benthos and Phytoplankton/Zooplankton sections of this RAP. The online version of the report can also be found here.
- WDNR analyzed the citizen-based aesthetic monitoring information from 2017. The results were presented at a Community Advisory Committee (CAC) meeting in June 2019. The final results are included in the Degradation of Aesthetics BUI section and Appendix J of this RAP. Based on support from the Community Advisory Committee (CAC) WDNR will recommend the removal of this BUI in 2020.
- UWM Field Station and Milwaukee County Parks completed a comprehensive wildlife survey throughout the AOC from 2014-2017. This GLRI funded work mapped and identified potential project opportunities and metrics for AOC population projects, which will aid in BUI removal. More information can be found in the Degradation of Fish and Wildlife Populations BUI section of this RAP.
- Ozaukee County Department of Planning & Parks (OCPP) and WDNR Fisheries Bureau collected and analyzed fish community and habitat suitability data for the wadeable portions of the AOC from 2015-2018. This work included a compilation of existing and new data along with modeling for suitable habitat to assist with population project planning. More information can be found in the Degradation of Fish and Wildlife Populations BUI section of this RAP.

- UWM SFS was funded by Fund for Lake Michigan (FFLM) and WDNR to complete fish habitat mapping in the Milwaukee Harbor. This work was completed in 2018. More information can be found in the Degradation of Fish and Wildlife Populations BUI section of this RAP.

Assessments planned for 2020 include the following:

- WDNR will complete the next round of fish consumption monitoring in the AOC, following the upper estuary sediment cleanup projects that were completed in Lincoln Park and Cedar Creek. Preliminary results should be available by the end of 2021.
- USGS will continue their long-term monitoring of tree swallows in the Milwaukee Estuary AOC at five different locations.
- The McLellan Lab at the UWM SFS will investigate sources of *Escherichia coli (E. coli)* at Milwaukee Estuary AOC beaches to refine the list of management actions necessary to reduce beach closures and address portions of the Beach Closings (Recreational Restrictions) target. Preliminary results and recommendations should be available in Fall 2020. More information can be found in the Beach Closings (Recreational Restrictions) BUI section of this RAP.

Community Outreach

Community Advisory Committee (CAC)

Role: Act as the community's "voice in" to the AOC process. Review and comment on RAPs and participate in the BUI removal process; devise and assist in implementation of strategies for building public and community support; provide a forum for meaningful resident and stakeholder input; advise state and federal agencies; share information with public.
Tasks: Develop community engagement opportunities and forums; Support the voice of all community members including underserved groups and populations of color; Advocate for project design elements based on community and non-profit voices; Provide letters of support at various program milestones (i.e. target revisions, BUI removal recommendations); Communicate and coordinate with Communications and Outreach Team and MAIT.

The CAC participated in activities and hosted community outreach events since the last RAP update. These outreach events include hosting multiple CAC meetings (December 18, 2018; June 27, 2019; January 21, 2020) and a public forum on upcoming efforts for sediment remediation in the AOC (November 13, 2019). CAC Leadership Team (LT) members attended the Great Lakes AOC Conference in Cleveland, OH (September 10-12, 2019) and presented at the Clean Rivers, Clean Lake Conference in Milwaukee (November 14, 2019). The CAC LT also attended project specific input sessions on South Shore Beach, Grand Trunk Wetland, and

Kletzsch Dam Fish Passage. In June 2019, results from the 2015-2017 citizen-based aesthetics monitoring efforts were presented to the CAC showing that the current Aesthetics BUI target is being met. The CAC voted to support the removal of the BUI. WDNR plans to develop a removal recommendation package in 2020. Finally, in collaboration with Reflo, Inc., the CAC supported and helped develop an AOC Story Map as part of Reflo's Milwaukee Community Map to provide a visual learning tool for the public focusing on the past, present and future of the AOC.

Milwaukee Estuary AOC Communication and Outreach Team

Role: Collaborate with and advise the Milwaukee Estuary AOC communications consultant to develop an effective and consistent "voice out" for the AOC program.
Tasks: Draft public/project communications plan and calendar; Develop communications and outreach content with the intent for diversifying community engagement and increasing the representation of stakeholders who are invested in the Milwaukee Estuary AOC; Develop communications and outreach collateral; Communicate and coordinate efforts directly with the CAC, technical work groups, and the MAIT.

Area of Concern Work Groups & Roles

In 2018 and 2019, the Milwaukee Estuary AOC developed several work groups, and added more structure for stakeholders to provide the support necessary for this large and complex AOC. The structure of currently active work groups is summarized below.

Management Action Implementation Team (MAIT)

Role: Assist in implementing management action lists through the Project Management (PM) Subcommittee; ensure coordination between parties; achieve consensus on major decisions that consider public input; work with CAC to share information with the public; ensure coordination between primary partners; provide guidance on tactical documents
Tasks: Make recommendations for standardize language and terms for RFPs issued as part of the AOC (i.e. community benefit criteria, local businesses, minority-owned business enterprises (MBEs), and/or woman-owned business enterprises (WBEs) etc.); Support alignment between Communication and Outreach work group and the CAC; Ensure CAC is serving as a check and balance for community voices; Define deliberate approaches to advance equity and social justice in the Milwaukee Estuary AOC; Work with Project Management Team to design and implement workforce development strategy; Stay up to date with timing of AOC actions including major project thresholds, critical communication and outreach dates, and board/commission meeting dates in order to identify beneficial outreach opportunities and provide guidance to the Communication and Outreach work group.

Project Management Team (MAIT subcommittee)

Role: Once targets are finalized and management action lists are developed by the technical work groups, align project development between project managers, local sponsors, and partners.
Tasks: Align components of active projects for efficiency and project success; Project scoping and proposal development; Oversee all phases of planning, design and construction projects; Allow for coordination between multiple projects; Provide information presentations to stakeholder and community groups on projects; Support technical work groups as needed; Communicate and coordinate with the technical work groups, Communication and Outreach group, the CAC, and MAIT.

Milwaukee Estuary AOC Technical Teams

Role: Provide technical expertise on AOC projects, prioritize actions, review/revise targets, evaluate results of post-implementation monitoring, and provide technical recommendations for BUI removal.
Tasks: Support development and prioritization of management action lists; Support the review and revision of BUI targets; Evaluate monitoring results and provide recommendations for BUI removal based on targets; Provide feedback and review of project deliverables. The following is a list of the currently established technical teams. Work groups will be formed for other BUIs as needed.

- Fish and Wildlife Technical Advisory Committee (Tech Team)
- Beaches Work Group
- Sediment Work Group
- Milwaukee GLLA FS, PDI, and RD Project Agreement Team
- Design Technical Work Group (DTWG) for the DMMF

Next Steps

Below is a summary of next steps within the Milwaukee Estuary AOC. The following activities are planned for 2020. Additional detailed information for the importance of these next steps can be found in the subsequent RAP sections and/or appendices :

- Collaborate with the Beaches Work Group to select Beach Closings (Recreational Restrictions) management actions based on data and recommendations from the UWM SFS study.
- Begin planning and design of Degradation of Fish and Wildlife Populations management actions.

- Contract communication and outreach support services for the AOC. See Community Outreach section for additional information for the roles and tasks of these support services through the Communications and Outreach Team.
- Utilize water column toxicity sampling results, along with previous USGS assessments, to determine the status of the Degradation of Phytoplankton and Zooplankton Populations BUI.
- Form a work group to develop the assessment design and monitoring plan for the Bird or Animal Deformities or Reproductive Problems BUI.
- Continue sediment characterization and evaluate data to determine where additional cleanups might be necessary.
- Work with stakeholders to develop a framework for recording and reporting on diverse and representative stakeholder and community engagement for decision making and goal setting processes for the AOC.
- The MAIT is actively developing a strategy for addressing environmental justice and improving the focus on equitable inclusion in the work of revitalizing the Milwaukee Estuary AOC. Specific examples of things being considered for inclusion in this strategy are: 1) modifications to hiring and procurement procedures for AOC projects, centering equity and social/economic justice; and 2) incorporation of equity and social justice related metrics into the measures of success for AOC projects and programs.
- Further develop team charters and work group structure in the Milwaukee Estuary AOC, clarifying how groups interact and function with other stakeholder groups and the public. This will provide a better communication pathway between AOC work groups. As part of this work, steps will also be taken to increase demographic representation of the stakeholder groups, where appropriate.

Table *1*. Current Status of Beneficial Use Impairments in the Milwaukee Estuary AOC.

Beneficial Use Impairment	Beneficial Use Remains Impaired	Summary Status
Fish tumors or other deformities*	Yes	The BUI was confirmed as impaired in 2014. More work needs to be done to control or eliminate the sources of contaminants. Sites with elevated PAHs, PCBs, and other substances must be addressed. Sediment remediation projects are scheduled to be complete in 2024. Sampling for fish tumors will occur after remediation, and when time has passed to allow white suckers born post-remediation to reach sexual maturity. A reassessment is tentatively scheduled for 2030.
Bird or animal deformities or reproductive problems*	Yes	Monitoring of tree swallows continues by USGS researchers. 2019 results confirm that there is an impairment. More sampling will occur in 2020 in five locations to build strong data sets before, during, and after remediation. In early 2020, the target was revised to include additional trophic groups in the impairment assessment. In 2020, a work group will be formed to develop the assessment design and monitoring plan for this BUI.
Restrictions on fish and wildlife consumption*	Yes	Areas of the AOC contaminated with PCBs or other bio-accumulative chemicals of concern need assessment and remediation to address this impairment. As contaminated sediments are addressed, consumption advisories for fish and wildlife will be reassessed periodically until removal targets are met. WDNR Fisheries Management sampling for the Milwaukee River and Cedar Creek is scheduled for 2020. Waterfowl sampling will occur again after sediment cleanup is completed.
Restrictions on dredging activities*	Yes	Work is being done to address harmful PCBs, PAHs, and heavy metals in contaminated hotspot project sites such as Cedar Creek, Solvay Coke, Burnham Canal, M&M, and MRD. Sediment characterization continued in Fall 2019 within the SMC. Future characterization of remaining areas in the AOC is scheduled for 2020. An analysis of dredged material disposal alternatives was prepared for the remaining contaminated sediment in the AOC; the best alternative was determined to manage material at a Dredged Material Management Facility (DMMF). A public meeting was held on November 13, 2019, followed by a public comment period on the alternatives' analysis through January 9, 2020. Design of the DMMF is underway.

Degradation of benthos*	Yes	Results of a USGS study on sediment-dwelling organisms was evaluated to determine the health of the benthic community. This assessment showed that for the Milwaukee and Menomonee River subsites, benthos was not statistically different from non-AOC reference sites. However, comparisons with historical data did not show improvement in benthic assemblages in the lower estuary, and the subsites are dominated by pollution tolerant species. The lower estuary is highly modified by bulkhead walls and navigation channel dredging; therefore, a high-quality benthic community is likely unachievable in this part of the AOC. The target has been altered to reflect these findings and now focuses on the upper estuary benthic community. Additional monitoring may be needed following sediment remediation and dredging projects.
Degradation of phytoplankton and zooplankton populations*	Yes	Results of the USGS plankton study indicate that phytoplankton populations are at acceptable levels with regards to richness, diversity, and total density; and overall, zooplankton populations are doing well similar to historic trends, but the Milwaukee River subsite continues to have low diversity when compared to non-AOC reference sites. Assessment of water column toxicity for phytoplankton and zooplankton is planned for 2020.
Loss of fish and wildlife habitat*	Yes	There has been continued implementation of the habitat restoration projects identified in the 2015 Remedial Action Plan. There were 11 projects identified and 5 are completed with the remaining projects at different stages (i.e. planning, feasibility, design, implementation). Metrics, goals, and project specific criteria can be found in Appendix D.
Degradation of fish and wildlife populations*	Yes	A draft list for management actions of fish and wildlife populations has been completed. Through a collaborative stakeholder process, 15 projects and 21 metrics were identified for meeting the target. Summaries of these projects can be found in Appendix F. Metrics, goals, and criteria can be found in Appendix E.
Beach closings (recreational restrictions)*	Yes	Milwaukee County continues working on beach improvements, focusing on South Shore Beach. In 2019, a Beaches Work Group was convened to revise targets for this BUI and to determine management actions to meet those revised targets. Management actions will be determined after preliminary review of results completed by the SFS McLellan Lab in 2020.

Eutrophication or undesirable algae	Yes	Work is still needed to further define the target and management actions for this BUI. Reviewing the Total Maximum Daily Loads (TMDL) in Milwaukee and what is currently covered under regulatory permits will assist in determining the next steps for this impairment. A working group will form in 2020 to start these conversations. The target will be adjusted based on this new information.
Degradation of aesthetics	Yes	Status of the Degradation of Aesthetics BUI was reviewed by stakeholders in 2019, and results were presented at a June 2019 CAC meeting. The supporting majority voted to proceed with the removal process. A BUI removal package will be prepared in 2020, making this the first BUI to be recommended for removal in the Milwaukee Estuary AOC.

*BUI target updated in 2020.

BENEFICIAL USE IMPAIRMENT UPDATES

RESTRICTIONS ON DREDGING ACTIVITIES

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Sediment and adjacent floodplain areas contaminated with legacy pollutants have been identified and remediated within the AOC.	In Progress & Action Needed
• All remedial actions have been implemented following Wisconsin Administrative NR 700 rules series and statutory requirements.	In Progress & Action Needed

Status

This BUI remains impaired in the Milwaukee Estuary AOC. While significant progress continues and a lot of work is happening in places that have already been identified for remediation, there is still considerable work needed to determine contamination levels in remaining areas of the AOC. This BUI target was revised in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* (Appendix G), which describes the changes and the reasons for revising AOC targets.

Management Actions

Milwaukee Estuary AOC Project Agreement for Focused Feasibility Study, Pre-Design Investigation, & Remedial Design of Impacted Sediments

In 2019, the Milwaukee Estuary AOC Sediment Working Group made significant progress towards addressing contaminated sediments in the Milwaukee Estuary AOC. Through discussions with all parties that participate in the work group, an application was submitted to USEPA GLNPO in June 2019 by non-federal sponsors (WDNR, City of Milwaukee, Milwaukee County Parks, Milwaukee Metropolitan Sewerage District, and We Energies) that encompasses the remaining contaminated sediment in the AOC. This application is unique and the first of its kind to be proposed within the Great Lakes AOCs. The uniqueness of this approach allows work in one area of the Milwaukee Estuary to leverage federal dollars in a different area, covering all remaining contaminated sediment sites in the AOC under one agreement. On January 6, 2020 a $29.2 million project agreement was signed, allowing certain sites to move into their next stages (feasibility and design) that require non-federal sponsor cost share. Remedial action is not included in this project agreement and will be included in a future amendment.

Milwaukee Estuary AOC Contaminated Sediment Investigation

Work to characterize sediments throughout the AOC continued via the Great Lakes Legacy Act (GLLA) Program in 2018 and 2019. Through the GLLA program, the state requests USEPA GLNPO to investigate and characterize the extent of sediment contamination in the AOC, which can position these areas for future cleanups. This work is usually completed by USEPA GLNPO contractors at full federal expense and is dependent on funding levels. However, in 2018 USEPA GLNPO awarded the WDNR a multi-year grant and entered into a cooperative agreement to execute the grant. Through this agreement, USEPA provides the funds for WDNR staff to manage contracts (via Wis. Admin. Code ch. NR 734) to continue investigation and characterization of the Milwaukee Estuary and St. Louis River AOCs – including the South Menomonee Canal (SMC), selected areas of the Kinnickinnic River, inner and outer harbors, and nearshore waters of the Milwaukee Estuary AOC. Characterization under this cooperative agreement started in Fall 2019. Characterization in 2020 of the Milwaukee Estuary AOC will include the Kinnickinnic River, inner and outer harbors, and nearshore waters of the AOC. USACE will characterize sediment in the federal navigation channel areas of the Kinnickinnic River and inner harbor, while WDNR will continue to work on the other areas. Results of this investigation, combined with historical information, will be used to determine areas that require remediation. Feasibility studies will be performed for those project areas identified, which will subsequently be added to the list of management actions for sediment remediation.

South Menomonee Canal (SMC) Project Site

In Fall 2019, characterization work started in the SMC under the cooperative agreement between WDNR and USEPA GLNPO. This work continued until conditions were such that sampling was no longer feasible due to cold weather and freezing water. Preliminary data was compiled and developed into a 50% Site Investigation Report (SIR) and will be used to determine if any areas in the SMC will be considered for feasibility. The goal is to merge these efforts into a future design that encompasses the FFS work that was completed for the M&M project area. Both sites are adjacent and have the similar types of contaminants (PAHs and heavy metals), although the SMC has PCBs and most of the M&M area did not. The final SIR for this site investigation work is expected to be complete in 2020.

PFAS Special Study

In Fall 2019, DNR performed a special study of PFAS in sediment and surface water of the AOC. Paired sediment and surface water samples were collected late last year at 14 locations throughout the lower estuary in Milwaukee. The 14 locations were spread throughout the Milwaukee River, Menomonee River, Kinnickinnic River, the inner and outer harbor, and Lake Michigan in areas likely to be dredged and for background purposes to inform the management of dredged material. The results of the sampling indicate the presence of PFAS in both sediment and surface water samples. Results will not necessarily influence the extent of sediment removal. Water extracted from dredged material will likely need to be permitted and treated with appropriate treatment technologies prior to discharge back to surface water. The news release and results from the work can be found online on DNR's website.

Milwaukee River Downstream (MRD) Project Site

In March 2017, a public meeting was held with landowners to share preliminary data for the upstream floodplain areas. These data indicated that although the polychlorinated biphenyl (PCB) levels in the floodplain soils are elevated, they are low enough that no risk to the public is expected. The Wisconsin Department of Health Services (DHS) worked with local health organizations to provide information and help people make wise decisions to minimize exposure to PCBs and other chemicals in the sediment. Signs were posted along the corridor to inform users of the conditions along the river. More information on the floodplain soil issue can be found in the 2017 RAP Update.

In 2018, additional sampling was performed to further investigate and delineate the contamination present in the sediments of Reach 4 and to perform ordinary high-water mark (OHWM) surveys in Reaches 1-3 (Figure 3). A final SIR for the area between the former Estabrook Dam and the confluence with the Menomonee River was completed in early 2020. Results indicate a large amount of contaminated material in Reach 4, with some material subject to the Toxic Substances Control Act (TSCA) of PCBs greater than 50 ppm. Current estimates are that roughly 600,000 cubic yards (CY) of contaminated material are over 1 ppm total PCBs in Reach 4, which is the largest known volume of contaminated material in the Milwaukee Estuary AOC. For comparison purposes, the volume of material in this section of the Milwaukee River is 3.5 times larger than the Lincoln Park Phase I & II cleanup projects in the Milwaukee Estuary AOC.

Next steps for this project include development of feasibility studies to look at remedial options for two reaches, the former Estabrook Dam to the Former North Avenue Dam and the former North Avenue Dam to the confluence with the Menomonee River. These feasibility studies will provide more detailed contaminated sediment volume estimates and may involve additional sampling to further delineate the footprint of TSCA level contamination. As this project progresses, USEPA GLNPO is working with all non-federal sponsors under the AOC-wide project agreement on the appropriate next steps for these sections of the Milwaukee River.

Milwaukee and Menomonee River (M&M) Project Site

In 2017, We Energies entered into a project agreement with USEPA GLNPO for a GLLA betterment project in portions of the Milwaukee and Menomonee Rivers. The project includes a remedial investigation and FFS to address sediments adjacent to two former coal gasification facilities (West Side MGP and Third Ward MGP). We Energies, as part of an in-kind contribution, hired a contractor to conduct sampling on the Milwaukee River portion of the project area, which was completed in May 2017. GLNPO hired a consultant to prepare the FFS for the entire project area to determine options for remediation of the sediments. The project area was separated into two operable units (OU1 and OU2; Figure 4). Additional sampling was completed in late October and early November 2017. In 2018, data analysis was completed, and a preferred alternative was selected for remediation. As part of the cost analysis for this preferred alternative, an option was to transport the material to a new facility to manage dredged material. As this project progresses, USEPA GLNPO is working with all non-federal sponsors under the AOC-wide project agreement on the appropriate next steps for these Operable Unit sections on the Milwaukee and Menomonee Rivers. In 2019 and 2020, We Energies and GLNPO ended the M&M project agreement to sign on to the AOC-wide project agreement.

Milwaukee Estuary AOC Dredged Material Management Facility (DMMF)

In 2019, We Energies acquired a Harbor Assistance Program (HAP) Grant from the Wisconsin Department of Transportation (DOT) to design a new facility as part of an agreement with the Port Milwaukee for use of existing dredged material disposal facility (DMDF) space. As a result, WDNR developed an *Analysis of Dredged Material Management Alternatives* document for the Milwaukee Estuary AOC GLLA Project(s), to further evaluate the cost of remediating the extent of known contamination in the AOC based on the preferred alternative developed from the M&M FFS. This document is attached as Appendix G to this RAP. The document was out for public comment for 45 days and received support to pursue designing and eventually constructing a new facility to address issues of sediment contamination in the Milwaukee Estuary AOC. The design of this new facility, which is being called the Milwaukee Estuary AOC Dredged Material Management Facility (DMMF), is underway and was included as part of an in-kind contribution by We Energies in the January 6, 2020 AOC-wide Project Agreement. A group of technical experts formed a Design Technical Work Group to collaboratively to develop the design of the Milwaukee Estuary AOC DMMF.

Superfund Project Sites

Burnham Canal Superfund Alternative Site

Miller Compressing has continued planning for remediation at the Burnham Canal Superfund Alternative site. The review and approval of design plans by the regulatory agencies is complete. Additional steps through the NR 700 process are almost complete and will allow Miller Compressing to start implementing their sediment management project in 2020.

Cedar Creek Superfund Alternative Site

Remediation is finished for a large portion of the Cedar Creek Superfund Alternative site by contractors for Mercury Marine to address legacy contamination. Remediation of sediments for the impounded areas of Operable Unit 2A (OU2A), from upstream to downstream, Ruck Raceway, Columbia Pond, Wire and Nail Pond are complete. The remaining portion of Cedar

Creek is Operable Unit 2B (OU2B) where a feasibility study is in progress to address the free-flowing reaches of Cedar Creek.

Solvay Coke Superfund Alternative Site
In August 2016, the Milwaukee Solvay Coke and Gas Superfund Alternative Site Remedial Investigation/Feasibility Study Group (RI/FS Group) submitted a Remedial Investigation Report. Upland remedial action started in 2019 at the Solvay Coke Superfund Alternative site. Sediment remedial investigation was completed under the Superfund program. We Energies and the WDNR are currently working towards deferring the sediment portion of the site from Superfund to WDNR jurisdiction. Future sediment remedial investigation, feasibility, and remedial action is likely to be combined with the Kinnickinnic River portion of the AOC-wide project agreement. Sampling is anticipated to be conducted by the end of summer 2020.

Moss-American Superfund Alternative Site
Post-remedial sampling and restoration work was implemented. This work consisted of up to eight post-remedial rounds of groundwater sampling, installation of three access gates to reduce vandalism and illegal dumping, refuse removal, remedial pad removal, remedial sheet pile removal, and other remaining site restoration activities. As of May 2020, three groundwater sampling rounds were completed, access gates were installed, and concrete pads and other refuse were removed from the site. USEPA signed off on a five-year review on December 11, 2019.

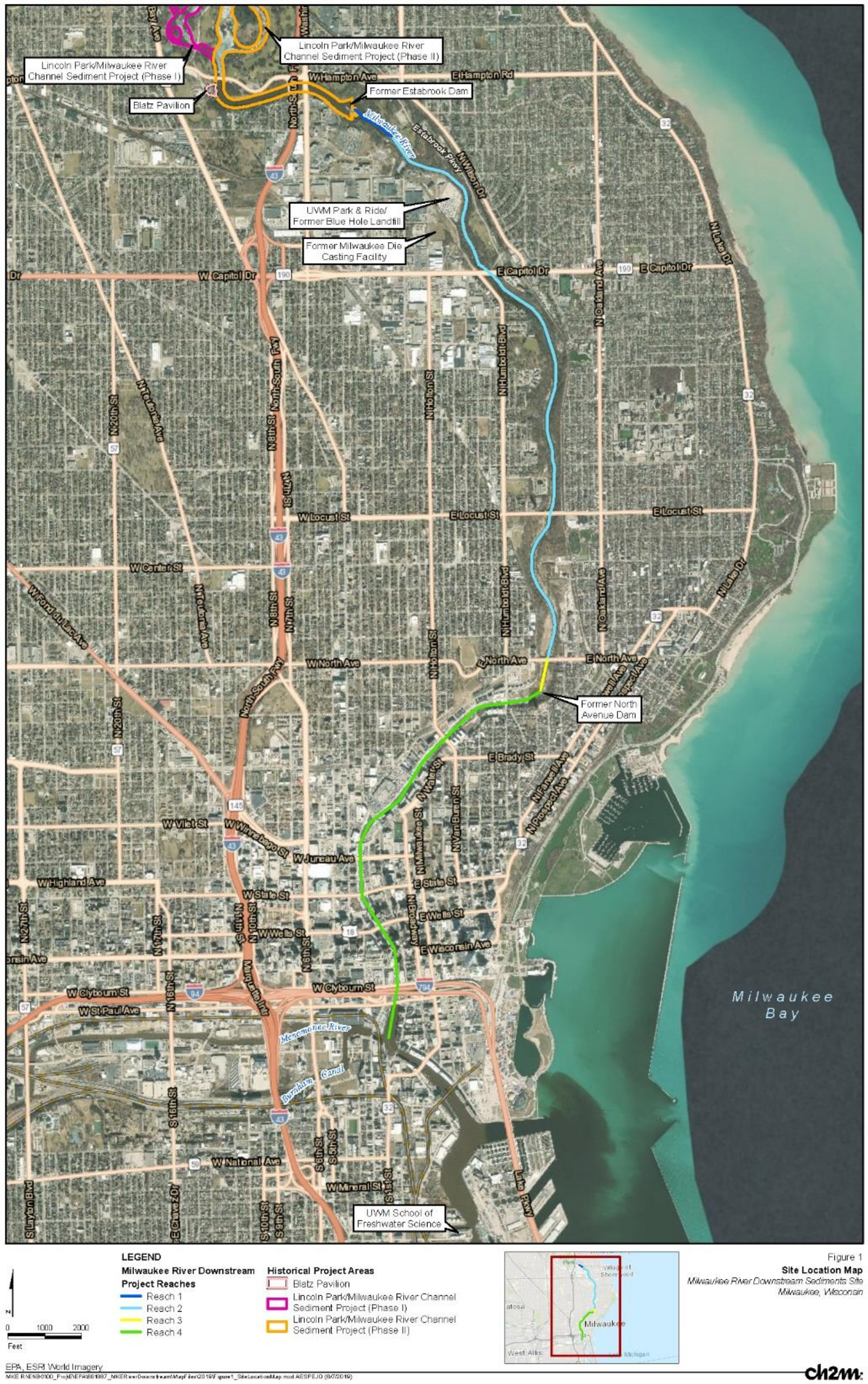

Figure 3. Milwaukee River Downstream (MRD) Project Reaches 1-4

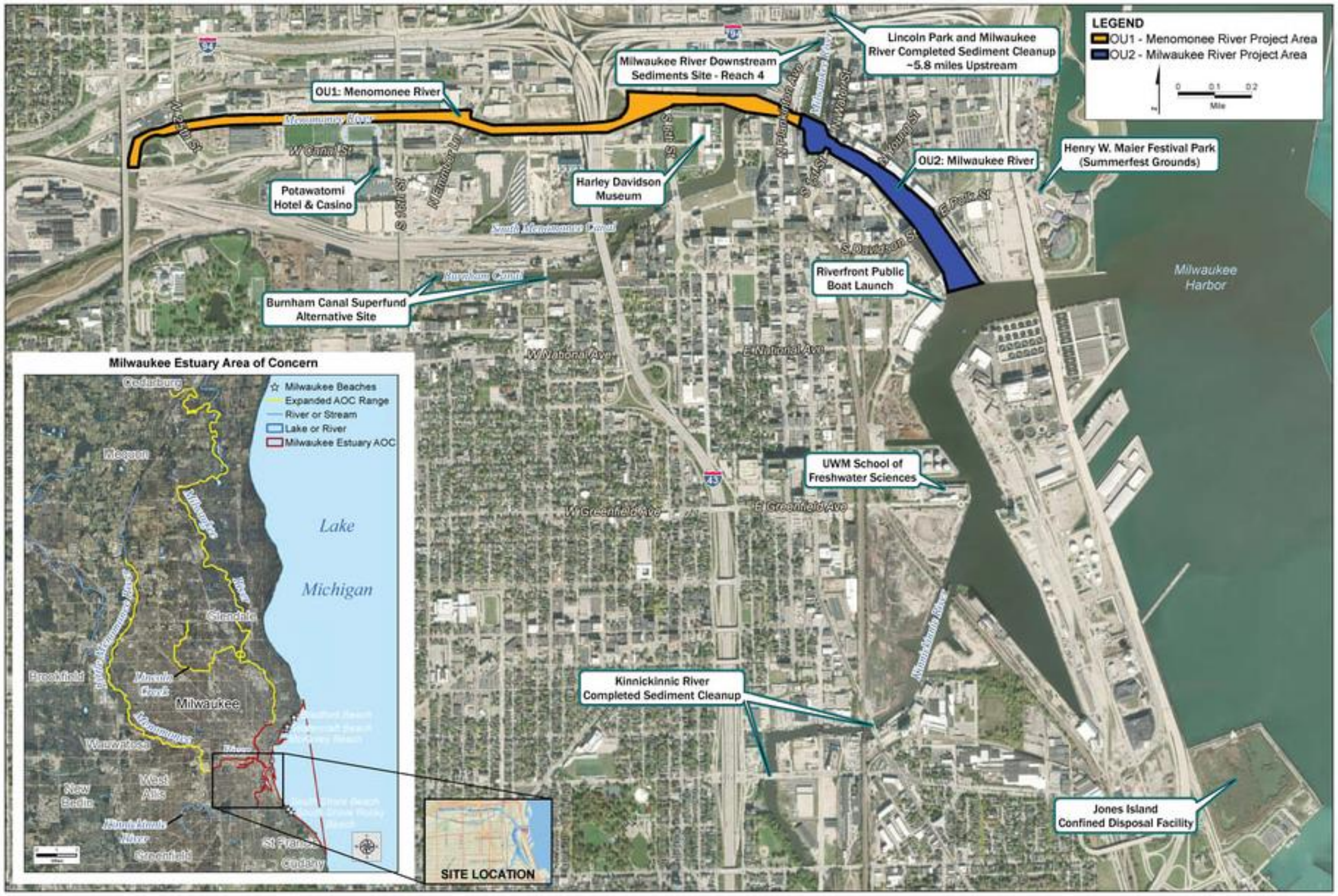

Figure 4. Milwaukee and Menomonee (M&M) River Project: Operable Units 1 and 2

FISH TUMORS OR OTHER DEFORMITIES

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Contaminated sediment sites within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
• A fish health survey of resident benthic fish species, such as white suckers, finds incidences of liver tumors to be less than the established Great Lakes background rate (5% for white suckers) with 95 percent confidence. OR, in cases where tumor rates exceed the established background rate: • A comparison study of resident benthic fish, such as white suckers, of comparable age and maturity with fish at a reference site indicates that there is no statistically significant difference (with 95% confidence) in the incidence of liver tumor. OR, in cases where tumor rates are representing a decline: • Multiple years of assessments of resident benthic fish, such as white suckers, indicate that incident rate of liver tumors is decreasing such that it can be reasonably expected that incident rate of liver tumors is below Great Lakes background rates or statistically comparable to a minimally impacted reference site, with 95 percent confidence, once all fish exposed to contaminated sediment have been naturally removed from the system.	Assessment Complete (2015); Reassess Post Sediment Remediation

Status

Based on fish tumor studies completed by USGS, West Virginia University, and University of Wisconsin-Madison in 2013 and 2014, additional work will need to be done to control or eliminate sources of legacy contaminants in the Milwaukee Estuary AOC before this BUI can be removed. Results from these studies showed a higher rate (15%) than the expected background rate (5%) for neoplastic liver tumors in the Great Lakes, as well as higher rates than an identical evaluation of white suckers in the Root River (8.5%) in 2014 (Blazer *et al.,* 2016). This impairment will be re-assessed after sediment remediation, tentatively in 2030.
This BUI target was revised in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* (Appendix G), which describes the changes and the reasons for revising AOC targets.

Management Actions

Management actions for this impairment are those projects which control or eliminate contaminants of concern from the AOC, as defined by the management action list for the Restrictions on Dredging Activities BUI.

Additional Actions

- Reassess when sediment remediation is complete and time has passed to allow white suckers born post-remediation to reach sexual maturity (3 years).

BIRD OR ANIMAL DEFORMITIES OR REPRODUCTIVE PROBLEMS

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Contaminated sediment sites within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
• Contaminant levels (PCBs, PAHs, heavy metals) in egg, young, and/or adult tissues for selected species (such as tree swallows AND fish-eating birds or wildlife) are at or below the Lowest Observable Effect Level (LOEL) for contaminants known to cause deformities or reproductive suppression, or if higher than the LOEL, are not statistically different than those at a minimally impacted reference site (with 95% confidence interval) over a 3-year-period. OR, where direct observation of bird and wildlife tissue data are not available: • Fish within the AOC, and of a size and species considered prey for fish-eating birds or other fish-eating wildlife, have tissue contaminant (PCBs, PAHs, heavy metals) concentrations at or below the LOEL for contaminants known to cause deformities or reproductive suppression in fish-eating birds or wildlife, or if higher than the LOEL, are not statistically different than those at a minimally impacted reference site (with 95% confidence interval) over a 3-year period.	Assessment Complete (2015); In-Progress Assessment; Reassess post sediment remediation.

Status

USGS researchers have been using tree swallows as indicators of environmental contamination in areas across the Great Lakes and United States; and to date, the tree swallow has been the only species used to assess this BUI in the Milwaukee Estuary AOC (Custer *et al.,* 2016). However, future monitoring efforts for this BUI will include a variety of species (tree swallows and fish-eating birds). Justification for this change in monitored species as part of the BUI target revision can be found in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* (Appendix G).

Management Actions

Management actions for this impairment are those projects which control or eliminate contaminants of concern from the AOC, as defined by the management action list for the Restrictions on Dredging Activities BUI.

Additional Actions

- Continue monitoring tree swallows for contaminant levels in the Milwaukee Estuary AOC.
- Develop a monitoring strategy for fish-eating birds or other fish-eating wildlife in the Milwaukee Estuary AOC.
- Form a work group in 2020, comprised of local and regional technical experts as well as local stakeholders.

RESTRICTIONS ON FISH AND WILDLIFE CONSUMPTION

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Contaminated sediment sites within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
Fish • State fish tissue monitoring confirms that AOC waterbody-specific fish consumption advisories are no longer needed for PCBs, mercury, dioxins, and furans for waters in the AOC. OR • A multi-year comparison study of fish tissue contaminant levels demonstrates that there is no statistically significant difference (with a 95% confidence interval) in fish tissue concentrations in the AOC compared to fish tissue concentrations in a representative non-AOC control site within the Lake Michigan Basin.	In Progress & Action Needed
Wildlife • There are no waterfowl consumption advisories for waterfowl due to contamination originating within the AOC.	Assessment Complete (2015); Reassess Post Remediation

Status

This BUI removal target was revised in 2020. Justification for the target revisions can be found in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* (Appendix G).

Fish

WDNR, in conjunction with the DHS, monitors fishes for contaminants from rivers within the Milwaukee River basin (including the AOC, upon request). These monitoring efforts have been occurring in waters of the state since the 1970s (Schrank, 2014), and includes analyses for PCBs, mercury, dioxins, and furans. Consumption advisories are updated by WDNR and DHS as needed based on sampling results. The Milwaukee Estuary AOC has a PCB consumption advisory for resident and transient species, but no additional advisories pertaining to the AOC (beyond the state-wide fish consumption advice that applies for mercury). WDNR Fisheries is scheduled to sample the AOC in 2020.

Wildlife

In 2013-2015, wildlife consumption advisories were re-evaluated and determined to still be necessary, with the addition of all diving ducks based on found PCB levels (Strom, 2016). These findings and report can be found in Appendix F of the 2016 RAP Update. Another wildlife consumption assessment will not be conducted until all sediment remediation is complete.

Management Actions

Management actions for this impairment are those projects which control or eliminate contaminants of concern from the AOC, as defined by the management action list for the Restrictions on Dredging Activities BUI.

Additional Actions

- Continue monitoring for contaminant levels in fishes in the Milwaukee Estuary AOC.
- Reassess waterfowl after contaminated sediment sites are remediated.

DEGRADATION OF BENTHOS

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Contaminated sediment sites within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
• The benthic community of the Milwaukee Estuary AOC, excluding the highly modified lower estuary (downstream of N. Humboldt Avenue on the Milwaukee River; downstream of N 25th Street on the Menomonee River; downstream of S Chase Avenue on the Kinnickinnic River, inner and outer harbors) is statistically similar to a non-AOC reference site with similar habitat.	In-Progress

Status

USGS completed sampling in 2012 and 2014 to assess both the planktonic and benthic communities of the Lake Michigan AOCs and reference rivers and published a final report in 2019 (Scudder Eikenberry *et al.,* 2019; Appendix I). The Menomonee River and Milwaukee River subsites were compared to two reference sites, the Manitowoc River and Root River, and also to a pre-determined set of Lake Michigan non-AOC comparison sites including the Escanaba River in Michigan and the Oconto, Ahnapee, Kewaunee, Manitowoc, and Root Rivers in Wisconsin (Scudder Eikenberry *et al.,* 2019).

Results from this research support that benthic assemblages at the Milwaukee AOC subsites are not degraded when compared to the two non-AOC reference sites. The Milwaukee River and Menomonee River subsites were compared to the Manitowoc and Root River non-AOC reference sites for benthic richness, diversity, total density, and Ephemeroptera-Plecoptera-Trichoptera (EPT) density, EPT percent, EPT richness, and index of biotic integrity (IBI). The Milwaukee River subsite was not significantly different from the average of the Manitowoc and Root River reference sites for any benthos metric except for EPT density. The Milwaukee River EPT density was higher (less degraded) than the reference sites. At the Menomonee River subsite, total density of combined benthos was higher (less degraded) than at the two non-AOC reference sites, but all other benthic measures were not statistically different from the reference sites. However, benthic assemblages at the two subsites did differ in the relative abundance of several pollution tolerant taxa – particularly caddisfly at the Milwaukee River subsite and highly tolerant oligochaetes at the Menomonee River subsite. Based on the data and results presented in the USGS study, the target was revised in 2020 to shift the focus of this BUI to the upper estuary benthic community. Justification for the target revisions can be found in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* (Appendix G).

At a minimum, sources of contamination to the benthic community within the AOC need to be remediated. The status and condition of the upper estuary benthic community needs to be determined. Next steps for this BUI are to take the compiled existing benthic sampling data from the upper estuary in the AOC and evaluate benthic community health.

Management Actions

Management actions for this impairment are those projects which control or eliminate contaminants of concern from the AOC, as defined by the management action list for the Restrictions on Dredging Activities BUI.

Additional Actions

- Evaluate existing data in order to determine the status of the upper estuary benthic community in comparison to a non-AOC reference site with similar habitat.

DEGRADATION OF PHYTOPLANKTON AND ZOOPLANKTON POPULATIONS

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Phytoplankton and zooplankton bioassays confirm there is no toxicity in ambient waters.	Action Needed
• The phytoplankton and zooplankton communities within the site being evaluated are statistically similar to a non-AOC reference site with similar habitat.	Assessment Complete (2019)

Status

USGS completed sampling in 2012 and 2014 to assess both the planktonic and benthic communities of the Lake Michigan AOCs and reference rivers and published a final report in 2019 (Scudder Eikenberry *et al.,* 2019; Appendix I). The Menomonee River and Milwaukee River subsites were compared to two reference sites, the Manitowoc River and Root River, and also to a pre-determined set of Lake Michigan non-AOC comparison sites including the Escanaba River in Michigan and the Oconto, Ahnapee, Kewaunee, Manitowoc, and Root River in Wisconsin (Scudder Eikenberry *et al.,* 2019).

The results from this research showed that no metrics for zooplankton in the Milwaukee River differed between the average of all non-AOC sites in 2014. Every metric for zooplankton was similar between the Milwaukee River, Manitowoc River, and Root River except for density (lower than the two reference sites). For phytoplankton in the Milwaukee and Menomonee River in 2014, there were no differences found when compared to all non-AOCs for richness, diversity, or total density. The Menomonee River in 2014 was the same as the Milwaukee River in that no metrics for zooplankton differed between the Menomonee River and the average of all non-AOC sites, including no difference between the average of the Manitowoc and Root River. Overall the key takeaway is that phytoplankton populations are at acceptable levels with regards to richness, diversity, and total density; and overall, zooplankton populations are doing well but continue to represent low diversity, similarly to historical trends (Scudder Eikenberry *et al.,* 2014, 2016, and 2019).

Based on the data and results presented in the USGS study, the target was revised in 2020 to focus on phytoplankton and zooplankton bioassays in ambient waters of the AOC to confirm that there are no toxicity related issues that may be impacting these communities. Additional information on the background of this BUI and the target revision can be found in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* (Appendix G).

Management Actions

Management actions are not expected to be needed for this BUI. Factors such as nutrient enrichment and toxicity due to sediment were removed from the target in 2020 as source control measures. These type of management actions were determined to be addressed in separate BUIs (Eutrophication or Undesirable Algae and Restrictions on Dredging Activities).

Additional Actions

- WDNR plans to collect water column toxicity samples in the Milwaukee Estuary AOC during 2021 at multiple sample locations throughout the Milwaukee River, Menomonee River, and Kinnickinnic River. Sampling for this work will most likely continue into 2022.

LOSS OF FISH AND WILDLIFE HABITAT

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Contaminated sediment sites within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
• All management actions/projects have been identified and implemented.	In Progress
• Post-implementation verification monitoring of the AOC shows that, in consultation with the Fish and Wildlife Tech Team, the Wisconsin WDNR concurs that the goals for this BUI, as identified in the RAP, have been met.	Future Assessment Needed

Status

Significant progress has been made on this BUI in the past several years for habitat restoration projects. A management action list of habitat projects was finalized in the 2015 RAP, and all projects are underway (planning, design, or construction) or complete. Progress made on these management actions can be found in the Progress Summary section of this RAP update. WDNR applied for and received grant funding for several habitat management action projects including: Kletzsch Dam Fish Passage, Grand Trunk Wetland Restoration, Little Menomonee Corridor Restoration, Burnham Canal Wetland Restoration, Estabrook Dam Fish Passage, and the Kinnickinnic River Habitat Rehabilitation. In the coming year, WDNR will work with partners to continue making progress on these and other management actions.

This BUI removal target was revised in 2020. Justification for this change can be found in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* (Appendix G).Through the target revision process, WDNR determined, in collaboration with the Milwaukee Estuary AOC Fish and Wildlife Technical Advisory Committee (Tech Team), that the *Fish and Wildlife Plan for the Milwaukee Estuary Area of Concern* is not necessary and should be removed from the target. However, a future verification monitoring plan will be developed for both fish and wildlife BUIs to re-evaluate status after management action completion.

Management Actions

In addition to projects which control or eliminate legacy contaminants of concern from the AOC, as defined by the management actions for the Restrictions on Dredging Activities BUI, management actions for this impairment are habitat restoration projects that address one or more physical or biological habitat goals for the BUI. Details on these management actions are in Appendix D of this RAP and will continue to be included as part of future RAP updates. Fish and wildlife habitat project summaries and explanations for most of these projects can be found in Appendix C of the 2015 RAP. These habitat restoration projects are necessary for removing this impairment and enhancing habitat in the AOC. The following is a complete list of the habitat restoration management actions. The actions that have been completed are italicized. Implementation will continue for the projects that are underway.

- *Little Menomonee River Parkway Grassland Restoration* (*completed in 2015*)
- Burnham Canal Wetland Restoration (in design and bidding phase)
- Grand Trunk Wetland Restoration (in design and bidding phase)
- *Milwaukee River Fish Habitat Enhancement and Expansion* (*completed in 2014*)
- *Wheelhouse Gateway Riparian Restoration* (*completed in 2014*)
- *Menomonee River Stream Management (Concrete Removal) Phases I & II* (*completed in 2019*)
- Kletzsch Park Dam Fish Passage (in design phase)
- Estabrook Dam Fish Passage (in maintenance and monitoring phase)
- *Five Low Flow Barriers on the Menomonee River* (*complete*d *in 2016*)
- Kinnickinnic River Habitat Rehabilitation (*Phase I completed in 2018*; Phase II underway)
- Little Menomonee River Corridor Restoration (in design and implementation phase)

Additional Actions

- Post-implementation verification monitoring of the AOC to show that the goals for this BUI, as identified in the RAP, have been met.

DEGRADATION OF FISH AND WILDLIFE POPULATIONS

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Contaminated sediment sites within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
• All management actions/projects have been identified and implemented.	Action Needed
• Post-implementation verification monitoring of the AOC shows that, in consultation with the Fish and Wildlife Tech Team, the WDNR concurs that the goals for this BUI, as identified in the updated RAP to reflect current conditions, have been met.	Future Assessment Needed

Status

Assessments

Four assessments were funded and completed between 2014 to 2018 to determine the current status of this BUI:

- A fish population assessment summary of historic densities and life history for the AOC was completed by the USGS and WDNR in 2014 (Sullivan and Fayram, 2014). Based on this summary, a non-wadeable fisheries population assessment (replicate of Holey 1984) was conducted from 2014-2016 by USGS (Sullivan, 2018).
- A wildlife population assessment summary of historic densities and life history for the AOC was completed by UW-Milwaukee Field Station. Based on this summary, a comprehensive wildlife survey throughout the AOC was ongoing from 2014-2017 by UW-Milwaukee Field Station and Milwaukee County Parks (Casper and Robson, 2018).
- A fisheries and aquatic habitat study in the wadeable portions of the AOC from 2016-2018 by Ozaukee County Planning and Parks (OCPP) (Struck *et al.,* 2018).
- An assessment of fish habitat in the Milwaukee Harbor from 2015-2018 by UW SFS (Dow, 2018).

Determining BUI Status and Management Actions

Results from the assessments mentioned above provided information for determining the status of this BUI. Starting in 2018, the Tech Team met twice-a-month, for full day meetings to reach agreement on updated target language, revised metrics to achieve the target, and a list of management actions. The Tech Team generated 93 proposed metrics for BUI removal as part of their recommendations. Many metrics were generated from the AOC-wide wildlife population assessment completed by UWM Field Station and Milwaukee County Parks. Through a collaborative process, the Tech Team refined the metrics from 93 to 21 that would represent the condition of fish and wildlife populations in the AOC, while allowing for flexibility based on habitat type and species guild (Table 2).

To draft a list of management actions, recommendations from assessments and project opportunities provided by Tech Team members were combined to develop a list of projects in the AOC to address this impairment. 120 project opportunities were identified in five geographical sub-areas of the AOC. These projects were initially given a low, medium, or high priority ranking on overall importance. This narrowed the list down to 34 high priority projects. Projects were then paired with the revised list of 21 metrics, to finalize a list of 15 projects necessary to address the Degradation of Fish and Wildlife Populations BUI (Table 2).

Table 2. Breakdown of metrics and projects for the Degradation of Fish and Wildlife Populations BUI.

	Previous	Revised
Fish	19	7
Breeding Birds	6	5
Migratory Birds	1	0
Bats	11	0
Mammals	4	3
Herptiles/Crayfish	0	1
Frogs	8	1
Turtles	3	1
Salamanders	7	1
Crayfish	6	1
Snakes	7	1
Mussels	21	0
TOTAL	**93**	**21**

Location	**# of projects**
Lakefront and Outer Harbor	15
Kinnickinnic River and Inner Harbor	4
Menomonee River	25
Little Menomonee River	13
Milwaukee River and Tributaries	41
TOTAL	**98** (synthesized from **120**)
High Priority	34
Draft Management Action List	**15**

Significant effort was expended by Tech Team members to sift through all these recommendations and to develop projects with accompanying measurable, achievable, and meaningful AOC-wide population metrics. Details on these projects, and the related goals and metrics can be found in Appendix E of this RAP and will continue to be included as part of future RAP updates. WDNR is planning on applying for funding for the initial stages (planning and design) of these projects in 2020 to further develop the management actions and refine implementation cost estimates for each project.

Additional information on the background of this BUI and the target revision can be found in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* (Appendix G). The Loss of Fish and Wildlife Habitat BUI, the Degradation of Fish and Wildlife Populations BUI, and the draft *Fish and Wildlife Plan for the Milwaukee Estuary Area of Concern* that was developed in 2015, were revisited based on information gathered for the status check and development of management actions for the Degradation of Fish and Wildlife Populations BUI as part of this process. Through the target revision process, WDNR determined, in collaboration with the Tech Team, that the *Fish and Wildlife Plan for the Milwaukee Estuary Area of Concern* is not necessary and should be removed from the target. However, a future verification monitoring plan will be developed for both fish and wildlife BUIs to re-evaluate status after completion of management actions.

Management Actions

In addition to projects which control or eliminate legacy contaminants of concern from the AOC, as defined by the management actions for the Restrictions on Dredging Activities BUI, management actions for this impairment are restoration projects that address one or more species specific population metrics identified for the BUI. Details on these management actions, and the related items are in Appendix E of this RAP and will continue to be included as part of future RAP updates. Fish and wildlife population project summaries and explanations of each of these projects can be found in Appendix F of this RAP. These population projects must be completed in order to improve habitat to support a better population of fish and wildlife indicator species and to remove this impairment. Below is a complete list of the population restoration management actions. WDNR is aiming to start a handful of these projects in 2020.

- Enhancements to City of Mequon Parks and Ozaukee Washington Land Trust (OWLT) Ville du Parc Property
- Enhancements to Milwaukee River Greenway
- Estabrook Falls and Fish Passage Improvements
- Aquatic Enhancements to the Outer Harbor
- Havenwoods State Forest Rehabilitation

- Wildlife Enhancements to Milwaukee County Grounds, Sanctuary Woods, MMSD Basins, and Hoyt Park
- Wildlife Enhancements to Kletzsch Park
- Enhancements to Schlitz Audubon Cleaver Property
- Enhancements to Menomonee River Parkway – Sections 5 and 6
- Currie Park Fish Passage Improvements
- Fisheries Improvements to Milwaukee River Downstream – E Cherry Street to N Humboldt Avenue
- Fisheries Improvements to Menomonee River – N 16th Street to N 25th Street
- Fish and Wildlife Enhancements to Little Menomonee River Parkway – Section 1
- Wildlife Enhancements to Kohl Park
- Fisheries Improvements to Lincoln Park Oxbow

Additional Actions

- Post-implementation verification monitoring of the AOC to show that the goals for this BUI, as identified in the RAP, have been met.

BEACH CLOSINGS (RECREATIONAL RESTRICTIONS)

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Known sources of bacterial contamination impacting the beaches in the AOC have been identified and, if feasible, have been controlled or treated to reduce possible exposures.	Assessment in Progress & Action Needed
• Stormwater outfalls in the AOC that discharge directly or influence beaches are assessed to confirm that there are no human sources of sanitary sewage contamination.	Assessment Needed
• Municipalities within the AOC have adopted and are implementing storm water reduction programs that include bacteria source reduction and illicit discharge elimination.	Complete
• Each public swimming beach within the AOC is open for at least 90% of the swimming season (between Memorial Day and Labor Day) averaged over a previous 5-year period based on Wisconsin Coastal Beach monitoring protocols for E. coli monitoring and BMPs are in place. OR • Public swimming beaches within the AOC are meeting EPA's 2012 recreational water quality criteria over a 3-year period. OR, in cases where known sources of bacterial contamination impacting beaches in the AOC have been controlled to the extent feasible and the above criteria cannot be met: • Each public swimming beach within the AOC is open during the swimming season (between Memorial Day and Labor Day) at least as often as the average of all non-AOC beaches in Milwaukee County over the same 5-year period.	In Progress & Action Needed
• No unpermitted discharges (combined or sanitary sewers in the Lower Milwaukee Estuary) at outfalls directly impacting AOC beaches during the swimming season (between Memorial Day and Labor Day) in a 3-year period.	Currently Meeting Target; Reassess After Management Actions are Completed
• Complete a plan that includes updates to existing advisory and closure procedures for AOC beaches to reduce human health risk during and after storm events.	In Progress

Status

Milwaukee County has made progress on planning improvements to beaches in the AOC. The focus for the past few years has been high bacteria levels at South Shore Beach, which is the most problematic beach in the AOC and throughout Lake Michigan. Milwaukee County Parks completed a Master Plan and redesign of park elements. This led to a reconstruction of the parking lot and addition of green infrastructure and other improvements to this area. Following this work, the planning moved to focus on the beach area, continuing work to address high bacteria levels and beach closures.

In late 2017, WDNR received GLRI funds which were then awarded to the County in order to hire a consultant team for the collection and analysis of data at South Shore Beach. The consultant team provided concept and final design plans to address the high bacterial issues at South Shore Beach. In September 2018, the County and WDNR held a public meeting to provide alternatives to the swimming area of the beach at South Shore Park. Four recommended alternatives were provided at this meeting for feedback from the public. These alternatives can be found on the Milwaukee County Parks website. Based on feedback from this public meeting and additional public interfacing venues (i.e. farmers market, local stakeholder meetings, etc.), the County and WDNR revisited the recommended alternatives to select a preferred alternative. In early December 2019, another public meeting was held to present the preferred alternative, and the complete design of this work is expected to be done with appropriate permitting requirements in early 2020.

In 2019, a Beaches Work Group was formed for the Milwaukee Estuary AOC to revise targets for this BUI as well as determine management actions to meet the revised targets. The collaborative work group includes roughly 20 partners from the WDNR, Milwaukee County, City of Milwaukee, DHS, UWM, USGS, USEPA GLNPO, MMSD, and other technical expert stakeholders. The work group recommended a revised target for this BUI. As a result, this BUI removal target was revised in 2020. Justification for this change can be found in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* (Appendix G). The Beaches Work Group also identified the need for additional investigation of factors leading to poor water quality at beaches within the AOC to inform management action recommendations at each beach.

To meet this need, the McLellan Lab at the UWM SFS will begin a beach assessment project in 2020. The project will analyze inventoried water and sand samples to provide site-specific information about sources of *E. coli* at beaches within the AOC. If needed, additional samples will be taken from outfalls and AOC beaches (McKinley, Bradford, South Shore, and Bayview). This information and recommendations from this work will be used by the WDNR, in collaboration with the McLellan Lab and the Beaches Work Group, to develop a draft list of management actions for this BUI. A summary of this proposed work can be found in Appendix K of this RAP.

Management Actions

- The only management action currently identified for this BUI is the rehabilitation of South Shore Beach. Beach rehabilitation projects will be identified in 2020 after review of pertinent information and data from the UWM SFS beaches investigation study.

Additional Actions

- The McLellan Lab at the UWM SFS will be investigating sources of *E. coli* at Milwaukee Estuary AOC beaches to refine management actions that will reduce the number of beach closures and address portions of the Beach Closings (Recreational Restrictions) target. Preliminary results and recommendations should be available in 2020.

EUTROPHICATION OR UNDESIRABLE ALGAE

Target (Updated 2011)	Status
Removal of this BUI can occur when:	
• Total phosphorus (TP) concentrations within the AOC rivers, harbors, and nearshore waters meet the criteria recommended for the State of Wisconsin, as established by WDNR.	In Progress & Action Needed
• When the results from the total maximum daily load study for phosphorus, total suspended solids, and bacteria are completed for the Menomonee, Kinnickinnic, and Milwaukee Rivers.	In Progress
• Measures to meet the Total Maximum Daily Loading Implementation Plan are being completed.	Action Needed
• No water bodies within the AOC are included on the list of impaired waters due to nutrients or excessive algal growths in the most recent WI Impaired Waters list.	Action Needed
• Chlorophyll-a concentrations within the AOC lake and impoundment areas do not exceed 4.0 µg/L.	Unknown
• There are no beach closures in the AOC due to excessive nuisance algae growth.	Unknown

Status

For the past twenty-plus years, extensive work has been done throughout the greater Milwaukee River Basin to significantly reduce sediment and nutrient loading to the harbor/estuary and resulting eutrophication. TMDL plans for total phosphorus (TP), TSS, and fecal coliform of the entire Milwaukee Basin were drafted and submitted to USEPA to meet Section 303(d) Clean Water Act requirements and USEPA's implementing regulations at 40 C.F.R. Part 130. In 2018, USEPA approved Wisconsin's three TMDLs in the Milwaukee River Basin. These TMDLs cover the Milwaukee, Menomonee, and Kinnickinnic River watersheds and the Milwaukee Harbor/Estuary.

Following the completion of the TMDL plan, a multi-partner initiative begun to develop an Integrated Watershed Management strategy and framework across the TMDL area that facilitates collaborative implementation of watershed best practices to meet TMDL goals. This initiative was captured in the recently published DRAFT Milwaukee River Basin Water Quality Improvement Plan (WQIP) that was required as part of the MMSD 2020 Wisconsin Pollutant Discharge Elimination System (WPDES) permit reissuance. The WQIP builds on the TMDL Report, 9-Key Element (9KE) Plans, MMSD's Regional Green Infrastructure and 2050 Facilities Plans, and a number of Southeastern Wisconsin Regional Planning Commission (SEWRPC) plans. The WQIP focuses on implementing recommendations from collective plans with monitoring to measure progress toward goals over time.

The framework presented in the WQIP will encapsulate a collection of 9KE plans covering the entire Milwaukee River Basin. The Kinnickinnic River Watershed Restoration Plan was approved in early 2020; the Menomonee River Watershed Restoration Plan is being finalized, with anticipated approval in late 2020; and, a collection of Hydrologic Unit Codes (HUC) 10/12 based 9KE plans are nearing completion for a major portion of the Milwaukee River Watershed. A draft 9KE plan covering three HUC12 watersheds (Fredonia/Newburg) is currently under review by WDNR, while another 9KE plan covering five HUC12 watersheds is being finalized this year.

While meeting the approved TMDLs for the Milwaukee River Basin and other watershed plans remains an important goal that many resource professionals, agencies, and citizens continue to strive for in the region, BUI removal targets that overlap existing permit or regulatory compliance functions are beyond the AOC program framework. It is important to note that while the WDNR and AOC program are currently trying to take a step back and revise the target for this impairment and develop subsequent management actions to address the status of the AOC, many ongoing efforts are underway to improve water quality within the AOC boundaries and surrounding landscape. WDNR will continue to work with partners and stakeholders to review and revise the BUI removal target in 2020. WDNR is expecting a draft list of management actions to be completed in 2021.

In order to achieve these goals, WDNR is planning to convene a Eutrophication Work Group. This group will revisit the Eutrophication or Undesirable Algae BUI target to refine the outcomes that will define success for the AOC program. Targets need to be viewed with the following attributes in mind: Specific, Measurable, Achievable, Reasonable, Time-bound (SMART).

Reasons that targets may be justifiably revised include the following:

- New information has become available;
- Target language needed clarification and format consistency;
- The target reflects goals that go beyond the AOC program framework (e.g. overlap existing permit or regulatory compliance program functions); and/or
- The scope of achievable activities within the AOC program has become better understood as program implementation has occurred.

Management Actions

- Management actions have not been defined for this impairment. Management actions will be determined after review of pertinent information and in consultation with stakeholders.

Additional Actions

- Establish a Eutrophication Work Group in 2020 to focus revising the BUI removal target and drafting a list of management actions.

DEGRADATION OF AESTHETICS

Target (Updated 2016)	Status
This delisting target is consistent with Chapter NR 102, Wisconsin Administrative Code, Water Quality Standards for Surface Waters. Delisting shall occur when monitoring data within the AOC and/or surveys collected by multiple observers for any two consecutive year period indicates that water bodies in the AOC do not exhibit unacceptable levels of the following properties in quantities which interfere with the Water Quality Standards for Surface Waters:	
a) Substances that will cause objectionable deposits on the shore or in the bed of a body of water shall not be present in such amounts as to interfere with public rights in waters of the state.	Assessment Complete
b) Floating or submerged debris, oil, scum, or other material shall not be present in such amounts as to interfere with public rights in waters of the state.	Assessment Complete
c) Materials producing color, odor, taste, or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the state.	Assessment Complete
The following target will also be met to determine when restoration has occurred:	
• Corrective action plans are in-place and being implemented for significant, persistent issues contributing to the degradation of aesthetics within the AOC identified via aesthetics monitoring/surveys.	No Corrective Actions Anticipated

Status

The Degradation of Aesthetics BUI for the Milwaukee Estuary AOC stemmed from the poor visual quality of the water resources and adjacent land (WDNR, 2012). The 1994 Milwaukee RAP identified the likely causes of impairment to be surface water debris, oil and grease, and overdevelopment along the Estuary (WDNR, 2012).

Milwaukee Estuary AOC stakeholders expressed a strong desire for a citizen-based monitoring approach to assess the status of this BUI. The Alliance for the Great Lakes and the Urban Ecology Center (UEC) coordinated citizen volunteers for a pilot Volunteer Aesthetics Monitoring Program in 2011. Using what was learned from the pilot program, protocols were updated in 2014 and Milwaukee Riverkeeper coordinated citizen volunteers and assisted with data collection from 2015-2017 (WDNR, 2017).

The monitoring program from 2015-2017 focused on nine aesthetics monitoring stations, which 30 volunteers assessed throughout the year (WDNR, 2015; Figure 5). In 2016, the BUI target language was adjusted to incorporate monitoring results collected by multiple observers, two consecutive survey seasons, and identification of significant or persistent issues identified by the surveys (WDNR, 2016). The citizen-based aesthetics monitoring continued in 2017. Results from the aesthetics monitoring assessment show that the current target is being met. Following a presentation on the assessment and results in June 2019, the Citizens Advisory Committee voted to support the removal of this BUI. Supporting results can be found in Appendix J.

Management Actions

- No management actions are anticipated for this BUI.

Additional Actions

- Develop a removal recommendation package for the Degradation of Aesthetics BUI in 2020.

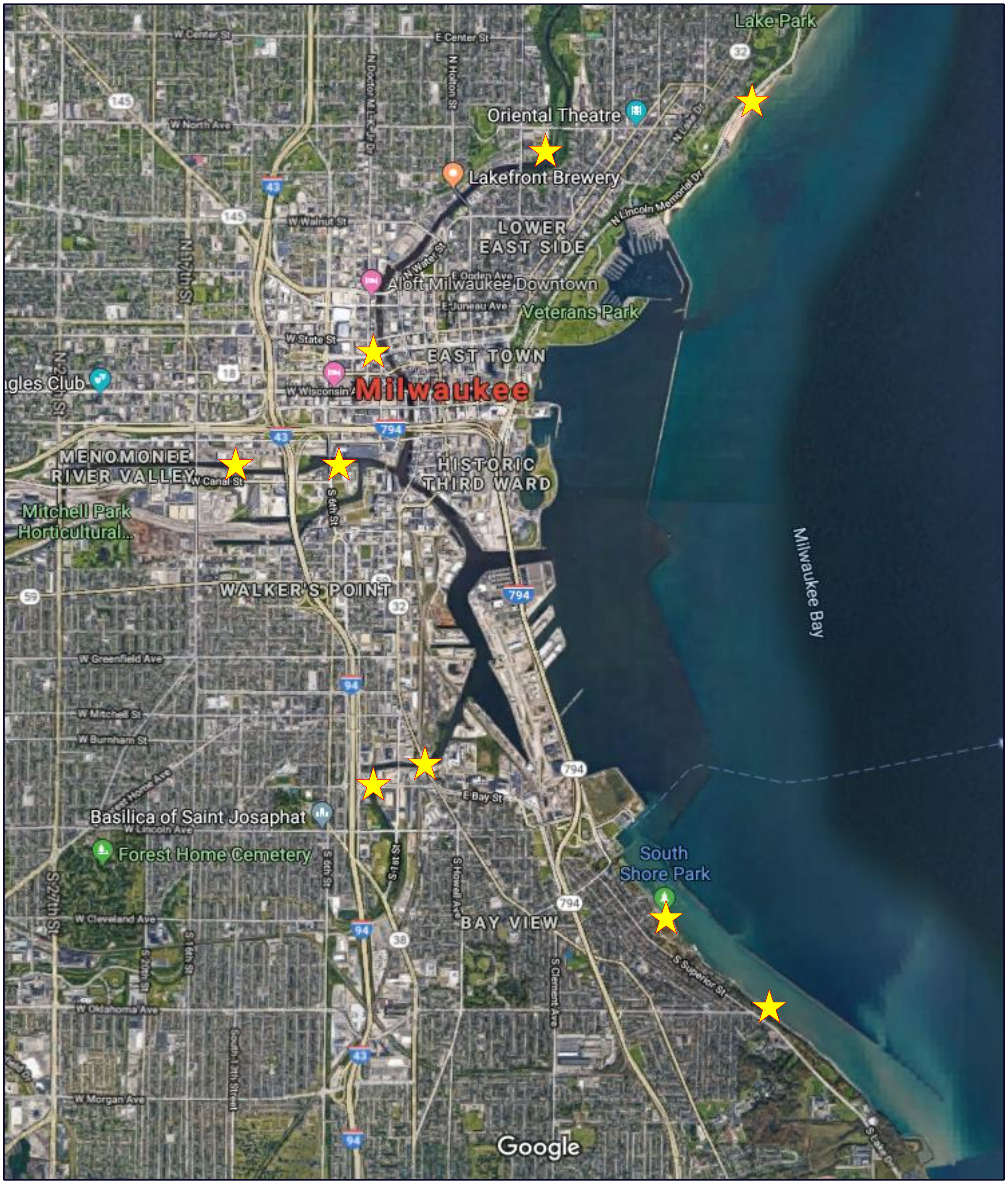

Figure 5. Nine Aesthetic Monitoring Stations (Milwaukee River: North Avenue Pedestrian Bridge, Pere Marquette Park; Menomonee River: Emmber Lane, Harley Davidson Museum; Kinnickinnic River: Lincoln Avenue Bridge, Kinnickinnic Avenue Bridge; Beaches: Bradford Beach, South Shore Beach, Bayview Beach).

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Other Resources

Cedar Creek Superfund

- Superfund Site: Background
- Superfund Site: Reports and Documents
- Superfund Site: Administrative Records

Moss-American Superfund

- Superfund Site: Background
- Superfund Site: Reports and Documents

Burnham Canal Superfund

- Superfund Site: Background
- Superfund Site: Reports and Documents
- Superfund Site: Administrative Records

Blatz/Lincoln Park Legacy Clean-up

Kinnickinnic River Legacy Clean-up

Turning Basin Characterization Report

Menomonee River Characterization Report

Wildlife Consumption Advisory

Fish Consumption

- Fish Consumption Advise for the Milwaukee Estuary Area of Concern
- Eat your catch – making healthy choices

TMDL

Built on Water Documentary

Bay View/Grand Trunk Wetland Restoration

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APPENDICES

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Appendix A – List of Acronyms

AOC	Area of Concern
BUI	Beneficial Use Impairment
CAC	Community Advisory Committee
CY	Cubic Yards
DHS	Wisconsin Department of Health Services
DMDF	Dredged Material Disposal Facility
DMMF	Dredged Material Management Facility
DOT	Department of Transportation
DTWG	Design Technical Work Group
EPT	Ephemeroptera, Plecoptera, and Tricoptera
FFLM	Fund for Lake Michigan
FFS	Focused Feasibility Study
FS	Feasibility Study
FSP	Field Sampling Plan
GLLA	Great Lakes Legacy Act
GLNPO	Great Lakes National Program Office
GLRI	Great Lakes Restoration Initiative
GLWQA	Great Lakes Water Quality Agreement
HAP	Harbor Assistance Program
HUC	Hydrologic Unit Codes
IBI	Index of Biotic Integrity
LT	Leadership Team
MAIT	Management Action Implementation Team
MGP	Manufactured Gas Plant
M&M	Milwaukee and Menomonee
MMSD	Milwaukee Metropolitan Sewerage District
MRD	Milwaukee River Downstream
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PDI	Pre-design Investigation
PFAS	Per- and polyfluoroalkyl substances
PM	Project Management
ppm	Part per million
QAPP	Quality Assurance Project Plan
SEWRPC	Southeastern Wisconsin Regional Planning Commission
OCPP	Ozaukee County Planning & Parks
OGW	Office of Great Waters
OU	Operable Unit
PEEC	Parks, Energy & Environment Committee
RACM	Redevelopment Authority of the City of Milwaukee

RAP	Remedial Action Plan
RD	Remedial Design
SFS	School of Freshwater Sciences
SIR	Site Investigation Report
SMART	Specific, Measurable, Achievable, Reasonable, Time-bound
SMC	South Menomonee Canal
SOW	Scope of Work
SSCHC	Sixteenth Street Community Health Center
SWWT	Southeastern Wisconsin Watersheds Trust
TMDL	Total Maximum Daily Load
TP	Total phosphorus
TSCA	Toxic Substances Control Act
TSS	Total suspended solids
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
UWM	University of Wisconsin – Milwaukee
WDNR	Wisconsin Department of Natural Resources
WinSLAMM	Windows Source Loading and Management Model
WPDES	Wisconsin Pollutant Discharge Elimination System
WQIP	Water Quality Improvement Plan
9KE	9 Key Element

Appendix B – Definitions

Area of Concern (AOC)
Defined by Annex 2 of the 2012 U.S.-Canada Great Lakes Water Quality Agreement (GLWQA) as a "geographic area designated by the Parties where significant impairment of beneficial uses has occurred as a result of human activities at the local level." These areas are, or were, the "most contaminated" areas of the Great Lakes, and the purpose of the AOC program is to bring these areas to a point at which they are not environmentally degraded more than other comparable areas of the Great Lakes. When that point has been reached, the AOC can be removed from the list of AOCs, or "delisted." The 2012 GLWQA can be found at https://binational.net/2012/09/05/2012-glwqa-aqegl/.

Beneficial Use Impairment (BUI)
Defined by the 2012 GLWQA as a reduction in the chemical, physical, or biological integrity of the Waters of the Great Lakes sufficient to cause impairment to a designated use. A "beneficial use" is any way that a water body can improve the quality of life for humans or for fish and wildlife (for example, providing fish that are safe to eat). If the beneficial use is unavailable due to environmental problems (for example if it is unsafe to eat the fish because of contamination) then that use is impaired. The 1987 Great Lakes Water Quality Agreement amendment established the list of 14 possible beneficial use impairments; these 14 BUIs were reaffirmed in the 2012 GLWQA.

Removal Target
Specific goals and objectives established for beneficial use impairments, with measurable indicators to track progress and determine when BUI removal can occur.

***Escherichia coli* (*E. coli*)**
A bacterium commonly found in natural bodies of water that serves as an indicator of possible presence of other health risks in the water, such as bacteria, viruses, and other organisms. They can often be linked to a specific source (i.e. humans, animals, etc).

Remedial Action Plan (RAP)
The 2012 Great Lakes Water Quality Agreement requires Remedial Action Plans to be "developed, periodically updated, and implemented for each AOC." RAPs identify the status of BUIs and their sources, document delisting targets, and list actions needed to reach those targets.

Total Maximum Daily Load (TMDL)
A TMDL is the amount of a pollutant a waterbody can receive and still meet water quality standards. It can be thought of as a pollution "budget" for a water body or watershed that establishes the pollutant reduction needed from each pollutant source to meet water quality goals.

Appendix C – BUI Tracking Matrix

Note that projects listed in the table below are the next clearly delineated action steps that have been identified by WDNR in collaboration with AOC partners and stakeholders to make progress toward delisting the AOC. This list does not necessarily reflect all actions that will ultimately be needed to remove impairments, and will be updated as more information is collected and as actions are completed.

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Project Name	BUI Short List	Project Type	Project Action Type	Action Modifier	Project Status	Project Start Date	Project End Date	Project Cost	Primary Funding Source	Project Lead Organization
Assess Menomonee River downstream of its confluence with the Little Menomonee River to the estuary	BUI 1, BUI 3, BUI 4, BUI 5, BUI 6, BUI 7, BUI 14	Sediment	Remediation	COMPLETED	Completed	2015	2016	Unknown	Great Lakes Legacy Act [GLRI]	USEPA
Assess portions of the Kinnickinnic River, Inner Harbor, South Menomonee Canal, Outer Harbor and Nearshore Waters of the Milwaukee Estuary	BUI 1, BUI 3, BUI 4, BUI 5, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Screening Level Assessment	In Progress *(awarding consultant)*	2019	2024	$3,300,000.00	Great Lakes Legacy Act [GLRI]	WDNR
Assess the Milwaukee River downstream of Estabrook Dam to the confluence with the Menomonee River	BUI 1, BUI 3, BUI 4, BUI 5, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Feasibility	In Progress *(Design planned for 2021)*	2016	2024	Unknown	Great Lakes Legacy Act [GLRI]	USEPA
Assess the Milwaukee River downstream of its confluence with Cedar Creek to the Milwaukee River Channels/Lincoln Park Great Lakes Legacy Act projects	BUI 1, BUI 3, BUI 4, BUI 5, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Not Started	Established *(no action needed)*			Unknown		WDNR
Assessment of Benthos and Plankton in Wisconsin's Lake Michigan Areas of Concern	BUI 6, BUI 13	Fish and Wildlife	Assessment	COMPLETED	Completed	2013	2019	$414,300.00	U.S. Environmental Protection Agency [GLRI]	USGS
Bay View-Grand Trunk Wetland Restoration	BUI 14	Fish and Wildlife	Restoration	Project Design	In Progress *(Construction planned for 2021)*	2015	2024	$6,955,000.00	U.S. Environmental Protection Agency [GLRI]	City of Milwaukee
Benthos & Plankton BUIs Evaluation in Wisconsin's Lake Michigan Areas of Concern	BUI 6, BUI 13	Fish and Wildlife	Assessment	COMPLETED	Completed	2011	2015	$451,500.00	U.S. Environmental Protection Agency [GLRI]	USGS

Blatz Pavilion Remediation	BUI 1, BUI 3, BUI 4, BUI 5, BUI 6, BUI 7, BUI 14	Sediment	Remediation	COMPLETED	Completed	2005	2009	$1,300,000.00	Wisconsin Dept of Natural Resources [Non-GLRI]	WDNR
Burnham Canal Superfund Alternative Remediation	BUI 1, BUI 3, BUI 4, BUI 5, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Remedial Implementation	In Progress *(Construction planned for 2021)*	2012		Unknown	Responsible Party [Non-GLRI]	
Burnham Canal Wetland Restoration	BUI 14	Fish and Wildlife	Restoration	Project Design	In Progress *(Construction planned for 2021)*	2014	2028	$4,600,000.00	U.S. Environmental Protection Agency [GLRI]	MMSD
Cedar Creek Superfund Alternative Remediation	BUI 1, BUI 3, BUI 4, BUI 5, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Remedial Implementation	In Progress	2015		Unknown	Responsible Party [Non-GLRI]	
Contaminant exposure of tree swallows in the Milwaukee Estuary: An expansion of sites	BUI 5	Fish and Wildlife	Assessment	COMPLETED	Completed	2014	2017	$18,500.00	U.S. Environmental Protection Agency [GLRI]	USGS
Developing TMDLs for the Milwaukee River, Menomonee River, Kinnickinnic River and Milwaukee Estuary	BUI 8, BUI 10	Nonpoint	Assessment	COMPLETED	Completed	2010	2017	$878,698.00	U.S. Environmental Protection Agency [GLRI]	MMSD
Estabrook Dam Fish Passage	BUI 14	Fish and Wildlife	Restoration	Implementation	In Progress *(vegetation maintenance in progress)*	2017	2020	$2,070,202.00	U.S. Environmental Protection Agency [GLRI]	MMSD
Fish Population Assessment	BUI 3	Fish and Wildlife	Assessment	COMPLETED	Completed	2014	2017	$268,836.00	U.S. Environmental Protection Agency [GLRI]	WDNR

Fisheries Population Target Refinement	BUI 3	Fish and Wildlife	Assessment	COMPLETED	Completed	10/1/2013	2014	$24,000.00	U.S. Environmental Protection Agency [GLRI]	WDNR
Identification and Quantification of Sanitary Sewage Contamination in the Milwaukee Estuary Area of Concern	BUI 10	Nonpoint	Assessment	COMPLETED	Completed	2014	2016	$502,266.00	U.S. Environmental Protection Agency [GLRI]	UW-M SFS
Kinnickinnic River Habitat Rehabilitation	BUI 14	Fish and Wildlife	Restoration	Implementation	In Progress *Phase II planned to start in 2021)*	2014	2024	Unknown	U.S. Environmental Protection Agency [GLRI]	MMSD
Kinnickinnic River Legacy	BUI 3, BUI 4, BUI 5, BUI 6, BUI 7, BUI 14	Sediment	Remediation	COMPLETED	Completed	2005	2009	$22,400,000.00	Great Lakes Legacy Act [Non-GLRI]	USEPA
Kletzsch Dam Fish Passage	BUI 14	Fish and Wildlife	Restoration	Implementation	In Progress *(Design on hold)*	2017	2020	$750,000.00	U.S. Environmental Protection Agency [GLRI]	Milwaukee County Parks
Lincoln Park/Milwaukee River Channels Remediation-Phase 1	BUI 1, BUI 3, BUI 4, BUI 5, BUI 6, BUI 7, BUI 14	Sediment	Remediation	COMPLETED	Completed	2011	2012	$27,919,434.00	Great Lakes Legacy Act [GLRI]	USEPA
Lincoln Park/Milwaukee River Channels Remediation-Phase 2	BUI 1, BUI 3, BUI 4, BUI 5, BUI 6, BUI 7, BUI 14	Sediment	Remediation	COMPLETED	Completed	2014	2017	$19,655,536.00	Great Lakes Legacy Act [GLRI]	USEPA
Little Menomonee Corridor Restoration	BUI 14	Fish and Wildlife	Restoration	Implementation	In Progress *(Restoration activities underway)*	2015	2024	$2,100,000.00	U.S. Environmental Protection Agency [GLRI]	Milwaukee County Parks
Little Menomonee Grassland Restoration	BUI 14	Fish and Wildlife	Restoration	COMPLETED	Completed	2013	2015	$37,000.00	U.S. Environmental Protection Agency [GLRI]	Milwaukee County

M&M/WE Energies Legacy Project	BUI 1, BUI 3, BUI 4, BUI 5, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Feasibility	Completed	2016	2019	$1,715,000.00	Great Lakes Legacy Act [GLRI]	USEPA
Menomonee River Concrete Removal Upstream of Soo Line RR Bridge to 1-94 (Phase 1)	BUI 14	Fish and Wildlife	Restoration	COMPLETED	Completed	2010	2019	$5,575,000.00	Milwaukee Metropolitan Sewerage District [Non-GLRI]	MMSD
Menomonee River Concrete Removal Upstream of Soo Line RR Bridge to 1-94 (Phase 2)	BUI 14	Fish and Wildlife	Restoration	COMPLETED	Completed	2013	2019	$7,500,000.00	U.S. Army Corps of Engineers [GLRI]	USACE
Milwaukee Estuary AOC Aquatic Habitat and Wadeable Fisheries Assessment	BUI 3	Fish and Wildlife	Assessment	COMPLETED	Completed	2016	2018	$12,844.00	U.S. Environmental Protection Agency [Non-GLRI]	WDNR
Milwaukee Estuary Area of Concern Fisheries and Aquatic Habitat Study	BUI 3	Fish and Wildlife	Assessment	COMPLETED	Completed	2017	2018	$49,000.00	U.S. Environmental Protection Agency [GLRI]	USGS
Milwaukee Estuary Fish Tumor Evaluation	BUI 4	Fish and Wildlife	Assessment	COMPLETED	Completed	2013	2015	$138,484.50	U.S. Environmental Protection Agency [GLRI]	WDNR
Milwaukee Estuary Wildlife Consumption Advisory Evaluation	BUI 1	Fish and Wildlife	Assessment	COMPLETED	Completed	2013	2016	$42,530.00	U.S. Environmental Protection Agency [GLRI]	WDNR
Milwaukee Harbor Habitat Mapping	BUI 3	Fish and Wildlife	Assessment	COMPLETED	Completed	2015	2018	$255,723.00	Fund for Lake Michigan [Non-GLRI]	UW-M SFS
Milwaukee River Fish Habitat Enhancement and Expansion	BUI 14	Fish and Wildlife	Restoration	COMPLETED	Completed	2014	2014	$63,310.00	Fund for Lake Michigan [Non-GLRI]	WDNR

Moss-American/Little Menomonee Superfund	BUI 1, BUI 3, BUI 4, BUI 5, BUI 6, BUI 7, BUI 14	Sediment	Remediation	COMPLETED	Completed	1990	2009	Unknown	Responsible Party [Non-GLRI]	
Removal of Five Low Flow Barriers on the Menomonee River	BUI 14	Fish and Wildlife	Restoration	COMPLETED	Completed	2014	2016	$1,942,000.00	Milwaukee Metropolitan Sewerage District [Non-GLRI]	MMSD
Sediment characterization in KK River turning basin	BUI 1, BUI 3, BUI 4, BUI 5, BUI 6, BUI 7, BUI 14	Sediment	Remediation	COMPLETED	Completed	2015	2016	$400,000.00	Great Lakes Legacy Act [GLRI]	USEPA
Solvay Coke Superfund Alternative Remediation	BUI 1, BUI 3, BUI 4, BUI 5, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Remedial Implementation	In Progress	2012		Unknown	Responsible Party [Non-GLRI]	
South Shore Beach Rehabilitation	BUI 10	Beaches	Restoration	Project Design	In Progress *(Permitting underway)*	2016	2025	$350,000.00	U.S. Environmental Protection Agency [GLRI]	Milwaukee County Parks
Volunteer Aesthetics Monitoring Program	BUI 11	Aesthetics	Assessment	COMPLETED	Completed	2015	2017	$31,500.00	U.S. Environmental Protection Agency [GLRI]	WDNR
Wheelhouse Gateway Riparian Restoration	BUI 14	Fish and Wildlife	Restoration	COMPLETED	Completed	2013	2014	Unknown	U.S. Environmental Protection Agency [GLRI]	RRF
Wildlife Population Assessment	BUI 3	Fish and Wildlife	Assessment	COMPLETED	Completed	2014	2017	$409,997.00	U.S. Environmental Protection Agency [GLRI]	WDNR
Wildlife Population Target Refinement	BUI 3	Fish and Wildlife	Assessment	COMPLETED	Completed	2013	2014	$30,000.00	U.S. Environmental Protection Agency [GLRI]	

BUI Number Key

BUI #	BUI Name	BUI #	BUI Name
BUI 1	Restrictions on Fish and Wildlife Consumption	BUI 8	Eutrophication or Undesirable Algae or Excessive Loading of Sediments and Nutrients
BUI 2	Tainting of Fish and Wildlife Flavor	BUI 9	Restrictions on Drinking Water Consumption or Taste and Odor Problems
BUI 3	Degradation of Fish and Wildlife Populations	BUI 10	Beach Closings and Body Contact Restrictions
BUI 4	Fish Tumors and Other Deformities	BUI 11	Degradation of Aesthetics
BUI 5	Bird or Animal Deformities or Reproductive Problems	BUI 12	Added Costs to Agriculture or Industry
BUI 6	Degradation of Benthos	BUI 13	Degradation of Phytoplankton and Zooplankton Populations
BUI 7	Restrictions on Dredging Activities	BUI 14	Loss of Fish and Wildlife Habitat

Appendix D – Loss of Fish and Wildlife Habitat Criteria

Habitat Project Criteria

Goals and Measures of Success for Fish and Wildlife Habitat for the Milwaukee Estuary AOC *(project specific goals are referenced in project summaries of the 2015 RAP; the previous monitoring plan with the information below can be found in the 2013 RAP).*

Physical/biological habitat primary goals:

1. Enhance/improve aquatic habitat by…
   A. Identifying and enhancing fish spawning sites from Lake Michigan to the tributaries and headwaters where opportunities exist (e.g., inner and outer harbors, Milwaukee River downstream of the North Ave. Dam pedestrian bridge), and/or
   B. Improving lateral connectivity by connecting aquatic habitat to floodplain wetland with suitable hydroperiod from Lake Michigan to the tributaries and headwaters where opportunities exist.

