East Shore Lower Green Bay Watershed Plan

Wequiock Creek, Mahon Creek, and Bay Shore Watersheds

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Prepared by

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We at the University of Wisconsin-Green Bay, City of Green Bay, Town of Scott, Town of Humboldt, and Brown County acknowledge the First Nations people who are the original inhabitants of the region. The Ho-Chunk (Hoocąk) Nation and the Menominee (Kāēyās maceqtawak) Indian Tribe of Wisconsin are the original First People of Wisconsin, and both Nations have ancient historical and spiritual connections to the land that our UW-Green Bay institution now resides upon.

Today, Wisconsin is home to 12 First Nations communities including the Oneida Nation of Wisconsin (Onʌyoteˀa·ká), Forest County Potawatomi (Bodwéwadmi), Ojibwe (Anishinaabe) Nation communities, Stockbridge (Moheconnew)-Munsee (Lunaapeew) Band of the Mohicans, and the Brothertown Indian Nation.

The watersheds we work in contain lands that are important to First Nations People of Wisconsin. We acknowledge the First Nations People of Wisconsin.

1. Introduction

1.1 Watershed Setting

Mahon and Wequiock Creeks and the small drainage between them, known as the Bay Shore watershed, empty directly into lower Green Bay (Figure 1). Collectively, the watersheds are referred to by the Wisconsin Department of Natural Resources (WDNR) as the East Shore of the Lower Green Bay or officially, "Point du Sable-Frontal Green Bay watershed" and are located in Brown County, spanning three municipal boundaries: the City of Green Bay, Town of Scott, and Town of Humboldt (see Figure 1). The HUC 12 is 040302040401. We will refer to the watershed as "East Shore Lower Green Bay" or "East Shore watershed" in this plan.

Authors' Note:
Wequiock and Mahon Creek watersheds have differing characteristics and challenges. The Wequiock Creek watershed is dominated by agricultural land use, while the Mahon Creek watershed is mostly suburban. Any aspects of this plan that may fail to distinguish these differences are unintentional.

Mahon Creek is approximately 3 mi (4.8 km) long, beginning south of Highway 57 and emptying into the bay of Green Bay. This watershed drains a total area of approximately 3.7 mi^2 (9.6 km^2). The lower one-third of the creek passes through a 25-ac (10.1 ha) riparian corridor, Mahon Woods, in the Cofrin Memorial Arboretum on the University of Wisconsin-Green Bay campus.

Wequiock Creek is approximately 8.5 mi (13.7 km) long, with several branches, and drains a total area of approximately 13.8 mi^2 (35.8 km^2). Wequiock Creek flows through a mostly agricultural and rural landscape. An expansive wetland complex, Point au Sable Natural Area, exists at the mouth of Wequiock Creek, before it empties into the bay of Green Bay. The Niagara Escarpment extends through the middle of the entire Lower East Shore watershed (Figure 1), creating dramatic topography including Wequiock Falls on Wequiock Creek.

The Bay Shore watershed is a series of short (0.5-0.75 mi [=0.8-1.2 km]) unnamed drainages, extending through agricultural, residential, and the UW-Green Bay campus, all west of the escarpment and draining directly into the bay of Green Bay. The total drainage of this watershed is approximately 3.8 mi^2 (9.9 km^2).

1.2 Purpose

The Mahon and Wequiock watersheds are not unique in that all of us living and working here desire clean water. What is less well known is that these watersheds flow directly into lower Green Bay and contain some of the most important wildlife habitat on the east shore of Green Bay (Howe et al. 2018). The lower bay has been severely impacted by excess nutrient and sediment inputs, and, in 2012, the US Environmental Protection Agency (EPA) approved the **Total Maximum Daily Load and Watershed Management Plan for Total Phosphorus and Total Suspended Solids in the Lower Fox River Basin and Lower Green Bay (TMDL)**.

The purpose of this project is to develop an implementation plan for the East Shore of the Lower Green Bay watershed to meet the requirements of the TMDL that is embraced by the community.

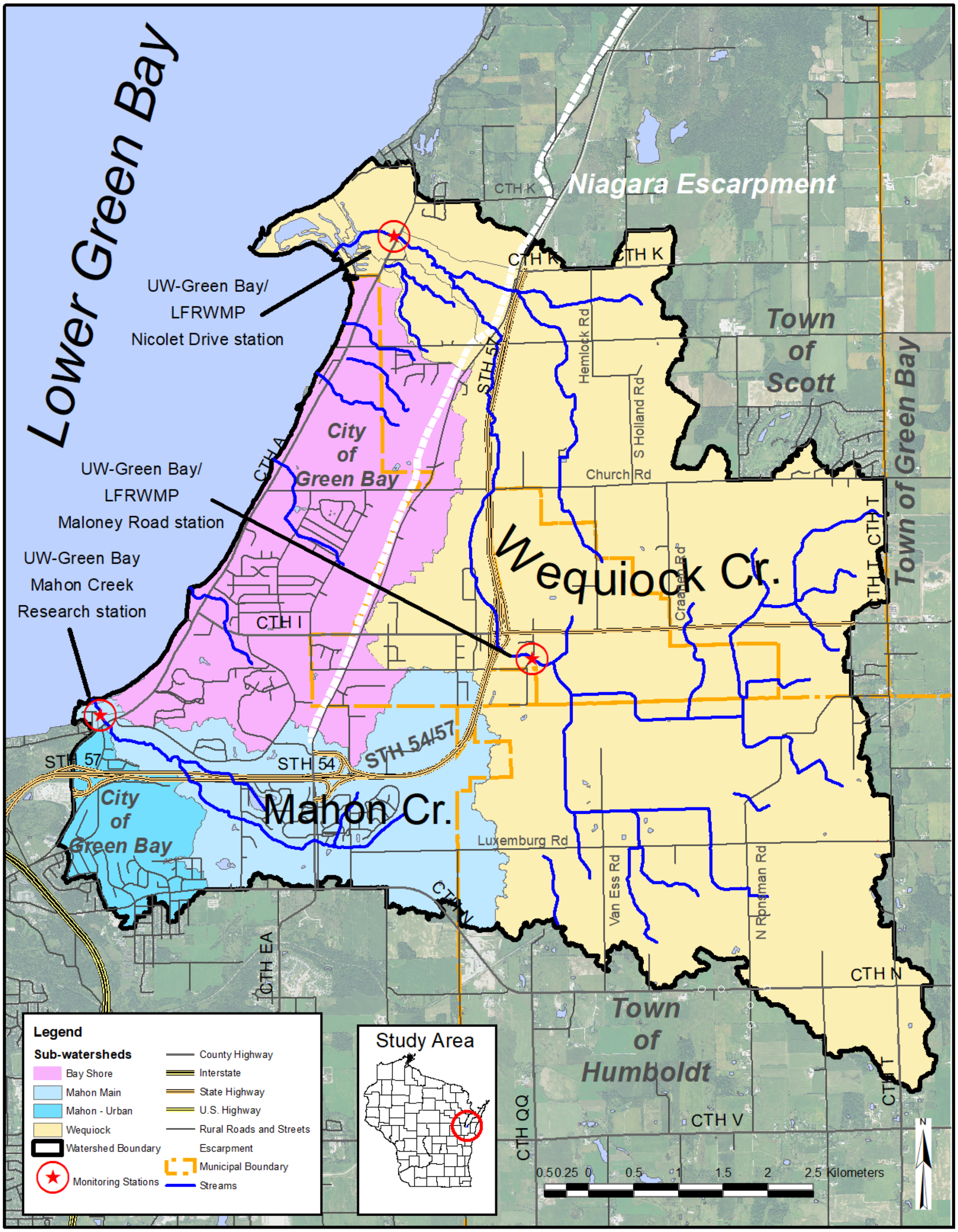

Figure 1. East Shore watersheds, municipalities, and other key landmarks.

1.3 U.S. EPA Watershed Plan Requirements

In 1987, Congress enacted Section 319 of the Clean Water Act, which established a national program to control non-point sources of water pollution. Section 319 grant funding is available to states, tribes, and territories for the restoration of impaired waters and to protect unimpaired/high quality waters. Watershed plans funded by Clean Water Act section 319 funds must address nine key elements that the EPA has identified as critical for achieving improvements in water quality (US EPA 2008). The nine elements from the EPA Nonpoint Source Program and Grants Guidelines for States and Territories are as follows:

1. Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions and any other goals identified in the watershed plan. Sources that need to be controlled should be identified at the significant subcategory level along with estimates of the extent to which they are present in the watershed.

2. An estimate of the load reductions expected from management measures.

3. A description of the nonpoint source management measures that will need to be implemented to achieve load reductions in element 2, and a description of the critical areas in which those measures will be needed to implement this plan.

4. Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.

5. An information and education component used to enhance public understanding of the plan and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.

6. Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.

7. A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.

8. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.

9. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under element 8.

Lower East Shore ahead of schedule

The Wequiock and Mahon Creek watersheds themselves are not designated as impaired waters under Section 319. However, since they are part of the Lower Fox TMDL, these watersheds were slated to receive a 9 Key element plan in 2023. Because of community engagement and momentum of recent community watershed monitoring efforts, the partners and involved communities decided to move forward ahead of the WDNR's schedule and create this plan in 2020-2021.

1.3.a Load Reductions Needed

The Lower Fox River Basin and Lower Green Bay TMDL requires that any tributaries to the Lower Fox River meet a median summer total phosphorus (TP) limit of 0.075 mg/L or less. A median total suspended solids (TSS) limit has not been determined for tributaries but is set at 18 mg/L for the outlet of the Fox River. The Lower Fox River and Lower Green Bay TMDL calls for a 56.3% reduction of TP and 54.0% reduction of TSS from the East Shore Lower Green Bay Watershed. These are based on separating the E/W shore watersheds, and then deriving the Load Allocations/Reductions.

See Appendix D for more explanation of how the allocations and reductions were derived. For additional information visit Lower Fox River Basin TMDL.

This watershed plan is a guide for the approaches and techniques that will be used over a 10-year period to reduce the levels of phosphorus and sediment entering Lower Green Bay through Mahon and Wequiock Creeks and the small unnamed tributaries in between them. This will be a cooperative and collaborative effort between community members, farmers, homeowners, land managers, state and local government, and others.

1.4 Prior Studies, Projects, and Existing Resource Management and Comprehensive Plans

Dozens of studies and resource management plans have been completed for the region that describe and analyze resources and conditions in the area, which is an indication of the importance of our watershed. These studies and plans are valuable and relevant but providing descriptions would be lengthy. Therefore, we have listed only the titles of key plans below. Please follow the links in the plan titles to learn more about these efforts and how they have set the foundation for this watershed plan.

Plan Title	Year
Lake Michigan Lakewide Management Plan	2008
Total Maximum Daily Load & Watershed Plan for Total Phosphorus and Total Suspended Solids in the Lower Fox River Basin and Lower Green Bay	2012
The State of the Bay: The Condition of the Bay of Green Bay/Lake Michigan 2013	2013
Town of Humboldt Comprehensive Plan	2013
Brown County Land and Water Resources Plan	2016
Town of Scott Comprehensive Plan	2017
Town of Scott Stormwater Ordinance	2017
Lower Green Bay and Fox River Area of Concern Fish and Wildlife Habitat Assessment - Wildlife Habitat and Water Quality Opportunities (The Nature Conservancy)	2018
Lower Green Bay and Fox River Area of Concern Habitat Restoration Plan and Path Toward Delisting Project (University of Wisconsin-Green Bay)	2018
Lower Green Bay Remedial Action Plan 1993-2019	2019
Evaluating Progress Toward Removing Fish and Wildlife Habitat and Populations Beneficial Use Impairments in the Lower Green Bay and Fox River Area of Concern	2020

1.5 Climate Change

In developing a community-based strategy to reduce nutrient and sediment loading in the East Shore of Lower Green Bay watershed, the impacts of our changing climate are important to acknowledge. The Wisconsin Initiative on Climate Change Impacts (WICCI) has projected the following changes to occur by 2055:

- winter precipitation to increase by approximately 1 in (2.5 cm),
- winter average temperature to increase by 7.5°F (4.2°C),
- summer average temperature to increase by 4.5°F (2.5°C),
- frequency of 2-in (5.1 cm) precipitation events (days/decade) will increase by 2½ days per year.

"In the absence of appropriate adaptation actions, we expect that soil erosion in Wisconsin will more than double by 2050, compared with the 1990s, as a result of predicted changes in hydro-climate". WICCI

The impact of future climate change on water quality has been simulated in the 6,250 mi^2 (16,200 km^2) Fox-Wolf basin, which includes the East Shore watershed. Two scenarios were modeled to capture a reasonable range of the projected change in air temperature: a) second largest increase in summer temperature, and b) the second smallest increase in summer temperature. An 8.2% to 9.6% increase in TP, and a 17% to 26% increase in TSS export to lower Green Bay were simulated for these two modeled scenarios by a mid-21st century (2046-2065) projected climate period (Klump and Fermanich 2017).

As we work together toward reducing soil erosion, excessive runoff, and the resulting impacts on aquatic ecosystems, the additional challenges presented by a changing climate will likely require greater focus on implementation and maintenance of both structural (terraces, grassed waterways) and non-structural (conservation tillage) soil conservation practices.

1.6 Land Use/Land Cover

Land cover in the Wequiock (11.7 mi^2 [=30.4 km^2]) and neighboring Mahon Creek (2.7 mi^2 [=6.9 km^2]) and Bay Shore (3.9 mi^2 [=10.1 km^2]) watersheds are shown in Table 1 and Figure 2 (sub-watershed boundaries demarked in Figure 1). The land cover data are based on the WDNR WISCLAND-2 imagery, as published in September 2016 (classification based on Landsat 2010 to 2014 satellite images and other sources). Because parts of these sub-watersheds are located within the Great Lakes coastal zone, the amount of open water and emergent/wet meadow, in particular, can vary drastically both within and across years due to changing Great Lakes water levels. WISCLAND-2 is based on imagery collected in 2010-2014 when Great Lakes water levels were low, including a historic low recorded in 2013. Lake levels rose shortly thereafter and have reached historic high levels in 2020. Nearly the entire peninsula of Pt. au Sable, for example, was reported as completely flooded with losses of emergent marsh in the lagoon and near the mouth of Wequiock Creek in summer 2020.

Table 1. Land cover in the Wequiock, Mahon, and Bay Shore watersheds based on the Level 2 classification of the Wisconsin Department of Natural Resources 2016 WISCLAND-2 land cover image (Figure 2).

Level 2 Land Cover Classification	Wequiock	Mahon	Bay Shore	Total
Developed, High Intensity	0.97%	4.43%	3.58%	2.04%
Developed, Low Intensity	8.05%	35.41%	38.37%	18.24%
Crop Rotation	58.49%	27.35%	29.12%	47.82%
Forage Grassland	9.59%	7.79%	13.11%	9.91%
Idle Grassland	1.16%	2.86%	2.39%	1.68%
Coniferous Forest	0.34%	1.91%	0.46%	0.63%
Broad-leaved Deciduous Forest	3.94%	8.23%	10.24%	5.81%
Open Water	0.07%	0.74%	0.89%	0.33%
Emergent/Wet Meadow	3.40%	2.24%	0.08%	2.60%
Lowland Scrub/Shrub	0.08%	0.07%	0.00%	0.06%
Forested Wetland	13.82%	8.98%	1.75%	10.81%
Barren	0.10%	0.00%	0.00%	0.06%

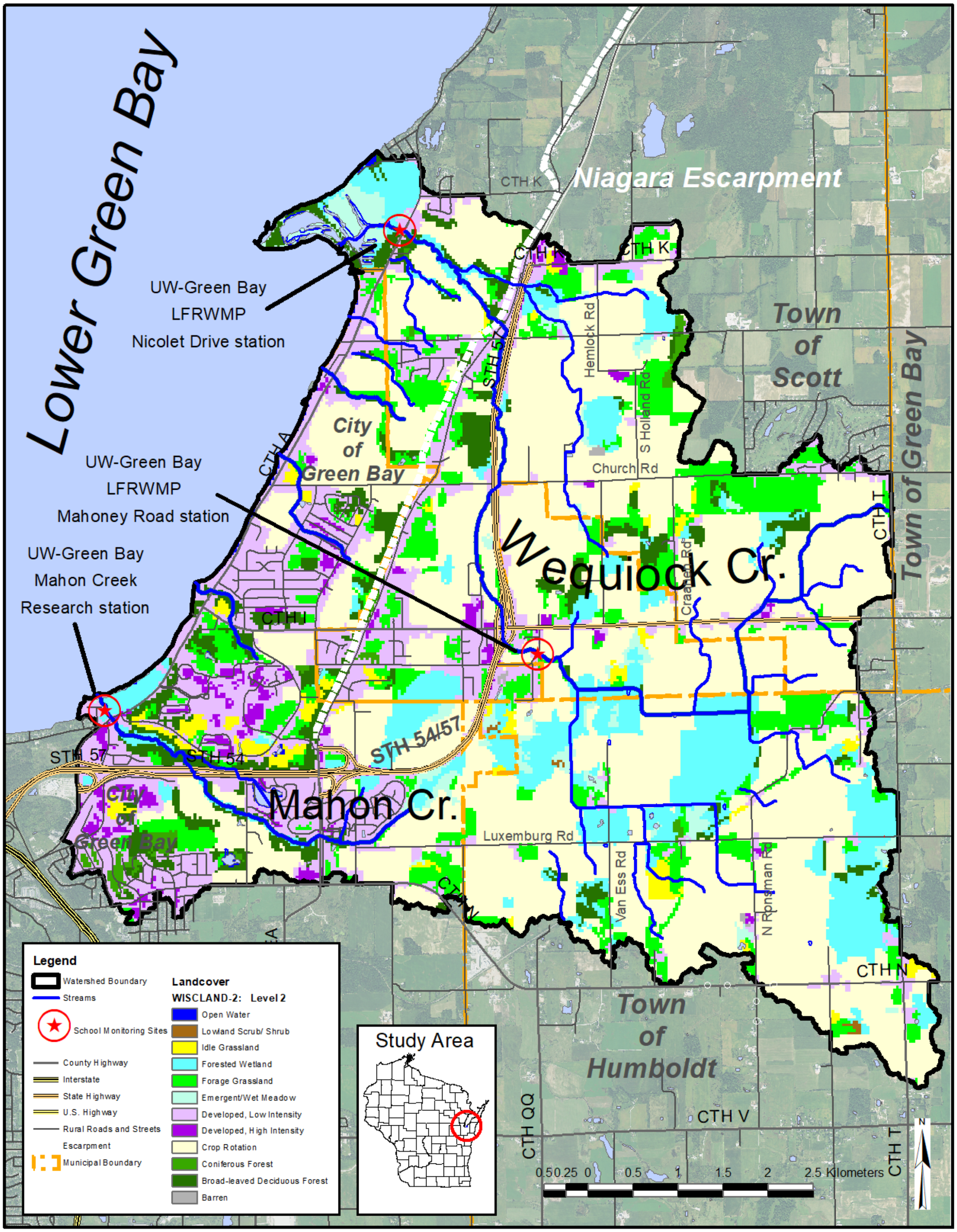

Figure 2. Land cover and land use within the East Shore Watershed (WDNR 2016, WISCLAND-2).

1.7 Topography and Geology

Both topography (the shape and elevation change in land surface) and geology (the rocks underlying or outcropping), and the physical, chemical, and biological changes they have undergone are important considerations for efforts to improve water quality. The watershed contains a unique combination of topographic features ranging from very flat areas where the direction of water flow is difficult to discern to areas of dramatic elevational change. Flat areas, such as those in the southeastern part of the watershed, tend to have drainage problems and can support extensive wetlands; whereas, areas with steep terrain, especially along the Niagara Escarpment, experience rapid runoff of water and have more upland habitats.

The geologic features in this watershed are noteworthy. The Niagara Escarpment extends through the middle of the watershed, creating the dramatic topography mentioned above and forming Wequiock Falls (Figure 1). Ancient Silurian dolomitic limestone bedrock underlies the watershed and, in some areas, forms karst features where the bedrock is fractured, which allows surface water to infiltrate into groundwater very quickly. These areas of the watershed are especially sensitive to water contamination.

For detailed information about the unique topography and geology of the watershed, see the Brown County Land and Water Resources Plan.

Niagara Escarpment

The Niagara Escarpment stretches in a wide arc from eastern Wisconsin through Michigan's Upper Peninsula, across Ontario, Canada, and on through to form Niagara Falls in New York.

The rock forming the escarpment was originally deposited as lime mud on an ancient sea floor about 430 million years ago. What remains is the result of uplift, weathering, and erosion.

The escarpment is home to over 240 different rare, threatened, or endangered plant and animal species. It is also an important source of groundwater recharge. However, the natural cracks in the rocks and the thin layer of soil covering it leave the groundwater extremely vulnerable to contaminants.

Source: WI Geologic & Natural History Survey 2020

1.8 Soil Characteristics

The soils of the Lower East Shore watershed are influenced by topography and geology as well as glacial activity. The soils are primarily glacial till plain, formed when a sheet of ice becomes detached from the main body of a glacier and melts in place, depositing the sediments it carried (NPS 2018). This melting period of the most recent glaciation in the region ended around 6,500 years ago after a glaciated period of about 13,500 years (WGNHS 2020).

The dominant soil types in the watershed are Kewaunee silt loam (37%), Manawa and Poygan silty clay loam (18%), Bonduel loam (2.4%), and small amounts of loamy sand and sandy loam. Kewaunee silty clay loam is an important agricultural soil in the county; the Kewaunee soils have light grayish-brown topsoils and dull-red, heavy clay subsoils containing some gravel and boulders. Surface drainage is generally good over these soils. Manawa soils are deep, somewhat poorly drained, and formed in clayey till. Poygan soils have black or dark-brown topsoils and mottled pinkish-red heavy clay subsoils. They occupy depressions within areas of Kewaunee soils. The moderately well drained Kewaunee and poorly drained Poygan form a drainage sequence with the somewhat poorly drained Manawa soils (USDA Soil series).

Most of the soils in the East Shore watershed are poorly drained, with low water infiltration rates, and primarily consist of Hydrologic Soil Group (HSG) type C soils (Figure 3). HSGs are a Natural Resource Conservation Service classification system in which soils are categorized into four runoff potential groups. The groups range from A soils, with high permeability and little runoff production, to D soils, which have low permeability rates and produce substantially more runoff.

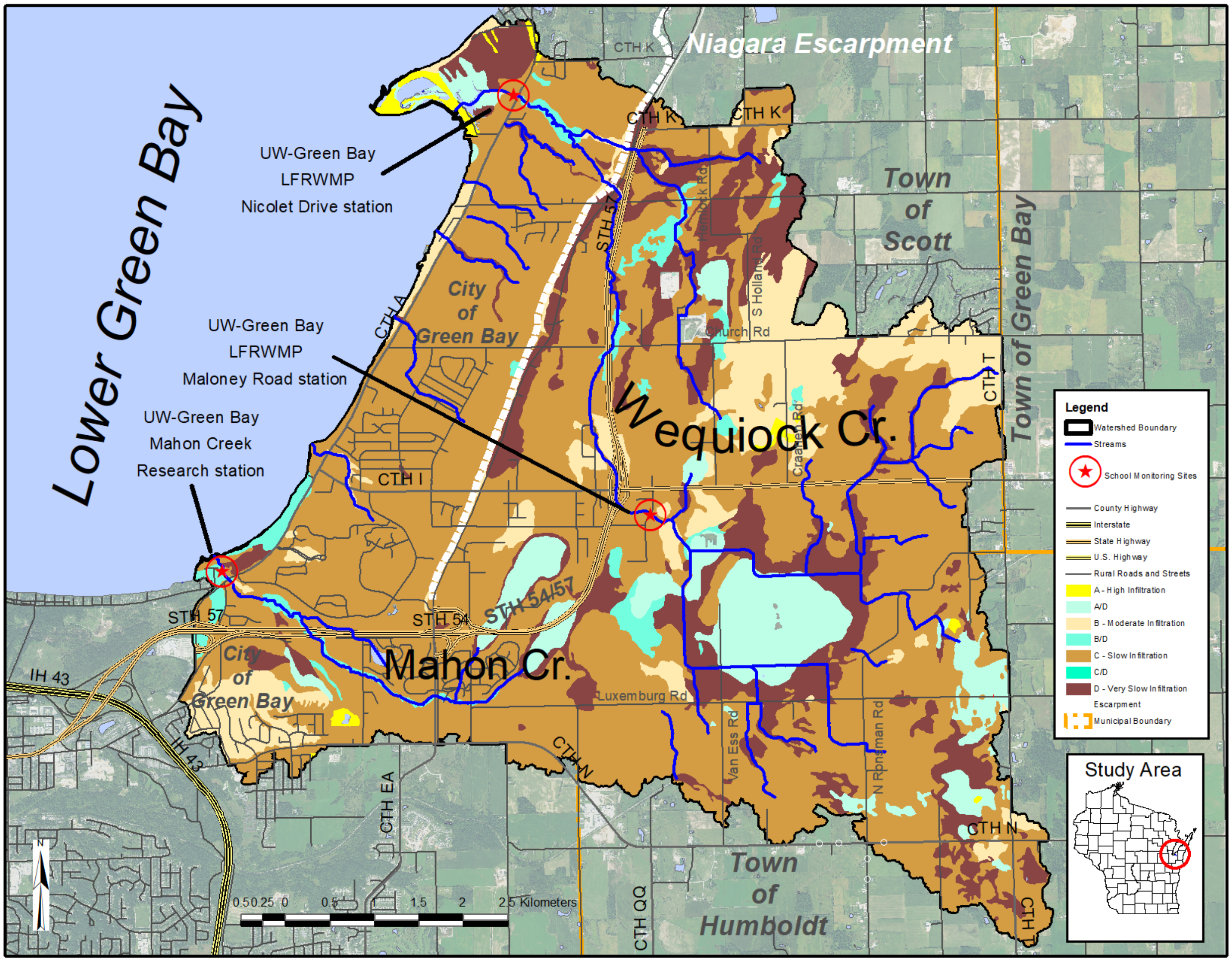

Figure 3. Natural Resource Conservation Service Hydrologic Soil Groups (HSG) of Mahon and Wequiock Creeks. Groups range from A soils, with high permeability and little runoff, to D soils, which have low permeability and produce substantially more runoff.

1.9 Groundwater

Depth to bedrock is fairly shallow over a moderate amount of the Wequiock Creek watershed. For example, our stream survey and water monitoring indicate that the stream bed is likely constrained by bedrock depth from below the Wequiock – Nicolet monitoring station to at least shortly above the Wequiock – Maloney Road station (Figure 1). Furthermore, Wequiock Creek seems to be gaining and losing streamflow at times, depending on location, time, and hydrologic conditions. These observations are probably due to contributions and losses of groundwater and stream water through fractured bedrock, respectively. An updated depth to bedrock map for Brown County is being developed by Dr. John Luczaj of UW-Green Bay. This map would be useful for prioritizing future nutrient management plan (NMP) enrollment and protecting surface water and groundwater. The most recent published map of depth to bedrock does not seem to have adequate depth resolution for water quality purposes within the East Shore watershed.

2. Water Quality

The federal Clean Water Act requires states to adopt water quality criteria that are published by the EPA under 304(a) of the Clean Water Act. These criteria require assigning a designated use to water bodies. According to the WDNR, "assessing the health of a waterbody starts with determining what types of activities the water should support, also commonly referred to as a waterbody's "Designated Uses." Under the Clean Water Act, Wisconsin waters are each assigned four "uses"… Recreation, Public Health and Welfare, Aquatic Life, and Wildlife. Water quality criteria are developed to protect specific uses" (WDNR 2020).

Like almost all surface waters in the state, the Lower East Shore watershed is considered appropriate for recreational, public health and welfare, and wildlife uses. Regarding aquatic life, the watershed is currently designated to the Warmwater Sport Fish (WWSF) Community. Aquatic life communities in this category usually require cool or warm temperatures and concentrations of dissolved oxygen (DO) that do not drop below 5 mg/L. Streams in the WWSF category can support a warmwater dependent sport fishery. The WDNR also uses a model to predict and/or verify which "natural community" subcategory a stream is likely to fall under based on its temperature and size. Most of Wequiock and all of Mahon Creeks are modeled in the Cool-Warm Headwater natural community, which is considered a subcategory of the "warmwater" designated use. A few small stream-stretches within the watershed are modeled as Cool-Cold Headwater, which, if verified through fish surveys, would more appropriately fall under the Coldwater Designated Use. See Wisconsin's Riverine and Lake Natural Communities for more information.

Every two years, Sections 303(d) and 305(b) of the Clean Water Act require states to publish a list of all waters not meeting water quality standards and an overall report on surface water quality status of all waters in the state. A 303(d) list is comprised of waters impaired or threatened by a pollutant and needing a TMDL. Wequiock and Mahon Creeks are not currently on EPA's 303(d) list of impaired waters. However, the watersheds are included in the Lower Fox River Basin TMDL.

The potential sources of pollution outlined below contribute to water quality concerns in the watershed to varying degrees.

2.1 Causes & Sources of Pollution

2.1.a Point Sources

Point sources of pollution are discharges that come from a pipe or point of discharge that can be attributed to a specific source. In Wisconsin, the Wisconsin Pollutant Discharge Elimination System (WPDES) regulates and enforces water pollution control measures. The WDNR Bureau of Water Quality issues the permits with oversight of the US EPA. There are four types of WPDES permits: Individual, General, Stormwater, and Agricultural permits.

Individual

There are no wastewater treatment facilities with individual WPDES permits that discharge in the watershed. Municipal wastewater generated in the watershed is serviced by NEW Water, the brand of the Green Bay Metropolitan Sewerage District. Municipal wastewater is pumped out of the watershed to the NEW Water wastewater treatment facility, which discharges treated effluent to an outlet located near the mouth of the Fox River. The NEW Water WPDES permit includes limits that are consistent with the approved TMDL Waste Load Allocations. NEW Water is also partnering on several innovative programs with local conservation organizations and municipalities to assist in the reduction of nutrient and sediment loading.

