

Appendix 9.1: Fox River

Written by Erin Giese and Dr. James Horn

Location (centroid)	Lat. 44.480266°, Lon. -88.042643° ¹ (NAD 1983, UTM Zone 16N)																																				
Total Area (ha)	526.34 ha																																				
Area Public Land (ha)	The boundaries of the Fox River priority area are located within the coastal zone/waters of the Fox River and are thus entirely publicly owned. Depending on lake levels, parts of the shoreline may overlap with the boundaries of other priority areas.																																				
Area of Habitat Types Present (ha) and Percent of Each Habitat Type	<p>Dominant Habitat Types: These habitat types were documented during a July 2015 habitat mapping effort led by the University of Wisconsin-Green Bay Cofrin Center for Biodiversity (CCB) across the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC)². Habitat types within the Fox River are displayed as a static map at the bottom of this document. Note that the extent of submergent marsh was refined by the CCB's 2017 submerged aquatic vegetation field surveys. There is a total of 526.58 ha of natural habitat in the Fox River.</p> <table border="1"> <thead> <tr> <th>Habitat Type</th> <th>Area (ha)</th> <th>Percent</th> </tr> </thead> <tbody> <tr> <td>Emergent Marsh (High Energy Coastal)</td> <td>0.04</td> <td>0.01</td> </tr> <tr> <td>Emergent Marsh (Inland)</td> <td>0.02</td> <td>0.00</td> </tr> <tr> <td>Emergent Marsh (Riparian)</td> <td>0.57</td> <td>0.11</td> </tr> <tr> <td>Fox River Open Water</td> <td>520.72</td> <td>98.89</td> </tr> <tr> <td>Great Lakes Beach</td> <td>0.01</td> <td>0.00</td> </tr> <tr> <td>Hardwood Swamp</td> <td>0.84</td> <td>0.16</td> </tr> <tr> <td>Other Forest</td> <td>0.23</td> <td>0.04</td> </tr> <tr> <td>Submergent Marsh</td> <td>3.61</td> <td>0.69</td> </tr> <tr> <td>Surrogate Grassland (Old Field)</td> <td>0.22</td> <td>0.04</td> </tr> <tr> <td>Tributary Open Water</td> <td>0.24</td> <td>0.04</td> </tr> <tr> <td>Wasteland</td> <td>0.09</td> <td>0.02</td> </tr> </tbody> </table> <p><i>Disclaimer!</i> Because this priority area is located within the Great Lakes coastal zone, the amount of habitat types can vary drastically across years and even within years (or months) due to changing Great Lakes water levels, precipitation, and seiche. Within this priority area specifically, the amounts of emergent and submergent marsh are known to fluctuate significantly from year to year and within years. The habitat types listed above and mapped below are based on a field effort conducted in July 2015. Plants recorded in the "Natural Habitat Communities and Significant Plants" section were primarily documented in July 2015 and late summer 2017. Great Lakes water levels were much higher in 2017 than in July 2015.</p>	Habitat Type	Area (ha)	Percent	Emergent Marsh (High Energy Coastal)	0.04	0.01	Emergent Marsh (Inland)	0.02	0.00	Emergent Marsh (Riparian)	0.57	0.11	Fox River Open Water	520.72	98.89	Great Lakes Beach	0.01	0.00	Hardwood Swamp	0.84	0.16	Other Forest	0.23	0.04	Submergent Marsh	3.61	0.69	Surrogate Grassland (Old Field)	0.22	0.04	Tributary Open Water	0.24	0.04	Wasteland	0.09	0.02
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General Description	The Fox River is a third order stream that flows northeast and forms the basis of the Lower Fox River basin, which is 1,654 km ² in size ³ . The lower Fox River starts from Lake Winnebago and empties into Green Bay, which is the western arm of Lake Michigan. The Fox River priority area only includes the Fox River open water from the mouth of the Fox River to the De Pere Dam. In order for small boats to travel upstream past the De Pere Dam, they must travel through the De Pere Locks. The shipping channel in the lower bay of Green Bay continues down the Fox River roughly 6.5 km																																				

¹ File "AOC_PriorityAreas.v09_20171212.shp"

² LGB&FR AOC 2015 habitat field mapping effort

³ WDNR's Lower Fox River basin webpage: <http://dnr.wi.gov/topic/Watersheds/basins/lowerfox/>

	<p>upstream to the south with depths of up to 7.32 km (24 ft) in the river⁴. Waters along the eastern and western shorelines of the Fox River range from 0.30-1.22 km (1-4 ft) deep⁴. The East River, Ashwaubenon Creek, and Dutchman Creek are smaller second order streams that empty into the Fox River. When the Fox River empties into the lower bay, the water currents move in a counterclockwise direction starting by traveling up the eastern shore of the bay to Sturgeon Bay, at which point the currents turn west⁵. Seiche can affect shorelines along the Fox River for up to 9.66 km (6 mi) upstream⁶. Sediments consist of sand and clay⁷.</p> <p>Unfortunately, water quality in the lower bay and Fox River has been poor for decades. The LGB&FR AOC was originally listed as a Great Lakes Area of Concern in 1988 due to poor water quality, contaminated sediments, and degraded or lost habitat and has a long history of pollution. Since 2009, the Fox River Cleanup Project has been working to dredge up historic polychlorinated biphenyls (PCB) in 20.92 km (13 mi) that are found in Fox River sediment⁸. Waters within the LGB&FR AOC regularly report high concentrations of total phosphorus, total suspended solids, nitrates/nitrites, and toxic chemicals, leading to poor overall water quality^{9,40}. It can also be turbid and experience summer and late fall blooms of harmful algae⁹. Fox River waters often contain low levels of oxygen, especially in the summer, which can be problematic and deadly for fish¹⁰. The land surrounding the Fox River between the De Pere Dam and mouth of the Fox River is heavily industrialized and urbanized, creating a significant amount of impervious surfaces, which contributes to the nutrient runoff problem.</p> <p>Despite water quality issues, a great number of wildlife still use the Fox River, especially fish species, and it is extremely well studied particularly in terms of fish and water quality. Over the past several decades, scientists from agencies, non-profit organizations, universities, and other organizations have conducted dozens of research projects and collected data on fish, water quality, odonates, bats, birds, anurans (frogs + toads), and plants.</p> <p>Like other Great Lakes, large ships and freighters regularly use the bay and Fox River shipping channel for transporting goods, such as coal, limestone, salt, wood products, and other products¹¹. Residents and visitors of Green Bay regularly use the waters of the lower bay and Fox River for fishing, hunting, boating, swimming, diving, water sports, and nature viewing. Therefore, improving the quality of lower Green Bay waters and associated habitats would improve the livelihood and economics of both wildlife and people.</p>
<p>Special Features</p>	<ul style="list-style-type: none"> • Three streams empty into the lower Fox River below the De Pere Dam, namely Ashwaubenon Creek and Dutchman Creek on the west shore and the East River on the east shore. • Features critical spawning habitat below the De Pere Dam for lake sturgeon (<i>Acipenser fulvescens</i>), walleye (<i>Sander vitreus</i>), smallmouth bass (<i>Micropterus dolomieu</i>), and lake whitefish (<i>Coregonus clupeaformis</i>). This area is known for being a world-class walleye fishery^{12,13}.