   Measures of success:
   - Amount (length) of habitat protected and/or created
   - Amount (length) connected and functional as fish and aquatic organism habitat
   - Area of adjacent floodplain reconnected for the 2-yr and 5-yr events
   - Area of adjacent wetlands reconnected and/or restored/created
   - Area of adjacent potentially restorable wetlands reconnected, as applicable
   - Number of existing critical habitat areas identified and protected, enhanced, reconnected, or re-created

2. Improve aquatic habitat connectivity by…
   A. Improving linear connectivity by restoring or enhancing fish and aquatic organism passage from Lake Michigan to the tributaries and headwaters, and/or
   B. Reconnecting high quality habitat downstream of the Bridge Street Dam and Lepper Dam to the main stem rivers of the AOC in cases where that habitat is directly connected to the estuary (i.e., there are no downstream barriers from the proposed project site).

   Measures of success:
   - Amount (length) of concrete removed
   - Number of impediments removed and/or retrofitted (e.g., bridge crossings or drop structures)
   - Amount of enclosed channel daylighted or retrofitted, number of tributary miles connected to mainstem, or length of stream channel restored.

3. Enhance/improve terrestrial, semi-aquatic, and/or riparian habitat by…
   A. Expanding habitat buffer width to a minimum of 75 feet, and/or

B. Where possible, expanding shoreline buffers up to 1,000 feet to meet core habitat area needs for semi-aquatic species

Measures of success:
- Length of streams inventoried and area of potential suitable buffer habitat identified
- Length of streams with suitable buffer habitat width of 75 feet or greater preserved or established
- Volume of historic fill and/or tons of trash removed from riparian areas
- Area of native wetland or upland suitable habitat reconstructed
- Area of Advanced Identification of Wetland Disposal Areas (ADID wetlands), upland within PEC, and/or 100-yr floodplain limits protected
- Area of exotic invasive species removed

4. Improve terrestrial riparian habitat connectivity by expanding riparian buffer habitat quality and continuity.

Measures of success:
- Length of streams of continuous suitable buffer habitat widths of 75 feet or greater preserved or established
- Number of riparian area crossings and/or impediments removed and/or retrofitted to improve or restore continuity of riparian buffers, including improvements to decrease resistance to animal movements
- Increase in suitable habitat patch size resulting from new connectivity

5. Protecting high-quality areas or environmentally sensitive lands, especially those supporting rare and protected species.

Measures of success:
- Length of streams inventoried and area of potential buffer identified
- Length of streams or area of land protected

Physical/biological habitat secondary goals:
1. Moderate flow regimes to decrease flashiness
2. Provide and preserve sufficient baseflow

Measures of success:
- Area of groundwater recharge protected
- Improvement in flashiness index
- Number of flow deflectors installed, pipes cut back from streambank, or land area treated by infiltration practices

Table 1: Overarching primary goals for the management actions identified for the Loss of Fish and Wildlife Habitat BUI.

Projects	1. Enhance/improve aquatic habitat	2. Improve aquatic habitat connectivity	3. Enhance/improve terrestrial, semi-aquatic, and/or riparian habitat	4. Improve terrestrial riparian habitat connectivity by expanding riparian buffer habitat quality and continuity.	5. Protecting high-quality areas or environmentally sensitive lands, especially those supporting rare and protected species.
Little Menomonee River Parkway Grassland Restoration				X	X
Bay View Wetland/Grand Trunk Wetland Restoration	X	X	X	X	X
Burnham Canal Wetland Restoration	X	X	X	X	
Milwaukee River Fish Habitat Enhancement and Expansion	X				
Wheelhouse Gateway Riparian Restoration			X	X	
Menomonee River Stream Management (Concrete Removal) Phases 1 & 2	X	X			
Kletzsch Park Dam Fish Passage	X	X			
Estabrook Dam Fish Passage	X	X			
Five Low Flow Barriers on the Menomonee River	X	X			
Kinnickinnic River Habitat Rehabilitation	X	X			
Little Menomonee River Corridor Restoration	X	X	X	X	X

Criteria for Measuring Habitat BUI Project Specific Goals are Met

The Little Menomonee Parkway Grassland Restoration Project

- Enhance/improve terrestrial habitat by expanding buffer width to a minimum of 75 feet or expanding the buffer width to 400' to 1,000' to meet core or habitat area needs.
- Enhance/improve terrestrial habitat by identifying and enhancing existing potentially restorable habitat areas through fish and wildlife assessments (for portions of the LMR, this process is already underway from a 2011 wildlife assessment).

Bay View Wetland/Grand Trunk Wetland Restoration

- Create and protect wetland habitat through the establishment of a functional seiche wetland with suitable Northern Pike spawning habitat on site.
- Spawning of Northern Pike demonstrated.
- Physical establishment of a functional, fish-free, ephemeral wetland habitat on site, occupied by ephemeral wetland dependent SLCI (e.g., amphibians, fairy shrimp).
- A goal of 6.5 acres of wetland and habitat present on site.
- Removing impediments to establish functional aquatic organism passage
- Removing historic fill.
- Creation or enhancement of upland buffer habitat surrounding wetland habitats.
- An increase in the number of SLCI utilizing the site, as measured by appropriate occupancy documentation.

Burnham Canal Wetland Restoration Project

- Establishment of a functional seiche wetland with suitable Northern Pike spawning habitat on site.
- Spawning of Northern Pike demonstrated.
- An increase of acres of wetland and other wildlife habitat present on site.
- An increase in the number of SLCI utilizing the site, as measured by appropriate occupancy documentation.
- Creation of 7.5 acres of wetland habitat.

Milwaukee River Fish Habitat Enhancement and Expansion

- Completions of spawning reef (size).
- Evidence of native fish spawning.

Wheelhouse Gateway Riparian Restoration

- Approximately 650 feet of shoreline restored.
- 2.8 acres of restored habitat connected to over 800 acres of Greenway habitat

- Expand riparian buffer of at least 100 feet between hardscape and river and enhance the quality of the buffer by replacing with native vegetation and habitat features.
- Extend the continuity of natural shoreline by approximately 650 feet, connected to existing natural shoreline.

Menomonee River Stream Management (Concrete Removal) Phases 1 & 2

- Providing fish passage through this section of the river to allow access to upstream spawning and rearing habitat.

Kletzsch Park Dam Fish Passage

- Enable fish and aquatic life access to an additional 22-mile of barrier free riverine habitat and 2,400-acres of wetland habitat.
- 22 miles of tributary connected to the mainstem of the Milwaukee River, Milwaukee Estuary and Lake Michigan.
- One critical impediment retrofitted for fish and aquatic life passage.
- One riparian area impediment retrofitted to improve continuity of riparian buffers, including improvements to decrease resistance to animal movements.
- Increase in suitable habitat patch size resulting from new connectivity.

Estabrook Dam Fish Passage

- Amount (length) connected as fish and aquatic organism habitat.
- One impediment removed and/or retrofitted.
- Number of tributary miles connected to mainstem.
- One riparian area impediment removed and/or retrofitted to improve continuity of riparian buffers, including improvements to decrease resistance to animal movements.
- Increase in suitable habitat patch size resulting from new connectivity.

Five Low Flow Barriers on the Menomonee River

- Amount (length) connected as fish and aquatic organism habitat.
- Five impediments removed and/or retrofitted.
- Number of tributary miles connected to mainstem.
- Increase in suitable habitat patch size resulting from new connectivity

Kinnickinnic River Habitat Rehabilitation

- Improving linear connectivity of the Kinnickinnic River within the AOC and to the estuary.
- Increase in suitable habitat patch size resulting from new connectivity
- Creation or enhancement of upland buffer habitat surrounding along the riparian corridor to improve connectivity.

Little Menomonee Corridor Restoration

- To protect the ecologically significant natural areas within the LMR Parkway.
- Maintain and increase native plant and wildlife diversity.
- Reduce the impact of invasive species.
- Enhance and maintain the environmental corridor.
- Implement restoration projects that are a priority for the Parks Dept. while also addressing BUIs associated with the Milwaukee Estuary AOC.
- Enhance fisheries habitat with low impact practices and procedures where appropriate.

Appendix E – Degradation of Fish and Wildlife Populations Criteria

Populations Project Criteria

Goals and Measures of Success for Fish and Wildlife Populations for the Milwaukee Estuary AOC

<u>Physical/biological populations primary goals:</u>

1. Improve the quality of terrestrial habitat types (i.e. forest, wetland, shrubland, grassland, semi-aquatic, and upland/grassland) to support a better population of wildlife indicator species:

   Measures of Success:
   - Species and area of exotic invasive species removed
   - Amount (area or number) of native species planted to benefit wildlife indicator species
   - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
   - Amount (area) of habitat types created, enhanced and/or protected

2. Improve the quality of aquatic habitat to support a better population of fish indicator species:

   Measures of Success:
   - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for lake sturgeon and northern pike, respectively
   - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species

3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:

   Measures of Success:
   - Amount (length or area) of fish habitat or stream channel enhanced or restored
   - Amount (length) of corridor habitat improved or reconnected

Table 2: Overarching primary goals for the management actions identified for the Degradation of Fish and Wildlife Populations BUI.

Projects	1. Improve the quality of terrestrial habitat (i.e. forest, wetland, shrubland, grassland, semi-aquatic, and upland/grassland) to support a better population of wildlife indicator species.	2. Improve the quality of aquatic habitat to support a better population of fish indicator species.	3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types.
Enhancements to City of Mequon Parks and Ozaukee Washington Land Trust (OWLT) Ville du Parc Property	X	X	X
Enhancements to Milwaukee River Greenway Parks	X	X	X
Estabrook Falls and Fish Passage Improvements	X	X	X
Aquatic Enhancements to the Outer Harbor		X	X
Havenwoods State Forest Rehabilitation	X	X	X
Wildlife Enhancements to Milwaukee County Grounds, Sanctuary Woods, MMSD Basins, and Hoyt Park	X		X
Wildlife Enhancements to Kletzsch Park	X		X
Enhancements to Schlitz Audubon Cleaver Property	X	X	X
Enhancements to Menomonee River Parkway - Sections 5 and 6	X	X	X
Currie Park Fish Passage Improvements		X	X
Fisheries Improvements to Milwaukee River Downstream - E Cherry Street to N Humboldt Avenue		X	X
Fisheries Improvements to Menomonee River - N 16th to N 25th Street		X	X
Fish and Wildlife Enhancements to Little Menomonee River Parkway - Section 1	X	X	X
Wildlife Enhancements to Kohl Park	X		X
Fisheries Improvements to Lincoln Park Oxbow	X	X	X

Fish Metrics
Lower Milwaukee Estuary AOC

(Downstream of Humboldt Avenue on the Milwaukee River; Downstream of N 25th Street on the Menomonee River; Downstream of W Becher Street on the Kinnickinnic River)

A stated criterion of BUI removal for native fishes within the Lower Milwaukee Estuary AOC is a 100% increase in relative population abundance in four indicator species (lake sturgeon, northern pike, greater redhorse, and smallmouth bass) AND an increase of any magnitude in 80% of native sub-indicator families (suckers, minnows and shiners, bullheads and catfishes, sunfishes, and perches) to be considered AND an overall mean value from all large river IBI sampling efforts of “Fair” or better (i.e. 41-60).

Indicator Species
Sturgeons – lake sturgeon
Pikes – northern pike
Suckers – greater redhorse
Sunfishes – smallmouth bass

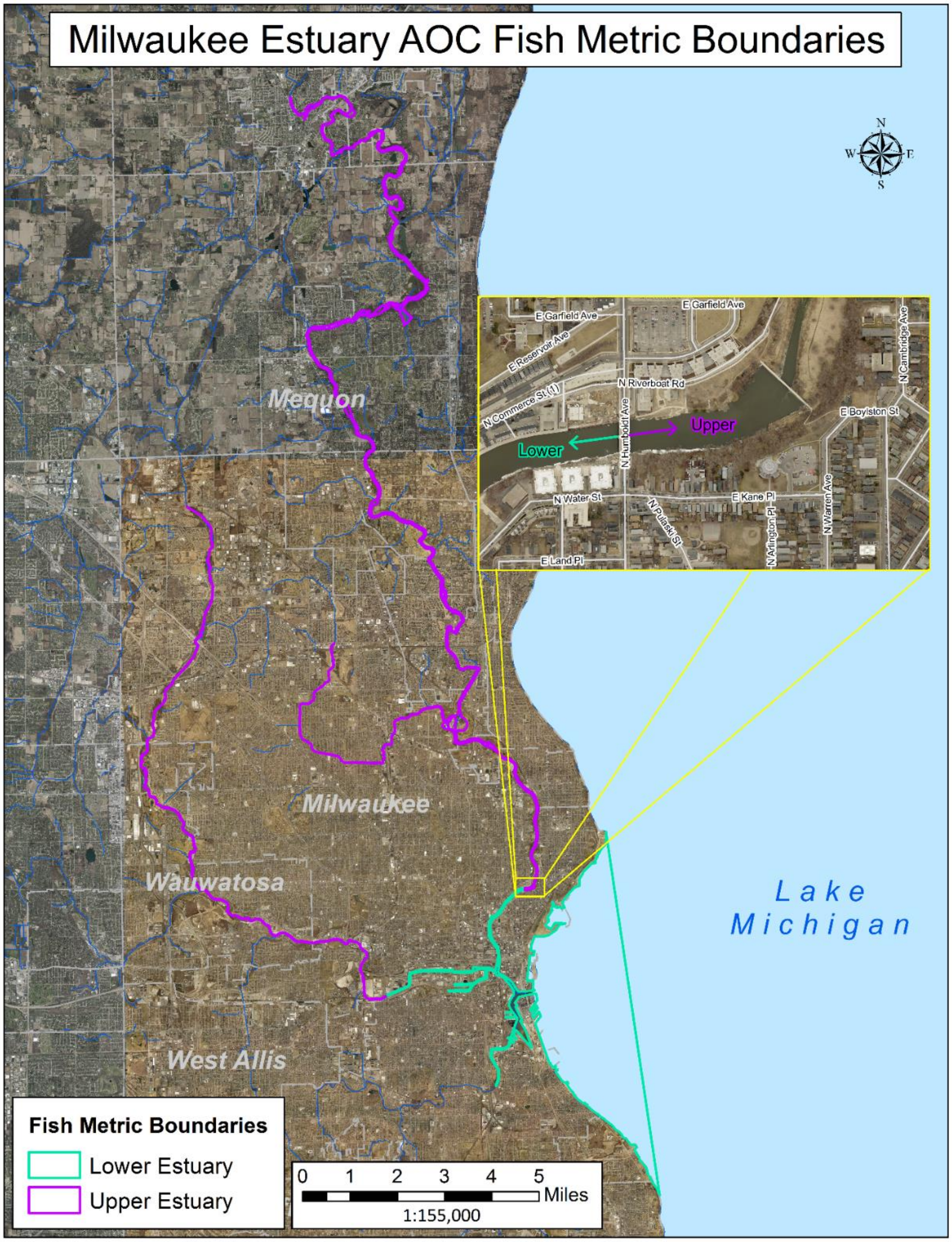
Sub-indicator Species
Suckers – golden redhorse, shorthead redhorse, silver redhorse, longnose sucker, white sucker
Minnows and Shiners – Emerald shiner, golden shiner, spottail shiner, fathead minnow
Bullheads and Catfishes – black bullhead, flathead catfish, channel catfish
Sunfishes – bluegill, green sunfish, pumpkinseed, black crappie, largemouth bass, rock bass
Perches – walleye, yellow perch

Upper Milwaukee Estuary AOC

(Upstream of Humboldt Avenue on the Milwaukee River to Bridge Road on Cedar Creek; Upstream of N 25th Street on the Menomonee River to Brown Deer Road on the Little Menomonee River; No upper reach for the Kinnickinnic River)

A stated criterion of BUI removal for native fishes within the Upper Milwaukee Estuary AOC is the presence of the indicator species, lake sturgeon, utilizing spawning habitat in the upper reaches of the Milwaukee River, AND the presence of the indicator species, northern pike, utilizing spawning habitat in the upper reaches of the Menomonee River AND an overall mean value from all warmwater IBI sampling efforts of “Good” or better (i.e. 51-65) in the upper reaches of the Milwaukee River AND an overall mean value from all warmwater IBI sampling efforts of “Fair” or better (i.e. 31-50) in the upper reaches of the Menomonee River.

*Fish metric boundaries for the Milwaukee Estuary AOC are shown on the next page.



*Upper and lower fish metric boundaries for the Milwaukee Estuary AOC

Table 3: Upper and lower fish metrics for the Degradation of Fish and Wildlife Populations BUI management actions.

Projects	100% increase in relative population abundance in 4 indicator species	Increase of any magniturde in 80% of native sub-indicator families (5)	Overall mean value from all large river IBI of "Fair or better (i.e. 41-60)	Presence of lake sturgeon utilizing spawning habitat in the Milwaukee River	Presence of northern pike utilizing spawning habitat in the Menomonee River	Milwauke River: Overall mean value from all warmwater IBI of "Good" or better (i.e. 51-65)	Menomonee River: Overall mean value from all warmwater IBI of "Fair" or better (i.e. 31-50)
Enhancements to City of Mequon Parks and Ozaukee Washington Land Trust (OWLT) Ville du Parc Property				X		X	
Enhancements to Milwaukee River Greenway Parks				X		X	
Estabrook Falls and Fish Passage Improvements				X		X	
Aquatic Enhancements to the Outer Harbor	X	X					
Havenwoods State Forest Rehabilitation							
Wildlife Enhancements to Milwaukee County Grounds, Sanctuary Woods, MMSD Basins, and Hoyt Park							
Wildlife Enhancements to Kletzsch Park							
Enhancements to Schlitz Audubon Cleaver Property				X		X	
Enhancements to Menomonee River Parkway - Sections 5 and 6					X		X
Currie Park Fish Passage Improvements					X		X
Fisheries Improvements to Milwaukee River Downstream - E Cherry Street to N Humboldt Avenue	X	X	X				
Fisheries Improvements to Menomonee River - N 16th to N 25th Street	X	X	X				
Fish and Wildlife Enhancements to Little Menomonee River Parkway - Section 1					X		X
Wildlife Enhancements to Kohl Park							
Fisheries Improvements to Lincoln Park Oxbow				X		X	

*Shaded rows are not applicable to this metric.

References for Fish Metrics

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Wildlife Metrics
Milwaukee Estuary AOC

Bats

There are no metrics for bats due to the risk of white-nose syndrome (WNS) and the anticipated management for a long-term study to determine separate populations, which is outside of AOC program capabilities. Regulatory programs provide institutional controls and limit bat take. However, bats should be used as an additional justification for projects that have important bat habitat and enhancements that are provided to support bat habitat should be incorporated as necessary.

Breeding Birds

The breeding bird metrics are divided into five different habitat types as follows (Forest, Wetland, Shrubland, Grassland, and Airspace/Urban):

- Forest, Wetland and Shrubland Habitat: At least 9 sites in the AOC support at least 3 breeding bird indicator species for each habitat type.

  Forest Habitat Species – American Woodcock, Veery, American Redstart, Bald Eagle, Red-shouldered Hawk, Black-billed Cuckoo, Carolina Wren, Hooded Warbler, Yellow-breasted Chat, Long-eared Owl, Acadian Flycatcher, Least Flycatcher, Merlin, Nashville Warbler, Ovenbird, Red Crossbill, Red-headed Woodpecker, Wood Thrush, Yellow-billed Cuckoo

  Wetland Habitat Species – American Woodcock, Veery, American Redstart, Bald Eagle, Red-shouldered Hawk, Alder Flycatcher, Willow Flycatcher, Blue-winged Teal, Sedge Wren, American Bittern, American Black Duck, Bank Swallow, Black-crowned Night-Heron, Common Gallinule, Great Blue Heron, Great Egret, Least Bittern, Marsh Wren, Osprey, Pied-billed Grebe, Purple Martin, Sora, Virginia Rail, Yellow-crowned Night-Heron

  Shrubland Habitat Species – American Woodcock, Veery, Black-billed Cuckoo, Carolina Wren, Hooded Warbler, Yellow-breasted Chat, Alder Flycatcher, Willow Flycatcher, Loggerhead Shrike, Vesper Sparrow, Blue-winged Warbler, Brown Thrasher, White-eyed Vireo

- Grassland Habitat: At least 6 sites in the AOC support at least 2 breeding bird indicator species.

  Grassland Habitat Species – Long-eared Owl, Blue-winged Teal, Sedge Wren, Loggerhead Shrike, Vesper Sparrow, American Kestrel, Bobolink, Dickcissel, Eastern Meadowlark, Field Sparrow, Grasshopper Sparrow, Henslow's Sparrow, Western Meadowlark

- Airspace/Urban Habitat: At least 9 sites support at least 1 breeding bird indicator species.

  Airspace/Urban Habitat Species – Purple Martin, Chimney Swift, Common Nighthawk

Herptiles/Crayfish

The herptiles/crayfish metrics are divided into two different habitat types as follows (Semi-aquatic Habitat, Upland/Grassland Habitat):

- Semi-aquatic Habitat: At least 30 sites in the AOC support at least 2 semi-aquatic guilds (Crayfish, Salamanders, Frogs, Turtles). Of these 30 sites, indicator species should be represented as follows…
    - At least 10 sites support at least one crayfish species.
      Crayfish Species – Devil Crayfish, Digger Crayfish, Prairie Crayfish
    - At least 15 sites support at least one frog species.
      Frog Species – Cope's Gray Treefrog, Gray Treefrog, Wood Frog, Spring Peeper, Boreal Chorus Frog, Northern Leopard Frog, Green Frog
    - At least 8 sites support Blue-spotted Salamanders.
    - At least 6 sites support at least one turtle species.
      Turtle Species – Eastern Spiny Softshell, Northern Map Turtle
- Upland/Grassland Habitat: At least 15 sites in the AOC support at least 2 different indicator species of snakes.

  Upland/Grassland Habitat Species – Butler's Gartersnake, Common Gartersnake, Eastern Milksnake, Midland Brownsnake, Northern Red-bellied Snake

Mammals

The mammal metrics are divided into three different habitat types as follows (Forest, Wetland, Grassland):

- Forest and Wetland Habitat: At least 10 sites in the AOC support at least 2 mammal indicator species for each habitat type.

  Forest Habitat Species – American Beaver, American Mink, Eastern Fox Squirrel, Gray Fox, North American River Otter, Southern Flying Squirrel

  Wetland Habitat Species – American Beaver, American Mink, Common Muskrat, Least Weasel, North American River Otter, Star-nosed Mole

- Grassland Habitat: At least 5 sites within the AOC support at least 1 mammal indicator species.

  Grassland Habitat Species – Eastern Fox Squirrel, Gray Fox, Least Weasel

Mussels

There are no metrics for mussels due to the large-scale issues that need to be addressed to incorporate mussels into this impairment. However, mussels should be used as an additional justification for work adjacent to or near current mussel beds. They can also be an indication for an indirect improvement through other BUI projects (i.e. fish and aquatic habitat, sediment).

Table 4: Breeding bird metrics for the Degradation of Fish and Wildlife Populations BUI management actions.

Projects	Forest Habitat: At least 9 sites in the AOC support at least 3 breeding birds	Wetland habitat: At least 9 sites in the AOC support at least 3 breeding birds	Shrubland Habitat: At least 9 sites in the AOC support at least 3 breeding sites	Grassland Habitat: At least 6 sites in the AOC support at least 2 breeding birds	Airspace/Urban Habitat: At least 9 sites in the AOC support at least 1 breeding bird
Enhancements to City of Mequon Parks and Ozaukee Washington Land Trust (OWLT) Ville du Parc Property	X	X	X	X	X
Enhancements to Milwaukee River Greenway Parks	X	X	X		X
Estabrook Falls and Fish Passage Improvements					
Aquatic Enhancements to the Outer Harbor					
Havenwoods State Forest Rehabilitation	X	X	X	X	X
Wildlife Enhancements to Milwaukee County Grounds, Sanctuary Woods, MMSD Basins, and Hoyt Park	X	X	X	X	X
Wildlife Enhancements to Kletzsch Park	X	X	X	X	
Enhancements to Schlitz Audubon Cleaver Property	X	X	X	X	
Enhancements to Menomonee River Parkway - Sections 5 and 6	X	X	X		X
Currie Park Fish Passage Improvements					
Fisheries Improvements to Milwaukee River Downstream - E Cherry Street to N Humboldt Avenue					
Fisheries Improvements to Menomonee River - N 16th to N 25th Street					
Fish and Wildlife Enhancements to Little Menomonee River Parkway - Section 1	X	X	X	X	X
Wildlife Enhancements to Kohl Park	X	X	X	X	X
Fisheries Improvements to Lincoln Park Oxbow					

*Shaded rows are not applicable to this metric.

Table 5: Herptile/crayfish metrics for the Degradation of Fish and Wildlife Populations BUI management actions.

Projects	Semi-Aquatic Habitat: At least 30 sites in the AOC support at least 2 guilds (Crayfish, Salamanders, Frogs, Turtles)	Crayfish: At least 10 sites support at least 1 crayfish species	Frogs: At least 15 sites support at least 1 frog species	Salamanders: At least 8 sites support Blue-spotted Salamanders	Turtles: At least 6 sites support at least 1 turtle species	Upland/Grassland Habitat: At least 15 sites in the AOC support at least 2 snake species
Enhancements to City of Mequon Parks and Ozaukee Washington Land Trust (OWLT) Ville du Parc Property	X	X	X		X	X
Enhancements to Milwaukee River Greenway Parks	X	X	X		X	X
Estabrook Falls and Fish Passage Improvements						
Aquatic Enhancements to the Outer Harbor						
Havenwoods State Forest Rehabilitation	X	X	X			X
Wildlife Enhancements to Milwaukee County Grounds, Sanctuary Woods, MMSD Basins, and Hoyt Park	X	X	X			X
Wildlife Enhancements to Kletzsch Park	X		X		X	
Enhancements to Schlitz Audubon Cleaver Property	X	X	X	X	X	X
Enhancements to Menomonee River Parkway - Sections 5 and 6	X	X	X	X		
Currie Park Fish Passage Improvements						
Fisheries Improvements to Milwaukee River Downstream - E Cherry Street to N Humboldt Avenue						
Fisheries Improvements to Menomonee River - N 16th to N 25th Street						
Fish and Wildlife Enhancements to Little Menomonee River Parkway - Section 1	X	X	X		X	X
Wildlife Enhancements to Kohl Park	X	X	X			X
Fisheries Improvements to Lincoln Park Oxbow	X		X		X	

*Shaded rows are not applicable to this metric.

Table 6: Mammal metrics for the Degradation of Fish and Wildlife Populations BUI management actions.

Projects	Forest Habitat: At least 10 sites in the AOC support at least 2 mammals	Wetland habitat: At least 10 sites in the AOC support at least 2 mammals	Grassland Habitat: At least 5 sites in the AOC support at least 1 mammal
Enhancements to City of Mequon Parks and Ozaukee Washington Land Trust (OWLT) Ville du Parc Property	X	X	X
Enhancements to Milwaukee River Greenway Parks	X	X	
Estabrook Falls and Fish Passage Improvements			
Aquatic Enhancements to the Outer Harbor			
Havenwoods State Forest Rehabilitation	X	X	X
Wildlife Enhancements to Milwaukee County Grounds, Sanctuary Woods, MMSD Basins, and Hoyt Park	X	X	X
Wildlife Enhancements to Kletzsch Park	X	X	
Enhancements to Schlitz Audubon Cleaver Property	X	X	
Enhancements to Menomonee River Parkway - Sections 5 and 6	X	X	
Currie Park Fish Passage Improvements			
Fisheries Improvements to Milwaukee River Downstream - E Cherry Street to N Humboldt Avenue			
Fisheries Improvements to Menomonee River - N 16th to N 25th Street			
Fish and Wildlife Enhancements to Little Menomonee River Parkway - Section 1	X	X	X
Wildlife Enhancements to Kohl Park	X	X	X
Fisheries Improvements to Lincoln Park Oxbow	X	X	

*Shaded rows are not applicable to this metric.

References for Wildlife Metrics

Casper, G.S. and Robson, J.L. 2018. Milwaukee Estuary Area of Concern Wildlife Population Assessment Report. Technical report to Wisconsin Department of Natural Resources, Office of Great Waters, 2300 N. Dr. Martin Luther King Jr. Dr., Milwaukee, WI 53212. 4 chapters with appendices.

Casper, G.S. and Robson, J.L. 2018. Milwaukee Estuary AOC Bats, Breeding Birds, Herptiles, Crayfish, Mammals, and Mussels Checklists.

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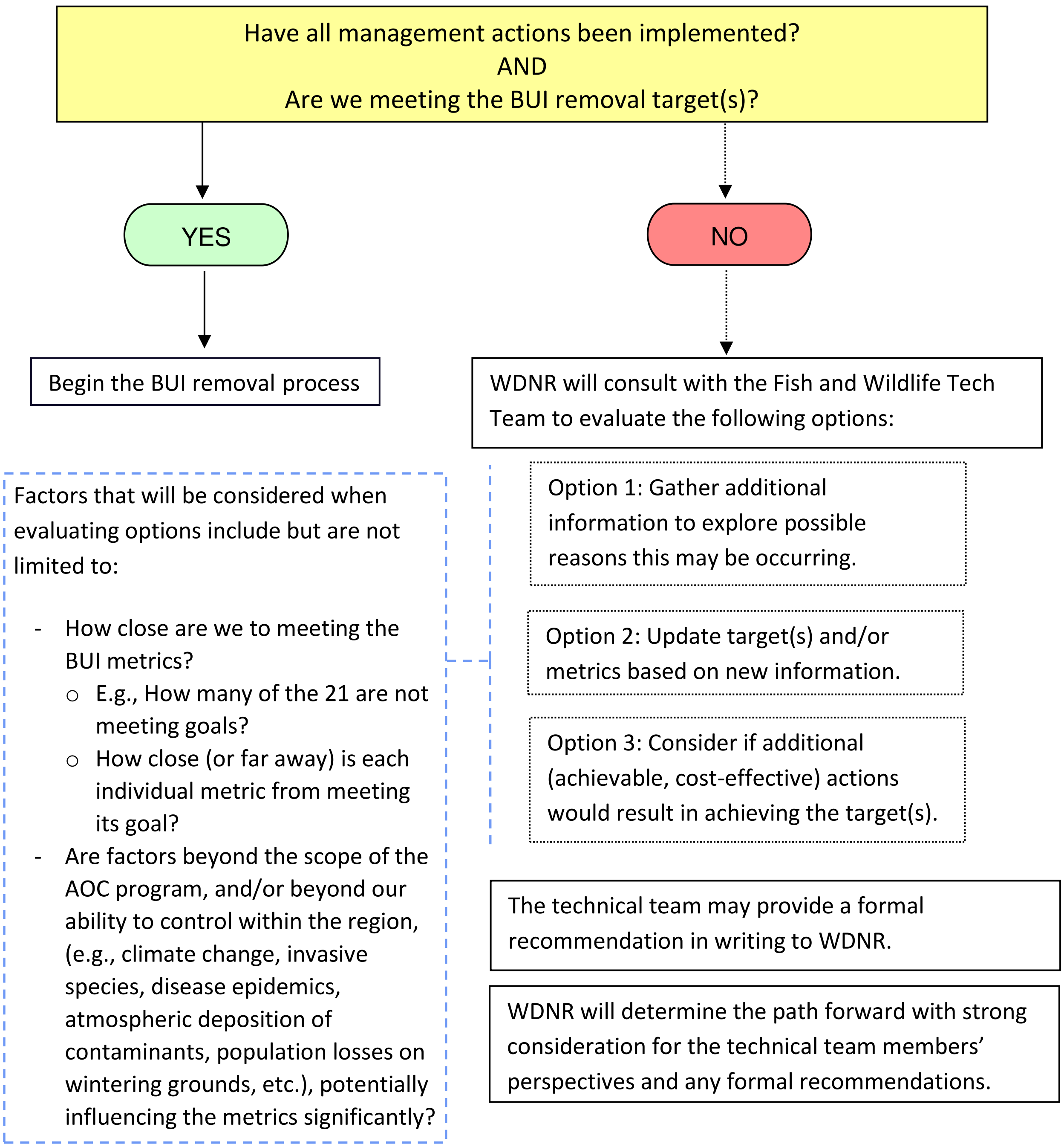
Casper, G.S. and Robson, J.L. 2018. Chapter 9 Crayfish. 1-25: 3 appendices. *In* Casper, G.S., Robson, J.L., Glasford, R., Mittermaier, B., Kroening, K.M. 2018. Milwaukee Estuary Area of Concern Wildlife Population Assessment Report. Technical report to Wisconsin Department of Natural Resources, Office of Great Waters.

Casper, G.S. and Robson, J.L. 2018. Chapter 10 Mussels. 1-37: 3 appendices. *In* Casper, G.S. and Dare, J.M. 2018. Milwaukee Estuary Area of Concern Wildlife Population Assessment Report. Technical report to Wisconsin Department of Natural Resources, Office of Great Waters.

Decision Tree Process for BUI Removal of Loss of Fish and Wildlife Habitat & Degradation of Fish and Wildlife Populations

Following implementation of management actions, verification monitoring will occur to determine if metrics are achieved. With verification monitoring results as the basis for discussion, the following “decision tree” applies:



Appendix F –
Degradation of Fish and Wildlife Populations Project Summaries

Degradation of Fish and Wildlife Populations
Project Summary

Project Title: Enhancements to City of Mequon Parks and Ozaukee Washington Land Trust (OWLT) Ville du Parc Property

Project Location: Riverview Park, Villa Grove Park, Scout Park, River Forest Nature Preserve, Shoreland Nature Preserve, Willow Bay Nature Preserve, OWLT Ville du Parc (VdP) Property

Project Sponsor(s): City of Mequon and Ozaukee Washington Land Trust

Project Landowner(s): City of Mequon, Ozaukee Washington Land Trust, Inc.

Background
Large habitat areas in the Milwaukee Estuary Area of Concern (AOC) that support a diverse number of fish and wildlife are unique and dispersed throughout the region. Through the recent efforts to determine management actions for the Degradation of Fish and Wildlife (F&W) Populations Beneficial Use Impairment (BUI) by the Milwaukee Estuary AOC Fish and Wildlife Technical Advisory Committee (Tech Team), this stretch of the Milwaukee River has been determined as a key location in the Milwaukee Estuary AOC that provides important habitat for many fish and wildlife indicator species. The process by which the F&W Tech Team determined management actions for the Degradation of F&W Populations BUI included a rigorous selection of high priority projects in the Milwaukee Estuary AOC to address this BUI. This site was determined to be extremely important for semi-aquatic habitat associated species. This project site provides important habitat breeding and migratory birds associated with forest and wetland habitat. This project area also supports a wide variety of indicator mammal species, which is unique for the Milwaukee Estuary AOC.

City of Mequon Parks
The City of Mequon parks along the Milwaukee River stretch over a long, primary environmental corridor in the Milwaukee Estuary Area of Concern (AOC) that support a diverse number of fish and wildlife that are unique and dispersed throughout the region. This area on the Milwaukee River provides important floodplain forest, shrubland, grassland, wetland and aquatic habitat for many indicator species in the Milwaukee Estuary AOC.

OWLT Ville du Parc (VdP) Property
OWLT VdP is one of the sites for this management action and carrying out this proposed project will enable informed implementation of enhancements to habitat that will address portions of the Degradation of F&W Populations BUI goals and metrics. This 19-acre property is owned by OWLT and was designated by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) as an Aquatic Area of Local Significance (AQ-3). The property was last surveyed in 1996 for vegetation, which showed a variety of grassland and wetland habitat types, including 10-acres of shallow marsh, southern sedge meadow, disturbed wet meadow, shrub-carr and southern wet-mesic lowland hardwood.

Collaboration with Partners
The City of Mequon is working with several partners on various aspects of park improvement and planning along the Milwaukee River and throughout their park system. Some of these partners are friends' groups, and others are non-profit organizations involved with restoration projects and initiatives throughout the County. In 2019, the City of Mequon revised their Comprehensive Park, Recreation and Open Space Plan, which was previously completed in 2014 and is updated every five years. This plan aims to address goals and objectives of the park system. Partners that play an important role in Ozaukee

County and this section of the Milwaukee River include, but are not limited to, Ozaukee County Planning and Parks (OCPP), Milwaukee Metropolitan Sewerage District Greenseams Program, Ozaukee Washington Land Trust (OWLT), Milwaukee River Advisory Committee and Milwaukee Riverkeeper.

Proposed Work

Plan and implement projects that are proposed through respective location-based management plans, while addressing portions of the Degradation of Fish and Wildlife BUI in the Milwaukee Estuary AOC. As part of this process, most of these sites were surveyed by the University of Wisconsin – Milwaukee Field Station (UWMFS) during an AOC-wide populations study. Results from this work provided important information about species and habitat found along this section of the Milwaukee River corridor. Potential enhancements to benefit fish and wildlife populations in this area include removal of invasive species, floodplain forest stand improvements due to loss of ash trees, improvements to limited savanna and grassland habitat, enhancements to fruit- and/or nut-bearing shrubs, preservation and enhancements to ephemeral wetlands, maintenance of aquatic buffer zones, and shoreline and connectivity enhancements to provide higher quality fish habitat.

Estimated Timetable and Duration (Calendar Year)

- Planning: Q1 2021 – Q2 2022
- Design and Permitting: Q3 2022 – Q2 2023
- Construction/Implementation: Q3 2023 – Q4 2024
- Maintenance and Vegetation Establishment: Q1 2025 – Q4 2028

Estimated Project Budget & Funding

The total project costs for this project are approximately $1.9M.

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)

The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet all three goals below (highlighted in green) and show measures of success by an AOC-wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (forest, wetland, shrubland, grassland, semi-aquatic, upland/grassland) to support a better population of wildlife indicator species:
   - Species and area of exotic invasive species removed
   - Amount (area or number) of native species planted to benefit wildlife indicator species
   - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
   - Amount (area) of habitat types created, enhanced and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
   - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for lake sturgeon and northern pike, respectively
   - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
   - Amount (length or area) of fish habitat or stream channel enhanced or restored
   - Amount (length) of corridor habitat improved or reconnected

Degradation of Fish and Wildlife Populations
Project Summary

Fish and Wildlife Metrics Addressed by Project

Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. Metrics were reviewed and agreed upon by the Tech Team to determine necessary steps and projects to remove this BUI. This project will take part in addressing certain aspects of following metrics:

Upper Milwaukee Estuary AOC

(Upstream of Humboldt Avenue on the Milwaukee River to Bridge Road on Cedar Creek; Upstream of N 25th Street on the Menomonee River to Brown Deer Road on the Little Menomonee River; No upper reach for the Kinnickinnic River)

- Presence of the indicator species, lake sturgeon, utilizing spawning habitat in the upper reaches of the Milwaukee River
- An overall mean value from all warmwater IBI sampling efforts of "Good" or better (i.e. 51-65) in the upper reaches of the Milwaukee River

Breeding Birds

- At least 9 sites in the AOC support at least 3 breeding bird indicator species for each habitat type (Forest, Wetland, and Shrubland)
- At least 6 sites in the AOC support at least 2 grassland breeding bird indicator species
- At least 9 sites in the AOC support at least 1 Airspace/Urban breeding bird indicator species

Herptiles/Crayfish

- At least 30 sites in the AOC support at least 2 semi-aquatic guilds (Crayfish, Salamanders, Frogs, Turtles).
    - At least 10 sites support at least one crayfish species
    - At least 15 sites support at least one frog species
    - At least 6 sites support at least one turtle species
- At least 15 sites in the AOC support at least 2 upland/grassland habitat species of snakes

Mammals

- At least 10 sites in the AOC support at least 2 mammal indicator species for each habitat type (Forest and Wetland)
- At least 5 sites in the AOC support at least 1 grassland mammal indicator species

Project Rationale/Why Critical for BUI Removal

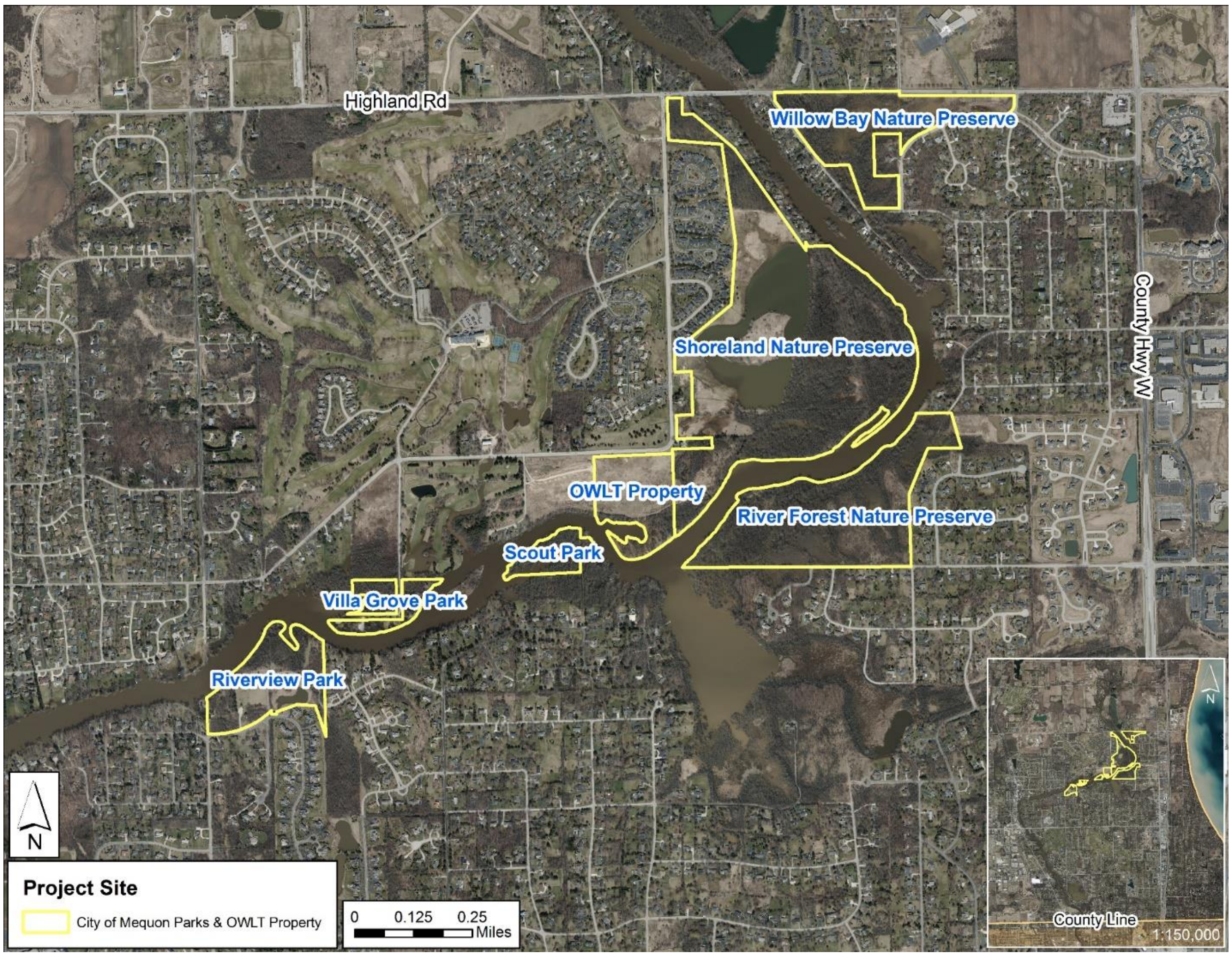
The process by the Milwaukee Estuary AOC Tech Team to determine management actions for the Degradation of Fish and Wildlife Populations BUI included a rigorous selection of high priority projects in the Milwaukee Estuary AOC to address this BUI. This project was ranked as a "Tier 1", high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only 15 (or 12.5%) were deemed Tier 1, high priority. It was determined to be extremely important for semi-aquatic habitat associated species. The large size of this project site provides important habitat for all breeding and migratory birds, but specifically those associated with forest and wetland habitat. This project area also supports a wide variety of indicator mammal species (bats included), which is unique for the Milwaukee Estuary AOC. It is well connected to the Milwaukee River corridor and is a project that will greatly help meet the wildlife metrics for BUI removal.

Degradation of Fish and Wildlife Populations
Project Summary

Necessary Project Elements

Elements for this project include:

- An invasive species and vegetation management plan with provisions made for long term implementation
- A conservation easement or equivalent for permanent protection of this site
- A conservation plan or equivalent that addresses the habitat goals of the associated parks/properties and the population goals for this stretch of the Milwaukee Estuary AOC
- Stakeholder and public input during all phases of the project



Degradation of Fish and Wildlife Populations
Project Summary

Project Title: High Priority Milwaukee River Greenway Parks

Project Location: Milwaukee River Greenway: MKE River Parkway – Section 5, Riverside Park, Gordon Park, Pleasant Valley Park, Kern Park, Hubbard Park, Lincoln Park

Project Sponsor: Milwaukee County Parks (MCP)

Project Landowner(s): Milwaukee County, Village of Shorewood

Background

The Milwaukee River Greenway is a long, contiguous seven-mile corridor (628 acres of parkland) in the lower portions of the Milwaukee River in need of enhancements in order to improve as an established refuge for diverse fish and wildlife (F&W) populations. There are 10 parks, containing a matrix of 240 acres of natural habitat, that make up the complexity of the Greenway, of which all but one, Hubbard Park, is owned by Milwaukee County Parks. These include (upstream to downstream): Lincoln Park, Estabrook Park, Hubbard Park, Kern Park, Pleasant Valley Park, Cambridge Woods, Gordon Park, Riverside Park, Milwaukee River Parkway – Section 5. All these parks except for Estabrook Park and Cambridge Woods were determined to be a high priority for enhancements to address the Degradation of F&W Populations BUI. This vital urban environmental corridor along the Milwaukee River provides important floodplain forest, upland forest, shrubland, wetland, and aquatic habitat for a diverse assemblage of F&W. The corridor also acts as a critical location for migratory species that are using these habitats during spring and autumn.

In the lower portions of the Milwaukee River Greenway, there are floodplains that were historically under water when the North Avenue dam was still in place. When the dam was removed in 1997 the water was lowered and settled into a more streamlined channel leaving contaminated sediments in the floodplain. Some of the parks that are part of this restoration project have designated floodplains where contamination was found as part of the current AOC-wide Great Lakes Legacy Act (GLLA) project agreement for feasibility (FS) and remedial design (RD). These include (upstream to downstream):

- Kern Park
- Pleasant Valley Park
- Gordon Park
- Riverside Park
- Milwaukee River Parkway – Section 5

Collaboration with Partners

Milwaukee County Parks is working with several partners on various aspects of park improvement and planning along the Milwaukee River Greenway. These partners, Urban Ecology Center (UEC), River Revitalization Foundation (RRF), and others are non-profit organizations that are involved with restoration projects and initiatives throughout the County. Recently, RRF, UEC, and MCP completed biodiversity surveys in the Greenway, informing the development of a larger Greenway habitat plan. This work, in combination with an AOC-wide, comprehensive fish and wildlife population study, helped inform the necessary steps to address population impairments in the Milwaukee Estuary AOC. Other partners that play an important role in the Greenway include but are not limited to the Koenen Nature Preserve, Village of Shorewood, Milwaukee Metropolitan Sewage District (MMSD), and Milwaukee

Riverkeeper. The project landowner for the majority (98%, 618 out of 628 acres) of these parks along the Greenway, Milwaukee County, has previously and continues to play an important role in implementing management actions for BUIs in the Milwaukee Estuary AOC.

Proposed Work

This project will plan and implement recommended activities that are proposed to be accomplished in these parks through a corridor wide management plan, while addressing portions of the fish and wildlife populations BUI in the Milwaukee Estuary AOC that best represent improvements of the impacted populations. As part of this process, these sites have been surveyed previously by Milwaukee County Parks many of the previously listed partners, and contractors. Results from this wildlife study, vegetative inventories, and habitat determinations and on-going park surveys provided important information about species and existing habitat found along the greenway. Recommended enhancements to benefit fish and wildlife populations in this area include but are not limited to the removal of invasive species (plants only); upland and lowland forest stand improvements that restore the canopy, sub-canopy, and herbaceous layer of the degraded woodlands found within this corridor within an emphasis towards planting fruit and nut bearing species;, improvements to the limited savanna and grassland habitat through prescribed burns, enhancement seedings, and woody vegetation removal; Enhancements to ephemeral wetlands and creation of potential additional ephemeral wetlands as part of the sediment remediation in the floodplain flats, maintenance of aquatic buffer zones through selective and appropriate reforestation of floodplain areas, and shoreline enhancements to provide higher quality fish habitat.

Estimated Timetable and Duration (Calendar Year)

- Planning: Q1 2020 – Q2 2021
- Design and Permitting: Q3 2021 – Q4 2022
- Construction/Implementation: Q1 2023 – Q4 2024
- Maintenance and Vegetation Establishment: Q1 2025 – Q2 2028

Estimated Project Budget & Funding

The total project costs for this project are approximately $2.8M.

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)

The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet all the goals below (highlighted in green) and show measures of success by an AOC wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (forest, wetland, shrubland, grassland, semi-aquatic, upland/grassland) to support a better population of wildlife indicator species:
    - Species and area of exotic invasive species removed
    - Amount (area or number) of native species planted to benefit wildlife indicator species
    - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
    - Amount (area) of habitat types created, enhanced and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
    - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for lake sturgeon and northern pike, respectively

    - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
    - Amount (length or area) of fish habitat or stream channel enhanced or restored
    - Amount (length) of corridor habitat improved or reconnected

Fish and Wildlife Metrics Addressed by Project

Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. Metrics were reviewed and agreed upon by the Tech Team to determine necessary steps and projects to remove this BUI. This project will take part in addressing certain aspects of following metrics:

Upper Milwaukee Estuary AOC

(Upstream of Humboldt Avenue on the Milwaukee River to Bridge Road on Cedar Creek; Upstream of N 25th Street on the Menomonee River to Brown Deer Road on the Little Menomonee River; No upper reach for the Kinnickinnic River)

- Presence of the indicator species, lake sturgeon, utilizing spawning habitat in the upper reaches of the Milwaukee River
- An overall mean value from all warmwater IBI sampling efforts of "Good" or better (i.e. 51-65) in the upper reaches of the Milwaukee River

Breeding Birds

- At least 9 sites in the AOC support at least 3 breeding bird indicator species for each habitat type (Forest, Wetland, and Shrubland)
- At least 9 sites in the AOC support at least 1 Airspace/Urban breeding bird indicator species

Herptiles/Crayfish

- At least 30 sites in the AOC support at least 2 semi-aquatic guilds (Crayfish, Salamanders, Frogs, Turtles).
    - At least 10 sites support at least one crayfish species.
    - At least 15 sites support at least one frog species.
    - At least 6 sites support at least one turtle species.
- At least 15 sites in the AOC support at least 2 upland/grassland habitat species of snakes.

Mammals

- At least 10 sites in the AOC support at least 2 mammal indicator species for each habitat type (Forest and Wetland)

Project Rationale/Why Critical for BUI Removal

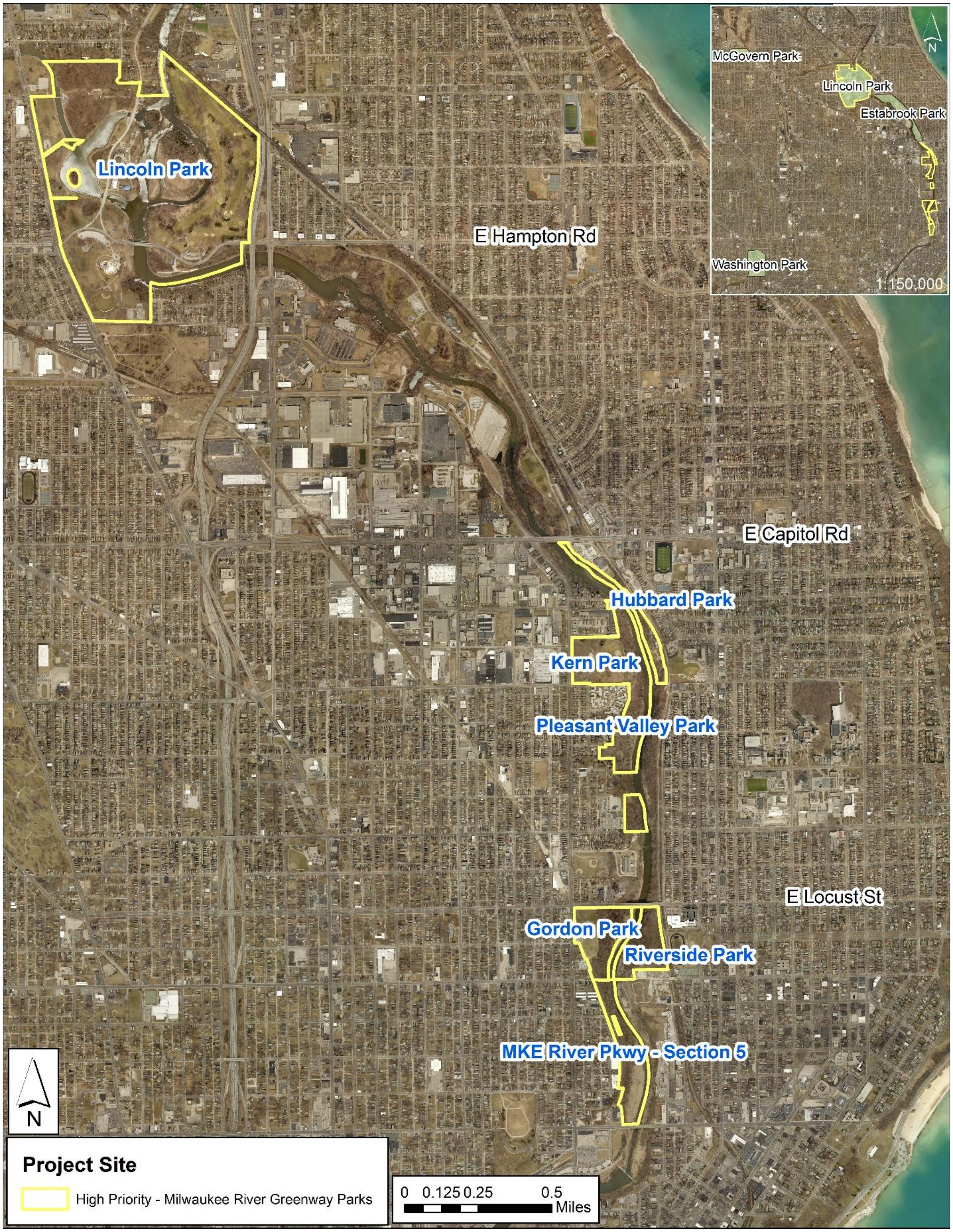
The process by the Milwaukee Estuary AOC Tech Team to determine management actions for the Degradation of Fish and Wildlife Populations BUI included a rigorous selection of high priority projects in the Milwaukee Estuary AOC to address this BUI. This project was ranked as a "Tier 1", high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only 15 (or 12.5%) were deemed Tier 1, high priority. It was determined to be important for semi-aquatic habitat associated species. The large size of this project site provides important habitat for forest and wetland breeding birds and mammals (bats included). This project is well connected to the Milwaukee River corridor and due to the goals, as well as metrics that it addresses, will greatly assist in the removal of this BUI. It also builds off all the work such as invasive species removals, reforestations, prescribed burns, sediment contamination removal, prairie planting, and ephemeral wetland creation that has been undertaken over the last 10 years within the Greenway. This clearly shows that this project area has a diverse partnership base that has already invested significant resources within the larger habitat restoration project as resources have allowed.

Necessary Project Elements

Elements for this project include:

- An invasive species and vegetation management plan with provisions made for long term implementation and management
- A conservation easement or equivalent for permanent protection of this site (i.e. non-developable land, zoned parkland)
- A conservation plan or equivalent that addresses the habitat goals of the associated parks and the population goals for this stretch of the Milwaukee Estuary AOC
- Stakeholder and public input during all phases of the project

Degradation of Fish and Wildlife Populations
Project Summary



Degradation of Fish and Wildlife Populations
Project Summary

Project Title: Estabrook Falls and Fish Passage Improvements

Project Location: Former North Avenue Dam to Estabrook Falls on the Milwaukee River

Project Sponsor: Milwaukee Metropolitan Sewerage District (MMSD)

Project Landowner: Milwaukee County

Background

Between 1870 and 1940 over 2-miles of the lower Milwaukee River were mined for cement production, widened and deepened for flood control. A dam was constructed resulting in a shallow and silt-laden 103 acres impoundment. Dredge spoils were used to fill 150 acres of floodplain wetland for park and road construction or inundated by the impoundment. Over 1 mile of deep meandering river habitat was lost and over 1 mile of channel is shallow pavement-like bedrock absent of fish cover. The quarried river headwall (current Estabrook Falls) is a partial barrier to fish passage and access to spawning and nursery habitat (Wawrzyn, 2014).

Following the removal of roughly 176,000 cubic yards of contaminated sediment in Lincoln Park and its vicinity, and removal of the Estabrook Park Dam in 2018, a *Milwaukee River Rehabilitation Alternatives Analysis Technical Memorandum* was completed in 2018 to look at alternatives for addressing these impacts to fish habitat (Lee, 2018). This alternative analysis identified the following goals: decreasing negative flood impacts; maximizing sustainability of the river reach with respect to sediment transport; enhancing recreation opportunities; enhancing riparian landowner experience of the river; Maximizing habitat requisites for fish and other wildlife populations; improving fish passage at Estabrook Falls; contribute to de-listing of Milwaukee Estuary AOC Beneficial Use Impairments (BUIs) related to Degradation of F&W Populations and Loss of F&W Habitat (Lee, 2018).

Consistent with the goals for rehabilitating lake sturgeon populations in the Milwaukee River, the WDNR located and quantified critical habitat and barriers to migration downstream and upstream of Estabrook Falls and former Estabrook Park Dam abandoned and removed in 2018 (WDNR, 2006). Pre-historic emergent wetlands (e.g., marsh and wet meadow) once covered thousands of acres in the Milwaukee Estuary and connecting rivers and were critical for various fish and wildlife life stages. These wetland cover types are currently absent in the estuary and lower river reaches. Some reaches of the former Estabrook impoundment provide one of the best opportunities for rehabilitating emergent wetlands for phytophilic spawning fishes (i.e. northern pike) in close proximity to the Milwaukee Estuary. The low-gradient (0.3-0.59 m/km) and shallow (0.5-1.9 m) reaches upstream of the former impoundment are dominated by silt, sand, and gravel substrate. These habitat features are near-optimum habitat for larval/juvenile lake sturgeon (Daugherty et al., 2009).

Thus, fish passage along the Milwaukee River has been part of a larger initiative to allow native fish species to move upstream for reproduction purposes and to build on previous investments made by stakeholders in Milwaukee and Ozaukee County. This includes ongoing efforts of achieving a solution for fish passage at Kletzsch Park Dam, which was determined as a management action for the Loss of F&W Habitat BUI. It also builds upon a fish bypass channel constructed at the Thiensville Village Park; the removal of the North Avenue, Estabrook, Lime Kiln, and Chair Factory dams; the Seminary Dam removal on Pigeon Creek; and the removal of numerous fish barrier culverts and other obstructions.

Degradation of Fish and Wildlife Populations
Project Summary

During certain flow conditions on the Milwaukee River, native fish movement is inhibited due to the Estabrook Falls, and potentially restricts movement downstream at the ACM found in the stream reach between the former North Avenue Dam and North Avenue, and at a historical wooden dam near Chambers Street. As a result, the Milwaukee Estuary AOC F&W Technical Advisory Committee (Tech Team) established Estabrook Falls design and implementation, and investigation of ACM and Chambers Street Dam fish movement restrictions, as required actions for addressing the fish portion of the population metrics for the Degradation of F&W Populations BUI. These three fish actions were bundled together and identified as "Estabrook Falls and Fish Passage Improvements."

Areas in the floodplain upstream of the former North Avenue Dam have previously been determined to contain contaminated sediments. Site investigation was completed in this area in 2019 and is part of a future feasibility study to look at the Milwaukee River Floodplains within the Milwaukee River Downtown (MRD) reach from the former Estabrook Dam on the Milwaukee River to the confluence with the Menomonee River. While the planning study of the ACM movement restriction portion of this project falls within the boundaries of the MRD Great Lakes Legacy Act (GLLA) project reach, no sediment characterization or remediation work will be completed as part of this project.

Collaboration with Partners
There will be collaboration between MMSD, DNR, Milwaukee County Parks, and other project stakeholders, including but not limited to: River Revitalization Foundation, Milwaukee Riverkeeper, Milwaukee River Revitalization Group, Friends of Estabrook Park, and private landowners through the life of the project to ensure its success. MMSD and DNR will directly solicit input from Milwaukee County Parks and the Tech Team as well as from the community through appropriate public notice and meetings. MMSD and DNR will highlight the project's progress through various outreach efforts. These may include AOC newsletters, GovDelivery list serve updates, social media, webpages, and traditional media.

Proposed Work

Estabrook Falls
This waterfall is an artificial relic of the historic mining of the limestone bedrock in the riverbed about 100 years ago. Fish movement enhancements at Estabrook Falls will build off the current and previous GLRI work invested in fish passage upstream at the Kletzsch and Estabrook Park Dams. Initial stages for this project were investigated as part of a MMSD project with a brief analysis completed to look at in *The Milwaukee River Rehabilitation Alternatives Analysis Technical Memorandum* completed in 2018 (Lee, 2018). The goal for this project site is to plan, design, and implement improvements to fish movement restrictions at Estabrook Falls.

Articulated Concrete Matting (ACM)
ACM was originally placed in selected areas in the floodplain and the entire bed of the river between the former North Avenue Dam and North Avenue to protect the riverbed and shoreline when the former North Avenue dam was removed. When the ACM was placed in the riverbed and the former North Avenue dam was removed, the river was no longer a wide, low flow river above the dam. It now cascades through what most stakeholders call "the shoot" (Figures 2 and 3). The ACM had some noticeable deterioration immediately after the dam removal in the late 1990's that was mostly repaired. This had the potential to cause fish movement restrictions due to velocity issues as well as in areas

where ACM had been found to be deteriorating. The goal for this project site is to complete a planning study that would involve developing and evaluating three feasible alternatives for the project area. A no action alternative would be included as one of the three alternatives if no fish movement restriction was found. Next steps for this project site will be determined based on evaluation of alternatives.

Chambers Street Dam

The Chambers Street Dam was originally constructed in the early 1850s to harvest ice from the Milwaukee River for refrigeration and drinking purposes. Since it was shut down in the 1900s, it has been decommissioned and portions of the original wooden dam structure remains. This has the potential to cause fish movement restrictions due to velocity issues as well as the remaining structures on both sides of the shoreline. The goal for this project site is to complete a planning study that would involve developing and evaluating three feasible alternatives for the project area. A no action alternative would be included as one of the three alternatives if no fish movement restriction was found. Next steps for this project site will be determined based on evaluation of alternatives.

Estimated Timetable and Duration (Calendar Year)

- Planning: Q1 2020 – Q4 2020
- Design and Permitting: Q1 2021 – Q1 2022
- Construction/Implementation: Q2 2022 – Q2 2024
- Maintenance and Vegetation Establishment: Q3 2024 – Q2 2026

Estimated Project Budget & Funding

The total project costs for this project are approximately $3.5M.

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)

The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet the two goals below (highlighted in green) and show measures of success by an AOC wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (i.e. forest, wetland, shrubland, grassland, semi-aquatic, and upland/grassland) to support a better population of wildlife indicator species:
    - Species and area of exotic invasive species removed
    - Amount (area or number) of native species planted to benefit wildlife indicator species
    - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
    - Amount (area) of habitat types created, enhanced, and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
    - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for lake sturgeon and northern pike, respectively
    - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
    - Amount (length or area) of fish habitat or stream channel enhanced or restored
    - Amount (length) of corridor habitat improved or reconnected

Degradation of Fish and Wildlife Populations
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Fish and Wildlife Metrics Addressed by Project

Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. Metrics were reviewed and agreed upon by the Tech Team to determine necessary steps and projects to remove this BUI. This project will take part in addressing certain aspects of following metrics:

Upper Milwaukee Estuary AOC

(*Upstream of Humboldt Avenue on the Milwaukee River to Bridge Road on Cedar Creek; Upstream of N 25th Street on the Menomonee River to Brown Deer Road on the Little Menomonee River; No upper reach for the Kinnickinnic River*)

- Presence of the indicator species, lake sturgeon, utilizing spawning habitat in the upper reaches of the Milwaukee River
- An overall mean value from all warmwater IBI sampling efforts of "Good" or better than good (i.e. 51-65) in the upper reaches of the Milwaukee River

Project Rationale/Why Critical for BUI Removal

The process by the Milwaukee Estuary AOC Tech Team to determine management actions for the Degradation of Fish and Wildlife Populations BUI included a rigorous selection of high priority projects in the Milwaukee Estuary AOC to address this BUI. This project was ranked as a "Tier 1", high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only 15 (or 12.5%) were deemed Tier 1, high priority. It was determined to be important for all four fish indicator species (i.e. northern pike, lake sturgeon, greater redhorse, and smallmouth bass). This project also scored the highest out of all 34 high priority projects for addressing natural reproduction of lake sturgeon in the Milwaukee Estuary AOC; as a result, it is essential to meet the metrics to remove the Degradation of Fish and Wildlife Populations BUI.

Necessary Project Elements

Elements for this project include:

- Operation and maintenance of the Estabrook Falls fish passage to allow continued usage by Milwaukee Estuary AOC fish
- Vegetation maintenance plan for Estabrook Falls
- Stakeholder and public input during all phases of the project

References:

Daugherty, D.J., Sutton, T.M., Elliott, R.F. 2009. Suitability Modeling of Lake Sturgeon Habitat in Five Northern Lake Michigan Tributaries: Implications for Population Rehabilitation. *Restoration Ecology.* 17(2): 245-257. 10.1111/j.1526-100X.2008.00368.x

Lee, B. 2018. Technical Memorandum RE: Milwaukee River Rehabilitation Alternatives Analysis. Milwaukee River Rehabilitation Project. Glendale, Milwaukee County, WI. Prepared for: Milwaukee Metropolitan Sewerage District.

Wawryzn, W. 2014. A Management Plan for Restoring a Sustainable Population of Northern Pike in the Milwaukee Estuary Area of Concern (AOC). Wisconsin Department of Natural Resources. 1-91. https://dnr.wi.gov/topic/fishing/documents/publications/MilwaukeeRiverNorthernPikeReport.pdf

WDNR, 2006. Lake Michigan Lake Sturgeon Rehabilitation. https://dnr.wi.gov/topic/fishing/lakemichigan/LakeSturgeon.html

Figure 1. Project reaches for Estabrook Falls and Fish Passage Improvements

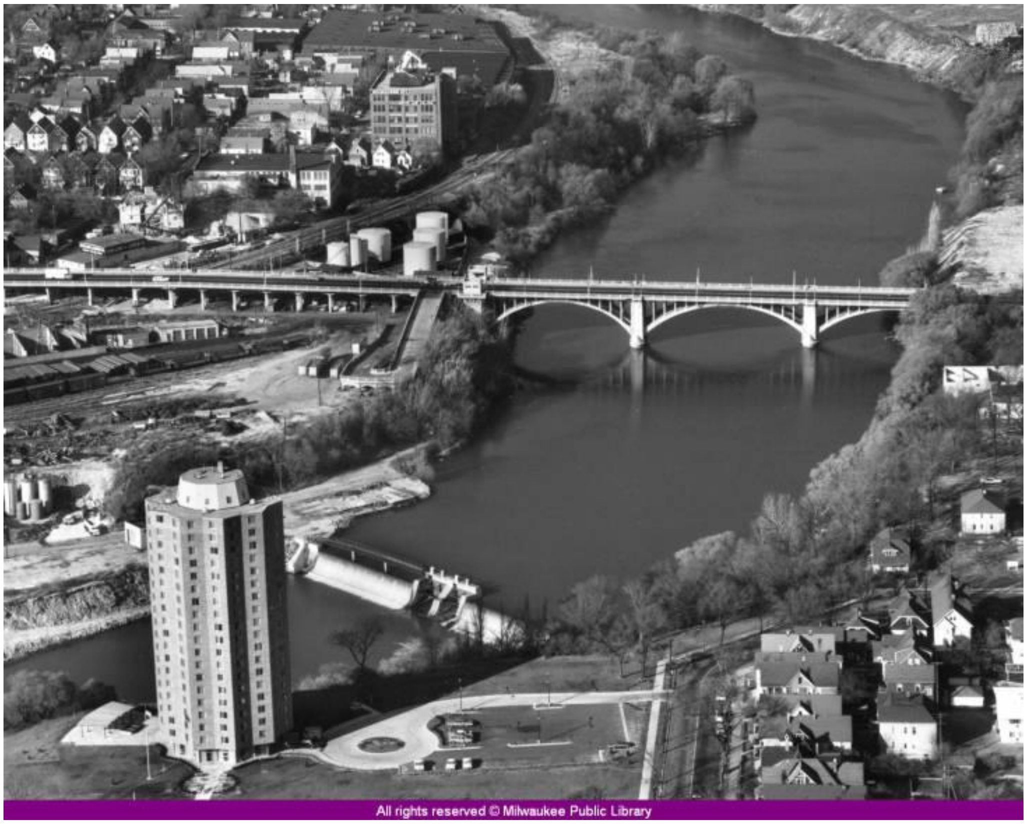


Figure 2. Historical photo before North Avenue dam was removed.

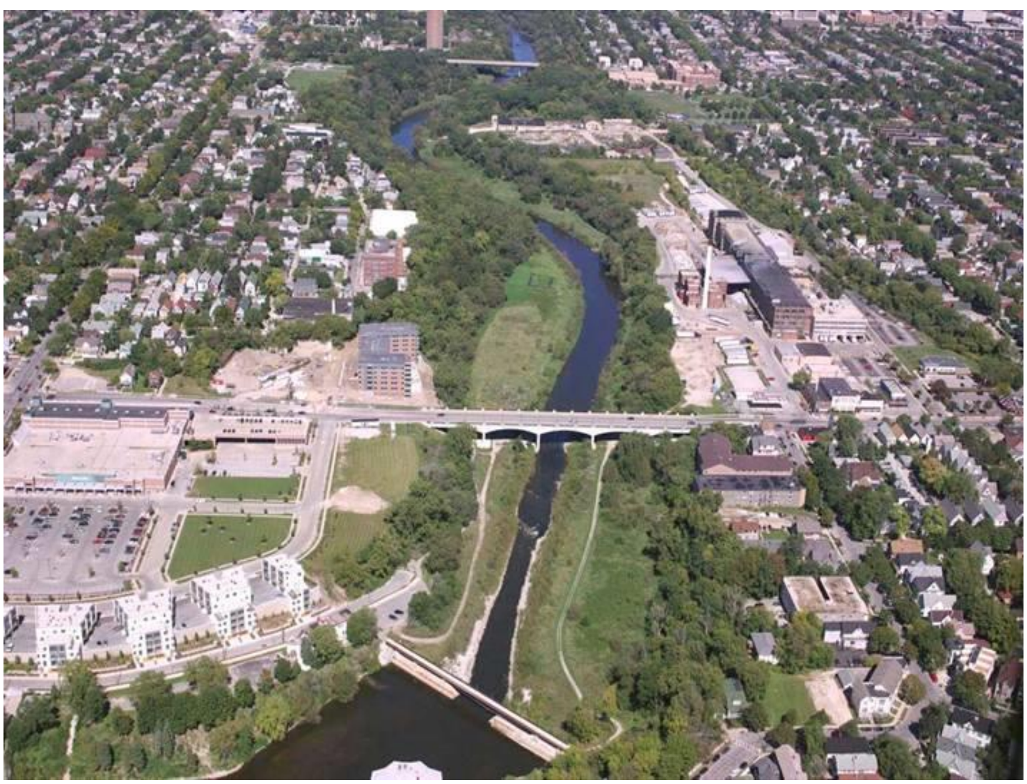


Figure 3. Photo after North Avenue dam was removed.

Degradation of Fish and Wildlife Populations
Project Summary

Project Title: Aquatic Enhancements to the Outer Harbor

Project Location: Nearshore Outer Milwaukee Harbor – NW corner of Outer Harbor near Art Museum & Veterans Park; Summerfest Lagoon

Project Sponsor: TBD

Project Landowner: State of Wisconsin, City of Milwaukee, Port Milwaukee, Milwaukee County

Background

The outer harbor of the Milwaukee Estuary Area of Concern (AOC) is an important transitional habitat that is the interface between the inner harbor and Lake Michigan. Sediment and nutrients are carried from the three tributaries that converge in the inner harbor and discharged under the Hoan Bridge into the outer harbor. The outer harbor encompasses many different types of habitats and varying depths. The largest area of littoral zone habitat in the outer harbor is a 30-acre site in the northwest corner near the Art Museum, at the center of two biological hotspots (the Summerfest Lagoon and Green Breakwall) that were previously identified by Dow, 2018 and Geisthardt, 2017, respectively. This 30-acre site provides sparse macrophyte growth, minimal rocky habitat, and shallowing depths. While there are shallow water depths (< 9 ft) in this location, sunlight penetration and muck substrate are not conducive for macrophyte growth with macrophytes currently present in small isolated patches. These isolated patches of rock/stone and macrophyte habitat cover types provide limited spatial connectivity between the Discovery World/Summerfest Lagoon and Veterans Park/McKinley Marina/Green Breakwall areas. Isolated patches of habitat may reduce fish colonization rates and recruitment. Wave action may also be the contributor to reduced macrophyte growth and sedimentation by fines over coarse substrates in this region.

The Summerfest Lagoon is a nursery habitat area that supports a large diversity of centrarchid species (sunfishes) which, throughout the year, have been found foraging on the outer harbor Green Breakwall site (Figure 1; Geisthardt, 2017). The route in which these centrarchids travel to the Green Breakwall is unknown, but it is believed that they follow the shoreline stretching from Discovery World to Veterans Park. The existing features between these two locations is lacking in cover and provides a unique opportunity to increase near-shore, open water rock/stone and macrophyte habitat cover types and habitat connectivity to benefit multiple life stages of many species in the outer harbor.

The eastern shoreline of the Lagoon is supported by a shallow, sloping shoreline with adequate spawning habitat and cover for sunfishes. However, there is limited surface area for reproduction due to the Lagoon's steep slope on the western shoreline. Currently, fishes that utilize this shoreline are reproducing on top of armor stone and dead quagga mussels. However, this habitat is not optimal and the introduction of more cover and substrate to help support better reproduction and recruitment is preferred. To further enhance this biological hotspot, better connecting the eastern and western shorelines will allow fish to move between different cover types and take advantage of both shorelines.

This Lagoon is well connected to Lake Michigan and often experiences temperature fluctuations due to seasonal changes and abrupt events (i.e. upwelling and seiche) in the outer harbor as well as significant water level fluctuations. For example, as of July 11, 2019, Lake Michigan water levels were at an elevation of 582 ft IGLD, which is 2.6 ft above the long-term monthly average for July (USACE, 2019). In comparison, the record low of 576 ft was during the winter of 2012-2013 (USGS, 2019). A new spawning area design must take into consideration these resiliency impacts and changes as part of project design.

Degradation of Fish and Wildlife Populations
Project Summary

From 2016 to 2019, the USFWS Green Bay Fish and Wildlife Conservation Office's Aquatic Invasive Species early detection team conducted surveys in the lower Milwaukee Estuary AOC. A total of 308 individual points were surveyed using a variety of gears including Gillnets, paired fyke nets, cloverleaf traps, and day and nighttime boat electrofishing. A total of 13,273 fish representing 58 species were surveyed. In the boundaries of this project, a total of 13 individual points were surveyed in the project area in September of 2016, 2017 and 2018 and August of 2019 by the USFWS' Aquatic Invasive Species early detection team, using a variety of gears (Figure 3). Combining the results of all gear types, a total of 2819 fish representing 35 different species were surveyed. These were dominated by white sucker (23.7% of total fish caught), round goby (14%), rock bass (12.4%), and yellow perch (10.5%), followed by alewife (8.1%), largemouth bass (7.6%), spottail shiners (6.5%), gizzard shad (6.3%), and bluegill (3.5%). Indicator species made up 1.8% of the total catch, dominated by smallmouth bass (1.1%) which were sampled in the inner harbor via electrofishing in August and September. A total of 9 lake sturgeon were sampled in gillnet surveys between the break wall and outer harbor. Sub-indicator species represented 66% of the total catch and were dominated by rock bass, yellow perch, largemouth bass, and spottail shiners (see percentages above).

Through the recent efforts to determine management actions for the Degradation of Fish and Wildlife Populations Beneficial Use Impairment (BUI) by using available data, the Milwaukee Estuary AOC Fish and Wildlife Technical Advisory Committee (Tech Team) have determined these sites as key locations in the Milwaukee Estuary AOC outer harbor that requires enhancements to benefit many fish indicator species.

Collaboration with Partners
The Wisconsin Department of Natural Resources (WDNR) is planning on determining the best course of action for planning, design, and implementation of this project. Stakeholders that have been involved with watercourse projects in the past for the Milwaukee Estuary AOC include the Milwaukee Metropolitan Sewerage District (MMSD), as well as the U.S. Army Corps of Engineers (USACE). It is important for the Wisconsin Department of Natural Resources (WDNR) to bring all stakeholders and partners involved to the table to discuss the improvement of fish nursery habitat and connectivity at these two locations in the outer harbor. These stakeholders include but are not limited to: Port Milwaukee, Milwaukee County Parks, UW-Milwaukee, Friends of Lakeshore State Park, Summerfest, Milwaukee Art Museum, Discovery World, and the Western Lake Michigan Working Group. There are multiple project landowners through lakebed grant leases and navigational structures for these sites: State of Wisconsin, City of Milwaukee, Milwaukee County, and USACE.

Proposed Work
<u>Objective 1:</u> Construction of aquatic habitat enhancements at Summerfest Lagoon.

Planning and design at the site is currently being led by the University of Wisconsin-Milwaukee School of Freshwater Sciences through a grant from Fund for Lake Michigan and the contractor Ramboll Group, formerly O'Brien & Gere (OBG). The team is currently at 80% design with starting to apply for permits and having conversations with WDNR, the City of Milwaukee, and the Milwaukee Metropolitan Sewerage District (MMSD) to see who the applicant and primary owner of the habitat feature would be long-term. The current design of the project has a cost estimate of roughly $1.2M. One of the current unknowns for this site is the potential of sediment contamination in the Summerfest Lagoon. Impacts to project timeline and implementer may result from extent of sediment contamination discovered in 2020.

Enhancements to this biological hotspot in the outer harbor includes expansion of the spawning zones on the western portion of the Summerfest Lagoon. A shallower shoreline would allow for a better slope and provide additional cover to enhance what is sub-optimal nursery habitat. Introductions of rocky habitat here could be staged as tiers, or shelves, to allow similar slopes as an inland lake and allow for changes in lake level fluctuations. Native macrophyte root stock and woody structures would also be placed along these shelves to provide more cover for fish. This project would also include better connection from the western shoreline to the eastern shoreline through rocky and woody cover in order to spread spawning habitat around the Lagoon, instead of just in "pocket" locations. One of the primary issues with this type of project is the seiche effect that impacts this area and the impact of ice cover damage to any habitat feature protruding above water level.

Objective 2: Planning and design of aquatic habitat enhancements for the 30-acre site Art Museum site, with other funding sources being sought out for construction.

The existing habitat in the shallow zone on the northern portion of the outer harbor (<3-4m) provides a unique opportunity to increase nearshore and open water rock/stone and macrophyte habitat cover types. The design of additional rock/stone cover for fish habitat may include barrier-like islands that also reduce storm surged wave impacts to macrophyte beds near the Art Museum. As an example, the large man-made Terrell's Island on Lake Butte des Morts was constructed to protect aquatic plants and historical wetlands while reducing sediment resuspension. In lieu of this one barrier island, several small islands could be implemented, similar to the eyebrow island in front of the Art Museum. To make sure nuisance waterfowl do not use these locations as nesting sites, emergent aquatic and terrestrial vegetation would be considered around the perimeters of the islands. Native macrophyte root stock could be densely planted in clusters to increase plant diversity and abundance and serve as a source of seed stock for expansion. Certain underwater groynes, that branch off from the determined island structures, could also be placed in the outer harbor, helping to increase the surface area of the rocky structure and allow for more fish cover. In addition, armor stone placed along the bare bulkhead shoreline of Veterans Park would better connect the proposed habitat and the Green Breakwall. Investigations of this shoreline would be completed to address any stability issues.