General

The WDNR is authorized to issue WPDES general permits to a designated area of the state authorizing discharges from specified categories or classes of point sources located within that area. A general permit is designed to cover multiple facilities under one permit when they perform similar operations.
The TMDL includes aggregate allocations for general WPDES permits in the watershed rather than individually assigned load allocations (Tables 2 and 3 in Section 2.2). Compliance with these TSS and total phosphorus (TP) allocations will therefore be determined by WDNR in aggregate. General WPDES permits include limits that are consistent with the approved TMDL Waste Load Allocations (WLAs) when they discharge to a waterbody with a TMDL. Holders of general permits will be considered in compliance with the TMDL if they comply with their general permit. Permits will be modified as necessary to ensure compliance with the aggregate load allocation. General permits cover facilities in watersheds across the state, so permit language requires facilities to implement measures consistent with the TMDLs.

A list of current WPDES general permit forms and requirements can be found at https://dnr.wi.gov/topic/wastewater/GeneralPermits.html (does not include a list of permittees). See the WDNR's Surface water data viewer to explore WPDES permits in the watershed.

Two non-metallic mining facilities (i.e., quarries) have WPDES general permits for wastewater discharge to portions of Wequiock Creek: Dannen and Jannsen, and Northeast Asphalt. These two facilities are located near the northeast intersection of STH 57 and Church Road. Their general permits require annual checks by WDNR to determine whether their facility discharges a stormwater or wastewater pollutant of concern to a water body included in an approved TMDL. If a discharge of concern occurs, the permittee shall assess whether the TMDL WLA for the facility's discharge is being met through the existing source area pollution prevention controls, stormwater best management practices, wastewater pollution prevention controls, or wastewater treatment facilities, or whether additional controls or treatment are necessary and feasible. The assessment of the feasibility of additional controls or treatment shall focus on the ability to improve the pollution.

Municipal Separate Stormwater Systems

A Municipal Separate Storm Sewer System (MS4) permit is required for municipalities within a federally designated urbanized area, large institutions (i.e., UW-Green Bay), or where the WDNR designates the municipality for permit coverage. MS4 permits require stormwater management programs to reduce polluted stormwater runoff. MS4s within the Lower Fox River Basin and Lower Green Bay TMDL are assigned individual WLAs that must be consistent with the assumptions and requirements contained in the TMDL. MS4 permittees must conduct a TMDL implementation and analysis plan that is included in their Stormwater Management Plan. There are three stormwater dischargers with MS4 permits in the Lower East Shore watershed that have WLAs that are listed in the TMDL: City of Green Bay, Town of Scott (TOS Stormwater Ordinance), and UW-Green Bay. TMDL WLAs and required reductions for each MS4 are listed in Table 2 for TSS and Table 3 for TP. Other potential stormwater permittees in the watershed that may require compliance with the TMDL may include Brown County (general MS4 permit # WI-S050075-2) and the State of Wisconsin for highway or other government properties.

MS4 permits for stormwater management programs require components for public education, outreach, involvement, and participation, all of which are critical to achieving the water quality goals established by our Plan.

Construction Site Stormwater Permits

Certain types of construction projects are regulated by the WDNR through construction site stormwater permits. Construction site general permits require landowners to install practices to help decrease the amount of erosion and sediment runoff during storm events. WDNR permits are required for construction projects that disturb one acre (0.4 ha) or more of land through: clearing, grading, excavating, or stockpiling of fill material. The construction permit requires permit holders to meet WLAs of a TMDL, if applicable, in their erosion control and stormwater management plans. In addition, all MS4 communities in the watershed have local ordinances requiring construction site erosion control and stormwater permits. Many of the MS4 communities have recently updated ordinances in the effort to comply with TMDL WLAs. Several communities have more stringent ordinances than the state standard and require permits for disturbed areas that are 4,000 ft^2 (371.6 m^2) or more. Construction activities in the watershed are considered in compliance with the TMDL if they obtain a WPDES construction general permit or meet local construction stormwater requirements if they are more restrictive than the general permit. TMDL WLAs and required reductions for construction sites are listed in Tables 2 and 3.

Agricultural Permits

State and federal laws require that Concentrated Animal Feeding Operations (CAFO) have water quality protection permits. An animal feeding operation is considered a CAFO if it has 1,000 animal units or more. A smaller animal feeding operation may be designated a CAFO by the WDNR if it discharges pollutants to navigable waters or groundwater. There are currently no CAFO facilities within the East Shore watershed. However, there are permitted CAFOs that own or rent cropland in the watershed, so they are required to comply with manure and nutrient management requirements for croplands associated with CAFO operations, such as Natural Resources Conservation Service (NRCS) Conservation Practice Standard 590.

2.1.b Nonpoint Sources

Nonpoint source pollution is generally diffuse, generated over a large area, not easily traced back to a single discharge point, often associated with runoff, and usually not discharged to a stream through a pipe (with some exceptions). Nonpoint sources contribute the majority of TSS (72%) and phosphorus (81%) loading in the East Shore watershed, of which agriculture is the dominant source (Figure 4, Tables 2 and 3). The dominant land uses in the watershed are agriculture (58.8%) and urban development (20.4%). Nonpoint sources in the watershed include:

- Erosion/runoff from agricultural land
- Tile drainage
- Livestock facilities that are not covered by CAFO permits
- Erosion from streambanks
- Erosion/runoff from construction sites that are not covered by a point source permit
- Erosion/runoff from lawns
- Runoff from impervious surfaces
- Fertilizer application
- Failing septic systems
- Pet/animal waste

Wisconsin Administrative Code Chapter NR 151 regulates runoff management in the state. Agricultural runoff is regulated under subchapter 2. This chapter describes regulations relating to phosphorus index, manure storage and management, nutrient management, soil erosion, and tillage setback. Implementation and enforcement procedures are also described in this chapter. Conservation practices used to meet performance standards in Ch. NR 151.2 are identified in Chapter ATCP 50 of the Wisconsin

Administrative Code. Subchapter 3 of NR 151 describes non-agricultural performance standards relating to construction sites, developed urban areas, turf and garden nutrient management, TSS, peak discharge, infiltration, and fueling and vehicle maintenance. Subchapter 4 describes similar performance standards as subchapter 3 but applies to transportation facilities.

The TMDL modeling framework lumped contributions from streambank erosion with agricultural land use; however, a streambank inventory and load contribution analysis were conducted during the development of this plan, which allowed for the separation of these sources. With this separation, the TMDL requires a 68.5% reduction in TP load and 54.5% reduction in TSS load from agricultural sources in the East Shore watershed, and a 66.6% reduction in the TP and TSS loads from streambank erosion (Tables 2 and 3). No reductions are required by the TMDL for non-regulated urban nonpoint sources.

2.2 Baseline and Allocated Source Loads of TSS and Total Phosphorus

Sources of baseline total suspended solids (TSS) and TP loads within the East Shore watershed are illustrated in Figure 4 by source. These values are based on the Lower Fox River Basin and Lower Green Bay TMDL (WDNR 2012), which utilized the Soil and Water Assessment Tool (SWAT; https://swat.tamu.edu) to estimate long-term average annual loads from nonpoint sources. However, the proportions were modified by accounting for the estimated net contribution from streambank erosion (non-bedload), which was based on a streambank inventory conducted through this study. More details on the streambank inventory are provided later in this document. Another modification was made from the TMDL to separate the East Shore from the West Shore watersheds, and values used in this document reflect those in the primary spreadsheets that were used to allocate TSS and TP loads to meet water quality objectives. A detailed explanation can be found in Appendix D. TSS and TP loads that are reported in this plan exclude the Mahon Creek urban sub-watershed shown in Figure 1 because this area was part of a much larger urban watershed in the City of Green Bay that was modeled separately in the TMDL.

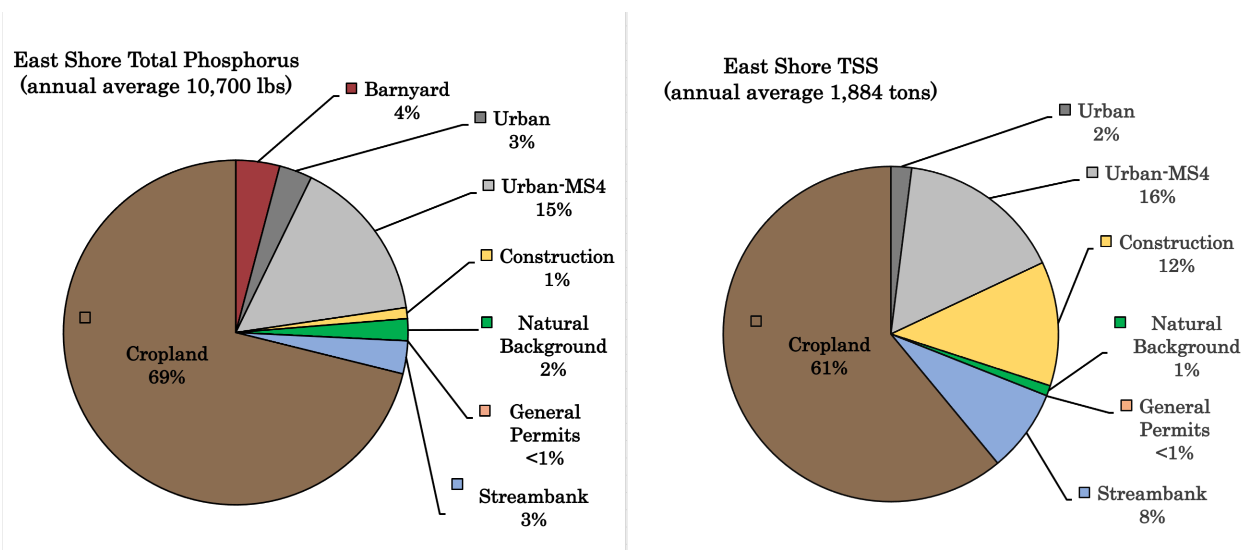

Figure 4. Baseline TP (left) and total suspended solids (TSS; right) average annual loads by land use and source for the East Shore watershed. Based on TMDL but modified to account for estimated streambank contributions. Source: WDNR 2012.

The objective of the TMDL was to allocate loads among pollutant sources so that appropriate control measures could be implemented and water quality standards achieved (WDNR 2012). In the TMDL, WLAs were assigned to point source discharges regulated by WPDES permits and load allocations (LAs) were assigned to unregulated nonpoint source loads. The TMDL is expressed as the sum of all individual WLAs for point source loads and LAs for nonpoint source loads. Load allocations, and the requisite reductions needed to meet these allocations, are listed in Table 2 (TSS) and Table 3 (phosphorus) for each major source category in the East Shore watershed. Municipal Separate Storm Sewer Systems are abbreviated in Figure 4, Tables 2 and 3, and throughout this document as simply MS4.

Table 2. Summary of TMDL baseline loads, allocated loads, and load reduction goals for Total Suspended Solids (TSS) in the Lower East Shore watershed by source. Based on TMDL but modified to account for estimated streambank contributions. Source: WDNR 2012.

Sources	Total Suspended Solids Load (tons/yr)			Reduction from Baseline
	Baseline	Allocated	Reduction	
Agriculture	1,154	525	629	54.5%
Urban (non-regulated)	46	46	-	-
Natural Background	23	23	-	-
Streambank Erosion (urban & rural)	141	47	94	66.6%
Load Allocation (LA)	**1,365**	**641**	**723**	**53.0%**
Urban (MS4)	299	180	120	40.0%
Construction	219	44	175	80.0%
General Permits	2	2	-	-
WWTF-Industrial	-	-	-	-
WWTF-Municipal	-	-	-	-
Wasteload Allocation (WLA)	**520**	**225**	**295**	**56.7%**
TOTAL (WLA + LA)	**1,884**	**866**	**1,018**	**54.0%**

Urban (MS4) by municipality	Total Suspended Solids Load (tons/yr)			Reduction from Baseline
	Baseline	Allocated	Reduction	
City of Green Bay	165	99	66	40.0%
Town of Scott	71	43	29	40.0%
UW-Green Bay	63	38	25	40.0%

Table 3. Summary of TMDL baseline loads, allocated loads, and load reduction goals for total phosphorus, in the Lower East Shore watershed, by source. Based on the TMDL but modified to account for estimated streambank contributions. Source: WDNR 2012.

Sources	Total Phosphorus Load (lb/yr)			Reduction from Baseline
	Baseline	Allocated	Reduction	
Agriculture	7,827	2,467	5,360	68.5%
Urban (non-regulated)	296	296	-	-
Natural Background	266	266	-	-
Streambank Erosion (urban & rural)	282	94	188	66.6%
Load Allocation (LA)	**8,671**	**3,123**	**5,548**	**64.0%**
Urban (MS4)	1,598	1,119	479	30.0%
Construction	397	397	-	-
General Permits	31	31	-	-
WWTF-Industrial	-	-	-	-
WWTF-Municipal	-	-	-	-
Wasteload Allocation (WLA)	**2,026**	**1,547**	**479**	**23.7%**
TOTAL (WLA + LA)	**10,697**	**4,670**	**6,027**	**56.3%**

Urban (MS4) by municipality	Total Phosphorus Load (lb/yr)			Reduction from Baseline
	Baseline	Allocated	Reduction	
City of Green Bay	898	629	269	30.0%
Town of Scott	422	295	127	30.0%
UW-Green Bay	278	195	83	30.0%

2.3 Water Quality Monitoring

Three primary water monitoring stations have been installed by UW-Green Bay in the East Shore watershed: 1) Mahon Creek UW-Green Bay research station on Mahon Creek near the outlet to Green Bay (catchment area of 2.79 mi^2 [=7.23 km^2]); 2) Wequiock Creek, 30 ft (9.1 m) downstream of Nicolet Drive and near the outlet to Green Bay (12.8 mi^2 [=33.1 km^2]); and 3) Wequiock Creek on Maloney Road near the STH 54 Park & Ride site (8.67 mi^2 [=22.5 km^2]; (Figure 1). The Mahon Creek station is powered by the electric grid with battery backup, and the other stations are solar-powered with battery backup. Monitoring station equipment and sampling regimes are briefly summarized in Table 4. This plan calls for continuing the existing stream monitoring program over the plan's ten-year schedule as described in this section if adequate funding can be obtained.

Water level (i.e., stage) is continuously measured at each of these stations. Discrete stream discharge measurements are made with an OTT handheld acoustic digital current (ADC) meter during lower flow conditions, and a StreamPro acoustic doppler current profiler (ADCP) boat during high flow conditions. The resulting stage-discharge relationship and water level data are used to calculate continuous stream flow (discharge).

Water samples are collected by an automated sampler and/or grab samples. Samples have been analyzed for TSS, TP, and dissolved phosphorus (DP). Daily loads of TSS and TP have been calculated for the Mahon station (2011-2016) and Wequiock-Nicolet station (2019 to present).

Table 4. Summary of UW-Green Bay primary stream water monitoring equipment and sampling regimes.

Stream Monitoring Station	Continuous Stage & Flow	Water Sampling	Continuous Turbidity	TSS and TP Daily Loads	Continuous Water Temperature
Mahon near outlet ($2.79\ mi^2$) Station house installed Dec. 2010, with modem and CS CR-1000 logger[5] ------------------- Adjacent site is urban culvert, equipped for continuous water level[6]	Jan. 2011 to present (all year)[1]	Events with ISCO automatic refrigerated sampler plus grab samples	temporary low-cost logger and probe upstream near Nicolet Drive	2011 to 2016 USGS GCLAS software: sample point to point integration	June 2019 to present[2]; and 2012 to 2015 Hydrolab sonde
Wequiock at Nicolet Drive ($12.8\ mi^2$) Station house installed spring 2019, with modem and CS CR1000x logger[5], and tipping buck rain gauge	2016-2018 (non-ice period)[2] 2019 to present (all year)[3]	Event and low flow grab	Campbell Scientific OBS-501	May 2019 to present Regression based on turbidity vs concentration relationship	June 2016-2018[2]; 2019 to present[3]
Wequiock at Maloney Road ($8.67\ mi^2$)	2018 to present (non-ice period)[2]	Event and low flow grab	Low cost logger and probe	Not available yet	2018 to present[2]

Concentrations of TSS, TP and DP (mg/L) in water samples collected from Mahon Creek are summarized in Table 5 for event, low flow, and combined sample categories. Roughly 800 samples have been analyzed thus far for TP and TSS, and 156 samples for DP. The maximum concentration of TP was 5.8 mg/L, with 64 samples of 0.9 mg/L or greater (7.7% of all samples). The mean concentration of TSS was 148 mg/L with a maximum of 3,520 mg/L.

The median TP concentration for Mahon Creek during the May to October 2019 period was 0.120 mg/L (n = 6), which exceeds the Wisconsin phosphorus criteria of 0.075 mg/L. The median DP concentration was 0.117 mg/L, indicating that most of the phosphorus is readily available for uptake by algae during low flow conditions. This period and statistic are consistent with the methodology used to establish the phosphorus criteria (Robertson et al, 2006, 2008); however, this methodology involved random sampling near mid-month, rather than only during non-event periods as was used in this project. If event data had been included in this project, the median concentrations may have increased. Only data collected from September 2018 onward were summarized for the May to October period because we recently started utilizing a phosphorus analysis method with a lower detection limit at the certified lab where the samples were submitted for analysis.

Samples were also collected just below the outlet of a nearby 6-ft (1.8 m) urban culvert, which is adjacent to the UW-Green Bay research station. This culvert drains 0.873 mi^2 (2.26 km^2) of mostly urban area within the City of Green Bay and joins the main stem of Mahon Creek just downstream of the primary stream monitoring location. Sample results from the urban culvert are summarized in Table 5b and indicate that phosphorus concentrations from the culvert (n = 62) are similar to those collected from the adjacent main stem of Mahon Creek during low flow conditions.

Table 5. Summary of water sample concentrations at UW-Green Bay Mahon Creek Research Station (mg/L).

a) Mahon Creek UW-Green Bay Research Station near outlet to Green Bay

	ALL samples			EVENT samples			LOW flow samples		
# samples	*831*	*156*	*795*	*718*	*74*	*678*	*113*	*82*	*116*
	TP	**DP**	**TSS**	**TP**	**DP**	**TSS**	**TP**	**DP**	**TSS**
Mean	0.325	0.092	148	0.362	0.136	171	0.089	0.053	12
Median	0.155	0.048	41	0.192	0.081	59	0.062	0.038	6
Max	5.78	1.77	3,523	5.78	1.77	3,523	1.14	0.29	154
# > 0.5 mg/L	130	2		129	2				
# > 0.9 mg/L	64	2		63	2		*May to Oct. period only, w/lower phosphorus detection limits*		
# > 2.0 mg/L	19								
# > 3.0 mg/L	7						*14*	*14*	*# samples*
							0.125	*0.0.95*	*mean*
							0.112	*0.072*	*median*
							0.120	*0.117*	***2019 median (n=6)***

b) Mahon Research Station: Urban Culvert

	ALL samples		
# samples	***62***	***43***	***62***
	TP	**DP**	**TSS**
Mean	0.089	0.051	20
Median	0.040	0.032	2
Max	1.03	0.60	932

NOTE: Only 3 events were sampled

Concentrations of TSS, TP, and DP (mg/L) in water samples collected from the two primary Wequiock Creek stations are summarized in Table 6 for event and low flow sample categories. A total of 52 samples were analyzed for TP and TSS from the Wequiock – Nicolet station and 31 from the Wequiock – Maloney station. The maximum concentration of TP was 1.3 mg/L, and the maximum concentration of TSS was 775 mg/L. Both samples were collected from the Maloney station.

The median TP concentration for low flow samples collected during the May to October 2019 period was 0.221 mg/L at the Wequiock Nicolet Drive station (n = 6) and 0.290 mg/L at the upstream Maloney Road station (n = 6). Both sites exceed the Wisconsin phosphorus criteria of 0.075 mg/L. The median DP concentration was 0.182 mg/L and 0.242 mg/L at Nicolet and Maloney sites, respectively; thereby indicating that most of the phosphorus is readily available for uptake by algae during low flow conditions. Results of May to October low flow water sample TP concentrations are compared along with those from Mahon Creek in Figure 5. The May to October 2019 period is bracketed. Under low flow conditions, TP concentrations were highest at Wequiock-Maloney, followed by Wequiock-Nicolet and Mahon stations.

Table 6. Wequiock Creek water sample summary.

	number of samples	TSS (mg/L)	TP (mg/L)	DP (mg/L)		
			mean concentration			
Wequiock - Nicolet	30	7	0.141	0.120	Low Flow	2016-20
Wequiock - Maloney	12	13	0.322	0.229	Low Flow	
Wequiock - Nicolet	22	175	0.534	0.191	Event	2016, 2019-20
Wequiock - Maloney	22	168	0.601	0.194	Event	
			maximum concentration			
Wequiock - Nicolet		466	1.036	0.307	Event	
Wequiock - Maloney		775	1.300	0.250	Event	

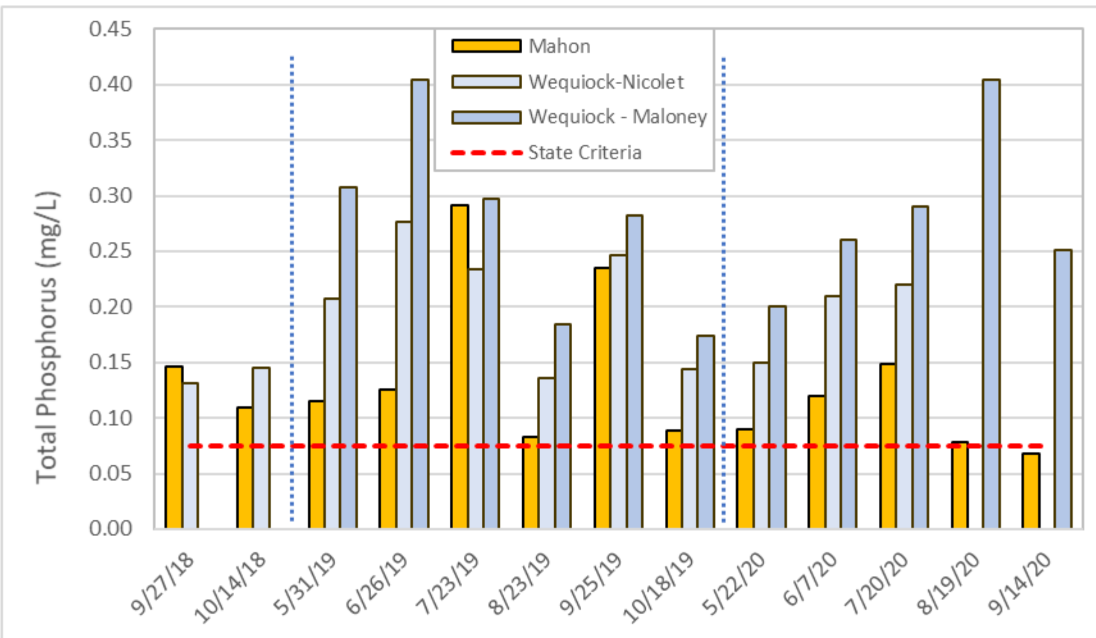

Figure 5. May to October total phosphorus concentrations under low flow conditions in Mahon and Wequiock Creeks, relative to the Wisconsin water quality standard.

2.4 Watershed Nonpoint Source Inventory

2.4.a Description

This section contains an inventory of nonpoint sources and data about them generated for the purposes of developing this plan, with particular emphasis on defining critical areas in the watershed that are most likely to disproportionally contribute to excessive phosphorus and TSS. While other factors play a role, higher-ranked source areas are preferable for achieving cost-effective targeted reductions over this plan's ten-year schedule.

Notably, detailed information was obtained through the creation of this plan to provide better spatial resolution and more accurate information than would be feasible for a large basin. In the development of the SWAT model in the TMDL process, certain types of data, such as soil phosphorus levels, were often lumped into a single value that was applied to an entire watershed modeling unit (e.g., Wequiock or Mahon), or even larger area, in part, because detailed spatial data were not available at the time for the entire Lower Fox River sub-basin. In addition, the data were meant to be summarized at the primary watershed modeling units. In the implementation of this plan, no such limitations apply, so detailed information should be employed to target critical source areas when feasible.

2.4.b Agriculture: Crop Rotations

In the process of creating an Erosion Vulnerability Index (EVI) GIS layer for the East Shore watershed, Luke Beringer of the WDNR also created a crop rotation layer for the watershed (Figure 6), which was based on NRCS Cropland data layers from 2013-2018. The primary crop rotation categories in our watershed are dairy and cash-grain crops. This is an important distinction because the management of farm fields that are associated with dairy operations is generally much more complex and because manure management can have a major impact on water quality. The latter is particularly problematic in the watershed, and northeastern Wisconsin in general, because typical manure application rates are such that the amount of phosphorus in the manure often exceeds the needs of the crop, which leads to increased soil phosphorus concentrations, over time. The continuous corn category could be considered a cash-crop operation (including from a phosphorus perspective), but the GIS analysis did not show that corn was likely rotated with another crop during the analysis period. Notably, some of the fields that were not marked as dairy rotation may have manure applied.

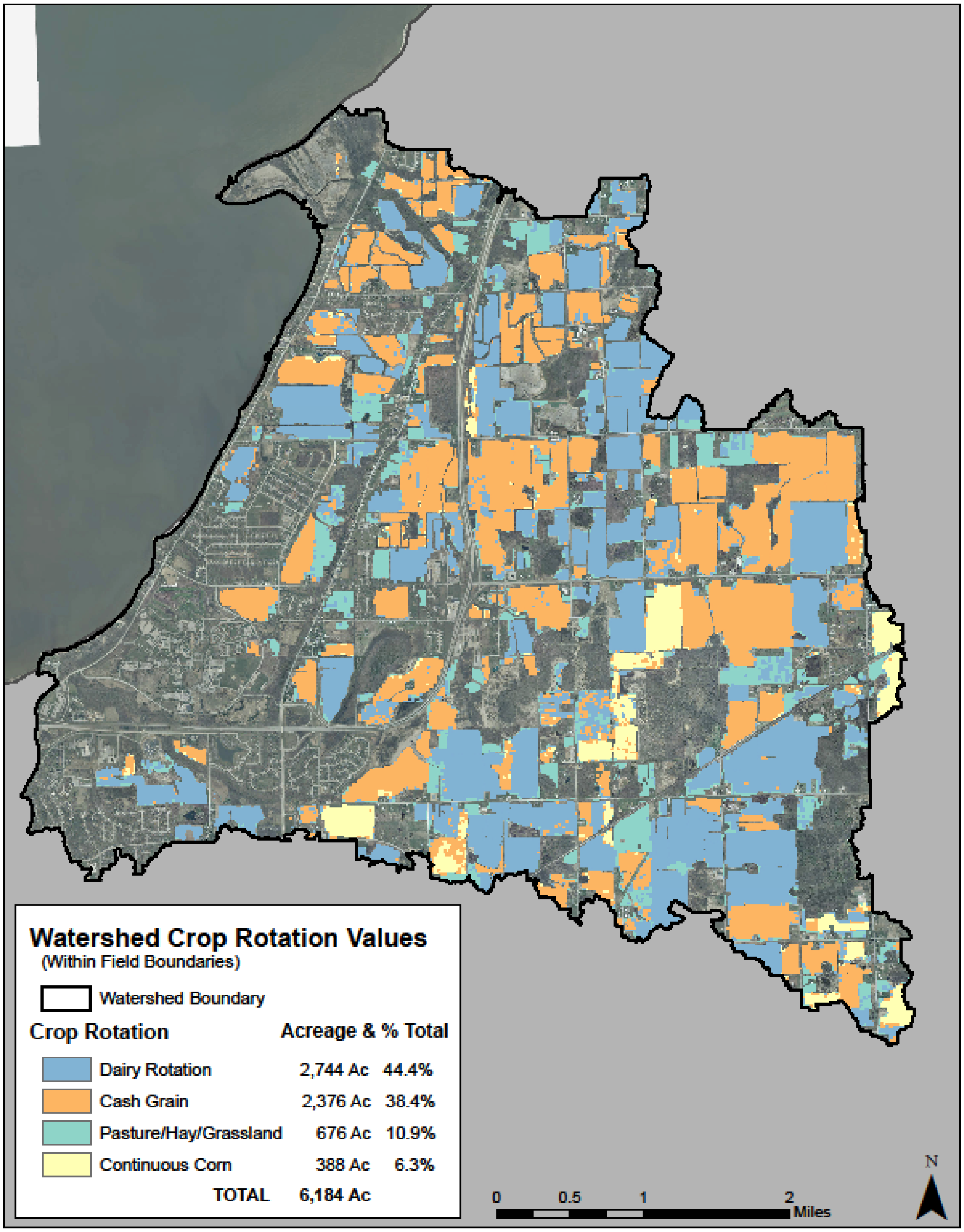

Figure 6. Agricultural crop rotations (dairy, cash grain, pasture/hay/grassland, and continuous corn) in the East Shore watershed. Map by Beringer 2019.

2.4.c Normalized Difference Tillage Index (NDTI)

Nick Peltier of the Brown County Land and Water Conservation Department created a Normalized Difference Tillage Index (NDTI) layer for Brown County based on LANDSAT 8 satellite imagery from November 28, 2018. The NDTI was averaged over each field in 30-m pixels. This layer was clipped to the East Shore Watershed boundary and is shown in Figure 7. The NDTI is a ratio of light wave reflectance using near-infrared bands. It uses satellite data to estimate tillage intensity, residue cover, and cropland condition at a specific point in time. A low NDTI value signifies intense tillage and less surface residue, whereas a high NDTI value indicates no-tillage and more residue on fields**. An NDTI analysis should be repeated annually to track tillage and residue management over time to determine trends in crop rotations and soil conservation practices such as reduced tillage practices and cover crops.** Furthermore, this analysis should utilize the standard methodology for creating and analyzing the NDTI in the watershed that is being developed for the watersheds in the Lower Fox River sub-basin, when it becomes available.