⁴ U.S. Army Corps of Engineers Map of the Head of Green Bay, including Fox River below De Pere, Wisconsin, Chart No. 725 from August 1966

⁵ Klump et al. 1997: Sedimentary phosphorus cycling and a phosphorus mass balance for the Green Bay, Lake Michigan ecosystem

⁶ Bertrand et al. 1976: "The Green Bay Watershed: Past/Present/Future"

⁷ Dorney 1975: The vegetation pattern around green Bay in the 1840s as related to geology, soils, and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico

⁸ Fox River Cleanup Project Webpage: <http://foxrivercleanup.com/>

⁹ Qualls et al. 2013: State of the Bay 2013:

<http://www.seagrant.wisc.edu/Home/Topics/HabitatsandEcosystems/Details.aspx?PostID=1840>

¹⁰ Howlett 1974: The rooted vegetation of west Green Bay with reference to environmental change

¹¹ Port of Green Bay Website: <http://www.portofgreenbay.com/>

¹² World-class walleye fishery: <http://www.wbay.com/content/news/Tagging-Study-Helps-Answer-Wheres-Walleye-418000233.html>

¹³ Top 10 Midwest Walleye Fisheries: <http://www.in-fisherman.com/rigged-ready/mw/top-10-midwest-walleye-fisheries/>

	<ul style="list-style-type: none"> • Provides significant open water and nearshore fish habitat. • Provides habitat for odonates (dragonfly/damselfly)¹⁴. • Provides relatively open foraging habitat for bats¹⁵. • Contains two submergent marshes located along the eastern shoreline by the Fox Point Boat Launch and in the outer reaches and mouth of Ashwaubenon Creek adjacent to the Fox River on the western Fox River shoreline. • Important waterfowl migratory bird stopover site at the De Pere Dam and the mouth of the Fox River¹⁶.
<p>Natural Habitat Communities and Significant Plants (ordered in terms of ecological importance and size/amount)</p>	<p>Nearly 99% of the Fox River priority area consists of Fox River open water (520.72 ha) with little to no plant life, with the exception of two patches of submergent marsh (3.61 ha total) that are located along the eastern shoreline of the Fox River by the Fox Point Boat Launch and in the outer reaches and mouth of Ashwaubenon Creek adjacent to the western shore of the Fox River^{2,17}. The submergent marsh on the eastern shoreline of the Fox River is dominated by sago pondweed (<i>Stuckenia pectinata</i>) and slender waterweed (<i>Elodea nuttallii</i>). Other native species that were present but rare were longleaf pondweed (<i>Potamogeton nodosus</i>) and leafy pondweed (<i>Potamogeton foliosus</i>) with invasive Eurasian watermilfoil (<i>Myriophyllum spicatum</i>). The submergent marsh located at the mouth of Ashwaubenon Creek had wild celery (<i>Vallisneria americana</i>), leafy pondweed, longleaf pondweed, sago pondweed, coontail (<i>Ceratophyllum demersum</i>), common waterweed (<i>Elodea canadensis</i>), and water stargrass (<i>Heteranthera dubia</i>).</p>
<p>Significant Animals</p>	<p>Birds:</p> <ul style="list-style-type: none"> • >130 bird species have been reported in recent years using the Fox River or terrestrial/riparian habitats along the Fox River¹⁸: <ul style="list-style-type: none"> ○ Ducks, waterfowl, and waterbirds that use the Fox River during migration, summer, and/or winter, including, but not limited to: <ul style="list-style-type: none"> ▪ Based on recent 2016-2017 LGB&FR AOC Migratory Waterfowl Study; surveys done by Tom Prestby: <ul style="list-style-type: none"> • Congregate in relatively large groups during migration at the De Pere Dam: <ul style="list-style-type: none"> ○ Ring-billed Gull (<i>Larus delawarensis</i>) ○ Herring Gull (<i>Larus smithsonianus</i>) ○ Mallard (<i>Anas platyrhynchos</i>), regional priority species from the North American Waterfowl Management Plan • Congregate in small numbers: <ul style="list-style-type: none"> ○ Canada Goose (<i>Branta canadensis</i>), regional priority species from the North American Waterfowl Management Plan ○ Double-crested Cormorant (<i>Phalacrocorax auritus</i>) ○ American White Pelican (<i>Pelecanus erythrorhynchos</i>), a state special concern species ○ Common Merganser (<i>Mergus merganser</i>) ○ Common Goldeneye (<i>Bucephala clangula</i>), a state special concern species

¹⁴ Willson Gaul's LGB&FR AOC 2016 odonate surveys

¹⁵ Jeremiah Shrovnal's LGB&FR AOC 2016 bat surveys

¹⁶ Epstein et al. 2002

¹⁷ LGB&FR AOC Submerged Aquatic Vegetation Mapping; led by Dr. Amy Wolf and Dr. James Horn

¹⁸ LGB&FR AOC Biota Database: file "AOCBiota_DB_ShareableVersion_20171213.accdb"

- Great Egret (*Ardea alba*), state threatened and listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern
- In recent years, according to the Wisconsin Breeding Bird Atlas II Project¹⁹, at least two Cliff Swallow (*Petrochelidon pyrrhonota*) colonies nest under bridges along the Fox River; Barn Swallows (*Hirundo rustica*) nest under the Main Avenue bridge next to the De Pere Dam. Chimney Swift (*Chaetura pelagica*), Peregrine Falcon (*Falco peregrinus*), Common Grackle (*Quiscalus quiscula*), Red-winged Blackbird, Mallard, Canada Goose, Rock Pigeon (*Columba livia*), and many other birds nest in coastal and terrestrial habitats along the Fox River.
- Songbirds and landbirds use the narrow terrestrial habitats along the Fox River Trail during migration.