Estimated Timetable and Duration (Calendar Year)

TIMEFRAME	DELIVERABLES COMPLETED
January 2021 – June 2022	• Complete Summerfest Lagoon design • Construction (pending sediment characterization) • Art Museum site planning
July 2022 – December 2024	• Summerfest Lagoon maintenance and vegetation establishment • Art Museum site planning, feasibility and design • Potential Art Museum implementation

Estimated Project Budget & Funding

Project costs are currently estimated at $2 million for the completion of design and construction at Summerfest Lagoon and $3 million for planning/design at the Art Museum site. The project lead for these site(s) will supply updated figures and project budget timelines for the work.

Degradation of Fish and Wildlife Populations
Project Summary

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)
The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet the two of the three goals below (highlighted in green) and show measures of success by an AOC wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (i.e. forest, wetland, shrubland, grassland, semi-aquatic, and upland/grassland) to support a better population of wildlife indicator species:
    - Species and area of exotic invasive species removed
    - Amount (area or number) of native species planted to benefit wildlife indicator species
    - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
    - Amount (area) of habitat types created, enhanced and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
    - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for lake sturgeon and northern pike, respectively
    - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
    - Amount (length or area) of fish habitat or stream channel enhanced or restored
    - Amount (length) of corridor habitat improved or reconnected

Fish and Wildlife Metrics Addressed by Project
Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. Metrics were reviewed and agreed upon by the Tech Team to determine necessary steps and projects to remove this BUI. This project will take part in addressing certain aspects of following metrics:

Lower Milwaukee Estuary AOC
(Downstream of Humboldt Avenue on the Milwaukee River; Downstream of N 25th Street on the Menomonee River; Downstream of W Becher Street on the Kinnickinnic River)
- A 100% increase in relative population density in four indicator species (i.e. lake sturgeon, northern pike, greater redhorse, and smallmouth bass)
- An increase of any magnitude in 80% of native sub-indicator families (i.e. suckers, minnows and shiners, bullheads and catfishes, sunfishes, and perches) to be considered

Project Rationale/Why Critical for BUI Removal
To address this BUI, the process was completed by the Milwaukee Estuary AOC Tech Team to determine management actions for the Degradation of Fish and Wildlife Populations BUI. The process included a rigorous selection of high priority projects in the Milwaukee Estuary AOC. This project was ranked as a “Tier 1”, high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only 15 (or 12.5%) were deemed Tier 1, high priority. It was determined to be important for all four fish indicator species (northern pike, lake sturgeon, greater redhorse, smallmouth bass). This project also scored the highest in all 34 high priority projects for benefiting sub-indicator fish families. As a result, this project provides the greatest enhancements for fish habitat and populations in the lower Milwaukee Estuary and the outer harbor. These enhancements were also associated with having the best possible cost-benefit score. This project is essential to meet the metrics in the lower Milwaukee Estuary for fishes;

therefore, is included as one of the management actions for the Degradation of Fish and Wildlife Populations BUI.

Necessary Project Elements

Elements for this project include:

- Follow all safety designations for public recreation and navigational purposes
- Design must be buildable, acceptable to landowners, and permittable by regulatory agencies
- Stakeholder and public input during all phases of the project
- Enhance and expand the Summerfest Lagoon's function and value for spawning fishes
- Include coastal resilience aspects to these project sites to ensure continued usage by focal species and the function of these enhancements
- Include submergent and emergent vegetation cover types
    - Shoreline vegetation should be selected to maximize food resources for migratory birds

References:

Dow, B. 2018. Assessment and Mapping of the Milwaukee Estuary Habitat. University of Wisconsin Milwaukee. Milwaukee, Wisconsin. *Masters thesis manuscript.* 1-49.

Geisthardt, E. 2017. A *Hemimysis* driven novel ecosystem at a modified boulder breakwall. University of Wisconsin Milwaukee. Milwaukee, Wisconsin. *Masters thesis manuscript.*

Suedel, B., Geisthardt, E., and Janssen, J. 2017. Monitoring the Milwaukee Harbor Breakwater: An Engineering With Nature (EWN) Demonstration Project.

USACE, 2019. Army Corps of Engineers Detroit District: Weekly Great Lakes Water Level Update.

USFWS, Stevens, A. 2020. Summary of the 2016-2019 USFWS' AIS Early Detection Fisheries Data collected in the Milwaukee River AOC.

USGS, 2019. National Water Information System: Web Interface. Water-stage recorder and acoustic velocity meter: USGS 04087170 Milwaukee River at Mouth at Milwaukee, WI. Hydrologic unit 04040003.

Figure 1. Aerial view of Milwaukee Harbor (left) showing the breakwalls that separate the outer harbor from Lake Michigan. The study area (boxed right) with the location of the GBW highlighted in orange and the reference site (REF) highlighted in green.

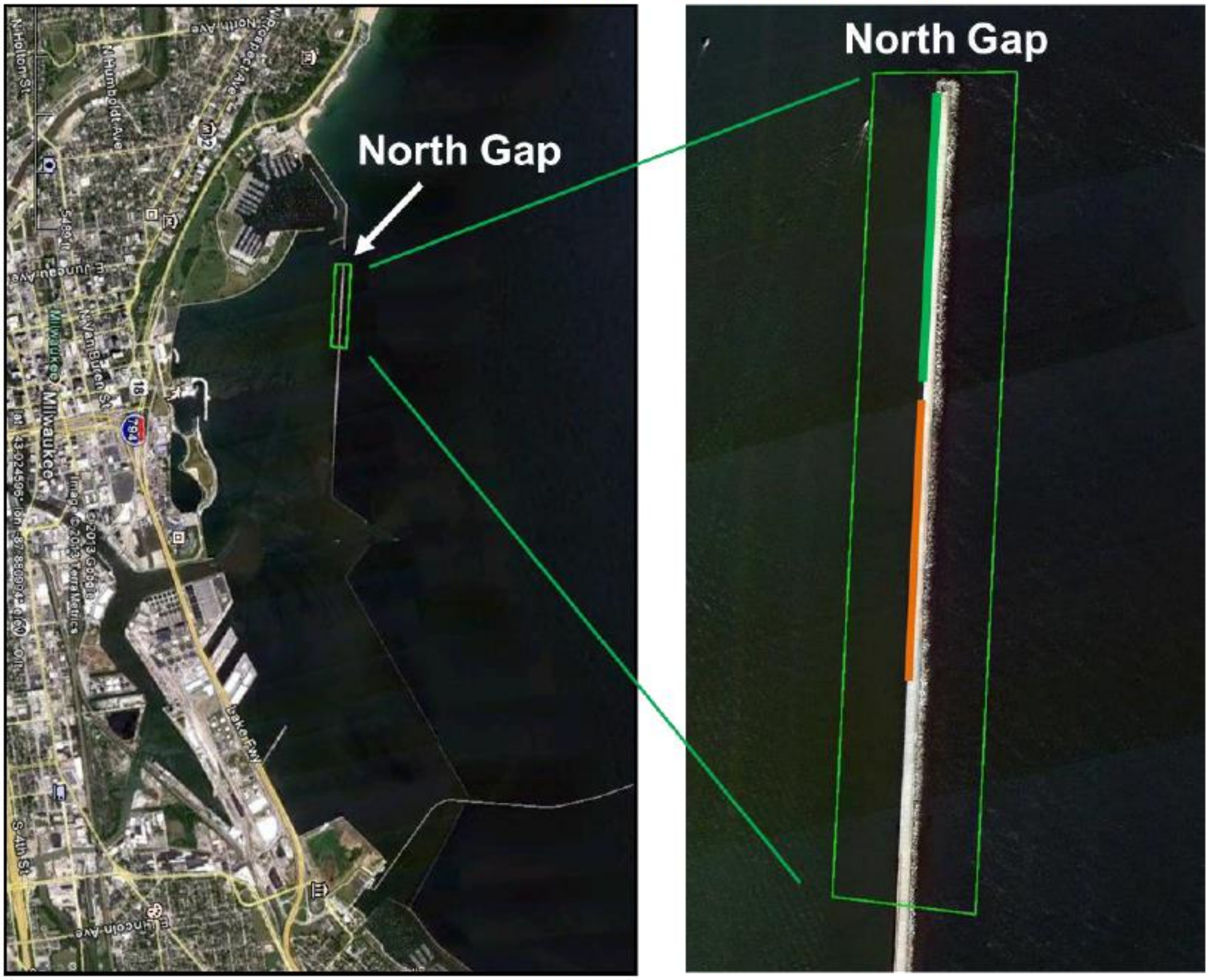


Figure 1. Taken from Geisthardt, 2017 to show the study area of the Pilot Green Breakwall Project.

Figure 2. Project sites for Aquatic Enhancements to the Outer Harbor.

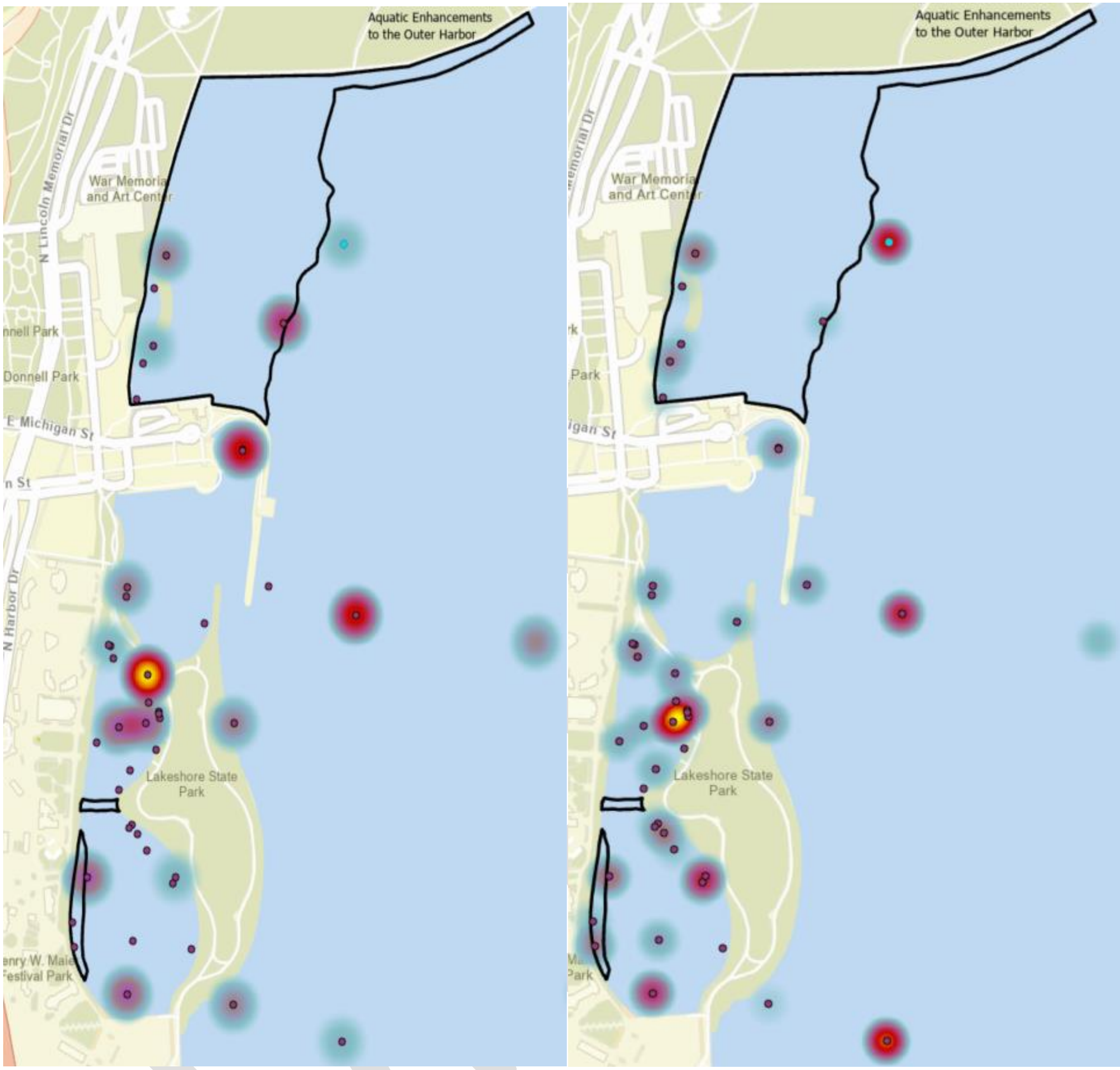


Figure 3. (left) Densities of indicator species surveyed by the USFWS Aquatic Invasive Species early detection team in the Outer Harbor project area from 2016-2019. (right) Densities of sub-indicator species. Project boundaries are outlined in black.

Degradation of Fish and Wildlife Populations
Project Summary

Project Title: Havenwoods State Forest Rehabilitation

Project Location: Havenwoods State Forest

Project Sponsor: Wisconsin Department of Natural Resources

Project Landowner: State of Wisconsin

Background
HSF is a quiet 237-acre urban state forest, but it has had an exciting and diverse background that has resulted in challenges for habitat management. The history of this property includes family homesteads from the mid-1800s transitioning to the Milwaukee County House of Corrections in the early 1900s. An Army Disciplinary Barracks, Nike Missile site, and city landfill soon followed. Progress and urbanization almost did away with Havenwoods. Thanks to a small group of citizens, community leaders, and public officials working together, this land was set aside as a green space in the middle of a large urban community. In 1979, the Department of Natural Resources began restoration of the area. Due to the disruption of the site over the past 150 years, the landscape is scarred and subject to habitat degradation and loss to invasive species.

In 2016-2017, a strategic alignment in the DNR provided different programs the need to develop statewide habitat and recreation priorities on state properties to focus limited resources and maximize habitat and wildlife impacts. These priorities were developed by using a list of predetermined criteria. While HSF fell lower on this list due to current site conditions, these planning activities and future enhancements will greatly contribute to increasing habitat management priorities. In addition, educational and recreation opportunities at HSF are currently the main drivers for property usability by the public. Increasing the accessibility and usability of the property through habitat enhancements will also develop better educational and recreational opportunities.

Habitat	Priority	Present at HSF
Oak Forest (specifically regeneration/perpetuation)	1	Yes – with more areas enhanced as part of this project
Oak Savanna/woodlands	1	Yes
Remnant and planted prairie in historic prairie areas	1	Yes – with more areas enhanced as part of this project
Forested Wetlands (bottomland hardwoods, floodplain and ash forest)	2	Yes
Hardwoods	2	Yes
Warmwater Streams	2	Yes – Lincoln Creek is a NR 102, 104 Cool-Warm Headwater

HSF was determined as a management action for the Degradation of F&W Populations BUI in the Milwaukee Estuary AOC. Carrying out this project will enable informed implementation enhancements to habitat that will address portions of the goals and metrics as part of this BUI. The property was last surveyed into habitat management stands as part of the forestry management plan. No recent surveys have been done for the entire property to the extent that will be covered under this project.

Degradation of Fish and Wildlife Populations
Project Summary

Through recent efforts to determine management actions for this BUI by the Milwaukee Estuary AOC F&W Technical Advisory Committee (Tech Team), this project was determined to address all three overall outcome goals for this BUI and portions of 12 specific output metrics for the AOC. This site has been surveyed previously by the University of Milwaukee Field Station (UWMFS) from 2014 to 2017. Results from this AOC-wide wildlife study provided important information about current conditions of habitat that support a variety of species found on this property. HSF was determined to be important for upland/terrestrial habitat for snakes and semi-aquatic habitat for frogs. This project scored the best possible cost-benefit score, as well as scoring the highest in all 34 high priority projects for benefiting from enhancements to all habitat associated breeding bird populations (forest, wetland, grassland, shrubland and airspace/urban). This area within the AOC is also serves as a very important property for supporting forest, wetland, and grassland mammals.

Collaboration with Partners

DNR will collaborate with important stakeholders to survey the property and to develop an restoration management plan for this property. Within DNR itself, collaboration between Office of Great Waters, Parks, Forestry, Wildlife, and NHC staff will be necessary for project success.

Since the designation of HSF there have been many important local partnerships to help address issues and maintenance on the property. In 1975, a local environmental organization called Equality and Quality of Life (EAQOL) solidified their relationship to HSF land by collaborating with citizens to form the Friends of Havenwoods (FOH). The FOH organizational goals are as follows: 1) help restore land at Havenwoods, 2) promote and enhance the use of Havenwoods as an environmental education facility, 3) provide space and opportunities for community participation, and 4) raise funds for the purposes. Over the course of FOH history, many citizens have joined and become active in its goals, and a few members have even remained since the early days. Along with FOH, other partnerships include those of Milwaukee Metropolitan Sewerage District (MMSD), Johnson Controls, and the local Sierra Club Great Waters Group.

Proposed Work

This project will plan, design, and implement recommendations that are proposed to be part of the future restoration management plan for this property. This includes implementing the proposed activities, while addressing portions of the Degradation of Fish and Wildlife populations BUI in the Milwaukee Estuary AOC and to produce a design that best represents improvements of the impacted populations. As part of this process, this site has been surveyed previously by University Milwaukee Field Station (UWFS). Results from this wildlife study provided important information about species and habitat found on this property. Potential enhancements to benefit fish and wildlife populations in this area include removal of invasive species, forest stand improvements due to loss of ash trees, backwater pond improvements, preservation and enhancements to ephemeral wetlands and maintenance of aquatic buffer zones.

Estimated Timetable and Duration

- Planning: Q1 2020 – Q4 2021
- Design and Permitting: Q1 2022 – Q3 2022
- Construction/Implementation: Q4 2022 – Q3 2024
- Maintenance and Vegetation Establishment: Q1 2025 – Q4 2027

Degradation of Fish and Wildlife Populations
Project Summary

Estimated Project Budget & Funding
The total project costs for this project is approximately $1M.

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)
The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet the all the goals below (highlighted in green) and show measures of success by an AOC wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (forest, wetland, shrubland, grassland, semi-aquatic, upland/grassland) to support a better population of wildlife indicator species:
    - Species and area of exotic invasive species removed
    - Amount (area or number) of native species planted to benefit wildlife indicator species
    - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
    - Amount (area) of habitat types created, enhanced and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
    - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for Lake sturgeon and Northern pike, respectively
    - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
    - Amount (length or area) of fish habitat or stream channel enhanced or restored
    - Amount (length) of corridor habitat improved or reconnected

Fish and Wildlife Metrics Addressed by Project
Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. Metrics were reviewed and agreed upon by the Tech Team to determine necessary steps and projects to remove this BUI. This project will take part in addressing certain aspects of following metrics:

Breeding Birds
- At least 9 sites in the AOC support at least 3 breeding bird indicator species for each habitat type (Forest, Wetland, and Shrubland)
- At least 6 sites in the AOC support at least 2 breeding bird grassland indicator species.
- At least 9 sites in the AOC support at least 1 breeding bird airspace/urban indicator species.

Herptiles/Crayfish
- At least 30 sites in the AOC support at least 2 semi-aquatic guilds (Crayfish, Salamanders, Frogs, Turtles).
    - At least 10 sites support at least one crayfish species.
    - At least 15 sites support at least one frog species.
- At least 15 sites in the AOC support at least 2 upland/grassland habitat indicator snake species.

Mammals
- At least 10 sites in the AOC support at least 2 mammal indicator species for each habitat type (Forest and Wetland)
- At least 5 sites within the AOC support at least 1 grassland mammal indicator species.

Degradation of Fish and Wildlife Populations
Project Summary

Project Rationale/Why Critical for BUI Removal

The process by the Milwaukee Estuary AOC Tech Team to determine management actions for the Degradation of Fish and Wildlife Populations BUI included a rigorous selection of high priority projects in the Milwaukee Estuary AOC to address this BUI. This project was ranked as a "Tier 1", high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only 15 (or 12.5%) were deemed Tier 1, high priority. It was determined to be important for upland/terrestrial habitat for snakes and semi-aquatic habitat for frogs. This project also scored the best possible cost-benefit score and scored the highest in all 34 high priority projects for benefiting from enhancements to all habitat associated breeding bird populations. It was also found to be important for forest mammals. The project is required to meet our metrics for removing the Degradation of Fish and Wildlife Populations BUI.

Necessary Project Elements

Elements for this project include:

- An invasive species and vegetation management plan with provisions made for long term implementation
- An ecological restoration management plan or equivalent that addresses the habitat goals of the Havenwoods State Forest and the population goals for this site of the Milwaukee Estuary AOC
- Stakeholder and public input during all phases of the project

Degradation of Fish and Wildlife Populations
Project Summary

Degradation of Fish and Wildlife Populations
Project Summary

Project Title: Wildlife Enhancements to Milwaukee County Grounds, Sanctuary Woods, MMSD Basins and Hoyt Park

Project Location: Area adjacent to and surrounding Milwaukee County Grounds Park

Project Sponsor: Milwaukee County Parks and MMSD

Project Landowner: Milwaukee County and MMSD

Background
Large habitat areas in the Milwaukee Estuary Area of Concern (AOC) that support a diverse number of wildlife and fish are unique and dispersed throughout the region. Through recent efforts to determine management actions (MA) for the Degradation of Fish and Wildlife Populations Beneficial Use Impairment (BUI) by the Milwaukee Estuary AOC Fish and Wildlife Technical Advisory Committee (Tech Team), this site has been determined as a key location in the Milwaukee Estuary AOC that provides important habitat for many wildlife indicator species. This 165-acre site on the Menomonee River and near the confluence with Underwood Creek comprises important habitat for numerous indicator species in the Milwaukee Estuary AOC, as well as being a well-documented autumn roosting area for migrating monarch butterflies. Important habitat areas at this site include upland grassland, forest, shrubland, and wetland/emergent marsh.

Collaboration with Partners
Milwaukee County is working with several partners on various aspects of park improvement and planning at Milwaukee County Grounds Park, Sanctuary Woods, and Hoyt Park. Some of these partners are friends' groups and others are non-profit organizations involved with restoration projects and initiatives throughout the County. It is important to the Wisconsin Department of Natural Resources (WNDR) to bring all stakeholders, partners and the landowners (Milwaukee County and MMSD) with an invested interest and involvement in this region to discuss the improvement of wildlife habitat at this large site along the Menomonee River. These stakeholders include but are not limited to Menomonee Valley Partners, Milwaukee Riverkeeper, Friends of Monarch Trail, The Park People, and the City of Wauwatosa.

Proposed Work
This project will plan and design project opportunities that proposes what is to be accomplished on the property. The project's proposition would include accomplishing the proposed activities, while addressing portions of the fish and wildlife populations BUI in the Milwaukee Estuary AOC. Projects should be designed in a way in which they can be sustained by project partners while best representing improvements of the impacted populations. As a part of this process, this site has been surveyed by staff from the University Milwaukee Field Station (UWFS) and Milwaukee County Parks. Results from this wildlife study provided important information about species and habitats found on this property. Potential enhancements to benefit wildlife populations in this area include removal of select invasive species populations, grassland/savanna enhancements focused on increasing forb diversity, forest stand improvements such as reforestation and wildlife shrub planting, basin improvements to wetland associated wildlife potentially creating small standing water pockets in the larger basins to provide

structural variability in water depths, preservation and enhancements to ephemeral wetlands and maintenance of aquatic buffer zones through the installation of native plants.

Estimated Timetable and Duration (Calendar Year)

- Planning: Q1 2021 – Q2 2022
- Design and Permitting: Q3 2022 – Q2 2023
- Construction/Implementation: Q3 2023 – Q4 2024
- Maintenance and Vegetation Establishment: Q1 2025 – Q2 2028

Estimated Project Budget & Funding

The total project costs from this project are approximately $3.2M.

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)

The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet the two goals below (highlighted in green) and show measures of success by an AOC wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (i.e. forest, wetland, shrubland, grassland, semi-aquatic, and upland/grassland) to support a better population of wildlife indicator species:
    - Species and area of exotic invasive species removed
    - Amount (area or number) of native species planted to benefit wildlife indicator species
    - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
    - Amount (area) of habitat types created, enhanced and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
    - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for lake sturgeon and northern pike, respectively
    - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
    - Amount (length or area) of fish habitat or stream channel enhanced or restored
    - Amount (length) of corridor habitat improved or reconnected

Fish and Wildlife Metrics Addressed by Project

Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. Metrics were reviewed and agreed upon by the Tech Team to determine necessary steps and projects to remove this BUI. This project will take part in addressing certain aspects of following metrics:

Breeding Birds

- At least 9 sites in the AOC support at least 3 breeding bird indicator species for each habitat type (Forest, Wetland, and Shrubland).
- At least 6 sites in the AOC support at least 2 breeding bird grassland indicator species.
- At least 9 sites in the AOC support at least 1 breeding bird Airspace/Urban species.

Herptiles/Crayfish

- At least 30 sites in the AOC support at least 2 semi-aquatic guilds (Crayfish, Salamanders, Frogs, and Turtles).
    - At least 10 sites support at least 1 crayfish species.
    - At least 15 sites support at least 1 frog species.
- At least 15 sites in the AOC support at least 2 upland/grassland habitat indicator snake species.

Mammals

- At least 10 sites in the AOC support at least 2 mammal indicator species for each habitat type (Forest and Wetland).
- At least 5 sites within the AOC support at least 1 grassland mammal indicator species.

Project Rationale/Why Critical for BUI Removal

The process by the Milwaukee Estuary AOC Tech Team to determine MAs for the Degradation of Fish and Wildlife Populations BUI included a rigorous selection of high priority projects in the Milwaukee Estuary AOC. This project was ranked as a "Tier 1", high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only 15 (or 12.5%) were deemed Tier 1, high priority. The proposed enhancements are important for semi-aquatic and upland/grassland habitat associated species. The site also contains 53 species of flora and fauna that the Milwaukee County Parks (primary site owner) lists as priority conservation species within Milwaukee County. The large size of this project (165 acres) provides important breeding habitat for forest, wetland, and grassland wildlife and migratory habitat for monarch butterflies and 159 species of birds documented using the site as part of their annual lifecycle. The opportunity to restore and manage the grassland and savanna habitat types is extremely rare in the Milwaukee Estuary AOC due to existing woodlands and urban development. This project scored the best possible cost-benefit score and scored the second highest in all 34 high priority projects for benefiting habitat-associated breeding-bird populations.

Necessary Project Elements

Elements for this project include:

- An invasive species and vegetation management plan with provisions made for long term implementation
- A conservation easement or equivalent for permanent protection of this site (i.e. non-developable land, zoned parkland)
- A conservation plan or equivalent that addresses the habitat goals of Milwaukee County Grounds, Sanctuary Woods, and Hoyt Park and the population goals for this site of the Milwaukee Estuary AOC
- An updated habitat management plan or equivalent for the MMSD basins
- Stakeholder and public input during all phases of the project

Degradation of Fish and Wildlife Populations
Project Summary

Degradation of Fish and Wildlife Populations
Project Summary

Project Title: Wildlife Enhancements to Kletzsch Park

Project Location: Kletzsch Park

Project Sponsor: Milwaukee County Parks

Project Landowner: Milwaukee County

Background

A large habitat area (86.2 acres) in the Milwaukee Estuary Area of Concern (AOC), directly adjacent to the Milwaukee River, supports a diverse number of wildlife and fish that are unique and dispersed throughout the region. This area on the Milwaukee River provides important grassland, forest, shrubland, and wetland habitat for several indicator species in the Milwaukee Estuary AOC. Through the recent efforts to determine management actions for the Degradation of Fish and Wildlife Populations Beneficial Use Impairment (BUI) by the Milwaukee Estuary AOC's Fish and Wildlife Technical Advisory Committee (Tech Team), this site has been determined as a key location in the Milwaukee Estuary AOC that provides important habitat for many wildlife indicator species.

Collaboration with Partners

Milwaukee County is working with several partners on various aspects of park improvement and planning at Kletzsch Park. While some of these partners are friends' groups, others are non-profit organizations that are involved with restoration projects and initiatives throughout the County. The project landowner for this site, Milwaukee County, has previously and continues to play an important role in implementing management actions for BUIs in the Milwaukee Estuary AOC.

Proposed Work

This project will plan and implement project opportunities that are proposed to be accomplished on this property, while addressing portions of the fish and wildlife populations BUI in the Milwaukee Estuary AOC that best represents improvements of the impacted populations. As part of this process, this site has been surveyed previously by Milwaukee County Parks. Results from this wildlife study and on-going park surveys provided important information about species and habitat found on this property. Potential enhancements to benefit wildlife populations in this area include removal of select invasive species populations; upland grassland/savanna enhancements by increasing native plant diversity through conversion of cool season grassland to a diverse prairie seeding and managing with prescribed burns; upland and lowland forest stand improvements such as reforestation to mitigate severe canopy loss from emerald ash borer; preservation and enhancements of ephemeral wetlands by lengthening hydro-periods; and maintenance of aquatic buffer zones through the installation of native plants.

Timetable and Duration

- Planning: Q1 2021 – Q4 2021
- Design and Permitting: Q1 2022 – Q4 2022
- Construction/Implementation: Q1 2023 – Q4 2024
- Maintenance and Vegetation Establishment: Q1 2025 – Q2 2028

Project Budget & Funding

The total project costs for this project is approximately $1.15M.

Degradation of Fish and Wildlife Populations
Project Summary

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)
The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet the two goals below (highlighted in green) and show measures of success by an AOC wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (i.e. forest, wetland, shrubland, grassland, semi-aquatic, and upland/grassland) to support a better population of wildlife indicator species:
    - Species and area of exotic invasive species removed
    - Amount (area or number) of native species planted to benefit wildlife indicator species
    - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
    - Amount (area) of habitat types created, enhanced and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
    - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for lake sturgeon and northern pike, respectively
    - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
    - Amount (length or area) of fish habitat or stream channel enhanced or restored
    - Amount (length) of corridor habitat improved or reconnected

Fish and Wildlife Metrics Addressed by Project
Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. Metrics were reviewed and agreed upon by the Tech Team to determine necessary steps and projects to remove this BUI. This project will take part in addressing certain aspects of following metrics:

Breeding Birds
- At least 9 sites in the AOC support at least 3 breeding bird indicator species for each habitat type (Forest, Wetland, and Shrubland)
- At least 6 sites in the AOC support at least 2 breeding bird grassland indicator species.

Herptiles/Crayfish
- At least 30 sites in the AOC support at least 2 semi-aquatic guilds (Crayfish, Salamanders, Frogs, and Turtles).
    - At least 15 sites support at least 1 frog species.
    - At least 6 sites support at least 1 turtle species.

Mammals
- At least 10 sites in the AOC support at least 2 mammal indicator species for each habitat type (Forest and Wetland)

Project Rationale/Why Critical for BUI Removal
The process by the Milwaukee Estuary AOC Tech Team to determine management actions for the Degradation of Fish and Wildlife Populations BUI included a rigorous selection of high priority projects in the Milwaukee Estuary AOC to address said BUI. This project was ranked as a "Tier 1", high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only

15 (or 12.5%) were deemed Tier 1, high priority. It was determined to be important for semi-aquatic habitat associated species. The site also contains 143 species of flora and fauna that the Milwaukee County Parks (site owner) lists as priority conservation species within Milwaukee County. The large size of this project site provides important habitat for forest and wetland breeding and migratory birds (165 species documented using this site during a portion of their annual life cycle), and breeding mammals. This park is part of the Milwaukee River corridor and is a required project to meet our wildlife metrics for BUI removal. It also builds off the current project at Kletzsch Park for improved river access and fish passage.

Necessary Project Elements

Elements for this project include:

- An invasive species and vegetation management plan with provisions made for long term implementation
- A conservation easement or equivalent for permanent protection of this site (i.e. non-developable land, zone parkland)
- A conservation plan or equivalent that addresses the habitat goals of Kletzsch Park and the population goals for this site of the Milwaukee Estuary AOC
- Stakeholder and public input during all phases of the project

Degradation of Fish and Wildlife Populations
Project Summary

Degradation of Fish and Wildlife Populations
Project Summary

Project Title: Enhancements to Schlitz Audubon Cleaver Property

Project Location: Schlitz Audubon Nature Center – Milwaukee River

Project Sponsor: Schlitz Audubon

Project Landowner: National Audubon Society, Inc.

Background
Schlitz Audubon Nature Center and their staff are in the process of developing a conservation management plan for their river site on the Milwaukee River. Through the recent efforts to determine management actions for the Degradation of Fish and Wildlife Populations Beneficial Use Impairment (BUI) by the Milwaukee Estuary Area of Concern (AOC) Fish and Wildlife Technical Advisory Committee (Tech Team), this site on the Milwaukee River, has been determined as a key location in the Milwaukee Estuary AOC that provides important habitat for many fish and wildlife indicator species.

Collaboration with Partners
The Wisconsin Department of Natural Resources are planning on working with the Schlitz Audubon Nature Center and their partners on achieving the conservation goals of the Audubon Society, as well as the AOC program to address the Degradation of Fish and Wildlife Populations BUI in the Milwaukee Estuary AOC. These partners include but are not limited to Ozaukee County, River Revitalization Foundation, Milwaukee Riverkeeper, and Village of River Hills.

Proposed Work
This project will plan and design project elements that are proposed to be part of the completed conservation management plan. This would include collaborating to address site management goals, including portions of the fish and wildlife populations BUI in the Milwaukee Estuary AOC and to produce a design that best represents improvements of the impacted populations. As part of this process, this site has been surveyed previously by University Milwaukee Field Station (UMFS). Results from this wildlife study provided important information about species and habitat found on this property. Potential enhancements to benefit fish and wildlife populations in this area of the Milwaukee River include removal of invasive species, forest stand improvements due to loss of ash trees, shoreline improvements, and preservation of ephemeral wetlands.

Estimated Timetable and Duration (Calendar Year)
- Planning: Q1 2021 – Q1 2022
- Design and Permitting: Q2 2022 – Q1 2023
- Construction/Implementation: Q2 2023 – Q3 2024
- Maintenance and Vegetation Establishment: Q4 2024 – Q4 2028

Estimated Project Budget & Funding
Total project costs for this project are approximately $1.3M.

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)

Degradation of Fish and Wildlife Populations
Project Summary

The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet all the goals below (highlighted in green) and show measures of success by an AOC wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (forest, wetland, shrubland, grassland, semi-aquatic, upland/grassland) to support a better population of wildlife indicator species:
    - Species and area of exotic invasive species removed
    - Amount (area or number) of native species planted to benefit wildlife indicator species
    - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
    - Amount (area) of habitat types created, enhanced and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
    - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for Lake sturgeon and Northern pike, respectively
    - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
    - Amount (length or area) of fish habitat or stream channel enhanced or restored
    - Amount (length) of corridor habitat improved or reconnected

Fish and Wildlife Metrics Addressed by Project
Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. Metrics were reviewed and agreed upon by the Tech Team to determine necessary steps and projects to remove this BUI. This project will take part in addressing certain aspects of following metrics:

Upper Milwaukee Estuary AOC
(Upstream of Humboldt Avenue on the Milwaukee River to Bridge Road on Cedar Creek; Upstream of N 25th Street on the Menomonee River to Brown Deer Road on the Little Menomonee River; No upper reach for the Kinnickinnic River)

- Presence of the indicator species, lake sturgeon, utilizing spawning habitat in the upper reaches of the Milwaukee River
- An overall mean value from all warmwater IBI sampling efforts of "Good" or better (i.e. 51-65) in the upper reaches of the Milwaukee River

Breeding Birds

- At least 9 sites in the AOC support at least 3 breeding bird indicator species for each habitat type (Forest, Wetland, and Shrubland)
- At least 6 sites in the AOC support at least 2 breeding bird grassland indicator species.

Herptiles/Crayfish

- At least 30 sites in the AOC support at least 2 semi-aquatic guilds (Crayfish, Salamanders, Frogs, Turtles).
    - At least 10 sites support at least one crayfish species.
    - At least 15 sites support at least one frog species.
    - At least 8 sites support Blue-spotted salamanders.
    - At least 6 sites support at least one turtle species.

- At least 15 sites in the AOC support at least 2 upland/grassland habitat indicator snake species.

Mammals

- At least 10 sites in the AOC support at least 2 mammal indicator species for each habitat type (Forest and Wetland)

Project Rationale/Why Critical for BUI Removal

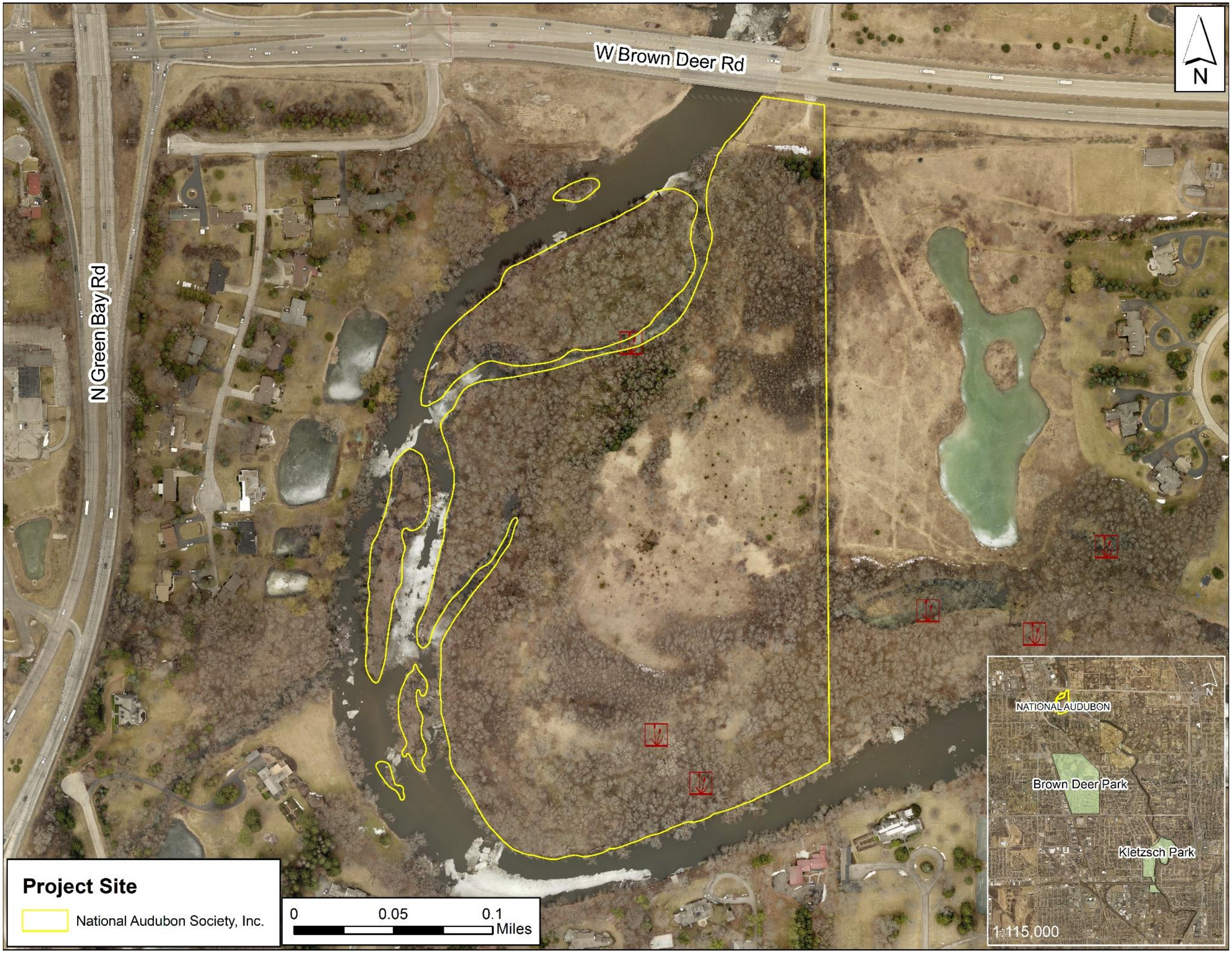
The process by the Milwaukee Estuary AOC Tech Team to determine management actions for the Degradation of Fish and Wildlife Populations BUI included a rigorous selection of high priority projects in the Milwaukee Estuary AOC to address this BUI. This project was ranked as a "Tier 1", high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only 15 (or 12.5%) were deemed Tier 1, high priority. It was determined to be important for frogs, salamanders, wetland breeding birds and all four fish indicator species (northern pike, lake sturgeon, greater redhorse, smallmouth bass). This project also scored the highest in all 34 high priority projects for addressing the semi-aquatic habitat impairment in the Milwaukee Estuary AOC.

Necessary Project Elements

Elements for this project include:

- An invasive species and vegetation management plan (aquatic and terrestrial) with provisions made for long term implementation
- A conservation easement or equivalent for permanent protection of this site
- A conservation plan that addresses the habitat goals of the National Audubon Society, Inc. and the population goals for this site of the Milwaukee Estuary AOC
- Stakeholder and public input during all phases of the project

Degradation of Fish and Wildlife Populations
Project Summary



Degradation of Fish and Wildlife Populations
Project Summary

Project Title: Enhancements to Menomonee River Parkway – Sections 5 & 6

Project Location: Menomonee River Parkway – Section 5 (W Hampton Ave to W Capitol Dr) and Section 6 (N Mayfair Rd to W Burleigh St)

Project Sponsor: Milwaukee County Parks

Project Landowner: Milwaukee County

Background
These focus areas within the Menomonee River (MNR) Parkway provide important habitat in the Menomonee River corridor. Menomonee River Parkway – Section 5 encompasses 135 acres of land, most of which is covered by declining floodplain forest (from emerald ash borer) and contains offline wetlands, as well as ephemeral ponds. As a result, it provides important wetland, forest, and fisheries habitat for indicator species in the Milwaukee Estuary Area of Concern (AOC). This area has the potential to become more valuable through much needed enhancements to the degraded forest canopy through replacing dead ash trees and the removal of invasive species.

Menomonee River Parkway – Section 6 covers 43 acres of natural habitat, which supports a diverse group of indicator species not found anywhere else in the lower sections of the Menomonee River Parkway. This provides important habitat for unique semi-aquatic species through five off-line ephemeral ponds. Preservation and enhancements to these valuable habitat types in the Milwaukee Estuary AOC is vital for the Degradation of Fish and Wildlife (F&W) Populations Beneficial Use Impairment (BUI). This area has the potential to become more valuable through much needed enhancements to the degraded forest canopy through replacing dead ash trees and removal of invasive species.

Collaboration with Partners
Milwaukee County is working with several partners on various aspects of park improvement and planning along the Menomonee River Parkway. While some of these partners are friends' groups, others are non-profit organizations and government entities that are involved with restoration projects and initiatives throughout the County. It is important to the Wisconsin Department of Natural Resources (WNDR) to bring all stakeholders, partners, and landowner (Milwaukee County) with an invested interest and involvement in this region to discuss the improvement of fish and wildlife habitat along the Menomonee River.

Proposed Work
This project will plan and design project opportunities that are proposed to be accomplished on this property. This would include the proposed activities, while addressing portions of the F&W Populations BUI in the Milwaukee Estuary AOC and to produce a design that best represents improvements of the impacted populations. As part of this process, these sites have been surveyed previously by the University Milwaukee Field Station (UWFS), Ozaukee County Planning and Parks (OCPP), and Milwaukee County Parks. Results from these studies provided important information about species and habitat found along this portion of the Menomonee River Parkway. Potential enhancements to benefit fish and wildlife populations in this area include removal of select invasive species populations, forest stand improvements such as reforestation and select canopy thinning due to the decline of ash trees, basin improvements to wetland associated wildlife and fishes to improve spawning habitat, preservation and

enhancements to 18 off-line ephemeral wetlands, and maintenance of aquatic buffer zones through the removal of debris jams and the installation of native plants.

Estimated Timetable and Duration (Calendar Year)

- Planning: Q1 2020 – Q1 2022
- Design and Permitting: Q2 2022 – Q1 2023
- Construction/Implementation: Q2 2023 – Q4 2024
- Maintenance and Vegetation Establishment: Q1 2025 – Q4 2028

Estimated Project Budget & Funding

The total projects costs for this project are approximately $3.2M.

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)

The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet all the goals below (highlighted in green) and show measures of success by an AOC wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (forest, wetland, shrubland, grassland, semi-aquatic, upland/grassland) to support a better population of wildlife indicator species:
    - Species and area of exotic invasive species removed
    - Amount (area or number) of native species planted to benefit wildlife indicator species
    - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
    - Amount (area) of habitat types created, enhanced and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
    - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for lake sturgeon and northern pike, respectively
    - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
    - Amount (length or area) of fish habitat or stream channel enhanced or restored
    - Amount (length) of corridor habitat improved or reconnected

Fish and Wildlife Metrics Addressed by Project

Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. Metrics were reviewed and agreed upon by the Tech Team to determine necessary steps and projects to remove this BUI. This project will take part in addressing certain aspects of following metrics:

Upper Milwaukee Estuary AOC

(Upstream of Humboldt Avenue on the Milwaukee River to Bridge Road on Cedar Creek; Upstream of N 25th Street on the Menomonee River to Brown Deer Road on the Little Menomonee River; No upper reach for the Kinnickinnic River)

- Presence of the indicator species, northern pike, utilizing spawning habitat in the upper reaches of the Menomonee/Little Menomonee River

- An overall mean value from all warmwater IBI sampling efforts of "Fair" or better (i.e. 31-50) in the upper reaches of the Menomonee River

Breeding Birds

- At least 9 sites in the AOC support at least 3 breeding bird indicator species for each habitat type (Forest, Wetland, and Shrubland)
- At least 9 sites in the AOC support at least 1 breeding bird airspace/urban indicator species.

Herptiles/Crayfish

- At least 30 sites in the AOC support at least 2 semi-aquatic guilds (Crayfish, Salamanders, Frogs, and Turtles).
    - At least 10 sites support at least 1 crayfish species.
    - At least 15 sites support at least 1 frog species.
    - At least 8 sites support Blue-spotted Salamanders.

Mammals

- At least 10 sites in the AOC support at least 2 mammal indicator species for each habitat type (Forest and Wetland)

Project Rationale/Why Critical for BUI Removal

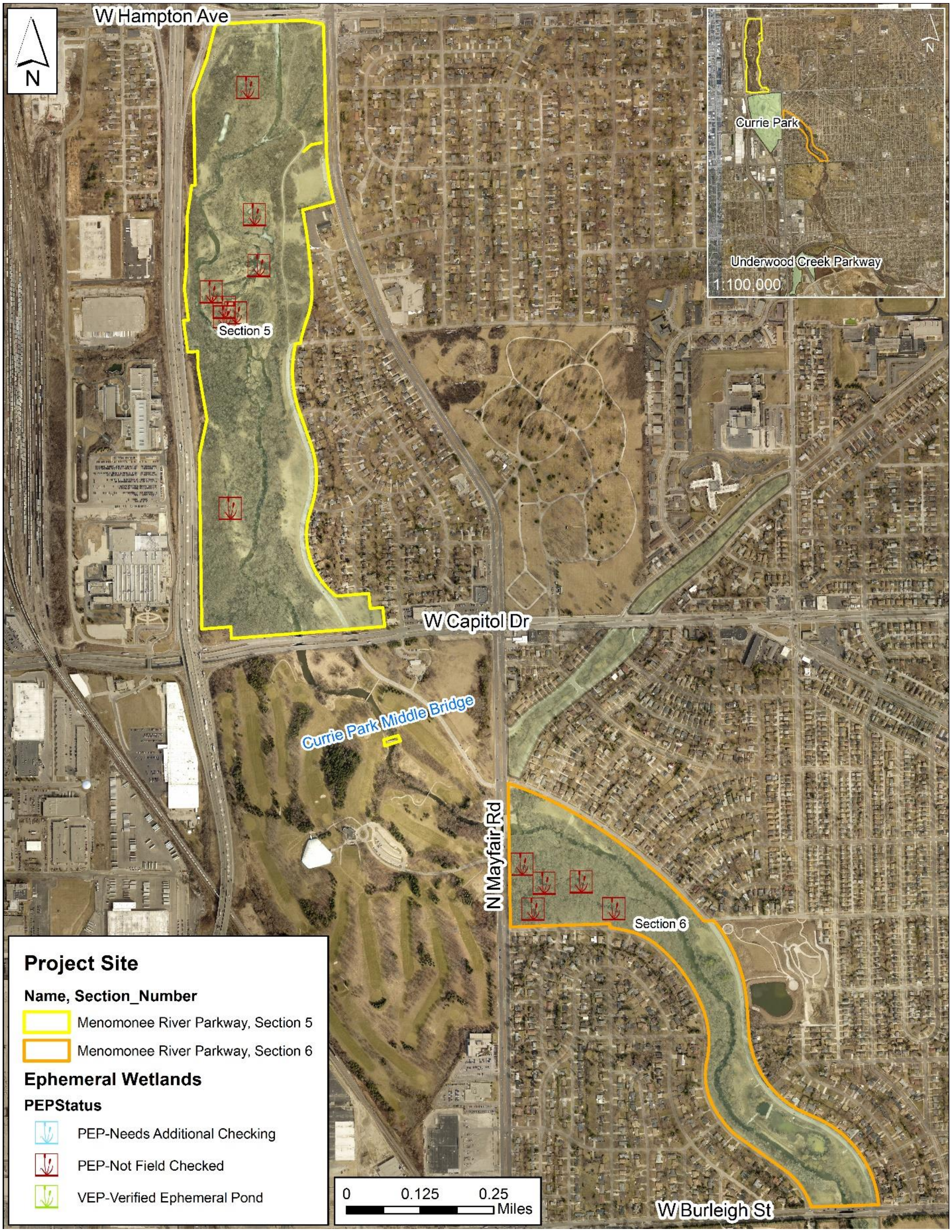
The process by the Milwaukee Estuary AOC Tech Team to determine MAs for the Degradation of Fish and Wildlife Populations BUI included a rigorous selection of high priority projects in the Milwaukee Estuary AOC in order to address it. This project was ranked as a "Tier 1", high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only 15 (or 12.5%) were deemed Tier 1, high priority. It was determined to be extremely important for semi-aquatic habitat indicator species (i.e. crayfish, frogs, and salamanders). This project also provides the best benefit for forest and wetland habitat associated breeding and migratory birds (121 species documented using this site as part of their annual lifecycle) and breeding and dispersing mammals. It also scored the best possible score for benefiting from enhancements to northern pike spawning habitat. It is well connected to the Menomonee River corridor and has the potential to greatly help our wildlife metrics for BUI removal. The site also contains 90 species of flora and fauna that the Milwaukee County Parks (site owner) lists as priority conservation species within Milwaukee County.

Necessary Project Elements

Elements for this project include:

- An invasive species and vegetation management plan with provisions made for long term implementation
- A conservation easement or equivalent for permanent protection of these sites (i.e. non-developable land, zoned parkland)
- A conservation plan or equivalent that addresses the goals of Menomonee River Parkway Sections 5 & 6 and the population goals for these sites in the Milwaukee Estuary AOC
- Stakeholder and public input during all phases of the project.

Degradation of Fish and Wildlife Populations
Project Summary



Degradation of Fish and Wildlife Populations
Project Summary

Project Title: Currie Park Fish Passage

Project Location: Currie Park Golf Course

Project Sponsor: DNR

Project Landowner: Milwaukee County

Background
The Menomonee River Watershed covers 136 square miles, originating in wetlands in southeastern Washington County and flowing 28 miles south and east where it joins the Milwaukee River just upstream from its confluence with Lake Michigan. The Menomonee River Watershed is 80% urbanized, and has been impacted by past filling activities, development, river channelization, agricultural runoff, and urban stormwater discharges. Despite this, most of the upper Menomonee River system contains fair to good warm water fish habitat. The river system is now undergoing a renaissance with recent removal of 4,000 feet of concrete channel downstream, as well as removal of four other low-flow fish passage barriers and construction of one rock ramp in downstream Hoyt Park of Wauwatosa. This previous work was completed by the Milwaukee Metropolitan Sewerage District in coordination with the WDNR as management actions for the Loss of F&W Habitat BUI. While this has addressed several major barriers to fish migration, other fish passage barriers still exist in the watershed.

The implementation and completion of this project is necessary to address the status of the Degradation of F&W Populations BUI in the Milwaukee Estuary AOC. Through the recent efforts to determine management actions for this BUI by the Milwaukee Estuary AOC Fish and Wildlife Technical Advisory Committee (Tech Team), this project was determined to address two of the overall outcome goals for this BUI and two specific output fish metrics for the Upper Milwaukee Estuary AOC. This site has been surveyed previously by Ozaukee County Planning and Parks (OCPP) and Milwaukee Riverkeeper for fish passage improvements. Results from these assessments provided important information about species native to the Menomonee River that would benefit from this work. These species include northern pike, brook stickleback, central stoneroller, and fantail and Johnny darter. Removing this impediment would improve stream connectivity during these low flow conditions and improve native fish passage for approximately 10 miles along the main stem until the next major stream barrier in Menomonee Falls. It is estimated that the project would also enhance connectivity for several miles of tributary streams leading to the Menomonee River. When this fish passage impediment is removed, this site on the Menomonee River will no longer deter movement of native fishes to move upstream during their spawning season.

Collaboration with Partners
Milwaukee County is working with several partners on various aspects of park improvement and planning along the Menomonee River and Little Menomonee River Parkway. While some of these partners are friends' groups, others are non-profit organizations and government entities that are involved with restoration projects and initiatives throughout the County. It is important to the WDNR to bring all stakeholders, partners, and landowner (Milwaukee County) with an invested interest and involvement in this region to discuss the improvement of fish habitat and movement along the Menomonee River.

Degradation of Fish and Wildlife Populations
Project Summary

Proposed Work

This project will plan and implement the removal of a low-head concrete slab pedestrian bridge, the middle access bridge at Currie Park. This golf course has three separate access bridges for golf carts and foot traffic throughout the 18-hole course. The middle access bridge is a concrete pedestrian bridge that also acts as a low-flow fish barrier that was historically placed on top of roughly a dozen small, undersized culverts. Work will include removal of this bridge and stabilization of the shoreline along the Menomonee River to allow fish passage improvements. The removal would be implemented by the WDNR Fisheries Operations Unit, who are experienced at removing these types of structures for fish passage. The WDNR Fisheries team will rent the heavy equipment needed for the removal and contract the hauling of the debris material offsite. WDNR has already looked for an associated permit to this bridge and found that this structure is in non-compliance. Removal of the fish passage impediment will benefit fish populations by allowing easier movement upstream and contribute to achieving the goals of this BUI and fish metrics for the Menomonee River in the Milwaukee Estuary AOC.

Estimated Timetable and Duration (Calendar Year)

- Planning: Q1 2020 – Q4 2020
- Permitting: Q3 2020 & Q4 2020
- Construction/Implementation: Q1 2021 & Q2 2021
- Maintenance and Vegetation Establishment: Q3 2021 & Q4 2021

Estimated Project Budget & Funding

- Planning/Feasibility: $5,000
- Permitting: $10,000
- Construction/Implementation: $40,000
- Maintenance: $5,000

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)

The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet the two of the three goals below (highlighted in green) and show measures of success by an AOC wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (i.e. forest, wetland, shrubland, grassland, semi-aquatic, and upland/grassland) to support a better population of wildlife indicator species:
    - Species and area of exotic invasive species removed
    - Amount (area or number) of native species planted to benefit wildlife indicator species
    - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
    - Amount (area) of habitat types created, enhanced and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
    - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for lake sturgeon and northern pike, respectively
    - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
    - Amount (length or area) of fish habitat or stream channel enhanced or restored

- Amount (length) of corridor habitat improved or reconnected

Fish and Wildlife Metrics Addressed by Project

Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. Metrics were reviewed and agreed upon by the Tech Team to determine necessary steps and projects to remove this BUI. This project will take part in addressing certain aspects of following metrics:

Upper Milwaukee Estuary AOC

(Upstream of Humboldt Avenue on the Milwaukee River to Bridge Road on Cedar Creek; Upstream of N 25th Street on the Menomonee River to Brown Deer Road on the Little Menomonee River; No upper reach for the Kinnickinnic River)

- Presence of the indicator species, northern pike, utilizing spawning habitat in the upper reaches of the Menomonee/Little Menomonee River
- An overall mean value from all warmwater IBI sampling efforts of “Fair” or better (i.e. 31-50) in the upper reaches of the Menomonee River

Project Rationale/Why Critical for BUI Removal

The process by the Milwaukee Estuary AOC Tech Team to determine MAs for the Degradation of Fish and Wildlife Populations BUI included a rigorous selection of high priority projects in the Milwaukee Estuary AOC in order to address it. This project was ranked as a “Tier 1”, high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only 15 (or 12.5%) were deemed Tier 1, high priority. It was determined to be extremely important and had the best possible score for benefiting from enhancements to northern pike spawning habitat on the Menomonee River.

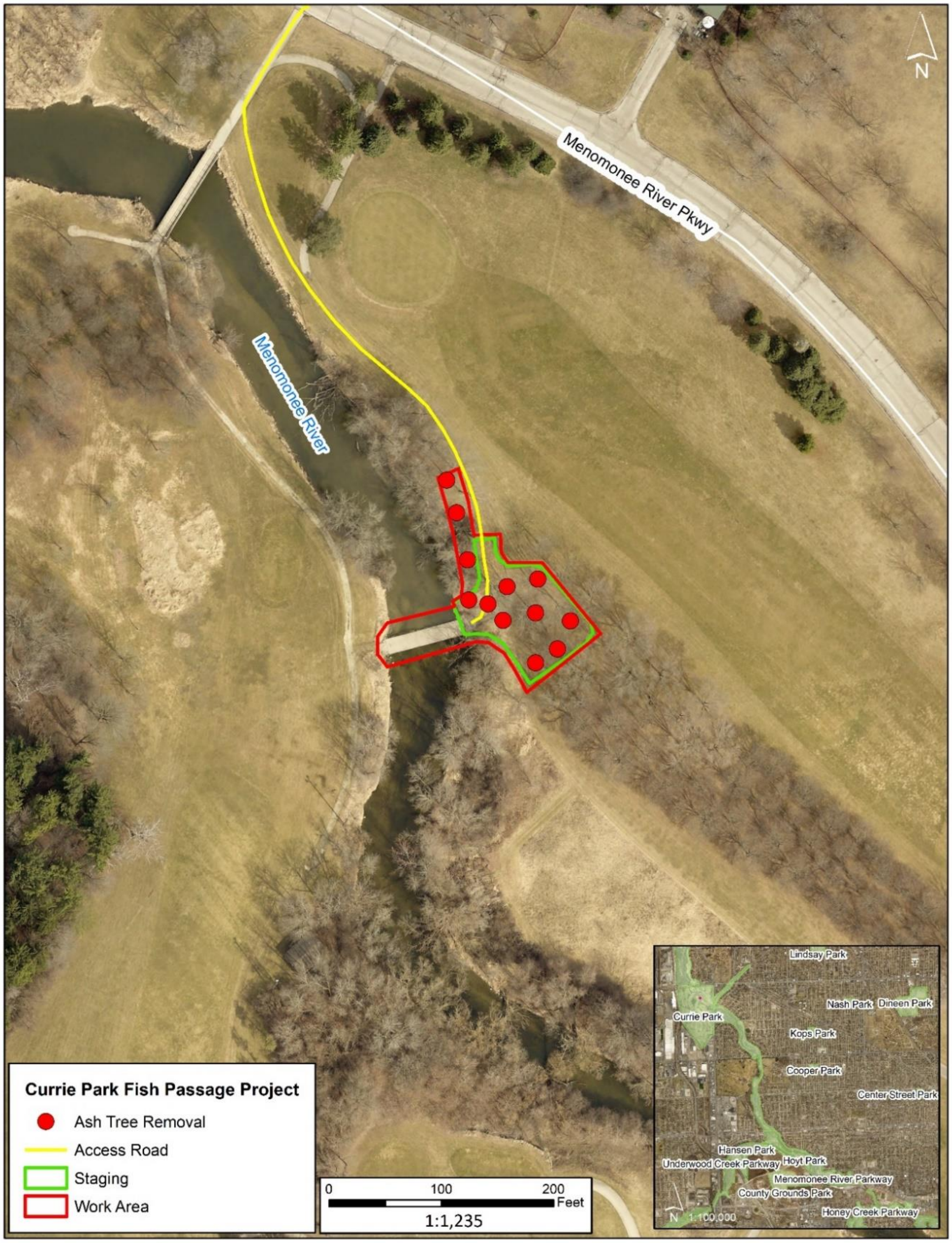
Necessary Project Elements

Elements for this project include:

- Removal of the low-head concrete bridge on the Menomonee River
- Shoreline stabilization of the bridge abutments
- Vegetation maintenance at the abutments and re-seeing of the access road
- Stakeholder and public input during all phases of the project


Currie Park low-head concrete bridge on the Menomonee River during relatively high water a few days after a rain event in Fall 2019.

Degradation of Fish and Wildlife Populations
Project Summary



Sources of Data: Wisconsin DNR, Milwaukee County Parks, ESRI
Date Created: 01/13/2020
Projection: NAD_1983 HARN_Wisconsin_TM

Degradation of Fish and Wildlife Populations
Project Summary

Project Title: Fisheries Improvements to Milwaukee River Downstream – E Cherry Street to N Humboldt Avenue

Project Location: Milwaukee River Downstream (Reach 4) – E Cherry Street to N Humboldt Avenue

Project Sponsor: Milwaukee Metropolitan Sewerage District (MMSD) or TBD

Project Landowners: City of Milwaukee and many private landowners

Background
The Lower Milwaukee Estuary in the Milwaukee Estuary Area of Concern (AOC) has limited fish habitat and cover in its three tributaries (Milwaukee River, Menomonee River, and Kinnickinnic River). Pre-historically, the natural productivity, functions, and values of the Milwaukee Estuary were driven by extensive and diverse aquatic primary producers, local sediment transport, and morphology. Engineered vertical bulkheads, dredging for commercial navigation maintenance depth, sediment quality, and greatly reduced light transparency currently limit rooted aquatic plants. These lower portions of the tributaries are impacted by multiple river hydrology inputs (i.e. urban runoff, warm/cool water discharge, combined sewage overflows, lake upwelling and seiche effects, etc.). Common seasonal water temperatures and flow regimes are impacted by all these factors. The Milwaukee River, being the largest and having the best water quality of the three tributaries, provides the best potential to generate better fish populations in the lower Milwaukee Estuary AOC. This section of the river is dominated by silt--much substrate and depths in most locations exceed the light penetrating photic zone. Other areas along the shoreline have experienced considerable shoaling and in combination with improved water quality provide potential habitat for macrophyte growth.

The Milwaukee River between E Cherry Street and N Humboldt Avenue is currently part of a Great Lakes Legacy Act (GLLA) project. The characterization of this section of river has been completed and is found in reach four of Milwaukee River Downstream (MRD). Results from this characterization highlighted that reach four contains the most known remaining sediment contamination in the Milwaukee Estuary AOC (> 600,000 CY of sediments contain total PCB concentrations greater than 1mg/kg). A future focused feasibility study (FFS), remedial design (RD) and action (RA) will be completed for this section of the river under the GLLA. It is unknown at this time within the project summary if the fisheries improvement project will be tied to the GLLA and post-remediation of MRD reach four. However, if this project were to be implemented through the Degradation of Fish and Wildlife Populations Beneficial Use Impairment (BUI), work would not start until after this site is remediated with the selected alternative.

From 2016 to 2019, the USFWS Green Bay Fish and Wildlife Conservation Office's Aquatic Invasive Species early detection team conducted surveys in the lower Milwaukee Estuary AOC. A total of 308 individual points were surveyed using a variety of gears including Gillnets, paired fyke nets, cloverleaf traps, and day and nighttime boat electrofishing. A total of 13,273 fish representing 58 species were surveyed. A total of 11 individual points were surveyed in or near the project area from August and September of 2016 – 2019 by the USFWS' Aquatic Invasive Species early detection team using boat electrofishing (Figure 2). A total of 593 fish representing 26 different species were surveyed. These were dominated by common shiner (28.2% of total fish caught) and smallmouth bass (26.5%) followed by golden redhorse (6.6%), white sucker (5.9%), sand shiner (4.7%), gizzard shad (3.5%), largemouth bass (3.2%), emerald shiner (2.9%), bluntnose minnow (2.7%), and shorthead redhorse (2.3%). Indicator species made up 28.1% of the total catch, dominated by smallmouth bass (26.5%). Sub-indicator species represented 29.2% of the total catch and were dominated by golden redhorse, white sucker, sand shiner, and largemouth bass (see percentages above). Of the 3 sites surveyed within the physical project boundary, a total of 46 fish were caught, 60.1% of which were sub-indicator species.

This project provides similar benefits to the Menomonee River project proposal, located between N 16th to N 25th Street. Both of which enhance biological deserts (Dow, 2018) in the lower Milwaukee Estuary that are commonly used for migratory spawning indicator fish (i.e. lake sturgeon, northern pike, and greater redhorse). Through the recent efforts to determine management actions for the Degradation of Fish and Wildlife Populations BUI by the Milwaukee Estuary AOC Fish and Wildlife Technical Advisory Committee (Tech Team), this site has been determined as a key location in the Milwaukee Estuary AOC that provides important habitat for many wildlife indicator species.

Collaboration with Partners

The Wisconsin Department of Natural Resources (WDNR) is planning on determining the best course of action for planning, design, and implementation of this project. Stakeholders that have been involved with watercourse projects in the past for the Milwaukee Estuary AOC include the Milwaukee Metropolitan Sewerage District (MMSD), as well as the U.S. Army Corps of Engineers (USACE). It is important for the WDNR to bring all stakeholders and partners involved to the table to discuss the improvement of fish habitat and populations in the lower sections of the Milwaukee River. There are many private landowners on both shorelines between the E Cherry Street and N Humboldt Avenue Bridges.

Proposed Work

The plan and design of this project will vary depending on the alternative that is selected for remediation in Reach 4 of the MRD project. The benefit of having this project implemented post-remediation is the well-known information and data in this section of the Milwaukee River. Implementing a fisheries project, bound by bulkhead steel sheet pilings, will require placing habitat features in specific locations to generate the best water flow throughout the year, while staying within regulations of the floodplain. Possible features include, but are not limited to: A meandering bottom morphology using clean, washed coarse gravels that benefit spawning fishes and set as submerged bars with specific slopes and elevations to keep the flow in main channel; the addition of sand/gravel bars along channel sides at appropriate varying elevations; establishment of native rooted submergent, emergent, and floating macrophytes in shallow bars; enhancement of larger rock material to provide cover on staggered, alternating sides of the channel to increase water flow; and enhancements to woody habitat by placing structures in combination with added boulders.

Timetable and Duration

- Planning: Q1 2021 – Q2 2022
- Design and Permitting: Q3 2022 – Q2 2023
- Construction/Implementation: Q3 2023 – Q3 2024
- Maintenance and Vegetation Establishment: Q4 2024 – Q4 2026

Project Budget & Funding

The total project costs for this project are approximately $4.5M.

Degradation of Fish and Wildlife Populations
Project Summary

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)

The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet the two goals below (highlighted in green) and show measures of success by an AOC wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (i.e. forest, wetland, shrubland, grassland, semi-aquatic, and upland/grassland) to support a better population of wildlife indicator species:
   - Species and area of exotic invasive species removed
   - Amount (area or number) of native species planted to benefit wildlife indicator species
   - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
   - Amount (area) of habitat types created, enhanced and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
   - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for lake sturgeon and northern pike, respectively
   - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
   - Amount (length or area) of fish habitat or stream channel enhanced or restored
   - Amount (length) of corridor habitat improved or reconnected

Fish and Wildlife Metrics Addressed by Project

Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. Metrics were reviewed and agreed upon by the Tech Team to determine necessary steps and projects to remove this BUI. This project will take part in addressing certain aspects of following metrics:

Lower Milwaukee Estuary AOC

(Downstream of Humboldt Avenue on the Milwaukee River; Downstream of N 25th Street on the Menomonee River; Downstream of W Becher Street on the Kinnickinnic River)

- A 100% increase in relative population density in four indicator species (i.e. lake sturgeon, northern pike, greater redhorse, and smallmouth bass)
- An increase of any magnitude in 80% of native sub-indicator families (i.e. suckers, minnows and shiners, bullheads and catfishes, sunfishes, and perches) to be considered
- An overall mean value from all large river IBI sampling efforts of “Fair” or better (i.e. 41-60)

Project Rationale/Why Critical for BUI Removal

The process by the Milwaukee Estuary AOC Tech Team to determine management actions for the Degradation of Fish and Wildlife Populations BUI included a rigorous selection of high priority projects in the Milwaukee Estuary AOC to address this BUI. This project was ranked as a “Tier 1”, high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only 15 (or 12.5%) were deemed Tier 1, high priority. It was determined to be important for all four fish indicator species (i.e. northern pike, lake sturgeon, greater redhorse, and smallmouth bass). This project also scored the highest possible cost-benefit score for implementation. It provides benefits to all sub-indicator families in the metrics, but specifically focuses on suckers, minnows, and shiners. The benefits to connecting fish populations are greatly enhancing cover in a section of the Milwaukee River, which has been previously described as a biological desert, is a major step for addressing the fish portion of this BUI in the lower Milwaukee Estuary.

Necessary Project Elements
Elements for this project include:

- A conservation easement or equivalent for protection of this site (i.e. deauthorized channel)
- Implementation of fish enhancements post site remediation under the GLLA or this BUI
- Stakeholder and public input during all phases of the project

Degradation of Fish and Wildlife Populations
Project Summary

Figure 1. Project site of Milwaukee River – Cherry to Humboldt Avenue

Degradation of Fish and Wildlife Populations
Project Summary

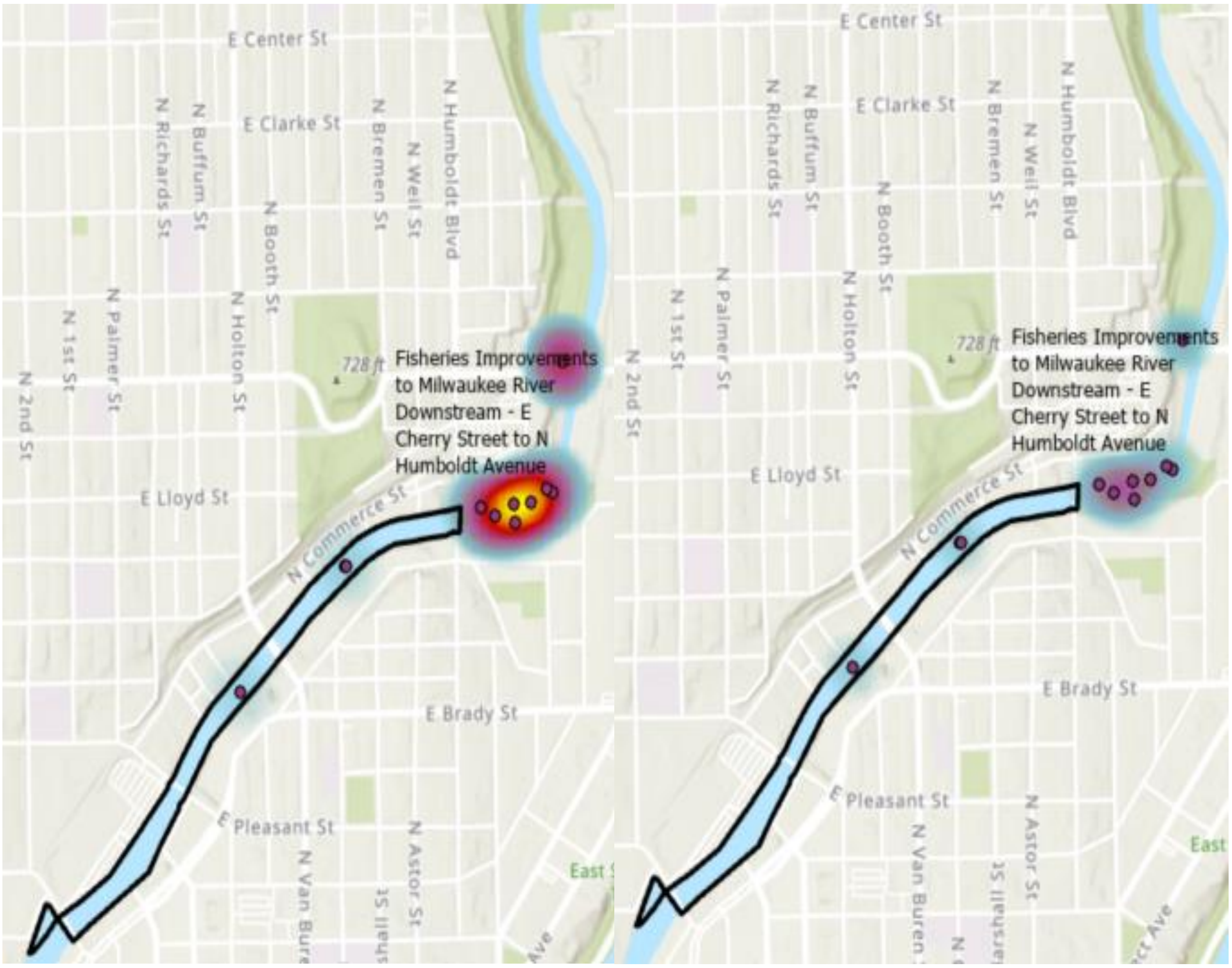


Figure 2. (left) Densities of indicator species surveyed by the USFWS Aquatic Invasive Species early detection team in and near the Cherry Street project area from 2016-2019. (right) Densities of sub-indicator species. Project boundary is outlined in black.

Degradation of Fish and Wildlife Populations
Project Summary

Project Title: Fisheries Improvements to Menomonee River – N 16th to N 25th Street

Project Location: Deauthorized Section of Menomonee River (N 16th to N 25th Street)

Project Sponsor: City of Milwaukee or TBD

Project Landowners: City of Milwaukee, Marquette University, Giuffre, LLC.

Background
The lower region of the Milwaukee Estuary Area of Concern (AOC) has limited fish habitat and cover in its three tributaries (Milwaukee River, Menomonee River, and Kinnickinnic River). Pre-historically, the natural productivity, functions, and values of the Milwaukee Estuary were driven by extensive and diverse aquatic primary producers, local sediment transport, and morphology. Engineered vertical bulkheads, dredging for commercial navigation maintenance depth, sediment quality, and greatly reduced light transparency currently limit rooted aquatic plants. These lower portions of the tributaries are impacted by multiple river hydrology inputs (i.e. urban runoff, warm/cool water discharge, combined sewage overflows, lake upwelling and seiche effects, etc.). Common seasonal water temperatures and flow regimes are impacted by all these factors. The main channel of the Menomonee River is deep (>15ft) up until the 16th street bridge. A large portion of the main channel is bordered with a hardened shoreline and provides limited surface area for fish habitat.

The Menomonee River, between the N 16th to N 25th Street bridges, was previously de-certified as a federal commercial navigation channel and had previously been part of a sediment characterization and focused feasibility study (FFS) for remediation. This section of the river contains the former West Side Manufactured Gas Plant (MGP) Facility, which under the Great Lakes Legacy Act (GLLA) for the Menomonee and Milwaukee (M&M) project will be remediated based on a selected alternative. This portion of the project falls within Operable Unit 1 (OU1), which is 1.9 river miles from the West Canal Street Bridge to the confluence with the Milwaukee River. Due to future sediment remedial design (RD) and action (RA) in this section of the Menomonee River, this project has the potential to fall under the Great Lakes Legacy Act (GLLA). If this project were to be implemented through the Degradation of Fish and Wildlife Populations Beneficial Use Impairment (BUI), implementation would not start until after this site is remediated with the selected alternative.

From 2016 to 2019, the USFWS Green Bay Fish and Wildlife Conservation Office's Aquatic Invasive Species early detection team conducted surveys in the lower Milwaukee Estuary AOC. A total of 308 individual points were surveyed using a variety of gears including Gillnets, paired fyke nets, cloverleaf traps, and day and nighttime boat electrofishing. A total of 13,273 fish representing 58 species were surveyed. Only 1 boat electrofishing survey was conducted in this project area in September of 2016 by the USFWS' Aquatic Invasive Species early detection team (Figure 5). A total of 112 fish representing 11 different species were surveyed. These were dominated by white sucker (54.5% of total fish caught) followed by largemouth bass (13.4%), gizzard shad (10.7%), smallmouth bass (7.14%), pumpkinseed, and bluegill (2.7%). Indicator species represented 7.14 % of the total catch and sub-indicator species represented 77.7%) of the total catch. Of note, a total of 16 smallmouth bass were caught at 2 survey sites just downstream from the project area (Figure 2).

Degradation of Fish and Wildlife Populations
Project Summary

Areas such as this in the lower Milwaukee Estuary, especially on the Menomonee River, are the best options to implement a fisheries improvement project. Due to this unique opportunity and the ability to provide valuable habitat to address the fish portion of this BUI, the Milwaukee Estuary AOC Fish and Wildlife Technical Advisory Committee (Tech Team) determined this site as a key location to implement a fisheries improvement project. Enhancement to this site on the Menomonee River will provide better surface area and cover for fish in a degraded and urbanized habitat.

Collaboration with Partners

The Wisconsin Department of Natural Resources (WDNR) is planning on determining the best course of action for planning, design, and implementation of this project. Stakeholders that have been involved with watercourse projects in the past for the Milwaukee Estuary AOC include the Milwaukee Metropolitan Sewerage District (MMSD), City of Milwaukee, Milwaukee County and the U.S. Army Corps of Engineers (USACE). It is important for the WDNR to bring all stakeholders and partners involved to the table to discuss the improvement of fish habitat and populations in the lower sections of the Menomonee River. These include but are not limited to Menomonee Valley Partners, Milwaukee Riverkeeper, and Sixteenth Street Health Community Center. There are multiple private landowners on both shorelines between the N 16th and N 25th Street Bridges.

Proposed Work

The plan and design of this project will vary depending on the alternative that is selected for remediation in OU1 of the M&M project. The benefit of having this project implemented post-remediation is the well-known information and data available in this section of the Menomonee River. Hydrologic modeling has been completed as part of the FFS for the M&M project. Determination of scouring and deposition has been previously investigated for this project site. Shoreline stability and bulkhead structure conditions have been inspected. Implementing a fisheries project, bound by bulkhead steel sheet pilings, will require placing habitat features in specific locations to generate the best water flow throughout the year, while staying within regulations of the floodplain. Possible features include, but are not limited to:

- A meandering bottom morphology using clean, washed coarse gravels that benefit spawning fishes and set as submerged bars with specific slopes and elevations to keep the flow in the main channel
- The addition of sand/gravel bars along channel sides at appropriate varying elevations
- Establishment of native rooted submergent, emergent, and floating macrophytes in shallow bars
- Enhancement of larger rock material to provide cover on staggered, alternating sides of the channel to increase water flow
- Enhancements to woody habitat by placing structures in combination with added boulders.

Estimated Timetable and Duration (Calendar Year)

- Planning: Q1 2021 – Q2 2022
- Design and Permitting: Q3 2022 – Q2 2023
- Construction/Implementation: Q3 2023 – Q3 2024
- Maintenance and Vegetation Establishment: Q4 2024 – Q4 2026

Estimated Project Budget & Funding

The total project costs for this project are approximately $3M.

Degradation of Fish and Wildlife Populations
Project Summary

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)
The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet the two goals below (highlighted in green) and show measures of success by an AOC wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (i.e. forest, wetland, shrubland, grassland, semi-aquatic, and upland/grassland) to support a better population of wildlife indicator species by:
   - Species and area of exotic invasive species removed
   - Amount (area or number) of native species planted to benefit wildlife indicator species
   - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
   - Amount (area) of habitat types created, enhanced, and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
   - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for lake sturgeon and northern pike, respectively
   - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
   - Amount (length or area) of fish habitat or stream channel enhanced or restored
   - Amount (length) of corridor habitat improved or reconnected

Fish and Wildlife Metrics Addressed by Project
Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. Metrics were reviewed and agreed upon by the Tech Team to determine necessary steps and projects to remove this BUI. This project will take part in addressing certain aspects of following metrics:

Lower Milwaukee Estuary AOC
(Downstream of Humboldt Avenue on the Milwaukee River; Downstream of N 25th Street on the Menomonee River; Downstream of W Becher Street on the Kinnickinnic River)

- A 100% increase in relative population density in four indicator species (i.e. lake sturgeon, northern pike, greater redhorse, and smallmouth bass)
- An increase of any magnitude in 80% of native sub-indicator families (i.e. suckers, minnows and shiners, bullheads and catfishes, sunfishes, and perches) to be considered
- An overall mean value from all large river IBI sampling efforts of “Fair” or better (i.e. 41-60) in the lower reaches of the Milwaukee Estuary

Project Rationale/Why Critical for BUI Removal
To address this BUI, the process was completed by the Milwaukee Estuary AOC Tech Team to determine management actions for the Degradation of Fish and Wildlife Populations BUI. The process included a rigorous selection of high priority projects in the Milwaukee Estuary AOC. This project was ranked as a “Tier 1”, high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only 15 (or 12.5%) were deemed Tier 1, high priority. It was determined to be important for three of the four fish indicator species (northern pike, greater redhorse, and smallmouth bass – the fourth being lake sturgeon). The highest possible cost-benefit score for implementation was

given to this project. It provides benefits to all sub-indicator families in the metrics, but specifically focuses on suckers, bullheads and catfishes, and sunfishes. The benefits to connecting fish populations and greatly enhancing cover in a section of the Menomonee River, which has been previously described as a biological desert, is a major step for addressing the fish portion of this BUI in the lower Milwaukee Estuary.