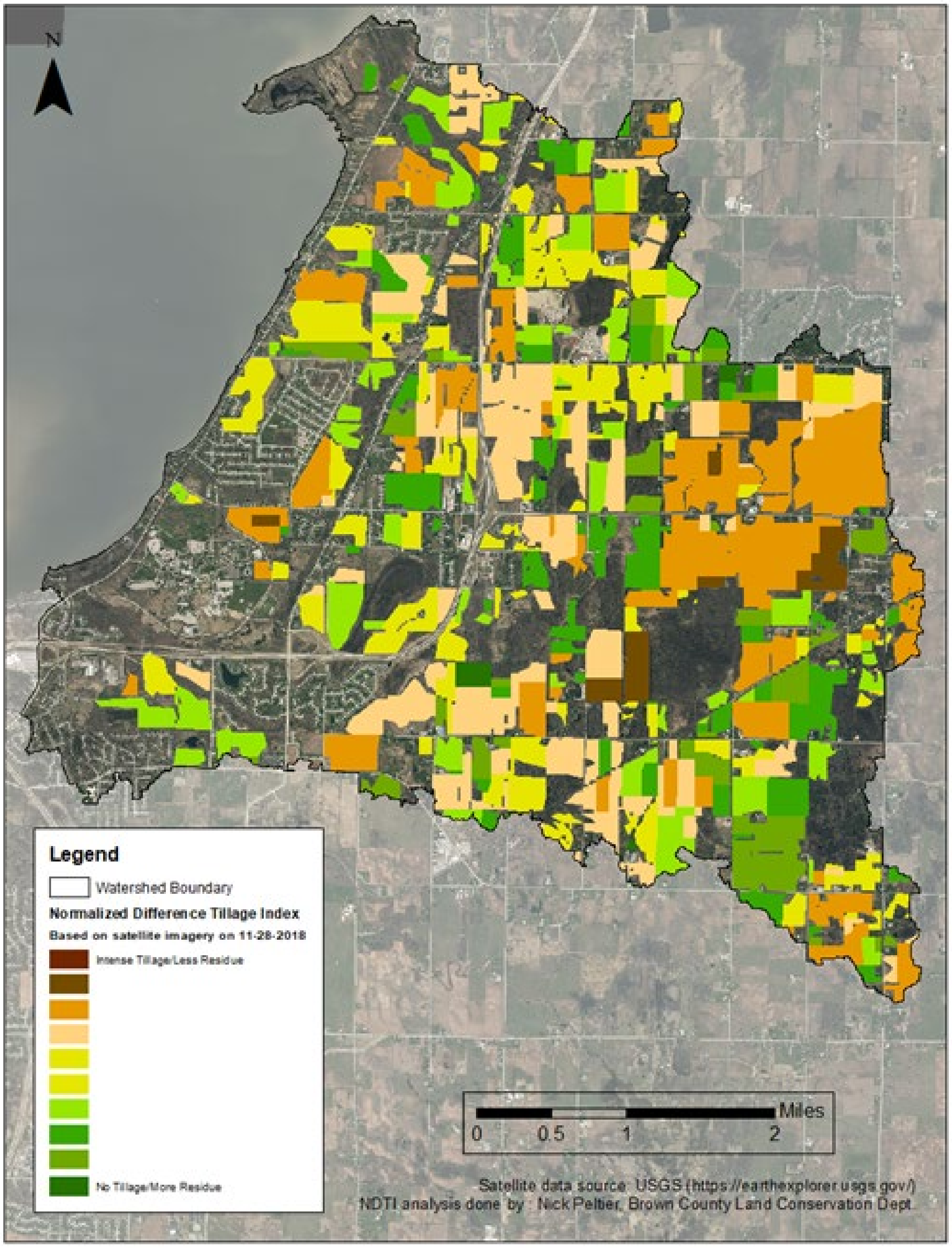

Figure 7. Normalized Difference Tillage Index. Orange to brown areas indicates intense tillage and less residue, whereas green areas indicate no tillage and more residue, or a perennial crop (Hoff 2020).

2.4.d Tillage Practices and Residue Management

An upland agriculture windshield survey was completed on May 16, 2019 with assistance from Erin Carviou, the Nonpoint Source Specialist for the WDNR (Hoff 2020). Tillage, residue, and field erosion estimates were collected for parcels at section and half-section corners in Mahon and Wequiock Creek watersheds using Collector Classic and ArcGIS Online. Out of the 88 fields that were surveyed, 50 were not tilled (57%; Figure 8). Based on conversations with Brown County Land and Water Conservation Department (LWCD) staff and soil health experts from UW-Green Bay, this value is an overestimation that can be explained by the extremely wet conditions from the previous fall, which prevented many farmers from tilling. In fact, many farmers were unable to plant in spring 2019 or planted so late they qualified for the USDA Prevented Planting insurance program. As a result, fields identified as no-till were often corn silage that was not fall-tilled and thus had low residue. Additionally, 40% of the fields were tilled using a chisel/disc plow, and 3% were tilled using a moldboard plow. It is recommended that this survey not only be repeated annually to track on-the-ground tillage practices and residue management but also compared with NDTI satellite imagery results over time.

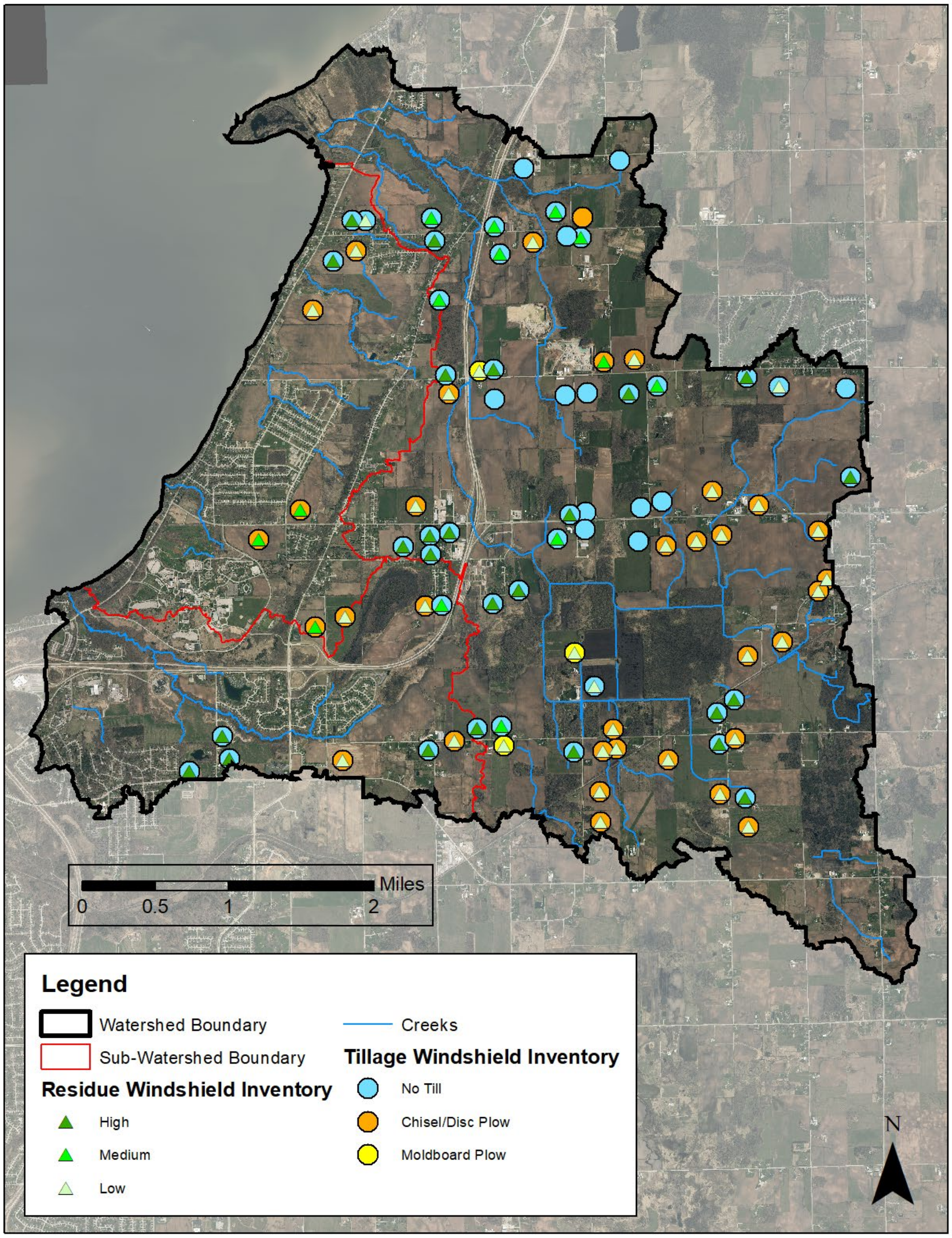

Figure 8. May 16, 2019 inventory of tillage practices and crop residue in the East Shore watershed (Hoff 2020). A high proportion of no-till fields had low residue because they were corn silage that had not been plowed the previous fall due to excessive precipitation.

2.4.e Nutrient Management Planning, Soil Test Phosphorus, and Livestock Facilities

Nutrient Management Plans

Areas, where nutrient management plans (NMPs) have been developed or are in the process of being developed, are shown in Figure 9. Data for this map were provided by the Brown County LWCD. NMPs are conservation plans specific to anyone applying manure or commercial fertilizer and address concerns related to soil erosion, manure management, and nutrient applications. There are approximately 7,053 acres of farm fields in the watershed. In 2019, about 80% (5,631 ac [2,278.8 ha]) were covered under an NMP and 20% (1,422 ac [575.5 ha]) did not have a NMP. NMPs must meet the criteria within the Wisconsin 2015 NRCS 590 standard, which has the intended purpose to minimize the risk of agricultural nonpoint source pollution of surface and groundwater resources. However, water samples from Mahon and Wequiock Creeks exceed the state phosphorus standard even though most farm fields in the watershed have NMPs (Tables 5 and 6). Therefore, further steps are needed to improve nutrient management practices that are part of existing and newly established NMPs in the watershed. Achieving the state phosphorus standard and load reductions objectives set by the TMDL may require going beyond the requirements in NRCS 590. Furthermore, we recommend that NMPs are developed for all fields in the watershed. An updated depth to bedrock map for Brown County is being developed by Dr. John Luczaj of UW-Green Bay, which would be useful for prioritizing future NMP enrollment and protecting surface water and groundwater.

Soil Test Phosphorus

Agronomically available Soil Test Phosphorus concentrations (STP) are shown in Figure 9, for those agricultural fields where NMPs are in place and STP data were available (as Bray P-1; Brown County LCD 2019). STP data were not yet available for some of the fields under a recently approved NMP. Those areas with higher STP concentrations are more likely to have higher concentrations of dissolved and particulate phosphorus in runoff and tile drainage. Some fields with the highest soil test P are located closest to the barnyards, indicating that farmers have historically, or are currently applying much of their manure on the fields closest to their barnyards, presumably because of convenience. It would be useful to view historical aerial photographs to see if livestock used to be present in other areas with high soil test P. About 28 fields (13%), 17 fields (8%), and 4 fields have STP concentrations of 50, 80 and 130 ppm or greater, respectively. According to Laboski and Peters (2012), STP concentrations of 16-20 ppm are considered optimal for corn, soybean, and wheat crops grown in Brown County loamy soils; whereas, 18-25 ppm is considered optimal for alfalfa. Levels higher than these are not needed for most crops and pose a problem to nearby surface waters from surface runoff or dissolved phosphorus and nitrogen loss via tile drainage. Therefore, fields with STP concentrations greater than 25 ppm, and especially those above 50 ppm, are a high priority for nutrient management in conjunction with other management practices that will reduce soil erosion and runoff. STP should continue to be tracked to prioritize the implementation of management practices and to track trends.

Livestock Facilities (barnyards)

There are 13 inventoried active livestock facilities that are owned by nine operators in the watershed, with roughly 386 animal units (AU) potentially utilizing paved and/or earthen feedlots at any one time (Figure 9). An NRCS BANRY tool analysis was conducted with the assistance of the Brown County LWCD in early 2020. However, due to time and resource constraints, no farm site visits took place. Livestock operation data were compiled through aerial imagery, windshield surveys, and available Brown County LWCD data. Only 1 of the 13 sites was identified as having a designed settling basin, and 5 of the 13 barnyards were at or above 20 lb of phosphorus per year. The total BARNY estimated phosphorus load from the livestock facilities in the watershed is about 343 lb/yr, which is close to the total of 413 lb/yr that was estimated for the watershed in the TMDL. The BARNY estimate assumes that about 40% of the runoff from one of the facilities drains toward the East Shore watershed, and the rest drains to another watershed. One facility is a major contributor with an estimated load of 120 lb/yr. A notice of intent action (NOI) has been initiated and as of August 2021, Brown County LCD has received a grant to help the operator reduce the export of solids and phosphorus from this facility. Another operator has a facility with an estimated contribution of 77 lb/yr, so this site is also likely a priority. Implementing recommended barnyard control practices at these two facilities results in a BARNY estimated phosphorus reduction of 169 lbs per year. These BARNY analyses serve as a general evaluation of the feedlot runoff issues/conditions and it is suggested that onsite visits be conducted to ground-truth these results and better analyze the potential for best management practice installation.

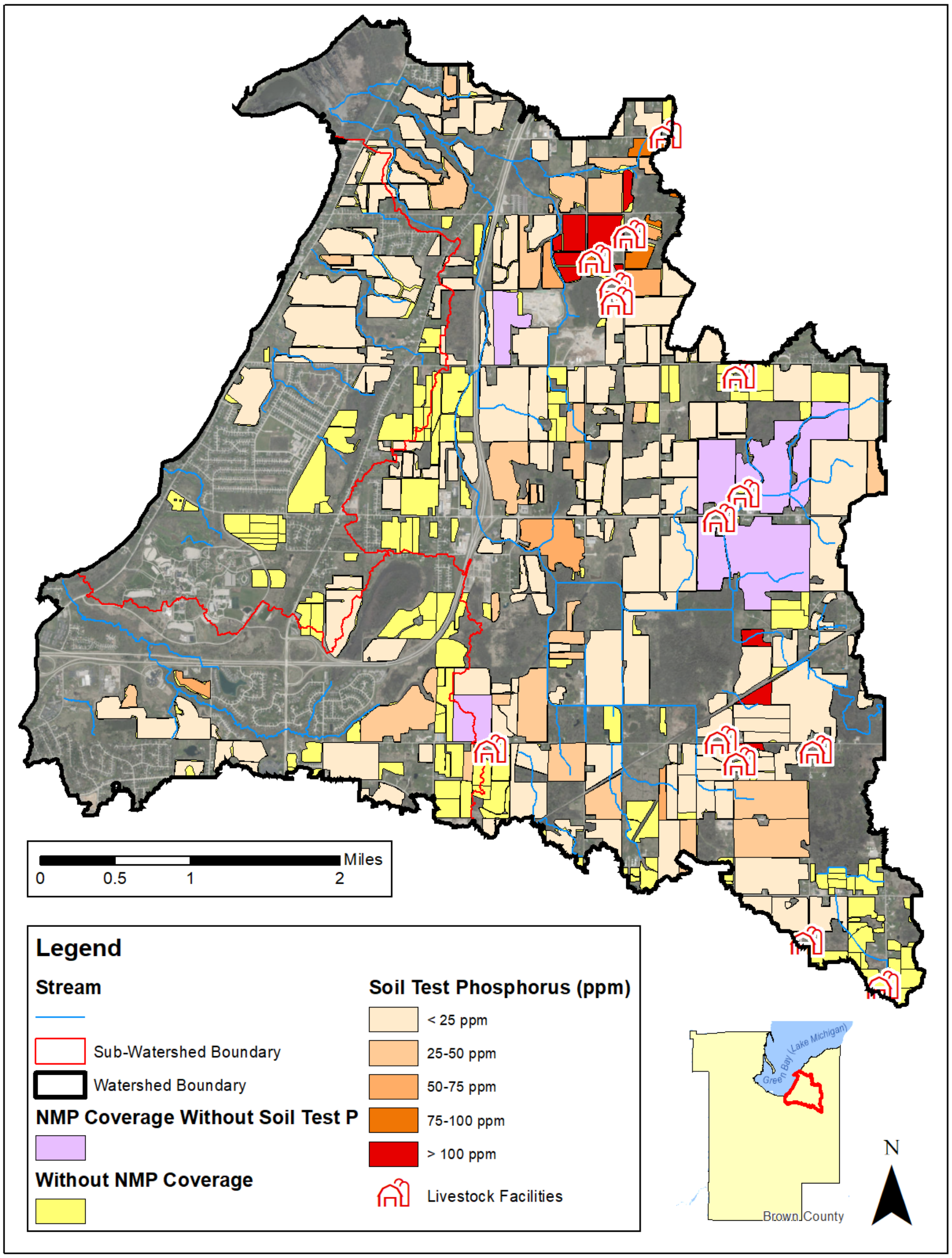

Figure 9. Livestock facilities, Soil Test Phosphorus concentrations (STP as Bray P1), and Nutrient Management Plan (NMP) coverage in the East Shore watershed (Brown County LWCD 2019 shapefiles). Fields with STP concentrations have an NMP in place. Map by Hoff (2020).

2.4.f Erosion Vulnerability Index for Farm Fields

The WDNR Bureau of Water Quality developed the Erosion Vulnerability Assessment for Agricultural Lands (EVAAL; https://dnr.wisconsin.gov/topic/Nonpoint/EVAAL.html) toolset to identify and prioritize areas that may be more vulnerable to erosion and greater soil and nutrient export to streams. EVAAL evaluates locations of relative vulnerability to sheet, rill, and gully erosion using topography, soils, rainfall, and land cover data. This tool enables managers to prioritize and focus field-scale data collection efforts and to increase the probability of locating fields with high sediment and nutrient export for implementation of best management practices (BMPs). EVAAL estimates vulnerability by separately assessing the risk for sheet and rill erosion, gully erosion (Stream Power Index, SPI), while de-prioritizing those areas that are not hydrologically connected to surface waters. These combined pieces produce an Erosion Vulnerability Index (EVI) value that can be assessed at the grid scale or aggregated to areas, such as field boundaries.

An EVI was developed by Luke Beringer of the WDNR for the East Shore watershed by applying the EVAAL toolset to GIS layers including watershed boundary, Brown County DEM, culvert and field boundaries, hydrology, NRCS soils, and NRCS Cropland layers from 2013-2018. Beringer's contribution to the creation of the EVI is greatly appreciated, particularly the effort it took to manually connect the hydrology where the GIS culvert layer was insufficient. In addition to the EVI that is summarized by field in Figure 10, a pixel level image was also created, which provides greater detail (not shown). It is recommended that areas with higher EVI scores receive a greater priority for implementing BMPs, unless there is good reason to believe that a farm field will soon be transitioning to urban land use. Universal Soil Loss Equation (USLE) difference and Stream Power Index GIS layers were also created by Beringer (not shown), and these layers will likely be used to prioritize BMP implementation efforts. In addition, the EVI map can be compared with other maps in this plan (e.g, high STP fields, lack of NMP, frequent tillage) to identify common critical areas for phosphorus and sediment reduction practices.

Agricultural land transitioning to urban

According to the 2019 Brown County, WI Comprehensive Plan, and the Brown County, WI Farmland Preservation Plan, City of Green Bay population is predicted to increase by 5% and Town of Scott is projected to increase by 21.2% by 2029.

Furthermore, agricultural lands across Brown County are projected to decrease by 16,853 acres, or 11.8% between 2020 and 2030 (BCPC 2017, BCPC 2019).

While this plan is not able to estimate which agricultural fields will likely convert to urban land use, there is a strong likelihood that at least some agricultural land in the watershed will be converted to another use, especially in the Town of Scott.

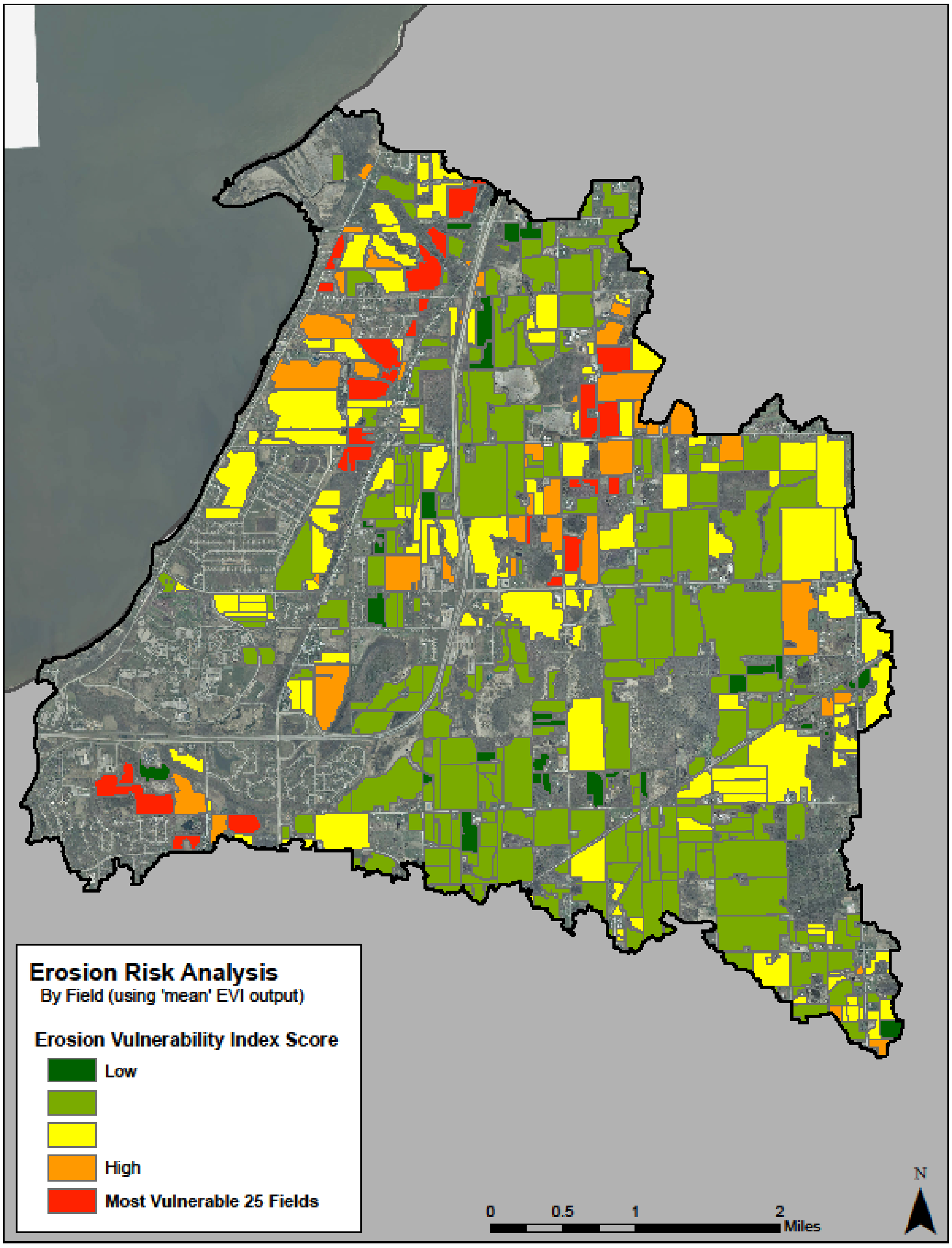

Figure 10. Erosion Vulnerability Index for farm fields in the East Shore watershed (Beringer 2019).

2.4.g Tile Drains and Outlets

Tile drains help improve drainage of agricultural lands, but also contribute soluble, and, to a lesser extent, particulate phosphorus to waterways. TSS can also be transported to waterways via tile drainage, especially when the tile drains are not functioning correctly (e.g., cracked or broken tiles/piping, cracked risers). In addition, cracks in the soil structure, worm holes, and holes left by dead roots can serve as direct soil surface to tile drainage pathways for runoff and associated pollutant loading to surface waters. However, little is known about the relative or absolute contribution of tile drainage to streams and drainage ditches in the watershed. Therefore, an analysis was conducted to assess the spatial extent of tile drainage. Fields estimated to have agricultural tile drainage were inventoried in 2019 by using multiple aerial photographs and heads-up digitizing (Hoff 2020). This first-cut inventory shown in Figure 11 was primarily created by identifying fields where linear patterns of soil moisture-induced color/shade differences were observed, primarily under bare soil conditions. Distinctions were made between fields that seem to have been densely tiled (e.g., grid network), and those where tile drainage was much less dense and primarily followed concentrated flow paths. This tile drain inventory was cross-checked with a tile drain inventory project that was produced for the Lower Fox River Basin by the Outagamie County Land Conservation Department and found to be nearly identical within the East Shore watershed area.

We recommend that the impact of tile drainage surface on water quality be assessed and reduced by a) conducting a more robust drain tile inventory that assesses the function of field verified drain tile systems, b) repairing poorly functioning drain tile systems, c) monitoring phosphorus and sediment loss from selected tile drains (flow and concentration), and d) piloting and monitoring a drain tile control structure (Table 8, objective 5).

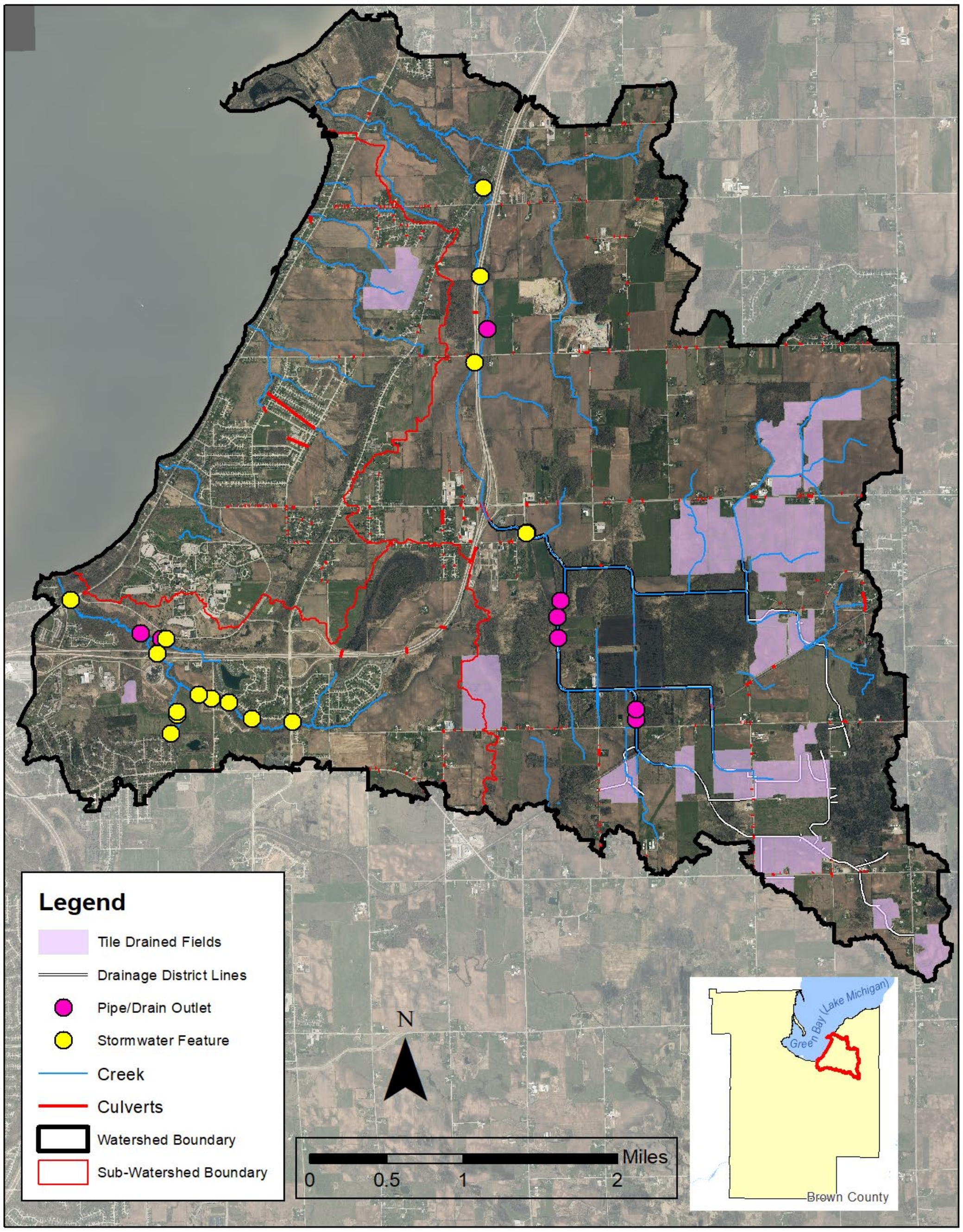

Figure 11. Estimated agricultural tile drainage inventory in the East Shore Watershed (Hoff 2020).