Fish:

- >80 fish species have been recorded in the pelagic zone of the lower bay, though not all have been reported in the Fox River, including¹⁸:
 - Lake sturgeon (*Acipenser fulvescens*), globally vulnerable and state special concern species; spawn below the De Pere Dam
 - Walleye (*Sander vitreus*), spawn below the De Pere Dam; other spawning reef habitat improvements have been made by Voyageur Park, Ashwaubomay Memorial River Park, and Fox Point Boat Launch
 - Lake whitefish (*Coregonus clupeaformis*), spawn below the De Pere Dam
 - Bluegill sunfish (*Lepomis macrochirus*)
 - Gizzard shad (*Dorosoma cepedianum*)
 - Smallmouth bass (*Micropterus dolomieu*), spawn below the De Pere Dam
 - Longnose gar (*Lepisosteus osseus*)
 - Muskellunge (*Esox masquinongy*), spawning habitat on the eastern shoreline of the Fox River north of Voyager Park and south of Mason Street
 - Northern pike (*Esox lucius*)
 - Smallmouth bass (*Micropterus dolomieu*)
 - Yellow perch (*Perca flavescens*)

Mammals:

- 10 species of mammals have been reported using areas along the Fox River:
 - Big brown bat (*Eptesicus fuscus*), state threatened
 - Eastern red bat (*Lasiurus borealis*), globally vulnerable
 - Hoary bat (*Lasiurus cinereus*)
 - Little brown bat (*Myotis lucifugus*), globally vulnerable and state threatened
 - Silver-haired bat (*Lasionycteris noctivagans*), globally vulnerable and state special concern species
 - Virginia opossum (*Didelphis virginiana*)
 - White-tailed deer (*Odocoileus virginianus*)
 - Eastern chipmunk (*Tamias striatus*)
 - Eastern cottontail (*Sylvilagus floridanus*)
 - Eastern gray squirrel (*Sciurus carolinensis*)

Amphibians:

- American toad and green frog have been recorded using emergent marsh habitat along the Fox River shoreline in 2015¹⁸

¹⁹ Wisconsin Breeding Bird Atlas II Project (2015-2019): <https://wsobirds.org/atlas>

	<p>Reptiles:</p> <ul style="list-style-type: none"> • Only one reptile has been reported using the Fox River, namely a spiny softshell turtle (<i>Apalone spinifera</i>), in 2015 though other turtles and snakes like also use the Fox River and/or adjacent terrestrial habitats <p>Arthropods:</p> <ul style="list-style-type: none"> • A few mayfly species were reported in 1998 along the Fox River¹⁸: <ul style="list-style-type: none"> ◦ E.g., <i>Hexagenia limbata</i>, <i>Baetis flavistriga</i>, <i>Labiobaetis frondalis</i>, etc. • Eight species of odonates (dragonfly/damselfly) were recorded using areas along the Fox River in 2016: <ul style="list-style-type: none"> ◦ Blue dasher (<i>Pachydiplax longipennis</i>) ◦ Blue-fronted dancer (<i>Argia apicalis</i>) ◦ Common green darner (<i>Anax junius</i>) ◦ Eastern amberwing (<i>Perithemis tenera</i>) ◦ Eastern forktail (<i>Ischnura verticalis</i>) ◦ Orange bluet (<i>Enallagma signatum</i>) ◦ Russet-tipped clubtail (<i>Stylurus plagiatus</i>) ◦ Slender spreadwing (<i>Lestes rectangularis</i>)
<p>Habitat Quality</p>	<p>Overall, the ecological quality of the entire lower bay of Green Bay and Fox River is relatively poor. The LGB&FR AOC was originally listed as a Great Lakes Area of Concern in 1988 due to poor water quality, contaminated sediments, and degraded or lost habitat.</p> <p>Qualls et al. (2013) assessed the status of the bay of Green Bay using several water quality parameters and a few other elements as described in their 2012 Green Bay Indicator Assessment from the 2013 “State of the Bay” report⁹. On a scale ranging from “poor” to “good,” elements that received a “poor” rating include total phosphorus (unchanging trend), total suspended solid (unchanging trend), Chlorophyll a (unchanging trend), water clarity (unchanging trend), toxic contaminants, aquatic invasive species (deteriorating trend), and benthic macroinvertebrates (undetermined trend)⁹. Nitrates received a “fair-good” rating with a deteriorating trend. Ammonia earned a “good” rating with an unchanging trend⁹. The lower bay also experiences summer and late fall blooms of harmful algae⁹.</p> <p>Between 1986 and 2013, NEW Water reported that the LGB&FR AOC's total phosphorus and total suspended solids were nearly always above the total maximum daily load (TMDL) targets, while water clarity (using secchi) was lower than the TMDL target²⁰.</p>
<p>Significant Invasive Species Issues</p>	<p>Invasive Plant Species: Each of these species outcompetes and crowds out native plants^{2,17}:</p> <ul style="list-style-type: none"> • Eurasian water-milfoil (<i>Myriophyllum spicatum</i>) <ul style="list-style-type: none"> ◦ Sparsely found within some of the submergent marshes • Common reed (<i>Phragmites australis</i>) <ul style="list-style-type: none"> ◦ Occurs along stretches of emergent marsh (riparian); in recent years, 0.51 ha (1.25 ac) in the emergent marsh (riparian) located at Ashwaubomay Memorial Park was treated⁴⁴ <p>Invasive Animal Species:</p> <ul style="list-style-type: none"> • <i>Fish</i>¹⁸ – These fish species have been reported in the pelagic zone of the lower bay:

²⁰ NEW Water: Report on Water Quality for Lower Green Bay Fox River and East River for Field Year 2013: http://newwater.us/media/167545/Annual-Report-2013_Final-Draft_11-17-16.pdf