Necessary Project Elements

Elements for this project include:

- A conservation easement or equivalent for protection of this site (i.e. deauthorized channel)
- Implementation of fish enhancements post site remediation under the GLLA or this BUI
- Stakeholder and public input during all phases of the project

Degradation of Fish and Wildlife Populations
Project Summary

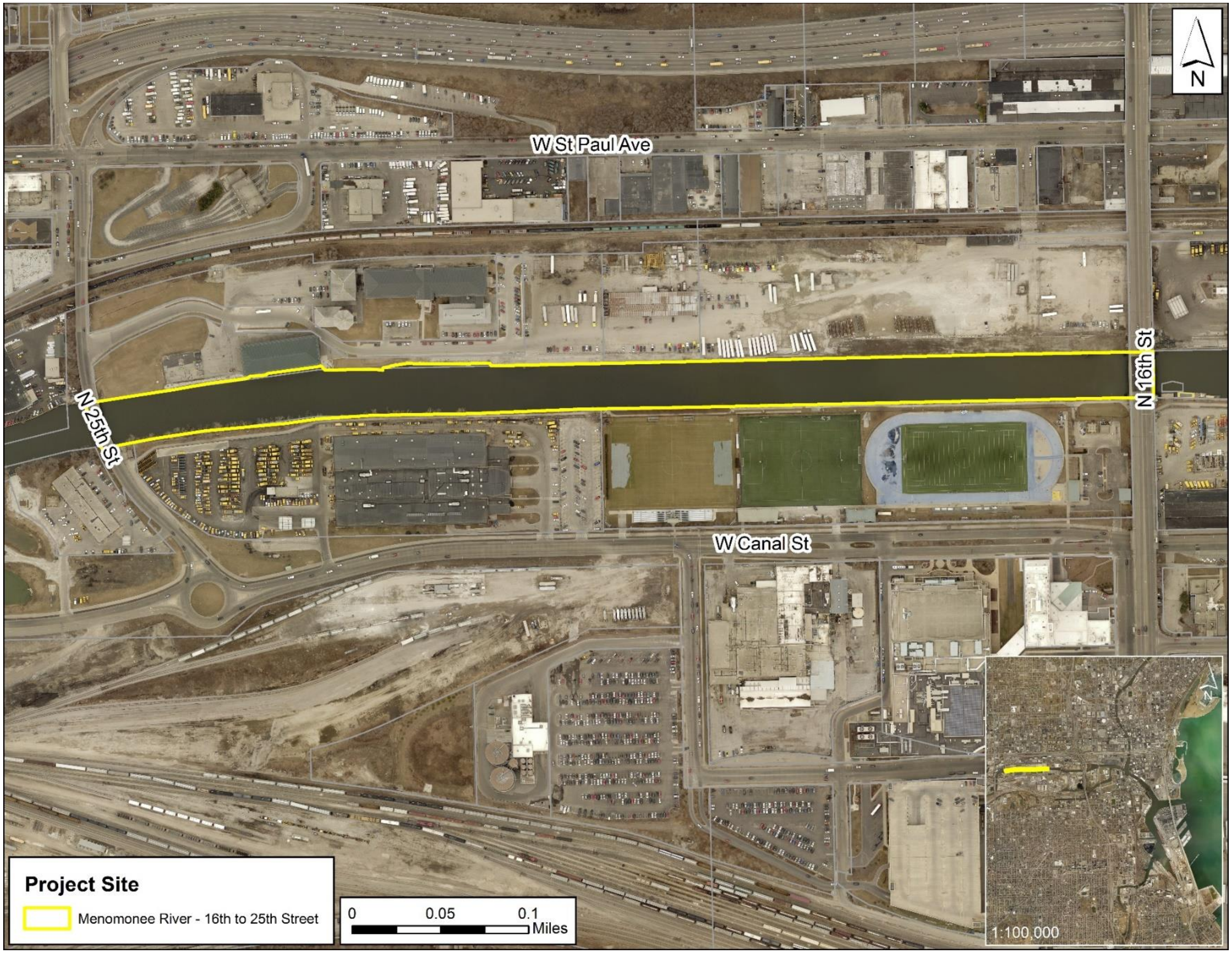


Figure 1. Project site for Menomonee River – 16th to 25th Street.

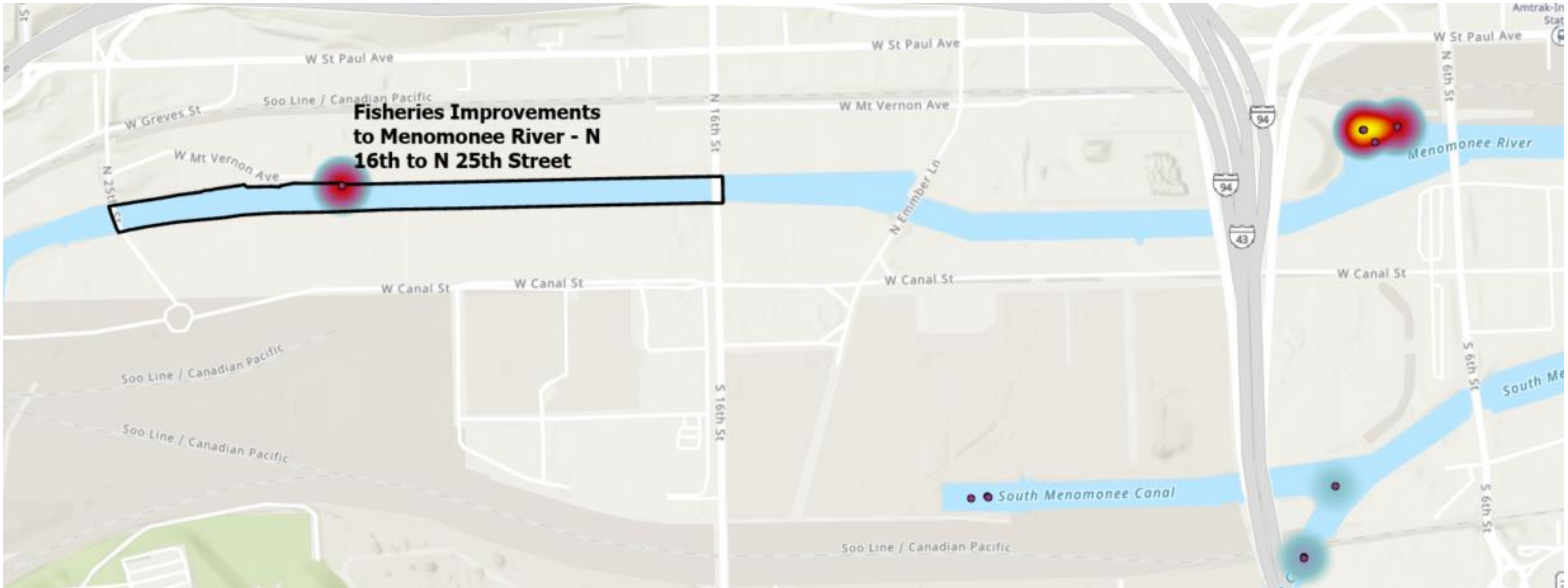


Figure 2. Densities of indicator species surveyed by the USFWS Aquatic Invasive Species early detection team in and near the 16th/25th street project area in 2016. Project boundary is outlined in black.

Degradation of Fish and Wildlife Populations
Project Summary

Project Title: Fish and Wildlife Enhancements to Little Menomonee River Parkway – Section 1

Project Location: Little Menomonee River Parkway – Section 1

Project Sponsor: Milwaukee County Parks

Project Landowner: Milwaukee County

Background

The Little Menomonee River Parkway – Section 1 is one of the largest (215.7 acres) and most important habitats in the Milwaukee Estuary Area of Concern (AOC), and it supports a diverse number of fish and wildlife. This area on the LMR provides important riparian forest, shrubland, grassland, and wetland habitat for many indicator species in the Milwaukee Estuary AOC. It is also provides important migratory stopover habitat for waterfowl (Documented: 18 species of ducks, 2 species of geese, 5 species of cranes/herons/egrets, 5 species of grebes/rails, 4 species of gulls/terns, and 9 species of shorebirds) and spawning habitat for Northern Pike. The site also contains 97 species of flora and fauna that the Milwaukee County Parks (site owner) lists as priority conservation species within Milwaukee County. A portion of the site is an old quarry that flooded and reverted to a variety of shallow water wetlands/emergent marshland. Former gravel spoil piles in the wetlands offer one of the only areas within the AOC where turtles can potentially nest safely. These spoil piles are surrounded by water, which block access for nest predators such as raccoons and skunks.

Through recent efforts to determine management actions for the Degradation of Fish and Wildlife Populations BUI, the Milwaukee Estuary AOC Fish and Wildlife Technical Advisory Committee (Tech Team) determined that this site is a key location in the Milwaukee Estuary AOC. It was determined to be important for semi-aquatic habitat associated species. The large size of this project site provides important habitat for forest as well as wetland breeding birds and mammals. It is well connected to the LMR River corridor and is a crucial project to meet our wildlife and fish metrics for BUI removal. Given this site's diverse wetland habitats, it drives the biological diversity of the entire LMR AOC corridor to the south. As the ecological engine for the entire LMR corridor to the south, it is important that this site receives much-needed enhancements to better support impaired reproducing populations within the Milwaukee Estuary AOC. This site is also directly adjacent to the Milwaukee Estuary AOC boundary on the LMR and provides the opportunity for earthwork habitat enhancements—which are limited in other areas of the LMR corridor due to location of the former Moss-American Superfund site directly to the south.

Collaboration with Partners

Current habitat restoration work that is being implemented directly north of W County Line Road in the LMR corridor includes Ozaukee County Planning and Parks (OCPP) projects on Milwaukee Metropolitan Sewerage District (MMSD) Greenseams properties, as well as ongoing Milwaukee County Parks planning for the LMR corridor directly to the south of this site. This work is being developed as part of an Ecological Restoration and Management Plan (ERMP) by Milwaukee County Parks and is a management action for the Loss of Fish and Wildlife Habitat BUI. It encompasses goals and objectives that can be found in the draft *Fish and Wildlife Plan* for the Milwaukee Estuary AOC. As a result, the project landowner for this site, Milwaukee County, has previously and continues to play an important role in implementing management actions for BUIs in the Milwaukee Estuary AOC.

Degradation of Fish and Wildlife Populations
Project Summary

Proposed Work

This project will plan and implement project recommendations that are proposed to be accomplished at LMR Section 1, while addressing portions of the fish and wildlife populations BUI in the Milwaukee Estuary AOC that best represents improvements of the impacted populations. As part of this process, this site has been surveyed previously by Milwaukee County Parks. Results from this wildlife study and on-going park surveys provided important information about species and habitat found on this property. Potential enhancements to benefit wildlife populations in this area include: removal of select invasive species populations that could degrade the ecological functions of the wetlands; grassland/savanna enhancements through the removal of woody vegetation; upland and lowland forest stand improvements such as reforestation and select forest thinning to improve canopy diversity; wetland creation through shallow scrapes and the installation of water control structures; maintenance of aquatic buffer zones; shoreline enhancements such as woody vegetation removal on turtle nesting islands and potentially the installation of solar powered electric fencing to deter nest predators; woody structure installations to provide higher quality fish habitat; semi-aquatic improvements through the installation of native plants for a variety of herptiles.

Estimated Timetable and Duration (Calendar Year)

- Planning: Q1 2020 – Q4 2021
- Design and Permitting: Q1 2022 – Q4 2022
- Construction/Implementation: Q1 2023 – Q4 2024
- Maintenance and Vegetation Establishment: Q1 2025 – Q4 2028

Estimated Project Budget & Funding

The total project costs for this project are approximately $6M.

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)

The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet all the goals below (highlighted in green) and show measures of success by an AOC wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (i.e. forest, wetland, shrubland, grassland, semi-aquatic, and upland/grassland) to support a better population of wildlife indicator species:
    - Species and area of exotic invasive species removed
    - Amount (area or number) of native species planted to benefit wildlife indicator species
    - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
    - Amount (area) of habitat types created, enhanced and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
    - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for lake sturgeon and northern pike, respectively
    - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
    - Amount (length or area) of fish habitat or stream channel enhanced or restored
    - Amount (length) of corridor habitat improved or reconnected

Degradation of Fish and Wildlife Populations
Project Summary

Fish and Wildlife Metrics Addressed by Project

Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. Metrics were reviewed and agreed upon by the Tech Team to determine necessary steps and projects to remove this BUI. This project will take part in addressing certain aspects of following metrics:

Upper Milwaukee Estuary AOC

(Upstream of Humboldt Avenue on the Milwaukee River to Bridge Road on Cedar Creek; Upstream of N 25th Street on the Menomonee River to Brown Deer Road on the Little Menomonee River; No upper reach for the Kinnickinnic River)

- Presence of the indicator species, northern pike, utilizing spawning habitat in the upper reaches of the Menomonee/Little Menomonee River.
- An overall mean value from all warmwater IBI sampling efforts of "Fair" or better (i.e. 31-50) in the upper reaches of the Menomonee River.

Breeding Birds

- At least 9 sites in the AOC support at least 3 breeding bird indicator species for each habitat type (Forest, Wetland, and Shrubland).
- At least 6 sites in the AOC support at least 2 breeding bird grassland indicator species.
- At least 9 sites in the AOC support at least 1 breeding bird Airspace/Urban species.

Herptiles/Crayfish

- At least 30 sites in the AOC support at least 2 semi-aquatic guilds (Crayfish, Salamanders, Frogs, and Turtles).
    - At least 10 sites support at least 1 crayfish species.
    - At least 15 sites support at least 1 frog species.
    - At least 6 sites support at least 1 turtle species.
- At least 15 sites in the AOC support at least 2 upland/grassland habitat indicator snake species.

Mammals

- At least 10 sites in the AOC support at least 2 mammal indicator species for each habitat type (Forest and Wetland).
- At least 5 sites within the AOC support at least 1 grassland mammal indicator species.

Project Rationale/Why Critical for BUI Removal

The process by the Milwaukee Estuary AOC Tech Team to determine management actions for the Degradation of Fish and Wildlife Populations BUI included a rigorous selection of high priority projects in the Milwaukee Estuary AOC to address said BUI. This project was ranked as a "Tier 1", high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only 15 (or 12.5%) were deemed Tier 1, high priority. It was determined to be important for semi-aquatic habitat associated species. The large size of this project site provides important habitat for forest as well as wetland breeding birds and mammals. It is well connected to the LMR River corridor and is a crucial project to meet our wildlife and fish metrics for BUI removal. As previously mentioned, given this site's diverse wetland habitats, it drives the biological diversity of the entire LMR AOC corridor to the south. Habitat improvements could significantly increase those benefits at a cost/benefit ratio likely lower than other habitat projects within the AOC. The site also contains 97 species of flora and fauna that the Milwaukee County Parks (site owner) lists as priority conservation species within Milwaukee County.

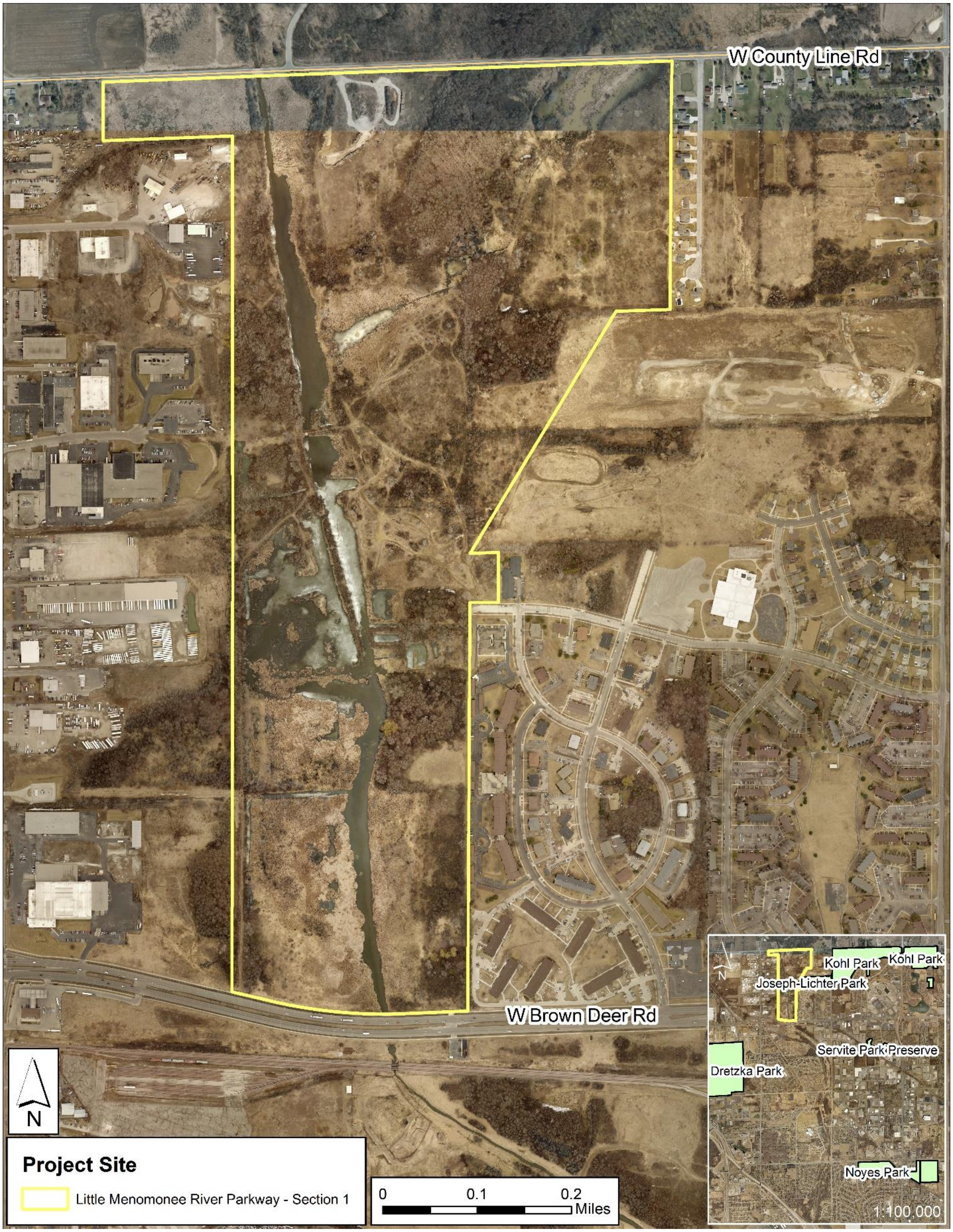
Necessary Project Elements

Elements for this project include:

Degradation of Fish and Wildlife Populations
Project Summary

- An invasive species and vegetation management plan (aquatic and terrestrial) with provisions made for long term implementation.
- A conservation easement or equivalent for permanent protection of this site (i.e. non-developable land, zoned parkland).
- A conservation plan or equivalent that addresses the goals of Little Menomonee River – Section 1 and the population goals for this site of the Milwaukee Estuary AOC.
- Stakeholder and public input during all phases of the project.

Degradation of Fish and Wildlife Populations
Project Summary



Degradation of Fish and Wildlife Populations
Project Summary

Project Title: Wildlife Enhancements to Kohl Park

Project Location: Kohl Park

Project Sponsor: Milwaukee County Parks

Project Landowner: Milwaukee County

Background

The land that constitutes Kohl Park has been donated to the Milwaukee County Parks over the course of a decade, including the most recent and final donation in 2018, by the Herb Kohl family. The leased agricultural lands contained within this site provide a unique opportunity for the creation of wildlife enhancements that are to be implemented as part of the County's land management plan and essential actions to address the wildlife population impairments in the Milwaukee Estuary Area of Concern (AOC). This large habitat area has the potential to support many more populations through restoration efforts included in this proposed project, because it is strategically located between other large publicly protected parcels directly connecting it to the Milwaukee River Estuary AOC. Kohl Park, in near proximity to the Little Menomonee River (LMR), potentially provides important forest, shrubland, grassland, and wetland habitat for Milwaukee Estuary AOC indicator species. Plans for this area include prairie restoration, and the expansion of the forested/shrubland areas to fill-in a larger contiguous corridor on the northern portion of Milwaukee County. It would also address known sediment and nutrient loading into Trinity Creek— a tributary of the Milwaukee River portion of the AOC.

Through the recent efforts to determine management actions for the Degradation of Fish and Wildlife Populations Beneficial Use Impairment (BUI) by the Milwaukee Estuary AOC Fish and Wildlife Technical Advisory Committee (Tech Team), this site has been determined as a key location in the Milwaukee Estuary AOC that provides important habitat for many fish and wildlife indicator species. This site is within a 0.5mi buffer of the AOC boundary that was used in determining the status of this impairment during the AOC-wide assessment. This project also provides a unique opportunity for ground moving work that other areas in the LMR corridor are limited due to previous superfund cleanup efforts.

Collaboration with Partners

Nearby habitat restoration work is currently being implemented directly north of W County Line Road in the LMR corridor by the Ozaukee County Planning and Parks (OCPP) on Milwaukee Metropolitan Sewerage District (MMSD) Greenseams' properties, ecological restoration activities on the adjacent Mequon Nature Preserve, and the potential AOC restoration work on the section of the LMR between County Line Road and Brown Deer Road which is also listed by the Fish & Wildlife Technical Advisory Committee as a "high priority" site for delisting BUIs. In addition, the Kohl Park restoration would directly tie into and compliment the Milwaukee County Parks planning for the LMR corridor below W Brown Deer Road. This work is being developed as part of an Ecological Restoration and Management Plan (ERMP) by Milwaukee County Parks and is a management action for the Loss of Fish and Wildlife Habitat BUI. It encompasses goals and objectives that can be found in the draft Fish and Wildlife Plan for the Milwaukee Estuary AOC. As a result, the project landowner for this site, Milwaukee County, has previously and continues to play an important role in implementing management actions for BUIs in the Milwaukee Estuary AOC.

Degradation of Fish and Wildlife Populations
Project Summary

Proposed Work
This project will plan and implement project opportunities that are proposed while addressing a large portion of this BUI in the Milwaukee Estuary AOC that best represents improvements of the impacted wildlife populations. As part of this process, this site has been surveyed previously by Milwaukee County Parks. Results from this wildlife study and on-going park surveys provided important information about species and habitat found on this property. Potential enhancements to benefit wildlife populations in this area include: control of select invasive species populations; prairie/oak savanna installation and management; upland and lowland forest stand improvements such as reforestation and select thinning to enhance canopy species diversity; preservation and enhancements to ephemeral and permanent wetlands through wetland scrapes and hydrological management practices; semi-aquatic and upland/grassland improvements for a variety of herptiles through the conversion of agricultural fields to grassland habitat and the removal of woody vegetation from existing grasslands.

Estimated Timetable and Duration (Calendar Year)
- Planning: Q1 2021 – Q2 2022
- Design and Permitting: Q3 2022 – Q2 2023
- Construction/Implementation: Q3 2023 – Q4 2024
- Maintenance and Vegetation Establishment: Q1 2025 – Q1 2028

Estimated Project Budget & Funding
The total project costs for this project are approximately $2.5M.

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)
The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet the two goals below (highlighted in green) and show measures of success by an AOC wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (i.e. forest, wetland, shrubland, grassland, semi-aquatic, and upland/grassland) to support a better population of wildlife indicator species:
   - Species and area of exotic invasive species removed
   - Amount (area or number) of native species planted to benefit wildlife indicator species
   - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
   - Amount (area) of habitat types created, enhanced and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
   - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for Lake sturgeon and Northern pike, respectively
   - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
   - Amount (length or area) of fish habitat or stream channel enhanced or restored
   - Amount (length) of corridor habitat improved or reconnected

Degradation of Fish and Wildlife Populations
Project Summary

Fish and Wildlife Metrics Addressed by Project

Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. This project will take part in addressing certain aspects of following metrics:

Breeding Birds
- At least 9 sites in the AOC support at least 3 breeding bird indicator species for each habitat type (Forest, Wetland, and Shrubland)
- At least 6 sites in the AOC support at least 2 breeding bird grassland indicator species
- At least 9 sites in the AOC support at least 1 breeding bird Airspace/Urban species

Herptiles/Crayfish
- At least 30 sites in the AOC support at least 2 semi-aquatic guilds (Crayfish, Salamanders, Frogs, Turtles).
    - At least 10 sites support at least 1 crayfish species.
    - At least 15 sites support at least 1 frog species.
- At least 15 sites in the AOC support at least 2 upland/grassland habitat indicator snake species.

Mammals
- At least 10 sites in the AOC support at least 2 mammal indicator species for each habitat type (Forest and Wetland).
- At least 5 sites within the AOC support at least 1 grassland mammal indicator species.

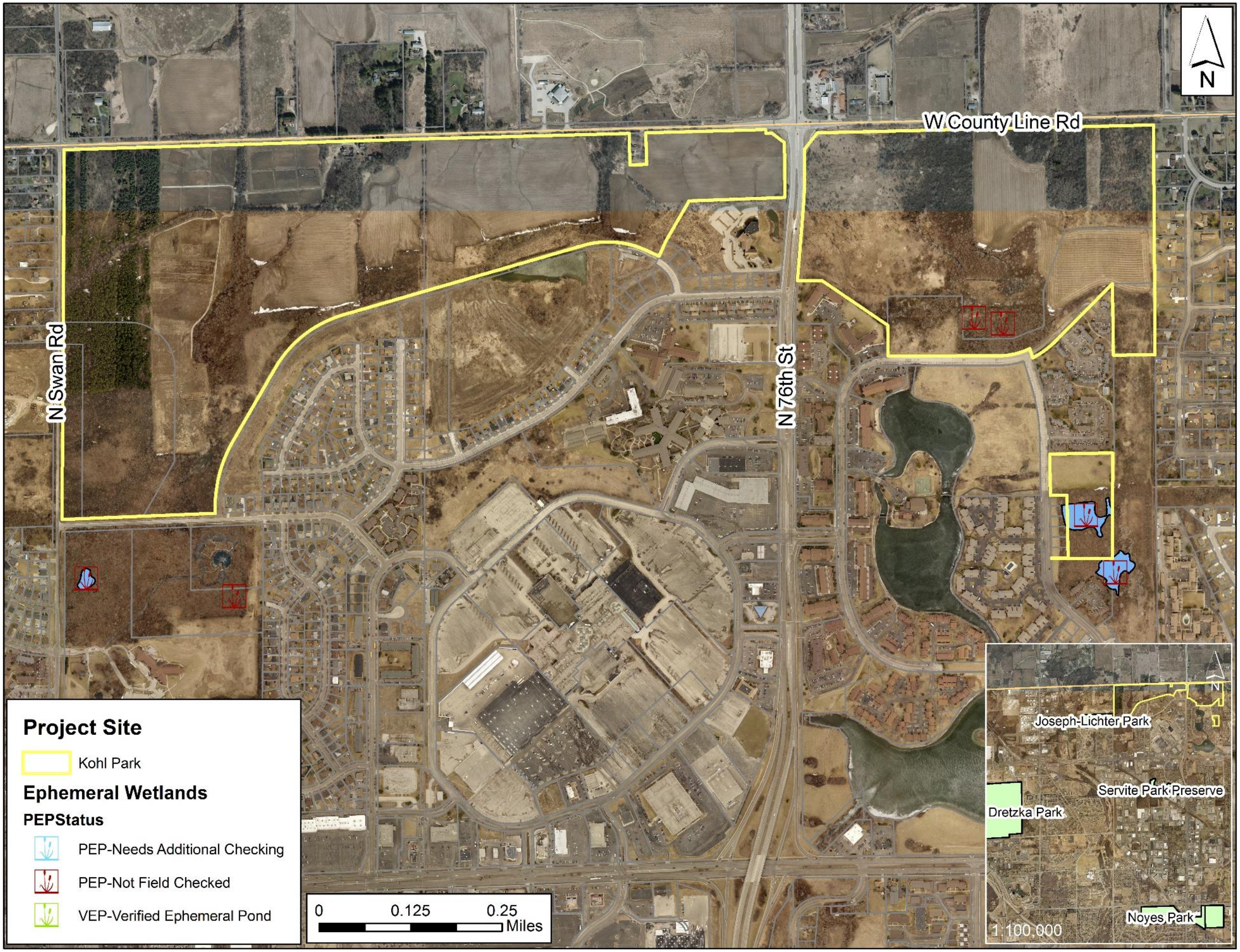
Project Rationale/Why Critical for BUI Removal

The process by the Milwaukee Estuary AOC Tech Team to determine management actions for the Degradation of Fish and Wildlife Populations BUI included a rigorous selection of high priority projects in the Milwaukee Estuary AOC to address said BUI. This project was ranked as a "Tier 1", high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only 15 (or 12.5%) were deemed Tier 1, high priority. It was determined to be important for semi-aquatic and upland/grassland habitat associated species (especially frogs and snakes). The large size of this project site provides important habitat for forest, shrubland, and grassland breeding birds and mammals, which scored the highest potential benefit in all the high priority projects. It is well connected to the LMR corridor through LMR Section 1 and Joseph-Lichter Park. As previously mentioned, Kohl Park falls between other large protected properties such as MMSD Greenseams parcels, Mequon Nature Preserve, and the LMR Parkway. The creation of new habitat and restoration of existing habitat at Kohl Park would complement other habitat areas and create a 1,143 acre habitat block, which would be the largest habitat block within the AOC. In addition, the conversion of the leased agricultural land at Kohl Park to grassland and savanna provides for a habitat type that is extremely rare in the AOC due to the predominance of woodlands and existing urban development.

Necessary Project Elements

Elements for this project include:
- An invasive species and vegetation management plant with provisions made for long term implementation.
- A conservation easement or equivalent for permanent protection of this site (i.e. non-developable land, zoned parkland).
- A conservation plan or equivalent that complements the County goals of Kohl Park and the population goals for this site within the Milwaukee Estuary AOC.
- Stakeholder and public input during all phases of the project.

Degradation of Fish and Wildlife Populations
Project Summary



Degradation of Fish and Wildlife Populations
Project Summary

Project Title: Fisheries Improvements to Lincoln Park Oxbow

Project Location: Lincoln Park Oxbow (Estabrook Island to Oak Leaf Trail Crossing on Milwaukee River)

Project Sponsor: Milwaukee Metropolitan Sewerage District (MMSD)

Project Landowner: Milwaukee County

Background
Pre-historic emergent wetlands (i.e., marsh and wet meadow) once covered thousands of acres in the Milwaukee Estuary and connecting rivers and were critical for various fish and wildlife life stages. These wetland cover types are currently absent in the estuary and lower river reaches. Some reaches of the former Estabrook impoundment provide one of the best opportunities for rehabilitating emergent wetlands for phytophilic spawning fishes (i.e. northern pike) in close proximity to the Milwaukee Estuary. The low-gradient (0.3-0.59 m/km) and shallow (0.5-1.9 m) reaches upstream of the former impoundment are dominated by silt, sand, and gravel substrate. These habitat features are near-optimum habitat for larval/juvenile lake sturgeon (Daugherty et al., 2009).

The Lincoln Park Oxbow and Estabrook Impoundment was remediated in two phases (2012 and 2015) as part of a GLLA cleanup project which removed roughly 176,000 cubic yards of contaminated sediments. As the remediation work concluded, the GLLA project stabilized the shoreline and re-established vegetation. The GLLA project's primary focus on stabilizing the channel means there is an opportunity to further enhance the large oxbow area for fish and wildlife populations. This project would provide those enhancements and represents an important contribution to the overall effort of partners such as Ozaukee County, Milwaukee County, Milwaukee Riverkeeper, Urban Ecology Center and others to restore the Milwaukee River.

Previous concepts for what this stretch of the river may look like were developed as part of a Habitat Rehabilitation Alternatives Analysis and can be found in a technical memorandum completed by InterFluve (Lee, 2018), sponsored by MMSD. Prehistoric emergent wetlands, such as those previously found at the Lincoln Park Oxbow, once covered thousands of acres in the Milwaukee Estuary and connecting rivers that were critical for a diversity of fish and wildlife species. These wetland cover types are currently absent in the estuary and lower river reaches. This area of the Milwaukee River provides the best opportunity for establishing emergent wetlands that will support all life stages of important fish indicator species (i.e. northern pike, lake sturgeon, greater redhorse, and smallmouth bass) in close proximity to the lower Milwaukee Estuary. Through the recent efforts to determine management actions for the Degradation of F&W Populations BUI by the Milwaukee Estuary AOC F&W Technical Advisory Committee (Tech Team), this stretch of the Milwaukee River has been determined as an important location that if restored, would benefit numerous fish and wildlife indicator species.

This project is important to address the status of the Degradation of F&W Populations BUI in the Milwaukee Estuary AOC. The Tech Team determined that this project will address all three overall outcome goals for this BUI and six output fish and wildlife metrics. This project scored the highest out of all 34 high priority projects for supporting the early life stages of lake sturgeon and scored a 9 out of 10 for benefits referring to fish sub-indicator families (i.e. suckers, minnows and shiners, bullheads and catfishes, sunfishes, and perches). It also provides important semi-aquatic habitat for frogs and turtles, as well as breeding and migratory bird habitat.

Collaboration with Partners

This project would specifically involve those that play an important role in Lincoln Park and this section of the Milwaukee River. The primary stakeholders that will be involved in this project include the landowner, Milwaukee County Parks, the Friends group of Lincoln Park, Milwaukee Riverkeeper, and the Milwaukee River Rehabilitation Work Group.

Milwaukee County Parks is working with several partners on various aspects of park improvement and planning along the Milwaukee River Greenway. While some of these partners, [i.e. Urban Ecology Center (UEC), River Revitalization Foundation (RRF), Milwaukee River Advocates, and the Friends of Lincoln Park] are friends' groups, others are non-profit organizations that are involved with restoration projects and initiatives throughout the county. Recently, RRF, UEC, University of Milwaukee Field Station, and Milwaukee County Parks completed biodiversity surveys in the Greenway. This work, in combination with an AOC-wide, comprehensive F&W population study, helped inform the necessary steps to address population impairments in the Milwaukee Estuary AOC. Other partners that play an important role in the greenway include—but are not limited to—the Koenen Nature Preserve, Village of Shorewood, MMSD, and Milwaukee Riverkeeper. The landowner for the majority of these parks along the greenway, Milwaukee County, has previously and continues to play an important role in implementing management actions for BUIs in the Milwaukee Estuary AOC.

Proposed Work

This project will plan, design, and implement project elements that are developed through the alternatives analysis and feasibility study that are proposed to be accomplished in this part of the Milwaukee River and Greenway, while addressing portions of the fish and wildlife populations BUI in the Milwaukee Estuary AOC that best represent improvements of the impacted populations. As part of this process, this site has been surveyed previously by Milwaukee County Parks, many of the previously listed partners, and contractors. Results from this wildlife study, vegetative inventories, habitat determinations and on-going park surveys provided important information about species and existing habitat found in this section of the Greenway. Recommended benefits to fish and wildlife populations in this area include--but are not limited to--enhancing wetland and backwaters for spawning and juvenile indicator and sub-indicator fish development (i.e. nursery habitat for juvenile lake sturgeon and spawning habitat for northern pike); establish and maintain wetland vegetation; place wood for bank protection and localized scour development for fish and wildlife; shoreline and aquatic buffer improvements for stabilization and cover; turtle nesting habitat enhancement and management; and addition of large rock in the river channel.

Estimated Timetable and Duration (Calendar Year)

- Planning: Q1 2020 – Q4 2020
- Design and Permitting: Q1 2021 – Q1 2022
- Construction/Implementation: Q2 2022 – Q2 2024
- Maintenance and Vegetation Establishment: Q3 2024 – Q4 2027

Estimated Project Budget & Funding

The project total costs for this project are approximately $6M.

Degradation of Fish and Wildlife Populations
Project Summary

Criteria for Measuring Project Goals are Met (Qualitative and/or Quantitative)
The overall goals of this project are to address the metrics that were set for the Milwaukee Estuary AOC. In doing so, the project will meet all the goals below (highlighted in green) and show measures of success by an AOC wide verification monitoring effort:

1. Improve the quality of terrestrial habitat types (i.e. forest, wetland, shrubland, grassland, semi-aquatic, and upland/grassland) to support a better population of wildlife indicator species:
    - Species and area of exotic invasive species removed
    - Amount (area or number) of native species planted to benefit wildlife indicator species
    - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
    - Amount (area) of habitat types created, enhanced and/or protected
2. Improve the quality of aquatic habitat to support a better population of fish indicator species:
    - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for lake sturgeon and northern pike, respectively
    - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species
3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:
    - Amount (length or area) of fish habitat or stream channel enhanced or restored
    - Amount (length) of corridor habitat improved or reconnected

Fish and Wildlife Metrics Addressed by Project
Assessments that are referenced in the *2020 Removal Target Updates for the Milwaukee Estuary Area of Concern* include those that were completed as part of the planning process. Metrics were reviewed and agreed upon by the Tech Team to determine necessary steps and projects to remove this BUI. This project will take part in addressing certain aspects of following metrics:

Upper Milwaukee Estuary AOC
(Upstream of Humboldt Avenue on the Milwaukee River to Bridge Road on Cedar Creek; Upstream of N 25th Street on the Menomonee River to Brown Deer Road on the Little Menomonee River; No upper reach for the Kinnickinnic River)

- Presence of the indicator species, lake sturgeon, utilizing spawning habitat in the upper reaches of the Milwaukee River
- An overall mean value from all warmwater IBI sampling efforts of “Good” or better than good (i.e. 51-65) in the upper reaches of the Milwaukee River

Herptiles/Crayfish

- At least 30 sites in the AOC support at least 2 semi-aquatic guilds (Crayfish, Salamanders, Frogs, Turtles)
    - At least 15 sites support at least one frog species
    - At least 6 sites support at least one turtle species

Mammals

- At least 10 sites in the AOC support at least 2 mammal indicator species for each habitat type (Forest and Wetland)

Degradation of Fish and Wildlife Populations
Project Summary

Project Rationale/Why Critical for BUI Removal

The process by the Milwaukee Estuary AOC Tech Team to determine management actions for the Degradation of Fish and Wildlife Populations BUI included a rigorous selection of high priority projects in the Milwaukee Estuary AOC to address this BUI. This project was ranked as a "Tier 1", high priority project in the AOC. Out of the original 120 projects that were vetted by the Tech Team for this BUI, only 15 (or 12.5%) were deemed Tier 1, high priority. It was determined to be important for all four fish indicator species (i.e. northern pike, lake sturgeon, greater redhorse, and smallmouth bass). This project also scored the highest out of all 34 high priority projects for supporting the early life stages of lake sturgeon in the Milwaukee Estuary AOC. This project scored a 9 out of 10 for benefits referring to fish sub-indicator families (i.e. suckers, minnows and shiners, bullheads and catfishes, sunfishes and perches). It also provides important semi-aquatic habitat for frogs and turtles, as well as breeding and migratory bird habitat (152 bird species documented using the site as part of their annual lifecycle). As a result, it is essential to meet the metrics to remove the Degradation of Fish and Wildlife Populations BUI.

Necessary Project Elements

Elements for this project include:

- An invasive species vegetation (terrestrial and aquatic) management plan with provisions made for long term implementation at Lincoln Park Oxbow
- A conservation easement or equivalent for permanent protection of this site (i.e. non-developable land, zoned parkland)
- A conservation plan or equivalent that addresses the goals of the Lincoln Park Oxbow and the population goals for this site in the Milwaukee Estuary AOC
- Stakeholder and public input during all phases of the project

Degradation of Fish and Wildlife Populations
Project Summary

Appendix G –
2020 Removal Target Updates for the Milwaukee Estuary Area of Concern

REMOVAL TARGET UPDATES

for the

MILWAUKEE ESTUARY AREA OF CONCERN


Stacy Hron

April 2020

Wisconsin Department of Natural Resources
Office of the Great Waters

EXECUTIVE SUMMARY

The Wisconsin Department of Natural Resources (DNR) Office of Great Waters (OGW) is responsible for implementing Wisconsin's Areas of Concern (AOC) Program, which is a non-regulatory program aimed at restoring Beneficial Use Impairments (BUIs) in AOCs. This program is intended to address legacy issues, such as problems caused by historical contamination, and does not replace or supplant existing regulatory programs.

Removal targets are a key element of the AOC program. They define the end goal that determines when BUIs can be considered adequately addressed for the AOC program, and thus eligible to be removed. The targets inform the selection of monitoring approaches to determine the status of the impairments and management actions to address them. Once all BUIs have met their targets, the AOC can be formally delisted. It is important to note that the BUI impairment determination is not the same as an impaired waters determination under the Clean Water Act. Targets and actions must be consistent with state regulatory programs and departmental policy.

In 2008, DNR engaged AOC stakeholders in establishing locally-derived removal targets and published the document entitled, *Delisting Targets for the Milwaukee Estuary Area of Concern*. These targets are AOC-specific rather than applicable statewide.

As part of the planning efforts to develop management action project lists for the Milwaukee Estuary AOC, it became clear that many of the BUI removal targets require modification in order to account for changes in the AOC since 2011, and to ensure they are meaningful, measurable, and achievable.

CONSIDERATIONS FOR CHANGING REMOVAL TARGETS

Target changes should be made with the recognition that the AOC program is a framework for achieving parity with conditions in similar areas that reflect impacts from development and industrialization, but where the extent of the impacts did not rise to the designation of an AOC. Targets need to be viewed with the following attributes in mind: Specific, Measurable, Achievable, Reasonable, and Time-bound (SMART). Reasons that targets may be justifiably revised include the following:

- New information has become available;
- Target language needed clarification and format consistency;
- The target reflects goals that go beyond the AOC program framework (e.g. overlap existing permit or regulatory compliance program functions); and/or
- The scope of achievable activities within the AOC program has become better understood as program implementation has occurred.

The targets were developed in concurrence-based processes and target changes require that an opportunity for stakeholder input and comment be provided. The approach to developing revisions and the opportunities for stakeholder input regarding the proposed changes may vary depending on the BUI. As part of this document, proposed changes to each BUI will be identified with one or more of the reasons stated above.

MILWAUKEE ESTUARY AOC HISTORY

The Milwaukee Estuary was designated as an AOC under the Great Lakes Water Quality Agreement (GLWQA) in 1987. Milwaukee and 42 other areas were designated as AOCs due to legacy contaminants and historical alterations to beneficial uses created by human modifications to the environment for more than a century. The Milwaukee Estuary's listing as an AOC was based on the presence or suspected presence of eleven out of the fourteen possible BUIs in the GLWQA. Many of the BUIs relate to legacy sediment contamination in the waters of the AOC from polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and metals. In accordance with the AOC Annex of the 1987 GLWQA, the DNR completed a Stage 1 Remedial Action Plan (RAP) in 1991 (DNR, 1991). The Milwaukee Estuary AOC boundary was expanded in 2008 to the upper portions of the Menomonee and Milwaukee River watersheds to include areas of legacy contamination in the Little Menomonee River, Lincoln Creek, and Cedar Creek. To date, none of the BUIs have been removed. However, significant progress has been made in addressing each of the eleven BUIs identified below:

- Restrictions on Dredging Activities*
- Fish Tumors or Other Deformities*
- Bird or Animal Deformities or Reproduction Problems*
- Restrictions on Fish and Wildlife Consumption*
- Degradation of Benthos*
- Degradation of Phytoplankton and Zooplankton Populations
- Loss of Fish and Wildlife Habitat*
- Degradation of Fish and Wildlife Populations*
- Beach Closings (Recreational Restrictions)
- Eutrophication or Undesirable Algae
- Degradation of Aesthetics

**BUIs that are linked to contaminated sediment in the Milwaukee Estuary AOC.*

NEXT STEPS

The DNR OGW team has and will continue to collaborate with stakeholders during the removal target revision process to assure that measurable and achievable endpoints specific to the Milwaukee Estuary AOC are defined. Coming to consensus on these revised targets allows for identification of specific actions needed to address the BUIs.

Once these removal targets have been met, removal of the BUI will be recommended. After all BUIs are removed, the AOC can be delisted. DNR will continue working in consultation with stakeholders and the public on restoration of these waters.

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RESTRICTIONS ON DREDGING ACTIVITIES

Contaminated sediments being excavated from 2012-2015 in Lincoln Park (Phase I & Phase II). Around 171,500 yd^3 of sediments contaminated with PCBs, PAHs and heavy metals were removed.

Background

Local stakeholders and communities have been working together to successfully address legacy contamination of the Milwaukee Estuary AOC for decades. The 1994 RAP listed 26 steps for contaminated sediment management, which provided the framework for previous cleanup activities. Since then, updated RAPs, as well as mass balance (Baird and Associates, 1997) and transport (Steuer *et al.*, 1999) studies have been used to guide the contaminated sediment management strategy for the Milwaukee Estuary AOC. Stakeholders in the AOC have been working on contaminated sediment remediation projects since the 1980s with the most recent project at Lincoln Park on the Milwaukee River, completed in 2015.

Building on the past success of remediation efforts, local stakeholders formed a Sediment Work Group in 2018. The group is facilitated by the City of Milwaukee and includes a diverse array of stakeholders working to accelerate remediation progress. Several of the stakeholders proposed a project agreement for a large-scale Great Lakes Legacy Act (GLLA) sediment remediation project in 2018. The purpose of this large-scale project is to facilitate the coordination of different projects at various stages of work throughout the entire AOC and enhance opportunities to leverage resources for completing the projects. In 2019, a $29.2 million Milwaukee Estuary AOC-wide project agreement was signed between US EPA Great Lakes National Program Office (GLNPO), WDNR, City of Milwaukee, Milwaukee County Parks, MMSD, and We Energies to cover focused feasibility studies, pre-design investigation, and remedial design of impacted sediments in the Estuary. This project will be an integral part of addressing remaining legacy contamination in the AOC as it includes significant portions of the remaining contaminated sediment. The target for this BUI was revised to clarify target language and criteria for eventual removal of this BUI.

Current Target: Restrictions on Dredging Activities

Target (Updated 2011)	Status
Removal of this BUI can occur when:	
• Contaminated sediment hotspots within and upstream from the AOC have been identified.	In Progress & Action Needed
• Implementation actions to remediate contaminated sites have been completed. As a source control measure and for AOC remediation, known contaminated sites must be addressed before BUI removal is possible.	In Progress & Action Needed
• There are no special handling requirements of material from routine navigational dredging due to contamination originating from controllable sources within the AOC.	In Progress & Action Needed

Revised Target: Restrictions on Dredging Activities

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Sediment and adjacent floodplain areas contaminated with legacy pollutants have been identified and remediated within the AOC.	In Progress & Action Needed
• All remedial actions have been implemented following Wisconsin Administrative Code NR 700 rules series and statutory requirements.	In Progress & Action Needed

Revision Determination
Justifiable Reason: Target language needed clarification and format consistency.

FISH TUMORS OR OTHER DEFORMITIES

Researcher collecting neoplastic liver tumor samples from a white sucker collected in the Milwaukee Estuary AOC. Previous tumor rates in the AOC are at 15% versus 8.5% at the Root River reference site.

Background

Liver tumors, particularly in benthic fish, have been well documented to be caused by environmental contaminants, in particular PAHs (Rafferty *et al.*, 2009; Pinkney *et al.*, 2011). The fish tumor beneficial use is considered impaired if incidence rate of fish tumors exceeds rates at background or reference sites or if survey data confirm the presence of neoplastic or preneoplastic liver tumors in bullhead or suckers (International Joint Commission, 1989). Target rates of 5% of neoplastic tumor incidence were suggested for benthic species in the Great Lakes as indicative of “environmental degradation” (Baumann *et al.*, 1996), although, due to association with PAHs, urban land uses may have higher rates of neoplastic tumor incidence (Blazer *et al.,* 2016).

In 2013, a fish tumor study (200 white suckers) was completed by the US Geological Survey (USGS), West Virginia University (WVU), and University of Wisconsin-Madison to determine tumor rates within the AOC. Results showed a higher rate (15%) than the expected background rate (5%) for neoplastic fish tumors in the Great Lakes, as well as higher rates than an identical evaluation of white suckers in the Root River (8.5%) in 2014. Results of these studies and comparison between the Milwaukee Estuary AOC and Root River reference site were published in 2016 (Blazer *et al.*, 2016).

These studies indicate additional work needs to be done to control or eliminate sources of contaminants within the Milwaukee Estuary AOC. Future sampling to determine decreases in fish tumor rates will occur after remediation has been completed. Additions were made to a revised target below, altering the target language and criteria based on new available information.

Current Target: Fish Tumors or Other Deformities

Target (Updated 2011)	Status
Removal may occur if:	
• All known major sources of PAHs and chlorinated organic compounds within the AOC and tributary watershed have been controlled or eliminated.	In Progress & Action Needed
• A fish health survey of resident benthic fish species, such as white suckers, finds incidences of tumors or other deformities at a statistically similar incidence rate of minimally impacted reference sites.	Assessment Complete (2015) Reassess Post Remediation
OR, in cases where tumors have been reported:	
• A comparison study of resident benthic fish such as white suckers of comparable age and maturity, or of fish species found with tumors in previous fish health surveys in the AOC, with fish at minimally impacted reference sites indicate that there is no statistically significant difference (with 95% confidence) in the incidence of liver tumors or deformities.	Assessment Complete (2015) Reassess Post Remediation

Revised Target: Fish Tumors or Other Deformities

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Contaminated sediment sites within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
• A fish health survey of resident benthic fish species, such as white suckers, finds incidences of liver tumors to be less than the established Great Lakes background rate (5% for white suckers) with 95 percent confidence. OR, in cases where tumor rates exceed the established background rate: • A comparison study of resident benthic fish, such as white suckers, of comparable age and maturity with fish at a reference site indicates that there is no statistically significant difference (with 95% confidence) in the incidence of liver tumor. OR, in cases where tumor rates are representing a decline: • Multiple years of assessments of resident benthic fish, such as white suckers, indicate that incident rate of liver tumors is decreasing such that it can be reasonably expected that incident rate of liver tumors is below Great Lakes background rates or statistically comparable to a minimally impacted reference site, with 95 percent confidence, once all fish exposed to contaminated sediment have been naturally removed from the system.	Assessment Complete (2015); Reassess Post Sediment Remediation

Revision Determination

Justifiable Reason: The scope of achievable activities within the AOC program has become better understood as program implementation has occurred.
New information has become available.

Target Language Changes

- Specific language relating to other deformities was removed because neoplastic liver tumors are closely correlated with contaminants. Other pathogen deformities can have a large list of causes not related to contaminants.
- Removed language related to other fish species separate from our benthic resident indicator, white sucker. Other benthic species that are used for this BUI (brown bullhead) are not available in the Milwaukee Estuary AOC.
- Added a third case in which this BUI can be removed. By comparing rate of decrease between sampling events, the BUI can be removed if data suggests that tumor rates will be at or below the reference site by the time fish that were exposed to contaminated sediment have been removed from the population.

BIRD OR ANIMAL DEFORMITIES OR REPRODUCTION PROBLEMS

Tree swallow nesting in a monitoring box at Lakeshore State Park in the Milwaukee Estuary AOC. Study by USGS from 2010-2015 determined elevated levels of PCBs, PAHs, dioxins, and furans (Custer et al., 2016).

Background

The 1994 RAP stated that this BUI was impaired due to contaminants like PCBs and heavy metals that are found in AOC sediments which may have the potential to impair reproduction and development in wildlife (King and Krynitsky, 1986; Scheuhammer, 1987). In 2011, research on tree swallows began in the Great Lakes Region. These birds have historically been a primary study species and are the suggested indicators of environmental contamination in areas across the US (Custer and Custer, 2003). They feed on emergent aquatic insects near their nests (within a few hundred meters) and offer the ability to assess bioavailability of metals and organic pollutants from contaminated sediments into aquatic insects, and further up trophic levels.

As of the 2017 RAP, tree swallows have been the species of focus for monitoring efforts for the Milwaukee Estuary AOC in relation to Approach 1 of the current target (updated in 2011). Results from a 2010-2015 USGS study that includes sampling tree swallows in Milwaukee Estuary AOC can be found in Appendix E of the 2017 RAP (Custer *et al.* 2016). Recently, multiple lines of evidence for this BUI have been used in Michigan AOCs to also look at species that represent higher trophic levels (Bush and Boer, 2015 and 2020). Fish-eating birds or wildlife have been found to better represent the extent of reproductive and health effects caused by contaminated sediments at higher trophic levels. Based on these results, a target revision was made to also include fish-eating birds or wildlife to more accurately represent bioaccumulation throughout the AOC as well as BUI recovery. In 2020, WDNR will pull together a group of technical experts to develop a monitoring and assessment plan.

Current Target: Bird or Animal Deformities or Reproduction Problems

Target (Updated 2011)	Status
This BUI can be removed if: • Studies conducted in the AOC indicate that the beneficial use should not be considered impaired, or	In Progress (2010-2018)
• If studies conducted in the AOC determine that this use is impaired, then two approaches can be considered for delisting: o Approach 1 – Observational Data and Direct Measurements of Birds and other Wildlife ▪ Evaluate observational data of bird or other animal deformities for a minimum of two successive monitoring cycles in indicator species identified in the initial studies as exhibiting deformities or reproductive problems. If deformity or reproductive problem rates are not statistically different than those at minimally impacted reference sites (at a 95% confidence interval), or no reproductive or deformity problems are identified during the two successive monitoring cycles, then the BUI can be removed. If the rates within the AOC are statistically higher than the reference site, it may indicate a source from either within or from outside the AOC. Therefore, if the rates are statistically higher or the data are insufficient for analysis to achieve agreed upon statistical power, then… ▪ Evaluate tissue contaminant levels in egg, young and/or adult wildlife. If contaminant levels are lower than the Lowest Observable Effect Level (LOEL) for that species for a particular contaminant that are not statistically different than those at minimally impacted reference sites (at a 95% confidence interval), then the BUI can be removed.	TBD (based on results of study)

Revised Target: Bird or Animal Deformities or Reproduction Problems

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Contaminated sediment sites within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
• Contaminant levels (PCBs, PAHs, heavy metals) in egg, young, and/or adult tissues for selected species (such as tree swallows AND fish-eating birds or wildlife) are at or below the Lowest Observable Effect Level (LOEL) for contaminants known to cause deformities or reproductive suppression, or if higher than the LOEL, are not statistically different than those at a minimally impacted reference site (with 95% confidence interval) over a 3-year-period. OR, where direct observation of bird and wildlife tissue data are not available: • Fish within the AOC, and of a size and species considered prey for fish-eating birds or other fish-eating wildlife, have tissue contaminant (PCBs, PAHs, heavy metals) concentrations at or below the LOEL for contaminants known to cause deformities or reproductive suppression in fish-eating birds or wildlife, or if higher than the LOEL, are not statistically different than those at a minimally impacted reference site (with 95% confidence interval) over a 3-year period.	Assessment Complete (2015); In-Progress Assessment; Reassess post sediment remediation.

• Where direct observation of wildlife and wildlife tissue data are not available, the following approach should be used: o Approach 2 – Fish Tissue Contaminant Levels as an Indicator of Deformities or Reproductive Problems ▪ If fish tissue concentrations of contaminants known to cause deformities or reproductive suppression identified in the AOC are at or lower than the LOEL known to cause reproductive or developmental problems in fish-eating birds and mammals, the BUI can be delisted, or ▪ If fish tissue concentrations of contaminants known to cause deformities or reproductive suppression identified in the AOC are not statistically different than Lake Michigan (at 95% confidence interval with sufficient and agreed upon statistical power), then the BUI can be removed. Fish of a size and species considered prey for the wildlife species under consideration must be used for the tissue data.	TBD (based on results of Approach 1)

Revision Determination

Justifiable Reason: The scope of achievable activities within the AOC program has become better understood as program implementation has occurred.
New information has become available.

Target Language Changes

- USGS has previously sampled tree swallows in the Milwaukee Estuary AOC. Since 2010, multiple sites in the AOC have been sampled each year. Data from these sampling events show high levels of PAHs and heavy metals.
- Removed the first two bullet points because status of AOC is better understood.
- Included sediment contamination management actions to be implemented – as a source of bird or animal deformities BUI in the AOC.
- Removed the Approach 1 and the first bullet point. The monitoring required to make this determination would be hard to achieve. The first bullet point and the second are now combined and wording revised to make it more possible and meaningful towards representing both birds and wildlife.
- Added clarifications around what type of contaminants are being assessed.
- Added a multi-year monitoring approach that can help show improvement instead of just a single year of sampling.
- Added fish eating birds or wildlife to both sections of the target to allow for sampling multiple trophic levels.
- Added how to address if contaminant levels are found to be higher than the LOEL.

RESTRICTIONS ON FISH AND WILDLIFE CONSUMPTION

WISCONSIN DEPT. OF NATURAL RESOURCES

Fish Consumption Advice for the Milwaukee Estuary Area of Concern

Benefits of eating your catch

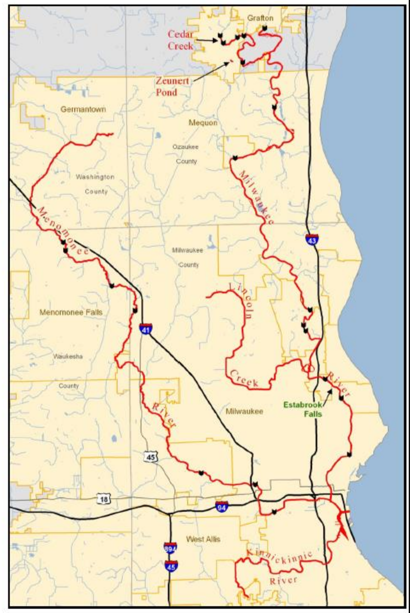
Fish are a nutritious family food. Some of the benefits of catching and eating 1-2 servings of fish per week include:

- Low cost and fun to catch your own fish
- Low in fat, yet high in protein
- Great source of vitamins, minerals, and omega-3 fatty acids

However, polychlorinated biphenyls (PCBs) pose health risks and prompt the need for fish consumption advisories. The advice for this area varies by species and location on the river *(see the advisory table on page 2)*. Fish from Cedar Creek and Zeunert Pond should not be eaten.

What are Polychlorinated biphenyls (PCBs)?

PCBs are man-made chemicals that were used in electrical equipment, industrial processes, and manufacturing and recycling of carbonless copy paper. PCBs were discharged into Cedar Creek, the Milwaukee, Menomonee, and Kinnickinnic Rivers, and Lincoln Creek for decades before it was discovered that these chemicals build up in the environment and pose health risks to humans and wildlife. Restrictions on PCB use, manufacturing, and disposal began in the 1970's, but PCBs remain in the sediment of these rivers. Efforts are underway to remediate contaminants in the affected river sediments.



The Milwaukee Estuary AOC is included in a PCB fish consumption advisory since 1976 that extends outside of the boundary to the upper portions of the Menomonee and Kinnickinnic Rivers.

Background

Fish

Wisconsin DNR, in conjunction with the Department of Health Services (DHS), monitors fishes for contaminants from rivers within the Milwaukee River basin (including the AOC, upon request). These monitoring efforts have been occurring for waters of the state since the 1970s (Schrank, 2014), and includes analyses for PCBs, mercury, dioxins, and furans. Consumption advisories are updated by DNR and DHS as needed based on sampling results. The Milwaukee Estuary AOC has a PCB consumption advisory for resident and transient species, but no additional advisories pertaining to the AOC (beyond the state-wide fish consumption advice that applies for mercury).

Updated information from previous and ongoing assessments for fishes in the AOC warranted a target revision to include sediment remediation and alter language of unobtainable criteria.

Wildlife

The waterfowl consumption advisory, initially issued in 1987, was for certain species (mallard, black ducks, scaup, and ruddy ducks) harvested in the Milwaukee Estuary AOC. A re-evaluation of wildlife consumption advisories in 2013-2015 indicate that the current advisories for waterfowl remain in effect and that all diving ducks are to be included as part of the consumption advisory (Strom, 2016). Waterfowl consumption advisories will be reassessed after sediment remediation occurs.

Current Target: Restrictions on Fish and Wildlife Consumption

Target (Updated 2011)	Status
Fish Approach to be used with current level of monitoring for fish consumption advisories within the AOC (every five years):	
• All known man-made sources of BCOCs (including PCBs, mercury, dioxins, and furans) within the AOC and tributary watershed have been controlled or eliminated; and	In Progress & Action Needed
• State fish tissue monitoring confirms that waterbody-specific fish consumption advisories are no longer needed for PCBs for waters in the AOC.	Action Needed
• Waters within the Milwaukee Estuary AOC are not listed as impaired due to fish consumption advisories in the most recent Clean Water Act 303(d) and 305(b) Wisconsin Water Quality Report to Congress (submitted to USEPA every two years).	In Progress (ongoing monitoring)
Approach to be used with funding to support additional monitoring:	
• All known man-made sources BCOCs (including PCBs, mercury, dioxins, and furans) within the AOC and tributary watershed have been controlled or eliminated; and	In Progress & Action Needed
• A multi-year comparison study of fish tissue contaminant levels demonstrates that there is no statistically significant difference (with a 95% confidence interval) in fish tissue BCOC concentrations in the AOC compared to fish tissue BCOC concentrations in a representative non- impacted control site within the Lake Michigan Basin.	TBD (based on results of current monitoring)
Wildlife There are no waterfowl consumption advisories for resident waterfowl due to contamination originating within the AOC.	Assessment Complete (2015) Reassess Post Remediation

Revised Target: Restrictions on Fish and Wildlife Consumption

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Contaminated sediment sites within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
Fish • State fish tissue monitoring confirms that AOC waterbody-specific fish consumption advisories are no longer needed for PCBs, mercury, dioxins, and furans for waters in the AOC. OR • A multi-year comparison study of fish tissue contaminant levels demonstrates that there is no statistically significant difference (with a 95% confidence interval) in fish tissue concentrations in the AOC compared to fish tissue concentrations in a representative non-AOC control site within the Lake Michigan Basin.	In Progress & Action Needed
Wildlife • There are no waterfowl consumption advisories for waterfowl due to contamination originating within the AOC.	Assessment Complete (2015) Reassess Post Remediation

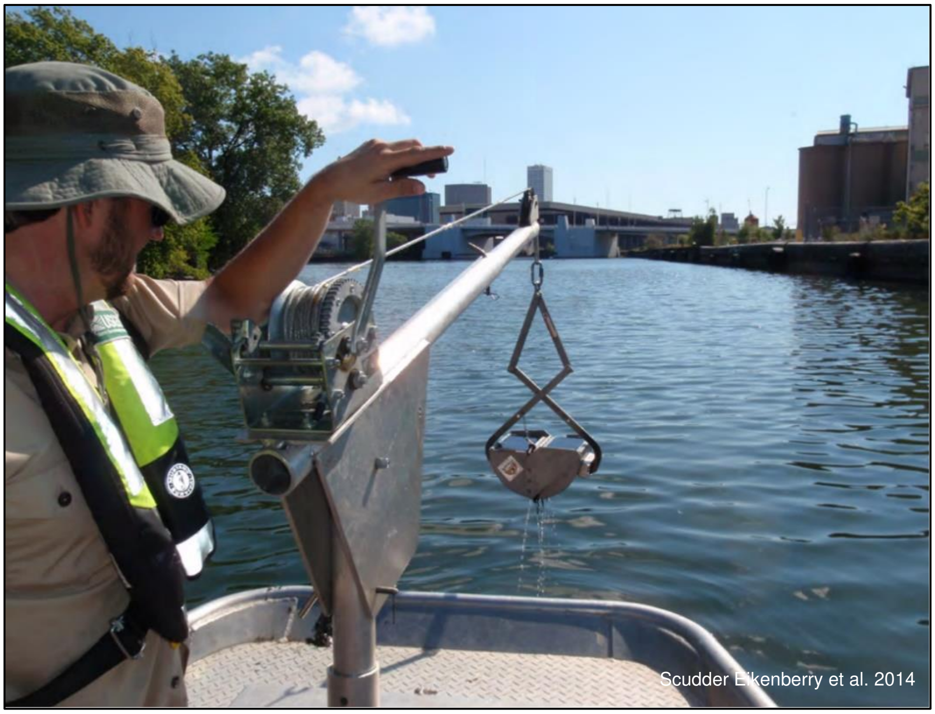
Revision Determination

Justifiable Reason: The target reflects goals that go beyond the AOC program framework.
The scope of achievable activities within the AOC program has become better understood as program implementation has occurred.
New information has become available.

Target Language Changes

- Removed the first sentence about identifying the approach that is currently used to monitor fish consumption advisories within the AOC.
- Removed the acronym BCOCs (Biological Chemicals of Concern) where the contaminants are already referenced.
- Removed 303(d) and 305(b) language because this designation is out of the AOC program framework.
- Removed the “approach to be used with funding to support additional monitoring” and combined the possibility of choosing between two levels of detail for fish consumption advisories (comparing to a reference site or having the Milwaukee Estuary AOC be listed as no longer impaired). If needed, this will allow there to still be a fish consumption advisory in effect when removing this BUI – if the fish tissue contaminant levels show no statistically significant difference between the reference site.
- State fish tissue monitoring confirms that AOC waterbody-specific fish consumption advisories… means that advisories are no more restrictive than statewide (for mercury) or Lake Michigan (for PCBs) advisories.

DEGRADATION OF BENTHOS



USGS retrieving a Ponar dredge on the Menomonee River for a benthos community sample in a multi-comparison study between AOCs and reference sites along the Western Lake Michigan Shoreline (Scudder Eikenberry et al., 2014 and 2016).

Background

Benthic surveys conducted in the Menomonee (1979, 1984), Kinnickinnic (1977, 1978), and Milwaukee (1975, 1980) Rivers revealed that benthos was dominated by populations of pollution tolerant species (SEWRPC, 1981; SEWRPC 1987; DNR, 1991), leading to the degradation of benthos designation in the Milwaukee Estuary AOC. Similar results were found again in 1990 where sampling of several locations throughout the original AOC boundary (Brooks and Kaster, 1992) showed dominance of pollution tolerant species.

In the most recent assessments completed by USGS in 2012 and 2014 (Scudder Eickenberry *et al.*, 2019), benthic assemblages did not improve in the past decades and are still dominated by pollution tolerant species in the lower estuary. Harbor benthic communities are subjected to regularly disturbed and altered physical conditions when compared to the upper portions of the AOC (i.e. tributaries). The lower estuary and harbor contain poor substrate, water-quality conditions, inadequate food resources, high sedimentation rates, and low dissolved oxygen concentrations (DNR 1991, 1994, 2014). However, results from these assessments also determined that benthic communities at subsites in the Menomonee and Milwaukee Rivers are not t significantly different than those found at non-AOC reference sites.

Updated information and a better understanding of the benthic community in the AOC has provided the need to update the current target. The lower estuary is highly modified by bulkhead walls and navigation channel dredging; therefore, a high-quality benthic community is likely unachievable in this part of the AOC. The target has been altered to reflect these findings and now focuses on the upper estuary benthic community.

Current Target: Degradation of Benthos

Target (Updated 2011)	Status
Removal may occur if:	
• Known contaminant sources contributing to sediment contamination and degraded benthos have been identified and control measures implemented; and	In Progress & Action Needed
• All remediation actions for contaminated sediments are completed and monitored according to an approved plan; or	In Progress & Action Needed
• The benthic community within the site being evaluated is statistically similar to a reference site with similar habitat and minimal sediment contamination.	Assessment In Progress (2012-2017)

Revised Target: Degradation of Benthos

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Contaminated sediment sites within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
• The benthic community of the Milwaukee Estuary AOC, excluding the highly modified lower estuary (*downstream of N. Humboldt Avenue on the Milwaukee River; downstream of N 25th Street on the Menomonee River; downstream of S Chase Avenue on the Kinnickinnic River, inner and outer harbors*) is statistically similar to a non-AOC reference site with similar habitat.	In-Progress

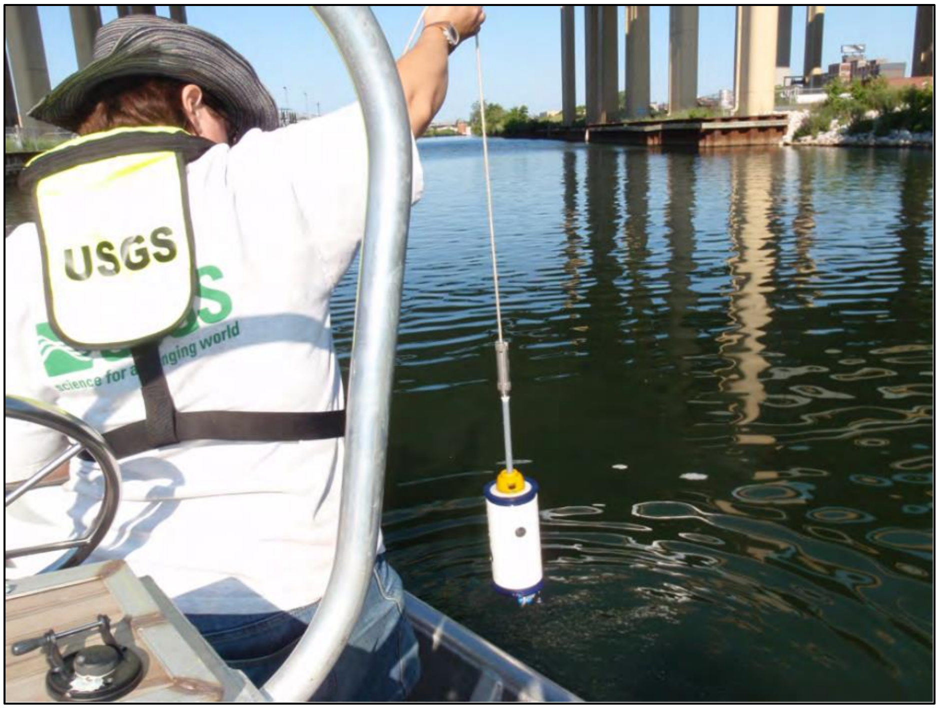
Revision Determination

Justifiable Reason: The scope of achievable activities within the AOC program has become better understood as program implementation has occurred.
New information has become available.

Target Language Changes

- Removed the second bullet point that references needing the remediation actions to be monitored according to an approved plan for this specific BUI. Contaminated sediment remediation is already referenced in the first bullet point.
- Provided language to separate the highly modified lower estuary from the upper estuary. There is continual disturbance in the lower estuary from dredging operations and other urban activities.

DEGRADATION OF PHYTOPLANKTON AND ZOOPLANKTON POPULATIONS



USGS collecting phytoplankton with a vertical water sampler on the Menomonee River in a multi-comparison study between AOCs and reference sites along the Western Lake Michigan Shoreline (Scudder Eikenberry et al., 2014 and 2016).

Background

Historical surveys by MMSD in the Milwaukee Estuary from 1979 through 1988 indicated decline of species richness and dominance of pollutant tolerant phytoplankton and zooplankton species in the outer harbor when compared to the nearshore waters (MMSD, 1987; DNR, 1991; DNR, 1994). These surveys were the basis for listing this BUI. Plankton communities rely on the nutrient loading from the three rivers, Jones Island Wastewater Facility discharge, and other point-source discharges (DNR, 1994). Other factors such as water quality, non-point sources, predation, food availability, and physical habitat also play a role on plankton communities.

During 2012, the Degradation of Phytoplankton and Zooplankton Populations target was revised to remove the requirement of the AOC to no longer be listed as impaired due to phytoplankton and/or zooplankton toxicity being on the most recent Wisconsin Impaired Waters List. The basis for the revision was that there were no considerations for listing waterbodies as impaired due to plankton toxicity (DNR, 2013).

In 2012 and 2014, USGS sampled plankton populations in the AOC and appropriate reference sites (Scudder Eikenberry *et al.,* 2014, 2016, and 2019). These publications determined that phytoplankton populations at the Menomonee and Milwaukee River subsites are not statistically different compared to reference sites with regards to richness, diversity, and total density. Overall, zooplankton populations are not different from reference sites but continue to have low diversity, similarly to historical trends. As a result, the target is being proposed for revisions with this current information.

Current Target: Degradation of Phytoplankton and Zooplankton Populations

Target (Updated 2012)	Status
A stepped approach is needed for delisting for this impairment:	
1. The first step toward delisting will be to establish a baseline condition for the estuary to evaluate the extent of this impairment. Phytoplankton and zooplankton community surveys should be conducted and compared to a non-impacted or minimally impacted reference site to set the baseline condition. If the community structure is statistically different than the reference conditions, this BUI should be considered impaired.	Assessment In Progress (2012-2017)
2. Identify the factors leading to this impairment. a. Ambient water chemistry sampling should be conducted to determine if nutrient enrichment is the main contributor. If nutrients are the main contributor, sources causing nutrient enrichment to the outer harbor and nearshore waters are identified and controlled. b. If nutrient enrichment is not considered the cause of the impairment, conduct bioassays to determine if ambient water toxicity is causing impairment.	Action Needed (based on results of current assessment)

Revised Target: Degradation of Phytoplankton and Zooplankton Populations

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Phytoplankton and zooplankton bioassays confirm there is no toxicity in ambient waters.	Action Needed
• The phytoplankton and zooplankton communities within the site being evaluated are statistically similar to a non-AOC reference site with similar habitat.	Assessment Complete (2019)

Revision Determination

Justifiable Reason: The scope of achievable activities within the AOC program has become better understood as program implementation has occurred. New information has become available.

Target Language Changes

- The previous target included performing the assessment and completing it to meet the first step of the target, without including any threshold or criteria.
- The second portion of the previous “stepped approach” focused on controlling nutrient sources and determining if ambient water toxicity is causing the impairment. This was tied directly into identifying the impairment and more of an action than a specific target. Previously, this wasn’t something that addressed the impairment itself. Therefore, targets were separated to those that need to be met in order to address this BUI.
- Factors such as nutrient enrichment and toxicity due to sediment were removed from the target as source control measures. These type of measures and management actions are addressed in separate BUIs (Eutrophication or Undesirable Algae and Restrictions on Dredging Activities).

LOSS OF FISH AND WILDLIFE HABITAT

Previous efforts through surveys and planning have been completed in Little Menomonee River Corridor with implementation efforts of restoration to occur in 2020.

Background

The 1991 and 1994 RAP identified this use as being impaired for critical fish and wildlife habitats, respectively. This determination was made due to human modifications to the physical environment with the hardening of shorelines, altering the conveyance of flow in the tributaries and subsequently, the inner and outer harbors. It also referenced water quality issues due to contaminated sediments, poor ambient water quality, and sediment/nutrient loading that further degraded habitat availability. The only significant habitat referenced in the early 1990s was at the parks along the near shore areas of Lake Michigan.

In 2011, Wisconsin DNR convened a technical team for Fish and Wildlife (F&W) related BUIs. This team was tasked with assisting in the preparation of a fish and wildlife plan that establishes measurable endpoints for the population and habitat BUIs. A goal of the team was to also utilize previous data and plans collected within the AOC to help determine necessary projects that address the status of both BUIs (see Degradation of Fish and Wildlife Populations).

In 2015, this F&W Tech Team completed project summaries for a management action list. Eleven projects were identified and can be found in the 2015 RAP update. As of 2019, the F&W Tech Team is now composed of 35 individuals representing 14 different federal, state, local, and non-governmental organizations. Since 2017, five projects have been completed with the remaining projects started but at different stages (i.e. planning, design, implementation).

With updated information on the status of the Degradation of Fish and Wildlife Populations BUI in 2019, the F&W Tech Team determined that updating the Loss of Fish and Wildlife Habitat BUI target would help keep all the goals, objectives, and metrics for both BUIs consistent. The alteration of this target language does not change the management action list (see table below).

Project	Date (Status)	Partner(s)	Funding Source(s)
Little Menomonee River Parkway Grassland Restoration	2013 – 2015 (complete)	MCP, WDNR	GLRI
Burnham Canal Wetland Restoration	2014 – present (underway)	MMSD, USACE, FFLM, WDNR	GLRI, USACE, FFLM, MMSD
Bay View Wetland/Grand Trunk Wetland Restoration	2015 – present (underway)	City of Milwaukee, HDI, WDNR	GLRI, WCMP, SOGL, FFLM, City of Milwaukee
Milwaukee River Fish Habitat Enhancement and Expansion	2014 (complete)	WDNR, RRF	FFLM
Wheelhouse Gateway Riparian Restoration	2013-2014 (complete)	RRF, WDNR	DNR Stewardship Fund, FFLM, SOGL, RRF
Menomonee River Stream Management (Concrete Removal) Phases 1 & 2	2010-2019 (complete)	MMSD, USACE, WDNR	GLRI, MMSD, USACE, USFWS
Kletzsch Park Dam Fish Passage	2016 – present (underway)	MCP, WDNR	GLRI, DNR Stewardship Fund, DNR Municipal Dam Grant, MCP
Estabrook Dam Fish Passage	2017 – 2020 (underway)	MMSD, WDNR	GLRI, FFLM, WDNR
Five Low Flow Barriers on the Menomonee River	2014 – 2016 (complete)	MMSD, WDNR	MMSD, SOGL, FFLM, NOAA
Kinnickinnic River Habitat Rehabilitation	2014 – present (Phase I complete, Phase II underway)	MMSD, WDNR	GLRI, MMSD, NOAA
Little Menomonee River Corridor Restoration	2017 – present (underway)	MCP, WDNR	GLRI

FFLM – Fund for Lake Michigan
GLRI – Great Lakes Restoration Initiative
HDI – Harbor District, Inc
MCP – Milwaukee County Parks
MMSD – Milwaukee Metropolitan Sewerage District
NOAA – National Oceanic and Atmospheric Administration
RRF – River Revitalization Foundation
SOGL – Sustain Our Great Lakes
USACE – United States Army Corps of Engineers
USFWS – United States Fish and Wildlife Service
WCMP – Wisconsin Coastal Management Program
WDNR – Wisconsin Department of Natural Resources

Current Target: Loss of Fish and Wildlife Habitat

Target (Updated 2011)	Status
This BUI will be considered to be eligible for removal when the following have occurred:	
• All contaminated sediment hotspots within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
• A local fish and wildlife management and rehabilitation plan has been compiled for the estuary that: ○ Defines the causes of all habitat impairments within the AOC ○ Establishes site-specific habitat and population targets for native indicator fish and wildlife species within the AOC ○ Identifies all fish and wildlife habitat rehabilitation programs/activities within the AOC and establishes a mechanism to assure coordination among all these programs/activities, including identification of lead agencies ○ Establishes a time table, funding mechanism, and lead agency or organization responsibility for all fish and wildlife habitat rehabilitation activities needed within the AOC.	In Progress
• The programs and actions necessary to accomplish the recommendations of the fish and wildlife habitat plan are implemented and modified as need to ensure continual improvement.	In Progress

Revised Target: Loss of Fish and Wildlife Habitat

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Contaminated sediment sites within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
• All management actions/projects have been identified and implemented.	In Progress
• Post-implementation verification monitoring of the AOC shows that, in consultation with the Fish and Wildlife Tech Team, the Wisconsin DNR concurs that the goals for this BUI, as identified in the updated RAP to reflect current conditions, have been met.	Future Assessment Needed

*Additional details about the goals and related metrics are available in the “Future RAP Appendix” section near the end of this document.

Revision Determination

Justifiable Reason: The scope of achievable activities within the AOC program has become better understood as program implementation has occurred. New information has become available.

Target Language Changes

- Removed language about Degradation of Fish and Wildlife Populations in the text, as the management action lists were split between the two BUIs.
- Changed the language to specify reference to meet the overarching primary and secondary goals, and project specific goals.
- The Loss of Fish and Wildlife Habitat BUI overarching goals, project specific goals and measures of success will be listed as an Appendix in every RAP update. An overarching table and bulleted list for each project was created to better represent the goals of these larger efforts.
- The management action list for this BUI that was finalized in 2016 does not change with the revised language.

DEGRADATION OF FISH AND WILDLIFE POPULATIONS

A juvenile lake sturgeon in the Milwaukee Harbor near Discovery World. A stocking program by Wisconsin DNR and Riveredge Nature Preserve, started in 2006, releases lake sturgeon every year in September during the Sturgeon Festival.

Background

When listed as an AOC, fish and wildlife populations in the Estuary were severely degraded. Pollutant tolerant fish species dominated surveys, indicative of the poor water quality conditions and contaminants present in the AOC (Holey, 1984; DNR, 1991). Factors contributing to historically poor water quality conditions included low dissolved oxygen and major contaminant spills often resulting in fish kills (DNR, 1991). Lack of physical habitat, especially the loss of wetlands and nearly-nonexistent natural areas along the streambanks in the harbor and rivers-edge in the lower estuary contributed to declines in wildlife populations (DNR, 1994). In 2008, studies completed to assess the ecological change in Milwaukee County concluded substantial losses of wildlife species richness with estimated declines of amphibians (44%), reptiles (47%), breeding birds (37%), and flora (37%) (Waller and Rooney, 2008).

Four assessments were funded and completed between 2014 to 2018 to determine the current status:

1. A fish population assessment summary of historic densities and life history for the AOC was completed by USGS and DNR in 2014 (Sullivan and Fayram, 2014). Based on this summary, a non-wadeable fisheries population assessment (replicate of Holey 1984) from 2014-2016 by United States Geological Survey (USGS) (Sullivan, 2018).
2. A wildlife population assessment summary of historic densities and life history for the AOC was completed by UW-Milwaukee Field Station. Based on this summary, a comprehensive wildlife survey throughout the AOC from 2014-2017 by UW-Milwaukee Field Station and Milwaukee County Dept. of Parks, Recreation and Culture (DPRC) (Casper and Robson, 2018).
3. A fisheries and aquatic habitat study in the wadeable portions of the AOC from 2016-2018 by Ozaukee County Planning and Parks (OCPP) (Struck et al. 2018).
4. An assessment of fish habitat in the Milwaukee Harbor from 2015-2018 by UW-Milwaukee School of Freshwater Sciences (Dow, 2018).

These baseline assessments provided information (proposed metrics and project recommendations) for extensive discussions within the Milwaukee Estuary AOC F&W Tech Team. Tech Team members were offered the opportunity to provide a list of projects that they would want to see implemented in the AOC to address the BUI. This list of projects, separated by geographical location, were ranked by priority on overall importance. These projects were paired with the revised metrics and a list of projects were determined. Metrics and proposed projects to address the status of this BUI were vetted in full day, every-other-week F&W Tech Team meetings for approximately one year. The F&W Tech Team evaluated the science as well as factors related to achievability and measurability to arrive at a list of projects, a suite of revised metrics, and as a result, a recommended revision to the target.