2.4.h Vegetative Filter Strips/Buffers

Vegetative filter strips, also known as buffers, slow water runoff and provide a setback from farm fields, thereby reducing sediment and nutrient export to adjacent stream or road ditch channels. Filter strips can also improve wildlife habitat and potentially reduce excessive stream temperatures with appropriate grass or tree plantings. A minimum 35 ft (10.7 m) buffer for streams is generally recommended for water quality protection (ATCP 50.04). Brown County has an agricultural shoreland management ordinance that requires an adequate vegetative buffer or equally effective erosion control practice in the agricultural shoreland corridor. The ordinance defines agricultural shoreland corridor as land extending 20 ft (6.1 m) from the top of bank on each side of a perennial stream or river, the centerline of an intermittent stream, or the ordinary high-water mark of any lake or pond shown on a United States Geological Survey quadrangle map with a scale of 1:24,000. Therefore, any intermittent or perennial streams with less than a 20 ft buffer will be a priority area for the installation of a filter strip of at least 20 ft. However, some priority areas may need a width up to 120 ft (36.6 m) to provide necessary reductions in pollutant loads based on the Wisconsin NRCS Technical Standard 393 for filter strips.

A filter strip GIS layer was created by identifying streams and connecting drainage ditches with an existing filter strip at least 20 ft-wide on either one or both sides (Hoff 2020). First a 40 ft (12.2 m)-wide buffer centered on the streamline was created (20 ft/side for 40 ft total width). Then heads-up digitizing was used to partition/segment the 40 ft-wide buffer layer wherever aerial photos appeared to show an adequate buffer was present. Finally, the database field associated with that segment was assigned a value based on whether there was no buffer (0), a buffer of less than 20 ft (1), or a 20 ft or wider buffer on both sides (2). The resulting filter strip layer shown in Figure 12 can be used to identify and prioritize cropland or possibly other areas where a filter strip might be added to improve water quality and enhance natural habitat with perennial vegetation. For this plan, we recommend that a minimum 20 ft wide filter strip be installed on at least 50% of the cropland identified as having less than a 20 ft riparian filter strip in this GIS analysis, for a total filter strip length of 66,500 ft (20.3 km) and area of 30.53 ac (12.4 ha; 1/2 potential buffer area of 61 ac [24.7 ha]).

The potential cropland that could be impacted by installing filter strips along road ditches was determined by using the data that was utilized in the TMDL (WDNR 2012). Using this methodology, about 24.5 mi (39.4 km) of roadway adjacent to cropland did not have a filter strip installed (total based on one side of a roadway), which equates to 59.4 ac (24.0 ha) of potential filter strips with a width of 20 ft. We recommend that about 10 ac (4.0 ha) of cropland adjacent to road ditches have a minimum 20 ft wide filter strip installed, which amounts to 16.8% of the potential area that could be buffered along road ditches.

Reductions of TSS and phosphorus associated with controlling erosion from cropland by installing filter strips are the same as those employed in the SWAT model that was applied in the TMDL (WDNR 2012), which utilized the methods described in the Natural Resource and Restoration Compensation Plan (RCDP; Stratus 2000) to determine the impact of both existing and potential buffers. Based on the methods utilized in the TMDL, the recommendation that a 20 ft wide filter strip be installed on at least 50% of unbuffered streams adjacent to cropland would result in reducing TSS and phosphorus export from cropland by 3.6% (41.6 t), and 2.8% (218 lb), respectively. Similarly, installing a 20 ft wide filter strip on the recommended length of road ditches would reduce TSS and phosphorus export from adjacent cropland by 1.65% (19 t), and 1.28% (100 lb), respectively. The total cost of installing the recommended 40.53 acres of filter strips along riparian areas and road ditches is $405,300, based on the unit cost of $10,000/ac listed in Table 16.

The Wequiock Creek watershed should be the focus of most or all filter strip installations because few areas were identified as needing a buffer strip in the Mahon Creek watershed. Furthermore, the areas identified for potential buffer strips in the Bay Shore watershed are within urban landscapes, are currently under urban development, or will likely undergo urbanization within 10 years (Figure 12, BCPC 2019).

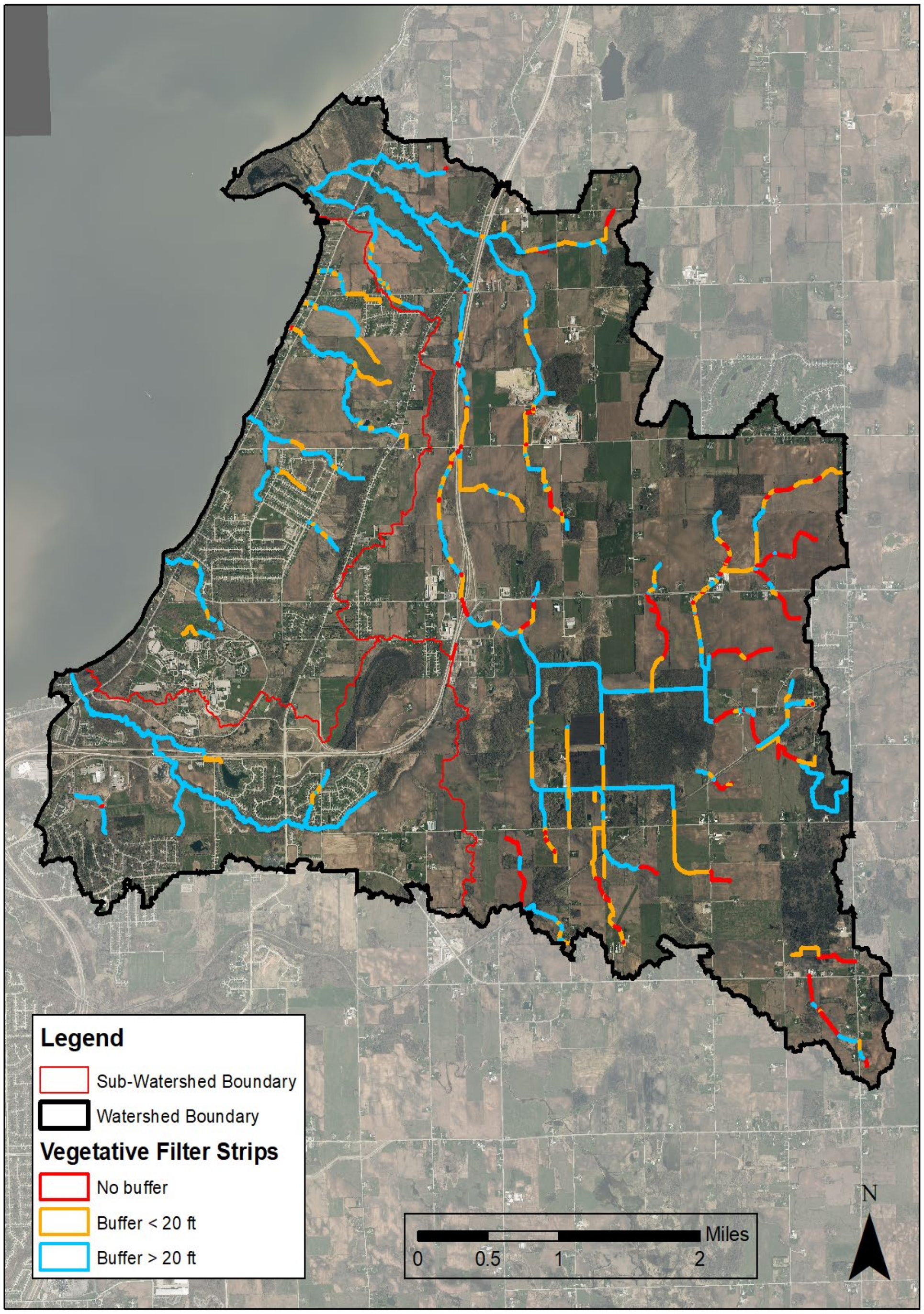

Figure 12. Vegetated filter strip (i.e., buffer strips) inventory along streams and connecting drainage ditches in the East Shore watershed. GIS layer created by UW-Green Bay (Hoff 2020).

2.4.i Streambank Erosion

An extensive and labor-intensive streambank erosion inventory was conducted in 2019 by UW-Green Bay in selected areas of the Mahon and Wequiock Creek watersheds using ESRI ArcGIS Collector to create a georeferenced real-time geodatabase (Hoff 2020). Eroding banks were identified, delineated by length and height, and classified according to lateral recession severity (slight, moderate, severe, very severe) based on the Rapid Stream Bank Erosion Assessment Method, and this ranking by segment is shown in Figure 13. Approximately 3.3 mi of Mahon Creek and 5.3 mi of Wequiock Creek were surveyed, which is about 20% of the total stream lengths. Surveyed erosion rates were not extrapolated to the remaining stream banks. However, roadside visual inspection of streams upstream of the surveyed locations indicated that un-surveyed bank erosion was likely to be relatively minimal. The stream bank inventory data were then used to calculate a value for estimated sediment loss from each delineated segment based on the NRCS direct volume method (depth, length and estimated annual recession rate, soil bulk density). Other parameters that were collected included: sediment deposition, stream crossings, riparian activities, outlets, agricultural activities, and flow and fish barriers. In addition, a rapid assessment of instream habitat characteristics was recorded on 7 of the 9 segments walked for the stream inventory. Parameters collected every 50 steps included: river unit (riffle, pool, run), deepest point (cm), stream width at bank toe (m), and dominant substrate.

The initial bank erosion totals were reviewed and adjusted downward by a factor of 0.3 because they seemed excessive. For example, the initial estimated annual bank erosion in Mahon Creek was 319 English tons (not counting riparian gully erosion), which greatly exceeded the observed 2011-16 average annual total TSS load of 140 tons and the highest load of 251 tons in 2011. This finding was not unexpected because the bank erosion estimation method is primarily meant to be used to provide a relative ranked scale classification that can be used to prioritize those areas where bank erosion is higher and remediation efforts are more likely to produce the greatest positive impact on downstream water quality. In addition, water samples that are collected for TSS analysis are based on material that is suspended in the water column, so they do not account for material that may erode into a stream but be transported downstream as bedload which, by definition, is not suspended. After applying the adjustment factor of 0.3 to the initial bank erosion estimates, the estimated average annual TSS contribution from streambanks to the outlets of Mahon and Wequiock creeks is 95.7 and 45.6 tons, respectively, for a total watershed contribution of 141.2 tons (for surveyed stream segments only). After applying the adjustment factor of 0.3 to the initial bank erosion estimates, and a phosphorus to TSS ratio of 1/1000, the estimated average annual streambank contribution of phosphorus delivered to the outlet of Mahon Creek is 191.3 lbs, to the outlet of Wequiock Creek is 92.1 lbs, with a total watershed contribution of 282 lbs (for surveyed stream segments).

Streambank erosion (tons/yr) is currently much greater in Mahon Creek. Hoff (2020) recommended an increase in upland water storage capacity in the urban and urbanizing areas, possibly including the UW-Green Bay campus. She also proposed the following actions: 1) install green infrastructure in the upland areas of the Mahon Creek watershed to increase water infiltration; 2) install intermediary natural infrastructure to intercept surface water runoff, and 3) restore and protect water holding ecosystems. Altogether, these actions could lessen the impact that upstream drainage has on downstream flashiness, velocity, flooding, and, consequently, streambank erosion. Practitioners should use these recommendations as a blueprint for future development in the Wequiock Creek watershed to mitigate to the extent possible future streambank erosion and sediment loading in Wequiock Creek. Current management should focus on implementing practices that limit soil exposure on agricultural fields in the Wequiock Creek watershed.

Streambanks targeted for remediation were selected based on greatest load. Our initial remediation cutoff estimate is eroding bank segments with estimated unadjusted contributions of ~2.25 or more TSS tons/yr, for total lengths of 3,260 ft in Mahon Creek and 1,740 ft in Wequiock Creek, which account for 67% of the inventoried bank load, but only 43% of the inventoried eroding banks. The estimated cost of restoring the 5,000 ft of identified streambank is $400,000, based on the unit cost of $80/ft listed in Table 16. More detailed descriptions of water quality issues and suggested actions to curb streambank erosion in Mahon and Wequiock Creeks are described by Hoff (2020; see Table 1).

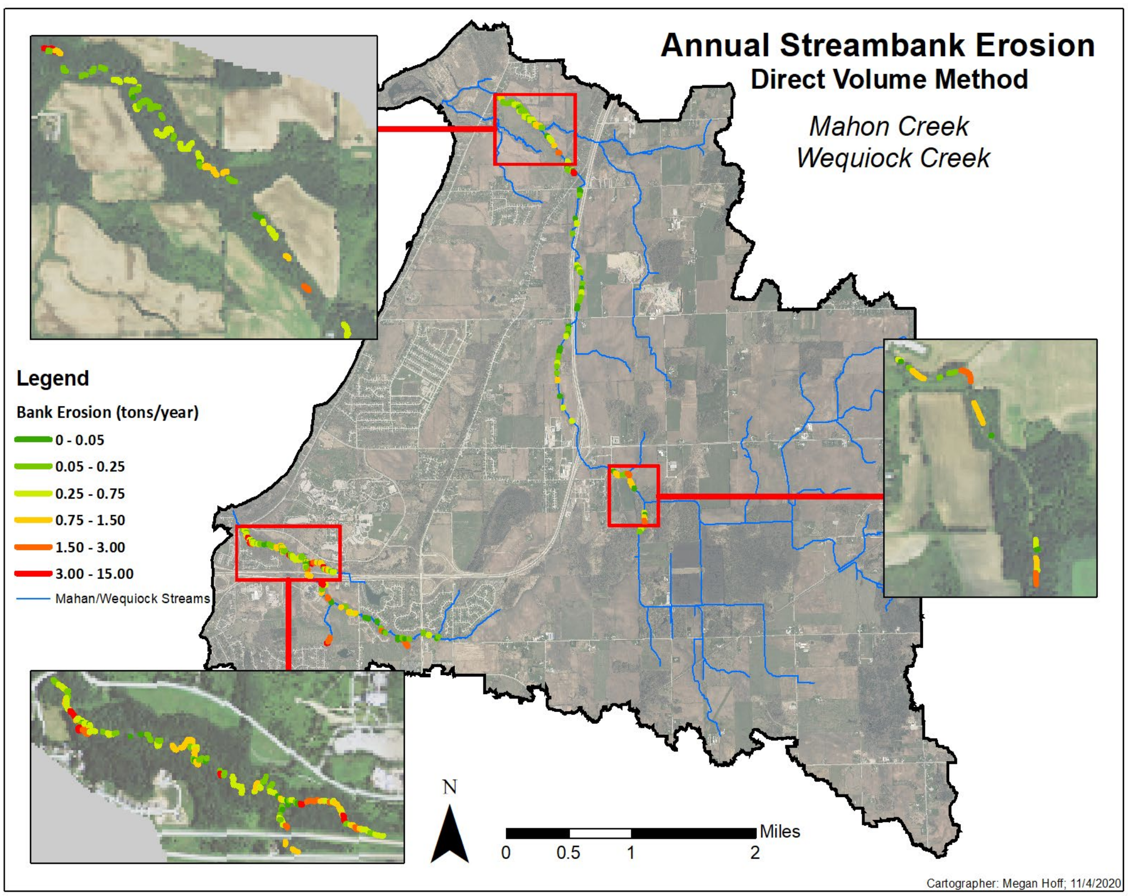

Figure 13. Estimated average annual streambank erosion from major contributing banks in the East Shore watershed (Hoff 2020). Streambank erosion contributions are based on estimated amount of suspended sediment to reach Mahon or Wequiock outlets to Green Bay.

2.4.j Upland Gully Erosion

Riparian corridor gullies have already been identified during the streambank erosion inventory, so this section applies to upland gully erosion management. Upland gullies form where flow is concentrated over erodible land for a long enough distance to form deep unvegetated rills that enlarge and become either ephemeral gullies, where tillage can level the gully out on an annual basis, or deeper perennial gullies that require repair (i.e., classic gully, or simply referred to as a gully). Excessive soil erosion can occur with both types of gullies, as well as increased sediment transport capacity within the concentrated flow path. Eroding soil is accompanied by phosphorus that is attached to the soil particles. Therefore, recurring gullies can disproportionally contribute to TSS and phosphorus export.

The Brown County LWCD supplied a GIS shapefile for this plan with an inventory of identified gullies in the East Shore watershed, with a total length of 20,320 ft. About 86% of the identified gullies were in the Wequiock Creek watershed, with the remainder in the Mahon Creek Watershed. However, the gully inventory layer may be incomplete, and it did not necessarily discriminate between ephemeral and perennial gullies. Aerial photos were overlaid with the Stream Power Index layer (SPI), which was described earlier, to estimate where active erosion from additional ephemeral and classic gullies are present in crop fields. We discovered that there were many more concentrated flow paths present, with relatively high SPI values, but it was not possible to accurately discern whether additional gullies were present without field verification. For this plan, we will therefore rely primarily on the current inventory to determine where and how to treat upland gullies in cropland. However, we multiplied the total inventoried gully length by a factor of 1.5 to provide an estimate of potential gullies (i.e., 20,320 ft * 1.5 = 30,480 ft) within the watershed. Further development and field verification of the current gully erosion inventory are recommended to more accurately prioritize gully stabilization efforts. Development of a revised gully erosion inventory should be completed within one year of an approved and funded watershed plan.

Where necessary, ephemeral gullies can be treated by leveling with standard tillage equipment and installation of vegetation that will protect the concentrated flow path from erosion (critical area plantings). Deeper perennial gullies would likely require some grade stabilization and a constructed grassed waterway. These two practices are traditional gully stabilization practices and are a requirement of Nutrient Management Plans. However, the network of gullies observed is so extensive, that it is not likely that all of the ephemeral and permanent gullies will be able to be adequately treated with critical area plantings or grassed waterways because it can be more difficult to farm a field with a network of grass strips or deeper grassed waterways. Finally, traditional approaches do not always work in the long run because they do not address the underlying problems.

Therefore, it is recommended that a more holistic preventative approach be emphasized, which focuses on regenerative agriculture practices across a majority of cropland acres within the watershed. Regenerative agricultural practices are designed to build soil health over time by implementing a combination of practices such as no-till, cover crops, low disturbance manure application, rotational grazing and providing vegetative cover year-round. These practices slow runoff, and improve infiltration and water retention, thereby reducing the need for traditional gully stabilization practices.

The EPA STEPL (Spreadsheet Tool for Estimating Pollutant Loading) version 4.4b model was used to estimate the impact of upland gully erosion on export of TSS and phosphorus from the watershed, as summarized in Table 7. In these calculations, it was assumed that installing critical area plantings or grassed waterways will reduce TSS and phosphorus export by 95%, and that 70% of the estimated load is delivered to the watershed outlets. Gullies that were adjacent to streams were also delineated during the streambank erosion survey, described in Subchapter 2.4.i. Erosion estimates for each riparian gully was derived with STEPL using the same techniques as was done with the other gullies. The total contribution from these riparian gullies is listed in Table 7.

Table 7. STEPL inputs for gully dimensions and load reductions from upland concentrated flow paths that require a grassed waterway (GW), less severe upland gullies where critical area plantings (CAP) will suffice, and riparian gullies that require a grass waterway (GW-R).

Gully BMP	Top Width (ft)	Bottom Width (ft)	Depth (ft)	Length (ft)	Years to Form	Soil Dry Weight (ton/ft^3)	BMP Efficiency	Load Reduction TSS (ton)	Load Reduction Phosphorus (lbs)
GW	0.75	0.75	0.5	9,144	1.5	0.0425	0.95	92.3	276.9
CAP	0.5	0.1	0.25	21,336	1	0.0425	0.95	64.6	193.8
GW-R	calculated separately			1,419	5.0	0.0425	0.95	35.5	74.5
							Total	192.4	545.2
							Delivered (70%)	134.7	381.7

Based on our current estimates, traditional management practices such as grassed waterways for perennial gullies (9,144 ft), grassed waterways for surveyed riparian gullies (1,419 ft), critical area plantings for ephemeral gullies (21,336 ft), and lined waterways (750 ft), are still recommended for controlling erosion and phosphorus export from concentrated flow paths (Table 8, Objective 2). The cost of installing grassed waterways is $52,815 ([9,144 ft + 1,419 ft] * $5/ft), critical area plantings is $3,306 (21,336 ft * 15 ft wide = 7.35 ac; 7.35 ac * $450/ac), and $26,250 for 750 ft of lined waterway ($35/ft), for a total of $82,370. The basis for these unit costs are listed in Table 16.

However, regenerative practices as summarized in Table 8, Objective 1 are highly recommended and will be necessary to reduce excessive soil erosion and phosphorus export from extensive poorly managed upland concentrated flow paths, especially given future climate change projections. Furthermore, more severe classic gullies in the riparian corridor may require extensive grade stabilization and/or Water And Sediment Control Basins (WASCOBs) in the watershed. The Agricultural Conservation Planning Framework (ACPF) tool can help predict best areas for WASCOBs and other sediment control BMPs. The cost of installing 15 WASCOBs ($11,000 each), for a total of $165,000 is included in the plan.

2.4.k Urban Non-MS4

Approximately 1,350 acres of urban non-regulated area is in the East Shore Watershed. The distribution of regulated (MS4) and non-regulated (Non-MS4) urban land use in the watershed is shown in Figure 14. Based on loads derived from the TMDL (WDNR 2012), the baseline average annual loads from Non-MS4 areas in the East Shore Watershed are 46 tons of TSS and 296 pounds of phosphorus (Tables 2 and 3). The baseline average annual loads from MS4 areas in the East Shore Watershed are 299 tons of TSS and 1,598 pounds of phosphorus (Tables 2 and 3). The TMDL, approved in 2012, did not recommend a

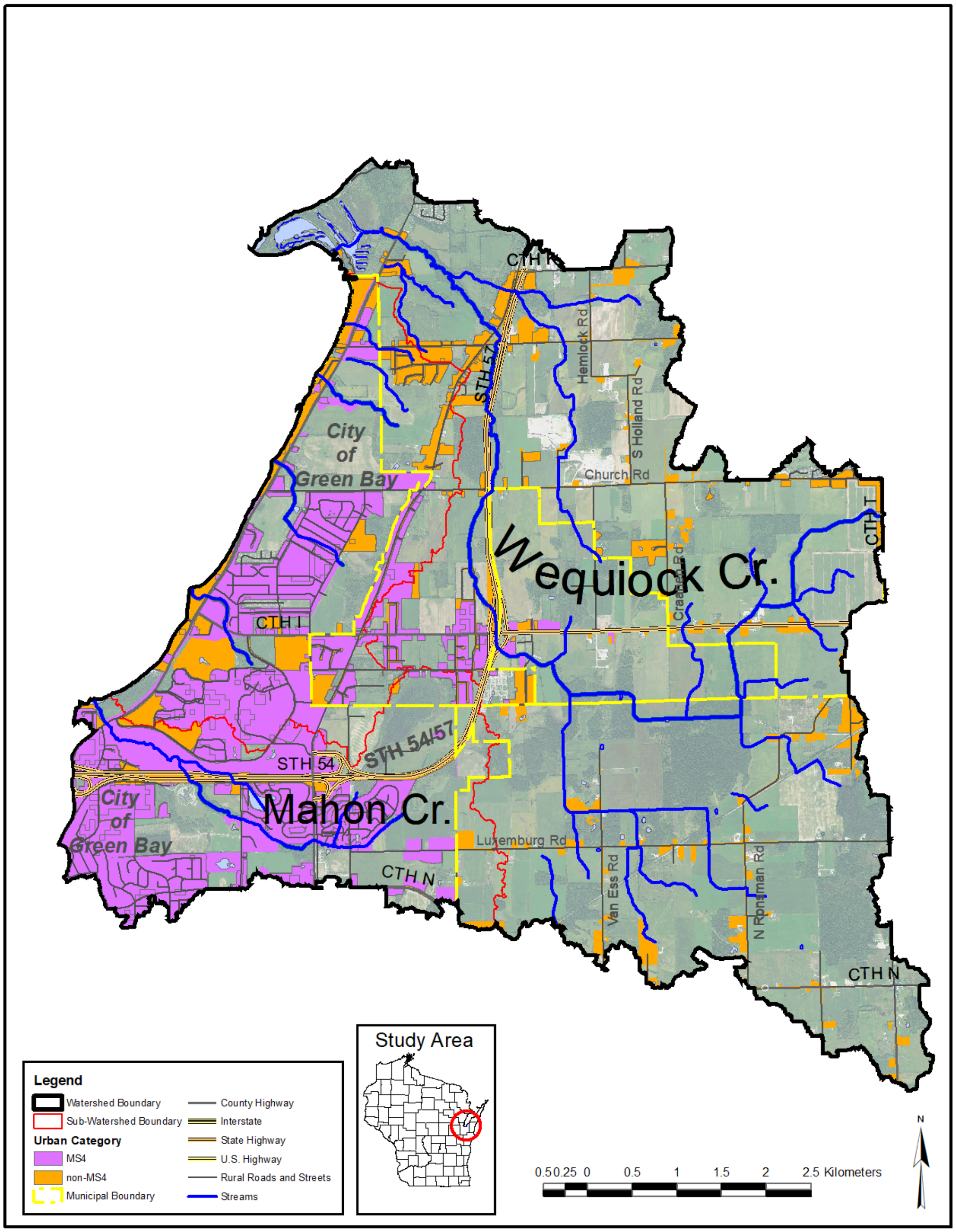

Figure 14. Urban regulated (MS4) and non-regulated land use in the East Shore Watershed.

reduction from baseline for either phosphorus or TSS for urban non-regulated areas in the East Shore Watershed.

However, as urban non-regulated land use continues to increase in this watershed, the amount of impermeable area will increase, resulting in an increase in runoff. Increased runoff may increase flooding and exacerbate erosion downstream in the watershed. To ensure TMDL goals are realized, it is recommended that townships that fall within the urban non-regulated area (Town of Scott & Town of Humboldt) assess their stormwater contribution and develop plans for stormwater control and develop local ordinances for stormwater management and erosion control.

Solutions that may be identified in Urban Non-Regulated stormwater management plans include but are not limited to: detention basins, bio-filters, street sweeping, filter strips, green roofs, porous pavement, rain gardens and rain barrels.

2.4.1 Legacy Phosphorus and Sediment

Legacy phosphorus is associated with excessive levels of phosphorus that have accumulated in the soil (Figure 9), or sediment deposited in ditches, wetlands, streams or other surface waters. In stream channels, legacy phosphorus can result from sediment deposition of particulate phosphorus, sorption of dissolved phosphorus onto riverbed sediments or suspended sediments, or by incorporation into the water column (Sharpley et al 2013). This buildup of phosphorus can serve as a long-term source of phosphorus to surface waters. If levels are high enough, it may be difficult to achieve TMDL reductions because the legacy phosphorus may mask improvements that are made to decrease phosphorus coming from agricultural and urban non-point sources, as well as from point sources.

Legacy instream sediment may need to be evaluated as another significant source of phosphorus in the East Shore watershed if substantial improvements in agricultural practices, including reducing phosphorus in the soil, are not accompanied by reduced in-stream concentrations and loads of phosphorus by the end of the ten-year East Shore watershed plan. However, we recommend that some measures could be taken at the beginning of the watershed plan, rather than waiting for the 10-year plan evaluation to take place. For example, one potential means of reducing legacy phosphorus in the upper portion of the Wequiock watershed would be to ensure that sediments removed from Drainage District channels during ditch maintenance are redistributed well upslope of the field/channel edge, or to another field with low soil phosphorus rather than placing the dredged sediment directly next to the drainage channel. This same approach could also apply to road ditches where sediment deposits have high phosphorus levels (e.g., > 50 ppm Bray-P1). Furthermore, where road ditches adjacent to fields with high soil phosphorus concentrations have substantial sediment deposits, we recommend that these deposits be evaluated for potential removal (see Figure 9). In-stream deposits could also be evaluated for removal, but they are likely to be more difficult to remove from both a physical and regulatory perspective.

2.5 Water Quality Goals

2.5.a Agriculture Goals

Vision:
Agriculture is recognized as an integral part of the community and a leader in land stewardship for restoring soil health, reducing runoff pollution, and promoting clean and safe water.

Goal 1:
The East Shore Lower Green Bay watershed meets the Lower Fox River and Green Bay Total Maximum Daily Load targets for phosphorus and Total Suspended Solids (TSS).

Goal 2:
Evaluate the extent to which the Wisconsin Department of Natural Resources (WDNR) and U.S. Environmental Protection Agency (EPA) surface water and groundwater requirements are met for other pollutants in the watershed (via water sampling and also monitoring salt application rates), such as fecal coliform, human and/or animal pathogens, Per- and polyfluoroalkyl substances (PFAS), chloride from road salt, nitrates, etc.

The load reductions and actions estimated to be needed from agricultural and rural sources to achieve Goal 1 are listed in Table 8. The total reductions estimated to come from implementing all of these measures is equivalent to achieving the load reduction targets in Tables 2 and 3. Importantly, the measures required to meet the TSS and phosphorus load reduction targets can be met by multiple combinations of actions listed in Table 8. The estimated total cost related to all actions listed in Table 8 is $5,552,250. The cost of individual actions is primarily based on the linear feet and acres of installed BMP practices, as listed in Tables 8 and 16, and described in previous sections of this chapter. The acreage of BMPs such as conservation tillage, cover crops and low disturbance manure application were based on the percent of required implementation, as applied to the total cropland area of 7,053 acres.

Most of the actions listed in Table 8 to reduce TSS and TP export from the watershed do not require additional remedial measures. However, remediation of streambanks that are actively eroding along Mahon Creek may offer only a short-term solution to the problem if changes in hydrology caused by urbanization within the watershed are not addressed. If urban runoff is not sufficiently controlled, excessive streambank erosion may continue despite efforts to fix eroding streambanks. Therefore, steps to address urban runoff and stream flashiness that are described in the next chapter are critical to addressing current and future problems related to streambank erosion within urbanized areas of the watershed. While streambank erosion along Wequiock Creek is not as severe as in Mahon Creek, future urbanization within the Wequiock watershed must be looked at closely to ensure that streambank erosion does not become a significant problem.