	<ul style="list-style-type: none"> ○ Alewife (<i>Alosa pseudoharengus</i>)²¹ <ul style="list-style-type: none"> ▪ Poses a threat to native fish species by consuming zooplankton and disturbing the natural food web; not currently being managed ○ Common carp (<i>Cyprinus carpio</i>)²² <ul style="list-style-type: none"> ▪ Destroy vegetation by uprooting plants and increasing cloudiness of water; not currently being managed ○ Rainbow smelt (<i>Osmerus mordax</i>)²³ <ul style="list-style-type: none"> ▪ Negatively affect uncommon to rare native fish species; not currently being managed ○ Round goby (<i>Neogobius melanostomus</i>)²⁴ <ul style="list-style-type: none"> ▪ Prey on small native fish and eggs (e.g., darters) and outcompete similarly sized native fish; not currently being managed ○ White perch (<i>Morone americana</i>)²⁵ <ul style="list-style-type: none"> ▪ Prey on native fish eggs, such as walleye; not currently being managed • <i>Birds</i> <ul style="list-style-type: none"> ○ House Sparrow (<i>Passer domesticus</i>) <ul style="list-style-type: none"> ▪ May pose a small threat to some native species by outcompeting them for food; tend to inhabit developed areas; not currently being managed ○ European Starling (<i>Sturnus vulgaris</i>) <ul style="list-style-type: none"> ▪ Poses some threat to native species, particularly cavity nesters (e.g., Tree Swallow), by outcompeting them and occupying potential nest sites; not currently being managed ○ Brown-headed Cowbird (<i>Molothrus ater</i>) <ul style="list-style-type: none"> ▪ Poses threat to some native species because they lay eggs in native bird species' nests through brood parasitism. ○ The exotic species, Rock Pigeon (<i>Columba livia</i>), generally does not significantly affect native birds because they tend to inhabit human areas (e.g., developed or agricultural areas) where natives do not frequently nest (e.g., on ledge under bridge or overpass).
Management and Restoration Recommendations	<ul style="list-style-type: none"> • Use The Nature Conservancy's fish passage GIS tool to identify and remove barriers that, if removed, would provide access to potential spawning areas. • Improve substrate (including gravel, riffles, and pool habitat) and reduce sediment pollution. • Remove unwanted debris and reduce invasive species in backwater channel located under Leo Frigo Bridge on east side of Fox River. • Explore opportunities for creating backwater habitats in vicinity of De Pere Dam and possibly Ashwaubomay Park, National Railroad Museum, and St. Francis Park.

²¹ Fuller, P., E. Maynard, D. Raikow, J. Larson, A. Fusaro, and M. Neilson. 2016. *Alosa pseudoharengus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. <https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=490> Revision Date: 9/25/2015. Accessed 17 Oct 2016.

²² Nico, L., E. Maynard, P.J. Schofield, M. Cannister, J. Larson, A. Fusaro, and M. Neilson. 2016. *Cyprinus carpio*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. <https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=4> Revision Date: 7/15/2015. Accessed 17 Oct 2016.

²³ Fuller, P., E. Maynard, J. Larson, A. Fusaro, T.H. Makled, and M. Neilson. 2016. *Osmerus mordax*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. <https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=796> Revision Date: 9/29/2015. Accessed on 17 Oct 2016.

²⁴ Fuller, P., A. Benson, E. Maynard, M. Neilson, J. Larson, and A. Fusaro. 2016. *Neogobius melanostomus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. <https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=713> Revision Date: 1/7/2016. Accessed on 17 Oct 2016.

²⁵ Fuller, P., E. Maynard, D. Raikow, J. Larson, A. Fusaro, and M. Neilson. 2016. *Morone americana*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. <https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=777> Revision Date: 1/15/2016. Accessed on 17 Oct 2016.

	<ul style="list-style-type: none"> • Evaluate the possibility of creating islands in the Fox River to provide fish and wildlife habitat. • Map and subsequently improve benthic substrate in vicinity of the De Pere Dam. • Protect or restore backwater habitats near mouth of Fox River, Ashwaubenon Creek, and Dutchman’s Creek. • Establish multiple rock/gravel reefs at other sites in Fox River. • Protect and enhance riparian habitats in parts of the East River. • Reduce magnitude of storm surges (flashiness) by creating or maintaining upstream vegetation buffers and mitigating inputs from stormwater drainages. • Stabilize falling banks to reduce sediment movement and protect habitat. • Implement Upper Fox, Wolf, and Lower Fox basin TMDLs. • Develop or restore important fish spawning and nursery habitats, such as rocky reefs, gravel, cobble, woody debris, and sandy areas for shoreline fish. • Control invasive plants (e.g., <i>Phragmites</i>, Eurasian water-milfoil). • Promote best management practices and innovative nutrient management measures in Fox River watershed. • Reduce unimpeded flow of toxins, nutrients, and sediments from urban/suburban storm water discharge pipes. • Implement effective non-point source pollution management plans in smaller watersheds and drainages.
<p>Reference Links and Documents</p>	<p>Web Links:</p> <ul style="list-style-type: none"> • Fox River PCB Clean-up Project: http://foxrivercleanup.com/ • Fox 11 video on Green Bay poor water quality (including interview with Dr. Val Klump): <ul style="list-style-type: none"> ◦ http://fox11online.com/news/fox-11-investigates/fox-11-investigates-poor-water-quality-plauing-green-bay • NEW Water’s Aquatic Monitoring Program: http://newwater.us/programs-initiatives/aquatic-monitoring-program/ • WDNR’s Surface Water Data Viewer: https://dnrgis.wi.gov/H5/?Viewer=SWDV • NOAA’s Lake Level Viewer: https://coast.noaa.gov/digitalcoast/tools/llv.html • TMDL and Watershed Management Plan for Total Phosphorus and Total Suspended Solids in the Lower Fox River Basin and Lower Green Bay: http://www.uwgb.edu/watershed/REPORTS/Related_reports/TMDLs/LFR_TMDL_EPA_Submittal_Aug_2011.PDF • “Dead zones haunt Green Bay as manure fuels algae blooms” (article by the <i>Journal Sentinel</i>): http://archive.jsonline.com/news/wisconsin/dead-zones-haunt-green-bay-as-manure-fuels-algae-blooms-die-offs-b99344902z1-274684741.html/ • Lower Fox Demonstration Farms Network: implementing farming best management practices in the lower Fox River watershed: https://fyi.uwex.edu/foxdemofarms/about-us/where-we-work/ • Nonpoint Source Control Plan for the Duck, Apple, and Ashwaubenon Creeks Priority Watershed Project: http://dnr.wi.gov/topic/nonpoint/documents/9kep/Duck_Apple_Ashwaubenon Creeks-Plan.pdf • 1845 Map of Green Bay: http://s3.amazonaws.com/labaye/data/1845%20Head%20Of%20Green%20Bay.pdf • WDNR Fisheries Biologists: http://dnr.wi.gov/topic/fishing/people/fisheriesbiologists.html • U.S. Fish and Wildlife Service Fisheries Programs: https://www.fws.gov/midwest/greenbayfisheries/programs.html