Current Target: Degradation of Fish and Wildlife Populations

Target (Updated 2011)	Status
Fish This BUI will be considered to be eligible for removal when the following have occurred:	
• All contaminated sediment hotspots within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
• A local fish and wildlife management and rehabilitation plan has been compiled for the estuary that: ○ Defines the causes of all population impairments within the AOC ○ Establishes site specific local population targets for native indicator fish and wildlife species within the AOC ○ Identifies all fish and wildlife population rehabilitation programs/activities within the AOC and establishes a mechanism to assure coordination among all these programs/activities, including identification of lead and coordinative agencies ○ Establishes a time table, funding mechanism, and lead agency or organization responsibility for all fish and wildlife population activities needed within the AOC. ○ The actions/projects necessary to accomplish the recommendations of the fish and wildlife management and restoration plan are implemented.	In Progress
• Populations for native indicator fish species are statistically similar to populations in reference sites with similar habitat but little to no contamination.	Unknown

Revised Target: Degradation of Fish and Wildlife Populations

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Contaminated sediment sites within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
• All management actions/projects have been identified and implemented.	Action Needed
• Post-implementation verification monitoring of the AOC shows that, in consultation with the Fish and Wildlife Tech Team, the Wisconsin DNR concurs that the goals for this BUI, as identified in the updated RAP to reflect current conditions, have been met.	Future Assessment Needed

*Additional details about the goals and related metrics are available in the "Future RAP Appendix" section near the end of this document.

Wildlife Assess wildlife populations and the possible extent of any impairment within the AOC before setting specific wildlife population targets.	In Progress

Revision Determination

Justifiable Reason: The scope of achievable activities within the AOC program has become better understood as program implementation has occurred. New information has become available.

Target Language Changes

- The previous targets for this BUI were previously put together in short notice and need to be updated with the known status for this BUI in the Milwaukee Estuary AOC.
- Different sections referencing Fish and Wildlife were removed and tied the entire target language together.
- Unlike most AOCs, the Loss of Fish and Wildlife Habitat BUI for the Milwaukee Estuary AOC has its own management action list of projects. The overarching goals and project specific goals with measures of success for these management actions can be found on page 39. They will also be included as an Appendix in future RAP updates.

BEACH CLOSINGS (RECREATIONAL RESTRICTIONS)

South Shore Beach is one out of four Area of Concern beaches in Milwaukee. It is by far the most researched and monitored beach throughout Lake Michigan due to frequent advisories and closures caused by high levels of *E. coli*.

Background

There are no swimming beaches along the Milwaukee, Menomonee, and Kinnickinnic Rivers in the AOC. However, there are four beaches along Lake Michigan in the nearshore waters of the AOC that close periodically during the swimming season for high bacteria levels. These beaches do not consistently meet water quality standards for recreation throughout the year based on *E. coli* in water samples during the swimming season.

Early RAP documents stated that high bacteria levels and sewer overflows in the AOC caused beach closings and recreational hazards. While sewer overflows can contribute to the closure of beaches in the AOC, high bacterial counts from urban nonpoint pollution throughout the AOC waterways often exceeded water quality standards for recreation. Since the early 1990s, sewer overflows have decreased substantially, largely because of MMSD's Deep Tunnel system.

In 2012, Milwaukee Riverkeeper and the Great Lakes WATER Institute analyzed data for pathogen source identification (DNR, 2012). These assessments informed where the most significant sources of bacteria are originating and, where achievable, procedures that could be taken to reduce the harmful source of bacteria to the AOC waterways (DNR, 2012). From 2014-2016, a bacterial source tracking study was conducted in the AOC to identify areas that posed a risk to human health through exceeding water quality standards for recreation due to large sources of contaminated urban stormwater (DNR, 2013).

Based on previous knowledge and research completed throughout the AOC on beaches and recreational restrictions, this target warrants revisions to determine necessary management actions that can be completed to address these issues.

Current Target: Beach Closings (Recreational Restrictions)

Target (Updated 2011 & 2012)	Status
This BUI will be considered removed when:	
• All known sources of bacterial contamination to the AOC and tributary watersheds have been identified and, if feasible, have been controlled or treated to reduce possible exposures; and	Assessment in Progress & Action Needed
• No unpermitted overflows (either from sanitary sewers or combined sewers) have occurred within the AOC during the previous five year period.	Unknown
• All municipalities within the AOC have adopted and are implementing storm water reduction programs including an illicit discharge elimination program; and	Complete
• No water bodies within the AOC are included on the list of impaired waters due to contamination with pathogens or chemicals having a public health concern (i.e., carcinogenic, mutagenic) in the most recent Wisconsin Impaired Waters list that is submitted to USEPA every two years; and	In Progress & Action Needed
• No local or state contact advisories related to the presence of a chemical contaminant have been issued within the AOC during the previous five years.	Unknown
• No water bodies (including beaches) within the AOC are included on the list of impaired waters for recreational restrictions in the most recent Wisconsin Impaired Waters list.	In Progress & Action Needed
• Implementation of the Milwaukee River Total Maximum Daily Load Study for bacteria is complete.	In Progress & Action Needed

Revised Target: Beach Closings (Recreational Restrictions)

Target (Updated 2020)	Status
Removal of this BUI can occur when:	
• Known sources of bacterial contamination impacting the beaches in the AOC have been identified, and if feasible, have been controlled or treated to reduce possible exposures.	Assessment in Progress & Action Needed
• Stormwater outfalls in the AOC that discharge directly or influence beaches are assessed to confirm that there are no human sources of sanitary sewage contamination.	Assessment Needed
• Municipalities within the AOC have adopted and are implementing storm water reduction programs that include bacteria source reduction and illicit discharge elimination.	Complete
• Each public swimming beach within the AOC is open for at least 90% of the swimming season (between Memorial Day and Labor Day) averaged over a previous 5-year period based on Wisconsin Coastal Beach monitoring protocols for *E. coli* monitoring and BMPs are in place. OR • Public swimming beaches within the AOC are meeting EPA's 2012 recreational water quality criteria over a 3-year period. OR, in cases where known sources of bacterial contamination impacting beaches in the AOC have been controlled to the extent feasible and the above criteria cannot be met: • Each public swimming beach within the AOC is open during the swimming season (between Memorial Day and Labor Day) at least as often as the average of all non-AOC beaches in Milwaukee County over the same 5-year period.	In Progress & Action Needed

• No unpermitted discharges (combined or sanitary sewers in the Lower Milwaukee Estuary) at outfalls directly impacting AOC beaches during the swimming season (between Memorial Day and Labor Day) in a 3-year period.	Currently Meeting Target; Reassess After Management Actions are Completed
• Complete a plan that includes updates to existing advisory and closure procedures for AOC beaches to reduce human health risks during and after storm events.	In Progress

Revision Determination

Justifiable Reason: The scope of achievable activities within the AOC program has become better understood as program implementation has occurred.
New information has become available.

Target Language Changes

- Removed language about no local or contact advisories related to the presence of a chemical contaminant. There are no known chemical contaminant issues at existing beaches within this AOC. We are addressing source control measures by addressing bacterial contamination in the first bullet point that remains as a target.
- Removed impaired waters language because this designation is out of the AOC program framework. It will be addressed through regulatory surface water quality standards – 305(b) and 303(d).
- Removed language about the TMDL. This is something that is covered through a separate program in the DNR.
- Changed language to a percentage of beach closures during the swimming season (90%) with input from how this relates to Great Lakes standards (95% is the state's statistics on best beaches in the entire State). Included the need for BMPs for each of these beaches to show a continued effort to reduce the number of closings that will happen during the swimming season. This bullet would be that each beach is open for 90% of the swimming season.
- Added two off-ramps to the 90% threshold: Public swimming beaches within the AOC are meeting EPA's 2012 recreational water quality criteria over a 3-year period or comparing each public swimming beach in the AOC to non-AOC public swimming beaches in Milwaukee County.
- Added the completion of a plan to better address how beaches in the AOC can be managed for storm events.
- While Beach Closings is the official BUI name in the Great Lakes Water Quality Agreement, recreational restrictions and partial body contact issues have been major problems since the AOC designation. To provide clarify for these purposes and the reasoning behind initial designation, WDNR will refer to this BUI for this AOC as Beach Closings (Recreational Restrictions).
- Note: A Beaches Work Group for the Milwaukee Estuary AOC, formed on October 7th, 2019, was created to revisit the Milwaukee Estuary AOC Beach Closing target and to determine important thresholds and/or milestones that will need to be met to eventually remove the BUI. This proposed determination was made by the Work Group with available information pertaining to the Milwaukee Estuary AOC and AOC Program. This Work Group will be used in future efforts to provide feedback as a technical team to ongoing and future beach projects within the Milwaukee Estuary AOC.

EUTROPHICATION OR UNDESIRABLE ALGAE

The Eutrophication or Undesirable Algae BUI designation for the Milwaukee Estuary AOC was due to nutrient loading through non-point and point source pollution to the tributaries that converge into the inner and outer harbors.

Background

The Milwaukee Estuary AOC was historically considered excessively eutrophic as a result of high nutrient levels of phosphorus and nitrogen (DNR, 1991). High levels of these nutrients can lead to nuisance algal blooms and oxygen depletion. Phosphorus, in excessive amounts, causes an increase in algae and weed growth that results in triggering this eutrophication process (DNR, 1991). Undesirable algal blooms occur in response to nutrient loading from combined sewer overflows (CSO), sanitary sewer overflows (SSO), upstream and urban non-point sources, and point sources from storm sewers. These blue-green algal blooms can often occur after a rain event which reduces dissolved oxygen levels and increases turbidity. The dramatic incline of algae growth, due to these high nutrient levels, is one of the reasons that this AOC was considered excessively eutrophic (MMSD, 1992; DNR, 1994).

The lower portion of the Milwaukee Estuary has changed dramatically since the AOC was designated. SSOs are no longer allowed and CSOs are now regulated through permits. These events have also drastically decreased with the implementation of MMSD's Deep Tunnel system in the early 1990s and increase in urban green infrastructure practices. Four TMDLs for the Milwaukee River Basin (Menomonee, Milwaukee, Kinnickinnic, and Inner and Outer harbors) have also been finalized (DNR, 2018). Implementation practices are underway to reduce total suspended solids (TSS), phosphorus, and bacteria, which will contribute to meeting the surface water quality standards. The lower estuary and nearshore waters also have changed with the introduction of invasive dreissenid mussels to the Great Lakes. Overall, this has changed Lake Michigan to become more oligotrophic, but the nearshore waters to the Estuary remain more productive than offshore waters.

Target revisions are anticipated for this BUI in a future RAP update.

Current Target: Eutrophication or Undesirable Algae

Target (Updated 2011)	Status
Removal of this BUI can occur when:	
• Total phosphorus (TP) concentrations within the AOC rivers, harbors, and nearshore waters meet the criteria recommended for the State of Wisconsin, as established by WDNR.	In Progress & Action Needed
• When the results from the total maximum daily load study for phosphorus, total suspended solids, and bacteria are completed for the Menomonee, Kinnickinnic, and Milwaukee Rivers.	In Progress
• Measures to meet the Total Maximum Daily Loading Implementation Plan are being completed.	Action Needed
• No water bodies within the AOC are included on the list of impaired waters due to nutrients or excessive algal growths in the most recent WI Impaired Waters list.	Action Needed
• Chlorophyll-a concentrations within the AOC lake and impoundment areas do not exceed 4.0 µg/L.	Unknown
• There are no beach closures in the AOC due to excessive nuisance algae growth.	Unknown

Not Revised Target: Eutrophication or Undesirable Algae

Target (Update Pending)	Status
Target to be revised and published in a future RAP update	

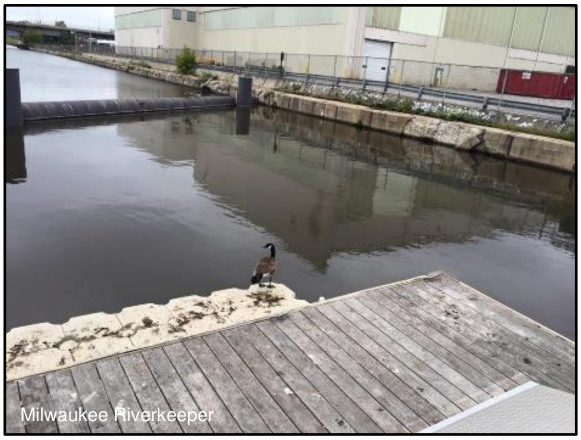
Revision Determination

Justifiable Reason: The scope of achievable activities within the AOC program has become better understood as program implementation has occurred. New information has become available.

Target Language Changes

- This target will not be revised as part of this delisting targets document. However, it will be revised at a future date and published in a RAP update.

DEGRADATION OF AESTHETICS



While this BUI is directly related to the historical issues that the AOC has had with surface water quality and aesthetic appearances, many organizations have taken part in reducing the amount of trash and pollution in the estuary (i.e. Milwaukee Riverkeeper, Milwaukee Metropolitan Sewerage District, City of Milwaukee and others).

Background

The Degradation of Aesthetics BUI for the Milwaukee Estuary AOC stemmed originally from the poor visual quality of the water resources and adjacent land (DNR, 2012). The likely causes of the impairment, attributed in the 1994 Milwaukee RAP, were surface water debris, oil and grease, and overdevelopment along the Estuary (DNR, 2012).

In discussing approaches to assess the status of this target, Milwaukee Estuary AOC stakeholders expressed a strong desire for a citizen-based monitoring approach. The Alliance for the Great Lakes and the Urban Ecology Center (UEC) coordinated citizen volunteers for a pilot Volunteer Aesthetics Monitoring Program. Using what was learned from the pilot program, protocols were updated in 2014. Milwaukee Riverkeeper took over as the volunteer coordinating organization, and assisted with data collection from 2015-2017 (DNR, 2017).

The monitoring program from 2015-2017 focused on nine sites that 30 volunteers assessed throughout the year (DNR, 2015). In 2016, the BUI target language was adjusted to incorporate monitoring results done by multiple observers, two consecutive survey seasons, and identification of significant or persistent issues identified by the surveys (DNR, 2016). The citizen-based aesthetics monitoring continued in 2017. Results from the aesthetics monitoring assessment show that the target is being met. Following a presentation on the assessment and results in June 2019, the Citizens Advisory Committee (also known as Milwaukee Blue Crew), voted to support the removal of this BUI.

As a result, no management actions are anticipated for this BUI and DNR is planning on removing the BUI for the Milwaukee Estuary AOC in 2020.

Current Target: Degradation of Aesthetics

Target (Updated 2016)	Status
This delisting target is consistent with Chapter NR 102, Wisconsin Administrative Code, Water Quality Standards for Surface Waters. Delisting shall occur when monitoring data within the AOC and/or surveys collected by multiple observers for any two consecutive year period indicates that water bodies in the AOC do not exhibit unacceptable levels of the following properties in quantities which interfere with the Water Quality Standards for Surface Waters:	
a) Substances that will cause objectionable deposits on the shore or in the bed of a body of water shall not be present in such amounts as to interfere with public rights in waters of the state.	Assessment in Progress
b) Floating or submerged debris, oil, scum, or other material shall not be present in such amounts as to interfere with public rights in waters of the state.	Assessment in Progress
c) Materials producing color, odor, taste, or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the state.	Assessment in Progress
The following target will also be met to determine when restoration has occurred:	
• Corrective action plans are in-place and being implemented for significant, persistent issues contributing to the degradation of aesthetics within the AOC identified via aesthetics monitoring/surveys.	Action Needed

No Changes: Degradation of Aesthetics

Target (Updated 2016)	Status
This delisting target is consistent with Chapter NR 102, Wisconsin Administrative Code, Water Quality Standards for Surface Waters. Delisting shall occur when monitoring data within the AOC and/or surveys collected by multiple observers for any two consecutive year period indicates that water bodies in the AOC do not exhibit unacceptable levels of the following properties in quantities which interfere with the Water Quality Standards for Surface Waters:	
a) Substances that will cause objectionable deposits on the shore or in the bed of a body of water shall not be present in such amounts as to interfere with public rights in waters of the state.	Assessment Complete
b) Floating or submerged debris, oil, scum, or other material shall not be present in such amounts as to interfere with public rights in waters of the state.	Assessment Complete
c) Materials producing color, odor, taste, or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the state.	Assessment Complete
The following target will also be met to determine when restoration has occurred:	
• Corrective action plans are in-place and being implemented for significant, persistent issues contributing to the degradation of aesthetics within the AOC identified via aesthetics monitoring/surveys.	No Corrective Actions Anticipated

No Revision Determination
Justifiable Reason: No revisions were determined necessary for this target as they were most recently revised and are currently being met.

CONCLUSION

Since 1987, when the Milwaukee Estuary was designated as an AOC under the Great Lakes Water Quality Agreement (GLWQA), many partners have worked to address the AOC impairments. The proposed target revisions will further focus implementation efforts and guide assessment activities to ensure BUI removal objectives have been met.

This document does not include a proposed revision for the Eutrophication or Undesirable Algae BUI target. A target revision is needed and discussions with stakeholders will be held at a future date. An updated target will be published with a future RAP update. This document also does not include an update for the Degradation of Aesthetics BUI target, as it was updated in 2016 and is proposed for removal.

The proposed revisions for the remaining BUIs reflect input from multiple stakeholders and represent an updated understanding of AOC conditions and program policies. They create the foundation for an achievable, measurable, and meaningful implementation effort that will lead to BUI removals. The revised targets will be incorporated into future RAP updates.

Once these delisting targets have been met, BUI removal can be recommended. After all BUIs are removed, the AOC can be delisted. DNR will continue working in consultation with stakeholders and the public on restoration of these waters.

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Future RAP Appendix: Loss of Fish and Wildlife Habitat

Habitat Project Criteria

Goals and Measures of Success for Fish and Wildlife Habitat for the Milwaukee Estuary AOC *(project specific goals are referenced in project summaries of the 2015 RAP; the previous monitoring plan with the information below can be found in the 2013 RAP).*

<u>Physical/biological habitat primary goals:</u>

1. Enhance/improve aquatic habitat by…
   A. Identifying and enhancing fish spawning sites from Lake Michigan to the tributaries and headwaters where opportunities exist (e.g., inner and outer harbors, Milwaukee River downstream of the North Ave. Dam pedestrian bridge), and/or
   B. Improving lateral connectivity by connecting aquatic habitat to floodplain wetland with suitable hydroperiod from Lake Michigan to the tributaries and headwaters where opportunities exist.

   Measures of success:
   - Amount (length) of habitat protected and/or created
   - Amount (length) connected and functional as fish and aquatic organism habitat
   - Area of adjacent floodplain reconnected for the 2-yr and 5-yr events
   - Area of adjacent wetlands reconnected and/or restored/created
   - Area of adjacent potentially restorable wetlands reconnected, as applicable
   - Number of existing critical habitat areas identified and protected, enhanced, reconnected, or re-created

2. Improve aquatic habitat connectivity by…
   A. Improving linear connectivity by restoring or enhancing fish and aquatic organism passage from Lake Michigan to the tributaries and headwaters, and/or
   B. Reconnecting high quality habitat downstream of the Bridge Street Dam and Lepper Dam to the main stem rivers of the AOC in cases where that habitat is directly connected to the estuary (i.e., there are no downstream barriers from the proposed project site).

   Measures of success:
   - Amount (length) of concrete removed
   - Number of impediments removed and/or retrofitted (e.g., bridge crossings or drop structures)
   - Amount of enclosed channel daylighted or retrofitted, number of tributary miles connected to mainstem, or length of stream channel restored

3. Enhance/improve terrestrial, semi-aquatic, and/or riparian habitat by…
   A. Expanding habitat buffer width to a minimum of 75 feet, and/or
   B. Where possible, expanding shoreline buffers up to 1,000 feet to meet core habitat area needs for semi-aquatic species

   Measures of success:
   - Length of streams inventoried and area of potential suitable buffer habitat identified
   - Length of streams with suitable buffer habitat width of 75 feet or greater preserved or established
   - Volume of historic fill and/or tons of trash removed from riparian areas
   - Area of native wetland or upland suitable habitat reconstructed
   - Area of Advanced Identification of Wetland Disposal Areas (ADID wetlands), upland within PEC, and/or 100-yr floodplain limits protected
   - Area of exotic invasive species removed

4. Improve terrestrial riparian habitat connectivity by expanding riparian buffer habitat quality and continuity.

   Measures of success:
   - Length of streams of continuous suitable buffer habitat widths of 75 feet or greater preserved or established
   - Number of riparian area crossings and/or impediments removed and/or retrofitted to improve or restore continuity of riparian buffers, including improvements to decrease resistance to animal movements
   - Increase in suitable habitat patch size resulting from new connectivity

5. Protecting high-quality areas or environmentally sensitive lands, especially those supporting rare and protected species.

   Measures of success:
   - Length of streams inventoried and area of potential buffer identified
   - Length of streams or area of land protected

<u>Physical/biological habitat secondary goals:</u>

1. Moderate flow regimes to decrease flashiness
2. Provide and preserve sufficient baseflow

   Measures of success:
   - Area of groundwater recharge protected
   - Improvement in flashiness index
   - Number of flow deflectors installed, pipes cut back from streambank, or land area treated by infiltration practices

Table 1: Overarching primary goals for the management actions identified for the Loss of Fish and Wildlife Habitat BUI.

Projects	1. Enhance/improve aquatic habitat	2. Improve aquatic habitat connectivity	3. Enhance/improve terrestrial, semi-aquatic, and/or riparian habitat	4. Improve terrestrial riparian habitat connectivity by expanding riparian buffer habitat quality and continuity.	5. Protecting high-quality areas or environmentally sensitive lands, especially those supporting rare and protected species.
Little Menomonee River Parkway Grassland Restoration				X	X
Bay View Wetland/Grand Trunk Wetland Restoration	X	X	X	X	X
Burnham Canal Wetland Restoration	X	X	X	X	
Milwaukee River Fish Habitat Enhancement and Expansion	X				
Wheelhouse Gateway Riparian Restoration			X	X	
Menomonee River Stream Management (Concrete Removal) Phases 1 & 2	X	X			
Kletzsch Park Dam Fish Passage	X	X			
Estabrook Dam Fish Passage	X	X			
Five Low Flow Barriers on the Menomonee River	X	X			
Kinnickinnic River Habitat Rehabilitation	X	X			
Little Menomonee River Corridor Restoration	X	X	X	X	X

Criteria for Measuring Habitat BUI Project Specific Goals are Met

The Little Menomonee Parkway Grassland Restoration Project

- Enhance/improve terrestrial habitat by expanding buffer width to a minimum of 75 feet or expanding the buffer width to 400’ to 1,000’ to meet core or habitat area needs.
- Enhance/improve terrestrial habitat by identifying and enhancing existing potentially restorable habitat areas through fish and wildlife assessments (for portions of the LMR, this process is already underway from a 2011 wildlife assessment).

Bay View Wetland/Grand Trunk Wetland Restoration

- Create and protect wetland habitat through the establishment of a functional seiche wetland with suitable Northern Pike spawning habitat on site.
- Spawning of Northern Pike demonstrated.
- Physical establishment of a functional, fish-free, ephemeral wetland habitat on site, occupied by ephemeral wetland dependent SLCI (e.g., amphibians, fairy shrimp).
- A goal of 6.5 acres of wetland and habitat present on site.
- Removing impediments to establish functional aquatic organism passage
- Removing historic fill.
- Creation or enhancement of upland buffer habitat surrounding wetland habitats.
- An increase in the number of SLCI utilizing the site, as measured by appropriate occupancy documentation.

Burnham Canal Wetland Restoration Project

- Establishment of a functional seiche wetland with suitable Northern Pike spawning habitat on site.
- Spawning of Northern Pike demonstrated.
- An increase of acres of wetland and other wildlife habitat present on site.
- An increase in the number of SLCI utilizing the site, as measured by appropriate occupancy documentation.
- Creation of 7.5 acres of wetland habitat.

Milwaukee River Fish Habitat Enhancement and Expansion

- Completions of spawning reef (size).
- Evidence of native fish spawning.

Wheelhouse Gateway Riparian Restoration

- Approximately 650 feet of shoreline restored.
- 2.8 acres of restored habitat connected to over 800 acres of Greenway habitat
- Expand riparian buffer of at least 100 feet between hardscape and river and enhance the quality of the buffer by replacing with native vegetation and habitat features.
- Extend the continuity of natural shoreline by approximately 650 feet, connected to existing natural shoreline.

Menomonee River Stream Management (Concrete Removal) Phases 1 & 2

- Providing fish passage through this section of the river to allow access to upstream spawning and rearing habitat.

Kletzsch Park Dam Fish Passage

- Enable fish and aquatic life access to an additional 22-mile of barrier free riverine habitat and 2,400-acres of wetland habitat.
- 22 miles of tributary connected to the mainstem of the Milwaukee River, Milwaukee Estuary and Lake Michigan.
- One critical impediment retrofitted for fish and aquatic life passage.
- One riparian area impediment retrofitted to improve continuity of riparian buffers, including improvements to decrease resistance to animal movements.
- Increase in suitable habitat patch size resulting from new connectivity.

Estabrook Dam Fish Passage

- Amount (length) connected as fish and aquatic organism habitat.
- One impediment removed and/or retrofitted.
- Number of tributary miles connected to mainstem.
- One riparian area impediment removed and/or retrofitted to improve continuity of riparian buffers, including improvements to decrease resistance to animal movements.
- Increase in suitable habitat patch size resulting from new connectivity

Five Low Flow Barriers on the Menomonee River

- Amount (length) connected as fish and aquatic organism habitat.
- Five impediments removed and/or retrofitted.
- Number of tributary miles connected to mainstem.
- Increase in suitable habitat patch size resulting from new connectivity

Kinnickinnic River Habitat Rehabilitation

- Improving linear connectivity of the Kinnickinnic River within the AOC and to the estuary.
- Increase in suitable habitat patch size resulting from new connectivity
- Creation or enhancement of upland buffer habitat surrounding along the riparian corridor to improve connectivity.

Little Menomonee Corridor Restoration

- To protect the ecologically significant natural areas within the LMR Parkway.
- Maintain and increase native plant and wildlife diversity.
- Reduce the impact of invasive species.
- Enhance and maintain the environmental corridor.
- Implement restoration projects that are a priority for the Parks Dept. while also addressing BUIs associated with the Milwaukee Estuary AOC.
- Enhance fisheries habitat with low impact practices and procedures where appropriate.

Future RAP Appendix: Degradation of Fish and Wildlife Populations

Populations Project Criteria
Goals and Measures of Success for Fish and Wildlife Populations for the Milwaukee Estuary AOC

<u>Physical/biological populations primary goals:</u>

1. Improve the quality of terrestrial habitat types (i.e. forest, wetland, shrubland, grassland, semi-aquatic, and upland/grassland) to support a better population of wildlife indicator species:

   Measures of Success:
   - Species and area of exotic invasive species removed
   - Amount (area or number) of native species planted to benefit wildlife indicator species
   - Number and species richness of wildlife indicator species found representing breeding behavior for consecutive years
   - Amount (area) of habitat types created, enhanced and/or protected

2. Improve the quality of aquatic habitat to support a better population of fish indicator species:

   Measures of Success:
   - Amount (length or area) of fish habitat established or enhanced in the upper reaches of the Milwaukee and Menomonee Rivers for lake sturgeon and northern pike, respectively
   - Amount (length or area) of fish habitat established or enhanced for indicator and sub-indicator species

3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types:

   Measures of Success:
   - Amount (length or area) of fish habitat or stream channel enhanced or restored
   - Amount (length) of corridor habitat improved or reconnected

Table 2: Overarching primary goals for the management actions identified for the Degradation of Fish and Wildlife Populations BUI.

Projects	1. Improve the quality of terrestrial habitat (i.e. forest, wetland, shrubland, grassland, semi-aquatic, and upland/grassland) to support a better population of wildlife indicator species.	2. Improve the quality of aquatic habitat to support a better population of fish indicator species.	3. Improve connectivity between fish and wildlife populations by improving size and connecting gaps or barriers of habitat types.
Enhancements to City of Mequon Parks and Ozaukee Washington Land Trust (OWLT) Ville du Parc Property	X	X	X
Enhancements to Milwaukee River Greenway Parks	X	X	X
Estabrook Falls and Fish Passage Improvements	X	X	X
Aquatic Enhancements to the Outer Harbor		X	X
Havenwoods State Forest Rehabilitation	X	X	X
Wildlife Enhancements to Milwaukee County Grounds, Sanctuary Woods, MMSD Basins, and Hoyt Park	X		X
Wildlife Enhancements to Kletzsch Park	X		X
Enhancements to Schlitz Audubon Cleaver Property	X	X	X
Enhancements to Menomonee River Parkway - Sections 5 and 6	X	X	X
Currie Park Fish Passage Improvements		X	X
Fisheries Improvements to Milwaukee River Downstream - E Cherry Street to N Humboldt Avenue		X	X
Fisheries Improvements to Menomonee River - N 16th to N 25th Street		X	X
Fish and Wildlife Enhancements to Little Menomonee River Parkway - Section 1	X	X	X
Wildlife Enhancements to Kohl Park	X		X
Fisheries Improvements to Lincoln Park Oxbow	X	X	X

Fish Metrics
Lower Milwaukee Estuary AOC

(Downstream of Humboldt Avenue on the Milwaukee River; Downstream of N 25th Street on the Menomonee River; Downstream of W Becher Street on the Kinnickinnic River)

A stated criterion of BUI removal for native fishes within the Lower Milwaukee Estuary AOC is a 100% increase in relative population abundance in four indicator species (lake sturgeon, northern pike, greater redhorse, and smallmouth bass) AND an increase of any magnitude in 80% of native sub-indicator families (suckers, minnows and shiners, bullheads and catfishes, sunfishes, and perches) to be considered AND an overall mean value from all large river IBI sampling efforts of "Fair" or better (i.e. 41-60).

Indicator Species
Sturgeons – lake sturgeon
Pikes – northern pike
Suckers – greater redhorse
Sunfishes – smallmouth bass

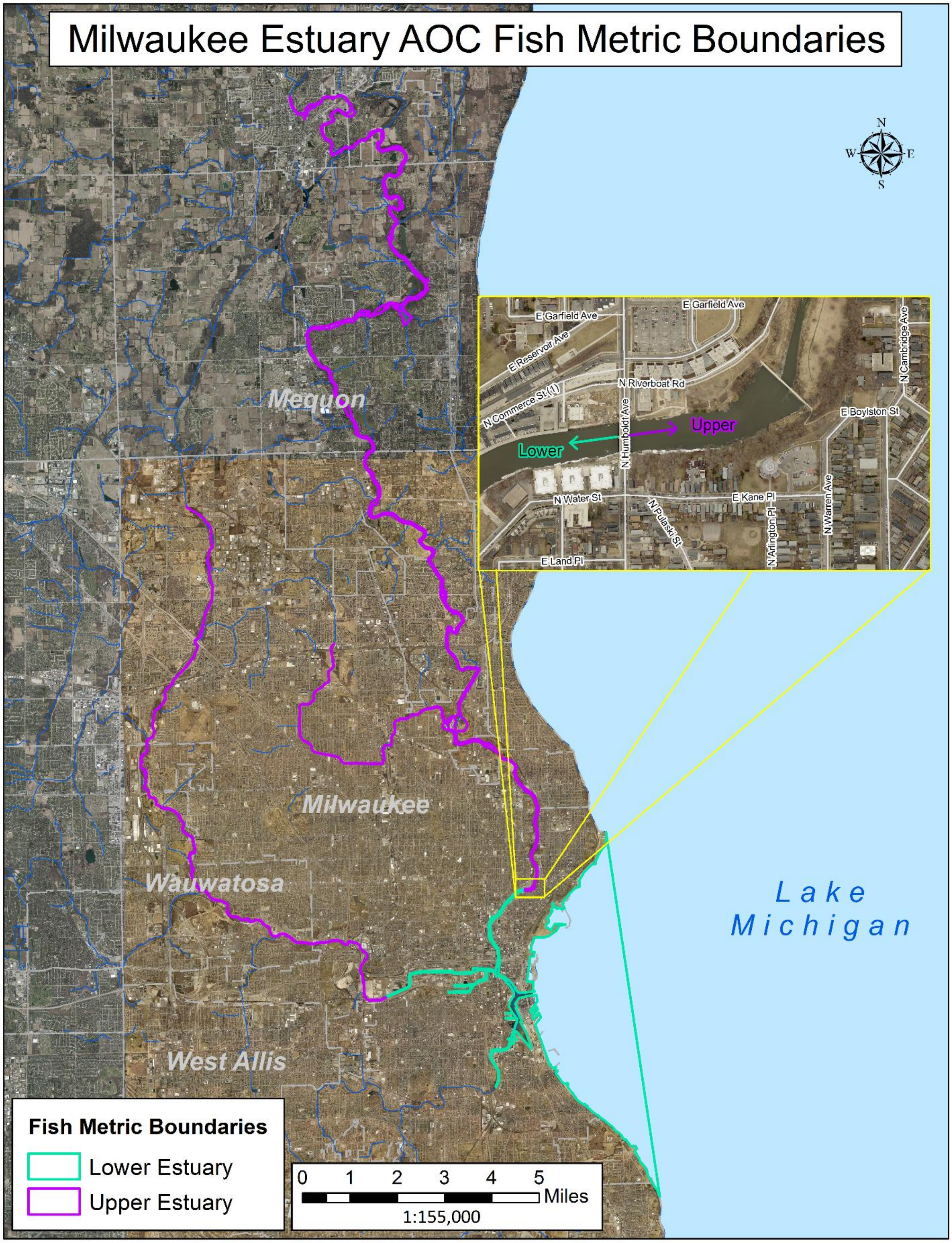
Sub-indicator Species
Suckers – golden redhorse, shorthead redhorse, silver redhorse, longnose sucker, white sucker
Minnows and Shiners – Emerald shiner, golden shiner, spottail shiner, fathead minnow
Bullheads and Catfishes – black bullhead, flathead catfish, channel catfish
Sunfishes – bluegill, green sunfish, pumpkinseed, black crappie, largemouth bass, rock bass
Perches – walleye, yellow perch

Upper Milwaukee Estuary AOC

(Upstream of Humboldt Avenue on the Milwaukee River to Bridge Road on Cedar Creek; Upstream of N 25th Street on the Menomonee River to Brown Deer Road on the Little Menomonee River; No upper reach for the Kinnickinnic River)

A stated criterion of BUI removal for native fishes within the Upper Milwaukee Estuary AOC is the presence of the indicator species, lake sturgeon, utilizing spawning habitat in the upper reaches of the Milwaukee River, AND the presence of the indicator species, northern pike, utilizing spawning habitat in the upper reaches of the Menomonee River AND an overall mean value from all warmwater IBI sampling efforts of "Good" or better (i.e. 51-65) in the upper reaches of the Milwaukee River AND an overall mean value from all warmwater IBI sampling efforts of "Fair" or better (i.e. 31-50) in the upper reaches of the Menomonee River.

*Fish metric boundaries for the Milwaukee Estuary AOC are shown on the next page.



*Upper and lower fish metric boundaries for the Milwaukee Estuary AOC.

Table 3: Upper and lower fish metrics for the Degradation of Fish and Wildlife Populations BUI management actions.

Projects	100% increase in relative population abundance in 4 indicator species	Increase of any magnitude in 80% of native sub-indicator families (5)	Overall mean value from all large river IBI of "Fair or better (i.e. 41-60)	Presence of lake sturgeon utilizing spawning habitat in the Milwaukee River	Presence of northern pike utilizing spawning habitat in the Menomonee River	Milwauke River: Overall mean value from all warmwater IBI of "Good" or better (i.e. 51-65)	Menomonee River: Overall mean value from all warmwater IBI of "Fair" or better (i.e. 31-50)
Enhancements to City of Mequon Parks and Ozaukee Washington Land Trust (OWLT) Ville du Parc Property				X		X	
Enhancements to Milwaukee River Greenway Parks				X		X	
Estabrook Falls and Fish Passage Improvements				X		X	
Aquatic Enhancements to the Outer Harbor	X	X					
Havenwoods State Forest Rehabilitation							
Wildlife Enhancements to Milwaukee County Grounds, Sanctuary Woods, MMSD Basins, and Hoyt Park							
Wildlife Enhancements to Kletzsch Park							
Enhancements to Schlitz Audubon Cleaver Property				X		X	
Enhancements to Menomonee River Parkway - Sections 5 and 6					X		X
Currie Park Fish Passage Improvements					X		X
Fisheries Improvements to Milwaukee River Downstream - E Cherry Street to N Humboldt Avenue	X	X	X				
Fisheries Improvements to Menomonee River - N 16th to N 25th Street	X	X	X				
Fish and Wildlife Enhancements to Little Menomonee River Parkway - Section 1					X		X
Wildlife Enhancements to Kohl Park							
Fisheries Improvements to Lincoln Park Oxbow				X		X	

*Shaded rows are not applicable to this metric.

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Wildlife Metrics
Milwaukee Estuary AOC

Bats

There are no metrics for bats due to the risk of white-nose syndrome (WNS) and the anticipated management for a long-term study to determine separate populations, which is outside of AOC program capabilities. Regulatory programs provide institutional controls and limit bat take. However, bats should be used as an additional justification for projects that have important bat habitat and enhancements that are provided to support bat habitat should be incorporated as necessary.

Breeding Birds

The breeding bird metrics are divided into five different habitat types as follows (Forest, Wetland, Shrubland, Grassland, and Airspace/Urban):

- Forest, Wetland and Shrubland Habitat: At least 9 sites in the AOC support at least 3 breeding bird indicator species for each habitat type.

  Forest Habitat Species – American Woodcock, Veery, American Redstart, Bald Eagle, Red-shouldered Hawk, Black-billed Cuckoo, Carolina Wren, Hooded Warbler, Yellow-breasted Chat, Long-eared Owl, Acadian Flycatcher, Least Flycatcher, Merlin, Nashville Warbler, Ovenbird, Red Crossbill, Red-headed Woodpecker, Wood Thrush, Yellow-billed Cuckoo

  Wetland Habitat Species – American Woodcock, Veery, American Redstart, Bald Eagle, Red-shouldered Hawk, Alder Flycatcher, Willow Flycatcher, Blue-winged Teal, Sedge Wren, American Bittern, American Black Duck, Bank Swallow, Black-crowned Night-Heron, Common Gallinule, Great Blue Heron, Great Egret, Least Bittern, Marsh Wren, Osprey, Pied-billed Grebe, Purple Martin, Sora, Virginia Rail, Yellow-crowned Night-Heron

  Shrubland Habitat Species – American Woodcock, Veery, Black-billed Cuckoo, Carolina Wren, Hooded Warbler, Yellow-breasted Chat, Alder Flycatcher, Willow Flycatcher, Loggerhead Shrike, Vesper Sparrow, Blue-winged Warbler, Brown Thrasher, White-eyed Vireo

- Grassland Habitat: At least 6 sites in the AOC support at least 2 breeding bird indicator species.

  Grassland Habitat Species – Long-eared Owl, Blue-winged Teal, Sedge Wren, Loggerhead Shrike, Vesper Sparrow, American Kestrel, Bobolink, Dickcissel, Eastern Meadowlark, Field Sparrow, Grasshopper Sparrow, Henslow's Sparrow, Western Meadowlark

- Airspace/Urban Habitat: At least 9 sites support at least 1 breeding bird indicator species.

  Airspace/Urban Habitat Species – Purple Martin, Chimney Swift, Common Nighthawk

Herptiles/Crayfish

The herptiles/crayfish metrics are divided into two different habitat types as follows (Semi-aquatic Habitat, Upland/Grassland Habitat):

- Semi-aquatic Habitat: At least 30 sites in the AOC support at least 2 semi-aquatic guilds (Crayfish, Salamanders, Frogs, Turtles). Of these 30 sites, indicator species should be represented as follows…
  - At least 10 sites support at least one crayfish species.
    Crayfish Species – Devil Crayfish, Digger Crayfish, Prairie Crayfish
  - At least 15 sites support at least one frog species.
    Frog Species – Cope's Gray Treefrog, Gray Treefrog, Wood Frog, Spring Peeper, Boreal Chorus Frog, Northern Leopard Frog, Green Frog
  - At least 8 sites support Blue-spotted Salamanders.
  - At least 6 sites support at least one turtle species.
    Turtle Species – Eastern Spiny Softshell, Northern Map Turtle

- Upland/Grassland Habitat: At least 15 sites in the AOC support at least 2 different indicator species of snakes.

  Upland/Grassland Habitat Species – Butler's Gartersnake, Common Gartersnake, Eastern Milksnake, Midland Brownsnake, Northern Red-bellied Snake

Mammals

The mammal metrics are divided into three different habitat types as follows (Forest, Wetland, Grassland):

- Forest and Wetland Habitat: At least 10 sites in the AOC support at least 2 mammal indicator species for each habitat type.

  Forest Habitat Species – American Beaver, American Mink, Eastern Fox Squirrel, Gray Fox, North American River Otter, Southern Flying Squirrel

  Wetland Habitat Species – American Beaver, American Mink, Common Muskrat, Least Weasel, North American River Otter, Star-nosed Mole

- Grassland Habitat: At least 5 sites within the AOC support at least 1 mammal indicator species.

  Grassland Habitat Species – Eastern Fox Squirrel, Gray Fox, Least Weasel

Mussels

There are no metrics for mussels due to the large-scale issues that need to be addressed to incorporate mussels into this impairment. However, mussels should be used as an additional justification for work adjacent to or near current mussel beds. They can also be an indication for an indirect improvement through other BUI projects (i.e. fish and aquatic habitat, sediment).

Table 4: Breeding bird metrics for the Degradation of Fish and Wildlife Populations BUI management actions.

Projects	Forest Habitat: At least 9 sites in the AOC support at least 3 breeding birds	Wetland habitat: At least 9 sites in the AOC support at least 3 breeding birds	Shrubland Habitat: At least 9 sites in the AOC support at least 3 breeding sites	Grassland Habitat: At least 6 sites in the AOC support at least 2 breeding birds	Airspace/Urban Habitat: At least 9 sites in the AOC support at least 1 breeding bird
Enhancements to City of Mequon Parks and Ozaukee Washington Land Trust (OWLT) Ville du Parc Property	X	X	X	X	X
Enhancements to Milwaukee River Greenway Parks	X	X	X		X
Estabrook Falls and Fish Passage Improvements					
Aquatic Enhancements to the Outer Harbor					
Havenwoods State Forest Rehabilitation	X	X	X	X	X
Wildlife Enhancements to Milwaukee County Grounds, Sanctuary Woods, MMSD Basins, and Hoyt Park	X	X	X	X	X
Wildlife Enhancements to Kletzsch Park	X	X	X	X	
Enhancements to Schlitz Audubon Cleaver Property	X	X	X	X	
Enhancements to Menomonee River Parkway - Sections 5 and 6	X	X	X		X
Currie Park Fish Passage Improvements					
Fisheries Improvements to Milwaukee River Downstream - E Cherry Street to N Humboldt Avenue					
Fisheries Improvements to Menomonee River - N 16th to N 25th Street					
Fish and Wildlife Enhancements to Little Menomonee River Parkway - Section 1	X	X	X	X	X
Wildlife Enhancements to Kohl Park	X	X	X	X	X
Fisheries Improvements to Lincoln Park Oxbow					

*Shaded rows are not applicable to this metric.

Table 5: Herptile/crayfish metrics for the Degradation of Fish and Wildlife Populations BUI management actions.

Projects	Semi-Aquatic Habitat: At least 30 sites in the AOC support at least 2 guilds (Crayfish, Salamanders, Frogs, Turtles)	Crayfish: At least 10 sites support at least 1 crayfish species	Frogs: At least 15 sites support at least 1 frog species	Salamanders: At least 8 sites support Blue-spotted Salamanders	Turtles: At least 6 sites support at least turtle species	Upland/Grassland Habitat: At least 15 sites in the AOC support at least 2 snake species
Enhancements to City of Mequon Parks and Ozaukee Washington Land Trust (OWLT) Ville du Parc Property	X	X	X		X	X
Enhancements to Milwaukee River Greenway Parks	X	X	X		X	X
Estabrook Falls and Fish Passage Improvements						
Aquatic Enhancements to the Outer Harbor						
Havenwoods State Forest Rehabilitation	X	X	X			X
Wildlife Enhancements to Milwaukee County Grounds, Sanctuary Woods, MMSD Basins, and Hoyt Park	X	X	X			X
Wildlife Enhancements to Kletzsch Park	X		X		X	
Enhancements to Schlitz Audubon Cleaver Property	X	X	X	X	X	X
Enhancements to Menomonee River Parkway - Sections 5 and 6	X	X	X	X		
Currie Park Fish Passage Improvements						
Fisheries Improvements to Milwaukee River Downstream - E Cherry Street to N Humboldt Avenue						
Fisheries Improvements to Menomonee River - N 16th to N 25th Street						
Fish and Wildlife Enhancements to Little Menomonee River Parkway - Section 1	X	X	X		X	X
Wildlife Enhancements to Kohl Park	X	X	X			X
Fisheries Improvements to Lincoln Park Oxbow	X		X		X	

*Shaded rows are not applicable to this metric.

Table 6: Mammal metrics for the Degradation of Fish and Wildlife Populations BUI management actions.

Projects	Forest Habitat: At least 10 sites in the AOC support at least 2 mammals	Wetland habitat: At least 10 sites in the AOC support at least 2 mammals	Grassland Habitat: At least 5 sites in the AOC support at least 1 mammal
Enhancements to City of Mequon Parks and Ozaukee Washington Land Trust (OWLT) Ville du Parc Property	X	X	X
Enhancements to Milwaukee River Greenway Parks	X	X	
Estabrook Falls and Fish Passage Improvements			
Aquatic Enhancements to the Outer Harbor			
Havenwoods State Forest Rehabilitation	X	X	X
Wildlife Enhancements to Milwaukee County Grounds, Sanctuary Woods, MMSD Basins, and Hoyt Park	X	X	X
Wildlife Enhancements to Kletzsch Park	X	X	
Enhancements to Schlitz Audubon Cleaver Property	X	X	
Enhancements to Menomonee River Parkway - Sections 5 and 6	X	X	
Currie Park Fish Passage Improvements			
Fisheries Improvements to Milwaukee River Downstream - E Cherry Street to N Humboldt Avenue			
Fisheries Improvements to Menomonee River - N 16th to N 25th Street			
Fish and Wildlife Enhancements to Little Menomonee River Parkway - Section 1	X	X	X
Wildlife Enhancements to Kohl Park	X	X	X
Fisheries Improvements to Lincoln Park Oxbow	X	X	

*Shaded rows are not applicable to this metric.

References for Wildlife Metrics

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Decision Tree Process for BUI Removal of Loss of Fish and Wildlife Habitat & Degradation of Fish and Wildlife Populations

Following implementation of management actions, verification monitoring will occur to determine if metrics are achieved. With verification monitoring results as the basis for discussion, the following "decision tree" applies:

Have all management actions been implemented?
AND
Are we meeting the BUI removal target(s)?

YES

Begin the BUI removal process

NO

DNR will consult with the Fish and Wildlife Tech Team to evaluate the following options:

Option 1: Gather additional information to explore possible reasons this may be occurring.

Option 2: Update target(s) and/or metrics based on new information.

Option 3: Consider if additional (achievable, cost-effective) actions would result in achieving the target(s).

Factors that will be considered when evaluating options include but are not limited to:

- How close are we to meeting the BUI metrics?
    - E.g., How many of the 21 are not meeting goals?
    - How close (or far away) is each individual metric from meeting its goal?
- Are factors beyond the scope of the AOC program, and/or beyond our ability to control within the region, (e.g., climate change, invasive species, disease epidemics, atmospheric deposition of contaminants, population losses on wintering grounds, etc.), potentially influencing the metrics significantly?

The technical team may provide a formal recommendation in writing to DNR.

DNR will determine the path forward with strong consideration for the technical team members' perspectives and any formal recommendations.

Appendix H –
Analysis of Dredged Material Management Alternatives for the Milwaukee Estuary Area of Concern Great Lakes Legacy Act Project(s)

Analysis of Dredged Material Management Alternatives for the Milwaukee Estuary Area of Concern Great Lakes Legacy Act Project(s)

This *Analysis of Dredged Material Management Alternatives* evaluates three alternatives for management of contaminated sediment from dredging projects in the Milwaukee Estuary Area of Concern (MKE AOC). These management alternatives are being contemplated by the stakeholders of the Wisconsin Department of Natural Resources (DNR), Milwaukee Metropolitan Sewerage District (MMSD), the City of Milwaukee and its divisions of the Redevelopment Authority of the City of Milwaukee and the Port Authority, Milwaukee County, We Energies, and the United States Environmental Protection Agency (EPA) as part of Great Lakes Legacy Act (GLLA) project(s). Management Alternatives include:

Alternative One (A1) – No Action
Alternative Two (A2) – Landfill Management
Alternative Three (A3) – Dredged Material Management Facility (DMMF)

This *Analysis of Dredged Material Management Alternatives* the evaluation criteria of **Natural Resources (NR) 722.07(4) Wisconsin (Wis.) Administration (Adm.) Code and the National Contingency Plan (40 CFR 300.430(e)(9))**, known as the nine criteria used in the Superfund process.

History

The MKE AOC has a long history of ecological degradation and pollution. Historical discharges resulted in sediment within the MKE AOC being contaminated with various pollutants, including metals, Polychlorinated Biphenyls (PCBs), and Polynuclear aromatic hydrocarbons (PAHs).

The DNR and EPA are committed to addressing eleven Beneficial Use Impairments (BUIs) in the MKE AOC as described in the Remedial Action Plan Update (DNR, 2017). Contaminated sediment is a principal source of impairments for seven of the BUIs due to impacts on water quality, healthy aquatic and fish habitats, fisheries, and safe consumption of fish and wildlife for humans. Meaningful progress on addressing the impacts of contaminated sediment in the AOC has been made, but the downstream areas of the Milwaukee, Menomonee, and Kinnickinnic Rivers still hold considerable quantities of legacy contamination. This contamination must be addressed to remove BUIs and ultimately delist the AOC.

The rivers in the MKE AOC were historically modified (straightened and dredged) to accommodate large vessel commercial shipping, making the estuary a settling basin for sediments. Over time, sections of the rivers that were previously maintained by dredging were no longer needed for deep draft navigation, but the sediments and their associated contaminants remain. The Milwaukee, Menomonee, Kinnickinnic Rivers, and inner and outer harbor contain between 1 to 2 million cubic yards (CY) contaminated sediment. Future investigations will refine these estimates.

The recently completed Focused Feasibility Study (FFS) for the Menomonee and Milwaukee (M&M) River project evaluated the use of a DMMF as a component of the remedy, as well as typical landfill disposal (Jacobs, 2019). For the M&M project, sediment volumes ranged from 100,000 to 400,000 CY. This *Analysis of Dredged Material Management Alternatives* expands the M&M FFS evaluation to a larger scale, with a proposed facility of 46 acres and a capacity of 1.7 million CY.

DMMF Background

A DMMF is neither a conventional wastewater treatment facility nor a conventional solid waste facility. What makes it different is the physical and chemical (discussed later) properties of the dredged material. Wastewater treatment facilities are designed to receive water with low levels of solids while solid waste facilities are designed to receive mostly solids with very little water. Dredged sediments placed in nearshore DMMFs typically contain 10-50% solids (dry weight basis) and closer to 10% when placed by hydraulic dredging— which is discussed in later sections. An effective DMMF must therefore borrow features from both the wastewater treatment facility and the solid waste facility in a combination that is unlike either (USACE, 2015). The DMMF must be volumetrically large enough to meet both short-term storage capacity requirements, during filling operations, and long-term requirements for the anticipated life. The DMMF must have sufficient surface area and dike height with freeboard retention of fine-grained material to maintain effluent and nearshore water quality.

Dredged Material Management Alternatives Description

Alternative One (A1) – No Action

A no-action alternative is used for comparison only. Under A1, there would be no actions conducted to control contaminant exposure by dredging sediments and therefore no management is required. All contaminated sediments would be left in the waterbody and subject to ongoing erosional and depositional forces. BUIs and fish consumption advisories would remain. Natural degradation of contaminants would not occur in many lifetimes.

Alternative Two (A2) – Landfill Management

A2 utilizes existing local facilities for the management of dredged material (sediment and debris). For the purpose of this analysis, Waste Management's Orchard Ridge Landfill at W 124 B 9355 Boundary Rd, Menomonee Falls, WI 53051 is used because it is the closest facility. Dredged material would require dewatering and stabilization to meet transportation and landfill acceptance requirements for free liquids using the paint filter test. The paint filter test is the United States Environmental Protection Agency (EPA) approved test method (EPA 9095B) to determine the presence of free liquids in a representative sample of waste. In addition, cured material strength requirements[1] are more stringent than the paint filter test.

Once the material is accepted by the landfill and in their possession, the material would be managed consistent with the landfill's plan of operation. The landfill's plan of operation may need

[1] Landfills have been requesting moisture content of less than 90%, a threshold of 10% less than the liquid limit, a minimum of 1,600 pounds per square foot of unconfined compressive strength and a minimum short-term friction angle of 25 degrees or minimum cohesive strength of 800 pounds per square foot from the consolidated triaxial undrained shear strength test.

to be updated to address the acceptance and management of this relatively large volume of dredged material. Dredged material management at the landfill would typically include dumping loads within a designated monofill area, grading the material by a bulldozer or excavator and, in certain cases, may include use for daily cover within the landfill. The landfill may place additional dredged material or solid waste until the final grade is achieved. Intermediate soil cover would be applied after reaching final grade, until the landfill's final cover system would be installed, and vegetation would be established. In some cases, additional dewatering and stabilization may need to occur at the landfill during disposal and prior to placement of intermediate or final cover.

The landfill owner would operate and maintain the landfill and its contents into perpetuity. Operation would include leachate and landfill gas collection systems as well as groundwater and perimeter gas well monitoring. The landfill owner would be required to provide financial assurance for Closure and Long -Term Care for 40 years.

For reference, the Orchard Ridge Landfill is currently the largest landfill in Wisconsin, and it accepted 959,000 tons of wastes in 2017. This is equivalent to about 1.6 million cubic yards of wastes. If the 1.7 million cubic yards of dredged materials were placed in the landfill over a 2.5-year period, the quantity of materials disposed in the landfill would increase by 70 percent during this period. Placement of this quantity of dredged material in the landfill would also consume permitted capacity and speed up the need for a landfill expansion (or new landfill) in order to provide for continued solid waste needs of the region.

Alternative Three (A3) – DMMF

A3 would utilize a proposed near-shore DMMF directly adjacent and north of the existing Jones Island Confined Disposal Facility (JI-CDF) as shown on (Figure 1) –Proposed DMMF Area. The near-shore DMMF would be an engineered structure for the containment of dredged material. The proposed facility would take advantage of components of the existing JI-CDF for the southern containment structure and the existing shoreline bulkhead wall for the western containment structure. The proposed DMMF would require northern and eastern dikes to be constructed for containment on the remaining two sides.

The dikes are currently proposed[2] with a crest elevation (top of the berm) of about 7.5 ft above current Lake Michigan water levels, which currently at a historical high, and 6 ft lower than the existing CDF. The proposed height would be resilient to long-term changes in Lake levels, while leaving room for vertical expansion to levels similar to the existing CDF.

When the hydraulically dredged material is initially deposited in the DMMF by hydraulic dredging methods it would occupy several times its original volume. Polymers may be used to assist with inital flocculation[3] and settling, particularly as the available capacity in the DMMF is reduced. After initial settlement, consolidation will occur as a function of time and the overburden pressure generated by the fill. Excess porewater pressures in the dredged material will dissipate until it

[2] The crest elevation will be determined in design.

[3] Flocculation refers to the process by which fine particulates are caused to clump together, forming what is called a floc. The floc may then float to the top of the liquid (creaming), settle to the bottom of the liquid (sedimentation), or be readily filtered from the liquid.

reaches its appoximate original in-situ density that the material was at in the waterbody. The material placed above the internal DMMF high water elevation may need to be managed with active dewatering operations such as surface trenching. Adequate volume must be provided during the dredging operation to contain the total volume of sediment to be dredged, accounting for any volume changes during placement.

Placement operations would need to be performed in a manner that minimizes rehandling. Once the DMMF is filled and at final grade, a cap would be placed and vegetated. The space could then be used for shipping, Port Milwaukee operations, or public space. The DMMF is anticipated to be owned and operated by Port Milwaukee. Port Milwaukee would maintain the DMMF into perpetuity. The need for long term monitoring would be determined as part of permitting the DMMF.

Dredged Material Management Alternative Common Elements

Landfill and DMMF management have the following common elements:

Time and Production Rate Common Elements

Time is the critical common element to both alternatives (A2 and A3). The intent of the stakeholders is to implement all necessary management actions to address BUIs associated with contaminated sediments by 2024, while keeping with the proposed priority AOC designation in the Great Lakes Restoration Initiative (GLRI) Action Plan III (EPA, 2019). Other than volume, time is the single most important variable to manage in the MKE AOC. The timeline proposed in the June 2019 Legacy Application indicated that remediation would begin in the summer of 2022. This leaves 2.5 years, until the end of 2024, to complete remediation. For this analysis, 2.5 years is used for both the landfill and DMMF alternatives.

A 1.7 million CY project executed over a period of 2.5 years would require an average annual production rate of 680,000 CY per year and 2,125 CY per day[4] (this simplified assumption is used for the following document). Further refinement of this assumption will be performed in design to account for construction details (e.g. first pass and residual dredging).

Dredging Technology Common Elements

DNR anticipates that hydraulic dredging will be the main dredging technology used in the MKE AOC due to the limitations of the existing bridges that impede marine traffic. There are 21 movable bridges in the MKE AOC that cross the Menomonee, Kinnickinnic, and Milwaukee Rivers (Milwaukee's NPR, 2019). These movable bridges would require coordinated opening for material handling scows to support mechanical dredging. This would be impractical at scale, due to the need to open and close bridges several times a day over a period of 2.5 years. Hydraulic dredging will likely require a smaller supporting mechanical dredge for debris, but for simplicity in this analysis, the DNR assumes all material would be hydraulically dredged.

Location Common Elements

[4] Assuming 320 work days per year.

Contaminated sediments are expected to be hydraulically dredged and pumped via pipeline from the different rivers and reaches of the MKE AOC to the material processing location. A material processing location will be required for both alternatives (A2 and A3). The existing JI-CDF is the proposed processing location for A2. The new DMMF would be the location for material processing under A3. The difference in processing location between the proposed DMMF and the existing JI-CDF is insignificant because they are adjacent. Therefore, the hydraulic dredging pipeline length is about the same.

Water Treatment System Common Elements

Both A2 and A3 will require a temporary water treatment system[5] of enough capacity to support hydraulic dredging at the desired production rate of 2,125 CY per day. The facilities will also need the ability to direct discharge to Lake Michigan with a Wisconsin Pollutant Discharge Elimination System (WPDES) permit for a new outfall. A combination of a one 8-inch diameter and one 12-inch diameter hydraulic dredge would provide about 2,400 CY/day of production and require about 5,100 gallons per minute (GPM) of treatment capacity, without consideration of storage. The hydraulic dredge(s) would be the primary source of water that would require treatment. Water would also be generated from other components of material processing, including:

- Dewatering pad drainage from sediment
- Backwash from the treatment system
- Decontamination water
- Precipitation

For this analysis, based on discussions with water treatment contractors, the DNR has assumed that a water treatment system would include lamella clarifiers, bag filters, and granular activated carbon. Regular sampling of wastewater discharge would be conducted to verify that the requirements for discharge are met. After startup, Discharge Monitoring Reports (DMR) would be provided to the DNR on a weekly basis.

Post Placement Common Elements

For both A2 and A3, once dredged material is placed in the final facility (either A2 or A3), it would be contained within an engineered structure that would be designed, constructed, and managed for that purpose.

Contaminants found in sediments, generally[6], are relatively stable and persistent, hydrophobic, have low solubility, an affinity for organics, and bound with the finer solid particles (e.g. silts and clays). These properties are the reason that the legacy contaminants of metals, PCBs, and PAHs remain in the MKE AOC's sediment (sometimes even more than a century after being released instead of being diluted and dispersed).

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[5] Utilizing MMSD's Jones Island Water Reclamation Facility is not an option because it produces Milorganite fertilizer and cannot accept any measurable amount of PCBs.

[6] This analysis is not meant for non-aqueous phase liquid (NAPL), which is a challenging material to manage and control. NAPL-containing dredged materials will likely be handled separately, with special provisions, such as a liner or stabilized monolith within the existing JI-CDF.

The contemplated MKE AOC projects are generally near the mouth of the estuary, where the Milwaukee, Menomonee, and Kinnickinnic Rivers merge and enter Lake Michigan. The estuarine conditions inherently create a depositional environment with higher silt content and organics[7].

Per- and Polyfluoroalkyl Substances (PFAS) Common Elements

Per- and Polyfluoroalkyl Substances (PFAS) are a class of man-made chemicals that are ubiquitous. They are present in a myriad of consumer products, industrial uses, and environmental media. PFAS are similar to typical sediment contaminants in that they are hydrophobic and persistent; however, PFAS are starkly different in that they are more soluble and much more mobile.

The DNR is unaware of any sediment samples tested for PFAS in the MKE AOC; however, its fish monitoring program has tested fish in Wisconsin's major rivers (Fox, Menominee, Milwaukee, Mississippi, Peshtigo, St. Louis, and Wisconsin as well as the Great Lakes), including those located in the MKE AOC. The Mississippi River data had the highest concentrations. DNR first issued fish consumption advice for Perfluorooctanesulfonic acid (PFOS) in 2007 (Williams & Schrank, 2016). Current fish consumption guidance for PFAS in Wisconsin is limited to PFOS and the Mississippi River. When fish tissue was last tested in the MKE AOC, concentrations of PFAS did not warrant issuance of a fish consumption advisory.

DNR plans to sample for PFAS in the MKE AOC to evaluate the presence of these chemicals in sediment and surface water and to account for it in remediation design. Detectable concentrations of PFAS in the MKE AOC are likely to be found. The science and knowledge of this class of compounds is rapidly changing and evolving. Granular activated carbon has been found to be an effective water treatment technology for many PFAS compounds. PFAS information would likely be necessary for both A2 and A3 scenarios. PFAS data may be needed to determine disposal for the water treatment system carbon units regardless of the alternative.

Dredged Material Management Alternative Differences

Landfills can only accept solid waste; hydraulically dredged sediments cannot be directly transported to a landfill as they contain too much water and will not meet strength criteria. The high-water content sediment must be dewatered before being suitable for landfill acceptance. Comparatively, a DMMF is itself designed to be part of the dewatering process and would not require upland space and processing for this purpose. The infrastructure and additional work needed to support A2 is common to remedial dredging and well understood. It is done in an environmental protective manner and in compliance with applicable laws. The main difference is in costs which are described in the following sections, which include differences in water treatment, bag field setup, bag field management, stabilization, trucking, material handling, and DMMF design and construction.

Water Treatment Differences

[7] The Milwaukee River Downstream Reach 4 investigation tested 40 samples for geotechnical parameters. Of these, 18 of the 40 (45%), classified as organic silt (OH) by the USCS classification system. The organic silts averaged 80% fines, a specific gravity of 2.5 and dry density of 50 pounds per cubic foot. The second most frequent classification was poorly graded sand (SP) for 5 of the 40 samples, which is 13%. The M&M Investigation duplicated the results of generally low sand content in sediments.

Because a DMMF itself is part of the dewatering process, the DNR expects that a smaller water treatment system could be used, compared to what would be needed for A2. A3 provides more space for settling, substantial storage, buffering capacity, and altogether more flexibility. However, the conservative cost estimate assumes that the same water treatment size and components (other than the geotextile tubes discussed in the following sections) would be used for water treatment and therefore no cost difference is provided.

Bag Field Setup Differences

The M&M FFS identified geotextile bag dewatering for A2. The need for a bag field is a key difference between A3 and A2. A bag field and perimeter haul roads are necessary infrastructure to support processing the sediment to be suitable for a landfill. This evaluation assumes that the existing JI-CDF[8], with about 20 acres of available upland space, would be utilized for dewatering and sediment stabilization with A2. This is expected to be the largest area in the MKE AOC that would be available for dewatering and stabilization. For consistency with the M&M FFS[9], this analysis assumes the same liner system and unit rates for a 12-inch base layer of 3-inch diameter base-rock, a 6-inch layer of ¾-inch gravel, a 6-inch sand bedding layer, a 16-ounce non-woven geotextile, and a 60-mil High-Density Polyethylene (HDPE) flexible membrane liner. Based on the unit rates in the M&M, with modifications provided by Jacobs for stacking the geotextile tubes three high, the DNR estimates the bag field setup would cost $7 million[10, 11] to support A2. This analysis excludes the cost for haul roads at the DMMF from this estimate for A2.

Bag Field Management Differences

After the bag field and water treatment system are installed, they must be managed throughout the dewatering process to support A2. Geotextile tube dewatering is a labor-intensive process compared to passive dewatering in the DMMF under A3. Tubes would need to be deployed with fill ports and control valves installed. Polymers and flocculants would be used for settling with continuous adjustment and quality control checks (note that polymers or flocculants will likely be used with A3 as well). Additional tube maintenance would include adjusting and moving fill ports and tubes, measuring tube fill level, vibrating and agitating the tube surface to promote dewatering, and deploying and stacking more tubes. The DNR estimates the costs for the geotextile tubes[12] and maintaining said tubes[13] to be $13 million of additional cost to support A2.

[8] The M&M FFS evaluated and identified about 12 acres of a series of adjacent properties owned by the city of Milwaukee and Department of Transportation located along the north shore of the Menomonee River adjacent to the I-94 overpass bridge (Figure 12). This is 40% less space available than the JI-CDF.
[9] The liner system for the bag field would be determined in design or by the contractor.
[10] $1.8, $1.3, and $1.5 per square foot, respectively for grading and compacting, geotextile, and a liner.
[11] $48, $32, and $31 per cubic yard, respectively, for 3-inch diameter baserock, 3/4-inch gravel, and a sand bedding layer
[12] $36/lineal foot and 243,000 lineal ft based on a 75-ft circumference and 7 CY per lineal foot
[13] $2.35 per cubic yard.

Stabilization Differences

For stabilization, several synergistic effects drive the need for and amount of stabilization agents in this analysis. Geotextile tubes need time for passive dewatering, on the scale of weeks to months. However, the large dredged material volume and lack of available bag field space for tubes to be stacked for the total size of the project means that material would need continuous haul out. Thus, the short construction time, large production volume (2,125 CY/day), high silt and organic content material requiring the use of polymers, and stringent landfill cured material strength requirements—as mentioned before—means that the DNR would expect that amendments and mixing would be necessary. The DNR has assumed 10% by weight of amendment to the dewatered dredged material based on the most recent experience at Wisconsin Public Services Former Green Bay Manufactured Gas Plant. The DNR estimates that stabilization would cost $15 million for the amendment itself and another $44 million for the mixing and loading to support landfill management over the project size of 1.7 million cubic yards. This totals to $59 million.

In addition to the cost, Portland Cement, a common stabilization agent, produces CO_2 during a necessary part of the manufacturing process. Approximately 0.9 tons of CO_2 are emitted for every ton of Portland Cement produced (National Ready Mixed Concrete Association, 2012). The 10% by weight dosage rate would generate 240,000 tons of Portland Cement and 210,000 tons of CO_2.

Trucking Differences

Trucking stabilized dredged material to the landfill and tipping fees are major differences between A2 and A3; trucking is not needed for A3 other than the construction of the facility, which is discussed later. Trucks would be required to have sealed gates, a retractable tarp, and need decontamination throughout the project. Over the life of the project, the DNR conservatively estimates that 130,900 truck trips[14] would be required, which would be a total of 5.9 million miles driven and 1.2 million gallons of diesel fuel and over 13,000 tons of related carbon dioxide emissions[15]. The DNR estimates that trucking and landfill fees would cost $130 million based on a unit rate of $48 per ton; the same unit rate as the M&M FFS.

Material Handling Summary Differences

This section summarizes the additional material handling differences between A2 and A3[16] :

1. Management of dredged material by dewatering in geotextile tubes includes manual agitation by vibration, tending fill ports, and leveling the tubes (as discussed in the bag field management section).
2. Opening geotextile tubes.
3. Adding and mixing amendments.
4. Testing aged and mixed materials to determine if materials pass paint filter and material strength criteria.
5. Loading dewatered and stabilized material into trucks.
6. Transporting trucks from the existing DMMF to the nearest landfill.
7. Trucks dumping the passing material at the landfill.

[14] Assumes trucks average 20 tons per trip and a final density of 1.54 tons/CY after amendment

[15] Assumes 22 pounds CO_2/gallon of diesel and 0.9 tons CO_2/ton Portland Cement Amendment

[16] Some of the handling below overlaps sections above, this is a summary.

8. The landfill operator grading dumped material at the landfill.

DMMF Design and Construction Differences

A major difference between DMMF and landfill alternatives is that A2 is permitted and existing, and the proposed A3 has not yet been constructed. If remedial projects were ready for construction in the MKE AOC, a landfill could be utilized sooner and allow a longer project duration. This would cut down on amendments dosage rate, water treatment plant size, and the overall production rate. However, remedial project(s) are not ready. No contaminated sediment project, as part of the Legacy Act application, has completed design. The closest project in the remedial phase is the M&M project, which identified Alterative 5: hydraulic dredging with DMMF disposal, as the preferred alternative.

The proposed DMMF would need to be designed, permitted, funded, and constructed. The design and construction process are expected to take, in total, two to four years. Preliminary cost estimates have ranged greatly, from $12 million for the most cost-effective option of a smaller-volume rubble mound dike-based structure to the most expensive of greater than $200 million for double sheet pile walls for the entire perimeter. At the time of this writing, currently at the 30% Design Stage, the DMMF design engineers (Foth) are estimating costs to range from $65 to $90 million depending on the type of structure and features.

Cost Summary Differences

This cost summary focuses on the differences in costs between A3 and A2; it does not include dredging.

Costs to support management at a landfill:

– Bag field setup:	$7 million
– Geotextile Tubes and Tube Dewatering:	$13 million
– Amendment at 10%:	$15 million
– Mixing and Loading:	$44 million
– Trucking and Landfill Fee:	$130 million
Total	**$200 million or $120/CY**

Cost range to support DMMF use:

Total **$65 million to $90 million**
$40/CY to $50/CY

Based on the assumptions in this analysis, A3 is expected to cost $110 to $135 million or 55 to 70% less than A2. On a unit rate basis, A3 costs $70 to $80/CY less than A2. This cost difference is largely due to the reduction in material handling and landfill fees.

These cost results are consistent with the Jacobs's findings in the M&M FFS, which identified hydraulic dredging and DMMF disposal (Alternative 5A) as the most cost-effective alternative for

$16 million[17]. Hydraulic dredging with DMMF costs were $33 million less (53% less) than for mechanical dredging with landfill disposal (Alternative 5C) (CH2M, 2019). In addition, the M&M FFS estimated that hydraulic dredging with DMMF (5A) costs were $140/CY less than mechanical dredging with landfill use (Alternative 5C).

Bird Use Differences

Both A2 and A3 will be used by birds, with the species and abundance changing as the facility, habitat, and food sources change. However, generally, there is less bird abundance and biodiversity at A2, as discussed in these next two paragraphs. At A2 and during filling, carrion birds, such as crows and gulls, are attracted to municipal solid waste (MSW) as a food source. Daily cover is used to limit available food sources and the abundance of birds. Carrion birds have the potential to be exposed to pollutants from the dredged material, if daily cover is not placed, but the dredged material itself is not a significant food source. The bird species change, at a certain area, most drastically at cell closure, when waste is no longer being accepted and the final cover system is placed and vegetated. Typical vegetation is grassland, that can be the habitat for pheasants, turkey, swallows, blackbirds, and numerous other native Wisconsin birds (DNR, 2008).

While filling, A3 would be used by more water-going birds and migratory birds as a stopover and resting point. The DMMF's dikes would create a sheltered water habitat in an otherwise uninhabitable area that is used for rest and forage by many migratory and resident anseriformes (ducks, geese, swans, magpie geese, screamers), passerines (swallows and martins), pelecaniformes (pelicans), seabirds, and shorebirds. The organic rich sediment and seed bed from the estuary quickly and prolifically vegetates to provide unique habitat. According to the Urban Ecology Center, the existing JI-CDF has become a "safe haven for several species of birds and possibly boasts the largest historical bird list of any single location in Wisconsin" (Urban Ecology Center, 2019). The JI-CDF is part of the 2019 Brew City Birding Festival by the Urban Ecology Center.

A DMMF's polluted sediment would contain heavy metals, PCBs, oil, grease, PAHs and pesticides. A Sentinel Duck Study was conducted at the JI-CDF in the summer of 1990 to determine if waterfowl were accumulating contaminants from the JI-CDF. Game farm mallards were released on the JI-CDF, collected 70 days later, and were analyzed for total PCBs, metals, pesticides and PAHs. The study concluded that ducks released into the JI-CDF did not accumulate significant concentrations of contaminants as compared to field and background levels (DNR, 1994). The DNR would expect similar bird usage with a new DMMF.

Per- and Polyfluoroalkyl Substances (PFAS) Differences

For a proposed DMMF, this contaminant class, if present, will be evaluated as a migration pathway through the dikes. Treatment, such as activated carbon amendments, may be added to the dike structure. Other measures could incorporated into the overall dike design to help address this contaminant class; which is expected to be evaluated during design.

[17] Note that M&M costs included all construction costs, including dredging. The M&M FFS did not evaluate hydraulic dredging with landfill disposal. However, it did evaluate mechanical dredging with both landfill and CDF use.

Groundwater Monitoring Differences

The DNR requires on-going groundwater monitoring at landfills. Groundwater monitoring is less likely, for various reasons, to be required at a DMMF. The need for groundwater monitoring would be determined through the design process and documented in a DNR grant of low-hazard waste exception. There are materials in the MKE AOC that would need to be addressed with special provisions, such as PAHs in the form of for non-aqueous phase liquid from former Manufactured Gas Plants. These are planned to be stabilized in a monolith at the existing CDF and are excluded from this analysis.

Analysis of Alternatives

This *Analysis of Dredged Material Management Alternatives* uses the evaluation criteria of Natural Resources (NR) 722.07(4) Wisconsin (Wis.) Administration (Adm.) Code and the National Contingency Plan (40 CFR3 00.430(e)(9)), known as the nine criteria used in the Superfund process. The criteria are grouped into the threshold, balancing and modifying criteria.

There is no flexibility in meeting the threshold criteria; they must be met. The threshold criteria are: compliance with applicable federal, state, and local regulations; and overall protection of human health and the environment.

Balancing criteria weighs the trade-offs between alternatives. A low rating on one balancing criterion can be compensated for by a high rating on another criterion. The five balancing criteria are: short and long-term effectiveness, reduction of toxicity, mobility or volume, implementability, and cost.

There are two modifying criteria: state and community acceptance. The degree of acceptance can alter the weighting of alternatives under the modifying criteria. Further, input from the community and the state can be used to adapt the Alternatives (A1, A2, and A3).

In addition to the nine criteria, before selecting an Alternative, sustainable actions will be evaluated with consideration of NR 722.09(2m). In summary, the nine criteria—which are divided up into three different sections—are:

Threshold Criteria
1. Compliance with applicable federal, state, and local regulations and standards
2. Overall protection of human health and the environment

Primary Balancing Criteria
3. Long-term effectiveness and permanence[18]
4. Reduction of toxicity, mobility, or volume[19]
5. Short-term effectiveness[20]
6. Implementability[21]
7. Cost[22]

Modifying Criteria
8. Community acceptance
9. State acceptance

Recommendation

The DNR recommends A3. A3 meets the threshold criteria of being compliant with applicable federal, state, and local regulations and standards as well as overall protection of human health and the environment. For the balancing criteria, the short- and long-term effectiveness, reduction of toxicity, mobility, or volume, and implementability of A2 and A3 are similar. The difference to the balancing criteria is cost. A3 costs approximately $135 million, or 70% less than A2. Additional costs for A2 are associated with bag field setup and management, water treatment, stabilization agents, material handling, landfill tipping fees, and trucking. The balancing criteria are intended to weigh the trade-offs between alternatives; and because the cost difference for A2 is substantial, it overwhelms the similarity of the other balancing criteria.

In addition to the nine criteria, the DNR also evaluated sustainability. A3 is more sustainable than A2; it saves approximately 1.2 million gallons of diesel fuel from reduced hauling and 240,000 tons of amendments. In total, this would reduce carbon emissions by 200,000 tons over the useful life of the facility.

Community acceptance, a modifying criterion, will be considered as part of the 45-day public comment period for this *Analysis of Dredged Material Management Alternatives* before issuing a decision document.

In summary, the DNR recommends A3 because it meets the threshold criteria, is similar to A2 for most balancing criteria but has significantly lower costs and is more sustainable.

Decision document

A decision document will be issued at the close of the 45-day public comment period with additional details on the selected alternative.

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[18] NR 722.07(4)(a)(1) Wis. Adm. Code
[19] NR 722.07(4)(a)1.a.NR 722.07(4)(a)1.a. Wis. Adm. Code
[20] NR 722.07(4)(a)(2) Wis. Adm. Code
[21] NR 722.07(4)(a)(3) Wis. Adm. Code
[22] NR 722.07(4)(b) Wis. Adm. Code

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Attachments

- Table 1: Detailed Comparison of Alternatives
- Table 2: Proposed Milwaukee Estuary Dredged Material Management Facility Authority and Requirements
- DMMF Layout
- Figure 12: M&M FFS

Table 1: Detailed Comparison of Alternatives

Criterion	Alternative 1 (A1) No Action	Alternative 2 (A2) Landfill Disposal	Alternative 3 (A3) Dredged Material Management Facility (DMMF)
Threshold Criteria			
1. Compliance with applicable federal, state, and local regulations and standards	No action; therefore, not applicable.	Use existing licensed landfills. Disposal of stabilized dredged material is expected to comply with all applicable federal, state, and local requirements including the plan of operation, Department of Natural Resources' (DNR) approval letters, and facility requests for material strength.	A DMMF would be designed, constructed, and filled with mostly hydraulically dredged material and operated in compliance with all applicable federal, state, and local requirements; as well as, additional requirements at the request of the DNR. The DNR would provide approval through low-hazardous waste exemption, would be required to provide a 401-Water Quality Certification, and Wisconsin Pollutant Discharge Elimination System (WPDES) permit.
2. Overall protection of human health and the environment	No action would be conducted to control contaminant exposure. All contaminated sediments would be left in the waterbody. Beneficial Use Impairments (BUIs) and fish consumption advisories would remain. Natural degradation of contaminants would not occur in a reasonable time. This alternative does not provide overall protection of the human health and the environment.	Landfill disposal is a common dredging material management alternative that is protective of human health and the environment. Contaminated sediments are removed from a waterbody, conditioned for disposal, and placed in a facility that is designed, constructed, and managed to handle dredged materials with a high level of protection.	Although not as common as landfill disposal, 35% of the total volume of material dredged to maintain Federal projects in the United States is placed in DMMFs (USACE, 2015). The current DMMF material, as shown by the JI-CDF investigation, has elevated levels of contamination (We Energies, 2018). The proposed DMMFs would be designed, constructed, and managed specifically for contaminated dredged material and provide a high level of protection.
Balancing Criteria			
3. Long term effectiveness and permanence	No action; therefore, this alternative is not effective in the long-term.	Landfills are operated and maintained into perpetuity. Landfills are required to provide financial responsibility for the closure and long-term care of the landfill through NR 520 Wis. Adm. Code.	A new DMMF would be operated and maintained into perpetuity by Port Milwaukee. The use of the DMMF itself for Port activities would generate revenue past closure. This is unlike a landfill that receives its revenue at the time of acceptance through a tipping fee. Port Milwaukee's revenue from the DMMF itself would help the Port pay for any required maintenance.

Criterion	Alternative 1 (A1) No Action	Alternative 2 (A2) Landfill Disposal	Alternative 3 (A3) Dredged Material Management Facility (DMMF)
4. Reduction of toxicity, mobility, or volume	No action; therefore, this alternative provides no reduction in toxicity, mobility or volume.	Landfill disposal will effectively eliminate the mobility of contaminants of concern. Toxicity will be vastly reduced by eliminating the routes of exposure to humans and the environment. The volume of contamination will be reduced by dewatering and increased density of the dredge material. In this alternative, the contaminated sediment are removed from the waterbody, conditioned for disposal, and placed in a facility designed for the perpetual containment of waste. Landfills contain the contaminants through various methods so that they do not render: – Unclean air, land or waters of the state—making similar injurious to public health, harmful for commercial or recreation use – Deleterious to fish, bird, animal or plant life Landfills are efficient, nuisance-free, and environmentally acceptable solid waste management procedures.	DMMF disposal will effectively eliminate the mobility of contaminants of concern. Toxicity will be vastly reduced by eliminating the routes of exposure to humans and the environment. The volume of contamination will be reduced by dewatering and increased density of the dredge material. In this alternative, the contaminated sediment are removed from the waterbody and placed in a facility designed for the perpetual containment of waste. DMMFs, with various methods, contain the contaminants so that they do not render unclean air, land or waters of the state, or making the same injurious to public health, harmful for commercial or recreational use, or deleterious to fish, bird, animal or plant life. DMMFs are efficient, nuisance-free, and environmentally acceptable dredged material management facilities.
5. Short-term effectiveness	No action; therefore, this alternative is not effective in the short-term.	Since this comparison is performed over the same time scale as the DMMF alternative, there are no differences in scope. The main difference in short-term effectiveness is a much larger amount of truck traffic. Engineering and administrative controls would be implemented to mitigate short-term effects, risks, and impacts on local communities associated with Landfill disposal, including: – Traffic planning to minimize the potential for vehicle accidents – Proper construction quality assurance procedures such as covering materials in trucks, dust suppression, and limiting truck speed for on-site haul routes. The short-term has the potential to expose carrion birds to bioaccumulating compounds.	Since this comparison is performed over the same scale as the landfill, there are no differences in scope. The DMMF would result in significantly less truck traffic than landfill disposal. The effectives of a DMMF changes over time with the worst-case condition being when the DMMF initially starts filling. Seiche, long term lake levels, and wind driven waves will drive water movement through the perimeter dikes, as well as other features that are used to control contaminant migration. The dredging material itself, comprised as mostly the silts and organics, works to slow contaminant transport. Once full, there would be no wind driven transport for the DMMF area itself because it would be land. The short term has the potential to expose migratory birds to bioaccumulating compounds. DNR game farm mallard studies did not find significant accumulation of contaminants compared to field and background levels (DNR, 1994).