Derivation of load reductions to achieve Goal #1:
The load reductions listed in Table 8 for achieving Goal #1 are based on several modeling techniques and assumptions. Reductions in Objective 1a are based on a SNAP-Plus modeling scenario that was modeled by Andrew Craig of the WDNR for watersheds in the Lower Fox River sub-basin (Scenario #1), which included the East and West shore watersheds as a single modeling unit. SNAP-Plus Scenario #1 included the following changes in management: 1) no-till used on all years of dairy and cash grain crop rotations; 2) dairy rotation has winter rye cover crop planted after corn silage harvest, and cover crop is successful for 2 out of 3 years; 3) cash grain has small grain cover crop after harvest every other year; 4) fields farmed along the contour; and 5) all liquid manure is injected and there is no winter application of manure. Cover crops are assumed to be successful 2 out of 3 years, so associated cost share will be

reimbursed on a Pay-for-Performance basis. These assumptions resulted in phosphorus, and TSS load reductions of 77.4% when applied across the East Shore watershed under an implementation rate of 100% of cropland acres. These simulated reductions were more than the reduction targets specified in the TMDL for the East Shore watershed for agricultural sources (Tables 2 and 3). Therefore, we assumed a 74.1% implementation level of Scenario #1, which was commensurate with the reductions required to meet most of the cropland load allocation specified in the TMDL for phosphorus (Table 3). Under this assumption, the remaining 25.9% of the agricultural acres would not change from current management practices. To wholly meet the agriculture phosphorus load allocations specified in Table 3, the Objective 1a actions were also accompanied by recommended actions to control barnyard runoff (Obj. 1b), gully erosion (Obj. 2), and runoff to streams by installing riparian filter strips (Obj. 3a,b). Recommendations to stabilize streambanks are under a separate action (Obj. 3d) because excessive streambank erosion was present in both urban and rural areas. Employing these actions to meet the phosphorus target results in a TSS load reduction that is greater than required for agricultural sources to meet the load allocation specified in the TMDL (Table 2).

As previously stated, reductions of phosphorus and TSS related to actions in Objective 1a were obtained with the SNAP-Plus model. The other means of deriving load reductions are described here. Gully erosion reduction estimates listed under Table 8, Objective 2 were calculated by assuming that there will be a 95% decrease in phosphorus and TSS when ephemeral and permanent gullies identified in item 2.4(j) are treated (Table 7). Reductions associated with stabilizing eroding streambanks identified, and targeted in section 2.4(i) for treatment, were calculated by assuming a 100% reduction in phosphorus and TSS. Reductions associated with controlling erosion by installing filter strips to the degree stipulated under Action Item 2.4(h) are the same as those estimated in the TMDL (WDNR 2012). Reductions associated with controlling barnyard runoff are described in section 2.4(e). Reductions of TP were assumed to be equivalent to those for TSS for both gully and streambank erosion because only the portion of eroded sediment that is delivered to the stream and transported as suspended sediment are counted in the source load estimates. That is, contributions from these sources to stream bedload or net deposition are excluded from load estimates, allocations, and reductions.

Installing agricultural reduction treatment systems (ARTS, i.e., treatment ponds) within cropland areas is an alternative management option that could reduce the extent that other practices would need to be implemented to reach the targeted load reductions. If ARTS are installed per Objective 4a, the Outagamie County LCD (2020) estimated that 78.8 ac of treatment ponds installed in the watershed would cost $5,482,700 ($69,580 per acre of installed treatment pond), would treat 5,580 agricultural acres, and result in estimated reductions of 2,180 lb of TP and 440 tons of TSS. In addition to reducing TSS and TP loads, ARTS could potentially reduce streambank erosion because peak event flows would be reduced. However, portions of cropland within the Bay Shore and Mahon Creek watersheds that are currently located near urban areas, or within the City of Green Bay boundary, are likely to transition to urban land use within ten years (Figures 1, 2, 14; and see City of Green Bay 2003). Therefore, permanent ARTS ponds are probably not recommended for such areas. Plus, streambank erosion does not appear to be a major source of TP or TSS in the Wequiock watershed at this time, especially when compared to the extensive streambank erosion inventoried in Mahon watershed (Figure 13, and see Hoff 2020), which is likely the result of the effects of urbanization rather than agricultural runoff. If ARTS are installed in the watershed, we recommend that estimated TSS and TP reductions be based on observed trapping efficiencies. For example, two constructed ARTS in the Plum Creek watershed were monitored by the U.S. Geological Survey, UW-Green Bay, The Nature Conservancy, and the Outagamie County LCD (UWGB 2021). Preliminary load reductions of 78% and 83% were estimated for TSS in the two ARTS, and a 45% load reduction of TP was estimated at both sites (2017-19 for one site, and 2019-20 for the other site). These two systems include native plant species in the pond, and automated monitoring at the surface water inlet, tile inlet, and pond outlet (i.e., mass-balance). The fractions of particulate and dissolved phosphorus (DP) to be treated by the ARTS should also be factored into potential phosphorus reductions from ARTs in this watershed, because settling ponds, including the two being studied in the Plum Creek watershed, are not good at trapping dissolved phosphorus. However, a study was initiated in 2021 to investigate the feasibility of treating at least some of the dissolved phosphorus entering or leaving one of the Plum watershed agricultural treatment pond sites.

Table 8. 10-Year Agriculture/Rural Land Use Management Measures and Plan Matrix.

Actions	*Indicators*	*Cumulative Milestones*			*Estimated load reduction[1]*		*Total Cost[2]*	*Funding Sources[4]*	*Implem-entation*
		0-3 yr	*4-7 yr*	*8-10 yr*	*TP (lb)*	*TSS (tons)*			
Objective 1. Reduce soil and nutrient loss from manure and commercial fertilizer to streams and other waterways.									
a. Achieve a P loss which is 57.4% below current conditions (*WDNR calculated baseline P loss is 3.0 lb/ac/yr*.)	Area weighted average P loss	2.4	1.85	1.28	4,491 51.8%	662[6] 48.5%[6]		GLSNRP	NRCS, LWCD WDNR
a(i). Increase conservation tillage acreage such as mulch till (MT), no-till (NT) & strip till	Percentage of total cropland in conservation tillage	30%	55%	74% if only no-till (5,226 ac), more if some MT	-	-	$418,100[3]	CIG, CSP, EQIP, GLRI, MDV, WQT, TRM	NRCS LWCD WDNR
a(ii). Cover crops planted and successful on 67% of row crops <u>where</u> Obj. 1a implemented	Percentage of row crop acres w/cover crops	20% (1,045 ac)	50% (2,610 ac)	67% (3,500 ac)	-	-	$1,050,480[3]	EQIP, CSP, GLRI, MDV TRM, WQT	NRCS LWCD
a(iii). All cropland has a Nutrient Management Plan (currently 80%)	% of acres under NMP	85%	90%	100% (1,425 ac)	-	-	$57,000[3]	CSP, EQIP, GLRI, MDV TRM, WQT	NRCS, LWCD
a(iv). Manure runoff risk is reduced while maintaining soil protection	Acres receiving manure with low disturbance	1,645 ac	3,300 ac	5,226 ac	-	-	$2,195,000[3]	CSP, EQIP, GLRI, MDV TRM, WQT	NRCS, LWCD
a(v). Assess the status of and eliminate winter manure application	Status report included in BCLWRM Plan	X	-	-	-	-	Staff time[5]	DATCP	NRCS, LWCD
a(vi). Soil health baseline assessment	# of fields assessed	5	20	40	-	-	$14,000	EQIP, FFAR,	NRCS, LWCD, UWGB, FWWA

Table 8. continued

Actions	*Indicators*	*Cumulative Milestones*			*Estimated load reduction*		*Total Cost*[2]	*Funding Sources*	*Implem-entation*
		0-3 yr	*4-7 yr*	*8-10 yr*	*TP (lb)*	*TSS (tons)*			
Objective 1. (continued)									
a(vii). Increase diversity of unconventional, soil health, and/or regenerative agriculture strategies such as: less erosive crop rotations, managed grazing, perennial crops such as kernza, biochar etc.	Number of acres cropland with conservation practices applied	150 ac	300 ac	500 ac	-	-	$135,000	CIG	NRCS, LWCD
a(viii). Identify land conservation opportunity areas such as: Conservation Reserve Program, putting land into conservancy, ag conservation easements, etc.	Report drafted and incorporated into LWCD work plan	-	-	-	-	-	Staff time[5]	ACEP, EQIP, CREP/CRP, GLRI, MDV, NRDA WQT	LWCD
b. No significant discharge from barnyards by implementing runoff management	Number of barnyards addressed	0	2	0	169 1.9 %	-	$600,000	EQIP, MDV, TRM, WQT,	NRCS, LWCD
Objective 2: Soil is protected from concentrated flow erosion.									
a. Stabilize concentrated flow channels that contribute to ephemeral and permanent gullies	# of feet with grassed waterway and acres with critical area planting	3,150/ 2.45 ac	7,500/ 5.5 ac	10,563/ 7.35 ac	382 4.4%	135 9.9%	$82,370	EQIP, CREP/CRP, MDV, WQT,	NRCS, LWCD
b. Store and control runoff with a Water and Sediment Control Basin (WASCOB)	# of WASCOBs installed	5	10	15	-	-	$165,000	EQIP, CREP/CRP, MDV, WQT,	NRCS, LWCD

Table 8. continued

Actions	*Indicators*	*Cumulative Milestones*			*Estimated load reduction*		*Total Cost[2]*	*Funding Sources*	*Implem-entation*
		0-3 yr	*4-7 yr*	*8-10 yr*	*TP (lb)*	*TSS (tons)*			
Objective 3. Waterways including perennial, intermittent, and ephemeral streams, are protected with a vegetated buffer.									
a. Minimum 20-foot vegetated buffer present along ≥50% of perennial and intermittent streams	linear feet of 20-ft buffers (acre equivalent)	26,000 (12 ac)	50,000 (23 ac)	66,500 (30.5 ac)	218 2.5%	41.6 3.05%	$305,300	CREP/CRP, EQIP, GLRI, MDV WQT	NRCS, LWCD
b. Minimum 5 to 20-ft vegetative buffer along road ditches, as deemed necessary	acres of 20-ft buffers (field borders)	3	7	10	100 1.2%	19 1.39%	$100,000	CSP, EQIP, MDV, GLRI, TRM, WQT	NRCS LWCD
c. Maintain 20-ft vegetative buffer along drainage ditches in Drainage District #4.[7]	linear feet of 20-ft buffers (acre equivalent)	1,005 (0.46 ac)	2,110 (1.0 ac)	3,694 (1.7 ac)	-	-	-	Drainage District #4	LWCD
d. Restore and stabilize stream banks (rural and urban sources)	# linear feet stabilized	1,670	3,300	5,000	188 2.2%	94 6.9%	$400,000	CSP, EQIP, GLRI, MDV TRM, WQT	NRCS, LWCD
d(i). install stream crossings	# of crossings	1	2	3	-	-	$15,000		
Objective 4. Stream flashiness is decreased (*some of these actions also pertain to Objective 1*).									
a. Install Agricultural Runoff Treatment Systems (ARTS)[9]	% of cropland draining to treatment pond	-	-	X[8] if feasible	-	-	($5,482,700)[9]	CWSRF	LWCD
b. Identify opportunities for preserving and improving wetlands in the watershed	LWRMP 2021	X[8]	-	-	-	-	Staff time[5]	EPA, ACE, TNC, WDNR	LWCD, NRCS, WDNR USFWS
c. Improve infiltration	NDTI, Soil Health indicator/index	-	-	-	-	-	Staff time[5]	EQIP, GLRI, MDV, TRM, WQT	NRCS, LWCD
d. Assess and prioritize areas of the stream where re-meandering could help decrease flashiness	status report included in BCLWRMP	X[8]	-	-	-	-	Staff time[5]	CSP, EQIP, GLRI, MDV, TRM	NRCS LWCD

Table 8. continued

Actions	Indicators	Cumulative Milestones			Estimated load reduction		Total Cost[2]	Funding Sources	Implem-entation
		0-3 yr	4-7 yr	8-10 yr	TP (lb)	TSS (tons)			
Objective 5. The impact of tile drainage on water quality is assessed and reduced.									
a. Conduct a drain tile inventory that assesses function of drain tile systems	Study conducted and published	X[8]	-	-	-	-	$5,000	GLRI	NRCS, LWCD, UWGB
b. Repair poorly functioning drain tile systems		-	X[8]	-	-	-	$5,000	EQIP, CREP, FWP	LWCD, FSA
c. Implement a monitoring project to assess phosphorous and sediment from tile drains	Data on P and sediment are collected and shared	X[8]	X[8]	-	-	-	$5,000		NRCS, LWCD, UWGB
d. Pilot and monitor a drain tile control structure	-	2	3	5	-	-	-	EQIP, MDV, TRM, WQT	NRCS, LWCD
e. Reduce excess phosphorus and sediment from drain tile outlets	-	-	-	-	-	-	-	CSP, EQIP, GLRI, MDV, TRM, WQT	NRCS, LWCD
Total					**5,548 64.0%**	**952 69.7%**	**$5,552,250**		

[1] Percent reductions are relative to non-point source baseline load.
[2] Costs may vary for each Action, depending on what combination is selected to achieve the P loss objective.
[3] Payment is for 4 years, after which the practice is continued by farmer, or funded elsewhere.
[4] For description see Funding Sources section.
[5] See Table 16 Cost estimates for technical assistance for implementation.
[6] SNAP-Plus P target achieves lower TSS reductions than needed (i.e., only 70.4% implementation level needed, along with other specified actions, to achieve Table 2 TSS targeted reduction of 629 tons from baseline agricultural sources, which does not include streambank source).
[7] The Drainage District requires a 20 ft buffer strip on each side of a drainage ditch, so payments cannot be made for installing a buffer strip where there is none (e.g. where an exemption has been granted by the district).
[8] X indicates this is the time period when this action should occur at the latest.
[9] See discussion on p 47. Cost is not part of tally because ARTS are an alternative that displaces some other practices, so they could be used instead

2.5.b Flooding and Stormwater Goals

*Goal 1***:** Improve water quality to meet EPA surface water requirements & Lower Fox River and Green Bay TMDL targets.

Goal 2: Reduce magnitude, extent and frequency of flooding events.

The actions listed in Table 9 for urban areas are recommended to achieve Goal 1 TMDL targets and Goal 2 stormwater modifications.

The Town of Scott (Mead and Hunt 2018), City of Green Bay and UW-Green Bay (Ayres 2018) MS4's have been working towards achieving TMDL goals by developing and implementing stormwater management plans and updating stormwater ordinances. These management plans identify Best Management Practices (BMP's) needed and estimated costs to achieve TMDL compliance.

Examples of stormwater BMP's used by municipalities to meet MS4 permits include: detention basins, street sweeping, filter strips, porous pavement, water quality inlets, grassed swales/ditches, green roofs, rain gardens and rain barrels. Several of these BMP's work by intercepting urban stormwater prior to entering the MS4 system. The use of these types of practices is recommended and will be beneficial in urban and suburban areas to reduce the load of stormwater and pollutants entering MS4 systems. The use of green infrastructure that simulates natural hydrology by capturing stormwater where it falls may not directly achieve the terms of a WPDES Stormwater permit in some situations. In these cases, best management practices implemented on areas outside of the MS4 permit area that intercept the water from entering the MS4 system may be fundable under EPA 319 funds.

Objective 2 below calls for actions to restore and stabilize eroding streambanks in urban areas, but also recommends decreasing stream flashiness and increasing runoff storage volumes to protect streambanks. Otherwise, the actions specified in Objective 1 will likely be insufficient to curb excessive streambank erosion in Mahon Creek. This will be especially true if urban and suburban development continues with bare minimum permit compliance measures.

As described earlier, streambank erosion is significantly greater in Mahon Creek compared to Wequiock Creek, and it is likely that the transition from agriculture to urban land use is responsible for this problem. However, restoring and stabilizing streambanks that are actively eroding along Mahon Creek may offer only a short-term solution to the problem if changes in hydrology caused by urbanization within the watershed are not addressed. Therefore, steps to address urban runoff and stream flashiness are critical to addressing current and future problems related to streambank erosion. While streambank erosion along Wequiock Creek is not as severe as in Mahon Creek, future urbanization within this watershed must be looked at closely to ensure that streambank erosion does not become a major problem (e.g., the potential business park near the Hwy 54/57 interchange in the City of Green Bay). Furthermore, streambank erosion could also occur on the small unnamed tributaries in the Bay Shore watershed, as this watershed is also rapidly urbanizing.

Primary recommendations to alleviate bank erosion issues in Mahon Creek and the overall Lower East Shore watershed are to increase the water storage capacity and infiltration above minimal permit compliance requirements in recent and expanding urban areas by using a combination of conventional stormwater storage and control measures, along with 1) Low-Impact Development, 2) Conservation by Design, 3) green infrastructure installations in upland areas of the watershed 4) intermediary natural infrastructure installation; and 5) restoration of natural hydrology and protection of water holding ecosystems, where possible.

The City of Green Bay is currently undergoing an audit of city codes and ordinances that are barriers to green infrastructure, and Objective 3a below recommends funding this type of action for all governmental units and MS4s in the watershed.

Table 9. 10-year Flooding and Stormwater Plan Matrix.

Actions	*Indicators*	*Cumulative Milestones*			*Estimated load reduction*[4]		*Total Cost*[1]	*Funding Sources*	*Implem-entation*
		0-3 yr	*4-7 yr*	*8-10 yr*	*TP (lb)*	*TSS (tons)*			
Objective 1. Urban stormwater P and TSS in MS4 and non-MS4 areas is reduced.									
a. Install treatment detention basins or treatment systems as recommended by TOS, City of Green Bay and UWGB stormwater plans or models	% reduction in P and TSS	10%	20%	30% for TP, 40% for TSS	479 23.7%	120 23.1%	$300,000	UNPS&SW	City GB, TOS, UWGB, Brown Co
b. Construction & industrial runoff permits are enforced to achieve 80% reduction compared to no action	# of violations indicated in progress reports	3	2	1	-	175 33.7%	Staff time	GPR, permit fees	City of GB, Brown Co, WDNR
c. Promote Conservation by Design[2] or conservation subdivisions that protect wetlands	City or Town ordinances or incentives/proportion of new subdivisions in CD	1/25%	2/50%	4/100%	-	-	Staff time	-	City GB, TOS, TOH Brown Co
d. Restore wetlands to maximize water retention, and avoid filling and other impacts	Acres of wetlands restored	25 ac	50 ac	100 ac	-	-	Staff time, 2,000,000	NFWF, NRDA, WDNR,	TOH, TOS, UWGB, Brown Co, WDNR, WSC
e. Protect wetlands by preventing encroachment, filling, development and other degradation	Acres of wetlands protected either formally or informally						Staff time	NFWF, NRDA, WDNR,	
Objective 2: Streambank structure is stabilized and protected (*also see Table 8 bank restoration costs and load reductions*).									
a. Decrease stream flashiness and increase runoff storage volumes to protect downstream streambanks under current conditions, future land use and projected climatic conditions*	Bank pin monitoring/inches of bank eroded/average BEPI, acres of storage established[5]	-	-	-	-	-	Staff time/	CSP, EQIP, GLRI, MDV TRM, WQT	NRCS, LWCD, USFWS, TOH, TOS, City GB, UWGB

Table 9. continued

b. Restore and stabilize stream banks (rural and urban are source of problem)	Length of streambank remediated	1,670 ft	3,300 ft	5,000 ft		see Table 8	see Table 8	CSP, EQIP, GLRI, MDV TRM, WQT	
Objective 3: Municipalities collaborate proactively to manage urban stormwater and its contribution to nutrient and sediment loading.									
a. UWGB and City of GB develop agreement as MS4 entities to eliminate duplication of fees, and collaborate on loading reductions and stormwater treatment.	MOA developed, UWGB joins NEWSC						Staff time	UNPS&SW, WCMP, FFLM, other foundations	City GB, TOS, UWGB, Brown Co, BCPF
b. UWGB and City of GB update this plan to include the urban section of the watershed							Additional staff time, likely grant funded ~$3,000		UWGB, City GB
c. Fund a full-time stormwater and drainage position at the Town of Scott	Stormwater position funded		X				$900,000		TOS, Brown Co
d. Fund an audit of codes and ordinances for barriers to green infrastructure for TOS, TOH and UWGB	Code audit funded and conducted		X				$30,000		TOS, TOH, UWGB
e. Fund a watershed coordinator to assist with implementation of actions defined in this plan	Watershed coordinator position funded and filled		X				$750,000		City GB, TOS, UWGB, Brown Co, BCPF
TOTAL							**$3,983,000**		

* *Minimum requirements specified in WNDR NR 151 performance standards may not be sufficiently protective for streambanks.*

[1] *Costs may vary for each Action item, depending on what combination is selected to achieve the objective.*

[2] https://www.uwsp.edu/cnr-ap/clue/Documents/PlanImplementation/Conservation_Design.pdf

[3] *Additional Funding:* https://datcp.wi.gov/Documents/GrantOpportunitiesPLWPG.pdf

[4] *Reduction percentage relative to baseline load*

3. Habitat Conservation & Recreation

"Fragmentation, especially of forested habitats, is severe in this Ecological Landscape. Many remnants of native vegetation are small and isolated, and there is not much public land. Where feasible, steps need to be taken to increase effective habitat area, and minimize isolation by connecting scattered remnants, especially along shorelines and waterways. Additional stopover sites for migratory birds are needed along the Lake Michigan shoreline. Invasive plants are a major problem in both upland and wetland vegetation types. The Lower Green Bay ecosystem continues to change rapidly; it seems unlikely that this area will stabilize in the immediate future. There is a need for an updated and expanded inventory of natural features here" (from the Wisconsin Wildlife Action Plan; Wisconsin Department of Natural Resources 2015).

Most of the actions that improve water quality in the East Shore watershed will simultaneously benefit wildlife. Conservation of headwater swamps, restoration of vegetation along riparian corridors, retention of instream woody debris, and protection of remnant wetlands throughout the watershed will have lasting benefits for fish, macroinvertebrates, breeding and migratory birds, bats, and other species of conservation concern or recreational value. This is especially true in the Wequiock Creek and Mahon Creek watersheds, where significant tracts of quality habitat exist in the upstream and (especially) downstream segments (Appendix C).

Appendix C contains the Lower East Shore Stream Habitat Restoration Plan, a detailed analysis of wildlife habitats in the East Shore watershed, with 18 recommended "best management practices" ranging from establishment of rain gardens at private homes to maintaining large habitat trees in riparian forests. Habitat conservation along Wequiock Creek, Mahon Creek, and smaller watersheds will provide many opportunities for hiking, birdwatching, hunting, fishing, kayaking, and other forms of outdoor recreation. Fish that spawn and feed in these streams are an important part of food webs in the lower Green Bay ecosystem. Proximity to elementary and middle schools and the University of Wisconsin-Green Bay also creates local educational opportunities for students and families. Bark and Osgood (2009) and Farmer et al. (2013) have shown that riparian habitats with quality wildlife lead to increased property values as well as enhanced quality of life. These and other benefits support our argument that implementation of habitat restoration measures and application of best management practices will have multiple economic and ecological returns on investment in the East Shore watershed.

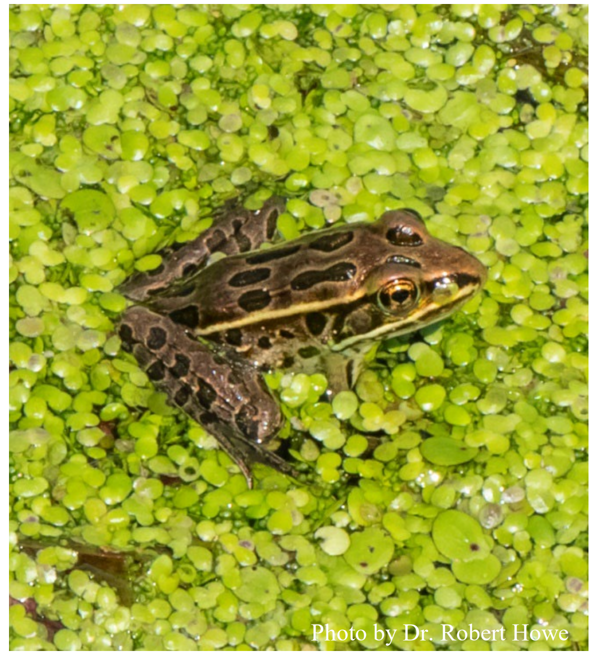

Figure 15. Sandhill cranes (*Grus canadensis*) and many other wildlife species, including the northern leopard frog (*Lithobates pipiens*), will benefit from restoration of wetlands and other riparian habitats in these watersheds.

Table 10. Conservation and Recreation Implementation Matrix.

Recommendations	Indicators (used to track Milestones)	Milestones 0-3 years	Milestones 3-7 years	Milestones 7-10 years	Potential Funding Sources	Implementation
Objective 1: Wetlands, riparian corridors, and other natural communities are protected and restored to provide habitat, connectivity, and recreation access.						
a. Conserve or restore habitat for species of greatest conservation need in the watershed and the Lower Green Bay and Fox River Area of Concern (AOC) (see Appendix C)	Acres of habitat protected or restored	73 ac	100 ac	150 ac	WDNR, USFWS, WRP, NRDA, GLRI, WCMP, FFLM, SPP, JV, NAWCA, BPF	TOS, TOH, CGB, NEWLT, UWGB, USFWS, WDNR, NRCS
b. Create buffers surrounding critical habitat and prevent the introduction or spread of invasive species, especially in aquatic habitats	Acres of buffer established	5 ac	10 ac	20 ac	WRP, CRP, CREP, FWP, JV, NAWCA, BPF	NRCS, FSA, LWCD, DU, PF, USFWS
c. Protect headwater forested wetlands and promote these areas as habitat	Acres of headwater and forested wetlands protected	10 ac	20 ac	40 ac	NRDA WFLGP, JV, NAWCA, BPF	WDNR, NEWLT, USFWS
d. Promote wetland conservation and restoration programs for private landowners such as Wetland Reserve Program, Partners for Fish and Wildlife, and the Wetland Restoration Handbook for Wisconsin Landowners	Acres of wetlands restored	10 ac	20 ac	50 ac	WRP, CRP, CREP, FWP	NRCS, FSA, LWCD
e. Promote Conservation Subdivisions and/or Conservation by Design	Status of new housing in the watershed	X	X	X	Municipal budgets	TOS, TOH, CGB, Brown County
f. Consider adoption of a model wetland conservation ordinance (Magyera et al 2016)	Adoption of ordinance	X			-	WWA

Table 10. continued

g. Promote creation of pollinator habitat by adopting a Turf Replacement Incentive or Lawns to Legumes* tax incentive	Adoption and rate of utilization of tax rebate		X	X		City of Green Bay, TOS, TOH, Brown County, DATCP
Objective 2: Community access to waterways, wetlands, and natural communities is enhanced.						
a. Promote hiking and cross-country skiing, connections to bicycle or multi-use trails, and river and bay access for canoes and kayaks that protects against erosion. Pursue recommendations in the Brown County Pedestrian and Bike Plan	Miles of trails/# of public water access points in watershed	7 mi / 3	8 mi / 5	10 mi / 7		Bay Lake RPC
b. Increase access to natural areas for education and enjoyment	Acres of natural area or park available to public in watershed	70 ac	75 ac	80 ac	KNSF, RTP, private foundation	NRCS, FSA, LWCD, DU, PF, USFWS, WDNR, BCCA
c. Create parks and open spaces that are accessible to all	# of parks or greenspace areas available to public in watershed	1	2	3	private foundations, Aurora	WDNR, TOH, TOS, Brown Co, GBBC

4. Watershed & Great Lakes Literacy

This information and education component is focused on watershed and Great Lakes literacy. While developing this watershed plan, a significant effort was made to engage the community and enhance public understanding of this project. Several focus groups were established, a community open house was held, and key stakeholders were interviewed. Conversations with farmers, educators, town board and drainage district board members, and others were important in shaping the goals, objectives, and actions throughout this plan. Continued community participation in implementing this watershed plan is highly valued in the watershed. See Table 11 below for the planned activities for achieving the goals and objectives established.

Goals of the Education and Outreach Plan:

- Empower local students and their families to engage in stewardship activities in their communities by becoming knowledgeable about the Great Lakes and their local watersheds.
- Create public awareness of water quality issues in the watershed and increase communication and coordination among municipal officials, businesses, and agricultural community.

Objectives:

- Integrate Great Lakes and place-based environmental literacy principles into school curriculum that meet Wisconsin Standards for Environmental Literacy and Sustainability.
- Implement watershed stewardship activities on school properties and in the community.
- Host workshops, meetings, and events that landowners can attend to learn about conservation practices.
- Increase landowners' adoption of conservation practices.
- Inform the public of current water quality issues in the Lower Fox River Watershed basin and how Wequiock and Mahon Creeks contribute.

Target Audience:
Target audiences in this watershed are schools, agricultural landowners and operators, urban homeowners, agricultural businesses and organizations, and local government officials. Focused attention on education will be on our schools to participate in multiple learning activities to increase their understanding about what a watershed is, why they are important, and how land use impacts the health of our groundwater and surface waters. Focused outreach will be on agricultural landowners and operators to reduce nonpoint pollutants from agricultural lands.

Existing Education Campaigns:
There are several existing educational campaigns and organizations operating in the Lower Fox Basin. This plan calls for the continuation of current efforts and continued support of existing programs.

- *Green and Healthy School Network:* The Green and Healthy Schools program is voluntary and available to all public and private schools in Wisconsin. It is administered through a partnership between the Wisconsin Department of Public Instruction, Wisconsin Department of Natural Resources, and Wisconsin Center for Environmental Education at UW-Stevens Point. The goal of Green and Healthy Schools is to reduce environmental impacts, improve health and wellness, and increase environmental literacy.

- *Fox-Wolf Watershed Alliance (FWWA):* The FWWA is a non-profit organization that works to protect and improve water quality in the Fox-Wolf basin. Their goal is to create clean waterways and inform the public of policies and practices that support aquatic environments. They sponsor watershed clean up days, public meetings, volunteer water monitoring opportunities, and educational activities as well as host an annual watershed conference.