	<p>Reference Documents:</p> <ul style="list-style-type: none"> • Cedillo, P.E. 2015. Hydrodynamic Modeling of the Green Bay of Lake Michigan Using the Environmental Fluid Dynamics Code. UW-Milwaukee Master's Thesis. Major Advisor: Dr. Hector Bravo. <ul style="list-style-type: none"> ◦ https://dc.uwm.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=2047&context=etd • Chow-Fraser P. 2006. Development of the wetland Water Quality Index for assessing the quality of Great Lakes coastal wetlands. In: Simon TP, Stewart PM (eds) Coastal wetlands of the Laurentian Great Lakes: health, habitat and indicators. Indiana Biological Survey, Bloomington, IN, pp 137-166. • Hamidi, S.A., H.R. Bravo, J.V. Klump, and J.T. Waples. 2015. The role of circulation and heat fluxes in the formation of stratification leading to hypoxia in Green Bay, Lake Michigan. <i>Journal of Great Lakes Research</i> 41:1024-1036. • Klump, J.V., D.N. Edgington, P.E. Sager, and D.M. Robertson. 1997. Sedimentary phosphorus cycling and a phosphorus mass balance for the Green Bay (Lake Michigan) ecosystem. <i>Canadian Journal of Fisheries and Aquatic Sciences</i> 54:10-26. • Qualls, T., H.J. Harris, and V. Harris. 2013. The State of the Bay: The Condition of Green Bay/Lake Michigan 2013. University of Wisconsin Sea Grant Institute. • Wisconsin Department of Natural Resources. 2014. Green Bay Planning Group Master Plan. Technical Report PUB-LF-075.
<p>Site History (e.g., original vegetation, past conservation projects)</p>	<p>In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes²⁶. Lower Green Bay consisted of large beds of wild rice (<i>Zizania</i> sp.) and wild celery (<i>Vallisneria americana</i>), extensive emergent marsh (<i>Schoenoplectus</i> sp., cattail), sedge meadows (<i>Calamagrostis canadensis</i>), shrub carr (e.g., <i>Cornus</i> spp., <i>Salix</i> spp.), swamps, and wet conifer forest (black spruce [<i>Picea mariana</i>], balsam fir [<i>Abies balsamea</i>])^{27,28,29,30,31}. Between the late 1600s and 1800s, European fur trade, duck hunting, fishing, logging, shipping, and agriculture were important early industries in lower Green Bay^{32,33,34}. In the early 1800s, there were a few small settlements and farms of Europeans and Native Americans in the lower Bay³³. Similar to the fur trade and logging, commercial fishing was an important industry in Green Bay, in which most fishermen primarily harvested whitefish, lake trout, and lake herring^{9,35}. Other fish caught in Brown County in 1888 included perch, pike pickerel, suckers, catfish, muskellunge, and many others^{9,36}. Unfortunately, overfishing and other significant anthropogenic changes, such as water pollution caused by the paper industry, led to the decline of many fish species^{9,35}.</p>

²⁶ Jean Nicolet: French Explorer. By The Editors of Encyclopaedia Britannica. Available: <https://www.britannica.com/biography/Jean-Nicolet> (accessed on 24 Oct 2016).

²⁷ Arthur C. Neville's Map of Historic Sites on Green Bay, Wisconsin 1669-1689. Available: <http://s3.amazonaws.com/labaye/data/Bay%20Settlement%20Map%20WI%20Historical%20Bulletin%201926.pdf> (accessed on 24 Oct 2016).

²⁸ Survey of the N.W. Lakes: East Shore of Green Bay 1843. Available: <http://s3.amazonaws.com/labaye/data/1843%20East%20Shore%20of%20Green%20Bay.jpg> (accessed on 24 Oct 2016).

²⁹ 1845 Chart of Green Bay. Available: <http://s3.amazonaws.com/labaye/data/1845%20Chart%20of%20Green%20Bay.pdf> (accessed on 24 Oct 2016).

³⁰ 1820s Fox River Military Road Map to Ft. Crawford. Available: <http://s3.amazonaws.com/labaye/data/1820s%20Fox%20River%20Military%20Road%20Map%20to%20Ft.%20Crawford.pdf> (accessed on 24 Oct 2016).

³¹ UW-Green Bay personal communication with Thomas Erdman.

³² City of Green Bay's History Webpage: <http://www.ci.green-bay.wi.us/history/1800s.html> (accessed on 20 Oct 2016).

³³ Excerpt from "Recollections of Green Bay in 1816-17" by James W. Biddle. Available: <http://s3.amazonaws.com/labaye/data/Recollections%20of%20Green%20Bay%20in%201816-1817.pdf> (accessed on 24 Oct 2016).

³⁴ The Early Outposts of Wisconsin: Green Bay for Two-Hundred Years, 1639-1839. Available: <http://labaye.org/item/70/2810> (accessed on 25 Oct 2016).

³⁵ Qualls et al. (2013) cited Kraft, C. 1982. Green Bay's Yellow Perch Fishery. Wisconsin Sea Grant Publication. WIS. SG.82-725.

³⁶ Qualls et al. (2013) cited Smith, H.M. & M.M Snell. 1891. Review of the fisheries of the Great Lakes in 1885. U.S. Commission of Fish & Fisheries.