Criterion	Alternative 1 (A1) No Action	Alternative 2 (A2) Landfill Disposal	Alternative 3 (A3) Dredged Material Management Facility (DMMF)
6. Implementability	No action; therefore, not applicable.	This is a proven technology. Local landfills are existing and licensed. All services and necessary materials are readily available and have been successfully implemented on numerous similar projects. Dewatering and trucking contaminated sediment is a well understood process.	DMMF disposal will require design, permitting, and construction of the proposed DMMF. All services and necessary materials are readily available to do this, but because new DMMFs have not been permitted in Wisconsin f decades, there is less certainty about the process and requirements.
7. Cost	No action; therefore, not applicable.	$200 million, $120/cubic yards (CY)	$65 million, $40/cubic yards (CY)
Modifying Criteria			
8. Community Acceptance	No action; therefore, not applicable.	Existing licensed landfills, by statute, went through a public meeting to be able to accept dredged materials. Landfills are used as an acceptable environmental management tool.	Community acceptance for a new DMMF will be determined through outreach and a proposed plan. There has not been community opposition to the continued use of the existing CDF.
9. State Acceptance	No action; therefore, not applicable.	The DNR accepts landfills as an acceptable dredged material management alternative.	The DNR would accept a DMMF that meets the threshold criteria, our authority outlined in Table _, and a design that provides robust and compelling protection over the long-term.
Sustainability	No action; therefore, not applicable.	Less sustainable than a DMMF in that more truck trips, diesel fuel, and amendments are needed. More sustainable than a DMMF in that existing landfills are already constructed and licensed. Although, with the volume of material projected, it is expect that new cells or expansions of existing landfill facilities would be needed.	Over the useful life of the DMMF, this alternative would save approximately 1.2 million gallons of diesel fuel due to reduced hauling and 240,000 tons of amendments. In total, this would reduce carbon emissions by 200,000 tons. This alternative uses 45 acres from Lake Michigan for construction of the facility. The City has been granted, by the Wisconsin State Legislature, the necessary lakebed of Lake Michigan required for the proposed DMMF.

Table 2: Proposed Milwaukee Estuary Dredged Material Management Facility Authority and Requirements

What	For	Agency or DNR Program or Bureau	Code or Statute
Lakebed Grant	An act that ceded submerged lands to the city of Milwaukee extending fifteen hundred feet into Lake Michigan between the harbor entrance and Russell Avenue (south of the existing CDF) for dock and wharf purpose and railway terminals.	Watershed Wetlands & Waterways	Chapter 358 of 1909
Lakebed Grant	Amends Chapter 358, granted and ceded submerged land to the City of Milwaukee, extending the area fifteen hundred feet into Lake Michigan between the harbor entrance and Russel Avenue (south of the existing CDF). The land is to be used by the city for public slips, basins, docks, wharves, structures, roads, highways, railroads, and railways, railway terminals, and lake and rail facilities and spurs for shipping.	Watershed Wetlands & Waterways	Chapter 285 of 1923
Lakebed Grant	Amends Chapter 358 of 1909 and Chapter 285 of 1923, ceded, granted and confirmed dry or submerged land under the waters of Lake Michigan to the city of Milwaukee for improving, filling, and utilizing the same for harbor purposes and in aid of navigation, in any manner the said city may deem expedient	Watershed Wetlands & Waterways	Chapter 381 of 1931
Environmental Analysis and Review Procedures	Review of an existing or proposed use of an existing lakebed grant is an integrated analysis action that does not require a separate environmental analysis process. The existing or proposed use must be consistent with the purpose and uses for which the grant was issued.	Watershed Wetlands & Waterways	NR 150.20(2) & NR 150.20(2)(a)19m
Exemption from Chapter 30	Exemption for submerged shorelands in Lake Michigan for the placing of structures from the Chapter because the title has been granted by the state to a municipality	Watershed Wetlands & Waterways	Chapter 30.05
Exempt from a request for public hearing under Chapter 30	The request for a public hearing under 30.208(3) is not applicable because Chapter 30 is exempt per Chap 30.05	Watershed Wetlands & Waterways	Chapter 30.208(3)
Water Quality Certification	The Clean Water Act Section 401 regulates actives that may result in a discharge of pollutants into the waters of the US.	Watershed Wetlands & Waterways	NR 299
Water Quality Certification Public Involvement	Public noticing for public comment or a public informational hearing is not a requirement. A public notice for a contested case hearing is a requirement per NR 299.05(4). The department shall provide notice of the decision to the applicant, the licensing or permitting agency, and known interested parties 310.14(2). Cause notice of its decision to be published by the applicant as a class I notice under Chapter 985, and shall identify the applicant and his or her address, describe the activity and its location, state the department’s determination, and appraise the public of the opportunity to request a hearing under this chapter.	Watershed Wetlands & Waterways	NR 299.05(4)
Low-hazard Waste Exemption from Regulation	Dredge Material Management Facility	Waste and Materials Management	289.43(8)
PCB Disposal - Required Public Meeting	DNR cannot approve of the disposal of PCBs without a public meeting.	Waste and Materials Management	289.54(2)

Table 2: Proposed Milwaukee Estuary Dredged Material Management Facility Authority and Requirements

What	For	Agency or DNR Program or Bureau	Code or Statute
Permits for Water Pollutant Discharge Elimination System (WPDES)	Base authority for permitting.	Wastewater	283.31
Water Quality Standards	For use with the Clean Water Act	Wastewater	281.15
Water Quality Standards	For use with the Clean Water Act	Wastewater	NR 102
Surface water quality criteria for toxic substance	For use with the Clean Water Act	Wastewater	NR 105
Calculating Water Quality Based Effluent Limitations for Point Source Discharges to Surface Waters	For use with the Clean Water Act	Wastewater	NR 106
Individual Permit requirement	The General Permit excludes discharges of dredging wastewater from contaminated sediment to waters classified as public water supply in ch. NR 104, Wis. Adm. Code	Wastewater	WPDES General Permit No. WI-0046558-06
governs the submission of plans and specifications	Provides DNR a 90-day timeline to review plans and specifications.	Wastewater	NR 108
Two permits (1) for a new WWTP & (2) discharge through the perimeter structure	Sets forth the requirements for filing applications for the discharge permits required by s. 283.31, Stats.	Wastewater	NR 200
Public Participation for WPDES	NR 203.05 lists when a discretionary or mandatory hearing is required, the notice requirements in NR 203.06, the location (NR 203.07) requirements, who is entitled to a hearing NR 203.08 and other hearing information.	Wastewater	NR 203
General provisions for WPDES	Sets forth the definitions applicable to and abbreviations used in chs. NR 200 - 299 and general conditions for all WPDES permits.	Wastewater	NR 205
Section 10 Rivers and Harbors Act	Under Section 10, a Corps permit is required to do any work in, over or under a 'Navigable Water of the U.S.' Waterbodies have been designated as 'Navigable Waters of the U.S.' based on their past, present or potential use for transportation for interstate commerce.	United States Army Corps of Engineers (St. Paul District)	33 CFR 323
Section 404 Clean Water Act	Under Section 404, a Corps permit is required for the discharge of dredged or fill material into waters of the U.S.	United States Army Corps of Engineers (St. Paul District)	33 CFR 323

Table 2: Proposed Milwaukee Estuary Dredged Material Management Facility Authority and Requirements

What	For	Agency or DNR Program or Bureau	Code or Statute
Section 408	Any use or alteration that has the potential to impact the usefulness of a USACE Civil Works project is subject to the approval of USACE.	United States Army Corps of Engineers (Detroit District)	Section 14 of the Rivers and Harbors Act of 1899 / 33 USC 408
Section 106 National Historic Preservation Act	Lead federal agency will evaluate the effects of the federal action on properties listed in the Natonal Register of Historic Places or eligible for such listing. In processing a permit application, the Corps generally accepts lead federal compliance with requirements of NHPA.	potential Corps coordination with State Historic Preservation Officer	36 CFR 800 / 33 CFR 325 App C
Section 7 Endangered Species Act	Lead federal agency will evaluate the effects of the federal action on federally listed endangered and threatened species. In processing a permit application, the Corps generally accepts lead federal compliance with requirements of ESA.	potential Corps consultation with US Fish and Wildlife	16 U.S. Code 1536(3)
National Environmental Policy Act	NEPA requires federal agencies to assess the environmental and related social and economic effects of the federal action prior to making decisions.	US Army Corps of Engineers	40 CFR Parts 1500-1508/33 CFR 325 App B
Endangered Resource Review Program	An Endangered Resources Review is required for projects that are conducted, funded, or approved by the state that may result in impacts to endangered resource.	Wisconsin Bureau of Natural Heritage and Conservation	NR 29
Groundwater Quality	protection of groundwater quality	Remediation & Redevelopment	NR 140
Safe Drinking Water Act	Lake Michigan is a drinking water source for the City of Milwaukee. The Linnwood Water Treatment Plant draws water from an intake 6,565 feet from shore, five miles north of the Milwaukee Harbor, where Lake Michigan is 62 feet deep. Howard Avenue Water Treatment Plant draws water from an intake 11,767 feet from shore where lake water depth is 57 feet deep.	DNR	42 U.S.C. §300f et seq. (1974)

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Foth Infrastructure & Environment, LLC
2121 Innovation Court
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De Pere, WI 54115
Phone: 920-497-2500 Fax: 920-497-8516

DRAFT DRAWINGS FOR MILWAUKEE ESTUARY DMMF

WEC BUSINESS SERVICES

MILWAUKEE COUNTY WI

REVISIONS

NO.	BY	DATE	DESCRIPTION

RECORD DRAWING OF COMPLETED CONSTRUCTION BY:

RECORD DRAWINGS OF COMPLETED CONSTRUCTION CONFORMING TO CONTRACTOR AND/OR OWNERS RECORDS.

BY ____ DATE ____

DATE OF PREPARATION

	BY	DATE
SURVEYED		
DRAWN	JRS6	8/26/2019
DESIGNED		
CHECKED	TSW	8/26/2019

PROPOSED DMMF AREA

HORIZONTAL SCALE(FEET)
0 200 400

PROJECT ID: 19W012

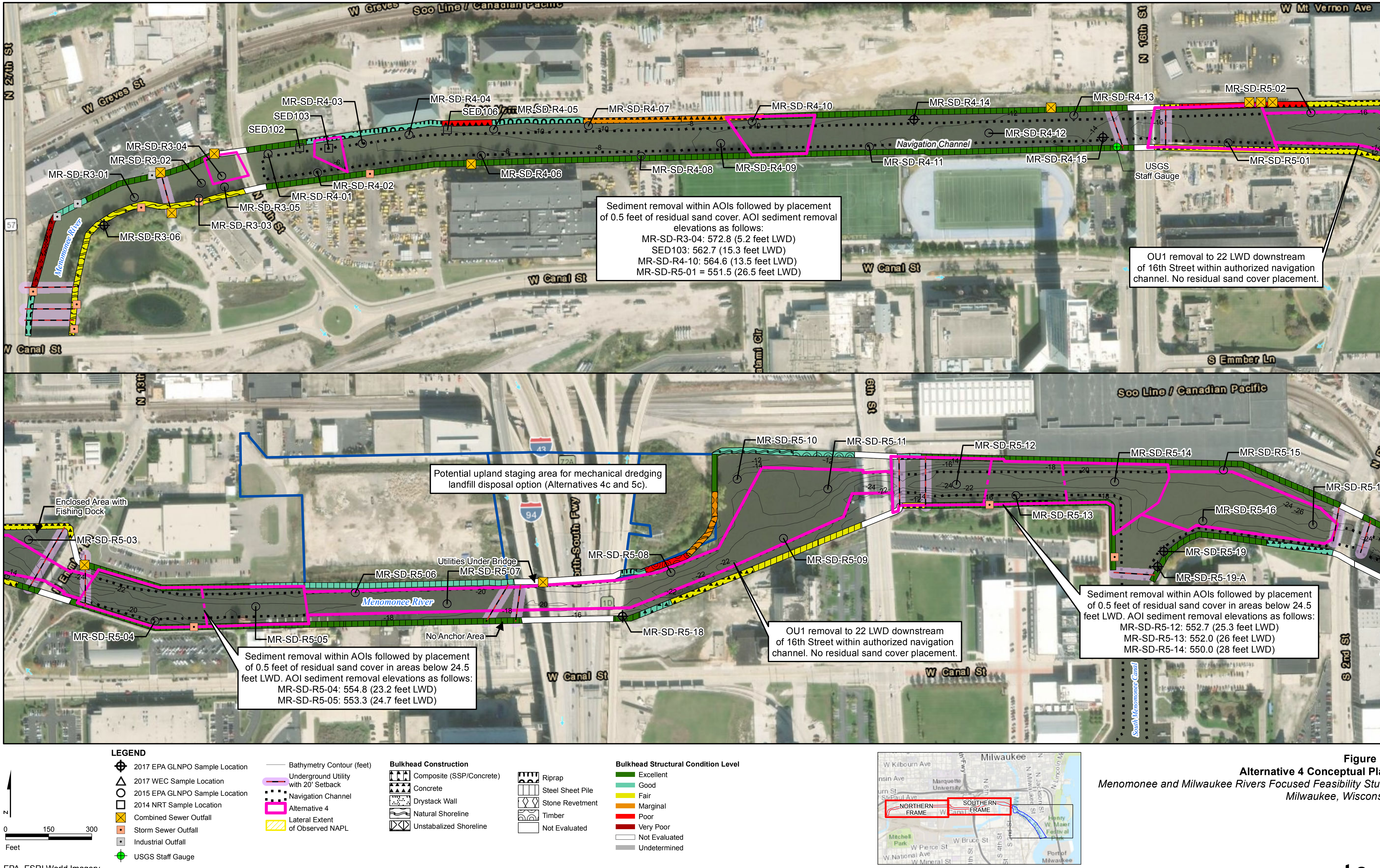

Figure 12
Alternative 4 Conceptual Plan
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

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Appendix I –
2019 USGS Benthos and Plankton Publication

USGS
science for a changing world

Prepared in cooperation with the Wisconsin Department of Natural Resources and the U.S. Environmental Protection Agency, Great Lakes National Program Office

Benthos and Plankton of Western Lake Michigan Areas of Concern in Comparison to Non-Areas of Concern for Selected Rivers and Harbors, 2012 and 2014

Scientific Investigations Report 2019–5051

U.S. Department of the Interior
U.S. Geological Survey

Cover. Photograph showing Sheboygan River South Pier (photograph by Amanda Bell, U.S. Geological Survey).

Benthos and Plankton of Western Lake Michigan Areas of Concern in Comparison to Non-Areas of Concern for Selected Rivers and Harbors, 2012 and 2014

By Barbara C. Scudder Eikenberry, Hayley T. Olds, Daniel J. Burns, Amanda H. Bell, and James L. Carter

Prepared in cooperation with the Wisconsin Department of Natural Resources and the U.S. Environmental Protection Agency, Great Lakes National Program Office

Scientific Investigations Report 2019–5051

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DAVID BERNHARDT, Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2019

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Kassidy T. Mapel, U.S. Geological Survey (USGS), assisted with all sampling in 2014; Nicolas Buer (USGS) assisted with Hester-Dendy sampler deployment in 2012. Michelle A. Nott and James L. Kennedy (USGS) assisted with geographic information systems and the creation of the map in figure 1; Leah Kammel (USGS) assisted with the finalization of figure 1. Scott A. Grotheer (USGS), Daniel J. Sullivan (USGS), and two anonymous reviewers provided technical comments on an earlier version of the report.

Contents

Figures

Tables

Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
micrometer (µm)	0.00003937	inch (in.)
meter (m)	3.281	foot (ft.)
meter (m)	1.094	yard (yd.)
kilometer (km)	0.6214	mile (mi.)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)
square meter (m^2)	1.19599	square yard (yd^2)
	Volume	
liter (L)	0.2624	gallon (gal.)
cubic meter (m^3)	264.2	gallon (gal.)
	Mass	
kilogram (kg)	2.205	pound (lb.)

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Supplemental Information

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L). The mesh opening size for the plankton net is given in micrometers (µm).

Abbreviations

ANOSIM	analysis of similarity
AOC	Area of Concern
BUI	Beneficial Use Impairment
EPT	Ephemeroptera-Plecoptera-Trichoptera
HD	Hester-Dendy (artificial substrate sampler)
IBI	Index of Biotic Integrity
MDS	multidimensional scaling
MMSD	Milwaukee Metropolitan Sewerage District
PCBs	polychlorinated biphenyl compounds
SIMPER	similarity percentage
TSS	total suspended solids
USGS	U.S. Geological Survey
VOI	volatile on ignition
VSS	volatile suspended solids
WDNR	Wisconsin Department of Natural Resources

Benthos and Plankton of Western Lake Michigan Areas of Concern in Comparison to Non-Areas of Concern for Selected Rivers and Harbors, 2012 and 2014

By Barbara C. Scudder Eikenberry, Hayley T. Olds, Daniel J. Burns, Amanda H. Bell, and James L. Carter

Abstract

Since their designation in the 1980s, Areas of Concern (AOCs) around the Great Lakes have been the focus of multi-State and international cleanup efforts that were needed after decades of human activity resulted in severely contaminated sediment, water-quality degradation, loss of habitat for aquatic organisms, and impaired public use. Although individual Great Lake States had been working to cleanup and mitigate environmental concerns, there was insufficient funding and little coordination between Federal and State efforts to address the large and complex set of problems. The Great Lakes Ecosystem Protection Act was passed in 2010, providing for comprehensive multi-State planning and dedicating Federal funds to accelerate cleanup and improve conditions at the AOCs with a particular focus on 14 beneficial use impairments, such as degradation of benthos and degradation of phytoplankton and zooplankton populations. Of Wisconsin's five AOCs, four lie adjacent to Lake Michigan: Lower Menominee River, Lower Green Bay and Fox River, Sheboygan River, and Milwaukee Estuary (which includes the Milwaukee River, Menomonee River, Kinnickinnic River, and Milwaukee Harbor). The Wisconsin Department of Natural Resources has focused much of the cleanup on removal of contaminated sediment from these AOCs because many beneficial use impairments were a result of contaminated sediment. However, recent and quantitative assessments of the status of benthos and plankton at the AOCs were lacking. Therefore, to inform management decisions regarding the status of benthos and plankton at AOCs, the U.S. Geological Survey, in cooperation with the Wisconsin Department of Natural Resources (WDNR) and the U.S. Environmental Protection Agency, Great Lakes National Program Office, assessed the condition of benthos (benthic invertebrates) and plankton (zooplankton and phytoplankton) at sites in the 4 AOCs and at 6 less-degraded comparison sites (hereafter referred to as "non-AOCs").

The U.S. Geological Survey collected benthos, plankton, sediment, and water three times per year in 2012 and 2014 between May and August at the AOC and non-AOC comparison sites. Except for Lower Green Bay and Milwaukee Harbor, each AOC site or subsite was paired with sites in two non-AOCs with similar environmental conditions. Community-based metrics were compared using univariate and multivariate statistics between each AOC and the mean of all non-AOCs and between each AOC and the mean of two non-AOC comparison sites. Although it was assumed that, because of their designation as AOCs, the relationships would indicate degraded conditions compared to the non-AOC sites, several metrics for the AOCs did not significantly differ between the AOCs and non-AOCs in 2014. Of all four AOCs examined for benthos, only the Lower Menominee River AOC differed from its two non-AOC comparison sites; the density and richness of taxa in insect orders Ephemeroptera-Plecoptera-Trichoptera (mayflies, stoneflies, and caddisflies) in combined benthos (dredge and artificial substrate samples) were lower at the AOC. For plankton, the assemblages for zooplankton at the Fox River near Allouez (a subsite in the Lower Green Bay AOC) and the Milwaukee River differed from their two non-AOC comparison sites; density of zooplankton was lower at both AOCs. Metrics for combined benthos and combined phytoplankton (soft algae and diatoms) at the Sheboygan River AOC did not differ from the two non-AOC comparison sites; however, the diversity of zooplankton in 2014 was lower at the Sheboygan River AOC than at the two non-AOC comparison sites. The combination of univariate and multivariate statistics provided a way to evaluate the status of the aquatic assemblage at each AOC and whether or not the assemblage differed from less-degraded non-AOC comparison sites. Results for this study provide multiple lines of evidence for evaluating the status of aquatic communities at AOC sites in Wisconsin along the western Lake Michigan shoreline in 2012 and 2014.

Introduction

Aquatic biological communities have been used for more than a century as sentinels and endpoints for quantifying the degree of water and sediment quality degradation as well as improvement after remediation. However, recent ecological assessments are few in river mouths and harbors of the Great Lakes, especially along the shoreline of Lake Michigan (Canfield and others, 1996; Scudder Eikenberry and others, 2016a). Benthic invertebrates (organisms living near, on, or in the bottom of a waterbody, hereafter referred to as "benthos") are considered good indicators of water quality and especially good indicators of sediment quality because they have direct contact with the sediment, are mostly sedentary compared to fish, and are constantly exposed to any chemical contaminants, low dissolved oxygen, high ammonia, and poor substrate conditions. In general, much less is known about the benthos of nonwadeable freshwater rivers, river mouths, and harbors than about wadeable riverine environments (Flotemersch and others, 2006; Larson and others, 2013; Weigel and Dimick, 2011; Wells and Demos, 1979). Zooplankton and phytoplankton (hereafter referred to as "plankton," mostly microscopic organisms living in the water column) are important food sources for many organisms and are useful indicators of water quality. Together, benthos and plankton can provide a more complete assessment of conditions and effectiveness of remediation at Great Lakes river mouths and harbors than either benthos or plankton can alone.

With the long period of human effects on ecosystems in Great Lakes river mouths and harbors, characterization of the taxa or abundances of aquatic organisms that should compose an unimpaired benthic or planktonic assemblage is a challenge. Also, the hydrodynamic effect of the large lakes can be significant because of their proximity as well as the effect of seiche and tidal action that can periodically transport lake water and organisms upriver for varying distances. Nevertheless, the primary effect is from the river and the benthos and plankton in the river mouth, and harbor samples should reflect this dynamic.

Relatively diverse fauna with at least modest abundances of various taxa in a healthy, downstream assemblage would be expected in a temperate river mouth or harbor (Larson and others, 2013). A study of benthos at 50 nearshore reference sites in lakes Superior, Huron, Erie, and Ontario by Bailey and others (1995) found that the 4 most abundant taxa were midges, oligochaetes, bivalves, and sponges; however, that study found considerable variation in benthos across sites and indicated that there was not a single, well-defined healthy ecosystem. The benthos of soft bottom sediment is usually dominated by worms (oligochaetes) and midges (chironomids), with some bivalves and occasional crustaceans, and less so water mites, flatworms, and various insect larvae, and the number of taxa usually decreases with depth (Wiederholm, 1980). For plankton, the zooplankton is usually dominated by rotifers and microcrustaceans, such as cladocerans and copepods, and protozoans. As secondary producers in aquatic food webs, benthos and zooplankton are important food sources for fish, aquatic birds, and other animals. As primary producers, phytoplankton play a major role at the base of aquatic food webs in large rivers and lakes, and assemblages are usually dominated by diatoms. The percentage of diatoms tends to decrease with pollution, and changes in the assemblage from dominance by diatoms to dominance by green algae or cyanobacteria (also known as "blue-green algae") can have a cascading effect on secondary consumers (Flotemersch and others, 2006; Wisconsin Department of Natural Resources, 1993).

In the 1987 Amendment to the Great Lakes Water Quality Agreement, the United States and Canada designated 43 Areas of Concern (AOCs). Of Wisconsin's five AOCs, four lie adjacent to Lake Michigan (International Joint Commission United States and Canada, 1987) and include the Lower Menominee River, the Lower Green Bay and Fox River, the Sheboygan River, and the Milwaukee Estuary (which includes the Milwaukee River, Menomonee River, Kinnickinnic River, and Milwaukee Harbor). AOCs are severely degraded areas that fail to meet quality objectives of the Agreement because of the presence of at least 1 of 14 beneficial use impairments (BUIs), including BUIs for the degradation of benthos and the degradation of phytoplankton and zooplankton populations. Historical and ongoing anthropogenic activities contribute to degraded sediment, benthos, and plankton at many AOCs. Removal or remediation of contaminated sediment has played a key role in Great Lakes Restoration Initiative efforts at AOCs. Recent data are lacking to assess whether or not the benthos and plankton have recovered.

In 2012 and 2014, the U.S. Geological Survey (USGS), in cooperation with the Wisconsin Department of Natural Resources (WDNR) and the U.S. Environmental Protection Agency, Great Lakes National Program Office, completed a study of the benthos and plankton at 10 sites in rivers and harbors along the western Lake Michigan shoreline. A total of 4 sampling sites (plus subsites) were in AOCs and 6 sites were in less-degraded sites (hereafter referred to as "non-AOCs"). The purpose of this study is to collect and evaluate data for determining whether or not the assemblages of benthos or plankton at four Wisconsin AOCs differ from the assemblages at presumptively less-degraded sites with comparable physical and chemical characteristics. This report presents an assessment of the status of assemblage structure of the benthos and plankton at the 4 AOC sites and 6 non-AOC comparison sites in 2014. The 2014 results are then compared to the results of the 2012 study (Scudder Eikenberry and others, 2016a), as well as to results for the AOCs from selected historical studies that used similar sampling methods, to provide context and evaluate potential progress in site remediation benefits in the four AOCs. State governments, citizen groups, and the U.S. Environmental Protection Agency can use the results of this study in making their BUI status determinations and as baseline information for future studies.

Methods

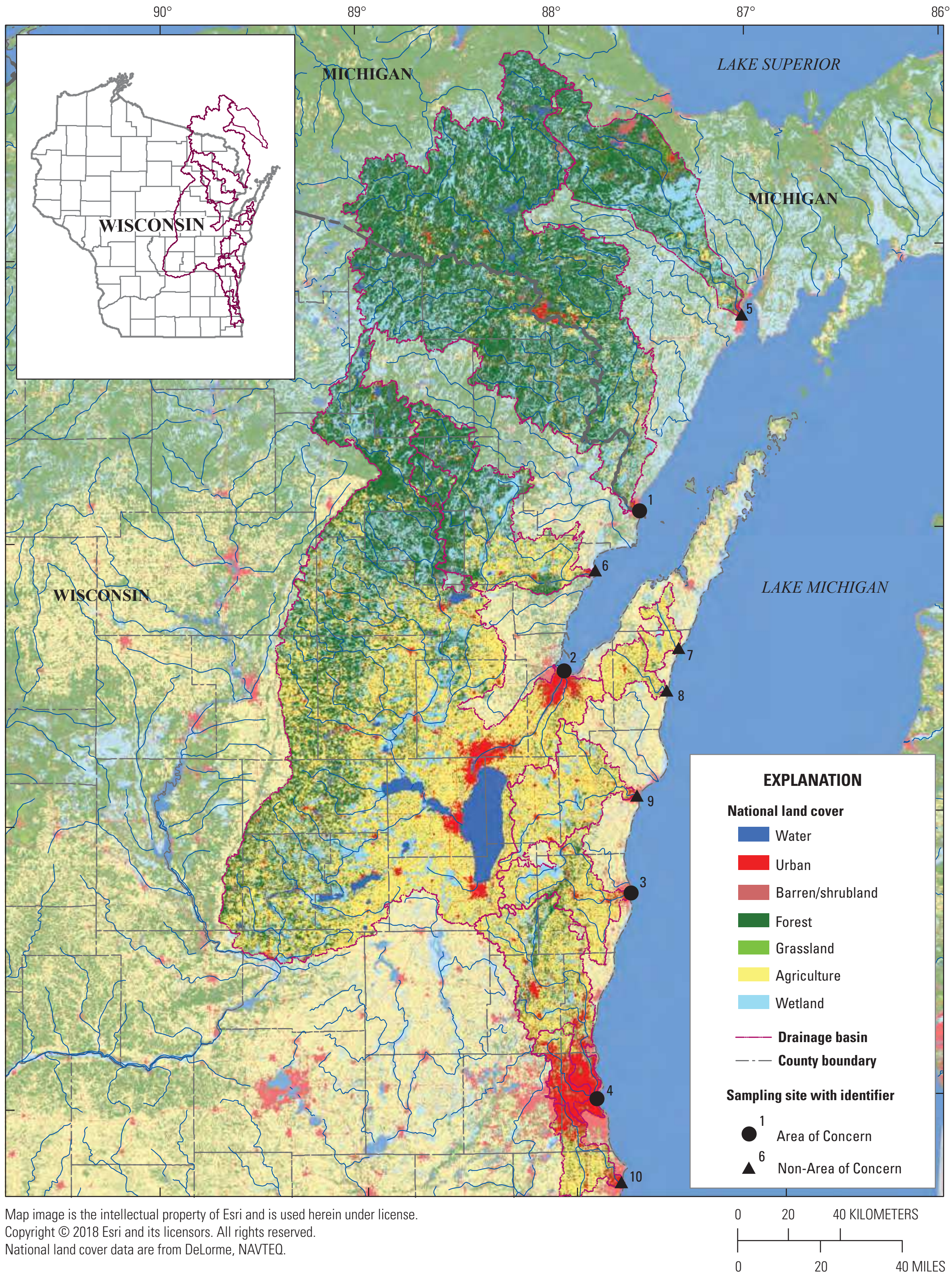
A total of 4 AOC sites and 6 non-AOC comparison sites, on the western shore of Lake Michigan, were selected for this study (fig. 1, table 1). Although all the river mouths or harbors along the western Lake Michigan shoreline are degraded to some degree, the non-AOCs selected for comparison with the AOCs have natural physical and chemical characteristics that are as close as possible to those of the AOCs, are presumptively less degraded because they are not designated AOCs, and are assumed to have biological assemblages similar to those that would be present in the AOCs if it were not for the specific contamination that was identified during the designation and listing of each AOC. That is, in the absence of effect, the less-degraded non-AOCs were assumed to have similar biological potential to the AOCs. The AOC sites sampled were the Lower Menominee River AOC at 1 site (hereafter referred to as “MENI”) and the Lower Green Bay and Fox River AOC (1 subsite [hereafter referred to as “FOXR”] was sampled at the Fox River near Allouez). A total of 6 subsites were sampled in lower Green Bay; only 1 subsite (the Lower Green Bay subsite, hereafter referred to as “GREE”) was sampled for benthos and plankton and the other 5 subsites were sampled for benthos only. The Sheboygan River AOC was sampled at 1 site (hereafter referred to as “SHEB”). The Milwaukee Estuary AOC is the largest Wisconsin AOC with respect to geographic area, population size, and the complexity of its drainage system. In the Milwaukee Estuary AOC, samples were collected at subsites in the Milwaukee River (1 subsite hereafter referred to as “MILR”) and the Menomonee River (1 subsite hereafter referred to as “MENO”), as well as the Milwaukee Harbor (1 subsite hereafter referred to as “MILH”), which lies downstream from the confluence of these two rivers and the Kinnickinnic River (not sampled). The terms “location” or “subsite” in this study are used when more than one area was sampled within an AOC site. Detailed site information is provided elsewhere (Scudder Eikenberry and others, 2014, 2016b).

Sample Collection and Processing

Detailed method descriptions are available elsewhere (Scudder Eikenberry and others, 2014, 2016b). Briefly, benthos and plankton were collected during three sampling events about 6 weeks apart in late May/early June, mid-July, and late August 2014. For simplicity, the three sampling events are hereafter referred to as the “spring,” “summer,” and “fall” seasonal samples. Unless otherwise specified, use of the term plankton in this report implies zooplankton and phytoplankton. High heat and drought during the summer and fall sampling periods in 2012 resulted in lower stream discharges at some sampling locations when compared to historical mean discharge. The sites most notably affected were MENI, the Milwaukee Estuary subsite MENO, and ROOT where annual mean discharges in 2012 were about two-thirds or less of the historical mean annual discharges at nearby streamgages. For this reason, and because remediation was completed at the Sheboygan River in 2013, benthos and plankton were sampled again in 2014 at all sites using the same methods. All sites were nonwadeable, so samples were collected from a boat. To quantify heterogeneity or “patchiness” of the organisms at sites, primary and replicate samples were collected at SHEB and its non-AOC comparison site on the Manitowoc River (hereafter referred to as “MANI”). Water quality at each site was determined during assemblage sampling by measuring pH, specific conductance, and water temperature with a Yellow Springs Instrument sonde.

Samples of the benthos were collected at most sites using two methods: (1) a standard Ponar dredge for grab samples of surficial bottom sediment and (2) Hester-Dendy (HD) artificial substrate samplers. HD samplers were deployed at the Fox River near Allouez subsite but were not deployed at the Green Bay subsites because of inadequate deployment conditions. A total of three to four grab samples of surficial sediment were collected and combined into one composite sample per site (U.S. Environmental Protection Agency, 2010a). A small amount of sediment (less than 50 grams) from each composite sample was split between two plastic bags for analysis of sand-silt-clay fractions and the volatile-on-ignition (VOI) component of the sediment. Large debris and empty shells in the remaining composite sample were examined for any attached invertebrates before being discarded, and the rest of the composite sample was washed through a 500-micrometer (μm) sieve. The retained debris and organisms were collected, and the organisms were identified and counted. A total of four individual HDs were deployed for 6 weeks at each site during each season (two each anchored to a cinder block). HD samplers were placed in areas with good flow to ensure velocities averaged at least 0.09 meters per second (m/s) as recommended (Ohio Environment Protection Agency, 1987). Once retrieved, three of the four HD samples were randomly chosen to represent the site and all organisms were scraped off and composited into one sample per season per site. Each dredge and HD sample was stained with rose bengal and preserved with 10-percent buffered formalin. Benthic invertebrates in samples were identified and counted by the Lake Superior Research Institute at the University of Wisconsin-Superior (U.S. Environmental Protection Agency, 2010b). Sediment samples were analyzed for sand-silt-clay fractions by the University of Wisconsin Soil and Plant Analysis Laboratory through the Wisconsin State Laboratory of Hygiene, except for five samples analyzed by the USGS Kentucky Water Science Center Sediment Laboratory because of low mass. Sediment samples were analyzed at the USGS in Middleton, Wis., using a VOI combustion method (U.S. Geological Survey, 1989; Wentworth, 1922) to provide an estimate of the organic content of sediment samples.

Artificial substrates such as the HD samplers measure short-term (1 month) colonization potential, and therefore, the attached invertebrates may not reflect the benthos of the location. Regardless, they may provide estimates of the organisms



National land cover data are from DeLorme, NAVTEQ.

Figure 1. Sampling sites and subsites investigated for the evaluation of benthic and planktonic assemblages at Wisconsin's 4 Lake Michigan Areas of Concern and 6 non-Area of Concern comparison sites in Wisconsin and Michigan. Site and subsite numbers with names are provided in table 1.

Table 1. U.S. Geological Survey sampling locations at Wisconsin's Lake Michigan Areas of Concern and non-Area of Concern comparison sites in Wisconsin and Michigan, including site or subsite number, latitude, longitude, and drainage area.

[All locations except historical Green Bay sites were also sampled in 2012. Plankton samples in the Lower Green Bay and Fox River Area of Concern were collected only at subsites GREE (2a) and FOXR (2b). A subsite, or additional sampling location within the geographic area of a site, is indicated by the addition of an alphabet letter to a site number. km^2, square kilometer; NA, not applicable]

Site or subsite name	Abbreviated name	Site or subsite number	Latitude[1] (decimal degrees)	Longitude[2] (decimal degrees)	Drainage[3] area (km^2)	Comparison site or subsite number
			Areas of Concern			
Lower Menominee River	MENI	1	45.09810	−87.60772	10,490	5, 6
Lower Green Bay and Fox River	NA	2	NA	NA	NA	NA
Lower Green Bay	GREE	2a	44.57751	−87.98600	16,584	NA
Green Bay Historical Subsite 3–1	GB03	GB03	44.56611	−87.99158	16,584	NA
Green Bay Historical Subsite 5	GB05	GB05	44.54444	−87.99444	16,584	NA
Green Bay Historical Subsite 8	GB08	GB08	44.54861	−87.94861	16,584	NA
Green Bay Historical Subsite 16	GB16	GB16	44.55972	−87.95972	16,584	NA
Green Bay Historical Subsite 17	GB17	GB17	44.57222	−87.93889	16,584	NA
Fox River near Allouez	FOXR	2b	44.49499	−88.02424	16,178	7, 8
Sheboygan River	SHEB	3	43.74887	−87.70352	1,043	8, 9
Milwaukee Estuary	NA	4	NA	NA	NA	NA
Milwaukee River	MILR	4a	43.04789	−87.91269	1,779	9, 10
Menomonee River	MENO	4b	43.03220	−87.92156	381	9, 10
Milwaukee Harbor	MILH	4c	43.02501	−87.89722	2,193	NA
			Non-Area of Concern comparison sites			
Escanaba River, Michigan	ESCA	5	45.77845	−87.06325	2,393	1
Oconto River	OCON	6	44.89198	−87.83678	2,502	1
Ahnapee River	AHNA	7	44.60979	−87.43484	274	2b
Kewaunee River	KEWA	8	44.46073	−87.50205	354	2b, 3
Manitowoc River	MANI	9	44.09190	−87.66183	1,341	3, 4a, 4b
Root River	ROOT	10	42.72866	−87.78827	514	4a, 4b

[1]Vertical coordinate information is referenced to the North American Vertical Datum of 1988.

[2]Horizontal coordinate information is referenced to the North American Datum of 1983.

[3]Drainage area determined using Hydrologic Unit Codes as described in Seaber and others, 1987.

associated with firmer (and potentially less contaminated) substrate than exists at a site. One advantage of using artificial substrates in assessments is to minimize the effect of habitat differences and allow the comparison of colonization potential on a single consistent substrate across all sites.

Samples of plankton for each site consisted of a plankton net sample to collect larger zooplankton and a set of whole-water samples to collect phytoplankton. Zooplankton were collected using a 63-µm mesh plankton net towed vertically from a depth of 5 meters (m) to the surface (U.S. Environmental Protection Agency, 2010c). If the available depth was less than 5 m, multiple tows were taken from just above the bottom to the surface until a 5-m total depth was sampled. A Kemmerer vertical water sampler was used to collect a set of five whole-water samples at 1-m depth intervals from 1 m below the surface to just above the bottom or, if the available depth was less than 5 m, samples were repeated at available 1-m intervals until five whole-water samples were collected. Subsamples were collected from the whole-water sample for the identification and counting of "soft" algae phytoplankton (cyanobacteria or "blue-greens," cryptomonads, desmids, dinoflagellates, euglenoids, and greens) and diatom phytoplankton, and analysis of chlorophyll-*a*, total suspended solids (TSS), and volatile suspended solids (VSS; U.S. Environmental Protection Agency, 2010d). Samples of zooplankton and phytoplankton were preserved with glutaraldehyde to a 1-percent final solution. Soft algae were identified and counted at the Wisconsin State Laboratory of Hygiene (Karner, 2005). Zooplankton and diatoms were identified and counted at the WDNR (U.S. Environmental Protection Agency, 2010e, f).

Analyses of chlorophyll-*a*, TSS, and VSS were done at the Wisconsin State Laboratory of Hygiene (American Public Health Association and others, 2006; Kennedy-Parker, 2011).

Data Analyses

Potential differences in assemblages between AOCs and non-AOCs were first determined within a year and then between years. Except for the Lower Green Bay and Milwaukee Harbor subsites, each AOC site and associated subsite was matched to two non-AOC sites (hereafter referred to as "non-AOC comparison sites") based on the similarity of available environmental data as described earlier in the "Methods" section. Some non-AOCs were used for more than one AOC in comparisons. Metrics were computed from the assemblage data for comparisons between sites and years. The metrics used for comparisons were total taxon richness (the total number of taxa), the Shannon diversity index (Shannon, 1948), and total abundance (density) for dredge and HD sampler data combined (hereafter referred to as "combined benthos"), zooplankton, and soft algae and diatoms combined (hereafter referred to as "combined phytoplankton"). Additional metrics were computed for the benthos. These metrics included richness, density, and percentage of individuals in insect orders Ephemeroptera-Plecoptera-Trichoptera (EPT; mayflies, stoneflies, and caddisflies) for combined benthos and a macroinvertebrate index of biotic integrity (IBI) based on HD sampler data only. The IBI was designed for use with HD sampler data for large, nonwadeable rivers of Wisconsin (Weigel and Dimick, 2011). An IBI is a multimetric that combines structural metrics (for example, richness, diversity, and relative abundance), functional metrics (for example, feeding groups), and tolerance metrics (for example, percentage of tolerant taxa) to generate a numeric value that indicates the assemblage condition. The combination of structural and functional metrics can make IBIs more effective than a single metric for defining differences or change in assemblages. Indices to evaluate the benthos of deep freshwater environments are still in development. At present, no IBIs exist for zooplankton or phytoplankton in river mouths or harbors; therefore, seven metrics/multimetrics were used when comparing benthos and three metrics were used when comparing plankton. Means of metric values for non-AOCs were calculated within a sampling event (season).

Paired *t*-tests were used to compare metrics between sites. Comparisons were made between AOCs and the mean of all non-AOCs and between AOCs and their two matched non-AOC comparison sites. Some non-AOCs were compared with more than one AOC. In all, the sample size (n) was 3; unless otherwise stated, use of the term "significant" refers to statistical values of probability (p) less than (<) 0.05 in data comparisons. To satisfy conditions of normality, all total densities for benthos and plankton were log-10 transformed ($\log_{10}$) before statistical comparisons between samples; other data transformations were done as needed on a case by case basis. Replicate sample data (SHEB and MANI only) were not used in comparisons between AOCs and non-AOCs. Comparisons were begun at a broad level by comparing each AOC site to all non-AOCs as a group across all seasons using the means of non-AOCs within a season (n=3). Comparisons were then narrowed to comparing each AOC site or subsite with its two non-AOC comparison sites across all seasons, again using the means of the two non-AOC comparison sites within season. Comparing each AOC to a matched pair of non-AOCs provided a more robust measure of potential difference. If a metric value was lower at the AOC than at the non-AOCs, then the AOC was rated as degraded for that metric. Lack of a significant difference does not imply that the AOC assemblage is not degraded but that it was not rated as degraded in comparison to the selected non-AOCs. Sample size for comparisons (n=3), with just 1 value per site for each of the 3 seasons in a year, was low in this study. The lower the sample size or number of samples, the lower the statistical power and the lower the ability to detect a true difference between samples or sites when a difference exits (Gotelli and Ellison, 2004). In some statistical comparisons, between-site seasonal differences may have led to high variances and contributed to an inability to detect differences between AOCs and non-AOCs. Also, values for some metrics differed between non-AOC comparison sites. High variability is also likely among the group of six non-AOCs; however, this metric was not tested.

A total of four PRIMER software (Clarke and Gorley, 2006) routines were used for multivariate analyses with relative abundances of taxa. Relative abundance was used because of the possibility of uneven effort among samples. The routines used were (1) DIVERSE—to calculate diversity in $\log_e$; (2) similarity percentage (SIMPER)—to assess differences in the relative abundances of taxa between each AOC and its non-AOC comparison sites, among primary and replicate samples collected each season at SHEB and MANI, and among subsites within the Lower Green Bay and Fox River (benthos only) and Milwaukee Estuary AOCs; (3) multidimensional scaling (MDS), a nonmetric method based on relative abundances of taxa—to derive assemblage site scores and create ordination plots of sites and (or) samples; and (4) analysis of similarity (ANOSIM)—to compare assemblages among sites and samples using similarity matrices in a procedure analogous to an analysis of variance.

For multivariate analyses with PRIMER software, the relative abundance of each taxon was determined for each sample and then fourth-root transformed to allow common and rare taxa to affect outcomes (Clarke and Gorley, 2006). A Bray-Curtis similarity matrix was calculated between each set of samples, and these similarity matrices formed the basis of SIMPER and ANOSIM comparisons. A one-way ANOSIM was used to determine the extent to which benthos and plankton varied across sites by sampling event and across sampling seasons. Differences between AOCs and non-AOCs as indicated by multivariate test results do not signify degradation at an AOC but only differences in the relative abundances of taxa making up the benthic assemblages at each AOC in comparison with the non-AOC comparison sites. Multivariate results allow for an evaluation of how similar or different the assemblages at each AOC and its two non-AOC comparison sites are and aid in understanding differences in metrics. However, because we assumed that non-AOCs represent the best available nondegraded condition, large differences between AOC and non-AOC assemblages may indicate that the AOC was not meeting expectations.

Ambiguous taxa, taxa whose abundances are reported for multiple and related taxonomic levels, were resolved on a per sample basis before calculating metrics and before completing multivariate analyses by distributing counts for the parent to the children present within each site, based on the proportion of counts already assigned to each child, and removing the counts for the parent (Cuffney and others, 2007). If no children were present in the sample, then counts were left with the parent as originally identified. This procedure for dealing with ambiguous taxa was applied to the benthos and zooplankton; there were no ambiguous soft algae in samples of phytoplankton, so this procedure was used on only diatoms in the phytoplankton.

Richness was computed by totaling the number of unambiguous taxa; diversity was calculated using the Shannon diversity index (in $\log_e$) on raw abundances of taxa without data standardization or transformation using all unambiguous taxa. Richness and diversity were calculated separately for the two benthic sampling types—dredge and HDs—as well as for the combined (dredge and HDs) benthic samples. The macroinvertebrate IBI was calculated only for the HD samples as described by Weigel and Dimick (2011). The IBI values or “scores” range from 0 (worst) to 100 (best) and are rated as follows: very poor (less than or equal to [≤] 19), poor (20–39), fair (40–59), good (60–79), and excellent (greater than or equal to 80). Richness and diversity were also calculated separately for soft algae and diatom phytoplankton, as well as for combined phytoplankton (soft algae and diatoms combined). Relative abundance or dominance of taxonomic groups in the phytoplankton was computed from densities in the original soft algal dataset, which also included the density of diatoms as a group.

Chemical and Physical Comparisons between Areas of Concern and Non-Area of Concern Sites

All physical and chemical data are available in Scudder Eikenberry and others (2014, 2016b). There were no differences between years within each site/subsite with respect to water temperature, pH, and specific conductance except at the MILH subsite in the Milwaukee Estuary AOC (table 2). Specific conductance at MILH was higher in 2014 than in 2012, reflecting differences in the type and (or) amount of dissolved major ions in the water. In 2014, one or more water-quality values differed between an AOC and non-AOC comparison sites. Values for mean specific conductance at MENI and FOXR in the Green Bay and Fox River AOC were lower than at their two respective non-AOC comparison sites, and specific conductance was higher at SHEB than at its two non-AOC comparison sites. Johnson and others (2015) found that values higher than 363 microsiemens per centimeter (µS/cm) inhibited the growth of mayfly larvae. Although mean specific conductances at MENI and one of its non-AOC comparison sites, the Oconto River non-AOC comparison site (hereafter referred to as “OCON”), were below this value in 2012 and 2014, the mean specific conductance at the other non-AOC comparison site, the Escanaba River, Michigan (hereafter referred to as “ESCA”), was below this value in 2014 only. Mean specific conductances at FOXR and its two non-AOC comparison sites, as well as at SHEB and its two non-AOC comparison sites, were all above 363 µS/cm. Water temperatures in 2014 were higher at MENI, FOXR, SHEB, and MENO in the Milwaukee Estuary AOC when compared to their non-AOC comparison sites. Higher water temperatures have implications for comparisons of plankton at these AOCs and non-AOC comparison sites because temperature is one control of growth for plankton.

Chlorophyll-*a* and suspended solids (TSS and VSS) are indicators of algal biomass (table 3). Nondetections for VSS data in summer and fall at MENI and MENO precluded testing VSS values for these two sites. Paired *t*-tests indicated that values for these measurements were not different between any AOC and non-AOC comparison sites in 2012 or 2014, and there were no differences within each site/subsite between 2012 and 2014 with respect to these three parameters. This result for chlorophyll-*a* and suspended solids indicates that the biomass of phytoplankton did not differ between AOCs and non-AOCs during these periods.

Although each AOC site or subsite except Green Bay sites and the MILH subsite was paired with two non-AOCs based on similar watershed characteristics, sediment size fraction and organic carbon content (as estimated by VOI) differed between AOCs and their non-AOC comparison sites (table 4). Results for size fraction and organic carbon content are included with results for benthic communities at each AOC.

Condition of the Benthos and Plankton of Areas of Concern in Comparison to Non-Areas of Concern for Selected Rivers and Harbors

Differences in benthos and plankton at AOCs were evaluated by comparing computed biological metrics as well as relative abundances of individual taxa comprising the aquatic assemblages at each site. Results for each AOC are discussed separately in the following sections to allow the reader to focus on the benthos or plankton of a single AOC

Table 2. Mean and standard deviation for water-quality measurements made in situ with a Yellow Springs Instrument sonde at about a 1-meter depth in 2012 and 2014 at Areas of Concern and non-Area of Concern comparison sites in Wisconsin and Michigan.

[The number of samples is 3 for each mean and standard deviation. °C, degree Celsius; µS/cm at 25 °C, microsiemens per centimeter at 25 °C; ±, plus or minus; MENI, Lower Menominee River; FOXR, Fox River near Allouez (Lower Green Bay and Fox River subsite); SHEB, Sheboygan River; MILR, Milwaukee River; MENO, Menomonee River; MILH, Milwaukee Harbor (MILR, MENO, and MILH are Milwaukee Estuary subsites); ESCA, Escanaba River, Mich.; OCON, Oconto River; AHNA, Ahnapee River; KEWA, Kewaunee River; MANI, Manitowoc River; ROOT, Root River]

Site	2012			2014		
	Water temperature (°C)	pH	Specific conductance (µS/cm at 25 °C)	Water temperature (°C)	pH	Specific conductance (µS/cm at 25 °C)
Areas of Concern						
MENI	24.1±1.9	7.60±0.16	283±39	22.0±1.5	7.77±0.08	256±34
FOXR	24.4±4.1	8.18±0.71	434±20	23.5±0.6	8.53±0.45	385±9
SHEB	19.8±2.7	8.28±0.23	485±144	21.2±0.7	7.96±0.15	594±53
MILR	22.6±4.4	8.15±0.53	805±171	22.3±0.3	7.88±0.11	656±45
MENO	23.4±2.9	7.47±0.40	621±74	24.1±1.8	7.70±0.08	875±230
MILH	21.1±3.4	7.91±0.43	524±74	21.0±2.4	7.76±0.08	734±70
Non-Area of Concern comparison sites						
ESCA	23.1±1.5	7.44±0.10	647±148	20.4±1.1	7.49±0.13	352±72
OCON	23.7±2.5	7.75±0.37	305±28	20.6±1.3	7.76±0.13	328±10
AHNA	17.5±6.1	8.15±0.11	422±109	17.9±1.3	7.72±0.23	584±6
KEWA	20.7±3.8	8.34±0.08	412±42	18.7±1.7	7.97±0.35	498±10
MANI	21.1±2.3	7.95±0.63	544±80	21.3±1.0	7.88±0.28	535±98
ROOT	22.8±1.9	7.94±0.13	800±263	20.6±2.9	8.01±0.39	930±83

of interest, and results for all comparisons are summarized. Because the Green Bay subsites and MILH were not compared to non-AOCs, they are presented in a separate section later in this report. Results and data for the 2012 sampling have been previously published (Scudder Eikenberry and others, 2014, 2016a), and data for the 2014 sampling are provided in Scudder Eikenberry and others (2016b).

Dreissena polymorpha (zebra mussels), an invasive species in Lake Michigan and many tributaries, were present in many samples from the benthos and plankton. Although *Dreissena* in the benthic samples were not identified to species, they were likely zebra mussels because all immature *Dreissena* ("veligers") in samples of zooplankton were identified as zebra mussels. Because of extremely high numbers of zebra mussel veligers in three samples of zooplankton, counts of this taxon were estimated at MILR and MILH (more than 2,000 at each) and ROOT (more than 4,000) in fall 2014.

There was minimal variability among field replicates within each season for most taxonomic groups. Primary and replicate samples were collected at two sites, SHEB and its non-AOC comparison site, MANI. Within each site, replicate samples had Bray-Curtis similarities higher than 60 percent except for fall diatom samples, which had only a 34- to 35-percent similarity. Because of the low similarity for fall diatom samples, similarities for fall combined phytoplankton were also low. In 2014, for example, fall diatom densities in the Sheboygan River primary and replicate samples were dominated (more than 75 percent) by one colony-forming centric taxon, but overall, there were fewer taxa and higher densities in the replicate sample. Also, fall diatom densities in the Manitowoc River primary and replicate samples in 2014 were dominated by other colony-forming centric taxa. Using relative abundances for samples of combined phytoplankton in comparisons with AOCs lessened the effect of differences in the fall diatom taxa. Results of paired *t*-tests indicated that there were no differences between metrics computed for primary and replicate samples of benthos, zooplankton, and combined phytoplankton for either SHEB or MANI in 2014.

Benthic Assemblage Comparisons between Areas of Concern and Non-Areas of Concern

The benthic assemblage that was compared between an AOC and non-AOCs was based on the combination of dredge and HD samples (hereafter referred to as "combined benthos") to better represent the potential assemblage at each site.

Table 3. Mean and standard deviation for chlorophyll-*a*, total suspended solids, and volatile suspended solids for composited water samples collected in 2012 and 2014 at Areas of Concern and non-Area of Concern comparison sites in Wisconsin and Michigan.

[The limit of detection for suspended solids is 2 mg/L. The number of samples is 3 for each mean and standard deviation. µg/L, microgram per liter; mg/L, milligram per liter; MENI, Lower Menominee River; ±, plus or minus; FOXR, Fox River near Allouez (Lower Green Bay and Fox River subsite); SHEB, Sheboygan River; MILR, Milwaukee River; MENO, Menomonee River; MILH, Milwaukee Harbor (MILR, MENO, and MILH are Milwaukee Estuary subsites); ESCA, Escanaba River, Mich.; OCON, Oconto River; AHNA, Ahnapee River; KEWA, Kewaunee River; MANI, Manitowoc River; ROOT, Root River]

Site	2012			2014		
	Chlorophyll-*a* (µg/L)	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Chlorophyll-*a* (µg/L)	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)
Areas of Concern						
MENI	3.44±1.65	4.0±1.0	2.67±1.15	4.51±1.82	3.60±1.98	7.67
FOXR	72.4±27.6	45.3±29.4	19.7±13.6	91.9±57.3	46.1±20.9	22.9±10.0
SHEB	44.4±33.3	16.0±8.9	6.67±3.06	15.2±11.9	16.8±9.7	9.17±8.25
MILR	22.6±13.4	17.0±14.0	9.00±9.54	7.26±4.43	20.9±5.9	8.72±5.88
MENO	18.5±18.2	7.67±4.04	4.50±2.12	11.0±3.8	16.2±12.9	17.0
MILH	23.3±22.5	5.0±3.0	3.50±2.12	6.99±4.16	7.55±3.08	6.33±2.83
Non-Area of Concern comparison sites						
ESCA	1.37±0.33	4.3±2.1	4.0±0.0	1.70±0.71	4	6.7
OCON	3.72±1.76	3.33±1.15	2.0±0.0	4.06±0.53	4.24±1.17	8.3
AHNA	22.0±16.7	11.7±5.0	7.7±5.1	19.3±5.3	7.78±6.26	11.7±11.8
KEWA	23.3±10.8	12.3±7.5	6.3±2.3	21.7±28.0	41.0±9.9	15.1±0.6
MANI	18.5±10.5	14.0±9.9	7.0±4.6	17.5±22.0	29.3±14.4	9.1±6.8
ROOT	19.9±4.0	20.7±19.4	7.3±4.2	13.9±12.2	33.2±33.5	9.8±8.8

Except for the IBI metric (computed from HD sampler data), all metrics used in comparisons were for combined benthos even though metrics were also computed for dredge and HD sampler data (table 5). Benthic communities collected by dredge in 2014 were dominated by oligochaetes (68 percent) and (or) midges (20 percent; chironomids). Of the 68 percent of oligochaetes, most were immature Tubificinae. Benthic assemblages collected by HD samplers in 2014 were dominated by midges (38 percent) and oligochaetes (21 percent). Statistical comparisons between AOCs and non-AOCs for combined benthos indicated differences in one or more metric values for every AOC. Differences in the relative abundance and distribution of combined benthic taxa at AOCs and non-AOCs in 2014 are shown in the MDS ordination plots (as described in the “Data Analyses” section). More similar samples appear closer together, indicating greater similarity, and less similar samples plot farther apart.

Lower Menominee River Area of Concern

The Lower Menominee River was designated an AOC because of sediment contamination with arsenic, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (also known as PAHs or coal tars), paint sludge, and heavy metals including cadmium, chromium, copper, lead, mercury, nickel, and zinc (U.S. Environmental Protection Agency, 2013a; Wisconsin Department of Natural Resources and Michigan Department of Environmental Quality, 2011). Sediment remediation was completed in November 2014 at the Lower Menominee River AOC and was therefore ongoing upstream when the 2014 samples were collected. The Escanaba River and Oconto River sites (ESCA and OCON) were the two non-AOC sites selected for comparisons to MENI because they have similar climate (cooler temperatures and higher snowfall than the more southern AOCs; Albert, 1995), latitude, and geology. All three are cold-water rivers (based on maximum daily mean temperatures less than about 20–22 °C with resultant fish assemblages; Lyons and others, 1996; Epstein, 2017) that have relatively high gradients, mostly sand and gravel (glaciated) surficial deposits, and parts that flow over bedrock. The Oconto River drains more clay surficial deposits than the other two rivers, mostly in the lower reaches (Robertson and Saad, 1995). Land cover/land is primarily forested and used for pulp production, with little

Table 4. Mean and standard deviation for sediment size fractions and volatile-on-ignition solids in bottom sediment collected in 2012 and 2014 at Areas of Concern and non-Area of Concern comparison sites in Wisconsin and Michigan.

[The number of samples is 3 for each mean and standard deviation. MENI, Lower Menominee River; ±, plus or minus; FOXR, Fox River near Allouez (Lower Green Bay and Fox River subsite); SHEB, Sheboygan River; MILR, Milwaukee River; MENO, Menomonee River; MILH, Milwaukee Harbor (MILR, MENO, and MILH are Milwaukee Estuary subsites); ESCA, Escanaba River, Mich.; OCON, Oconto River; AHNA, Ahnapee River; KEWA, Kewaunee River; MANI, Manitowoc River; ROOT, Root River]

Site	2012				2014			
	Sand (percent)	Silt (percent)	Clay (percent)	Volatile-on-ignition solids (percent)	Sand (percent)	Silt (percent)	Clay (percent)	Volatile-on-ignition solids (percent)
Areas of Concern								
MENI	89.7±5.1	6.3±4.2	4.0±1.0	3.42±1.47	90.3±4.6	3.0±5.2	6.7±0.6	1.18±0.32
FOXR	61.0±19.2	32.7±17.6	6.3±2.1	18.3±13.9	78.0±12.5	13.3±10.1	8.7±2.5	8.70±5.31
SHEB[1]	88.7±8.1	6.33±5.0	5.0±3.5	2.21±1.34	67.0±11.1	23.7±9.1	9.3±2.9	3.33±1.13
MILR	72.0±9.2	21.0±6.0	7.0±3.5	5.15±2.12	90.7±2.1	3.3±3.1	6.0±1.7	3.06±2.04
MENO	53.3±13.3	38.3±9.9	8.3±4.2	14.3±8.4	20.3±6.4	64.3±5.9	15.3±2.1	13.2±2.6
MILH	50.3±20.6	33.3±5.5	16.3±17.0	7.42±1.19	34.0±6.1	42.6±8.1	23.4±13.9	16.4±6.2
Non-Area of Concern comparison sites								
ESCA	89.3±8.3	7.7±9.0	6.3±5.1	5.04±5.43	92.5±5.0	3.5±2.1	4.0±2.8	6.33±7.65
OCON	97.3±1.5	2.0±1.7	0.67±0.58	1.46±1.74	95.7±1.5	0.67±0.58	3.7±1.2	0.95±0.19
AHNA	60.0±29.5	31.3±27.5	8.7±3.2	12.3±6.3	50	36	14	27.8±11.8
KEWA	45.7±28.9	44.7±24.0	9.7±4.9	28.6±9.4	34	50	16	29.9±8.2
MANI	28.3±1.5	58.0±4.4	13.7±3.5	12.0±2.2	18.0±2.0	58.0±2.0	24.0±3.5	9.58±0.33
ROOT	89.7±3.5	6.0±1.7	4.3±2.3	2.77±0.41	86.3±5.8	5.7±4.9	8.0±1.0	2.14±0.21

[1]Values for SHEB in 2012 are for the replicate sample because of missing data in the primary sample.

other agriculture. Because of these similarities, the three rivers were expected to have similar benthic assemblages, despite the smaller drainage areas of the Escanaba and Oconto Rivers compared to the Lower Menominee River. The City of Oconto dredged the lower part of the Oconto River for navigation in 2012 through 2014, and it is possible that one or more of the 2014 dredge samples may have been affected (Jeremy Wusterbarth, City of Oconto, written commun., August 8, 2017) even though the samples were collected at a site upstream from and outside of the area where maps indicated planned dredging was done. No dredging was recorded in the lower Escanaba River during 2012–14 (Ryan McCone, Michigan Department of Environmental Quality, written commun., August 28, 2017).

Sediment size fraction and organic carbon content (estimated by VOI of solids) in sediment did not differ between MENI and its two non-AOC comparison sites (table 4). Similar to ESCA and OCON, the substrate at MENI was primarily hard sand (90 percent), making sediment difficult to obtain with the dredge; VOI analyses indicated low amounts of organic matter in the samples. Substrate that is mostly sand is a poor substrate for a variety of organisms (Wood and Armitage, 1997), especially if it contains only low amounts of organic matter to provide nutrients for benthic organisms.

At MENI in 2014, results were mixed for metric comparisons with non-AOCs using combined benthos (fig. 2, table 5). Diversity, total density, and EPT density differed between MENI and the mean of all non-AOCs in 2014; diversity at MENI was higher, indicating a less degraded condition, and both densities were lower, indicating a more degraded condition (table 6). Only EPT density and EPT richness differed between MENI and the mean of the two non-AOC comparison sites, ESCA and OCON; both metrics at MENI were lower. Lower EPT density and richness indicate poorer quality assemblages and, therefore, these metrics were rated as degraded at MENI relative to mean of the two non-AOC comparison sites in 2014. The mean IBI in 2014 was 25.0 plus or minus (±) 8.7, and this score is in the "poor" rating category that ranges from 20 to 39 (fig. 2*B*, table 5). The mean IBI for the two non-AOC comparison sites in 2014 was 38.3±3.8, which is also "poor." Metrics did not differ between 2012 and 2014 at MENI. This result was not unexpected because sediment remediation was still ongoing during both years and the sampling site was downstream from contaminated areas.

Table 5. Metric means and standard deviations for benthos sampled in 2012 and 2014 at 4 Lake Michigan Areas of Concern in Wisconsin and 6 non-Area of Concern comparison sites in Wisconsin and Michigan.

[Richness was computed as the number of unique taxa in the sample. Diversity is Shannon diversity, calculated as $\log_e$. EPT, Ephemeroptera-Plecoptera-Trichoptera; IBI, index of biotic integrity; MENI, Lower Menominee River; SD, standard deviation; ESCA, Escanaba River, Mich.; OCON, Oconto River; FOXR, Fox River near Allouez (FOXR is a Lower Green Bay and Fox River subsite); AHNA, Ahnapee River; KEWA, Kewaunee River; SHEB, Sheboygan River; MANI, Manitowoc River; MILR, Milwaukee River; MENO, Menomonee River; ROOT, Root River; MILH, Milwaukee Harbor (MILR, MENO, and MILH are Milwaukee Estuary subsites)]

Statistic	Year	Dredge		Hester-Dendy			Combined benthos[1]					
		All taxa		All taxa			All taxa			EPT taxa		
		Richness	Diversity	Richness	Diversity	IBI[2]	Richness	Diversity	Density[3]	Richness	Density[3]	EPT percentage[4]
MENI Area of Concern site												
Mean	2012	13.3	2.1	27.7	1.9	18.3	38.7	2.4	4,414	6.7	342.6	7.8
SD	2012	4.0	0.3	9.7	0.9	2.9	13.1	0.9	2,239	2.3	192.2	3.0
Mean	2014	16.3	2.2	32	2.9	25	45.7	3.1	3,459	7.7	149.1	4.3
SD	2014	1.2	0.5	7.2	0.1	8.7	6.7	0.3	1,291	2.1	54.5	0.3
ESCA non-Area of Concern comparison site												
Mean	2012	16.7	2.1	23.3	2.3	26.7	34.7	2.6	5,776	6.7	847.8	16.9
SD	2012	4.9	0.4	3.2	0.2	2.9	7.6	0.5	2,260	0.6	117.7	8.9
Mean	2014	28.3	2.8	26.3	2.1	30	49	3.1	9,478	8.3	991.0	15.3
SD	2014	16.7	0.4	11.2	0.6	5	9.6	0	6,085	1.5	294.5	11.2
OCON non-Area of Concern comparison site												
Mean	2012	20.0	2.0	36.3	2.6	35	49	2.4	12,968	13.0	1,217.7	17.0
SD	2012	3.6	0.6	11	0.5	13.2	12.1	0.5	10,723	1.0	638.2	13.9
Mean	2014	28.7	2.5	41.7	3.0	46.7	63	3.0	10,937	14.3	1,000.7	10.7
SD	2014	6.7	0.2	14	0.1	10.4	9.6	0.1	3,939	3.1	447.2	6.9
ESCA–OCON non-Area of Concern comparison sites												
Mean	2012	18.3	2.0	29.8	2.5	30.8	41.8	2.5	9,372	9.8	1,032.7	17.0
SD	2012	4.3	0.1	5.9	0.2	8.0	8.5	0.2	6,294	0.8	376.5	11.2
Mean	2014	28.5	2.6	34.0	2.6	38.3	56.0	3.0	10,207	11.3	995.9	13.0
SD	2014	9.6	0.2	10.4	0.3	3.8	9.5	0.1	5,011	1.6	319.3	8.9
FOXR Area of Concern subsite												
Mean	2012	10.7	1.1	23.7	1.3	16.7	29.3	1.5	40,157	1.3	99.1	0.4
SD	2012	2.3	0.4	18.5	1.4	5.8	17.1	0.6	39,557	0.6	43.7	0.2
Mean	2014	15.0	1.7	27.3	2.6	13.3	38.7	2.4	18,841	4.3	476.2	3.7
SD	2014	4.4	0.1	4.2	0.1	10.4	9.0	0.2	13,046	0.6	224.2	2.7

Table 5. Metric means and standard deviations for benthos sampled in 2012 and 2014 at 4 Lake Michigan Areas of Concern in Wisconsin and 6 non-Area of Concern comparison sites in Wisconsin and Michigan.—Continued

[Richness was computed as the number of unique taxa in the sample. Diversity is Shannon diversity, calculated as $\log_e$. EPT, Ephemeroptera-Plecoptera-Trichoptera; IBI, index of biotic integrity; MENI, Lower Menominee River; SD, standard deviation; ESCA, Escanaba River, Mich.; OCON, Oconto River; FOXR, Fox River near Allouez (FOXR is a Lower Green Bay and Fox River subsite); AHNA, Ahnapee River; KEWA, Kewaunee River; SHEB, Sheboygan River; MANI, Manitowoc River; MILR, Milwaukee River; MENO, Menomonee River; ROOT, Root River; MILH, Milwaukee Harbor (MILR, MENO, and MILH are Milwaukee Estuary subsites)]

Statistic	Year	Dredge		Hester-Dendy			Combined benthos[1]					
		All taxa		All taxa			All taxa			EPT taxa		
		Richness	Diversity	Richness	Diversity	IBI[2]	Richness	Diversity	Density[3]	Richness	Density[3]	EPT percentage[4]
AHNA non-Area of Concern comparison site												
Mean	2012	3.7	0.8	24.7	2.2	11.7	27.7	1.9	6,917	3.3	175.1	2.5
SD	2012	1.5	0.5	10.2	0.6	2.9	8.4	0.1	927	2.1	48.0	0.7
Mean	2014	9.0	1.7	27.7	2.3	6.7	35.0	2.3	11,249	3.0	68.9	0.6
SD	2014	1.7	0.1	7.1	0.3	2.9	7.9	0.3	3,779	0	33.6	0.4
KEWA non-Area of Concern comparison site												
Mean	2012	9.0	0.6	12.7	1.3	8.3	20.7	1.6	53,986	1.0	126.3	0.3
SD	2012	1.7	0.2	7.5	0.7	7.6	8.5	0.6	15,497	0	130.4	0.4
Mean	2014	7.7	0.4	23	2.0	3.3	30.0	1.4	38,329	2.3	137.8	0.4
SD	2014	2.3	0.2	5.3	0.4	2.9	7.5	0.5	5,672	1.2	119.3	0.3
AHNA–KEWA non-Area of Concern comparison site												
Mean	2012	6.3	0.7	18.7	1.7	10.0	24.2	1.7	30,452	2.2	150.7	1.4
SD	2012	1.0	0.4	8.4	0.6	2.5	8.1	0.3	7,297	1.0	74.1	0.3
Mean	2014	8.3	1.1	25.3	2.2	5.0	32.5	1.9	24,789	2.7	103.4	0.5
SD	2014	2.0	0.2	1.9	0.1	2.5	4.6	0.4	4,247	0.6	70.4	0.2
SHEB Area of Concern site												
Mean	2012	13.0	0.5	25.7	2.0	8.3	35.3	1.1	48,318	1.3	15.8	0.1
SD	2012	6.6	0.4	6.7	0.9	2.9	14.2	0.6	33,987	1.2	17.4	0.1
Mean	2014	16.7	1.1	27.3	2.3	15	39.0	1.5	37,748	2.3	57.2	0.2
SD	2014	5.1	0.5	4.7	0.4	5	4.4	0.6	10,629	1.2	43.0	0.1
KEWA non-Area of Concern comparison site												
Mean	2012	9.0	0.6	12.7	1.3	8.3	20.7	1.6	53,986	1.0	126.3	0.3
SD	2012	1.7	0.2	7.5	0.7	7.6	8.5	0.6	15,497	0	130.4	0.4
Mean	2014	7.7	0.4	23	2.0	3.3	30.0	1.4	38,329	2.3	137.8	0.4
SD	2014	2.3	0.2	5.3	0.4	2.9	7.5	0.5	5,672	1.2	119.3	0.3

Table 5. Metric means and standard deviations for benthos sampled in 2012 and 2014 at 4 Lake Michigan Areas of Concern in Wisconsin and 6 non-Area of Concern comparison sites in Wisconsin and Michigan.—Continued

[Richness was computed as the number of unique taxa in the sample. Diversity is Shannon diversity, calculated as $\log_e$. EPT, Ephemeroptera-Plecoptera-Trichoptera; IBI, index of biotic integrity; MENI, Lower Menominee River; SD, standard deviation; ESCA, Escanaba River, Mich.; OCON, Oconto River; FOXR, Fox River near Allouez (FOXR is a Lower Green Bay and Fox River subsite); AHNA, Ahnapee River; KEWA, Kewaunee River; SHEB, Sheboygan River; MANI, Manitowoc River; MILR, Milwaukee River; MENO, Menomonee River; ROOT, Root River; MILH, Milwaukee Harbor (MILR, MENO, and MILH are Milwaukee Estuary subsites)]

Statistic	Year	Dredge		Hester-Dendy			Combined benthos[1]					
		All taxa		All taxa			All taxa			EPT taxa		
		Richness	Diversity	Richness	Diversity	IBI[2]	Richness	Diversity	Density[3]	Richness	Density[3]	EPT percentage[4]
MANI non-Area of Concern comparison site												
Mean	2012	7.3	0.6	33.7	2.1	8.3	38.3	1.0	61,637	1.7	14.4	0
SD	2012	0.6	0.1	9.5	0.3	7.6	10.3	0.4	41,640	2.9	24.9	0
Mean	2014	14.3	0.8	29.3	2.4	15	40.3	1.2	25,405	3.0	53.1	0.2
SD	2014	5.9	0.2	9.5	0.4	10	13.1	0	1,281	2.0	17.4	0.1
KEWA–MANI non-Area of Concern comparison sites												
Mean	2012	8.2	0.6	23.2	1.7	8.3	29.5	1.3	57,811	1.3	70.3	0.2
SD	2012	1.0	0.1	8.4	0.4	3.8	9.3	0.1	13,417	1.4	77.6	0.2
Mean	2014	11.0	0.6	26.2	2.2	9.2	35.2	1.3	31,867	2.7	95.5	0.3
SD	2014	3.8	0.0	7.3	0.2	6.3	10.3	0.2	2,954	1.5	61.5	0.1
MILR Area of Concern subsite												
Mean	2012	12.3	0.6	18.7	1.8	6.7	27.7	1.1	41,406	1.0	251.2	0.9
SD	2012	3.8	0.3	6	0.5	5.8	7.2	0.4	19,031	1.0	227.6	1.2
Mean	2014	14.3	1.1	32.7	2.4	30.0	42.0	1.4	30,574	6.7	676.1	4.1
SD	2014	2.1	0.5	14.6	0.6	15.0	13	0.3	23,330	3.2	295.6	4.7
MENO Area of Concern subsite												
Mean	2012	13.7	1.0	21	1.8	5.0	31.3	1.2	74,158	1.3	144.1	0.2
SD	2012	2.1	0.2	9.5	0.6	5.0	5.0	0.2	32,908	0.6	156.5	0.2
Mean	2014	11.0	1.1	26.3	2.5	10.0	32.3	1.2	110,579	1.7	228.3	0.3
SD	2014	0	0	10.1	0.5	5.0	12.0	0.1	65,789	1.2	339.4	0.4
MANI non-Area of Concern comparison site												
Mean	2012	7.3	0.6	33.7	2.1	8.3	38.3	1.0	61,637	1.7	14.4	0
SD	2012	0.6	0.1	9.5	0.3	7.6	10.3	0.4	41,640	2.9	24.9	0
Mean	2014	14.3	0.8	29.3	2.4	15.0	40.3	1.2	25,405	3.0	53.1	0.2
SD	2014	5.9	0.2	9.5	0.4	10.0	13.1	0	1,281	2.0	17.4	0.1

Table 5. Metric means and standard deviations for benthos sampled in 2012 and 2014 at 4 Lake Michigan Areas of Concern in Wisconsin and 6 non-Area of Concern comparison sites in Wisconsin and Michigan.—Continued

[Richness was computed as the number of unique taxa in the sample. Diversity is Shannon diversity, calculated as $\log_e$. EPT, Ephemeroptera-Plecoptera-Trichoptera; IBI, index of biotic integrity; MENI, Lower Menominee River; SD, standard deviation; ESCA, Escanaba River, Mich.; OCON, Oconto River; FOXR, Fox River near Allouez (FOXR is a Lower Green Bay and Fox River subsite); AHNA, Ahnapee River; KEWA, Kewaunee River; SHEB, Sheboygan River; MANI, Manitowoc River; MILR, Milwaukee River; MENO, Menomonee River; ROOT, Root River; MILH, Milwaukee Harbor (MILR, MENO, and MILH are Milwaukee Estuary subsites)]

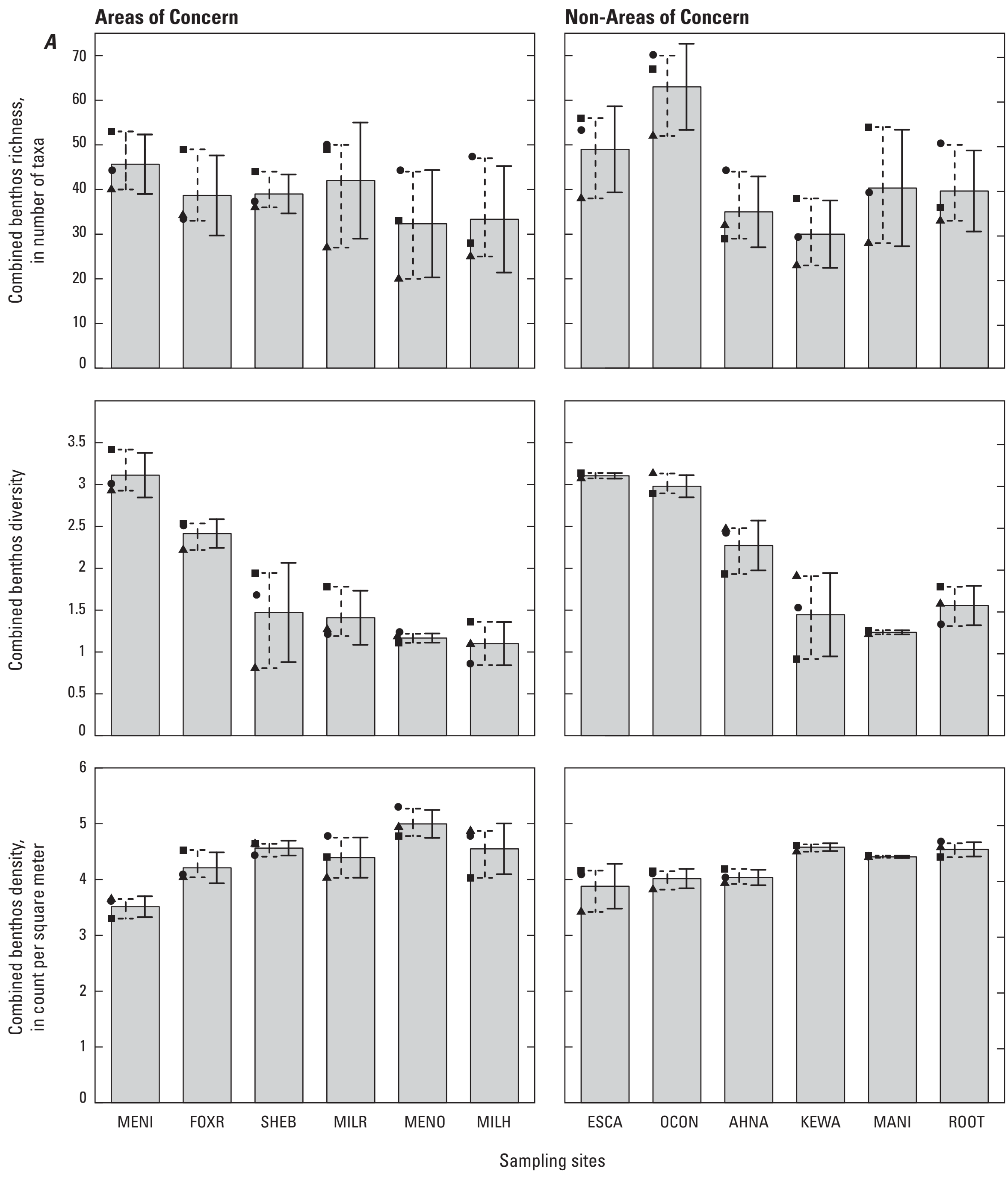
Statistic	Year	Dredge		Hester-Dendy			Combined benthos[1]					
		All taxa		All taxa			All taxa			EPT taxa		
		Richness	Diversity	Richness	Diversity	IBI[2]	Richness	Diversity	Density[3]	Richness	Density[3]	EPT percentage[4]
ROOT non-Area of Concern comparison site												
Mean	2012	10.7	0.9	24.0	1.9	13.3	31.0	1.6	25,264	3.0	165.1	0.8
SD	2012	3.8	0.1	13.5	1.0	7.6	12.5	0.5	13,403	1.7	126.0	0.6
Mean	2014	16.0	1.0	30.3	2.4	10.0	39.7	1.6	35,482	1.7	87.1	0.2
SD	2014	1.0	0.2	10.2	0.3	10.0	9.1	0.2	9,797	0.6	30.7	0
MANI–ROOT non-Area of Concern comparison sites												
Mean	2012	9.0	0.7	28.8	2.0	10.8	34.7	1.3	43,451	2.3	89.7	0.4
SD	2012	2.2	0.1	11.4	0.6	7.6	11.4	0.1	15,152	1.3	58.8	0.3
Mean	2014	15.2	0.9	29.8	2.4	12.5	40.0	1.4	30,443	2.3	70.1	0.2
SD	2014	3.1	0.2	6.3	0.2	10.0	8.2	0.1	4,260	1.3	16.9	0.03
MILH Area of Concern subsite												
Mean	2012	13.0	0.9	23.7	1.7	18.3	31.3	1.0	61,650	0.3	5.7	0
SD	2012	4.4	0.3	14.8	1.3	7.6	12.3	0.2	44,509	0.6	9.9	0.1
Mean	2014	6.0	0.6	29.0	1.9	26.7	33.3	1.1	46,815	2.0	33.0	0.1
SD	2014	1.7	0.1	11.5	1.5	5.8	11.9	0.3	32,487	1.0	15.1	0.2
All non-Area of Concern comparison sites												
Mean	2012	11.2	1.1	25.8	2.1	17.2	33.6	1.8	27,758	4.8	424.4	6.3
SD	2012	2.0	0.1	6.3	0.3	1.3	6.6	0.1	4,586	0.1	95.6	3.8
Mean	2014	17.3	1.5	29.7	2.4	18.6	42.8	2.1	21,813	5.4	389.8	4.6
SD	2014	4.5	0.1	5.9	0.1	4.6	7.4	0.1	2,902	1.1	91.8	3.0

[1]Metrics for combined benthos are for combined dredge and Hester-Dendy samples.

[2]IBI is designed for use with Hester-Dendy artificial substrates in nonwadeable rivers, calculated as in Weigel and Dimick (2011). The IBI score ranges from 0 (worst) to 100 (best): very poor (less than or equal to 19), poor (20–39), fair (40–59), good (60–79), and excellent (greater than or equal to 80).

[3]Density values for combined benthos are in count per square meter.

[4]Denotes the percentage of EPT individuals in the total sample.



EXPLANATION

[MENI, Lower Menominee River; FOXR, Fox River near Allouez subsite; SHEB, Sheboygan River; MILR, Milwaukee River subsite; MENO, Menomonee River subsite; MILH, Milwaukee Harbor subsite; ESCA, Escanaba River; OCON, Oconto River; AHNA, Ahnapee River; KEWA, Kewaunee River; MANI, Manitowoc River; ROOT, Root River; FOXR is a Lower Green Bay and Fox River Area of Concern subsite. MILR, MENO, and MILH are Milwaukee Estuary Area of Concern subsites]

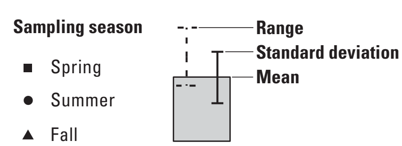


Figure 2. Metric values for benthos from 4 Lake Michigan Areas of Concern and 6 non-Area of Concern comparison sites. *A*, Richness, diversity, and total density of combined benthos (dredge and Hester-Dendy samples combined); and *B*, Ephemeroptera-Plecoptera-Trichoptera (EPT) density and EPT richness for combined benthos and the index of biotic integrity for Hester-Dendy samples.