- *Save the Bay:* A collaborative initiative where agriculture, academia, industry, government, and nonprofit leaders identify, share, and promote conservation practices to reduce phosphorus, nitrogen, and sediment flowing into the waters of Green Bay and Lake Michigan. For more information go to https://gallagher.house.gov/issues/save-bay.

- *FIELD Edventures*: FIELD Edventures connects with educators to explore the outdoors, foster inquiry, and engage learners through discovery. Rooted in Wisconsin, they are developing a robust network of educators across the state and beyond to engage the rock-skipping, frog-catching spirit that lives in each of us—from school leaders to teachers to students.

- *Wequiock Elementary School - Children's Center for Environmental Science*: Located in a local elementary school, provides students with a solid foundation in all core curricular areas. An environmental focus is integrated throughout all units of study, which provides students with a well-rounded education.

- *Holy Cross Catholic School*: A local elementary school that works with the Green and Healthy Schools Network.

- *UW-Green Bay Lower Fox River Watershed Monitoring Program* (LFRWMP): A network of teachers and students from high schools in Northeast Wisconsin collaborating with university scientists on a long-term watershed monitoring program. Students and teachers monitor nine environmentally-impaired streams in the Fox River watershed for water quality and ecological health.

4.1 Watershed & Great Lakes Literacy Goals

Table 11. Watershed and Great Lakes Literacy Implementation Matrix.

Objective 1: Local schools have integrated Great Lakes and place-based environmental literacy principles into curriculum that meets Wisconsin Standards for Environmental Literacy and Sustainability.				
Actions	***Implementation Strategies***	***Timeline***	***Cost***	***Implem-entation***
a. Needs assessment to identify curriculum gaps and opportunities for integrating Great Lakes and place-based environmental literacy principles across all disciplines	• Develop a go-to contact list of experts and educational resources.	short-term	Staff time	WES, RSS, HCCS
b. Identify and/or develop board-approved curriculum and experiential learning activities focused on Great Lakes and place-based environmental literacy principles	• Collaborate with FIELD Edventures to identify funding opportunities and develop a curriculum that can be integrated into current classroom activities and support the goals of Wisconsin Green and Healthy Schools. • Leverage and fund teacher professional learning and planning days.	mid-term	$3,000	WES, RSS, HCCS, UWSG, UWGB
c. School staff participate in professional development and training on Great Lakes and place-based environmental literacy concepts	• Work with schools to identify constraints and opportunities for professional development and trainings. • Identify a designated staff cohort that includes administrators, teachers, and paraprofessionals. • Incorporate into new staff onboarding training. • Develop a list of professional development opportunities.	ongoing	$50,000	WES, RSS, HCCS, UWSG, CGLL, UWGB

Table 11. continued

Objective 2: Schools provide Great Lakes and place-based environmental experiential learning opportunities in their classrooms, on school grounds, and in the community				
Actions	***Implementation Strategies***	***Timeline***	***Cost***	***Implem-entation***
a. Develop an annual Great Lakes and place-based environmental experiential education plan that includes goals, objectives, evaluation, collaborators/partners, funding, and sustainability	• Identify existing successful programs, activities and resources. • Develop a list of local ecological and cultural sites. • Develop a go-to contact list of experts and educational resources.	short-term	$20,000	WES, RSS, HCCS, UWSG, CGLL, UWGB, GLSI
b. Students participate in place-based environmental experiential learning activities that include expert speakers, are safe and accessible, and evaluated over time for updates, trainings, and enrichment of tools and activities	• Place-based field trips focused on the area's natural and cultural history, watershed health, and community. *Examples: University of Wisconsin-Green Bay, Richter Museum of Natural History, Wequiock Falls, Red Banks Alvar State Natural Area, New Franken Swamp, Baird Creek Parkway, local farms, Mahon Creek, Wequiock Creek, Scott Quarry, Bayshore County Park, and Red Banks Historical areas* • Place-based field day to celebrate and learn about the Great Lakes, watersheds, biodiversity, water quality and local cultural history. *Examples: Watershed Day, Fall Prairie Day* • Water quality monitoring programs for middle school-aged students. *Examples: install a water quality monitoring station on school property, establish a UW-Green Bay Lower Fox River Watershed Monitoring Team, conduct water quality monitoring on school property or at an existing water quality monitoring station in the community, older to younger student mentoring*	ongoing	$250,000	WES, RSS, HCCS, UWSG, CGLL, UWGB, GLSI,

Table 11. continued

	• Conservation-focused science experiments and restoration activities. *Examples: grow wild rice for wetland restoration, build bat houses, trail cameras, grow seedlings for plant restoration* • In-classroom hands-on environmental learning activities. *Examples: EnviroScape* • Informal, fun, family-oriented restoration workdays on school property or at sites in the community. *Examples: invasive species removal, native and pollinator plantings, build rain barrels and rain gardens*			
Objective 3: 4K-8 Schools participate in the Green and Healthy Schools Wisconsin and/or partner with FIELD Edventures.				
Actions	***Implementation Strategies***	***Timeline***	***Cost***	***Implem-entation***
a. Identify the level to which local schools want to participate in the Green and Healthy Schools program	• Local schools will complete the Green and Healthy schools online survey which documents their schools' accomplishments, collects data and recognizes the school's effort at a state level. https://survey123.arcgis.com/share/a38bb3812ab34222ad97cae1032cedaa	short-term	Staff time	WES, RSS, HCCS
b. Identify how the integration of environmental education curriculum and implementation of practices helps move the school through Green and Healthy Schools Wisconsin	• Set goals and benchmarks and implement activities in the classroom. *Examples: reduce food waste*	short-term	Staff time	WES, RSS, HCCS, GHSW
c. Identify how curriculum can be tied into conservation activities that meet Wisconsin State Standards	• Local schools set goals and benchmarks within each unit to include conservation activities in their school or the community.	short-term	$3,000	WES, RSS, HCCS, UWGB

Table 11. continued

Objective 4: Schools and families have implemented watershed stewardship activities on their properties and throughout the community.				
Actions	***Implementation Strategies***	***Timeline***	***Cost***	***Implem-entation***
a. Complete a school grounds biodiversity and natural assets inventory	• *Examples*: *5th grade capstone project focused on mapping the school grounds, calculating biodiversity like the one developed by Washington Biodiversity Council:* https://www.fishwildlife.org/application/files/4815/1373/1123/ConEd-Schoolyard-Biodiversity-Guide.pdf	short-term	$1,500	WES, RSS, HCCS, GHSW UWGB
b. Develop master environmental plan for watershed stewardship activities on school grounds that includes input from students and staff	• 5th grade capstone projects focused on watershed stewardship activities. *Examples: rain barrel design contest, storm drain murals*	short-term	$30,000	WES, RSS, HCCS, UWSG, UWGB, GHSW
c. Implement conservation practices on school property	• Install green stormwater infrastructure practices. *Examples: rain gardens, rain barrels, bioswales, permeable surfacing, green roofs* • Restore native plant communities *Examples: pollinator habitats, oak savanna, prairie, wetlands, riparian buffers*	mid to long-term	$500,000	WES, RSS, HCCS, UWSG, UWGB, GHSW
d. School teachers, staff, students and their families engage in stewardship activities	• *Examples: reduce winter salt use, watershed clean-up day, adopt a storm drain or ditch to remove trash and debris after a storm, install a rain barrel at home*	ongoing	Volunteer time	WES, RSS, HCCS, community

Table 11. continued

Objective 5: Educate public about opportunities to conduct restoration on private land.				
Actions	***Implementation Strategies***	***Timeline***	***Cost***	***Implem-entation***
a. Share progress and news with the public and local municipalities regarding habitat preservation or restoration projects	• Mailings, newsletters, social media posts by and collaboration between UWGB, GBCP, NEWLT, USFWS, WDNR, TOH, TOS, City GB, Brown Co	ongoing, short- to long-term	Staff time or as part of funded projects	TOS & TOH newsletter via UWGB, GBCP, NEWLT, USFWS, WDNR, TOH, TOS, City GB, Brown Co WWA
b. Provide information to residential landowners regarding invasive species management and wetland restoration	• Mailings, newsletters, social media posts, etc.	ongoing	Staff time or as part of funded projects	
c. Create a variety of opportunities for the public to learn more about the important flora and fauna in the watershed	• Number and type of opportunities made available and accessible.	ongoing and long-term	Staff time or as part of funded projects	UWGB, GBCP, NEWLT, TOH, TOS, City GB, Brown Co, USFWS, NRCS, WDNR, WWA, Wild Ones
d. Create an environmental interpretive center to provide public education	*See other education centers ex. Schmeeckle Reserve, Thousand Islands Environmental Center, Mosquito Hill, Crossroads Environmental Center* https://ur.umich.edu/0001/May21_01/4.htm	long-term	$4,000,000	UWGB, TT, TOH, TOS, City GB, Brown Co

Potential Funding Sources:

Potential sources of funding to help implement the actions outlined in Table 11 include, but are certainly not limited to, the following:

- Fund for Lake Michigan
- Great Lake Fishery Trust
- Wisconsin Green and Healthy Schools
- UW Sea Grant
- Local and regional foundations

5. Cultural Resources

The Ho-Chunk (Hoocąk) Nation and the Menominee (Kāēyās maceqtawak) Indian Tribe of Wisconsin are the original First People of Wisconsin, and both nations have ancient historical and spiritual connections to the land that includes the Mahon and Wequiock Creek watersheds. They utilized many of the lower Green Bay's abundant natural resources that provided for their livelihoods, such as wild rice, wildlife for fishing and hunting, and fertile soil for farming (Milwaukee Public Museum). Europeans, including those from Belgium, Holland, and France, colonized this region throughout the 1600s and 1800s. They engaged in activities, such as fur trading, duck hunting, logging, and farming (City of Green Bay; James W. Biddle's "Recollections of Green Bay in 1816-17").

Given the deeply rooted heritage of these First Nations people and early Europeans, whenever possible, cultural and historical sites, structures, burial grounds, and other important areas should be protected and celebrated within the Town of Scott, Town of Humboldt, and City of Green Bay using any of the following suggested ways:

- Take inventory of and protect identified historic structures to preserve historical remnants.
- Protect all archeological sites, such as in the Red Banks area or other areas.
- Protect and do not disturb human burial mounds or sites.
- Work with the State Historical Society to consider appropriate designation and preservation of potential historic sites as they are identified to maintain examples of the Town's or City's culture and history.
- Encourage natural, historical, cultural, and archaeological education so that these histories are not lost or forgotten.

6. Measuring Plan Progress & Success

Tracking and evaluating plan progress is essential to achieving the water quality, habitat conservation and recreation, and information and education goals described above. Plan authors and key partners will measure progress in complying with the Lower Fox River TMDL and meeting water quality objectives set forth in this plan by continuing to monitor several water quality parameters as well as tracking milestones established in the plan.

6.1 Water Quality Monitoring

Water quality monitoring will be conducted throughout the ten-year plan term. Physical, chemical, and biological data will be collected to ensure that water quality is meeting TMDL standards, state phosphorus standards, and designated use standards over time and in locations that reflect areas in the watershed that adopt multiple P and sediment reduction practices.

See section 6.2 for a discussion of how progress will be tracked.

Water quality data are currently collected in Wequiock and Mahon Creeks at the three primary monitoring locations shown in Figure 1 by UW-Green Bay and volunteers (WDNR Lower Fox River Volunteer Monitoring Program). A summary of current surface water quality monitoring activities is provided in Tables 4, 5, and 6. Notably, water level (i.e., stage) is continuously recorded at each of these stations, and discrete stream discharge measurements are made to capture the flow regime. The resulting stage-discharge relationship and water level data are used to calculate continuous stream flow (discharge). This plan calls for the continuation of the current monitoring programs, plus expanding it to include aquatic macroinvertebrates and school-based monitoring.

LFRWMP Lower Fox River Watershed Monitoring Program	vs.	LFRMP Lower Fox River Monitoring Program
High School Students		Adult Volunteers
Nitrate, ammonia, dissolved reactive phosphorous, turbidity, streamflow, aquatic macroinvertebrates		Total phosphorus, dissolved reactive phosphorus, and total suspended solids. May add diatom phosphorous index in future
Spring, Summer, Fall		Monthly May - October
To Be Determined		Nicolet Drive
Funding: Private Donors & UWGB		Funding: WDNR Water Action Volunteers (WAV)

UW-Green Bay (professors, students, and researchers), community Water Action Volunteers (WAV) volunteers, WDNR, Lower Fox River Monitoring Program (LFRMP), and other volunteers will continue conducting monitoring. Median May to October phosphorus concentrations and aquatic macroinvertebrate index of biotic integrity (IBI) will serve to determine measurable improvements in water quality throughout the 10-year plan period. These indicators for successful water quality improvements are summarized in Table 12 and include short-term, medium-term, and long-term targets.

Both monthly and, at least six event-based water samples, will be collected each year at our sampling stations throughout the plan period. One of the primary ways of assessing improvement in water quality will be to continue collecting monthly water samples at the three primary locations from May to October and comparing the median total phosphorus (TP) concentration to the state criteria of 0.075 mg/L (Table 12). These samples will be analyzed at a certified lab (e.g., NEW Water, Wisconsin State Lab of Hygiene [SLOH]). Dissolved P analysis will also continue to be performed on these monthly samples to help identify possible sources of phosphorus, the proportion of the dissolved fraction, and what practices may be best suited to reduce TP. Suspended sediment will also be analyzed monthly to track progress in reducing suspended solids (total suspended solids [TSS] analysis at certified labs, and suspended sediment concentration [SSC] at UW-Green Bay).

Runoff event-based water samples will be collected from the three primary stations by UW-Green Bay staff and volunteers either manually or with an automated sampler. Event samples will be analyzed for TP and TSS or SSC and integrated with continuous stream discharge to calculate daily stream loads of TP and TSS or SSC using regression analysis, or with the Graphical Constituent Load Analysis tool (USGS 2004) when the sample frequency is sufficiently high, as was done at the Mahon research station. At the Wequiock Creek Nicolet Drive and Maloney Road stations, continuous turbidity will be recorded and used as a surrogate for estimating TSS and TP on a continuous basis by applying regression analysis-based relationships between turbidity and discrete concentrations of TSS and TP. These estimated TSS and TP concentrations will be combined with continuous stream discharge to calculate daily TSS and TP loads. The resulting annual loads will be compared to the baseline and allocated loads in Tables 2 and 3 to track progress in achieving the TMDL load allocations for TSS and TP on an annual basis. Progress related to TMDL targets for TP and TSS will also be tracked by assessing trends in concentrations during events. Some stations may be monitored more frequently than others based upon practice adoption rates/extent within the watershed.

A water monitoring network consisting of 10 or more low-cost turbidity probes and loggers will be installed in tributaries throughout the watershed at key locations to provide a spatially detailed assessment of where the greatest contributions of TSS, and, possibly phosphorus, are occurring. This monitoring network and program will be based on the equipment and system that was successfully constructed and tested at bench, edge-of-field and stream scales by Schmidt (2020) in his evaluation of the utility of these probes and loggers. Bench-scale calibration of the probes will be conducted to establish a regression-based relationship between turbidity and both TSS and phosphorus. Grab samples collected from streams during events will serve to augment or modify this initial calibration of the turbidity probes. Turbidity and estimated TSS will be measured and logged continuously. The estimated TSS concentrations will be tracked throughout a series of runoff events to determine where and when major contributions of TSS are occurring, and to track potential progress during implementation of the watershed plan at finer spatial scales than permitted at the three major monitoring stations in Mahon and Wequiock Creeks.

At this time, we anticipate that UW-Green Bay will collect and assess aquatic macroinvertebrates with a biotic index at the three primary stations on a regularly scheduled basis (at least once every two years) through university classes. UW-Green Bay professors and plan authors will meet to establish an aquatic macroinvertebrate monitoring plan within one year of watershed plan approval. This monitoring strategy is expected to continue throughout the 10-year span of this watershed plan. Baseline aquatic macroinvertebrate conditions at the three primary monitoring stations are summarized in Table 12, along with the interim biotic index targets at 3 years and 7 years, and the target value at the end of the plan schedule in 10 years. There is a possibility that fifth to twelfth-grade students will conduct complementary aquatic macroinvertebrate monitoring if LFRWMP sites are funded in the watershed.

As described in section 1, the Lower Fox River TMDL has set limits for TP and TSS for the lower Fox River and Green Bay area. The TP target for tributary streams in the lower Fox River basin is 0.075 mg/L (summer median TP). The target for TSS at the mouth of the lower Fox River is a summer median concentration of 18 mg/L. Current water quality data in the East Shore watershed show levels to be much higher than that. For example, current May to October median TP concentrations during low flow periods range from 0.120 mg/L at the UW-Green Bay Research Station near the mouth of Mahon Creek, to as high as 0.290 mg/L at the Maloney Road crossing of Wequiock Creek (Table 12).

6.2 Tracking Implementation of Plan

Implementation progress and success of this plan will be tracked using the following components:

1) Pollution reduction evaluation based on best management practices installed
2) Conservation and recreation actions
3) Information and education activities and participation
4) Water quality monitoring
5) Administrative review

Brown County Land and Water Conservation Department (LWCD) will be responsible for tracking progress of this plan, which overlaps substantially with their regular workplan. Brown County LWCD will work with NRCS, UW-Extension, and other partners to track progress and implement projects. Reports will be completed annually, and a final report will be prepared at the end of the project in 2031. If a watershed coordinator is hired, then they will take on partial responsibility for tracking progress and collaborating with LWCD on reporting.

6.2a Tracking Pollution Reduction Based on BMPs Installed

Implementation of best management practices (BMPs) listed in Tables 8 and 9 will be key benchmarks to track plan progress and contribute to determining whether interim water quality goals are being met.

Installed BMPs will be mapped using GIS software, led by Brown County LWCD. Pollution reductions from completed projects will be evaluated using models and spreadsheet tools, such as SnapPlus for upland practices, STEPL for upland gully erosion, and the BARNY model for barnyard practices. SnapPlus is recommended for modeling upland practices because it was used in this plan to estimate agricultural load reductions and associated implementation levels; plus, many agricultural consulting firms utilize this model to develop farm management plans. It is recommended that STEPL only be utilized for modeling upland practices on a limited basis if it is strongly preferred by Brown County staff. Installation dates, design specifications, operation and maintenance periods, practice inspections, estimated load reductions, and cost-share sources/amounts will also be tracked in a GIS database. Furthermore, satellite data may be used to track crop residue as this capability is available. The methods outlined in the US EPA technical memo, "Adjusting for Depreciation of Land Treatment When Planning Watershed Projects," will be used when evaluating BMP effectiveness and identifying factors that may affect BMP performance levels and implementation (Meals 2015). Phosphorus and Sediment pollutant reductions estimates (lbs/yr or lbs/acre) derived from SnapPlus or STEPL or BARNY will not be compared to SWAT model results as the models have different assumptions and are not comparable. Instead, this plan will use the Lower Fox TMDL percent reduction as a means to track the extent of pollutant reductions.

Reports on pollutant reduction evaluation for installed BMPs will be provided to DNR in 2024, 2028, and 2031. Report parameters will include:

1) Planned and completed BMPs.
2) Pollutant load reductions and percent of goal planned and achieved.
3) Cost-share funding source of planned and installed BMPs.
4) Number of checks to make sure management plans (nutrient management, grazing management, tillage and crop rotations) are being followed by landowners.
5) Number of checks to make sure practices are being operated and maintained properly.
6) Any fields and practices selected and funded by a point source (adaptive management or water quality trading) compliance option to assure that Section 319 funds are not being used to implement practices that are part of a point source permit compliance strategy.
7) Number of new and alternative technologies and management measures assessed for feasibility, used and incorporated into plan.
8) Changes in land use or land management in watershed that may impact BMP effectiveness.
9) Variations in weather that may have influenced implementation of BMPs or effectiveness of installed BMPs.

6.2b Tracking Conservation and Recreation Implementation

The recommendations in Table 10, as well as the best management practices in the Habitat Conservation Strategy for this plan (Appendix C) will guide efforts in this area. UWGB and all partners involved in creating this plan, along with a variety of other conservation partners (NEWLT, USFWS, TNC, Audubon Great Lakes, and more), will collectively work to implement the recommendations and BMPS.

During 2021-2025, the WDNR will be launching a series of Great Lakes Restoration Initiative (GLRI)-funded restoration and enhancement projects targeted to improve fish and wildlife habitats and populations in the Lower Green Bay and Fox River Area of Concern. Within 1 km inland from the bay shoreline, the UW-Green Bay campus, Mahon Creek, Point au Sable, and Wequiock Creek have been identified as several of this effort's high priority sites where improvements will be made. Proposed work will take place in forest, marsh, wet meadow, in-stream, and Great Lakes beach habitats, which will likely lead to the improvement of water quality, restoration and enhancement of wetlands, management of invasive plant species, restoration of habitat for species of greatest conservation need (e.g., American Woodcock, great egret), and improvement of pollinator habitat (important components identified in Tables 7-9). Verification monitoring will take place in 2029-2031. Because UW-Green Bay owns several of the high-priority sites, they will be heavily involved with the implementation and monitoring of these projects, which will work in tandem with the efforts of this plan.

UWGB will work collaboratively with these partners to develop a companion report for Brown County LWCD to submit during the three milestone periods. The report will include:

1) Progress made and status of each milestone in Table 10
2) Actions taken and progress on each of the 18 BMPS in the Habitat Conservation Strategy
3) Status of three monitoring efforts recommended the Habitat Conservation Strategy (birds, stream macroinvertebrates, and understory vascular plants)
4) Link to, or insertion of reports related to GLRI activities in the watershed

6.2c Tracking Information and Education Activities and Participation

The information and education (I&E) section of this plan seeks to integrate all members of the watershed to learn and act together towards its improvement. A Watershed and Great Lakes Literacy Implementation matrix (Table 11) was developed as a tool to help implement the I&E plan. Many of the objectives and actions in this section are focused on students, teachers and the community, not just agricultural producers. The I&E section is structured in this manner because: 1. There was overwhelming interest from educators in the watershed to become more involved in the unique and important teaching opportunities available here; and 2. Students who receive place-based stewardship education, like that proposed in the Watershed & Great Lakes Literacy section, are more likely to engage in environmentally responsible behaviors, as well as take action and make future decisions to protect watersheds. This is especially true in rural settings such as the Lower East Shore watershed (Gallay et al 2016). We believe that while this strategy may have less of an immediate impact on phosphorous and sediment loading, it has long-term, positive implications for our watershed and likely others across the Great Lakes basin.

The tracking reports for the I&E goals will be a collaborative effort between the Brown County LWCD as well as teachers and staff from Wequiock Elementary School Children's Center for Environmental Science, Holy Cross School, and Field Edventures. Brown County LWCD will prepare a traditional report that includes the following:

1) Number of landowners/operators in the watershed plan area.
2) Number of eligible landowners/operators in the watershed plan area.
3) Number of landowners/operators contacted.
4) Number of cost-share agreements signed.
5) Number and type of information and education activities held, who led the activity, how many were invited, how many attended, and any measurable results of I&E activities.
6) Number of informational flyers/brochures distributed per a given time period.
7) Number of one-on-one contacts made with landowners in the watershed.
8) Number of radio broadcasts and newspaper articles related to water quality protection.
9) Percent change in attendance at information and education activities held.
10) Comments or suggestions for future activities.

Brown County LWCD staff will collaborate with staff at Wequiock Elementary School Children's Center for Environmental Science and Holy Cross School and/or the future watershed coordinator to create a companion report that addresses the tracking of objectives and actions identified in the Watershed and Great Lakes Literacy section (Table 11).

6.2d Tracking Implementation of Water Quality Monitoring

While plan progress will be measured by water quality data, median summer phosphorus concentrations and macroinvertebrate indices of biotic integrity will also be used to determine improvement in water quality. Water quality monitoring indicators for success are shown in Table 12; water quality indices for macroinvertebrates are described in Table 13. As described above, estimated load reductions from implemented BMPs will also be used to determine if interim water quality goals are being met (Table 14).

Staff from Brown County LWCD, UWGB, others involved in monitoring, and hopefully the future watershed coordinator, will meet with WDNR water quality staff at least once per year to assess monitoring efforts, and progress toward meeting water quality benchmarks. Monitoring locations and frequency described in this plan may vary based upon the extent and types of practices adopted in the watershed over the plan's ten-year schedule.

Table 12. Water quality targets for Lower East Shore watershed listed by monitoring site and indicator.

Monitoring Sites	Indicators	Current Values	Target Value or Goal for East Shore Watershed	Short Term (3 yrs)	Medium Term (7 yrs)	Long Term (10 yrs)	Implementation	Funding[5]
Wequiock Creek - Nicolet Drive	Summer median total phosphorus (mg/L)[4]	0.221	0.075	0.17	0.11	0.075	LFRMP and LFRWMP*	WAV-WDNR
Wequiock Creek – Maloney Rd.	Summer median total phosphorus (mg/L)[4]	0.290	0.075	0.22	0.11	0.075	UWGB and volunteers LFRWMP*	None
Mahon Creek - UWGB Research Station	Summer median total phosphorus (mg/L)[4]	0.120	0.075	0.1	0.085	0.075	UWGB and volunteers LFRWMP*	None
Mahon Creek – stormwater outlet	Summer median total phosphorus (mg/L)[4]	N/A	0.075	TBD	0.085	0.075	UWGB and LFRWMP*	None
Wequiock Creek - Nicolet Drive	Macroinvertebrates biotic index (WAV[1] or FBI[2])	poor[2] (6.58 in 2019)	good	poor	fairly poor	good	UWGB class and/or volunteers	None
Wequiock Creek – Maloney Rd.	Macroinvertebrates biotic index (WAV[1] or FBI[3])	very poor[3]	good	poor	fairly poor	good	UWGB class and/or volunteers	None
Mahon Creek - UWGB Research Station	Macroinvertebrates biotic Index (WAV[1] or FBI[2])	fair[2] (5.33 in 2019)	very good	good	good to very good	very good	UWGB class and/or volunteers	None
Mahon Creek – stormwater outlet	Macroinvertebrates biotic Index (WAV[1] or FBI[2])	N/A	good	good to very good	good to very good	good to very good	UWGB and LFRWMP*	None

[1] Citizens Monitoring Biotic Index utilized by the Wisconsin Water Action Volunteers (WAV)
[2] Most recent Hilsenhoff Family Level Biotic Index (FBI) was used as baseline (Struck 2008; WDNR 1990 to 2019) and reported here as one of seven major categories listed in Table 13 below
[3] WDNR 2003 FBI value of 7.76 from USFWS facility site (#10010780) downstream of Maloney Road site.
[4] Analyzed at either SLOH, NEW Water, or other WDNR-certified lab
** Teams do not exist yet, nor are these teams funded. Funding will be pursued*
[5] Funding will be pursued by Brown County LWCD, UWGB, WDNR and partners to fund processing of TP samples

Table 13. Water quality index for the family-level Hilsenhoff Biotic Index (HBI; Hilsenhoff 1988).

Family Biotic Index Value	Water Quality Rating	Degree of Organic Pollution
≤ 3.75	Excellent	Unlikely
3.76-4.25	Very Good	Possible Slight
4.26-5.00	Good	Some Probable
5.01-5.75	Fair	Fairly Substantial
5.76-6.50	Fairly Poor	Substantial Likely
6.51-7.25	Poor	Very Substantial
7.26-10.00	Very Poor	Severe

Table 14. Interim phosphorus and suspended sediment reduction goals for East Shore Watershed

Indicators	Current Values (TMDL SWAT)	Target Value for East Shore Watershed	Reduction Milestones in East Shore Watershed		
			Short Term (3 yrs)	Medium Term (7 yrs)	Long Term (10 yrs)
# lbs phosphorus/yr	8,671*	3,123*	7,283 (16%)	5,376 (38%)	3,123 (64%)
# tons total suspended solids/yr	1,365^	641^	1,160 (15%)	901 (34%)	641 (53%)

* Reflects Table 3 Load Allocation values, not including Urban, Construction, or General Permits
^ Reflects Table 2 Load Allocation values, not including Urban, Construction, or General Permits

Water quality monitoring data reports will be prepared by UW-Green Bay and shared with WDNR and Brown County LWCD annually. The water quality monitoring reports will include the following parameters (reports by UW-Green Bay completed annually, a more in-depth report of results and trends at end of 2023, 2028, and 2031, and a final report at the end of the plan period):

1) Discharge, turbidity, suspended sediment, and total phosphorus data from the UW-Green Bay Wequiock Creek – Nicolet Drive and Maloney Road stream monitoring stations.
2) Discharge, suspended sediment, and total phosphorus data from the UW-Green Bay Mahon Creek stream monitoring research station when Bay of Green Bay water levels permit (too high in 2020).
3) Total phosphorus, dissolved reactive phosphorus, total suspended solids, and clarity data from grab samples collected by volunteers through the WAV/WDNR Lower Fox River Monitoring Program: currently at Wequiock – Nicolet drive station. May to October monthly samples.
4) Macroinvertebrate Index of Biotic Integrity.
5) Legacy phosphorous levels in Drainage District #4 channels, road ditch sediment, and in-stream deposits

If LFRWMP program receives funding for new sites:

6) Dissolved reactive phosphorus, nitrate, ammonia, and clarity data from grab samples collected by school students through the UW-Green Bay Lower Fox River Watershed Monitoring Program. In stream dissolved oxygen, conductivity, pH, water temperature, and discharge. Monitoring to occur in spring, summer, and fall in Wequiock Creek at the Nicolet Drive and Maloney stations.