	<p>Historically, the mouth of the Fox River consisted of extensive meadows and marshes, though even wild rice was found along the Fox River^{7,29,37}. Sauk Native Americans lived near the mouth of the Fox River until 1733, at which point they moved south (fact from Neville Public Museum)⁷. Villages, campsites, and burial sites occurred along the Fox River from both the Sauk and Fox Native American Tribes⁷. Upland, riparian vegetation along the lower Fox River consisted of beech (<i>Fagus</i> sp.), maple (<i>Acer</i> sp.), basswood (<i>Tilia</i> sp.), and oak (<i>Quercus</i> sp.)⁷. Between the present day De Pere Dam and the Mason Street bridge, there used to be extensive emergent marsh vegetation. In fact, this vegetation is visible on the 1938 Brown County air photo, especially the large, open section of water on the western side of the Fox River by the De Pere Dam. This area contained submergent marsh and cattail (<i>Typha</i> sp.) beds, including floating mats, which were heavily used by fish and nesting birds (e.g., Least Bittern [<i>Ixobrychus exilis</i>], Blue-winged Teal [<i>Anas discors</i>], Marsh Wren [<i>Cistothorus palustris</i>], rails)³¹. These emergent marshes along the Fox River are still visible in the 1960 Brown County air photo. This area also provided important migratory bird stopover habitat³¹.</p> <p>Because of extensive shallow areas in the lower bay and miles-long sand bars, ship navigation was extremely challenging and in some cases nearly impossible³⁸. Therefore, in an effort to improve Green Bay shipping access and navigation, Congress provided \$30,500 in funding in 1866 to construct a shipping channel 60.96 m (200 ft) wide and 3.66 m (12 ft) deep that traverses through Grassy Island and in between Longtail Point and the western edge of Point Sable Bar/Frying Pan Shoal^{38,39}. Construction began in May the following year and was quickly finished by September 1867³⁸. Over the next several decades, the channel was widened and made deeper: June 1896: increased depth to 4.57 m (15 ft); June 1902: increased depth to 5.49 m (18 ft) in the northern channel; June 1910: created a ship turning area that was 4.57 m (15 ft) deep; September 1902: increased depth to 6.10 m (20 ft) in northern channel; March 1925: increased depth of southern channel to 5.49 m (18 ft); and January 1927: increased northern channel depth to 6.40 m (21 ft)³⁸. By the early 1930s, the channel was widened again and increased depth to 6.71 m (22 ft)³⁸. Today, the main channel in the bay is anywhere between 7.32 m (24 ft) and 7.92 m (26 ft) and around 152.4 m (500 ft) wide.</p> <p>Over the past several decades, the entire bay of Green Bay has been heavily studied by scientists from agencies, non-profit organizations, universities, and other organizations. The amount of knowledge accrued is significant. Summary of relatively recent projects:</p> <ul style="list-style-type: none"> • The U.S. Fish and Wildlife Service coordinates an early detection and monitoring program of aquatic invasive species in Lake Michigan, and many of their sampling locations are in the LGB&FR AOC, including sites in the Fox River⁴⁰. They survey for ichthyoplankton, carp, macroinvertebrates, and nearshore fishes⁴⁰. In the Fox River, they also conduct larval Coregonid surveys (i.e., whitefishes)⁴⁰. • NEW Water leads a long-term aquatic monitoring program with multiple sampling locations within the LGB&FR AOC as well as other parts of the bay of Green Bay and Fox River. They collect data on water temperature, dissolved oxygen, pH, phosphorus, nitrogen, turbidity, total suspended solids, and many others⁴¹. • WDNR juvenile whitefish assessments and lake sturgeon sampling in the Fox River⁴³. • WDNR walleye and musky management by Steve Hogler, Rod Lange, and Steve Surendonk⁴³. • WDNR Lower Fox River IBI Surveys between the De Pere Dam and the bay (2015)⁴³.
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³⁷ Original 1800s PLSS Surveys: converted from tier/range/sections into transects by Ellie Roark

³⁸ *Green Bay Press Gazette* article from 1934 on increasing the depth of the Green Bay shipping channel; available in David A. Cofrin Library's Special Collections

³⁹ U.S. Army Corps of Engineers Map of the shipping channel from 1898 and 1898; provided by Tom Erdman

⁴⁰ Green Bay Fish Working Group Annual Meetings on 20 March 2015, 6 January 2016, and 4 January 2017

⁴¹ NEW Water Aquatic Monitoring Program: <http://newwater.us/programs-initiatives/aquatic-monitoring-program/>