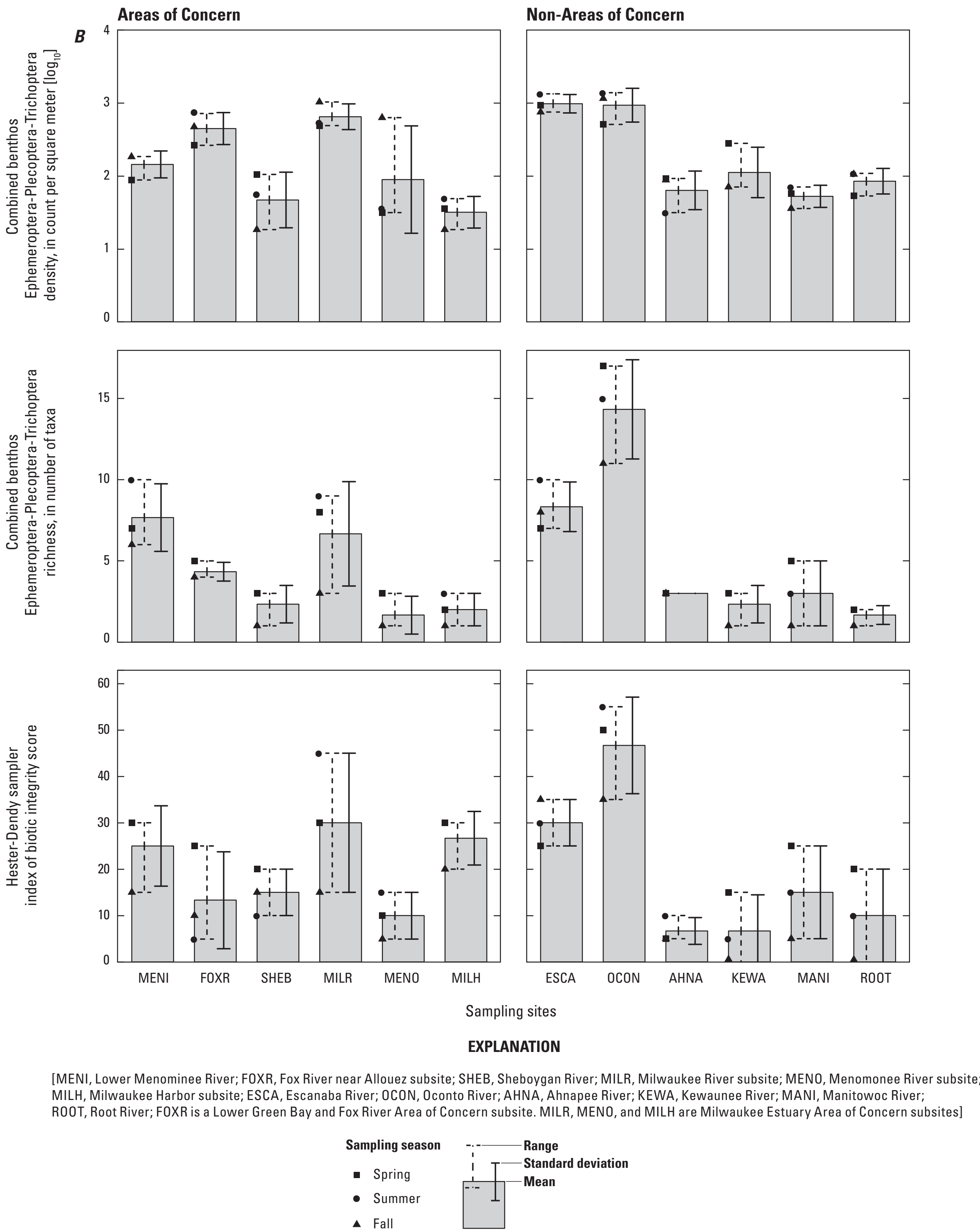


Figure 2. Metric values for benthos from 4 Lake Michigan Areas of Concern and 6 non-Area of Concern comparison sites. *A*, Richness, diversity, and total density of combined benthos (dredge and Hester-Dendy samples combined); and *B*, Ephemeroptera-Plecoptera-Trichoptera (EPT) density and EPT richness for combined benthos and the index of biotic integrity for Hester-Dendy samples.—Continued

A comparison of the benthic assemblage at MENI to non-AOCs by multivariate ordination indicated that MENI was similar to its two non-AOC comparison sites. MENI, ESCA, and OCON grouped together and away from the more southern sites in the MDS ordination plots, when seasons were combined (fig. 3*A*) and when seasons were separate (fig. 3*B*). The ANOSIM results did not indicate a difference between the assemblages at these sites, but results indicated that MENI was 61 percent dissimilar from its two non-AOC comparison sites. SIMPER analysis further indicated that the three taxa contributing most to this dissimilarity were (in order of contribution) the oligochaete *Nais simplex*, immature Tubificinae oligochaetes, and the pea clam *Pisidium*. In spring 2014, densities of *Nais simplex* at OCON were several times higher than at MENI or ESCA. *Nais simplex* is considered moderately tolerant to pollution (Bode and others, 2002). There were lower relative abundances of highly tolerant immature Tubificinae at MENI than at ESCA and OCON. *Pisidium* was common at MENI in all seasons, absent at ESCA, and present only in the fall at OCON. Pea clams such as *Pisidium* are moderately tolerant and common in Lake Michigan and its tributaries, and some species can be locally abundant and found in a variety of substrates (Barbour and others, 1999; Heard, 1962; Mackie and others, 1980). They are an important food source for fish.

Dominance of benthic taxa at MENI in 2014 was similar to dominance at its two non-AOC comparison sites. In all seasons, midges had the highest relative abundance of all taxa at MENI (more than 40 percent), ESCA (more than 30 percent), and OCON (more than 41 percent). Oligochaetes were moderately abundant at all three sites, and abundances at MENI were higher in the spring and summer (22 percent) than in the fall (9 percent), which likely reflects the life histories of these organisms. Abundances of pea clams were higher (28 percent) in the fall than in the spring or summer. Mayflies and caddisflies were rare or absent in 2014 samples from most sites. Together, they comprised 4–5 percent of the overall abundance in all three seasons at MENI and 3–6 percent in the spring and 17–28 percent in the fall at ESCA and OCON. Amphipods were found in low abundance (5–15 percent) in 2014 samples from MENI and ESCA, and they were rare or absent at OCON and other sites. Zebra mussels were present at all three sites but were absent from some samples or in low abundance in others (less than 3 percent).

In addition, there were differences in metrics between the two non-AOC comparison sites. The total richness of combined benthos at MENI (45.7±6.7) and ESCA (49.0±9.6) was similar in 2014; however, this metric was higher at OCON (63.0±9.6) than at ESCA. These differences in metrics highlight the fact that some non-AOC comparison sites were different from each other, and some non-AOCs were slightly degraded and thus similar to their AOCs; therefore, these slightly degraded non-AOCs may not have been appropriate as comparison sites for assessing the degradation status of their respective AOCs.

Lower Green Bay and Fox River Area of Concern

Farther south, the Fox River historically received contaminant discharges, primarily PCBs, that were noted as the main cause of AOC designation because of the resultant severe sediment contamination; however, nutrient enrichment in nonpoint runoff from agricultural and urban lands was a contributing factor as well (U.S. Environmental Protection Agency, 2013b; Wisconsin Department of Natural Resources, 2013). Drainage of contaminants and nutrients from the Fox River into Green Bay led to lower Green Bay near the mouth of the Fox River being designated as part of the AOC. Sediment remediation was ongoing in the Lower Green Bay and Fox River AOC at the time of sampling. There is no river or estuary system on the western shoreline of Lake Michigan that can truly compare to Green Bay, and therefore, only the Fox River near Allouez subsite (FOXR) was compared to the non-AOC comparison sites. Despite smaller drainage areas, sites on the Ahnapee River (sampling site hereafter referred to as “AHNA”) and Kewaunee River (sampling site hereafter referred to as “KEWA”) were chosen for comparison to the Fox River based on similar climate (Albert, 1995), latitude, and geology. The Fox River, Ahnapee River, and Kewaunee River are all warm-water (based on maximum daily mean temperatures greater than about 24 °C with resultant fish assemblages; Lyons and others, 1996; Epstein, 2017), low-gradient streams that flow through predominantly agricultural land and wetlands. Surficial deposits are glaciated and clay is dominant (Robertson and Saad, 1995).

The substrate at FOXR in 2014 was mostly sand (average of 78±12.5 percent) with some silt and clay and generally low to moderate organic carbon content sites (table 4). Missing data (insufficient material) for sediment size fractions precluded comparisons between FOXR, AHNA, and KEWA in the spring and summer; however, results for the fall indicated that sediment at AHNA and KEWA was lower in sand and higher in silt and organic carbon content than FOXR. The percentage of clay in FOXR sediment was higher in 2014 compared to 2012 but was still low overall. Lower Green Bay is discussed later in this report in the “Overview of Benthos and Plankton in Lower Green Bay and Milwaukee Harbor” section.

For combined benthos, no metrics differed between FOXR and the mean of all non-AOCs in 2014. Only EPT richness differed in comparisons between FOXR and the mean of the two non-AOC comparison sites in 2014; EPT richness was higher at FOXR than at AHNA and KEWA (fig. 2, table 6). EPT (mayflies, stoneflies, and caddisflies) richness was actually low at all three sites in 2014 (fig. 2*B*, table 5). A total of one to three mayfly taxa were found at all three sites. No stonefly taxa were found at FOXR or KEWA, and only one stonefly taxon was found in the spring at AHNA. For caddisfly taxa, zero to two taxa were found at AHNA and only one taxon in one season was found at KEWA. In each season at FOXR, two to three caddisfly taxa were present: *Cheumatopsyche* in the spring and summer and *Cyrnellus fraternus*

Table 6. Probability values for significance in paired *t*-tests comparing metrics for benthos at Areas of Concern (AOCs) with the mean of all non-AOCs or the mean of the two non-AOC comparison sites.

[All metrics are for combined benthos (combined dredge and Hester-Dendy samples) except the index of biotic integrity (Hester-Dendy samples only). Values in bold italics indicate the AOC metrics were significantly lower than non-AOCs compared; the number of samples is 3 in all comparisons. MENI, Lower Menominee River; EPT, Ephemeroptera-Plecoptera-Trichoptera; IBI, index of biotic integrity; FOXR, Fox River near Allouez (Lower Green Bay and Fox River subsite); SHEB, Sheboygan River; MILR, Milwaukee River; MENO, Menomonee River (MILR and MENO are Milwaukee Estuary subsites)]

Metric	2012		2014	
	AOC: non-AOC group	AOC: non-AOC pair	AOC: non-AOC group	AOC: non-AOC pair
MENI site				
Richness	0.543	0.814	0.466	0.109
Diversity	0.371	0.844	0.043	0.722
Total density[1]	***0.025***	0.313	***0.023***	0.206
EPT density[1]	0.307	***0.017***	***0.029***	***0.005***
EPT percent	0.100	0.194	0.904	0.241
EPT richness	0.278	0.202	0.141	***0.037***
IBI	0.621	0.082	0.118	0.067
FOXR subsite				
Richness	0.585	0.582	0.509	0.378
Diversity	0.423	0.461	0.201	0.218
Total density[1]	0.927	0.986	0.498	0.311
EPT density[1]	0.064	0.263	0.499	0.141
EPT percent	0.126	***0.041***	0.651	0.197
EPT richness	***0.008***	0.464	0.171	0.038
IBI	0.895	0.208	0.379	0.319
SHEB site				
Richness	0.749	0.173	0.394	0.402
Diversity	0.117	0.499	0.268	0.806
Total density[1]	0.731	0.606	0.162	0.570
EPT density[1]	0.063	0.187	0.061	0.122
EPT percent	0.108	0.349	0.132	0.155
EPT richness	***0.038***	1.000	***0.0003***	1.000
IBI	***0.012***	1.000	0.370	0.423
MILR subsite				
Richness	0.059	0.256	0.822	0.547
Diversity	0.083	0.315	0.105	0.919
Total density[1]	0.353	0.722	0.786	0.696
EPT density[1]	0.423	0.825	0.209	0.013
EPT percent	0.088	0.414	0.787	0.288
EPT richness	***0.019***	***0.015***	0.429	0.080
IBI	0.115	0.130	0.253	0.149

Table 6. Probability values for significance in paired *t*-tests comparing metrics for benthos at Areas of Concern (AOCs) with the mean of all non-AOCs or the mean of the two non-AOC comparison sites.—Continued

[All metrics are for combined benthos (combined dredge and Hester-Dendy samples) except the index of biotic integrity (Hester-Dendy samples only). Values in bold italics indicate the AOC metrics were significantly lower than non-AOCs compared; the number of samples is 3 in all comparisons. MENI, Lower Menominee River; EPT, Ephemeroptera-Plecoptera-Trichoptera; IBI, index of biotic integrity; FOXR, Fox River near Allouez (Lower Green Bay and Fox River subsite); SHEB, Sheboygan River; MILR, Milwaukee River; MENO, Menomonee River (MILR and MENO are Milwaukee Estuary subsites)]

Metric	2012		2014	
	AOC: non-AOC group	AOC: non-AOC pair	AOC: non-AOC group	AOC: non-AOC pair
MENO subsite				
Richness	0.268	0.458	0.096	0.168
Diversity	***0.037***	0.238	***0.004***	0.158
Total density[1]	0.048	0.114	0.039	0.043
EPT density[1]	0.102	0.832	0.283	0.833
EPT percent	0.110	0.535	0.105	0.892
EPT richness	***0.013***	0.438	***0.025***	0.270
IBI	***0.038***	0.317	0.053	0.667

[1]Log_{10}-transformed data.

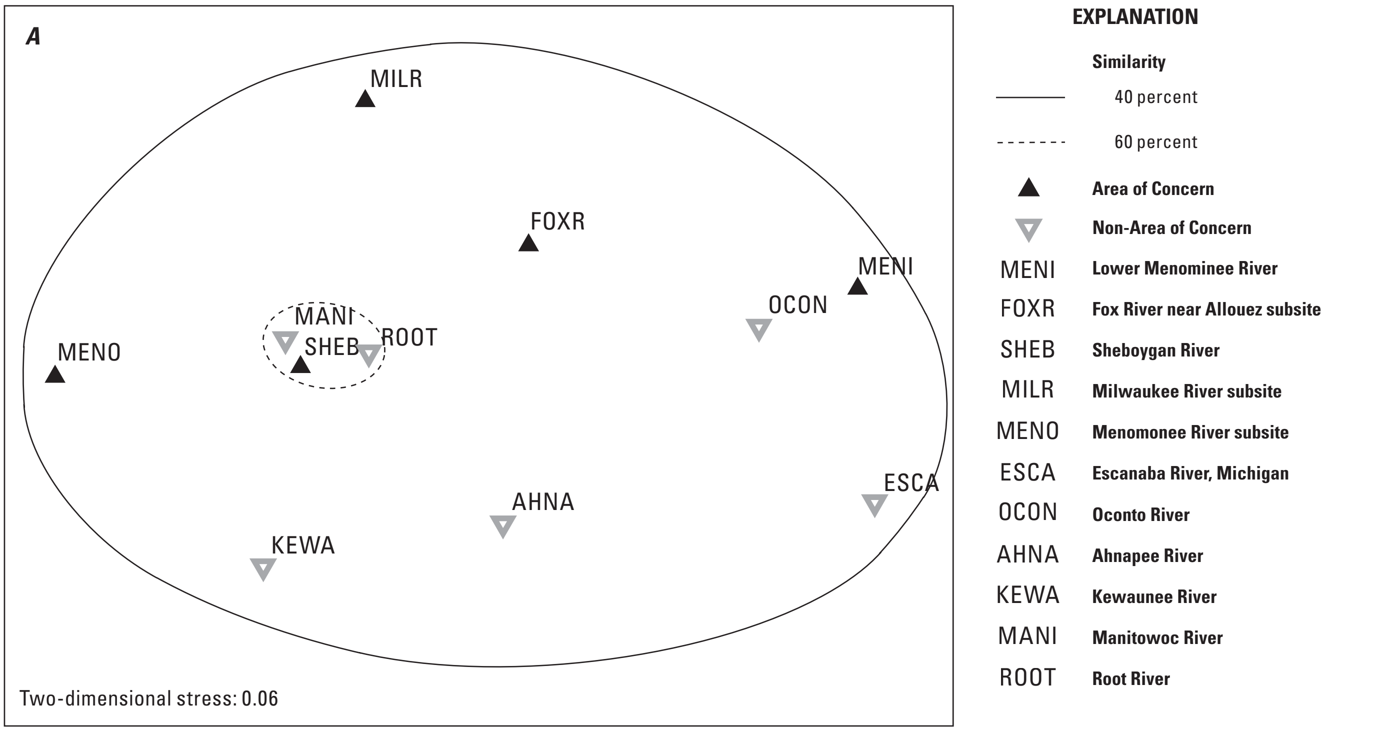
in all seasons. Although different species of *Cheumatopsyche* can vary in their tolerance to pollution, *Cyrnellus fraternus* is highly tolerant (Hilsenhoff, 1987). Although higher EPT richness is a positive indicator, the mean IBI at FOXR was 13.3±10.4, and this score is in the "very poor" rating category that includes all scores less than or equal to 19 (fig. 2, table 5). The mean IBI for the two non-AOC comparison sites, AHNA and KEWA, was only 5.0±3.2 in 2014. Only EPT richness differed between 2012 and 2014 at FOXR, with 2014 higher than 2012.

Multivariate ordination indicated that the combined benthic assemblage at FOXR was distinct, plotting away from all other sites in MDS ordination plots when seasons were combined (fig. 3*A*); however, with seasons separate, the summer and fall samples at FOXR were less similar to the two non-AOC comparison sites (AHNA and KEWA) than the spring FOXR sample (fig. 3*B*). An ANOSIM indicated that the 2014 benthic assemblages at FOXR were different from benthic assemblages at its two non-AOC comparison sites. Additional SIMPER testing indicated that FOXR was 62 percent dissimilar from its non-AOC comparison sites, mostly because of higher relative abundances of oligochaetes *Limnodrilus cervix*, *Aulodrilus pigueti*, and *Branchiura sowerbyi* at FOXR. *Limnodrilus cervix* is tolerant of highly polluted conditions including extremely eutrophic conditions; *A. pigueti* and *B. sowerbyi* are also pollution tolerant but less so than *L. cervix* (Bode and others, 2002; Rodriguez and Reynoldson, 2011). *Branchiura sowerbyi* is common around the Great Lakes but was not reported until the 1930s and is possibly nonnative (Spencer and Hudson, 2003; Great Lakes Aquatic Nonindigenous Species Information System, 2018).

Oligochaetes had the highest relative abundance in all seasons in 2014 at FOXR (more than 56 percent), and this was similar to AHNA and KEWA, except in the fall at AHNA when midges were higher in abundance (69 percent). Midges were moderately abundant (more than 16 percent) at FOXR, as well as at AHNA and KEWA (except in the spring at KEWA). Zebra mussels comprised less than 1 percent of the relative abundance at FOXR in 2014, were found at AHNA in the fall only and in low abundance (2 percent), and were not found at KEWA.

Sheboygan River Area of Concern

The Sheboygan River AOC was designated because of concerns about sediment contamination from PCBs, polycyclic aromatic hydrocarbons, and heavy metals (Burzynski, 2000; Wisconsin Department of Natural Resources, 1995, 2012). Sediment remediation was completed in June 2013; therefore, sample collection in 2014 was postremediation. The sampling sites on the Kewaunee and Manitowoc Rivers were the two non-AOCs selected for comparison to the Sheboygan River AOC, the smallest AOC in Wisconsin. The Kewaunee and Manitowoc Rivers are nearby tributaries to the Sheboygan River, and sites on these rivers (KEWA and MANI) were selected because of similar climate (Albert, 1995), latitude, geology, and land use. The Manitowoc River and Sheboygan River have similar drainage areas (1,341 and 1,043 square kilometers [km^2], respectively), but the Kewaunee River is smaller (329 km^2). There is a U.S. Environmental Protection Agency Superfund site on the Manitowoc River, about 1 mile from the mouth (U.S. Environmental Protection Agency, 2019), but the river does not have an AOC designation.



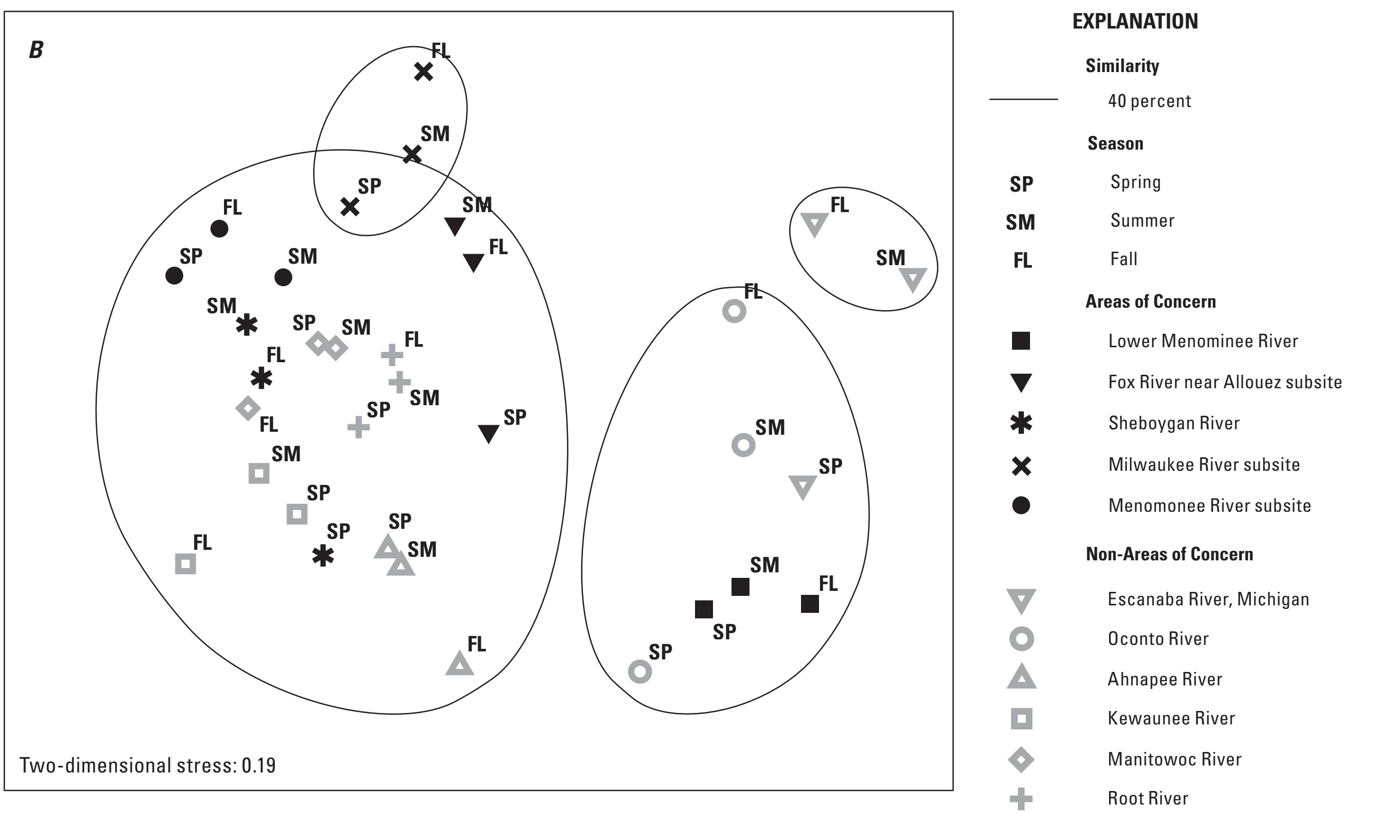


Figure 3. Multidimensional scaling ordination plots for combined benthos (dredge and Hester-Dendy samples combined) at 4 Lake Michigan Areas of Concern and 6 non-Area of Concern comparison sites, based on relative abundance with no rare or ambiguous taxa. *A*, Seasons combined; and *B*, seasons separate. Distances between sites are representative of their similarity or dissimilarity to each other. [The Fox River near Allouez is a subsite of the Green Bay and Fox River Area of Concern. The Milwaukee River and Menomonee River are subsites of the Milwaukee Estuary Area of Concern]

Surficial deposits for all three rivers are primarily clay with some areas of sand and gravel (Robertson and Saad, 1995). All three rivers are low gradient and flow through predominantly agricultural land and wetlands with urban land use at the mouth, and all are warm-water rivers.

Sediment percentages of silt and organic carbon were lower at SHEB than at MANI and KEWA in 2014, the percentages of clay did not differ, and the percentages of sand were higher at SHEB (table 4). Sediment at SHEB was mostly sand (average of 78±14 percent) followed by silt, with low organic content (less than 5 percent), whereas sediment at MANI and KEWA was about one-third sand and one-half silt with higher organic content.

Only EPT richness differed between SHEB and the mean of all non-AOCs, and SHEB was lower in 2012 and 2014. The IBI was lower at SHEB than at all non-AOCs in 2012 but not in 2014 after sediment remediation was complete. In 2014, the mean IBI at SHEB was 15.0±5.0, in the "very poor" rating category (≤19), and the mean IBI for the two non-AOC comparison sites was 9.2±9.2 (fig. 2*A*, table 5). No metrics differed between SHEB and the two non-AOC comparison sites, KEWA and MANI in 2014 (fig. 2*B*, table 6). Metrics did not differ between 2012 and 2014 at SHEB. In summary, no differences were found between SHEB and the non-AOC comparison sites in 2014, postremediation.

Multivariate ordination using ANOSIM indicated that the 2014 assemblage at SHEB for combined benthos was different from the two non-AOC comparison sites, KEWA and MANI. However, the MDS ordination plot indicated that this difference was due more to a difference between SHEB and KEWA for summer and fall (fig. 3*B*). Except for the spring sample at SHEB, relative abundances of benthic taxa were similar for SHEB and MANI, as evidenced by samples for these sites that plotted close to each other and away from KEWA when seasons were combined (fig. 3*A*). SIMPER results indicated that SHEB was 54 percent dissimilar from its two non-AOC comparison sites, mostly because of the midge *Glyptotendipes*, the oligochaete *Paranais*, and zebra mussels. *Glyptotendipes* was found in low abundance or was absent at the SHEB but was abundant at KEWA and uncommon to abundant at MANI. *Glyptotendipes* is highly tolerant of pollution (Barbour and others, 1999) and so is *Paranais* (Bode and others, 2002; Rodriguez and Reynoldson, 2011). *Paranais* and zebra mussels were relatively abundant at SHEB but were uncommon or absent at MANI and KEWA.

Oligochaetes had the highest relative abundance of all taxa at SHEB (more than 70 percent), as well as at KEWA (more than 52 percent) and MANI (more than 88 percent). The abundance of oligochaetes was lowest in the spring and highest in the fall at SHEB, but this was opposite of their abundance at KEWA; oligochaete abundance at MANI was only slightly lower in the summer than in the spring and fall. Although midges comprised 26 percent of the abundance at SHEB in spring 2014, midge abundance was only a fraction of that in other seasons (7 and 3 percent in summer and fall, respectively). In contrast, midge abundance was lowest in the spring and highest in the fall at KEWA, ranging from 3.5 percent in the spring to 44 percent in the fall. The abundance of midges at MANI was less than 7 percent in all seasons in 2014. Other insects, such as mayflies and caddisflies, made up less than 0.5 percent of the relative abundance at the three sites in any season.

Milwaukee Estuary Area of Concern

Contaminants of concern in the Milwaukee Estuary AOC are mainly PCBs, polycyclic aromatic hydrocarbons, pesticides, and heavy metals such as cadmium, copper, and zinc (U.S. Environmental Protection Agency, 2013c; Wisconsin Department of Natural Resources, 1994, 2014). Sediment remediation was ongoing during both years of sampling for benthos and plankton. The MILH subsite was not compared to non-AOCs because of its size and complexity and, therefore, results for MILH are discussed in a separate section. The MILR and MENO subsites were compared to two non-AOC comparison sites, MANI and the Root River sampling site (hereafter referred to as "ROOT"), because of similar climate (Albert, 1995), geology, and land use. Surficial deposits in all these rivers are glaciated, with primarily clay and sand but also some areas of sand and gravel (Robertson and Saad, 1995). All these rivers have agricultural land in the headwaters transitioning to urban land near the mouth. The Milwaukee River and Manitowoc River are similar in drainage area and the Menomonee River and Root River are similar in drainage area. All are warm-water rivers water (based on maximum daily mean temperatures greater than about 24 °C with resultant fish assemblages; Lyons and others, 1996; Epstein, 2017).

Sediment contained more sand and less silt and clay at MILR than at MANI and ROOT, but organic carbon content was similar between the three sites (table 4). Organic carbon content at MILR was higher in 2012 than in 2014 but was still low both years. In contrast, sediment contained less sand and more silt at MENO than at MANI and ROOT, and higher values for organic carbon content were found at MENO; the percentage of sand at MENO was higher, and the percentage of silt was lower, in 2012 compared to 2014. Across 2012 and 2014, the substrate at MILR was mostly sand (81±12 percent) with low organic carbon content (4.1±2.2 percent), and the substrate at MENO was lower in sand (37±20 percent) and higher in silt (51±16 percent) and organic carbon content (14±5.6 percent; table 4). The sediment at MANI was more similar to MILR, whereas the sediment at ROOT was more similar to MENO.

For benthos at MILR in 2014, no metrics differed between MILR and the mean of all non-AOCs. Only EPT density differed between MILR and the mean of the two non-AOC comparison sites, MANI and ROOT, and the value at MILR was higher (fig. 2*B*, table 6). Densities of mayflies were low and there were no stoneflies at the three sites. Densities of most caddisflies were low to moderate at the sites. However, densities of the caddisfly *Cyrnellus fraternus* at MILR ranged from 108 to 965 individuals per square meter, which led to higher EPT densities at MILR compared to MANI and ROOT. As was mentioned earlier for the occurrence of this taxon at FOXR, *C. fraternus* is considered to be highly tolerant to pollution (Hilsenhoff, 1987). Although EPT richness in 2012 was lower than the mean of all non-AOCs as well as the two non-AOC comparison sites, no difference was found in 2014. Diversity was low at a mean of 1.4±0.3 (table 5). Surprisingly, there was no difference (p=0.060) between years at MILR for the IBI, which averaged 6.7±5.8 in 2012 (“very poor” rating category) and 30.0±15.0 (“poor” rating category) in 2014 (fig. 2*A*, table 5). The mean IBI for the two non-AOC comparison sites in 2014 was 12.5±10.0. There was no difference between 2012 and 2014 for any metrics at MILR.

Diversity, total density, and EPT richness differed between MENO and the mean of all non-AOCs in 2014, as well as in 2012. MENO was lower for diversity and EPT richness and was higher for total density. The relation for diversity was highly significant in 2014 (p<0.01; fig. 2*A*, table 6). Only total density differed between MENO and the mean of the two non-AOC comparison sites in 2014; total density at MENO was higher. The higher density at MENO was because of higher densities for oligochaetes, especially highly tolerant *Limnodrilus cervix*, *Limnodrilus hoffmeisteri*, and immature Tubificinae. The mean IBI was rated “very poor” in 2012 and 2014 at 5.0±5.0 and 10.0±5.0, respectively. Although the IBI at MENO was lower than the mean of all non-AOCs in 2012, the relation was not quite significant in 2014 (p=0.053), and the mean of the two non-AOC comparison sites was also rated “very poor” in 2012 and 2014 at 10.8±7.6 and 12.5±10.0, respectively. There was no difference between 2012 and 2014 for any metrics at MENO.

For multivariate ordination, all seasons for MILR plotted as a distinct grouping away from MANI and ROOT and closer or similar in makeup to MENO in 2014 (fig. 3*A*), especially the summer and fall samples (fig. 3*B*). The ANOSIM indicated that MILR was 58 percent dissimilar from MANI and ROOT, mostly because of differences in the abundances of the pea clam *Pisidium*, the oligochaete *Aulodrilus pluriseta*, and the caddisfly *Cyrnellus fraternus*. Abundances of *Pisidium* and *A. pluriseta* were relatively high at MILR in the spring and summer when compared to the low abundance or absence of these two taxa at MANI and ROOT; *C. fraternus* was found in higher abundance at MILR than the two non-AOC comparison sites. *Aulodrilus pluriseta* is moderately tolerant of pollution (Bode and others, 2002; Rodriguez and Reynoldson, 2011) and so is *C. fraternus* (Barbour and others, 1999). In 2014, the assemblage of combined benthos at MENO was different from its two non-AOC comparison sites MANI and ROOT. SIMPER results indicated that MENO was 51 percent dissimilar from these sites, primarily because of differences in the abundances of oligochaetes, *Aulodrilus pluriseta* and *Ilyodrilus templetoni*, and midges in the *Polypedilum halterale* group. There was a higher abundance of *A. pluriseta* in the summer and fall and a lack of *I. templetoni* and the *P. halterale* group at MENO.

As was seen at most other sites, oligochaetes were the dominant taxa at MILR and MENO in 2014. At MILR, the highest relative abundance for oligochaetes was in the spring (more than 88 percent) and the lowest was in the fall (more than 75 percent). Oligochaete abundance was similar across seasons (96–97 percent) at MENO. This abundance was similar to MANI (more than 88 percent) and ROOT (more than 75 percent). Midges were found in low abundance (less than 10 percent) at MILR, in lower abundance at MENO and MANI, and in moderate abundance at ROOT in all seasons (15 percent or more). Surprisingly, caddisflies made up 9 percent of the relative abundance in the fall at MILR but were never more than 1 percent at MENO or the non-AOC comparison sites. Zebra mussels were absent from MILR and were present in low abundance at MENO, MANI, and ROOT.

Of all four AOCs examined for benthos, only the Lower Menominee River AOC differed from its two non-AOC comparison sites; density and richness of EPT taxa (individuals in insect orders Ephemeroptera-Plecoptera-Trichoptera (EPT; mayflies, stoneflies, and caddisflies) in combined benthos (dredge and artificial substrate samples) were lower at the AOC.

Planktonic Assemblage Comparisons between Areas of Concern and Non-Areas of Concern

Comparisons between each AOC and its non-AOC comparison sites were made for zooplankton and for combined phytoplankton (soft algae and diatoms combined). The metrics compared were richness, diversity, and total density (table 7). Assemblages of zooplankton at most sampled sites were dominated by rotifers in 2014, followed by copepods or zebra mussel veligers (means of 65, 17, and 13 percent abundance overall, respectively). The ANOSIM did not reveal differences between assemblages of zooplankton at any AOC when compared to the non-AOC comparison sites, possibly because there were often low similarities between the non-AOC comparison sites for zooplankton as indicated by SIMPER tests and MDS ordination plots., Differences in the relative abundances of taxa making up the assemblages at each AOC in comparison with the non-AOC comparison sites may signify degradation. Assemblages of phytoplankton at most sites were dominated by diatoms, followed by green algae and cryptophytes (means of 33-, 28-, and 22-percent abundance overall, respectively). Paired t-tests indicated no differences in chlorophyll-a concentration or TSS and VSS between any AOCs and their non-AOC comparison sites in 2014, indicating that the biomass of phytoplankton was not different between the sites. This finding was supported in tests directly comparing densities of phytoplankton at sites. Missing data for VSS in two seasons at MENI and MENO precluded statistical analyses. Detailed assessments of planktonic assemblages at each AOC are provided in this section.

Table 7. Metric means and standard deviations for plankton sampled in 2012 and 2014 at 4 Lake Michigan Areas of Concern in Wisconsin and 6 non-Area of Concern comparison sites in Wisconsin and Michigan.

[Richness was computed as the number of unique taxa in the sample. Diversity is Shannon diversity, calculated as $\log_e$. MENI, Lower Menominee River; SD, standard deviation; ESCA, Escanaba River, Mich.; OCON, Oconto River; GREE, Lower Green Bay; FOXR, Fox River near Allouez (GREE and FOXR are Lower Green Bay and Fox River subsites); AHNA, Ahnapee River; KEWA, Kewaunee River; SHEB, Sheboygan River; MANI, Manitowoc River; MILR, Milwaukee River; MENO, Menomonee River; ROOT, Root River; MILH, Milwaukee Harbor (MILR, MENO, and MILH are Milwaukee Estuary subsites)]

Statistic	Year	Zooplankton[1]			Soft algae		Diatoms		Combined phytoplankton[2]		
		Richness	Diversity	Density[3]	Richness	Diversity	Richness	Diversity	Richness	Diversity	Density
MENI Area of Concern site											
Mean	2012	29.0	2.3	9,364	12.0	1.4	16.7	2.2	28.7	2.5	2,829
SD	2012	5.3	0.6	5,903	3.6	0.4	10.3	0.8	12.5	0.5	321
Mean	2014	33.0	2.3	9,958	7.0	1.1	75.0	3.6	82.0	3.0	2,725
SD	2014	7.9	0.3	688	1.7	0.1	9.5	0.5	8.9	0.2	1,499
ESCA non-Area of Concern comparison site											
Mean	2012	24.0	2.2	2,430	11.0	1.5	18.7	2.5	29.7	2.7	1,530
SD	2012	3.0	0.5	833	2.0	0.4	11.5	0.4	9.9	0.2	223
Mean	2014	32.3	2.4	6,668	8.0	1.3	67.3	3.1	75.3	2.9	2,087
SD	2014	6.7	0.4	2,116	2.0	0.7	0.6	0.4	1.5	0.5	1,975
OCON non-Area of Concern comparison site											
Mean	2012	22.0	2.2	2,123	10.0	1.4	23.3	2.6	33.3	2.8	3,841
SD	2012	3.6	0.2	1,379	5.3	0.6	11.7	0.3	15.1	0.4	2,051
Mean	2014	32.7	2.3	8,787	9.3	1.1	79.7	3.9	89.0	3.2	1,957
SD	2014	4.0	0.3	3,618	3.5	0.4	5.0	0.1	4.6	0.2	436
ESCA–OCON non-Area of Concern comparison sites											
Mean	2012	23.0	2.2	2,277	10.5	1.5	21.0	2.6	31.5	2.7	2,686
SD	2012	2.0	0.4	1,081	3.6	0.5	1.0	0.0	3.0	0.2	914
Mean	2014	32.5	2.4	7,727	8.7	1.2	73.5	3.5	82.2	3.0	2,022
SD	2014	5.2	0.1	950	2.5	0.6	2.8	0.2	2.0	0.4	816
GREE Area of Concern subsite											
Mean	2012	21.3	2.1	50,848	17.3	1.7	32.7	2.3	50.0	2.7	69,025
SD	2012	7.6	0.5	11,726	5.0	0.2	26.2	1.3	29.8	0.7	62,668
Mean	2014	30.3	2.5	725,831	14.0	1.6	62.0	3.3	76.0	3.1	24,816
SD	2014	1.5	0.3	492,988	1.7	0.5	16.1	0.4	16.0	0.2	18,669

Table 7. Metric means and standard deviations for plankton sampled in 2012 and 2014 at 4 Lake Michigan Areas of Concern in Wisconsin and 6 non-Area of Concern comparison sites in Wisconsin and Michigan.—Continued

[Richness was computed as the number of unique taxa in the sample. Diversity is Shannon diversity, calculated as $\log_e$. MENI, Lower Menominee River; SD, standard deviation; ESCA, Escanaba River, Mich.; OCON, Oconto River; GREE, Lower Green Bay; FOXR, Fox River near Allouez (GREE and FOXR are Lower Green Bay and Fox River subsites); AHNA, Ahnapee River; KEWA, Kewaunee River; SHEB, Sheboygan River; MANI, Manitowoc River; MILR, Milwaukee River; MENO, Menomonee River; ROOT, Root River; MILH, Milwaukee Harbor (MILR, MENO, and MILH are Milwaukee Estuary subsites)]

Statistic	Year	Zooplankton[1]			Soft algae		Diatoms		Combined phytoplankton[2]		
		Richness	Diversity	Density[3]	Richness	Diversity	Richness	Diversity	Richness	Diversity	Density
FOXR Area of Concern subsite											
Mean	2012	7.7	1.2	48,967	13.0	1.2	56.7	3.0	69.7	2.8	36,806
SD	2012	2.5	0.3	36,111	1.0	0.4	7.6	0.2	8.3	0.3	38,867
Mean	2014	20.3	2.0	83,012	10.3	0.7	61.0	3.0	71.3	2.6	23,717
SD	2014	5.1	0.1	62,916	3.5	0.6	6.0	0.1	5.5	0.3	9,741
AHNA non-Area of Concern comparison site											
Mean	2012	15.3	1.6	334,847	15.7	0.9	22.3	2.5	38.0	2.4	35,387
SD	2012	7.2	0.6	380,341	2.1	0.1	2.9	0.4	1	0.1	16,691
Mean	2014	29.7	2.0	342,654	12.0	0.8	84.3	3.9	96.3	3.0	26,045
SD	2014	8.6	0.7	491,362	3.6	0.1	4.2	0.1	4	0	13,055
KEWA non-Area of Concern comparison site											
Mean	2012	21.0	1.8	63,020	15.7	1.9	34.0	2.0	49.7	2.6	19,128
SD	2012	6.6	0	22,661	2.3	0.2	28.2	1.2	30.4	0.5	10,528
Mean	2014	29.7	2.2	954,523	11.3	1.6	69.7	3.3	81.0	3.1	5,661
SD	2014	9.0	0.3	873,820	3.5	0.4	15.5	0.2	12.8	0.2	4,857
AHNA–KEWA non-Area of Concern comparison sites											
Mean	2012	18.2	1.7	198,934	15.7	1.4	28.2	2.2	43.8	2.5	27,257
SD	2012	6.7	0.3	188,766	2.0	0.1	13.2	0.6	15.1	0.2	12,780
Mean	2014	29.7	2.1	648,588	11.7	1.2	77.0	3.6	88.7	3.1	15,853
SD	2014	3.2	0.4	507,750	3.5	0.2	9.5	0.1	7.0	0.1	4,104
SHEB Area of Concern site											
Mean	2012	20.3	2.0	47,985	11.7	1.5	45.3	2.5	57.0	2.7	24,485
SD	2012	3.2	0.2	29,636	3.2	0.3	21.7	0.8	18.5	0.3	17,681
Mean	2014	27.0	1.1	379,864	9.0	1.7	66.3	2.8	75.3	3.0	4,099
SD	2014	8.7	0.6	421,132	2.0	0.1	24.0	1.3	23.0	0.6	2,775

Table 7. Metric means and standard deviations for plankton sampled in 2012 and 2014 at 4 Lake Michigan Areas of Concern in Wisconsin and 6 non-Area of Concern comparison sites in Wisconsin and Michigan.—Continued

[Richness was computed as the number of unique taxa in the sample. Diversity is Shannon diversity, calculated as $\log_e$. MENI, Lower Menominee River; SD, standard deviation; ESCA, Escanaba River, Mich.; OCON, Oconto River; GREE, Lower Green Bay; FOXR, Fox River near Allouez (GREE and FOXR are Lower Green Bay and Fox River subsites); AHNA, Ahnapee River; KEWA, Kewaunee River; SHEB, Sheboygan River; MANI, Manitowoc River; MILR, Milwaukee River; MENO, Menomonee River; ROOT, Root River; MILH, Milwaukee Harbor (MILR, MENO, and MILH are Milwaukee Estuary subsites)]

Statistic	Year	Zooplankton[1]			Soft algae		Diatoms		Combined phytoplankton[2]		
		Richness	Diversity	Density[3]	Richness	Diversity	Richness	Diversity	Richness	Diversity	Density
KEWA non-Area of Concern comparison site											
Mean	2012	21.0	1.8	63,020	15.7	1.9	34.0	2.0	49.7	2.6	19,128
SD	2012	6.6	0.0	22,661	2.3	0.2	28.2	1.2	30.4	0.5	10,528
Mean	2014	29.7	2.2	954,523	11.3	1.6	69.7	3.3	81.0	3.1	5,661
SD	2014	9.0	0.3	873,820	3.5	0.4	15.5	0.2	12.8	0.2	4,857
MANI non-Area of Concern comparison site											
Mean	2012	20.7	1.6	104,977	12.7	1.1	20.7	2.4	33.3	2.4	17,938
SD	2012	5.9	0.7	139,569	5.8	0.2	10.7	0.4	7.4	0.3	16,548
Mean	2014	21.3	1.7	121,837	10.3	1.4	73.0	3.5	83.3	3.2	10,200
SD	2014	11.5	0.9	175,317	4.5	0.2	16.5	0.5	12.1	0.3	13,127
KEWA–MANI non-Area of Concern comparison sites											
Mean	2012	20.8	1.7	83,999	14.2	1.5	27.3	2.2	41.5	2.5	18,533
SD	2012	6.0	0.4	59,954	4.0	0.2	11.5	0.7	15.1	0.3	12,799
Mean	2014	25.5	2.0	538,180	10.8	1.5	71.3	3.4	82.2	3.1	7,931
SD	2014	10.0	0.6	514,780	3.6	0.1	15.7	0.4	12.3	0.1	8,980
MILR Area of Concern subsite											
Mean	2012	20.3	2.1	13,953	14.0	1.5	43.0	3.2	57.0	3.1	36,165
SD	2012	7.0	0.2	8,331	5.6	0.7	11.4	0.1	16.4	0.4	35,555
Mean	2014	28.7	1.8	29,488	8.0	1.4	72.0	3.6	80.0	3.2	3,865
SD	2014	9.3	0.6	35,897	2.0	0.2	11.1	0.4	12.0	0.2	1,715
MENO Area of Concern subsite											
Mean	2012	19.3	2.3	39,922	13.0	1.8	30.0	2.9	43.0	3.1	9,132
SD	2012	5.0	0.1	20,418	5.6	0.3	18.7	0.6	13.1	0.2	4,974
Mean	2014	28.7	1.9	45,744	8.0	1.6	64.7	3.2	72.7	3.1	3,696
SD	2014	7.2	0.6	22,668	1.0	0.1	10.6	0.2	11.2	0.1	832

Table 7. Metric means and standard deviations for plankton sampled in 2012 and 2014 at 4 Lake Michigan Areas of Concern in Wisconsin and 6 non-Area of Concern comparison sites in Wisconsin and Michigan.—Continued

[Richness was computed as the number of unique taxa in the sample. Diversity is Shannon diversity, calculated as $\log_e$. MENI, Lower Menominee River; SD, standard deviation; ESCA, Escanaba River, Mich.; OCON, Oconto River; GREE, Lower Green Bay; FOXR, Fox River near Allouez (GREE and FOXR are Lower Green Bay and Fox River subsites); AHNA, Ahnapee River; KEWA, Kewaunee River; SHEB, Sheboygan River; MANI, Manitowoc River; MILR, Milwaukee River; MENO, Menomonee River; ROOT, Root River; MILH, Milwaukee Harbor (MILR, MENO, and MILH are Milwaukee Estuary subsites)]

Statistic	Year	Zooplankton[1]			Soft algae		Diatoms		Combined phytoplankton[2]		
		Richness	Diversity	Density[3]	Richness	Diversity	Richness	Diversity	Richness	Diversity	Density
MANI non-Area of Concern comparison site											
Mean	2012	20.7	1.6	104,977	12.7	1.1	20.7	2.4	33.3	2.4	17,938
SD	2012	5.9	0.7	139,569	5.8	0.2	10.7	0.4	7.4	0.3	16,548
Mean	2014	21.3	1.7	121,837	10.3	1.4	73	3.5	83.3	3.2	10,200
SD	2014	11.5	0.9	175,317	4.5	0.2	16.5	0.5	12.1	0.3	13,127
ROOT non-Area of Concern comparison site											
Mean	2012	19.7	1.1	69,911	14.3	1.7	36.7	2.8	51.0	2.9	11,911
SD	2012	4.5	0.5	46,177	0.6	0.3	30.1	0.8	30.6	0.5	5,871
Mean	2014	27.0	1.5	59,270	9.7	1.3	49.7	2.3	59.3	2.5	5,813
SD	2014	0.0	1.0	65,990	2.1	0.3	29.4	1.4	27.6	0.8	5,720
MANI–ROOT non-Area of Concern comparison sites											
Mean	2012	20.2	1.3	87,444	13.5	1.4	28.7	2.6	42.2	2.7	14,925
SD	2012	5.1	0.5	90,648	2.6	0.2	18.9	0.4	16.4	0.3	10,785
Mean	2014	24.2	1.6	90,554	10.0	1.4	61.3	2.9	71.3	2.8	8,007
SD	2014	5.8	0.6	118,901	3.1	0.1	22.7	1.0	19.6	0.5	9,423
MILH Area of Concern subsite											
Mean	2012	20.7	1.5	74,702	10.3	1.6	12.7	2.0	23.0	2.5	6,843
SD	2012	4.6	0.3	24,965	4.0	0.5	8.7	0.9	10.4	0.6	3,856
Mean	2014	25.7	1.2	115,742	7.3	1.4	77.3	3.7	84.7	3.2	3,970
SD	2014	9.5	0.8	61,086	1.5	0.4	4.7	0.1	5.8	0.2	321

Table 7. Metric means and standard deviations for plankton sampled in 2012 and 2014 at 4 Lake Michigan Areas of Concern in Wisconsin and 6 non-Area of Concern comparison sites in Wisconsin and Michigan.—Continued

[Richness was computed as the number of unique taxa in the sample. Diversity is Shannon diversity, calculated as $\log_e$. MENI, Lower Menominee River; SD, standard deviation; ESCA, Escanaba River, Mich.; OCON, Oconto River; GREE, Lower Green Bay; FOXR, Fox River near Allouez (GREE and FOXR are Lower Green Bay and Fox River subsites); AHNA, Ahnapee River; KEWA, Kewaunee River; SHEB, Sheboygan River; MANI, Manitowoc River; MILR, Milwaukee River; MENO, Menomonee River; ROOT, Root River; MILH, Milwaukee Harbor (MILR, MENO, and MILH are Milwaukee Estuary subsites)]

Statistic	Year	Zooplankton[1]			Soft algae		Diatoms		Combined phytoplankton[2]		
		Richness	Diversity	Density[3]	Richness	Diversity	Richness	Diversity	Richness	Diversity	Density
All non-Area of Concern comparison sites											
Mean	2012	20.4	1.7	96,218	13.2	1.4	25.9	2.5	39.2	2.6	14,956
SD	2012	3.9	0.3	54,986	2.4	0.1	2.3	0.1	0.7	0.0	6,761
Mean	2014	28.8	2.0	248,956	10.1	1.2	70.6	3.3	80.7	3.0	8,627
SD	2014	3.5	0.1	189,852	2.9	0.2	11.2	0.3	8.5	0.1	1,647

[1]For zooplankton in 2012, high algal counts precluded identification of rotifers other than *Asplanchna priodonta* in all Fox River samples and in summer samples for Ahnapee River.

[2]Richness and diversity of combined phytoplankton were calculated for combined soft algae and diatoms; density values were from the soft algae analyses, which also included densities for diatoms. Density is in cells per milliliter.

[3]Density of zooplankton was total density, including nauplii, in number per cubic meter.

Lower Menominee River Area of Concern

For zooplankton at MENI, metrics did not differ between either the mean of all non-AOCs or the mean of the two non-AOC comparison sites, ESCA and OCON (fig. 4, table 8). This finding was similar to 2012 when no differences were found. Lastly, no differences were found between 2012 and 2014 metrics for zooplankton at MENI.

There were no differences in the assemblages of zooplankton at MENI, ESCA, and OCON in 2014, based on results of the ANOSIM, with all three sites plotting adjacent to each other in a tight grouping within the MDS ordination plot when seasons were combined (fig. 5*A*). With seasons separate, the spring assemblage at MENI also had higher similarity to the spring assemblage at OCON than to the spring assemblage at ESCA (fig. 5*B*). Yet SIMPER results indicated that MENI and its two non-AOC comparison sites were 43 percent dissimilar, based mostly on the relative abundances of zebra mussel veligers, as well as rotifers *Lecane tenuiseta* and the bdelloid rotifer *Philodina*. Zebra mussel veligers were absent from all three sites in the spring and were present in the fall at low abundances; abundances in summer were much higher at MENI and ESCA than at OCON. The rotifer *L. tenuiseta* was in higher abundance at MENI compared to ESCA and OCON. Although abundances of *Philodina* were similar seasonally at MENI and OCON, abundances at ESCA were much lower overall. *Philodina* is commonly found in the benthos near river mouths in the Great Lakes (Stemberger, 1979), but this taxon and other bdelloid rotifers are the least well known of all the rotifer groups because they are fragile and can be damaged with some collection methods (National Oceanic and Atmospheric Administration, 2018). Rotifers in the genus *Lecane* are common in shallow areas as well as eutrophic areas such as river mouths and Great Lakes harbors in late spring through fall (Stemberger, 1979).

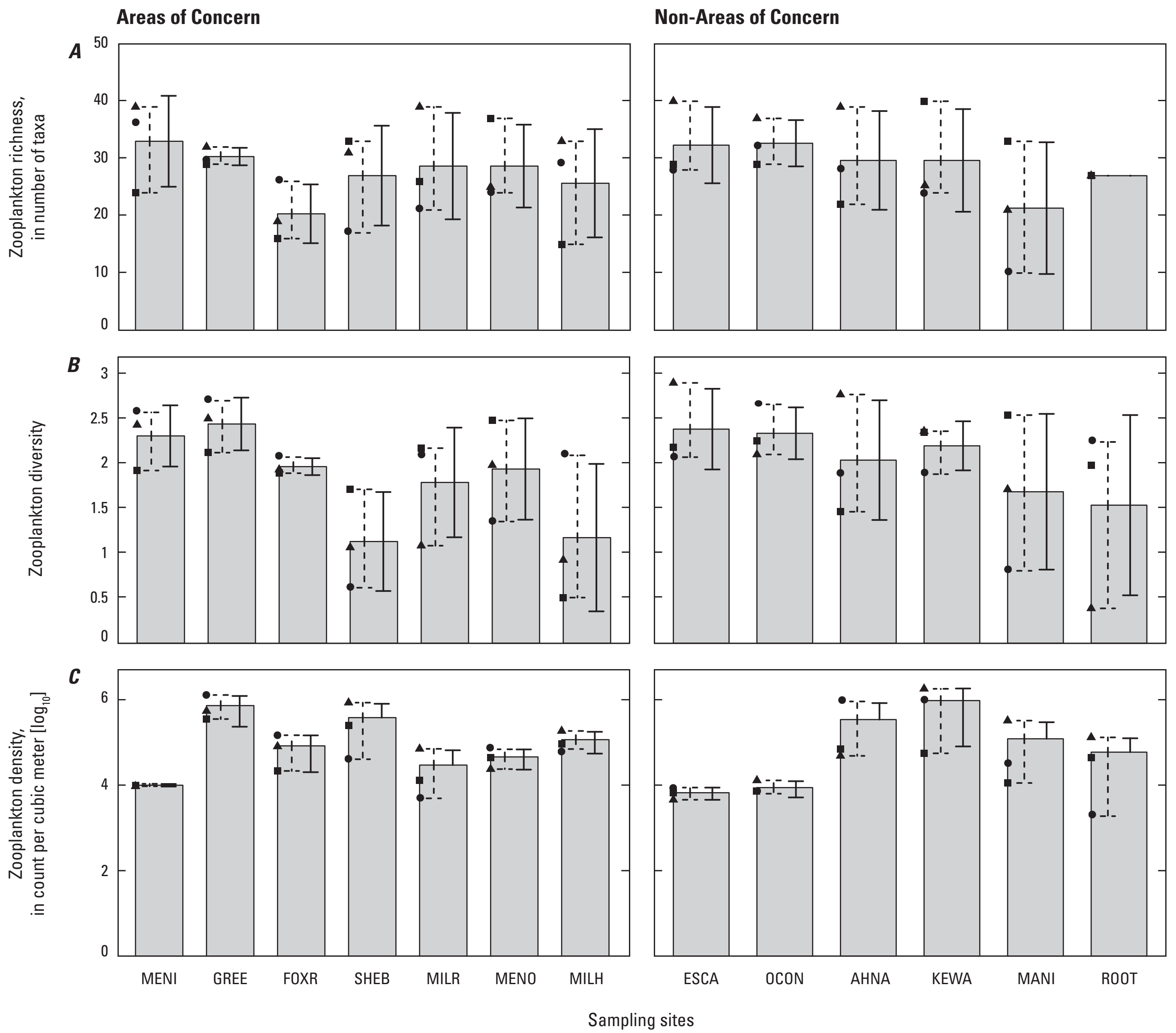
Metrics for combined phytoplankton at MENI did not differ from either the mean of all non-AOCs or the mean of the two non-AOC comparison sites (fig. 6, table 9). Richness was higher in 2014 than in 2012 (table 7), and this was because the diatom richness was higher in 2014 ($p<0.01$). Diversity and total density of combined phytoplankton did not differ between years even though diatom diversity was higher in 2014.

As was found in multivariate analyses for zooplankton, the assemblage of combined phytoplankton at MENI did not differ from ESCA and OCON, based on the results of the ANOSIM. The assemblage for MENI was more similar to OCON and both sites plotted close together in the MDS ordination plot (fig. 7*A*), whereas ESCA plotted distant from these two sites and all other sampled sites, underscoring the distinct assemblage at ESCA. When examined with seasons separate, samples in all seasons at OCON were similar to those at MENI, whereas those at ESCA differed from both sites (fig. 7*B*). SIMPER results indicated that MENI, ESCA, and OCON were 54 percent dissimilar, based mostly on the presence of *Microcystis aeruginosa*, *Thalassiosira pseudonana*, and *Klebsormidium*. The toxin-forming cyanobacterium *Microcystis aeruginosa* was not found at MENI but was found at ESCA and OCON in the summer and (or) the fall at low to moderate abundances. The centric diatom *T. pseudonana* was common at MENI in summer and otherwise was absent or at low abundance in other seasons; in all seasons, this diatom was absent at ESCA and at low abundance at OCON. This chain-forming diatom was thought to be a marine or brackish water species before being found in high densities in areas of the Great Lakes Basin beginning several decades ago (Lowe and Busch, 1975). Transport by ballast water from Europe to the Great Lakes is suspected for the occurrence of *T. pseudonana* in the region (Mills and others, 1993). In other parts of the world, this taxon is indicative of polluted waters where there are high nutrient concentrations and a resultant high chemical oxygen demand (Weckström and Juggins, 2006; U.S. Geological Survey, 2018). The filamentous green alga *Klebsormidium*, a cosmopolitan genus, was common in summer samples at MENI but absent from ESCA and OCON and from spring and fall samples at MENI. It is a cosmopolitan genus but identification to species has historically been difficult, and its presence in a wide variety of habitats seems to have hampered assignment of any pollution tolerance (Rindi and others, 2008).

For dominance of zooplankton, rotifers had the highest relative abundance during all seasons at MENI in 2014, ranging from 93 percent in the spring to 66 percent in the summer and back to 81 percent in the fall. Second in abundance in the summer were zebra mussel veligers; summer abundances of zebra mussel veligers ranged from 25 to 45 percent at MENI and ESCA, respectively, but comprised only 2.5 percent at OCON. For combined phytoplankton, cryptophytes were the dominant algal group in the spring and fall at MENI with more than a 42-percent abundance, and green algae were the dominant group in the summer with a 49-percent abundance. Diatoms were second in percent abundance in the spring and fall, and cryptophytes were second in percent abundance in the summer. Diatoms and cryptophytes have generally high food value for aquatic organisms (Stewart and Wetzel, 1986).

Lower Green Bay and Fox River Area of Concern

Metrics for zooplankton did not differ between FOXR and the mean of all non-AOCs in 2014. Only the density of zooplankton differed between FOXR and the mean of the two non-AOC comparison sites, AHNA and KEWA in 2014 (fig. 4, table 8); FOXR had lower density, which indicates that density was degraded at FOXR relative to the two non-AOC comparison sites. Notably, densities in fall 2014 were higher at KEWA than at FOXR (fig. 4), primarily because of high densities of *Bosmina longirostris* that were several times higher at KEWA than at FOXR (230,000 and 4,050 individuals per cubic meter [m^3], respectively). The total density of zooplankton at FOXR, with nauplii included, averaged 83,012±62,916 individuals/m^3 but actually may have been higher (fig. 4, table 7) because large amounts of cyanobacteria made concentrating



EXPLANATION

[MENI, Lower Menominee River; FOXR, Fox River near Allouez subsite; SHEB, Sheboygan River; MILR, Milwaukee River subsite; MENO, Menomonee River subsite; MILH, Milwaukee Harbor subsite; ESCA, Escanaba River; OCON, Oconto River; AHNA, Ahnapee River; KEWA, Kewaunee River; MANI, Manitowoc River; ROOT, Root River; FOXR is a Lower Green Bay and Fox River Area of Concern subsite. MILR, MENO, and MILH are Milwaukee Estuary Area of Concern subsites]

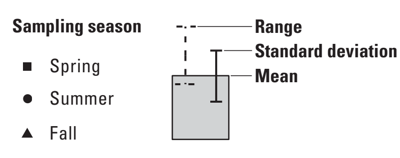


Figure 4. Metrics for zooplankton at 4 Lake Michigan Areas of Concern and 6 non-Area of Concern comparison sites. *A*, Zooplankton richness; *B*, zooplankton diversity; and *C*, zooplankton density.

Table 8. Probability values for significance in paired *t*-tests comparing metrics for zooplankton at Areas of Concern (AOCs) with the mean of all non-AOCs or the mean of the two non-AOC comparison sites.

[For zooplankton in 2012, high algal counts precluded identification of rotifers other than *Asplanchna priodonta* in summer samples for Ahnapee River and all Fox River samples; therefore, comparisons for these sites excluded other rotifers. Density comparisons are for log-10 transformed data. Values in bold italics indicate the AOC metrics were significantly lower than non-AOCs compared; the number of samples is 3 in all comparisons. MENI, Lower Menominee River; FOXR, Fox River near Allouez (Lower Green Bay and Fox River subsite); SHEB, Sheboygan River; MILR, Milwaukee River; MENO, Menomonee River (MILR and MENO are Milwaukee Estuary subsites)]

Metric	2012		2014	
	AOC: non-AOC group	AOC: non-AOC pair	AOC: non-AOC group	AOC: non-AOC pair
		MENI site		
Richness	0.249	0.225	0.503	0.889
Diversity	0.366	0.854	0.391	0.733
Density	0.092	0.131	0.072	0.107
		FOXR subsite		
Richness	0.508	0.362	0.223	0.186
Diversity	0.354	0.924	0.620	0.594
Density	0.341	0.818	0.112	***0.046***
		SHEB site		
Richness	0.964	0.900	0.635	0.703
Diversity	0.460	0.432	0.074	***0.0099***
Density	0.477	0.428	0.861	0.863
		MILR subsite		
Richness	0.984	0.974	0.981	0.504
Diversity	0.144	0.178	0.570	0.488
Density	***0.010***	0.159	0.148	***0.016***
		MENO subsite		
Richness	0.585	0.721	0.982	0.130
Diversity	0.055	0.105	0.759	0.417
Density	0.123	0.532	0.275	0.929

the sample difficult for the laboratory. In 2012, cyanobacterial cells impeded the identification and counting of rotifers when the only rotifer quantified was the large-sized *Asplanchna priodonta*. For this reason, comparisons with non-AOCs and between years at FOXR excluded rotifers except *A. priodonta*. The total density of zooplankton was higher in 2012 than in 2014 at FOXR if nauplii were excluded (p<0.01) but not if nauplii were included; richness and diversity did not differ between 2012 and 2014 at FOXR. Metrics for combined phytoplankton did not differ between FOXR and either the mean of all non-AOCs or the mean of the two non-AOC comparison sites (fig. 6, table 9). Although richness for combined phytoplankton at FOXR in 2014 did not differ from non-AOCs, richness in 2012 was higher than the mean of all non-AOCs. Lastly, metrics for combined phytoplankton did not differ between 2012 and 2014 at FOXR.

For multivariate analyses of zooplankton, the FOXR assemblage in 2014 plotted most closely to AHNA and KEWA but separately from other sites in the MDS ordination plot with seasons combined (fig. 5*A*). Based on the ANOSIM, FOXR did not differ from its two non-AOC comparison sites (AHNA and KEWA), as shown by the MDS ordination plot with seasons separate (fig. 5*B*). This result may have been because of high seasonal variability at all three sites. Still, a SIMPER test indicated that assemblages of zooplankton at FOXR, AHNA, and KEWA were 59 percent dissimilar, primarily because of differences in the abundances of rotifers *Brachionus calyciflorus*, *Keratella crassa*, and *Conochilus unicornis*. *Brachionus calyciflorus* was more abundant at AHNA and KEWA, was detected at less than a 1-percent abundance in the spring and was otherwise absent. *Keratella crassa* was more abundant at FOXR in all seasons, especially in the spring with a 36-percent relative abundance; *C. unicornis* was also more abundant in the spring and summer at FOXR but was absent from AHNA and was in low abundance in the spring only at KEWA. Rotifers in the genus *Brachionus* as well as *K. crassa*

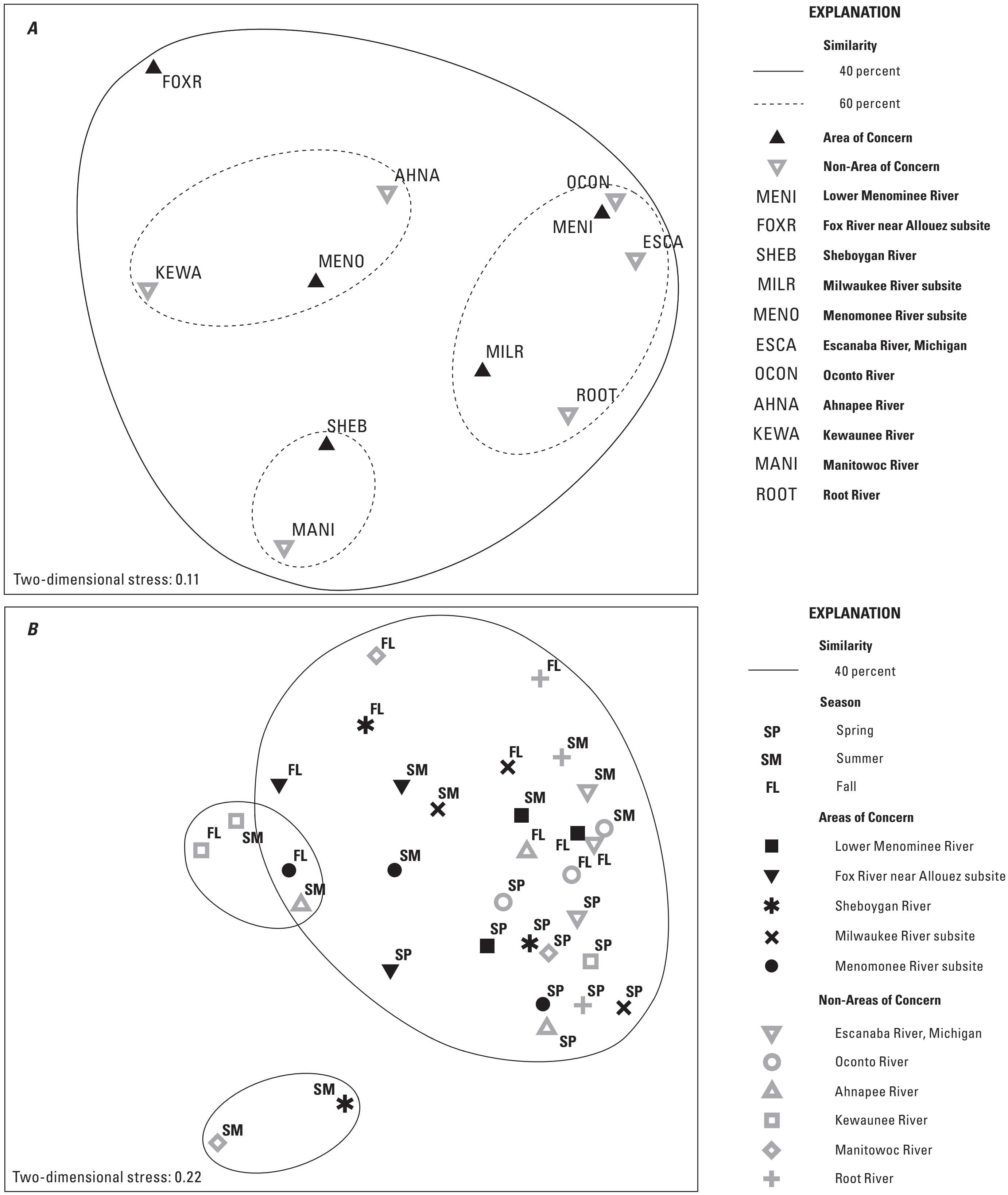
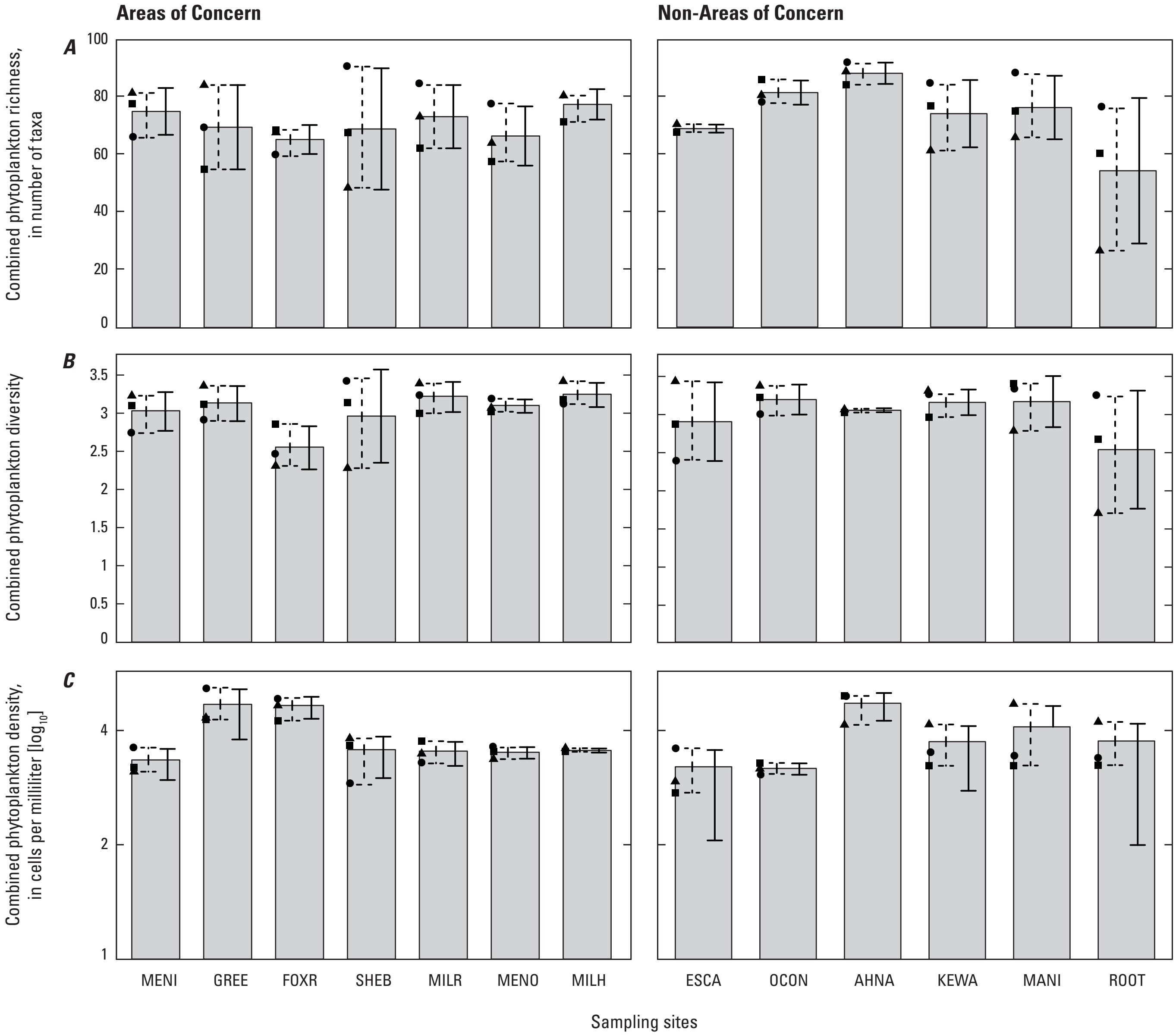


Figure 5. Multidimensional scaling ordination plots for zooplankton at 4 Lake Michigan Areas of Concern and 6 non-Area of Concern comparison sites, based on relative abundance (fourth-root transformed) with no rare or ambiguous taxa. *A*, Seasons combined; and *B*, seasons separate. [The Fox River near Allouez is a subsite of the Green Bay and Fox River Area of Concern. The Milwaukee River and Menomonee River are subsites of the Milwaukee Estuary Area of Concern]



EXPLANATION

[MENI, Lower Menominee River; FOXR, Fox River near Allouez subsite; SHEB, Sheboygan River; MILR, Milwaukee River subsite; MENO, Menomonee River subsite; MILH, Milwaukee Harbor subsite; ESCA, Escanaba River; OCON, Oconto River; AHNA, Ahnapee River; KEWA, Kewaunee River; MANI, Manitowoc River; ROOT, Root River; FOXR is a Lower Green Bay and Fox River Area of Concern subsite. MILR, MENO, and MILH are Milwaukee Estuary Area of Concern subsites]

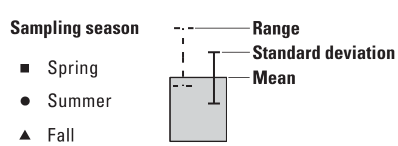


Figure 6. Metrics for combined (soft algae and diatoms) at 4 Lake Michigan Areas of Concern and 6 non-Area of Concern comparison sites. *A*, Combined phytoplankton richness; *B*, combined phytoplankton diversity; and *C*, combined phytoplankton density.

Table 9. Probability values for significance in paired *t*-tests comparing metrics for combined phytoplankton (soft algae and diatoms combined) at each Area of Concern (AOC) with the mean of all non-AOCs or the mean of the two non-AOC comparison sites.

[Values in bold italics indicate the AOC metrics were significantly lower than non-AOCs compared and, therefore, there were no such outcomes; the number of samples is 3 in all comparisons. Density comparisons are for log-10 transformed data. MENI, Lower Menominee River; FOXR, Fox River near Allouez (Lower Green Bay and Fox River subsite); SHEB, Sheboygan River; MILR, Milwaukee River; MENO, Menomonee River (MILR and MENO are Milwaukee Estuary subsites)]

Metric	2012		2014	
	AOC: non-AOC group	AOC: non-AOC pair	AOC: non-AOC group	AOC: non-AOC pair
MENI site				
Richness	0.285	0.782	0.909	0.972
Diversity	0.664	0.608	0.827	0.968
Density	0.033	0.687	0.075	0.090
FOXR subsite				
Richness	0.027	0.110	0.339	0.131
Diversity	0.555	0.401	0.093	0.134
Density	0.346	0.988	0.059	0.430
SHEB site				
Richness	0.225	0.082	0.591	0.391
Diversity	0.849	0.238	0.940	0.565
Density	0.337	0.422	0.204	0.535
MILR subsite				
Richness	0.188	0.407	0.981	0.469[1]
Diversity	0.223	0.047	0.241	0.434[1]
Density	0.336	0.071	0.104	0.441
MENO subsite				
Richness	0.678	0.908	0.265[2]	0.989[2]
Diversity	0.065	0.278	0.163[1]	0.498[1]
Density	0.091	0.390	0.067	0.733

[1]Double-squared-transformed data (X^4).

[2]Squared-transformed data (X^2).

were categorized as indicators of highly eutrophic conditions by Gannon and Stemberger (1978). *Keratella* may be the most common genus of freshwater limnetic rotifer and at least three species often cooccur in the Great Lakes (Stemberger, 1979). *Conochilus unicornis* prefers cooler water temperatures, and it can be found in moderately eutrophic to oligotrophic conditions (Gannon and Stemberger, 1978).

As was seen with the zooplankton, combined phytoplankton at FOXR plotted nearest to AHNA and KEWA but away from all other sites in the MDS ordination plot (fig. 7*A*). Examining seasons separately, the summer and fall samples for FOXR plotted away from AHNA and KEWA samples with the exception of the fall KEWA sample (fig. 7*B*). The ANOSIM indicated that only the assemblage at FOXR, out of all four AOCs, differed from its non-AOC comparison sites, AHNA and KEWA (p=0.012). The SIMPER test indicated that FOXR was 61 percent dissimilar, primarily because of the presence of the cyanobacterium *Microcystis aeruginosa*, the green alga *Scenedesmus* sp., and the diatom *Staurosira construens*, and these three taxa contributed to most of the dissimilarity between the subsite and its non-AOCs. *Microcystis aeruginosa* was detected at FOXR but not at AHNA or KEWA. *Scenedesmus* was present in a much lower abundance at FOXR and KEWA than at AHNA, where it was relatively abundant in all seasons. The genus *Scenedesmus* is common worldwide and some species are tolerant of waters with high inorganic nitrogen (Wehr and Sheath, 2003; Porter, 2008). *Staurosira construens*, although found in low abundance at AHNA and KEWA, was absent from FOXR. This diatom is sensitive to eutrophic conditions (Porter, 2008), which explains its absence from FOXR where conditions range from eutrophic to hypereutrophic.

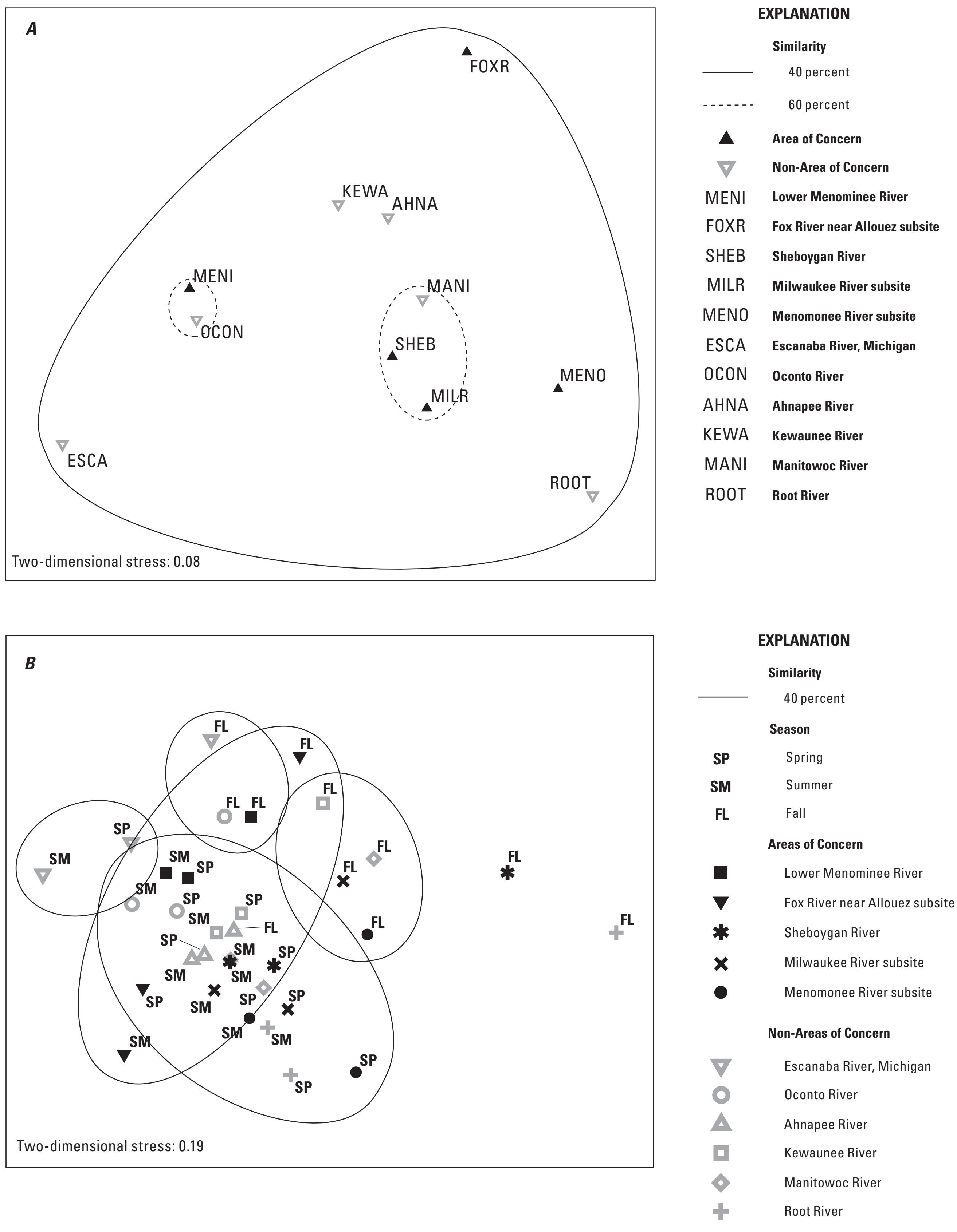


Figure 7. Multidimensional scaling ordination plots for combined phytoplankton (soft algae and diatoms) at 4 Lake Michigan Areas of Concern and 6 non-Area of Concern comparison sites, based on relative abundance (fourth-root transformed) with no rare or ambiguous taxa. *A*, Seasons combined; and *B*, seasons separate. [The Fox River near Allouez is a subsite of the Green Bay and Fox River Area of Concern. The Milwaukee River and Menomonee River are subsites of the Milwaukee Estuary Area of Concern]

Rotifers were the dominant taxonomic group in the zooplankton at FOXR in 2014 (81- to 87-percent relative abundance). Second in abundance were microcrustaceans: copepods (16 percent), zebra mussels (12 percent), and cladocerans (8 percent) in the spring, summer, and fall, respectively. Cyanobacteria were the dominant group of phytoplankton at FOXR in all seasons in 2014, with more than 70 percent of the relative abundance. In eutrophic conditions, cyanobacteria tend to dominate. Spring cyanobacteria were mostly the toxin producers *Anabaena* and *Microcystis aeruginosa* (36 and 27 percent, respectively). *Anabaena* is a filamentous alga and the genus is found worldwide (Wehr and Sheath, 2003). *Microcystis aeruginosa* was the dominant cyanobacterium in summer and fall 2014 with more than 80 percent of the total algal abundance. It is a coccoid and colonial organism, and it is an indicator of eutrophic conditions (Porter, 2008). Diatoms were second in abundance to cyanobacteria, and the highest diatom abundances were in the spring at 21 percent, after which abundances were 13 percent in the summer and fall samples.