6.2e Administrative Tracking

Brown County LWCD will track the administrative activities involved in implementing this plan. Their annual reporting to DNR will include:

1) Status of grants relating to project.
2) Status of project administration including data management, staff training, and BMP monitoring.
3) Status of nutrient management planning, easement acquisition, and development.
4) Number of cost-share agreements.
5) Total amount of money on cost-share agreements.
6) Total amount of landowner reimbursements made.
7) Staff salary and fringe benefits expenditures.
8) Staff travel expenditures.
9) Information and education expenditures.
10) Equipment, materials, and supply expenses.
11) Professional services and staff support costs.
12) Total expenditures for Brown County.
13) Total amount paid for installation of BMPs and amount encumbered for cost-share agreements.
14) Number of water quality trading/adaptive management contracts (if applicable).

6.3 Plan Progress Evaluation Criteria

Due to the uncertainty of models, effectiveness of best management practices, and what combination of BMPs will be implemented, an adaptive management-type approach should be taken with this watershed. Milestones are essential when determining if management measures are being implemented and how effective they are at achieving plan goals over given time periods. Milestones are established for short term (0-3 years), medium term (3-7 years), and long term (7-10 years) timeframes. As conservation practices are implemented and water quality monitoring progresses, overall plan progress and success should be evaluated after each milestone period.

In addition to the annual report, an additional progress report should be completed at the end of each milestone period. The progress report will be used to identify and track plan implementation to ensure that progress is being made and to make corrections, as necessary. Plan progress will be determined by minimum progress criteria for management practices, water quality monitoring, and information and education activities held. If lack of progress is demonstrated, factors resulting in milestones not being met should be included in the report. Adjustments should be made to the plan based on plan progress, new data, and/or watershed tools.

6.3a BMP Implementation/Pollution Reduction Progress Evaluation

Implementation milestones for management measures are shown in the 10-Year Agriculture/Rural Land Use Management Measures Plan Matrix (Table 8) and the 10-year Flooding and Stormwater Plan Matrix (Table 9). In addition to tracking and mapping installed BMPs, another tool is being developed by WDNR to standardize methods for evaluating progress of crop residue across watershed. Brown County LWCD should plan to implement this tool by 2023. If less than 70% of the implementation milestones are being met for each milestone period, the plan will need to be evaluated by the Brown County LWCD and WDNR and revised to either edit the milestone(s) or to implement projects or actions to achieve the milestone(s) that are not being met.

6.3b Conservation and Recreation Progress Evaluation

Implementation milestones for conservation and recreation are show in Table 10. If less than 70% of these milestones are being met for each milestone period, the plan will need to be evaluated by the Brown County LWCD and WDNR and revised to either edit the milestone(s) or to implement projects or actions to achieve the milestone(s) that are not being met.

6.3c Information and Education Implementation Progress Evaluation

Implementation milestones for Information and Education Plan implementation are shown in both Table 11 and below in Table 15. Collectively, this I&E plan should be evaluated annually to assess the effectiveness of the outreach campaigns. If less than 70% of the implementation milestones are being met for each milestone period, this part of the plan will need to be evaluated and revised to either modify the milestone(s) or to implement projects or actions to achieve the milestone(s) that are not being met.

Table 15. Information and education plan implementation milestones.

Short Term (0-3 years)
a) Completed watershed plan announced on Brown County Facebook and Twitter accounts with all partners and Fox Wolf Watershed Association tagged. b) Completed watershed plan permanently provided on county website. c) Plan implementation milestone updates posted on county website or Facebook and Twitter accounts at least once per year. d) One exhibit displayed at local library, government office, and/or local event. e) Information on watershed project and conservation practices distributed by mail to all eligible land owners in watershed. f) At least 20 one on one contacts made with agricultural landowners. g) At least 2 agricultural producers in watershed attend workshops/tours at a demonstration farm. h) At least three issues of "Basin Buzz" newsletter distributed to all agricultural producers in watershed. i) At least 2 meetings to share goals of watershed project held with local agricultural businesses, landowners and organizations.
j) At least 1 media/press release highlighting conservation effort resulting from the plan submitted. ***Watershed and Great Lakes Literacy milestone action items*** k) Completed: needs assessment to identify curriculum gaps and opportunities for integrating Great Lakes and place-based environmental literacy principles across all disciplines. l) Developed: annual Great Lakes and place-based environmental experiential education plan. m) Identified: participation level of Green and Healthy Schools program by local schools. n) Identified: ways environmental education curriculum aligns with becoming a Green and Healthy School Wisconsin. o) Identified: ways curriculum can be tied into conservation activities that meet Wisconsin State Standards. p) Completed: school grounds biodiversity and natural assets inventories. q) Completed: Master environmental plan for watershed stewardship activities on school grounds.

Table 15. continued

r) Progress and news on habitat preservation and restoration projects is shared with the public and local municipalities.
Medium Term (3-7 years)
a) At least 2 educational workshops held for general public to share goals of watershed project and provide update on progress. b) At least 2 municipalities/governing bodies/MS4s in watershed adopt/amend current code or ordinance to match goals of watershed plan. c) At least 3 issues of "Basin Buzz" newsletter distributed to all agricultural producers in watershed. ***Watershed and Great Lakes Literacy milestone action items*** d) Identified: board-approved curriculum and experiential learning activities focused on Great Lakes and place-based environmental literacy principles. e) School staff participate in professional development and training on Great Lakes and place-based environmental literacy concepts. f) Students participate in place-based environmental experiential learning activities. g) School teachers, staff, students and their families engage in stewardship activities. h) Information regarding invasive species management and wetland restoration is provided to residential landowners. e) Conservation practices are implemented on school property.
Long Term (7-10 years)
a) Conduct survey of agricultural landowners on watershed issues (At least 75% surveyed can identify the major source of water pollution in the watershed and methods to protect water quality). b) At least 3 issues of "Basin Buzz" newsletter distributed to all agricultural producers in watershed. ***Watershed and Great Lakes Literacy milestone action items*** c) Conservation practices are implemented on school property. d) A variety of opportunities for the public to learn more about the important flora and fauna in the watershed are created. e) An environmental interpretive center to provide public education is created.

6.3d Water Quality Monitoring Progress Evaluation

Pollutant load reductions and improvement in water quality or aquatic habitat may not occur immediately following implementation of practices due to several factors that will need to be considered when evaluating water quality data. These factors can affect or mask progress that plan implementation has made elsewhere. Consultation with the WDNR and water quality biologists will be critical when evaluating water quality or aquatic habitat monitoring results.

Milestones for pollutant load reductions are shown in Table 14. If the target values/goals for water quality improvement for the milestone periods are not being achieved, the water quality targets or timetable for pollutant reductions will need to be evaluated and modified.

During each milestone period (presumably after implementation of practices and/or at the 3, 7- and 10-year points into this plan), the following criteria will be evaluated in conjunction with water quality and aquatic habitat monitoring to evaluate water quality data:

- Changes in land use or crop rotations within the same watershed where practices are implemented. (Increase in cattle numbers, corn silage acres, and/or urban areas can negatively impact stream quality and water quality efforts)

- Location in the watershed where land-use changes or crop rotations occur. (Where are these changes occurring in relation to implemented practices?)
- Watershed size, location where practices are implemented and location of monitoring sites.
- Climate, precipitation and soil conditions that occurred before and during monitoring periods. (Climate and weather patterns can significantly affect growing season, soil conditions, and water quality)
- Frequency and timing of monitoring.
- Percent of watershed area (acres) or facilities (number) meeting NR 151 performance standards and prohibitions.
- Percent of watershed area (acres) or facilities (number) that maintain implemented practices over time.
- Extent of gully erosion on crop fields within watershed over time. (How many are maintained in perennial vegetation vs. plowed under each year?)
- Stability of bank sediments and how much this sediment may be contributing P and TSS to the stream.
- How legacy sediments already within the stream and watershed may be contributing P and sediment loads to stream, based on sediment monitoring in Drainage District, road ditches, and streambed.
- Presence and extent of drain tiles in watershed area in relation to monitoring locations. (Do these drainage systems contribute significant P and sediment loads to receiving streams?)
- Does monitored stream meet IBI and habitat criteria but not TMDL water quality criteria?
- Are targets reasonable? Load reductions predicted by models could be overly optimistic.
- What green infrastructure has been installed in the watershed?
- What natural infrastructure to intercept runoff has been installed or enhanced in the watershed?
- How many acres of water-holding ecosystems have been restored or enhanced in the watershed?

7. Cost Analysis

The total cost to implement the watershed plan over 10 years is estimated to be $12,046,300. This cost is based on current cost-share rates, incentives payments to promote participation, and current conservation project installation rates provided by Brown County LWCD. In addition, the creation of an environmental interpretive center, which was recommended by community and focus groups, is estimated to cost around $4,000,000 based on similar known centers in the Midwest.

Landowners will be responsible for maintenance costs associated with installed practices. Detailed cost estimates for best management practice (BMP) implementation, technical/programmatic assistance, and water quality monitoring are shown in Table 16. A summary of the cost analysis breakdown is shown below.

It’s important to acknowledge that current staff capacity at Brown County cannot support the implementation of this plan. Brown county currently has four existing 9 key element plans they are working to implement: Lower East River, Upper East River, Lower Fox – main stem, and Bower Creek. New funding and staff will be necessary for Brown County LCD to work towards meeting this plan’s agricultural implementation milestones (cropland and barnyard practices). As referenced elsewhere in the plan, funding a watershed coordinator would help alleviate pressure on Brown County staff.

As of this writing, Wisconsin’s County Land and Water Conservation Departments do not generally receive the full funding allocation they are designated to receive under state statute 92.14. This shortfall impacts implementation of soil and water conservation and creates the need to pursue additional grant funding.

A long-overlooked cost issue that could result in important conservation gains is the duplicate MS4 payments being made by UWGB to the City of Green Bay. Since UWGB is a MS4 and conducts its own reporting and monitoring under this designation, it is not part of the City of Green Bay's stormwater system, yet continues to be charged a significant annual fee. Were this to be resolved, UWGB could afford to significantly invest in green infrastructure, education, and other practices to reduce nutrient and sediment loading from the UWGB campus.

7.1 Water Quality Monitoring Costs

Based on previous monitoring, the monthly monitoring strategy described in section 6 (to conduct monitoring of total phosphorous (TP), dissolved phosphorous (DP) and total suspended solids (TSS) at the Mahon Creek and Wequiock Creek Maloney Road stations), will cost approximately $900 per year for a total of $9,000 for the 10-year plan period. If the WDNR sponsored monitoring at the Wequiock Creek Nicolet Station is discontinued, then the cost would be about $1,300 per year, for a total of $13,000 for the 10-year plan period.

If the aquatic macroinvertebrate monitoring can be solely conducted through UW-Green Bay classes each year, then there will be no additional cost for this monitoring. If not, we estimate that the cost of performing this monitoring at the 3 primary stations will be $1,200 every 2 years, for a total cost of $6,000 over the 10-year plan period.

Based on previous monitoring, the continuous discharge and event-based sample monitoring strategy (to conduct monitoring of TP, DP and TSS at all 3 primary monitoring stations), will cost approximately $7,005 per year for a total of $70,050 for the 10-year plan period. This cost includes an annual analysis of the data and an annual monitoring report of our findings. The cost of installing and operating a low-cost turbidity probe and logger network at 10 sites is estimated to be $10,000 for the 10-year plan period.

The potential for additional monitoring that could encompass more sites or event sampling could cost another $800-$1,200 per site per year, or $8,000-$12,000 total. This would depend on what parameters are added and whether sondes or stream height monitoring stations are added.

7.2 Plan Implementation Cost Analysis

Summary of Cost Analysis:

- $5,552,250 to implement best management practices (as indicated in Table 8).
- $3,983,000 to implement urban and stormwater practices in MS4 and non-MS4 areas (as summarized in Table 9).
- $1,560,000 for technical and administrative support (summarized in Table 16).
- $3,975,000 for implementing AOC de-listing and other habitat management actions (Kupsky & Stevens 2020).
- $857,500 for information and education;
    - Plus, an additional $4 million for creation of an environmental interpretive center to provide public education as described in Section 4.1.
- $86,550 - $108,550 for water quality monitoring as described in Section 6.1.

Table 16. Cost estimates for implementation of best management practices (BMP).

Practice	Quantity	Cost /Unit	Total Cost
Cropland Control (7,053 total acres)			
Conservation Tillage (ac)[1]	5,226 (74%)	$20	$418,100
Cover Crops (ac)[1]	3,500 (67%)	$75	$1,050,480
Grassed Waterways (linear ft)	10,563	$5	$52,815
Lined Waterway (linear ft)	750	$35	$26,250
Concentrated Flow Area Seeding/Critical Area Planting (ac)	7.34	$450	$3,306
Riparian Buffers/Filter Strips (ac)	40.53	$10,000	$405,300*
Nutrient Management (ac)[1]	1,425 (20%)	$40	$57,000
Low Disturbance Manure Injection (ac)[1]	4,940 (70%)	$105	$2,195,000
Regenerative or Non-traditional Agriculture Strategies			
Prescribed Grazing (ac)[2]	500	$270	$135,000
Perennial crops (ac)[5]	10	$50	$500
Water and Sediment Control Basin (each)	15	$11,000	$165,000
Agriculture Runoff Treatment System (ac)[5]	10	($69,580)	($695,800)
Barnyard Runoff/Livestock Facility Control			
Waste Storage and Barnyard Runoff Management (fencing, filter strip, roof runoff, critical area planting, leachate collection/treatment, etc)[3]	2	-	$600,000[3]
Streambank\Riparian Corridor\ Wetland Restoration			
Streambank Restoration (shaping, seeding, rip rap, biostabilization, obstruction removal) (linear ft)	5,000	$80	$400,000
Riparian Corridor Restoration (weed/invasive species control, brush management, tree/shrub establishment, conservation cover) (ac)	120	$3,000	$360,000
Crossing (each)	3	$5,000	$15,000
Wetland Restoration/Creation (ac)	100	$20,000	$2,000,000
Other Natural Area Restoration			
Upland habitat improvement/creation (forest stand improvement, upland wildlife habitat management/wildlife habitat planting, pollinator habitat)	60	$700	$42,000
Technical Assistance			
Conservation/Project Technician[4]	0.50	$96,000/year	$480,000
Agronomist[4]	0.50	$96,000/year	$480,000
Watershed Coordinator[4]	0.5	$85,000/year	$425,000
Administrative Support[4]	0.25	$70,000/year	$175,000
		Technical Assistance TOTAL	1,560,000

1. Cost based on cost-sharing for 4-year time period.
2. Cost estimate based on 3 years of grazing plan and forage and biomass planting.
3. Cost based on $556,540 estimate by Brown County LCD for one facility with the remainder for the other facility.
4. Cost based on 10 years of employment including benefits and 3% increase per year for salary and fringe costs.

5. Agricultural Runoff Treatment System (ARTs) ponds option that could displace the need and cost associated with some other BMPs, so cost is not included in final tally.
** Does not include Drainage District, which would have funds to install their buffers.*

8. Conclusion

Unlike many model watershed efforts in Wisconsin (Marengo, Red Cedar, etc.), a watershed association or group does not currently exist for the Lower East Shore watershed. Although we strongly recommend pursuing the creation of a more locally-focused watershed group and formal coordinator, there are several existing high-quality resources available including the Fox-Wolf Watershed Alliance, Fox Demonstration Farm Network, and Lower Fox River Watershed Monitoring Program. These groups have been involved in creating this plan and we can expect them to continue to serve as resources and partners in its implementation.

Two strategies might be considered to help municipalities and producers achieve the goals they indicated were important to them; these strategies were not emphasized in the plan because they were not identified specifically by focus groups or community outreach. First, a producer-led watershed group can leverage additional funding by applying for DATCP's Producer-Led Watershed Protection Grant Program (PLWPG). This successful and growing program provides funding to producer-led groups that focus on nonpoint source pollution abatement activities. Another strategy that may be beneficial in this particular watershed is the Agricultural Enterprise Areas program; AEAs are community-led efforts establishing designated areas important to Wisconsin's agricultural future. They provide a way for landowners to participate in the Farmland Preservation Program through Farmland Preservation Agreements. As part of the state's Farmland Preservation Program, AEAs strive to support local farmland protection goals, the agricultural economy, and environmental efforts (DATCP 2020).

There is a great deal of momentum toward watershed conservation in this region because of concurrent work happening in the Lower Fox River TMDL. The Baird Creek watershed, which is just to the south of the Mahon Creek watershed, will soon have a nine key element plan that addresses similar challenges as the Lower East Shore watershed. The Lower and Upper East River watershed plans are in the full implementation phase and have spawned several important efforts, including the East River Community Resilience Project. These efforts and the heightened community interest they have generated signal a strong likelihood for success in implementing many of the goals and actions outlined in this plan. We expect that partnering and pooling resources with neighboring watershed efforts will be a key strategy for the implementation of this plan.

Another opportunity for partnership and collaboration is in monitoring and reporting. Given that several nearby watersheds have recently or will soon begin a nine key element plan period and will need to create annual reports to WDNR, this may be a good opportunity for these watersheds to report and share information. This could be via a live or virtual gathering with presentations given to WDNR as well as other partners instead of each entity reporting one by one. This could also alleviate strain on the Brown County LWCD.

Finally, UWGB is now better positioned than ever to take a leadership role in watershed protection and restoration efforts. There is a new water science degree being offered, as well as an engineering degree, with new faculty for both programs. The Lower Fox River Watershed Monitoring Program is going strong and seeking additional funding. The Brown County STEM building, which houses county offices, is now located on campus; this allows for closer collaboration with the Brown County LWCD, UW

Extension, and UWGB faculty and students. UWGB has also welcomed a Director of Freshwater Strategy who will lead the establishment of a National Estuarine Research Reserve somewhere near Green Bay. As climate change impacts continue to bring additional challenges to watershed management, now is the opportunity and the moment to involve students in a relevant and real-world opportunity preparing them for careers dealing with these challenges. UWGB has proven to be able to collaborate effectively in watershed protection, assisting the Northeast Wisconsin Land Trust with a recent acquisition of riparian land and agricultural field along Wequiock Creek. This acquisition is significant ecologically and culturally in a rapidly urbanizing watershed. The completion of this document is a signal of UWGB's commitment to continue educating about and acting as a catalyst for protecting and improving water quality in the Lower East Shore and larger Green Bay and Great Lakes watersheds.

Appendix

Appendix A. Glossary of Acronyms

Funding Sources

ACEP - Agricultural Conservation Easement Program
CWSRF - Clean Water State Revolving Fund
CIG - Conservation Innovation Grant
CPP - Conservation Partners Program
CRP - Conservation Reserve Program
CREP - Conservation Reserve Enhancement Program
CSP - Conservation Stewardship Program
EQIP - Environmental Quality Incentives Program
FWP - Farmable Wetlands Program
FFAR - Foundation for Food and Agriculture Research
FFLM – Fund For Lake Michigan
GPR – General Purpose Revenue
GLRI - Great Lakes Restoration Initiative
GBBC - Green Bay Bicycle Collective
GLSNRP – Great Lakes Sediment and Nutrient Reduction Program
JV - Joint Venture Flex Fund Grant
KNSF - Knowles Nelson Stewardship Fund
NFWF – National Fish & Wildlife Foundation
NRDA – Natural Resource Damage Assessment
NAWCA - North American Wetlands Conservation Act
RTF - Recreational Trails Fund
SPP - Streambank Protection Program
TT - Titletown Tech
TRM - Targeted Runoff Management Grant Program
UNPS&SW - Urban Nonpoint Source & Storm Water Management Grant Program
WCMP – Wisconsin Coastal Management Program
WWA - WI Wetlands Association
WDNR – Wisconsin Department of Natural Resources
WFLGP - Wisconsin Forest Landowner Grant Program
WQT – Water Quality Trading

Implementation Partners

BCPF – Baird Creek Preservation Foundation
BLRPC - Bay-Lake Regional Planning Commission
BCCA - Brown County Conservation Alliance
BPF - Bird Protection Fund through the Natural Resources Foundation of Wisconsin
Brown Co - Brown County
City GB - City of Green Bay
CGLL – Center for Great Lakes Literacy
FSA - Farm Service Agency
GBCP – Green Bay Conservation Partners

GHSW – Green and Healthy Schools Wisconsin
GLSI – Great Lakes Stewardship Initiative
HCCS – Holy Cross Catholic School
LWCD - Land and Water Conservation Department
NWLT – Northeast Wisconsin Land Trust
NRCS - Natural Resource Conservation Service
RSS – Red Smith School
TOS - Town of Scott
TOH - Town of Humboldt
TT- Titletown Tech
USFWS – United States Fish and Wildlife Service
UWGB - University of Wisconsin-Green Bay
UWSG – University of Wisconsin Sea Grant
WDNR – Wisconsin Department of Natural Resources
WES – Wequiock Elementary School: Center for Environmental Science
WSC - Wetland Study Council
WWA - Wisconsin Wetlands Association

Appendix B. Selected Species of Greatest Conservation Need Most Associated with Habitats in the Watershed.

Referenced from the 2015 – 2025 Wisconsin Wildlife Action Plan.

Amphibians	
Four-toed Salamander	*Hemidactylium scutatum*
Insects	
Rusty-patched Bumble Bee	*Bombus affinis*
Cherrystone Drop	*Hendersonia occulta*
Ribbed Striate	*Striatura exigua*
Hairy-necked Tiger Beetle	*Cicindela hirticollis rhodensis*
A Predaceous Diving Beetle	*Ilybius angustior*
A Riffle Beetle	*Stenelmis quadrimaculata*
Birds	
Great Egret	*Ardea alba*
Black-crowned Night-Heron	*Nycticorax nycticorax*
Peregrine Falcon	*Falco peregrinus*
Upland Sandpiper	*Bartramia longicauda*
American Woodcock	*Scolopax minor*
Black Tern	*Chlidonias niger*
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Least Flycatcher	*Empidonax minimus*
Purple Martin	*Progne subis*
Caddisflies	
A Fingernet Caddisfly	*Wormaldia moesta*
A Fingernet Caddisfly	*Wormaldia shawnee*
Fish	
River Redhorse	*Moxostoma carinatum*

Appendix C. Stream Habitat Restoration Plan for the Lower East Shore Watershed.

East Shore Lower Green Bay Watershed Plan

Habitat Conservation Strategy

27 OCTOBER 2020

Robert Howe, Amy Wolf, Bobbie Webster, Erin Gnass Giese,

Megan Hoff, Paul Baumgart, Lynn Terrien, and Julia Noordyk

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Photo by Dr. Robert Howe

1.2 Objectives

This document is an appendix to the East Shore Lower Green Bay Watershed Plan (Webster et al. 2020), which addresses "nine key elements" identified by the U.S. Environmental Protection Agency (U.S. EPA 2013) as vital for improving water quality in watersheds affected by nonpoint source pollution. Like the companion document, we focus on two local watersheds (Wequiock Creek and Mahon Creek) in northeastern Wisconsin, USA, and several smaller intermittent streams that drain into the east shore of lower Green Bay between the two larger watercourses. We articulate strategies for improving plant and animal habitats in these watersheds, beginning with a review of historical conditions, followed by analysis of human activities and environmental changes that have modified habitats and populations during the past two centuries. We identify and map important natural communities and species present in these watersheds today. Armed with this information, we recommend policies and best management practices that can help protect desirable species and restore high quality natural communities in these watersheds.

The information and recommendations reported here represent two important steps in the long-term stewardship of habitats in the East Shore watershed. Specifically, we aim to 1) establish a baseline for comparisons with future assessments and 2) describe methods for continued monitoring of key biodiversity and ecological assets. We acknowledge that this plan is a work in progress. Ongoing assessments and adaptive management will be critically important for protecting habitats and species in the respective riparian zones. As new information becomes available, new assessment methods may be needed to account for species or ecological services that are not adequately recognized today. To effectively implement this vision of adaptive management, a clearinghouse of information and biological monitoring is needed. Because of its ownership and cooperative partnership in management of significant lands in the Wequiock Creek and Mahon Creek Watersheds, the University of Wisconsin-Green Bay, through the Cofrin Center for Biodiversity, commits to take a leadership role in creating and maintaining a clearinghouse of data relevant to the area covered by the East Shore Watershed Nine Key Element Plan. This report initiates the Cofrin Center for Biodiversity's commitment.

2. East Shore Watersheds

2.1 Historical Environment

Prior to the 20th century, lower Green Bay was fringed by mosaics of relatively undisturbed natural communities, including beds of wild rice (*Zizania* sp.) and wild celery (*Vallisneria americana*); extensive emergent coastal marshes dominated by bulrush (*Schoenoplectus* sp.) and cattail (*Typha* sp.); wet meadows dominated by sedges (*Carex* spp.) and native grasses (e.g., *Calamagrostis canadensis*); transitional bands of shrub carr with dogwood (*Cornus* spp.), willow (*Salix* spp.), and other native woody species; hardwood swamps of American elm (*Ulmus americana*), black ash (*Fraxinus nigra*), red maple (*Acer rubrum*), and yellow birch (*Betula alleghaniensis*); and wet conifer forests dominated by black spruce (*Picea mariana*), tamarack (*Larix laricina*), and balsam fir (*Abies balsamea*), particularly along the west shore, Duck Creek, and Point au Sable (U.S. General Land Office 1834; Neville 1905; Curtis 1959; Finley 1976; Bolliger et al. 2004). Wetland habitats were particularly extensive at the mouths of rivers and streams.

Oak woodlands were common from the inner eastern shoreline of lower Green Bay to the Niagara Escarpment (Dorney 1975; Dorney and Dorney 1989), an area that was once submerged by glacial Lake Algonquin (10,000-12,000 years BP) and Lake Nippissing (7,500 years BP). Dominant trees in these oak woodlands included bur oak (*Quercus macrocarpa*), white oak (*Quercus alba*), and black oak (*Quercus velutina*). Areas further inland in northeastern Wisconsin were largely dominated by upland forests, including beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), basswood (*Tilia americana*), oaks, hemlock (*Tsuga canadensis*), yellow birch (*Betula alleghaniensis*), and pine (*Pinus* spp). Upstream reaches of Wequiock Creek and Mahon Creek east of the escarpment were often lined with shrubs and swamp conifers (Figure C1).

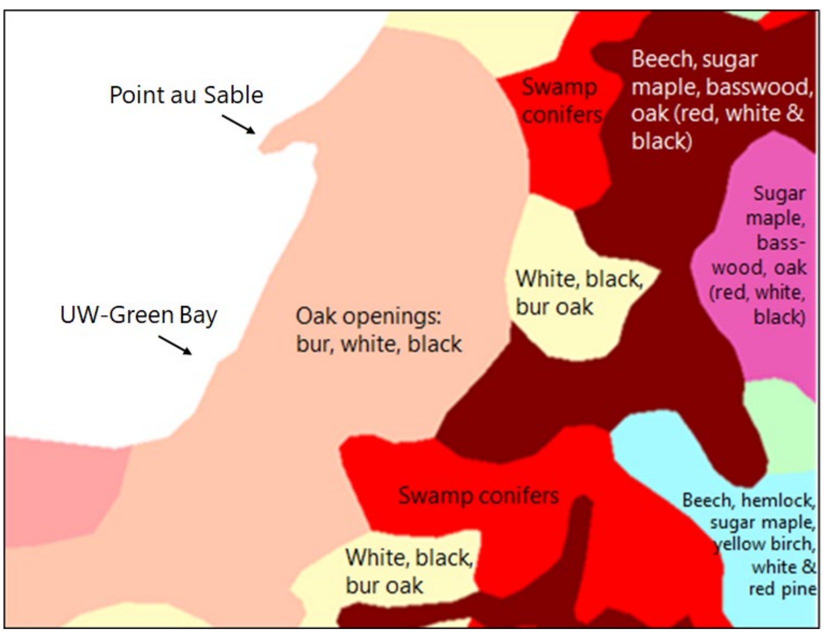


Figure C1. Land cover map based on field notes and maps from the Wisconsin Public Land Survey during the 1830s along the eastern coast of lower Green Bay Except for the text labels, this map was produced using the Wisconsin Department of Natural Resources' Surface Water Data Viewer: https://dnrmaps.wi.gov/H5/?Viewer=SWDV on 23 July 2020. Wetlands at Point au Sable and along the Green Bay coast are not represented on this map.

Generations of human activities have helped shape the East Shore landscape (Brown 1909; Overstreet et al. 2005; Speth *in* Howe et al. 2009). The First Nations inhabitants of the lower Green Bay area included people from a variety of tribal origins, attracted by the region's important natural resources, especially wild rice (Loew 2013). The Ho-Chunk (Hoocąk) Nation and Menominee (Kāēyās maceqtawak) Indian Tribe of Wisconsin were well established along the shores of Green Bay, where their ancestors had lived for thousands of years. During the 1600s and two centuries after Frenchman Jean Nicolet's arrival in 1634, the fur trade, duck hunting, logging, shipping, and agriculture became important early industries in lower Green Bay, largely due to the natural resources and fertile landscape available in this region (Biddle 1854; Neville 1905; Martin 1913; City of Green Bay 2008).

Figure C2. Air photos from 1938 featuring Point au Sable and the lower Wequiock Creek watershed (top) and the University of Wisconsin-Green Bay campus and Mahon Creek watershed (bottom).
Source: Brown County, Wisconsin online GIS portal.

Agriculture by both First Nations farmers and Europeans was well established by the mid-1800s in the area covered by the East Shore watersheds (Brown 1909, Sasso 2003 and others). By the 1930s and early 1940s, native oak forests and woodlands between the east shore of Green Bay and the Niagara Escarpment were largely replaced by cropland, pasture, and farmsteads (Figure C2). Remnant natural habitats persisted mainly in riparian floodplains and near the mouth of Wequiock Creek at Pt. au Sable, which remains largely undeveloped even today.