	<ul style="list-style-type: none"> • WDNR musky spawning surveys on the Fox River. • Since the early 2000s, the Fox River Cleanup Project has been working to dredge up historic polychlorinated biphenyls (PCB) in 20.92 km (13 mi) that are found in Fox River sediment⁸. • Brown County's young-of-the-year northern pike surveys in Ashwaubenon Creek, Dutchman Creek, and the East River (Chuck Larscheid)⁴⁴. • WDNR Fox River Fish Index Surveys (fall) for walleye recruitment between the De Pere Dam and the bay, since 1987, led by Steve Hogler⁴³. • In 2014-2016, UW-Milwaukee's Dr. Jerry Kaster and graduate student Christopher Groff released 120 million eggs of <i>Hexagenia</i> (mayfly) into the bay of Green Bay in an attempt to reintroduce mayflies into the Green Bay ecosystem. In 2016, adult exuviae were found in 2016 at Longtail Point, Little Tail Point, and Sturgeon Bay⁴⁰. • In the fall of 2017, the UW-Green Bay's Cofrin Center for Biodiversity's (CCB) Dr. Amy Wolf, Dr. James Horn, and Dr. Robert Howe mapped submerged aquatic plant beds throughout the LGB&FR AOC¹⁷. • The Nature Conservancy is currently leading an effort to identify fish passage barriers in the LGB&FR AOC and other areas. • In 2016-2017, under the guidance of CCB's Dr. Howe, Dr. Wolf, and Erin Giese, Tom Prestby surveyed migratory waterfowl within the LGB&FR AOC and mapped rafts. Within the Fox River, one survey location is at the mouth of the Fox River and the other is at the De Pere Dam. • Multiple locations along the Fox River were surveyed for birds and anurans in 2015 as a part of a larger effort in the LGB&FR AOC; surveys coordinated by CCB's Erin Giese, Dr. Howe, and Dr. Wolf. • Fox River walleye habitat improvement projects at Voyageur Park, Brown County Fairgrounds, and Fox Point Marina on the Fox River, 1986-1994⁴³. • <i>Phragmites</i> management at Ashwaubomay Memorial River Park⁴⁴. • Lower Fox River Basin Integrated Management Plan, 2011⁴³. • Lower Fox River Volunteer TMDL Monitoring at Dutchman Creek, Ashwaubenon Creek, and the East River and a targeted watershed assessment (WDNR, 2015). • Dr. Val Klump has spent a significant part of his career studying Green Bay water quality issues. <ul style="list-style-type: none"> ○ http://waterbase.uwm.edu/docs/Klump_Fermanich_2017_FinalReport_NA10NOS4780139_26Jan2017.pdf • Recently, FWS' Steve Choy has led a project aimed to draft up habitat restoration designs in the Fox River near the De Pere Dam. • Glacierland RC&D (2013-2016) investigated phosphorus reductions through grass-based farming and managed grazing⁴³. • The U.S. Environmental Protection Agency conducted a PCB transport study in the Fox River in 1995. • UW-Green Bay graduate student, Tony Rieth, and his major advisor, Dr. John Stoll, conducted an economic feasibility study of agricultural land conversion to switchgrass in the lower Fox River watershed⁴³. • UW-Extension is leading the Lower Fox Demonstration Farms Project, whose goal is to implement agricultural best management practices to reduce nutrient runoff that is carried into the Fox River and ultimately the lower bay⁴². • The Northeast Wisconsin Land Trust's Green Bay and Lower Fox Project, which involves identifying high priority land parcels that could potentially improve water quality through conservation easements, etc.⁴³. • Green Bay Ecosystem Modeling, UW-Extension's Chad Cook⁴³. • Management Analysis Tool, which looks at how climate and landscape conservation can impact Green Bay water quality (Dr. Kevin Fermanich)⁴³. • WPS coal cleanup near the mouth of the East River⁴⁴.
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⁴² Lower Fox Demonstration Farms Network: <https://fyi.uwex.edu/foxdemofarms/about-us/where-we-work/>

⁴³ AOC Conservation Project Catalogue.

⁴⁴ LGB&FR AOC Stakeholder's Meeting in June 2015.

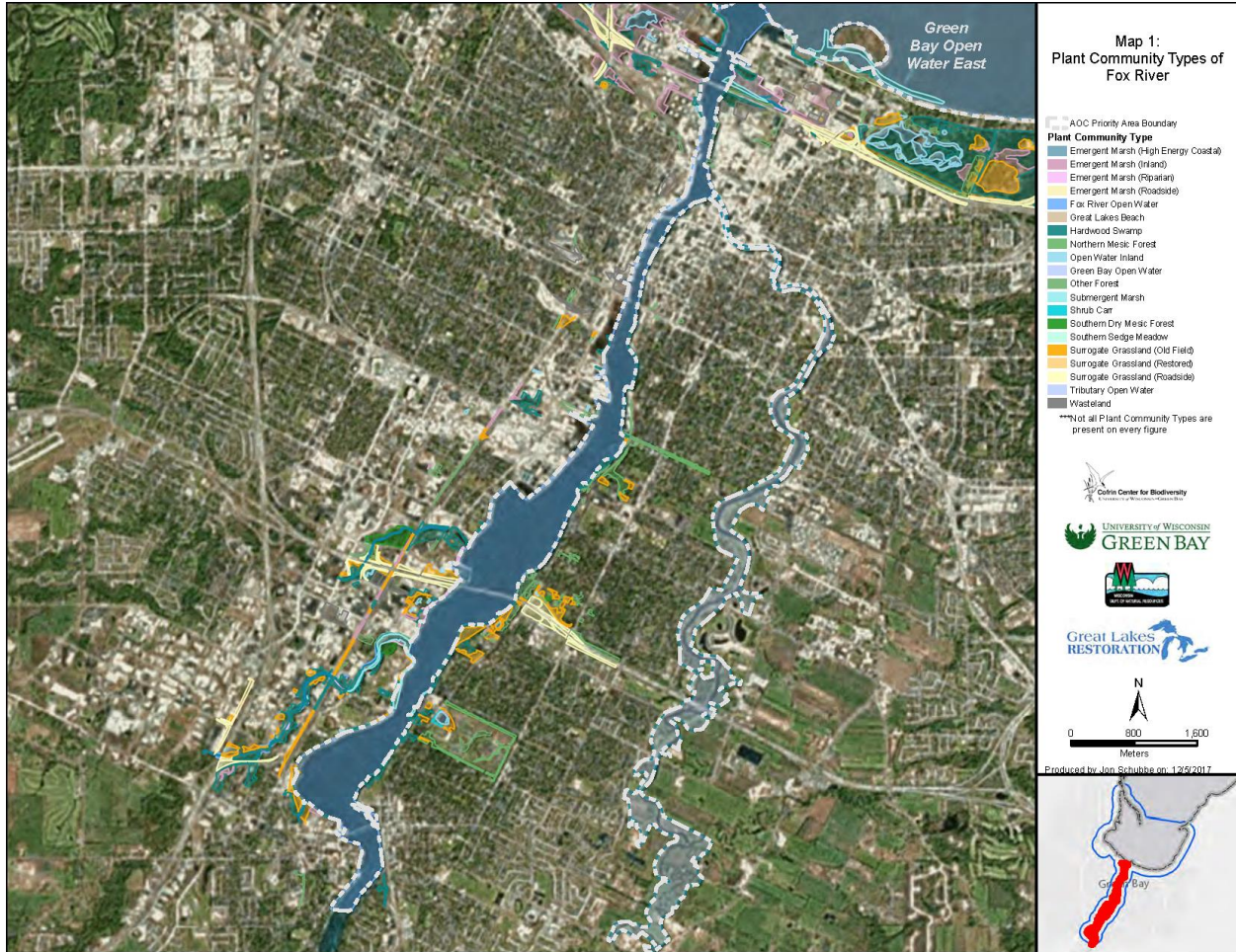
	<p>The Fox River provides significant and in most cases rather critical habitat for many fish species, odonates, waterfowl, waterbirds, bats, anurans, and reptiles. Water quality is relatively poor due to high nutrient and sediment loadings in the Fox River and pollution. Like other bodies of water, the bay and Fox River have experienced (and in some cases still experience) harmful algal blooms, fish kills, and avian botulism^{9,45,46,47}. However, despite the poor water quality, other structural improvements, restoration efforts, and in some cases monitoring and species re-introduction are needed in the bay and the Fox River. Restoration of shoreline fish spawning and nursery habitats, such as rocky reefs, gravel, cobble, woody debris, and sandy areas, are needed. Backwater habitats near mouth of Fox River, Ashwaubenon Creek, and Dutchman's Creek should be protected or restored. Efforts should continue to be made to re-introduce <i>Hexagenia</i> in the bay. To improve water quality, implementing best management practices for agriculture and TMDLs for the Upper Fox, Wolf, and Lower Fox basins will be necessary.</p> <p>There is no doubt that a significant amount of work is needed in the bay and the Fox River, however, thankfully there is a large cohort of scientists, biologists, policy makers, land managers, and concerned citizens actively seeking ways to improve the Green Bay ecosystem.</p>
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⁴⁵ Silliman et al. 2001: "A hypothesis for the origin of perylene based on its low abundance in sediments of Green Bay, Wisconsin"