Sheboygan River Area of Concern

Metrics for zooplankton did not differ between SHEB and the mean of all non-AOCs in 2014 (fig. 4, table 8). Only diversity differed between SHEB and its two non-AOC comparison sites (KEWA and MANI at $p<0.01$) in 2014, so SHEB was rated as degraded for diversity (fig. 4, table 8). Diversity did not differ in 2012. In addition, diversity in 2014 did not differ between primary and replicate samples from the Sheboygan River AOC (Scudder Eikenberry and others, 2016a) and it averaged relatively low at 1.1±0.6 (table 7). No metrics for combined phytoplankton differed between the mean of all non-AOCs or the mean of the two non-AOC comparison sites in 2014 (fig. 6, table 9). There was no difference between 2012 and 2014 at SHEB for metrics with either zooplankton or combined phytoplankton.

For multivariate analyses with 2014 zooplankton abundances, an ANOSIM indicated the assemblage at SHEB did not differ from KEWA and MANI. In the MDS ordination plot, spring samples for SHEB, KEWA, and MANI showed their similarity by plotting close to each other; however, differences in the communities were in the summer and fall samples at KEWA, which plotted away from SHEB and MANI (fig. 5*A* and *B*). The assemblages of zooplankton at KEWA and MANI averaged a 65-percent dissimilarity to each other, and the zooplankton at SHEB was 61 percent dissimilar to the two non-AOC comparison sites. The dissimilarity between SHEB and its two non-AOC comparison sites was mostly because of the rotifer *Synchaeta*, followed by zebra mussel veligers and the rotifer *Euchlanis dilatata*. *Synchaeta* was minor in abundance in the spring at MANI and gradually diminished, it was abundant in the spring only at KEWA, and it was higher in abundance in the summer at SHEB than at the other two sites. Zebra mussel veligers were present only in the fall at SHEB and MANI, were absent at KEWA, and were nearly twice as abundant at SHEB. *Euchlanis dilatata*, a rotifer present only in spring, was more than twice as abundant at SHEB when compared to the two non-AOC comparison sites. *Synchaeta* is common in the Great Lakes and is tolerant to pollution; most species have a higher abundance in the fall through the spring when temperatures are cooler (Gannon and Stemberger, 1978; Stemberger, 1979).

An ANOSIM with combined phytoplankton found that the assemblage at SHEB did not differ from the two non-AOC comparison sites, KEWA and MANI. In the MDS ordination plot with seasons combined, the assemblage at SHEB was only 40 percent or less dissimilar to MANI but it was more dissimilar to KEWA (fig. 7*A*). In the MDS ordination plot with seasons separate, it was the fall SHEB sample that was distinct, and the spring and summer samples for SHEB and its two non-AOC comparison sites were similar (fig. 7*B*). SIMPER results indicated a 58-percent dissimilarity between SHEB and the two non-AOC comparison sites, mostly because of differences in the abundances of two taxa in the fall samples. The diatom *Aulacoseira muzzanensis* accounted for 38 percent of density in the fall for combined phytoplankton at SHEB. Otherwise, this taxon was absent or in low abundance at SHEB, similar to the taxon's distribution at KEWA and MANI. This centric diatom is an indicator of high total phosphorus (Porter, 2008). The green alga *Klebsormidium* was absent from SHEB in all seasons but found at a 34-percent relative density at MANI in the fall.

Rotifers dominated abundance in the spring and summer 2014 samples of zooplankton in the Sheboygan River AOC (96 and 94 percent, respectively). Zebra mussel veligers dominated abundance in the fall 2014 samples (73 percent). Diatoms were the dominant taxonomic group of phytoplankton at SHEB in 2014 (42, 59, and 62 percent, respectively). Second in dominance in all seasons was green algae, with abundance highest in the spring at 38 percent, nearly as high as that for the diatoms. *Scenedesmus* was the green algal taxon with the highest abundance; it is common worldwide and some species are tolerant of high inorganic nitrogen (Wehr and Sheath, 2003; Porter, 2008).

Milwaukee Estuary Area of Concern

Comparisons with non-AOCs were made for the Milwaukee Estuary AOC with respect to only MILR and MENO and not MILH. The assemblages of plankton at MILH are discussed later in a separate section. The two non-AOC comparison sites for MILR and MENO were MANI and ROOT.

For zooplankton at MILR and MENO in 2014, no metrics differed between MILR and the mean of all non-AOCs (table 8). Only the density of zooplankton differed between MILR and the two non-AOC comparison sites; total density in 2014 was lower at MILR, so MILR was rated as degraded for density of zooplankton (fig. 4, table 8). Mean values for richness and diversity of zooplankton in 2014 were similar between MILR and MENO, with a mean richness of 28.7 at both and a slightly higher diversity at MENO. Metrics did not differ between MENO and the mean of all non-AOCs or the mean of the two non-AOC comparison sites in 2014. For combined phytoplankton, no difference was found between richness, diversity, or total density for MILR or MENO in 2014 (fig. 6, table 9) when compared to non-AOCs. Values for mean richness were 80.0±12.0 at MILR compared to 72.7±11.2 at MENO, and average diversity was the same at both (table 7). There were no differences between 2012 and 2014 metrics for combined phytoplankton at MILR or MENO.

In ordinations of zooplankton at MILR and MENO for 2014, the ANOSIM indicated no differences from MANI and ROOT. In the MDS ordination plot with seasons combined, MILR and ROOT plotted near each other but MENO and MANI plotted distant and less similar (fig. 5*A*). In the MDS ordination plot with seasons separate, spring samples for MILR and MENO were similar to each other and plotted near MANI and ROOT spring samples, with ROOT closer to MILR and MENO (fig. 5*B*). MILR and ROOT also plotted near each other in the summer and fall but MANI plotted away, especially in the summer. ROOT is closer to MILR and MENO in latitude, compared to MANI, which is much farther north, and differences in water temperatures could be a contributing factor. Overall in 2014, water temperatures at MILR were higher than at MANI at 22.3±0.3 degrees Celsius (ºC) for MILR compared to 21.3±1.0 ºC for MANI; water temperatures at MENO were higher than at MANI and ROOT (p<0.01) with 24.1±1.8 ºC for MENO compared to 21.3±1.0 ºC for MANI and 20.6±2.6 ºC for ROOT (table 2). A SIMPER test indicated that a 57-percent difference between assemblages at MILR and the two non-AOC comparison sites was mostly because of zebra mussel veligers and the rotifers *Euchlanis dilatata* and *Proales*. The spring-only rotifer, *E. dilatata*, was in higher abundance at MANI and ROOT, and nearly twice as high at ROOT than at MANI. Oddly, though zebra mussel veligers were abundant in fall 2014 at MILR, MANI, and ROOT, they were absent from all 2014 samples at MENO. Though zebra mussel veligers and *E. dilatata* also were among the top three taxa contributing to the 60-percent dissimilarity between MENO and the two non-AOC comparison sites, *Conochilus unicornis* was the primary taxon contributing to the dissimilarity for MENO. Although *C. unicornis* was detected in low abundance at the non-AOCs, it comprised more than two-thirds of the relative abundance in summer at MENO. *C. unicornis* prefers cooler water temperatures, and it can be found in moderately eutrophic to oligotrophic conditions (Gannon and Stemberger, 1978).

The ANOSIM with combined phytoplankton also indicated no differences between MILR or MENO and the two non-AOC comparison sites for 2014. In the MDS ordination plot with seasons combined, MILR and MANI plotted near each other with at least a 60-percent similarity overall between their assemblages (fig. 7*A*). MENO and ROOT plotted distant from MILR and MANI but near each other. With seasons separate, fall samples were distinct and the fall sample for ROOT was most different, plotting distant from all other samples (fig. 7*B*). Spring and summer samples for all four sites were more similar despite the spring samples for MENO and ROOT segregating slightly. MILR and MENO were 58 and 60 percent dissimilar, respectively, from the two non-AOC comparison sites. For MILR, the diatom *Cyclostephanos invisitatus* comprised nearly 10 percent of the relative abundance, but this taxon was only 2 percent or less at the two non-AOC comparison sites. This centric diatom is an indicator of eutrophic conditions resulting from high nitrogen and high phosphorus (Porter, 2008). In the fall, the cyanobacterium *Merismopedia* was present at ROOT at a relative abundance nearly six times higher than MILR or MANI. This genus is also an indicator of eutrophic conditions (Porter, 2008). The third taxon contributing most to the dissimilarity between MILR and its two non-AOC comparison sites was the diatom *Thalassiosira pseudonana*, which was detected at a 7-percent relative abundance in the spring at MILR. For MENO, the diatoms *Nitzschia inconspicua*, *T. pseudonana*, and *Thalassiosira weissflogii* contributed most to its dissimilarity with the two non-AOC comparison sites. *Nitzschia inconspicua* was at a higher, but still low, abundance at MENO compared to the two non-AOC comparison sites. *Thalassiosira weissflogii* comprised 43 percent of the relative abundance in the fall at ROOT but was absent or in low abundance at the other sites. All three diatom taxa are indicators of hypereutrophic conditions (high total nitrogen and phosphorus) and moderately high salinity (500–1,000 milligrams per liter chloride; Porter, 2008).

With respect to the dominance of various taxa at MILR and MENO in 2014, rotifers were dominant at both sites in the spring and summer with more than a 52-percent abundance at MILR and more than a 73-percent abundance at MENO; zebra mussel veligers comprised more than 78 percent of the density in fall zooplankton at MILR but were absent from MENO. Instead, copepods were the dominant taxonomic group in the fall at MENO (41 percent), with rotifers second. Diatoms were the dominant taxonomic group in the phytoplankton during all seasons at MILR in 2014 (41, 60, and 59 percent, respectively). Diatoms were the dominant taxonomic group at MENO in spring and fall 2014 (57 and 32 percent), but cryptophytes were the dominant group in summer 2014 (32 percent). Both have generally high food value for aquatic organisms (Stewart and Wetzel, 1986).

Out of all four AOCs assessed for plankton, only the assemblages for zooplankton at the Fox River near Allouez (a subsite in the Lower Green Bay AOC) and the Milwaukee River differed from the two non-AOC comparison sites; density of zooplankton was lower at both AOCs. Metrics for combined benthos and combined phytoplankton (diatoms and soft algae) at the Sheboygan River AOC did not differ from the two non-AOC comparison sites; however, the diversity of zooplankton in 2014 was lower at the Sheboygan River AOC than at the two non-AOC comparison sites (table 10).

Table 10. Summary of metric comparisons for benthos and plankton collected by the U.S. Geological Survey at Areas of Concern (AOCs) and non-AOC comparison sites in 2014, indicating where AOC metrics were significantly lower than non-AOC metrics.

[Metrics for benthos are for combined (dredge and Hester-Dendy) data except for the index of biotic integrity (IBI), which was computed for Hester-Dendy samples only. Metrics for phytoplankton are for combined (soft algae and diatom) data; the number of samples is 3 in all comparisons. Density comparisons are for log-10 transformed data. MENI, Lower Menominee River; EPT, Ephemeroptera-Plecoptera-Trichoptera; FOXR, Fox River near Allouez (Lower Green Bay and Fox River subsite); SHEB, Sheboygan River; MILR, Milwaukee River; MENO, Menomonee River (MILR and MENO are Milwaukee Estuary subsites)]

Metric	2012		2014	
	AOC: non-AOC group	AOC: non-AOC pair	AOC: non-AOC group	AOC: non-AOC pair
Benthos				
Richness	None	None	None	None
Diversity	MENO	None	MENO	None
Total density	MENI	None	MENI	None
EPT density	None	MENI	MENI	MENI
EPT percent	None	FOXR	None	None
EPT richness	FOXR, SHEB, MILR, MENO	MILR	SHEB, MENO	MENI
IBI	SHEB, MENO	None	None	None
Zooplankton[1]				
Richness	None	None	None	None
Diversity	None	None	None	SHEB
Total density	MILR	None	None	FOXR, MILR
Combined phytoplankton				
Richness	None	None	None	None
Diversity	None	None	None	None
Total density	None	None	None	None

[1]For zooplankton in 2012, high algal counts precluded identification of rotifers other than *Asplanchna priodonta* in summer samples for Ahnapee River and all Fox River samples; therefore, the comparisons for these sites excluded other rotifers.

Overview of Benthos and Plankton in Lower Green Bay and Milwaukee Harbor

Although subsites in lower Green Bay (GREE, Green Bay Historical Subsite 3–1 [hereafter referred to as “GB03”], Green Bay Historical Subsite 5 [hereafter referred to as “GB05”], Green Bay Historical Subsite 8 [hereafter referred to as “GB08”], Green Bay Historical Subsite 16 [hereafter referred to as “GB16”], and Green Bay Historical Subsite 17 [hereafter referred to as “GB17”]) and the Milwaukee Harbor (MILH) were not included in direct comparisons with non-AOC comparison sites, results of this study provide an ecological assessment of the benthos and plankton that can be used for BUI evaluations and comparison to historical studies at the AOCs.

Lower Green Bay

Within the Lower Green Bay and Fox River AOC, samples for benthos (dredge only) and plankton were collected from Green Bay at one subsite (GREE) near Long Tail Point in all three seasons in 2012 and 2014. In 2014 only, dredge samples for benthos were collected at an additional five subsites in Green Bay in all three seasons. Assemblages of benthos and plankton were compared among the other subsites sampled in the AOC. On average, GB03 had the highest richness and diversity and GB17 had the lowest of these two measures among the Lower Green Bay sites (table 11). The FOXR subsite had mean richness and diversity values that were near the median values when compared to all Green Bay subsites. An MDS ordination plot indicated that the benthic assemblages collected from GB17 during all three seasons grouped further away from the rest of the samples collected in Green Bay and the Fox River (fig. 8*A* and *B*). GB17 was east of the dredging channel on a shoal west of Point Au Sable, and its substrate material was dominated by sand. Although most samples at Green Bay subsites were dominated by oligochaetes, GB17 was dominated by midges in the spring and summer (more than 61 percent) and by zebra mussels in the fall (58 percent). GB05 was also dominated by zebra mussels in the fall, and GB03 was dominated by *Pisidium* pea clams in the fall. The ANOSIM indicated that there were differences between the benthic assemblages collected at GB17 in comparison to all

Table 11. Richness, diversity, and density values for benthos collected by dredge at Green Bay subsites in 2014.

[Benthic samples were not collected in 2012 and only dredge samples were collected in 2014. GREE, Lower Green Bay subsite; GB03, Green Bay Historical Subsite 3–1; GB05, Green Bay Historical Subsite 5; GB08, Green Bay Historical Subsite 8; GB16, Green Bay Historical Subsite 16; GB17, Green Bay Historical Subsite 17]

Season	Richness[1]	Diversity[2]	Density[3]
GREE subsite			
Spring	21	1.22	15,740
Summer	15	1.72	14,082
Fall	22	1.81	10,115
GB03 subsite			
Spring	23	2.23	9,165
Summer	26	2.18	10,510
Fall	26	1.92	8,546
GB05 subsite			
Spring	24	2.23	7,653
Summer	18	2.07	13,316
Fall	17	1.77	12,105
GB08 subsite			
Spring	9	1.30	8,903
Summer	11	0.96	12,015
Fall	11	0.94	9,388
GB16 subsite			
Spring	14	1.52	8,852
Summer	12	1.61	5,370
Fall	13	1.08	7,003
GB17 subsite			
Spring	7	0.30	5,772
Summer	7	1.36	1,594
Fall	9	1.48	427

[1]Richness was computed as the number of unique taxa in the sample.

[2]Shannon diversity index, calculated as $\log_e$.

[3]Density values are in count per square meter.

other Green Bay and Fox River sites. Mean dissimilarity between assemblages in GB17 and the other Green Bay and Fox River sites ranged from 76 percent (GB03) to 88 percent (GB08) according to a SIMPER test. Midge species of the genus *Cladotanytarsus* accounted for the most dissimilarity among all sites, explaining 5.9 to 11 percent of total dissimilarity. Relative abundances of zebra mussels explained 5.2 to 8.4 percent of dissimilarities between assemblages in GB17 and all other sites. Dissimilarities in these assemblages were also commonly due to differences in the abundances of several midge taxa (*Procladius* and *Chironomus*) and oligochaete taxa (immature Tubificinae, *Aulodrilus limnobius*, and *Limnodrilus hoffmeisteri*). *Aulodrilus limnobius* is an indicator of moderately eutrophic conditions and it is tolerant of moderate levels of pollution. *Limnodrilus hoffmeisteri* has a worldwide distribution; it can be locally abundant and dominant because of its adaptable nature and high tolerance to pollution, salinity, and highly eutrophic or "hypereutrophic" conditions (Bode and others, 2002; Rodriguez and Reynoldson, 2011). Based on ANOSIM and SIMPER results, the remaining 5 Green Bay sites can be placed into 2 general groupings: GB03, GB05, and GREE had similar assemblages, and GB08 and GB16 had similar assemblages (fig. 8*A* and *B*). The benthic assemblage in the Fox River was most similar to GREE and GB05 and moderately similar to GB03. The benthic assemblage at FOXR was most different from GB16 and GB17. Differences between FOXR and GB16 were mainly due the oligochaetes *Branchiura sowerbyi* and *Aulodrilus pigueti* and the midge species of the genus *Cryptochironomus*. All three taxa are highly tolerant of pollution (Barbour and others, 1999; Bode and others, 2002; Rodriguez and Reynoldson, 2011). Differences between FOXR and GB17 were mainly due to *Cladotanytarsus*, zebra mussels, and immature Tubificinae. *Cladotanytarsus* is moderately pollution tolerant and immature Tubificinae are considered to be highly tolerant (Barbour and others, 1999). Samples for benthos were not collected in Green Bay in 2012, so comparisons could not be made between years.

At the only Green Bay site where planktonic assemblages were sampled (GREE), neither the richness nor the diversity of zooplankton differed between 2012 and 2014 but the total density was higher in 2014. In 2014, the dominant group was rotifers (52 to 78 percent) with copepods second in dominance overall. The rotifer *Synchaeta* was dominant in spring 2014 (36 percent), followed by the rotifer *Polyarthra vulgaris* in summer 2014 (17 percent), and copepod nauplii in fall 2014 (23 percent). The rotifer *Keratella crassa* was second in dominance in spring and fall 2014.

The richness, diversity, and total density of combined phytoplankton at GREE did not differ between 2012 and 2014, but the total density was quite variable between seasons each year. In 2014, the dominant group was cyanobacteria (50 to 86 percent) with the highest abundance in the summer. Diatoms were second in abundance (8 to 22 percent) in all seasons. The cyanobacterium *Planktolyngbya* was dominant in spring and fall 2014 (35 and 28 percent, respectively), and *Aphanocapsa* was dominant in summer 2014 (62 percent). Second in dominance in summer and fall 2014 was the toxin producer *Microcystis aeruginosa* (21 to 24 percent), and the toxin producer Anabaena made up 6 percent of the total algal density in spring 2014. Also, in fall 2014, two other toxin-producing algae were present at GREE at a 3-percent relative abundance for *Aphanizomenon issatschenkoi* and *Planktothrix*. These results underscore the highly eutrophic character of Green Bay with the added concern of potentially toxic algal blooms. Much higher concentrations of *Anabaena* and *Microcystis aeruginosa* during all seasons in 2014 at FOXR implicate the Fox River as a potential source of these cyanobacteria to Green Bay. As an additional indicator of nutrients in the

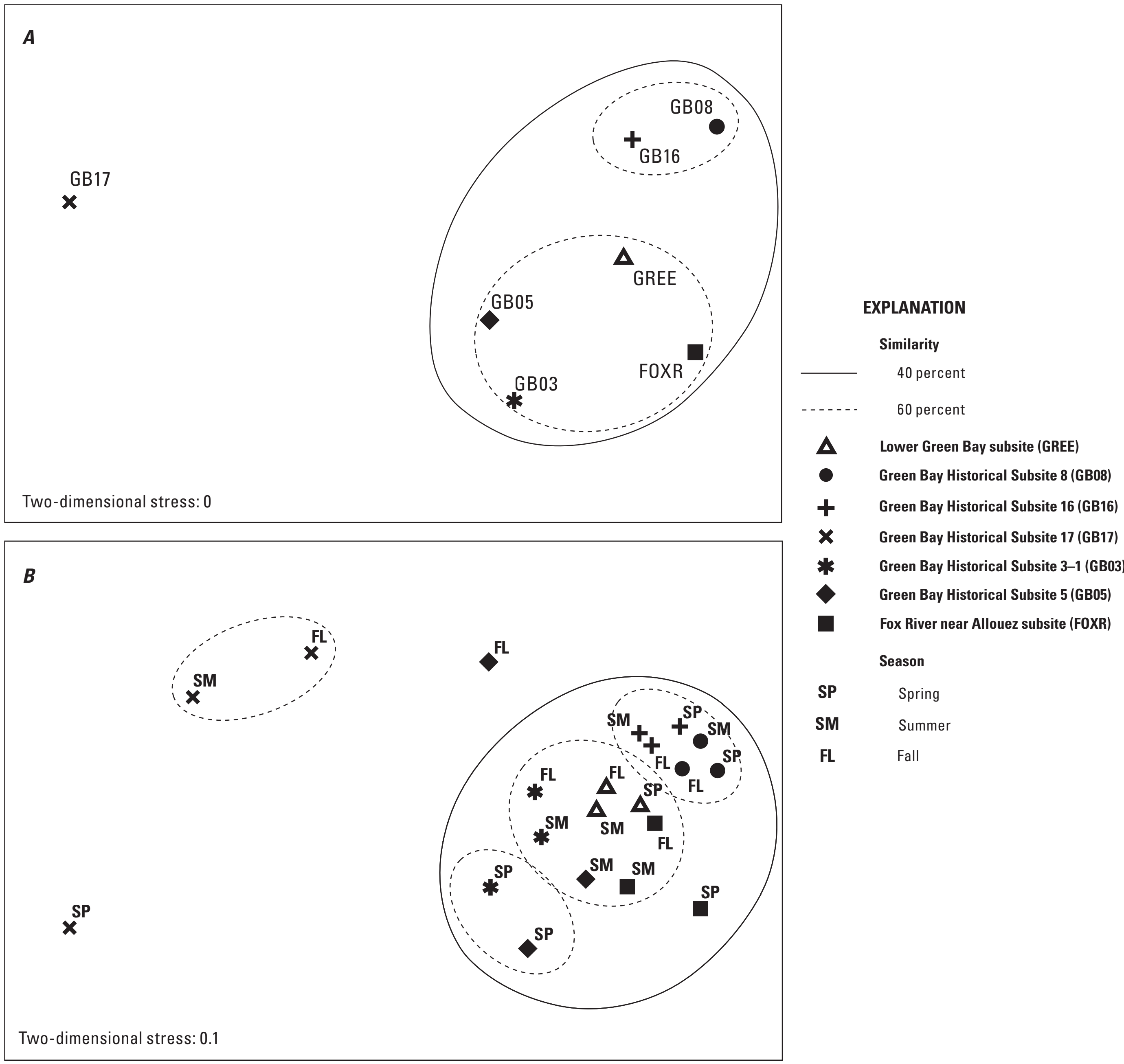


Figure 8. Multidimensional scaling ordination plots for the benthos collected by dredge at the Green Bay and Lower Fox River Area of Concern, based on relative abundance (fourth-root transformed) with no rare or ambiguous taxa. *A*, Seasons combined; and *B*, seasons separate.

Fox River and Green Bay, the mean chlorophyll-*a* concentration was 56 µg/L in Green Bay, compared to 150 µg/L in the fall at the Fox River subsite FOXR. Excess nutrients from the watershed have been a decades-long concern for the AOC and the watershed.

Milwaukee Harbor

Benthos and plankton in Milwaukee Harbor were sampled at one site near the mouth by the USGS streamgage Milwaukee River at Mouth at Milwaukee, Wis., on Jones Island (USGS station 04087170). For benthos, the total richness, diversity, and density of combined benthos, as well as the IBI, did not differ between 2012 and 2014 (table 5). The mean IBI across years was 22.5±7.6 and this score is in the "poor" category. For dominance in combined benthos, oligochaetes had the highest percentages of relative abundance (87, 97, and 69 percent in the spring, summer, and fall, respectively), which were mostly due to immature Tubificinae. Zebra mussels were 29 percent of the abundance in the fall. Midges comprised less than 10 percent of the total abundance. The most common midges at MILH in 2012 and 2014 were *Dicrotendipes*, *Paratendipes*, and *Cricotopus/Orthocladius*, genera that are moderately to highly tolerant of pollution (Barbour and others, 1999). Silt was dominant in sediment at MILH, which varied by season and year somewhat, but overall, the substrate was a mix of sand and silt with a moderate amount of clay (42, 38, and 20 percent, respectively). The organic carbon content, as estimated by VOI samples was 12 percent, which is moderate relative to other sampled sites.

For zooplankton, there were no differences between 2012 and 2014 for richness, diversity, or density at MILH. For 2014 only, although rotifers dominated the assemblage in the spring and summer (76 and 98 percent), zebra mussel veligers dominated in the fall (78 percent), which followed a similar pattern to MILR that year. The most abundant rotifer at MILH in spring 2014 was *Synchaeta* (90 percent) followed by other rotifers, and less than 1 percent consisted of nonrotifer taxa. The rotifer *Keratella crassa* was dominant in summer 2014 (35 percent) with *Synchaeta* second (20 percent). *Synchaeta* was also dominant in spring 2012 at the site but zebra mussel veligers were nearly as abundant, and this relation was opposite in the summer with zebra mussel veligers being the most abundant. *Keratella crassa* was dominant in fall 2012 and zebra mussel veligers comprised nearly a quarter of the overall abundance. *Synchaeta* is a pollution-tolerant rotifer that is common in the Great Lakes and has higher abundances in the fall through the spring when water temperatures are cooler; *Keratella* is a common rotifer and several species can cooccur in the Great Lakes (Gannon and Stemberger, 1978; Stemberger, 1979).

The richness of combined phytoplankton at MILH was higher in 2014 than in 2012 because of higher diatom richness in 2014; however, laboratory processing problems with the 2012 diatom samples from MILH may have contributed to this difference. Also, specific conductance at MILH was higher in 2014 than in 2012, possibly reflecting the effects of the drought in 2012. The richness of diatoms at MILH was low in 2012, with an average of 12.7±8.7 (compared to an average richness of 77.3±4.7 in 2014). In contrast, the richness of soft algae was not different between years. The diversity and density of combined phytoplankton were not different between years. In 2014, diatoms were dominant in the spring (42 percent). Green algae became dominant in the summer (44 percent), followed by diatoms and then cryptophytes. Diatoms became dominant again in the fall (39 percent), followed by green algae. Although absent in spring and summer 2014, cyanobacteria became common in the fall. *Diatoma tenuis* was the most common diatom in the spring, and it is commonly associated with moderately eutrophic conditions (Porter, 2008). *Cyclostephanos invisitatus* was the most common diatom in the fall, and this centric taxon is an indicator of high nutrient conditions (Porter, 2008). The dominant green alga in the summer (39 percent) was the filamentous taxon *Klebsormidium* sp., and it was still important in the fall (20 percent).

Comparison to Historical Data

Although many studies of benthos and plankton have been done in Lake Michigan, few have been done at river mouths and harbors, and most of those studies do not conform to the standards required for quantitative comparison. Taxonomic resolution and changes in taxonomic classifications over time—especially for the phytoplankton—pose large problems with using historical data. Even when site locations are relatively close, field collection methods can vary greatly between studies, and quality assurance and quality control procedures are not always reported; however, comparisons between the current study and some historical data can be made, and these comparisons are addressed for each AOC in order, with one exception. Data comparisons with Weigel and Dimick (2011) are discussed last because multiple AOCs were included.

Benthic Assemblage Comparisons to Other Studies

In the current study, the predominant benthic taxa in bottom sediment at all sampled sites, AOCs and non-AOCs, were oligochaetes and midges. The richness, diversity, and density as well as the pollution tolerances of taxa present varied among sites. Multiple independent studies during the 1970s and 1980s of the Lower Menominee River AOC characterized the benthos as predominantly pollution-tolerant oligochaetes and midges, which were low in abundance or lacking in areas with high sediment chemical concentrations and poor substrate (Wisconsin Department of Natural Resources, 1996; Elwin Evans, unpub. data, July 1980, as cited in Wisconsin Department of Natural Resources and Michigan Department of Natural Resources, 1990). In the current study, the substrate was poor at MENI and organism densities were lower than at all non-AOCs in 2012 and 2014. Although many taxa were pollution tolerant, the dominance by taxa other than oligochaetes and the common presence of the clam *Pisidium* in all seasons in 2014 are good results for MENI and may indicate that conditions are improving.

Benthic invertebrates of Green Bay and the Fox River have shown improvements with time and water- and sediment-remediation efforts but remain generally poor quality. Historical studies of Green Bay indicated that when first assessed in the fall and winter 1938–9, the benthos of the southern bay had few populations of oligochaetes and midges except near the mouth of the Fox River (Wisconsin State Committee on Water Pollution and others, 1939). In the early 1950s, Surber and Cooley (1952) found a large increase in the abundance of these two groups of invertebrates (Surber and Cooley, 1952); however, Bertrand and others (1976) indicated that seasonal differences may have added to the differences in abundance between the two studies (Bertrand and others, 1976), which was also found in the current study. Previous studies of the Lower Green Bay and Fox River AOC found the benthos to be low in diversity and predominantly composed of tolerant Tubificinae oligochaete worms and midges (Ankley and others, 1992; Balch and others, 1956; Federal Water Pollution Control Administration, 1968; Howmiller and Beeton, 1971; Integrated Paper Services, Inc., 2000; Surber and Cooley, 1952; Wisconsin Department of Natural Resources, 1993; Wisconsin State Committee on Water Pollution and others, 1939). The change from rocky to soft, silty bottom substrates along with increases in toxins and increases in low oxygen events in the lower Fox River and into lower Green Bay near the river's mouth was accompanied by a change in the benthos from a mix of tolerant and intolerant taxa, to mostly tolerant taxa, to a lack of even tolerant taxa (Balch and others, 1956). The results of the current study still showed primarily oligochaetes and secondarily midges except at the lower Green Bay subsite, GB17, a sandy (94–97 percent; Scudder Eikenberry and others, 2016b) site where midges were dominant and either oligochaetes or pea clams were subdominant in spring and summer 2014. Burrowing mayfly larvae (*Hexagenia*), which are referred to as "fish flies" or "Green Bay flies" when adults, were once abundant in the region but declined with increasing pollution (Surber and Cooley, 1952). In 1938 and 1939, *Hexagenia* larvae were found in low densities in dredge samples of Lower Green Bay (Wisconsin State Committee on Water Pollution and others, 1939). These mayflies were also collected at 16 of 51 stations in surveys of Green Bay by Balch and others (1956) but were only rarely collected in later years (Ball and others, 1985; Wisconsin Department of Natural Resources, 2013). In the current study, *Hexagenia* were found in 2012 only in dredge samples from MENI and its two non-AOC comparison sites, ESCA and OCON, and this taxon was found in 2014 in only three samples: in summer HD samples from the Manitowoc River (MANI sampling site) and the Sheboygan River (SHEB sampling site) and in a fall dredge sample from MENI; no samples for benthos were collected in Green Bay in 2012 and no *Hexagenia* were found in Green Bay samples in 2014. A return of this species would signal improvement to the benthos of the Green Bay and Fox River AOC.

Comparisons across years for benthic assemblages in the Sheboygan River AOC are difficult because few studies have been done (Wisconsin Department of Natural Resources, 2012). A study in 1997 using dredge samples found immature Tubificinae oligochaetes made up more than 90 percent of the benthic assemblage at most Sheboygan River sites sampled, and analyses of a subset of these sites determined that there were just two species present: *Limnodrilus hoffmeisteri* and *Limnodrilus cervi*x (EVS Environment Consultants, Inc., and National Oceanic and Atmospheric Administration, 1998). In the current study, immature Tubificinae oligochaetes made up more than 80 percent of the benthic invertebrates in dredge samples at SHEB. The remaining oligochaetes were primarily the tolerant species *L. hoffmeisteri* and *L. cervix*. In 2014, highly tolerant immature Tubificinae oligochaetes were 58, 67, and 88 percent of the benthos in the spring, summer, and fall, respectively, and the highly tolerant *L. hoffmeisteri* was again the dominant oligochaete found. However, metrics for combined benthos did not differ from the two non-AOC comparison sites in 2014, and the benthic assemblage is expected to improve with time because sediment remediation was completed in 2013.

For the Milwaukee Estuary AOC, benthic assemblages do not seem to have improved in recent decades; however, sediment remediation is still in progress. Benthic studies in the late 1970s and early 1980s found low diversity and a dominance of pollution-tolerant taxa—primarily oligochaetes—in the Milwaukee and Menomonee Rivers that was related to sediment contaminants, poor substrate and water-quality conditions, and inadequate food resources (Wisconsin Department of Natural Resources, 1991, 1994). Benthos in the inner harbor of the estuary also must contend with high sedimentation rates and low dissolved oxygen concentrations (Wisconsin Department of Natural Resources, 2014). In the current study, even though diversity was low but not lower than the two non-AOC comparison sites, almost complete dominance (86 to 99 percent) by oligochaetes was found in dredge samples from sites in the Milwaukee River (MILR), Menomonee River (MENO), and the Milwaukee Harbor (MILH). Highly tolerant oligochaete taxa were dominant in these samples (75 to 96 percent), indicating that the status of these assemblages has changed little over recent decades.

At several AOCs, the HD data for benthos in the current study were compared quantitatively to historical HD data from the WDNR (Brian Weigel [WDNR] and Jeffrey Dimick [Aquatic Biomonitoring Laboratory–University of Wisconsin at Stevens Point], unpub. data, 2013). Values for eight invertebrate metrics from HD sampler data collected in 2012 and 2014 as part of the current study were compared with historical study values for HD relative abundance data and metrics collected by Weigel and Dimick (2011) using similar methods near the same AOC locations in the summer or fall of 2003 and (or) 2005. Methods using HD samplers in the current study were based on methods described in Weigel and Dimick (2011), and the same laboratory processed both sets of samples. ANOSIM tests did not indicate any differences in benthic assemblages between summer and fall samples for the current study and this historical dataset, and little difference was found between the two studies for metrics. For the Lower Menominee River AOC, the Weigel and Dimick (2011) summer IBI score was 45 (fair) in 2005. In the current study, IBI scores at MENI were 15 (very poor) in spring and 20 (poor) in summer and fall in 2012; IBI scores in 2014 were 30 (poor) in spring and summer and 15 (very poor) in fall. At the Sheboygan River AOC, the percentage of EPT individuals was 2.6 in summer 2003, compared with summer and fall 2012 and fall 2014 when values were less than 1.0 percent; the percentage of EPT individuals was 2.0 percent in summer 2014. The percentage of insects, primarily gatherer-type insects, was 95 percent in 2003, compared with summer and fall 2014 when values were 28 to 34 percent and with values in 2012 that were lower. Lastly, IBIs for 2014 at the Sheboygan River AOC were higher than for 2003 but still very poor at 10 and 15 for summer and fall 2014, respectively, compared to 5 in 2003. Metric values were similar between 2005 and 2012 at MILR; however, the IBI for summer 2014 was 45 (fair), apparently because of higher richness from insects. Weigel and Dimick (2011) state that their nonwadable river IBI may not be comparable to an IBI determined at upstream wadable riverine locations because the IBI tends to underrate sites with semilacustrine flows, such as those found downstream at river mouths, and rate them lower. IBI values within these ranges would be rated as poor for a large river system (poor rating ranges from 20 to 39); however, a large river IBI may not be able to accurately rate them. A benthic IBI for river mouths and harbors may be more valuable with the addition of functional and tolerance information for oligochaetes given their importance in these ecosystems and the range in environmental preferences. The large river IBI used in the current study includes oligochaetes, because they contribute to the proportion of noninsects, but not with regard to tolerance or functional roles.

Planktonic Assemblage Comparisons to Other Studies

Historical studies in the 1980s and 1990s in the lower Menominee River did not indicate impairment of the planktonic assemblage in the AOC with respect to contaminants, except for zooplankton in the turning basin and the 8th Street slip, where toxic effects in bioassays were found in 1989 by the WDNR (Wisconsin Department of Natural Resources and Michigan Department of Natural Resources, unpub. data, 1990). More recent studies of plankton in the Lower Menominee River were not found.

In the Lower Green Bay and Fox River AOC, the plankton assemblage still reflects the effects of decades of pollution but now also is troubled by invasive species. Historical studies in 1938 and 1939 found zooplankton such as rotifers and microcrustaceans were usually present in low numbers (Wisconsin State Committee on Water Pollution and others, 1939). Later studies in the 1980s found rotifer abundance higher than that of other microcrustaceans in the lower eutrophic part of Green Bay (Richman and others, 1984a; Richman and others, 1984b). In a study of Green Bay and near the mouth of the Fox River, the phytoplankton found in 1938 and 1939 (Wisconsin State Committee on Water Pollution and others, 1939) included mostly diatoms and cyanobacteria, with blooms of the toxin producer *Aphanizomenon*. Later surveys found the plankton to be dominated by cyanobacteria and small crustaceans, both with little food value to consumer organisms. Studies of the plankton during the 1980s found green algae dominant (as much as 80 percent) in the lower eutrophic part of Green Bay (Richman and others, 1984a; Richman and others, 1984b). Zebra mussels were first found in Green Bay in 1992 and became abundant (De Stasio and Richman, 1998). Their high densities and ability to filter large volumes of water in the bay correlated with a change in dominance from green algae to cyanobacteria, with large increases in the abundance of cyanobacteria *Anabaena* and *Microcystis* and an increase in the biovolume and chlorophyll of phytoplankton (De Stasio and others, 2014). In the current study at the Green Bay subsite GREE, the cyanobacterium *Microcystis aeruginosa* comprised 21 and 24 percent of the total density of phytoplankton in summer and fall 2014, respectively. *Microcystis* is known to thrive in high nutrient conditions. Other potentially toxic cyanobacteria including *Aphanizomenon issatschenkoi*, *Anabaena*, and *Planktothrix* also contributed 3 to 6 percent of the density in 2014 at GREE.

The WDNR stated in 1989 that there was no information on planktonic assemblages in the Sheboygan River AOC and no later publications have been found other than USGS research completed as part of the current study and a study by Olds and others (2017), which was done as a followup to the current study using the same methods. Olds and others (2017) found only the diversity of the zooplankton was lower at SHEB than at the two non-AOC comparison sites, KEWA and MANI, just as was found for 2014 in the current study.

The 2012 and 2014 data for plankton from the Milwaukee Estuary AOC were compared to data for plankton from the Milwaukee Metropolitan Sewerage District (MMSD; Eric Waldmer, MMSD, electronic files provided April 22, 2013). The MMSD collected zooplankton and phytoplankton periodically from 1980 through 1997 in the Milwaukee Estuary using methods fairly similar to those used in the current study. Specifically, the MMSD collected zooplankton using an 80-µm mesh plankton net (compared to the 63-µm mesh in the current study) with vertical hauls from 1 m off the bottom to the surface; phytoplankton were collected using a whole-water sampler but depth was not specified. Most MMSD sites were in the outer harbor and nearshore areas of Lake Michigan near Milwaukee, but one site, NS 28 (also called OH 1), was near MILH, which was sampled in 2012 and 2014 for the current study. At NS 28, rotifers and copepods were the dominant zooplankton present in samples during 1980–97. Rotifers were the dominant (59 to 75 percent) zooplankton in all seasons at the Milwaukee Harbor subsite in 2012; however, zebra mussel veligers were subdominant in 2012, and copepods and cladocerans were only minor components of the assemblage. In 2014, rotifers were also the dominant zooplankton in the spring and summer but zebra mussel veligers were the dominant (78 percent) zooplankton in the fall. With regard to specific rotifer taxa, *Filinia longiseta* was dominant during 1980–85, with species of *Synchaeta*, *Keratella*, and *Brachionus* subdominant; however, during 1988–97, *F. longiseta* was no longer a dominant rotifer and the previously subdominant taxa became more abundant. At MILH, *Synchaeta oblonga* was the dominant rotifer in spring and summer 2012 and in spring 2014; *Keratella crassa* was dominant in fall 2012 and summer 2014, and together these two taxa were the next most common zooplankton to the dominant zebra mussel veligers in fall 2014 (totaling 15 percent). At NS 28, the dominant copepod taxa during 1980–94 were cyclopoid copepods and unidentified immature copepods—nauplii and copepodids or copepodites; during 1995–97, the copepods were predominantly nauplii and the taxon *Diacyclops thomasi*, a cyclopoid copepod. The copepod taxa in 2012 were grossly similar to 1995–7, with nauplii and cyclopoid copepodites dominant and calanoid copepodites subdominant. Unidentified immature copepods (nauplii) were the dominant copepod life stages in 2014 and cyclopoid copepodites were subdominant in spring and fall; however, adult females of the cyclopoid copepod *Eucyclops elegans* and the calanoid copepod *Eurytemora affinis* were subdominant in summer 2014. Harpacticoid copepods, a benthic taxon, were first reported in the 1997 sample in low abundance, and these copepods were present at MILR in 2012 and 2014 in low abundance. Within the cladocerans, *Bosmina longirostris* was the dominant taxon in all MMSD samples as well as all seasons in 2012 and spring and summer in 2014. *Ceriodaphnia lacustris* and *Diaphanosoma birgei* were subdominant in the summer and fall 2012 samples, respectively, whereas subdominant taxa were distributed fairly evenly across all four taxa in the fall of 2014.

In the MMSD samples of phytoplankton collected near MILH, diatoms and green algae were generally the dominant algal group, followed by cyanobacteria and (or) cryptophytes, depending on the season. In 2012, diatoms were the dominant group (58 percent) in the spring, cryptophytes were dominant (50 percent) in the summer, and green algae (37 percent) and cyanobacteria (36 percent) were codominant in the fall. In 2014, diatoms were the dominant group in the spring and fall (42 and 39 percent, respectively), green algae were dominant (44 percent) in the summer (primarily *Klebsormidium*), and cryptophytes decreased from 30 percent in the spring to only 16 percent in the fall. Cyanobacteria were not found in 2014 samples. Diatom taxa were identified in about one-third of the MMSD samples and, in those samples, dominant taxa varied by season and year, so comparisons with specific diatom taxa are difficult and were not attempted here.

Summary and Conclusions

The benthos (benthic invertebrates) and plankton (zooplankton and phytoplankton) at Wisconsin's 4 Areas of Concern (AOCs) on Lake Michigan were evaluated by collecting samples at the AOCs and 6 less-degraded comparison sites (hereafter referred to as "non-AOCs") in 2012 and 2014. This was followed by an assessment of the relative abundance and distribution of taxa as well as computed metrics representing the health of aquatic communities in those samples. Except for Green Bay and the Milwaukee Harbor, results for combined benthos (dredge and artificial substrate samples), zooplankton, and combined phytoplankton (soft algae and diatoms combined) were compared statistically between each AOC and the means of all non-AOCs and between each AOC and the means of two non-AOC comparison sites.

The status of assemblages of benthos and plankton at the AOC sites and subsites may be summarized as follows for 2014:

Lower Menominee River AOC site (MENI)

Benthos

- Only Ephemeroptera-Plecoptera-Trichoptera (EPT) density and EPT richness of combined benthos differed from the mean of the two non-AOC comparison sites (the Escanaba River, Michigan, non-AOC comparison site [ESCA] and the Oconto River non-AOC comparison site [OCON]). Both metrics at MENI were lower than the mean of the two non-AOC comparison sites and were therefore rated as degraded; however, this study did not investigate the benthos at MENI after remediation was completed in late 2014 and so results of the current study may not reflect the status of the postremediation assemblage.
- No benthic metrics differed between 2012 and 2014 at MENI.
- Midges were the dominant taxonomic group in spring and summer 2014 at MENI but, in fall 2014, pea clams were dominant with midges second in dominance.

Plankton

- No metrics for zooplankton or combined phytoplankton differed between MENI and the two non-AOC comparison sites in 2014.
- Only the richness of combined phytoplankton differed between 2012 and 2014 at MENI; richness was higher in 2014.

- In the zooplankton, rotifers were the dominant taxonomic group during all seasons in 2014 at MENI.
- In the phytoplankton, dominance varied by season at MENI; the highest abundances for cryptophytes were detected in the spring and fall, and the highest abundances for green algae were detected in the summer.

Lower Green Bay and Fox River AOC—Fox River near Allouez subsite (FOXR)

Benthos

- For 2014, only the EPT richness of combined benthos differed between FOXR and the mean of the two non-AOC comparison sites (the Ahnapee River non-AOC comparison site [AHNA] and the Kewaunee River non-AOC comparison site [KEWA]); EPT richness at FOXR was higher. The higher EPT richness seemed to be from the presence of two caddisfly taxa, including a highly tolerant taxon and a moderately tolerant taxon.
- EPT richness was higher at FOXR in 2014 than in 2012.
- Multivariate analyses indicated that the 2014 combined benthos at FOXR differed from the two non-AOC comparison sites, mostly because of higher relative abundances of three pollution-tolerant oligochaete taxa.
- Oligochaetes were by far the dominant taxonomic group at FOXR in 2014, and sediment remediation was ongoing during sampling.

Plankton

- For zooplankton in 2014, only density differed between FOXR and the mean of the two non-AOC comparison sites; FOXR was lower and this result indicates that the assemblage of zooplankton at FOXR was degraded relative to the non-AOCs.
- For zooplankton in 2014, rotifers were the dominant taxonomic group in all seasons at FOXR.
- Metrics for combined phytoplankton did not differ between FOXR and the two non-AOC comparison sites.
- The combined phytoplankton assemblage at FOXR differed from its two non-AOC comparison sites. Out of all four AOCs examined, this was the only one in which this was true.
- For phytoplankton in 2014, cyanobacteria were the dominant taxa at FOXR in all seasons in 2014. Spring cyanobacteria were mostly the toxin producers *Anabaena* and *Microcystis aeruginosa*, and *M. aeruginosa* was the dominant cyanobacterium in summer and fall 2014 with more than 80 percent of the total algal abundance. The dominance of harmful algae underscores the highly eutrophic nature of the Fox River and is a symptom of larger watershed concerns for high concentrations of nutrients.

Sheboygan River AOC site (SHEB)

Benthos

- No metrics for combined benthos differed from the two non-AOC comparison sites (the Kewaunee River non-AOC comparison site [KEWA] and the Manitowoc River non-AOC comparison site [MANI]) in 2014.
- No metrics for combined benthos differed between 2012 and 2014 at SHEB.
- Highly tolerant immature Tubificinae oligochaetes were dominant at SHEB and the highly tolerant *Limnodrilus hoffmeisteri* was the dominant mature oligochaete found.
- The benthic assemblage at SHEB differed from the two non-AOC comparison sites. This was mostly because the highly tolerant oligochaete *Paranais* and the zebra mussel were abundant at SHEB but were uncommon or absent at the two non-AOC comparison sites, and the highly tolerant midge *Glyptotendipes* was absent or nearly so at SHEB but was uncommon to abundant at the non-AOC comparison sites.

Plankton

- For zooplankton in 2014, only diversity differed between SHEB and the mean of the two non-AOC comparison sites; diversity was lower at SHEB and was rated as degraded.
- Rotifers dominated abundance of zooplankton in spring and summer 2014 samples of zooplankton at SHEB; zebra mussel veligers dominated abundance in fall 2014.
- For combined phytoplankton in 2014, no metrics differed between SHEB and the mean of the two non-AOC comparison sites.
- Diatoms were the dominant algal group in the phytoplankton at SHEB in 2014.

Milwaukee Estuary AOC—Milwaukee River subsite (MILR) and Menomonee River subsite (MENO)

Benthos

- At MILR in 2014, only EPT density for combined benthos differed from the mean of the two non-AOC comparison sites (MANI and the Root River non-AOC comparison site [ROOT]), and MILR was higher (less degraded); however, the higher EPT density at MILR may have been because of high densities of a pollution-tolerant caddisfly at MILR.
- At MENO in 2014, only the total density of combined benthos differed from the mean of the two non-AOC comparison sites, and it was higher (less degraded) at MENO. The higher total density at MENO was because of higher densities for oligochaetes, especially some taxa that have a high pollution tolerance.
- The benthic assemblages at MILR and MENO differed from the two non-AOC comparison sites because of differences in the relative abundances of several taxa. Pea clams, a tolerant oligochaete, and a tolerant caddisfly were found in higher abundance at MILR; a tolerant oligochaete was found in higher abundance at MENO but another oligochaete and a midge were absent from MENO.
- There was no difference in metrics between 2012 and 2014 for combined benthos at MILR or MENO.

Plankton

- The total density of zooplankton in 2014 was lower at MILR than the mean of the two non-AOC comparison sites, so MILR was rated as degraded for density.
- No metrics for zooplankton at MENO differed from the two non-AOC comparison sites.
- For zooplankton in 2014, rotifers were dominant at MILR and MENO in the spring and summer; zebra mussel veligers were dominant in the fall at MILR but were absent from MENO. Copepods (nauplii) were the dominant taxonomic group in the fall at MENO.
- For combined phytoplankton in 2014, metrics did not differ for MILR or MENO from the mean of the two non-AOC comparison sites.
- At MILR in 2014, diatoms were the dominant taxonomic group in all seasons.
- At MENO in 2014, diatoms were the dominant taxonomic group in spring, cyanobacteria were dominant in summer, and green algae were dominant in fall.

In summary for benthos, only the Lower Menominee River AOC differed from its two non-AOC comparison sites; the density and richness of taxa in insect orders Ephemeroptera-Plecoptera-Trichoptera (mayflies, stoneflies, and caddisflies) in combined benthos (dredge and artificial substrate samples) were lower at the AOC. For plankton, the assemblages for zooplankton at the Fox River near Allouez (a subsite in the Lower Green Bay AOC) and the Milwaukee River differed from their two non-AOC comparison sites; density of zooplankton was lower at both AOCs. Metrics for combined benthos and combined phytoplankton (soft algae and diatoms) at the Sheboygan River AOC did not differ from the two non-AOC comparison sites; however, the diversity of zooplankton in 2014 was lower at the Sheboygan River AOC than at the two non-AOC comparison sites.

In assessments of ecological status, it is important to consider the effect that an invasive species such as the zebra mussel can have on the benthic and planktonic assemblages included in the current study. Though seldom a component of the benthos in soft sediment, zebra mussels were numerous on the Hester-Dendy samplers, and their immature forms were a large component of the plankton in the fall at the Sheboygan River AOC and at the Milwaukee River subsite in the Milwaukee Estuary AOC. Other studies have also indicated their effect in the Green Bay and Fox River AOC. Depending on the magnitude of effect that an invasive species has, it could reduce values for metrics such as richness, diversity, density, and index of biotic integrity (IBI) at sites. The adverse effects of invasive species would be separate from the effects of sediment contamination or remediation and could hinder or even prevent the ability of ecosystems to recover after remediation efforts.

The non-AOCs selected as comparison sites in this study were selected because (a) they were thought to have similar physical characteristics (land use, surficial geology, latitude, and climate) to the AOCs, (b) they are on the western shoreline of Lake Michigan where the AOCs are, and (c) they are not AOCs and are therefore presumed to be less degraded. However, there is a great deal of complexity in these comparisons. A finding of no statistical difference between a metric at an AOC site or subsite and the two non-AOC comparison sites does not mean that the benthic or planktonic assemblage at an AOC is not degraded in some aspect. However, where a metric for an AOC site or subsite was lower and therefore more degraded than at the non-AOC comparison sites, whether or not the two non-AOC comparison sites have some degradation themselves, this potentially supports the finding of degradation at an AOC site. Unfortunately, the low number of samples made it harder to discern that an AOC site differed from non-AOCs; however, the weight of evidence across multiple metrics representing the assemblages adds confidence to the overall assessment in this study. For multivariate comparisons, large differences between AOC and non-AOC assemblages may indicate that the AOC was not meeting expectations. Lastly, there are likely physical, chemical, and biological factors influencing the assemblages that are beyond the scope of this report as well as beyond the scope of AOC designations.

It is critical to consider a variety of measures when comparing assemblages at an AOC with one or more less-degraded sites because some measures address only a single aspect of the assemblage. Use of structural measures that relate to the relative numbers of different organisms (for example, richness, diversity, and relative abundance) and functional measures that relate to the role or preferences of different organisms (for example, environmental tolerances) is important in any complete assessment of ecological status. An aquatic assemblage can change in many ways without a significant change in richness or structural diversity, such as when more tolerant taxa replace less tolerant taxa or when green algae or cyanobacteria replace diatoms. An IBI is a multimetric that combines structural and functional measures and may therefore be a more effective measure to use for defining differences or change. The benthic IBI for river mouths and harbors may be more valuable with the addition of functional and tolerance information for oligochaetes because of their importance in these ecosystems and the range in environmental preferences for this large and diverse group of organisms. At present, there are no planktonic IBIs for use in river mouths or harbors.

These assessments at Wisconsin's four AOCs along the western shoreline of Lake Michigan provide a way to evaluate the current status of assemblages of benthos and plankton in relation to other rivers and harbors along the same shoreline. Assessments using a combination of standard statistics with computed biological metrics as well as multivariate analyses with assemblage abundance data indicated whether or not the aquatic assemblage at each AOC was different from the comparison sites. Methods and results for the current study should have application to evaluations of benthic and planktonic assemblages in other Great Lakes river mouths and harbors.

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Appendix J –
Degradation of Aesthetics BUI Results from 2015-2017 Volunteer Monitoring Program

Degradation of Aesthetics BUI Results from 2015-2017 Volunteer Monitoring Program

The volunteer monitoring program resulted in completion of 1,416 total surveys (400 in 2015, 562 in 2016, and 454 in 2017). A ranking system was utilized to assess overall aesthetic impression values and questions regarding recreational effects as a result of the presence of objectionable substances were assigned a point value (Figures 1A and 1B). Volunteer monitors were required to rank the overall aesthetic impression of the site as: very pleasing (rank = 0), somewhat pleasing (rank = 1), neutral (rank = 2), somewhat displeasing (rank = 3), or very displeasing (rank = 4). An overall aesthetic assessment score was also calculated for each survey that included adding the points for seven yes or no questions regarding whether or not objectionable substances would prevent the respondent from recreating in the water; if the respondent indicated that the objectionable substance would prevent them from recreating in the water, a score of 1 was given; if the objectionable substance was not present or did not prevent the respondent from recreating in the water a score of 0 was given. Mean overall aesthetic impression and assessment scores were calculated for each site allowing the comparisons to be made among sites (higher scores indicated a more aesthetically displeasing site). In addition, sites were also assessed individually by examining specific aesthetic parameters and calculating the percent of surveys that were chosen as aesthetically displeasing (i.e. if yes was selected for invasive species in 3 of 4 surveys the percent would be 75%). Histograms were plotted to examine the aesthetic parameters within each site and to compare the spatial trends across all sites and years.

In order to develop site-based management recommendations, several criteria for identifying problem areas were developed to determine if any stations required any management actions to be undertaken to meet the BUI target:

- The arithmetic mean overall aesthetic impression ranks of ≥ 3
- The arithmetic mean assessment score of ≥ 4
- Sites with individual aesthetic parameter that are classified as aesthetically displeasing in ≥ 75% of total surveys.

Results of the aesthetic monitoring survey within the Milwaukee Estuary AOC between 2015-2017 showed that aesthetic impression score and assessment score were below the action criteria score that requires a management action for any of the sites. Also, none of the percentage mean for which a parameter was selected for being displeasing was ≥75% (Figure 2). The overall mean assessment score across all sites surveyed was 0.51, which was significantly below the action criteria score of 4 (Figure 3). The overall mean aesthetic impression score across the sites throughout the survey period was 1.13, which was also below the action criteria score of 3 (Figure 4).

Milwaukee Estuary Volunteer Aesthetics Monitoring Data Sheet

Please answer all questions on the datasheet completely and to the best of your ability.
DNR cannot use incomplete data sheets in station data analysis.

If you have questions or to return this survey, please contact <insert contractor's name and contact info>

Form revision date: 05/05/14

1. Your name:		**2. Station name:**	
3. Monitoring date:	mm/dd/yy	**4. Start time (include AM/PM):**	
5. Water conditions:	Calm / Slight movement / Moderate flow or waves / Rough or fast flowing		
6. Water level:	High / Normal / Low		

Overall aesthetic impression of site

7. Overall, how aesthetically pleasing do you find the site?

Circle one of the following: Very pleasing / Somewhat pleasing / Neither pleasing nor displeasing / Somewhat displeasing / Very displeasing

Please describe. List any factors that make it pleasing or not pleasing.

Objectionable deposits in/characteristics of the water

8. Does the color or clarity of the water present an unsightliness to the extent that it makes the area unpleasant or blocks your ability to access, enjoy, or use the water?

Yes / No

If yes, please describe:

9. Please describe the characteristics of the water during this particular visit. Note: characteristics may be present or absent regardless of their ability to make the area unpleasant or block your ability to access, enjoy, or use the water.

A. Water Color: Colorless / Red / Green / Brown / Other (please indicate)________

B. Water Clarity: Completely clear / Fairly clear / Fairly cloudy / Completely cloudy

C. Water Surface: (Choose all that apply) Normal / Oily sheen / Foamy / Floating aquatic plants / Natural debris / Neon green sheen / Other (please indicate)________

10. Is there floating or submerged garbage present in the water to the extent that it makes the area unpleasant or blocks your ability to access, enjoy, or use the water?

Yes / No

If yes, indicate visible item(s): Street litter / Building materials / Medical items / Household waste / Sewage-related litter / Food-related litter / Fishing-related litter / Other (please indicate)________

11. Are any other substances present in the water to the extent that they make the area unpleasant or block your ability to access, enjoy, or use the water?

Yes / No

If yes, list type(s) and reason(s):

Figure 1A. Milwaukee Volunteer Aesthetics Monitoring Program Survey Forms with Scoring (2015-2017).

12. Is there garbage present along the shoreline to the extent that it makes the area unpleasant or blocks your ability to access, enjoy, or use the water?					*Objectionable deposits on the shoreline*
	Yes		No		
If yes, circle type(s):	Street litter	Building materials	Medical items	Household waste	Sewage-related litter
	Food-related litter		Fishing-related litter	Other (please indicate)______________	
13. Are there problem animals or problems caused by animals present along the shoreline to the extent that it makes the area unpleasant or blocks your ability to access, enjoy, or use the water?					
	Yes		No		
If yes, list type(s) and reason for problem(s):					
14. Are there dead animals present along the shoreline to the extent that it makes the area unpleasant or blocks your ability to access, enjoy, or use the water?					
	Yes		No		
If yes, list type and amount:					
15. Are there invasive species present along the shoreline to the extent that it makes the area unpleasant or blocks your ability to access, enjoy, or use the water?					
	Yes		No		
If yes, list type(s):					
16. Are any other substances present along the shoreline to the extent that they make the area unpleasant or block your ability to access, enjoy, or use the water?					
	Yes		No		
If yes, please type(s) and reason(s):					
17. Have you previously evaluated this station?	Yes		No		*Additional feedback*
If you have previously evaluated this station, what changes if any have you noticed in the aesthetic quality of the water or along the shoreline since your last visit?					
Comments: Please include anything else you thought should be reported while completing this survey.					
18. END TIME:					
For volunteer coordinator/DNR use only					*QA/QC*
Date the data sheet was reviewed by DNR:			Data entered into SWIMS?	☐	
Aesthetic impression score (for DNR use only):					
Assessment score (for DNR use only):					

Figure 1B. Milwaukee Volunteer Aesthetics Monitoring Program Survey Forms with Scoring (2015-2017).

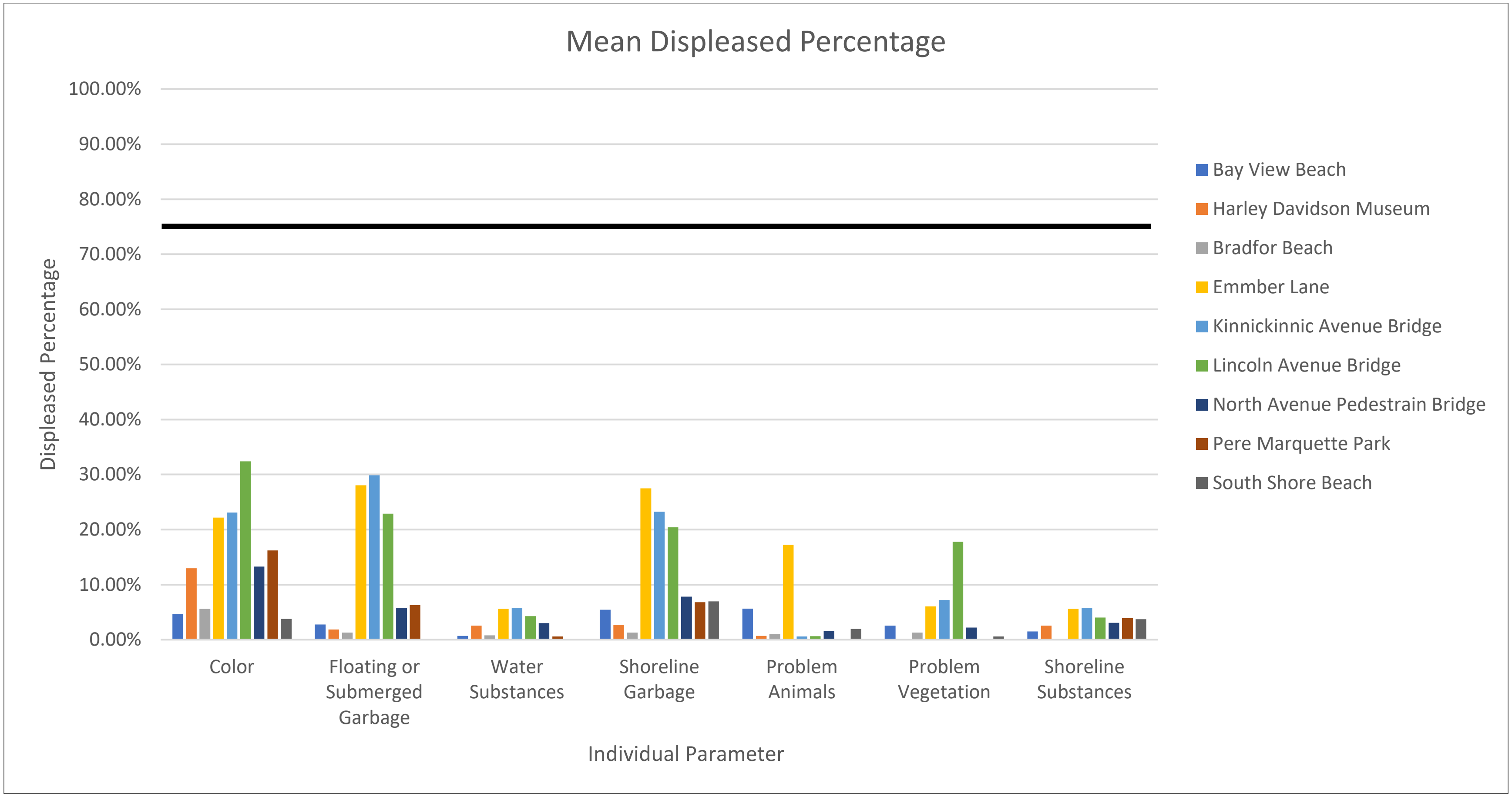

Figure 2. Percentage mean for all aesthetics parameters at each site within the Milwaukee Estuary AOC. The black line indicates the threshold at which management actions would be needed for a specific site.

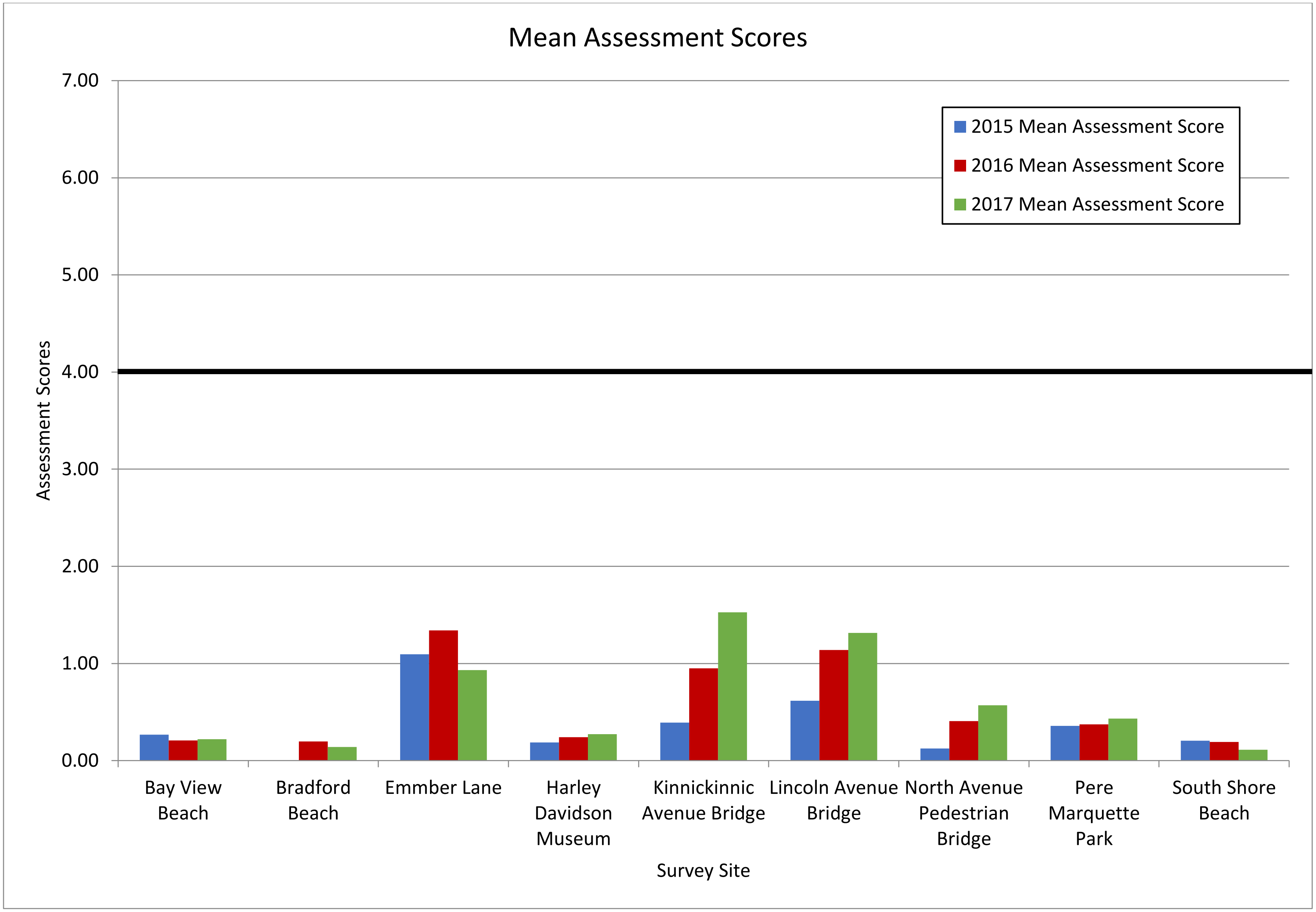

Figure 3. Mean assessment scores for all Milwaukee Estuary AOC survey sites. The black line indicates the threshold at which management actions would be needed for a specific site.

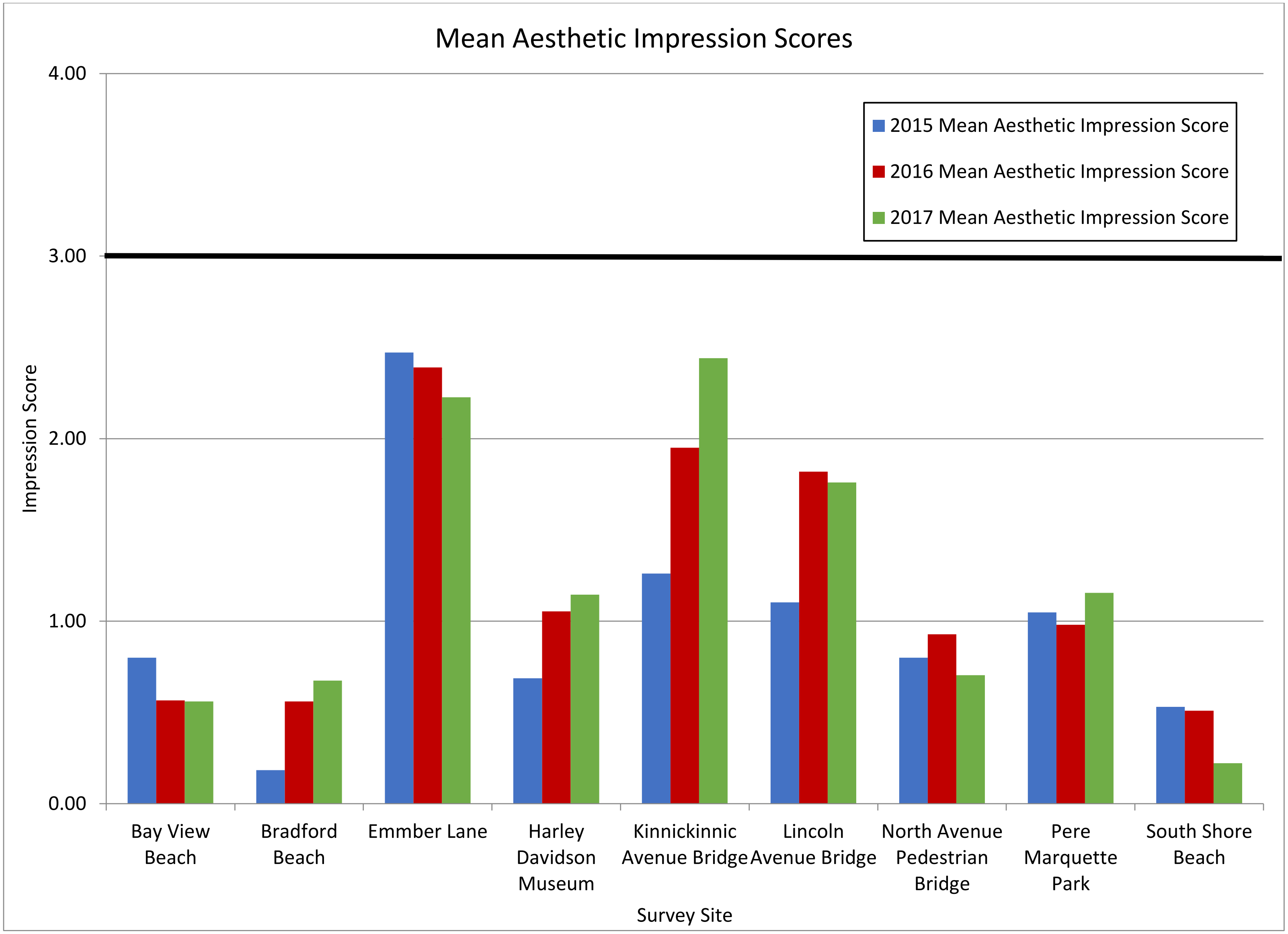

Figure 4. Mean aesthetic impression scores for all Milwaukee Estuary AOC survey sites. The black line indicates the threshold at which management actions would be needed for a specific site.

Appendix K –
University of Wisconsin – Milwaukee School of Freshwater Sciences Beach Closings Assessment for Management Action Recommendations

Beach Closings Assessment for Management Action Recommendations

Brief Project Description:

The McLellan Lab at the University of Wisconsin-Milwaukee (UWM) will analyze new and archived water and sand samples, conduct bacterial pollution flow modeling analysis, and will statistically analyze data to provide site-specific information about sources of *Escherichia coli* (*E. coli*) at beaches within the Milwaukee Estuary AOC. This information will be used by the Wisconsin Department of Natural Resources (WDNR), in collaboration with the McLellan Lab, to develop a recommended list of management actions for the Beach Closings (Recreational Restrictions) beneficial use impairment (BUI) for the AOC. Additionally, these partners, in collaboration with the City of Milwaukee Health Department and South Milwaukee Health Department, will refine existing decision criteria, that is protective of public health, for closure of AOC beaches after combined sewer overflow (CSO), sanitary sewer overflow (SSO), blending, and rain events have occurred.

Outcome(s):

a. Determine and refine the management action list for the Beach Closings (Recreational Restrictions) BUI in the Milwaukee Estuary AOC, which will ultimately reduce closures of public swimming beaches within the AOC.
b. Provide information for the City of Milwaukee Health Department and South Milwaukee Health Department to develop a beach advisory and closure plan that is protective of public health.

Both outcomes will meet portions of the 2020 Beach Closings (Recreational Restrictions) revised target.

Project Background/Purpose:

One of the eleven BUIs in the Milwaukee Estuary AOC is the Beach Closings/Recreational Restrictions BUI. This BUI is listed as impaired due to high bacterial levels and sewer overflows in the AOC, which has caused beach closings and recreational hazards. Certain monitoring components of the revised 2020 target for the Beach Closings/Recreational Restrictions BUI that will be addressed by this project are:

- Known sources of bacterial contamination impacting the beaches in the AOC have been identified, and if feasible, have been controlled or treated to reduce possible exposures.
  <u>AND</u>
- Stormwater outfalls in the AOC that discharge directly or influence beaches are assessed to confirm that there are no human sources of sanitary sewage contamination.
- Each public swimming beach within the AOC is open for at least 90% of the swimming season (between Memorial Day and Labor Day) averaged over a previous 5-year period based on Wisconsin Coastal Beach monitoring protocols for *E. coli* monitoring and BMPs are in place.
  <u>OR</u>
- Public swimming beaches within the AOC are meeting EPA's 2012 recreational water quality criteria over a 3-year period.
  <u>OR, in cases where known sources of bacterial contamination impacting beaches in the AOC have been controlled to the extent feasible and the above criteria cannot be met:</u>
- Each public swimming beach within the AOC is open during the swimming season (between Memorial Day and Labor Day) at least as often as the average of all non-AOC beaches in Milwaukee County over the same 5-year period.
  <u>AND</u>

- Complete a plan that includes updates to existing advisory and closure procedures for AOC beaches to reduce human health risks during and after storm events.

There are four public swimming beaches within the AOC: Bradford Beach, Bay View Park Beach, McKinley Beach, and South Shore Beach. Currently, the only beach that meets these components of the drafted target is Bay View Park Beach. From 2010-2018, AOC beaches were open 92% (Bay View Park Beach); 76% (Bradford Beach); 63% (McKinley Beach); and 44% (South Shore Beach) of the swimming season, respectively. These beach closures are due to the presence of *Escherichia coli* (*E. coli*) in the swimming areas of those beaches. Bay View beach is monitored once per week by the City of Racine, and advisories are issued by the South Milwaukee Health Department. Other AOC beaches are monitored 3-5 times per week by University of Wisconsin – Milwaukee, and advisories are issued by the City of Milwaukee Health Department. While monitoring is in place at the beaches, location-specific decision criteria to post advisories or closures at beaches within the AOC after rainfall, overflow, or blending events needs improvement to be protective of public health.

Previous work by the McLellan lab at the University of Wisconsin-Milwaukee characterized the spatial distribution of *E. coli* from river plumes into Lake Michigan and compared this to *E. coli* densities found at shoreline beach sites. Their work found that under heavy rain events and CSO conditions, contamination can reach all the AOC beaches, but on many days during the beach season, *E. coli* levels are elevated only near the shoreline within 10 meters of the beach and show very low concentrations offshore (7-9). Additional work identified possible sources of *E. coli* at the beaches. Many beaches are impacted by gull waste, but underlying contamination from human sources exists under certain conditions (3,6). Stormwater outfalls are often located near public swimming beaches acting as an *E. coli* source from both surface water runoff and, recurrently, from sewage discharge due to cross connections or leaking sanitary sewers (10). Additionally, the McLellan lab has found that beach sand can act as a reservoir for *E. coli*, that can then be washed into the water due to wave action or rainfall (1,3). Survival of *E. coli* in sand at Milwaukee beaches is directly related to sand moisture (1), and additional studies from other Great Lakes beaches indicate this is a common phenomenon (4,5,11).

The Wisconsin DNR is currently working to develop the management action list for the Beach Closings/Recreational Restrictions BUI in the Milwaukee Estuary AOC. Using work by the McLellan lab from 2001-2016, WDNR have identified relocation of the publicly accessible swimming area at South Shore as one management action, but remaining management actions for all four AOC beaches remain in development. The proposed work will refine specific management actions to be taken at the beaches to reduce the number of advisories and closures to meet the BUI target.

This assessment will refine the management action list at the AOC beaches and refine decision factors for preemptive closures of those beaches to protect public health. Completing both tasks will directly lead to meeting the goals of the BUI removal criteria.

Proposed Work:

<u>Objective 1:</u> Investigate sources of *E. coli* at the Milwaukee AOC beaches to refine a list of management actions that will reduce the number of beach closures and address the 2020 Beach Closings/Recreational Restrictions revised target.

The McLellan lab at UW-Milwaukee has monitored the AOC beaches yearly and archived samples to be analyzed for source specific indicators. Additionally, existing data collected by the lab can be analyzed to characterize the dynamics at the beaches and to gauge the influence of offshore versus shoreline sources. Approximatley 6,500 samples have been collected from beach surface water, beach sand, beach outfalls, and lake/harbor surface water within the AOC for other projects. The McLellan lab will analyze stored samples and combine with existing data to answer the following sub-objectives:

1.1. Determine the sources of contamination at AOC beaches when *E. coli* levels are high: The McLellan lab will perform an initial data review of surface water during each of four conditions: low-flow, rain, CSO, and post-CSO samples for each beach. They will also perform quantitative polymerase chain reaction (qPCR) analysis on 240 archived samples to determine the distribution of human, gull, dog, and/or ruminant bacterial genetic markers in samples with high *E. coli* plate count levels. Comparing bacterial sources between sampling sub-sets will help identify sources of *E. coli* at the beaches during different weather conditions.

1.2. Investigate local outfalls near or adjacent to AOC beaches to identify outfalls of concern for human contamination at the beach. This portion of the project will involve the review of past data, analysis of archived samples, and additional sample collections in spring and early summer of 2020.

1.3. Investigate sand reservoirs and sand water interactions: Data at Bradford and McKinley beaches will be analyzed to determine the effect of rain or wave action, and subsequently wet sand, on the levels of *E. coli* that are detected in sand and water. Literature shows that *E. coli* in sand at beaches can lead to high levels in the water, leading to a beach closure (1,3). This work will determine if the beach slope, proximity to water table, or sand characteristlcs at the beaches leads to *E. coli* burden. Possible management actions that could be encouraged or ruled out include beach nourishment and re-grading or re-sloping to reduce sand *E. coli* burden at the beaches.

1.4. Analyze water quality trends before and after remediation projects at Bradford and South Shore beaches and develop general pre- and post- monitoring recommendations: Archived data before and after the Bradford beach rain garden installation will be analyzed to characterize water quality trends over time and characterize the effectiveness of those measures to reduce *E. coli* at Bradford beach. Similarly, using two years worth of data after the green parking lot construction at South Shore Beach, the McLellan lab will characterize reductions in *E. coli* levels post-project implementation. This analysis will consider annual weather patterns and lake levels to make a determination on the effectivess of these actions and their possible success at other AOC beaches.

<u>Objective 2:</u> Use past and new data collection to improve criteria used by the City of Milwaukee Health Department and South Milwaukee Health Department when determining pre-emptive closures of AOC beaches after rainfall, CSO, SSO, and blending events. This objective specifically helps to meet the component of the target for managing human health risk during extreme storm events.

The McLellan lab will use information from Objective 1 and additional information collected in Objective 2 to better evaluate when beaches should be closed to protect public health. This information will be shared with City of Milwaukee Health Department and South Milwaukee Health Department to aid in the refinement of existing criteria:

2.1 The McLellan lab will use archived data from 20 rain events and 5 CSO events, where ISCO sampling captured concentrations of human and cattle markers across hydrographs, to model bacterial pollution movement from the Milwaukee Estuary to AOC beaches in different meteorological conditions (2).

2.2 Examine CSO beach and lake surveys to compare levels of human marker before, during, and after a CSO. Identifying patterns of human marker will inform a set of improved decision criteria on when to close AOC beaches during and after CSO, SSO, and blending events.

2.3 Using results from Objective 1, 2.1, and 2.2, the McLellan lab will work collaboratively with the City of Milwaukee Health Department, South Milwaukee Health Department, and the WDNR Beach Program Manager to refine existing decision criteria for AOC beach closures that is protective of public health.

Collaboration with Partners:

Ongoing projects with the Milwaukee Metropolitan Sewerage District (MMSD) and Wisconsin Sea Grant will add supporting information (data and analyses) that will be useful for the modeling and sand investigations in Objective 1.

Outputs/Deliverables:

- An interim project presentation given to the Milwaukee AOC Beaches Work Group that includes the following elements:
    a. A preliminary summary of results and data interpretation
    b. A recommendation of management actions for each AOC beach
- An interim report detailing recommended management actions for each AOC beach
- A final project portfolio that includes the following elements:
    a. All project data
    b. A summary of results and data interpretation from analysis of archived data and newly collected data
        i. Final Report
        ii. Fact sheet on water quality at Bradford Beach and South Shore beaches before and after non-AOC management actions
        iii. AOC beaches Best Management Practices (BMP) Policy brief that includes refined decision criteria for AOC beach closures
        iv. Preliminary estuary/nearshore flow model for bacterial pollution
    c. Management action recommendations for each AOC beach

2. Peer-reviewed publication(s)
3. Presentation(s) at local and/or national venues/conferences on project results