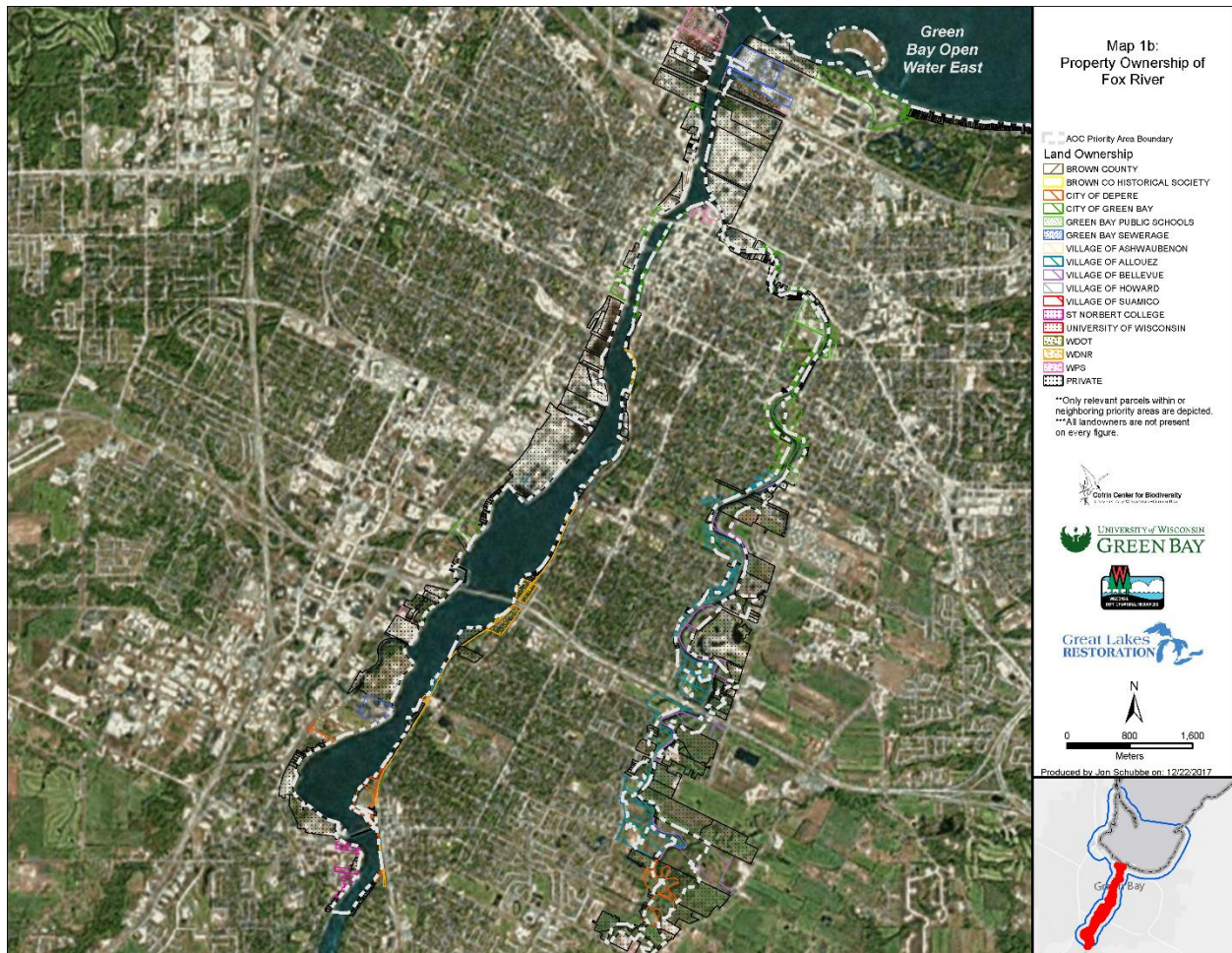
⁴⁶ Smith et al. 1988: "Estuary Rehabilitation: The Green Bay Story"

⁴⁷ Brand et al. 1983: "Waterbird mortality from botulism type E in Lake Michigan: an update"

Map of Fox River plant communities, which are delineated based on the UW-Green Bay 2015 habitat mapping effort and 2017 submerged aquatic vegetation surveys. Map made by UW-Green Bay's Jon Schubbe.



Map of land ownership for the Fox River. Map made by UW-Green Bay's Jon Schubbe.



Photograph of the Fox River facing the De Pere Dam (back), Abbey Pond (left), and Ashwaubomay Memorial River Park (center). Photograph taken by Erin Giese on 2 December 2016 facing southwest.



Photograph of the mouth of the Fox River facing the Leo Frigo Bridge (center) and Renard Island (left). Photograph taken by Erin Giese on 2 December 2016 facing east/southeast.



Photograph of the Fox River facing the Mason Street Bridge (left) and railroad crossing (right/central). Photograph taken by Erin Giese on 2 December 2016 facing southeast.



Photograph of the Fox River south of the De Pere Dam in Little Rapids facing the Lost Dauphin Park (bottom). Photograph taken by Erin Giese on 2 December 2016 facing south.