A large estuarine emergent marsh and open water lagoon dominate most of the Pt. au Sable peninsula at the mouth of Wequiock Creek. Like most Great Lakes coastal wetlands, the marsh and wet meadow are regularly affected by fluctuating Great Lakes water levels. In the 1970s, for example, rising Great Lakes water levels flooded Pt. au Sable's emergent marsh and lagoon (Tulbure et al. 2007), a dramatic transformation that is being repeated today with record high water levels in 2020. The emergent marsh at Point au Sable originally consisted of native cattail (*Typha latifolia*), broad-leaved arrowhead (*Sagittaria latifolia*), soft-stem bulrush (*Schoenoplectus tabernaemontani*), and other native wetland species (Tulbure et al. 2007). Southern sedge meadow, dominated by sedges (*Carex* spp.) and Canada bluejoint grass, is still present today on a small scale at Pt. au Sable and likely covered much of the shallow wetlands near the mouth of Wequiock Creek (Howe et al. 2013).

Most of Pt. au Sable was owned by a private duck hunting club from the 1800s through the 1990s (Epstein et al. 2002). Club members and other local landowners recognized the importance of the Point for migratory waterfowl and other wildlife. In fact, among many places in lower Green Bay, Pt. au Sable was known (and is still known) as one of the best duck hunting areas in northeastern Wisconsin. By the late 1960s, duck hunting club members sold their shares of the Point to one of the partners, John ("Jake") Rose, a prominent local banker and ardent conservationist. In 1997 Rose donated most of his property to The Nature Conservancy (TNC) to protect the Point for waterfowl and other wildlife. TNC subsequently transferred the property to the University of Wisconsin, which has managed Pt. au Sable through the University of Wisconsin-Green Bay's Cofrin Center for Biodiversity (CCB). Additional land acquisitions and donations from TNC led to the creation of the Point au Sable Nature Preserve, a 185-acre coastal natural area at the mouth of Wequiock Creek.

In the late 1990s and early 2000s, Great Lakes water levels dropped significantly, facilitating the spread of the invasive grass, *Phragmites australis*, into many Green Bay coastal wetlands, including the open water lagoon, emergent marsh, and shoreline at Pt. au Sable. Here, like at the mouth of Mahon Creek, sandy beaches also were replaced extensively by piles of zebra and quagga (dreissenid) mussels. Herbicide treatments, a massive prescribed burn, and rising lake levels combined to eliminate most of the extensive *Phragmites* stands between 2015-2020. Ongoing management continues to keep the *Phragmites* in check, although hybrid cattail (*Typha* × *glauca*) has heavily invaded areas where the invasive *Phragmites* has been removed.

The rich cultural heritage of the East Shore watershed is an important feature of the area's ecological history. In the early 1840s, Native American campsites and burial mounds were located within the present-day UW-Green Bay campus (Dorney 1975) and elsewhere along the east shore of Green Bay. The predominant upland vegetation was oak openings dominated by red and white oaks and bur oak. Post-disturbance successional habitats consisted of aspen (*Populus* spp.) and birch (*Betula* spp). Fires by Indigenous people, livestock grazing by settlers in the late 1800s and early 1900s, and introduction of non-native species all have left their mark today.

The history of Mahon Creek is in many ways like that of Wequiock Creek, but on a smaller scale. When UW-Green Bay was founded as a four-year college in 1965, agricultural fields dominated most of the campus landscape, but important natural features, such as the lower Mahon Creek riparian corridor, lowland forests along the Green Bay shoreline, and a significant segment of the Niagara Escarpment were part of the campus property. In 1971, former Chancellor Edward Weidner and a small committee recommended that UW-Green Bay create a system of trails and an arboretum encircling the campus. Thanks to the family of John Cofrin, an endowment was established to pay for developing the hiking trails, enhancing the remnant natural communities, and purchasing additional adjacent property to develop what is today the Cofrin Memorial Arboretum. When the UW-Green Bay Cofrin Center for Biodiversity (CCB) was established in 1999, one of its responsibilities was to manage the campus natural areas, which included the arboretum and, eventually, Pt. au Sable. Today, the Cofrin Memorial Arboretum preserves important forest, wetland, and grassland habitats adjacent to and including the lower Mahon Creek floodplain. In addition to the Arboretum's value for habitat conservation, public access is provided through an extensive trail system.

2.2 Habitat Impairments

The lower Green Bay watershed, including Wequiock Creek, Mahon Creek, and several smaller unnamed watercourses, has been greatly modified since the early 1900s. By the time of the earliest aerial photograph in 1938, most of the wooded uplands had been replaced by farmland, roads, and houses, increasing rates of surface runoff, and re-directing natural drainage patterns. Floodplain vegetation and wetlands were eliminated or degraded, leading to flash flooding with alternating periods of little or no flow. Clearing of riparian forests reduced sources of woody debris, further modifying the character of stream channels and instream habitats. Removal and fragmentation of pre-colonial woodlands and wetlands also indirectly disrupted regional ecosystems by altering predator-prey interactions and pollinator services. For example, local elimination of apex predators like gray wolf (*Canis lupus*), mountain lion (*Puma concolor*), and bobcat (*Lynx rufus*) led to unhealthy increases in populations of white-tailed deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), and other prey species. Plant-pollinator dynamics have been modified by wide scale changes in plant community composition. Few, if any, of these changes have been explicitly documented, but a comparison of land surveyor notes from the 1830s with 1938 air photos reveals profound changes in the landscape, which modified the regional ecosystem dramatically.

During the last century, the total area of forest vegetation in the East Shore watershed changed very little; in fact, the forest cover even increased in some areas, especially along the lower reaches of Mahon and Wequiock Creeks. Long-term degradation of wildlife habitats in the East Shore watershed continued, however, through at least three major mechanisms: 1) physical changes to drainage patterns and stream morphology; 2) introduction and proliferation of invasive species; and 3) environmental pollution caused by fertilizers, pesticides, and sediment runoff.

By the 1950s, a four-lane highway (Highway 57) was constructed east of the Niagara Escarpment. The four-lane section was extended further during the late 1990s and early 2000s. The newly constructed highway crossed both the Mahon Creek and Wequiock Creek drainages, re-directing large volumes of surface flow into ditches along the right-of-way. Like other historical changes, the effects of highway construction on the habitats and hydrologic regime of the East Shore watershed are not well chronicled, but surely the road corridor has significantly impacted local wildlife habitats and surface water drainage patterns.

The second major impairment during the last century has been the gradual accumulation of invasive plants and animals. The list of destructive species is very long, including fungi (e.g., the ascomycete causing Dutch elm disease), insects (e.g., Asian emerald ash borer, *Agrilus planipennis*), woody plants (e.g., Eurasian buckthorn, *Rhamnus cathartica*), understory herbs (e.g., garlic mustard, *Alliaria petiolata*), aggressive grasses (e.g., *Phragmites australis*), fishes (e.g., European carp, *Cyprinyus carpio*), mussels (e.g., zebra and quagga mussels, *Dreissena* spp.), earthworms, feral cats, and many other taxa. As riparian forests and stream reaches became fragmented and disturbed by logging, grazing, and other human-related activities, vulnerability of natural communities to invasive species increased. Today, invasive species are (probably irreversibly) significant elements of the flora and fauna. Management of undesirable invasive species will be a core element of our recommendations for improving stream and riparian habitats in the East Shore watershed.

Finally, repeated applications of agricultural fertilizers and pesticides in the East Shore watersheds have affected biological communities both directly and indirectly. The introduction of synthetic insecticides after World War II led to well-documented reproductive impairments of Bald Eagle (*Haliaeetus leucocephalus*), Peregrine Falcon (*Falco peregrinus*), and other predatory birds (Hickey and Anderson 1968; Mitra et al. 2011). Declines or local extirpations of these high-profile species may cause broad ecological impacts that persist for generations, even after the most dangerous toxins have been banned from use (McKnight et al. 2015). The ecological ramifications of fertilizers and sediments are less obvious, but their intensive use also impacts terrestrial and aquatic habitats for many generations by modifying soil acidity (Barak et al. 1997), biological oxygen demand (dos Reis Oliveira et al. 2018), and nutrient dynamics (Liu et al. 2016).

2.3 Desired Future Condition / Benchmark Watersheds

Destruction and degradation of natural communities in the Green Bay East Shore watershed can never be totally reversed. Nevertheless, valuable habitat remnants are present in the landscape, and certain degraded areas can be significantly improved by informed land management and strategic ecological restoration. Rehabilitation efforts can be guided by realistic restoration targets, both at the species and community level. Here we identify some of the benchmarks that might be achieved through future conservation measures.

More than 60 Species of Greatest Conservation Need in Wisconsin have been documented in the Wequiock and Mahon Creek watersheds. Many of these are migrants or irregular visitors, but at least 24 species, including 8-9 state or federally endangered or threatened species (Table C1), are regularly observed in the East Shore watershed during the breeding season. Ecological restoration and best management practices will be most beneficial for these species, and therefore our recommendations are focused on their habitats. We propose six species groups and three natural community types (Table C2) as priority natural features of the East Shore watershed. Riparian corridors along east shore tributaries like Wequiock Creek and Mahon Creek are regionally very significant because they represent some of the only places along the east shore of lower Green Bay where relatively unfragmented habitats and natural communities can be sustained or restored today.

The fundamental desired future condition of habitats in the East Shore watershed is a landscape where these 9 target species groups are thriving. Many of the targets are interconnected; thus, steps to benefit one of them will have positive effects on others. For example, native plantings designed to create quality oak savanna for Red-headed Woodpecker, Eastern Meadowlark, and American Woodcock also will benefit native pollinators. Likewise, the juxtaposition of southern hardwood swamp adjacent to the savanna uplands will benefit American Woodcock and Red-headed Woodpecker, as well as endangered/threatened bats, which forage along the forest edge.

Table C1. Endangered, threatened, or special concern species regularly observed in the East Shore Lower Green Bay watersheds. Status is derived from the Wisconsin Natural Heritage Working List of rare or vulnerable species.

Common Name	Scientific Name	Type	State Status	Federal Status
1. Rusty-patched Bumble Bee	*Bombus affinis*	insect	special concern	endangered
2. Yellow-banded Bumble Bee	*Bombus terricola*	insect	special concern	special concern
3. Hairy-necked Tiger Beetle	*Cicindela hirticollis*	insect	endangered	-
4. Cherrystone Drop	*Hendersonia occulta*	land snail	threatened	-
5. River Redhorse	*Moxostoma carinatum*	fish	threatened	-
6. American Black Duck	*Anas rubripes*	bird	special concern	-
7. Great Egret	*Ardea alba*	bird	threatened	-
8. American Bittern	*Botaurus lentiginosus*	bird	special concern	-
9. Least Bittern	*Ixobrychus exilis*	bird	special concern	-
10. Black-crowned Night-Heron	*Nycticorax nycticorax*	bird	special concern	-
11. Common Tern	*Sterna hirundo*	bird	endangered	special concern
12. Forster's Tern	*Sterna forsteri*	bird	endangered	-
13. Caspian Tern	*Hydroprogne caspia*	bird	endangered	-
14. Black Tern	*Chlidonias niger*	bird	endangered	special concern
15. American Woodcock	*Scolopax minor*	bird	special concern	-
16. Peregrine Falcon	*Falco peregrinus*	bird	endangered	-
17. Red-headed Woodpecker	*Melanerpes erythrocephalus*	bird	special concern	-
18. Purple Martin	*Progne subis*	bird	special concern	-
19. Eastern Meadowlark	*Sturnella magna*	bird	special concern	-
20. Little Brown Bat	*Myotis lucifugus*	mammal	threatened	-
21. Northern Long-eared Bat	*Myotis septentrionalis*	mammal	threatened	threatened
22. Big Brown Bat	*Eptesicus fuscus*	mammal	threatened	-
23. Tricolored Bat	*Perimyotis subflavus*	mammal	threatened	-
24. Silver-haired Bat	*Lasionycteris noctivagans*	mammal	special concern	-

Table C2. Targeted species groups and habitat types in the riparian zone of the lower Green Bay East Shore watershed. Endangered, threatened, or special concern species associated with the group or habitat type are listed as numbers, which are referenced in Table C1. Each species group includes many species besides the listed endangered/threatened/special concern species.

Species Group / Habitat Type	Endangered / Threatened / Special Concern Species
Native forest bats	20, 21, 22, 23, 24
Grassland/savanna birds	15, 17, 19
Native pollinators	1, 2
Wetland birds	6, 7, 8, 9, 10, 12, 14
Great Lakes coastal birds	6, 7, 11, 12, 13, 16, 18
Green Bay fishes	5
Floodplain forest	20, 21, 22, 23, 24
Hardwood swamp	20, 21, 22, 23, 24
Warmwater stream	5

Ecological restorations of quality oak savanna, hardwood swamp, floodplain forest, coastal wetlands, and warmwater stream also provide opportunities for translocating or planting species that have been extirpated from the area, potentially expanding the list of species included in our desired future condition. We anticipate that additional conservation priority species will be discovered as biologists further explore the East Shore watershed. Recommended best practices and ecological restoration strategies therefore should be considered works in progress, subject to revision as restoration measures are implemented and as more information becomes available.

Fitzpatrick et al. (1996) identified five northeastern Wisconsin "benchmark streams" in the region characterized by clay soils over carbonate bedrock, covering much of Manitowoc, Brown, Kewaunee, and Door Counties. This region includes the upper reaches of Wequiock and Mahon Creeks above the Niagara Escarpment. We visited relatively intact and minimally-disturbed sections of four of these benchmark streams during 2020, excluding only Hibbard Creek in northern Door County. Our goal was to identify riparian vegetation and stream features that can help guide ecological restoration in the Green Bay East Shore watersheds. Three of the four streams (Casco Creek, Little Scarboro Creek, and Tisch Mills Creek) were considered reference streams based on their high-water quality and stream morphology (Figure C3). Only Krok Creek in Kewaunee County failed to meet the standards of a reference stream for this geophysical region.

All four benchmark streams (Figure C3) have at least local patches of northern white cedar (*Thuja occidentalis*) along the banks, with dense growth in openings dominated by speckled alder (*Alnus incana*), willows (*Salix* spp.), and dogwoods (*Cornus* spp.). Other tree species present in the riparian zone include black ash (*Fraxinus nigra*), aspen/poplar (*Populus* spp.), birch (*Betula papyrifera* and *Betula alleghaniensis*), basswood (*Tilia americana*), American elm, box elder (*Acer negundo*), and red maple (*Acer rubrum*). Relatively undisturbed streams closer to the Wequiock Creek and Mahon Creek watersheds such as Gilson Creek also have extensive areas of cedar along the banks, and small remnant patches of cedar are present in the vicinity of Mahon Creek on UW-Green Bay's Cofrin Memorial Arboretum.

Epstein (2020) pointed out that northern hardwood swamps (and similarly, northern wet-mesic forest communities), often including northern white cedar, are prevalent in saturated soils where organic material can accumulate over time. This community type, which we observed in the "benchmark" streams described above, is more typical of headwater streams. Most of the upper reaches of the Green Bay East Shore tributaries would likely have resembled this habitat type, although today they have been almost entirely replaced by farmland or early successional riparian vegetation.

Figure C3. Benchmark streams in northeastern Wisconsin identified by Fitzpatrick et al. (1996). upper left, Casco Creek; upper right, Krok Creek; lower left, Little Scarboro Creek; lower right, Tisch Mills Creek. Photo credit: Dr. Robert Howe

Below the Niagara Escarpment and closer to Green Bay, the lower reaches of Mahon and Wequiock Creeks are more prone to dramatic seasonal flooding, which inhibits the accumulation of rich, organic soils along the banks. In these parts of the watershed, the riparian zone is more likely to resemble floodplain forests, dominated by trees that are better adapted to periodic inundation/drying and the mechanical scouring associated with flash flooding. Fast-growing trees like eastern cottonwood (*Populus deltoides*) and green ash (*Fraxinus pennsylvanicus*), along with swamp white oak (*Quercus bicolor*) and (formerly) American elm are prominent in these floodplains. Unlike the slower-growing cedars, these trees often attain very large diameters with cavities and crevices that provide critical roosting or nesting habitats for bats, birds, and other wildlife.

This analysis suggests that restoration efforts in the Lower Green Bay East Shores Watershed should acknowledge natural communities at two ends of a continuum: 1) hardwood/conifer swamps along headwater reaches, with riparian vegetation on more organic alluvial soils, typically including a conifer component of northern white cedar and associated non-conifers like speckled alder, white birch, and black willow (*Salix nigra*) and 2) floodplain forests located downstream, where flash flooding is more dramatic and mineral soils are more prominent. Trees and other plant species that are adapted to seasonal inundation (and drying) are more characteristic of these downstream reaches.

3. Restoration Opportunities

Despite the degraded character of the upper Wequiock Creek and Mahon Creek watersheds, significant restoration potential exists in both the stream networks as well as in the swamp forests where many of these watercourses originate. Critical areas in the Mahon and Wequiock Creeks are zoned as Environmentally Sensitive Areas (ESAs) by the Brown County Planning and Land Services Department through the authority of the State of Wisconsin Administrative Code Chapters NR 121 and related local regulations (Figure C4). ESA maps for the East Shore watershed are available in pdf format (see maps for the City of Green Bay, Town of Humboldt, and Town of Scott) or from the online Brown County GIS map application. ESAs have been historically administered by the Brown County Zoning Office; related designations of Shoreland Zones (State of Wisconsin Administrative Code Chapters NR 115 and NR 116), which broadly overlap with the ESAs, have been administered by the Brown County Planning Commission (Brown County Planning Commission 2012). Many of the critical areas associated with the East Shore watershed are also designated as mapped wetlands by the Wisconsin Department of Natural Resources (WDNR). These areas can be viewed online at the WDNR Surface Water Data Viewer or directly from the Brown County GIS application.

3.1 Upstream Habitats

The headwaters of both Wequiock and Mahon Creeks are spread across agricultural landscapes east of the Niagara Escarpment. Prior to intensive European settlement of the region in the late 1800s and early 1900s, both watersheds originated in forests or swamps once dominated by tamarack, black ash, northern white cedar, American elm, and other wet forest species (U.S. General Land Office 1834, Figure C5). Sugar maple, American beech, eastern hemlock, white pine, butternut, black walnut, and several species of oaks were present on drier parts of this landscape. Remnants of the headwater swamps are present today as generally degraded and highly fragmented woodlots (Figure C6). These forests undoubtedly provided habitat for many species that are gone today from this region. Most conspicuously absent are large mammals like gray wolf, black bear (*Ursus americanus*), and large mustelids, but smaller vertebrates like certain forest songbirds and undoubtedly many invertebrates also have been extirpated from the region.

Headwater wetlands and floodplain wetlands are generally recognized as critical features of watersheds (Colvin et al. 2019). Like many other watersheds, these habitats in Wequiock Creek and Mahon Creek are severely impaired. Land survey notes from the 1830s also describe “willow swamps” in the headwaters region and throughout the watershed. Again, small remnants are present today, but these are fragmented and typically are heavily invaded by non-native plant species (Figure C7), including hybrid cattail.

Stream networks (watercourses) in the upper regions of Mahon and Wequiock Creeks are highly modified by channelization and water diversions (Figure C9). Road ditches and agricultural tile drainage systems are prominent features of these systems. Although frogs and toads are still thriving in some of these modified watercourses, native stream invertebrates and other aquatic organisms are generally low in diversity and quality in the upper Wequiock Creek and Mahon Creek watersheds today (McReynolds 2020).

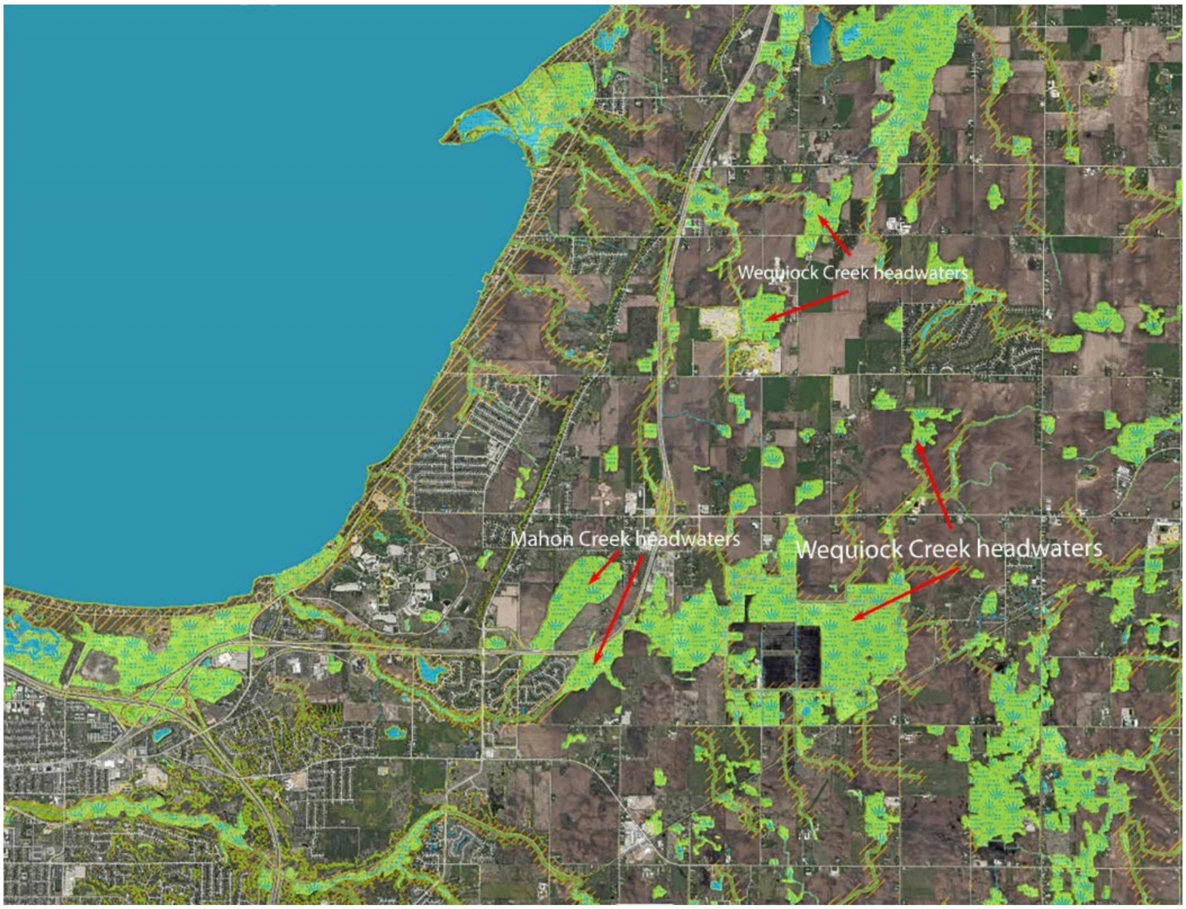
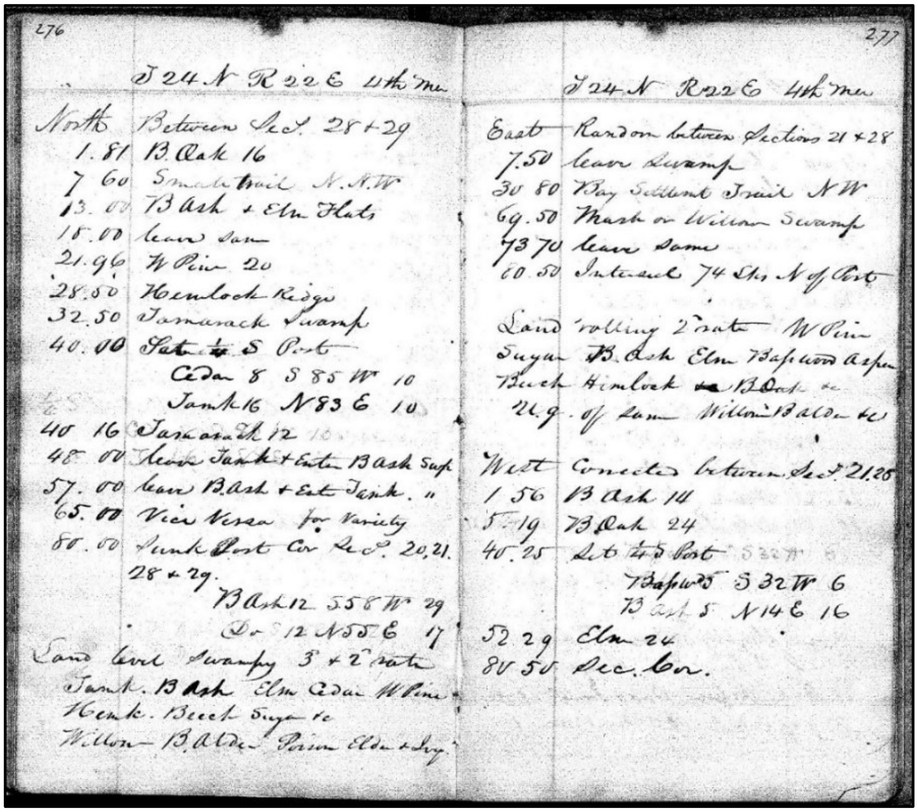


Figure C4. Wetlands (light green with wetland icons), environmentally sensitive areas (ESAs – dark green), and shoreland zones (brown diagonal lines) in the East Shore watershed. Note the large swamp wetlands at headwaters of Wequiock and Mahon Creek watersheds. Map was created using the Brown County GIS map application.

The Nature Conservancy (TNC) and Wisconsin Department of Natural Resources (WDNR) have used geographic information system (GIS) tools and remote-sensing data (vegetation cover, elevation, etc.) to develop an online tool for identifying existing wetlands and potentially restorable wetlands, including both forested and non-forested habitats (Miller et al. 2017). Potentially restorable wetlands are low-lying areas where wetlands once occurred and where changes in human land use can lead to the restoration of wetland habitat. Both existing and potentially restorable wetlands were ranked as high, moderate, and low priority based on wetland area and proximity and connection to significant waterways (Figure C8). Results reveal useful information for conservation planning. Hoff (2020) used the tool to identify 2,048 total acres of wetlands in the Mahon and Wequiock Creek watersheds, in addition to 3,929 acres of potentially restorable wetlands. Largest areas of existing and potentially restorable wetlands exist east of Highway 54/57 in upper reaches of the Mahon and Wequiock Creek watersheds. Most of the existing wetlands are successional hardwood swamps dominated by cottonwood, box elder, American elm, ash

(*Fraxinus* sp.), or degraded wetland openings invaded with *Phragmites australis*, hybrid cattail, reed canary grass, and other indicators of disturbance.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T 24 N R 22 E 4th Mer

North Between Sec. 28 + 29
1.81 B. Oak 16
7.60 Small trail N.N.W
13.00 B Ash + Elm Flats
18.00 leave same
21.96 W Pine 20
28.50 Hemlock Ridge
32.50 Tamarack Swamp
40.00 Set ¼ S Post
Cedar 8 S 85 W 10
Tamk 16 N 83 E 10
40.16 Tamarack 12
48.00 Leave Tamk + Enter B Ash Swp
57.00 leave B Ash + Ent Tamk "
65.00 Vice Versa for Variety
80.00 Sunk Post Cor Sec. 20, 21, 28 + 29.
B Ash 12 S 58 W 29
Do 12 N 55 E 17
Land level Swampy 3 + 2 rate
Tamk. B Ash Elm Cedar W Pine
Hemk. Beech Sugar &c
Willow — B. Alder Poison Elder & Ivy.

277

T 24 N R 22 E 4th Mer

East Random between Sections 21 + 28
7.50 leave Swamp
30.80 Bay Settlement Trail N W
69.50 Marsh or Willow Swamp
73.70 leave same
80.50 Intersect 74 Lks N of Post
Land rolling 2 rate W Pine
Sugar B. Ash Elm Basswood Aspen
Beech Hemlock B. Oak &c
N.g. of same Willow B Alder &c
West Corrected between Sec. 21 + 28
1.56 B Ash 14
5.19 B Oak 24
40.25 Set ¼ S Post
Basswood S 32 W 6
B Ash 5 N 14 E 16
52.29 Elm 24
80.50 Sec. Cor.

Figure C5. Original notes from land surveyor J. Hathaway in 1834 describing northward line between sections 28 and 29 (left half of surveyor's notebook) and eastward route between Sections 21 and 28 (right half of surveyor's notebook) in T24N R22E in Brown County in the town of New Franken. The described area lies within the headwaters of a major branch of Wequiock Creek as shown in the Google Earth map (see area outlined with a white box to the south of Algoma Road).

The upper portions of both Wequiock Creek and Mahon Creek are mostly privately owned but provide some of the best opportunities in the watersheds for conservation of hardwood or (in the case of Mahon Creek) mixed hardwood/conifer swamps and associated species. For example, a 100-acre (40.5 ha) conifer/hardwood swamp at the headwaters of one branch of Mahon Creek (Figure C6) provides an outstanding opportunity to protect forested wetland habitat and its associated ecological services. This tract, located between North Spartan Road and Highway 54/57 east of the UW-Green Bay campus, was described in the 1834 land surveys as a "swamp with small tamaracks," adjacent to "birch and alder thicket." The remnant conifer bog has become increasingly forested since the first aerial photograph in 1938, but it represents one of the least disturbed, if not the most pristine, headwater wetland in the East Shore watersheds. Protection of this area should be a high priority, not only because it provides excellent contiguous wildlife habitat, but because it is critical for protecting water quality at the headwaters of Mahon Creek.

Figure C6. Edge of remnant conifer/hardwood swamp at headwaters of a major branch of Mahon Creek. Inset shows Google Earth image of the landscape; location of photograph shown as yellow pin.

Figure C7. Remnant marsh bordered by scattered willows and shrubs along Van Lanen Road in the Wequiock Creek watershed. Note the invasive grass, *Phragmites australis*, at far end of marsh (upper center of image) and another invasive, reed canary grass (*Phalaris arundinacea*), in lower left. Most of the interior marsh is covered by hybrid cattail (*Typha* × *glauca*.)

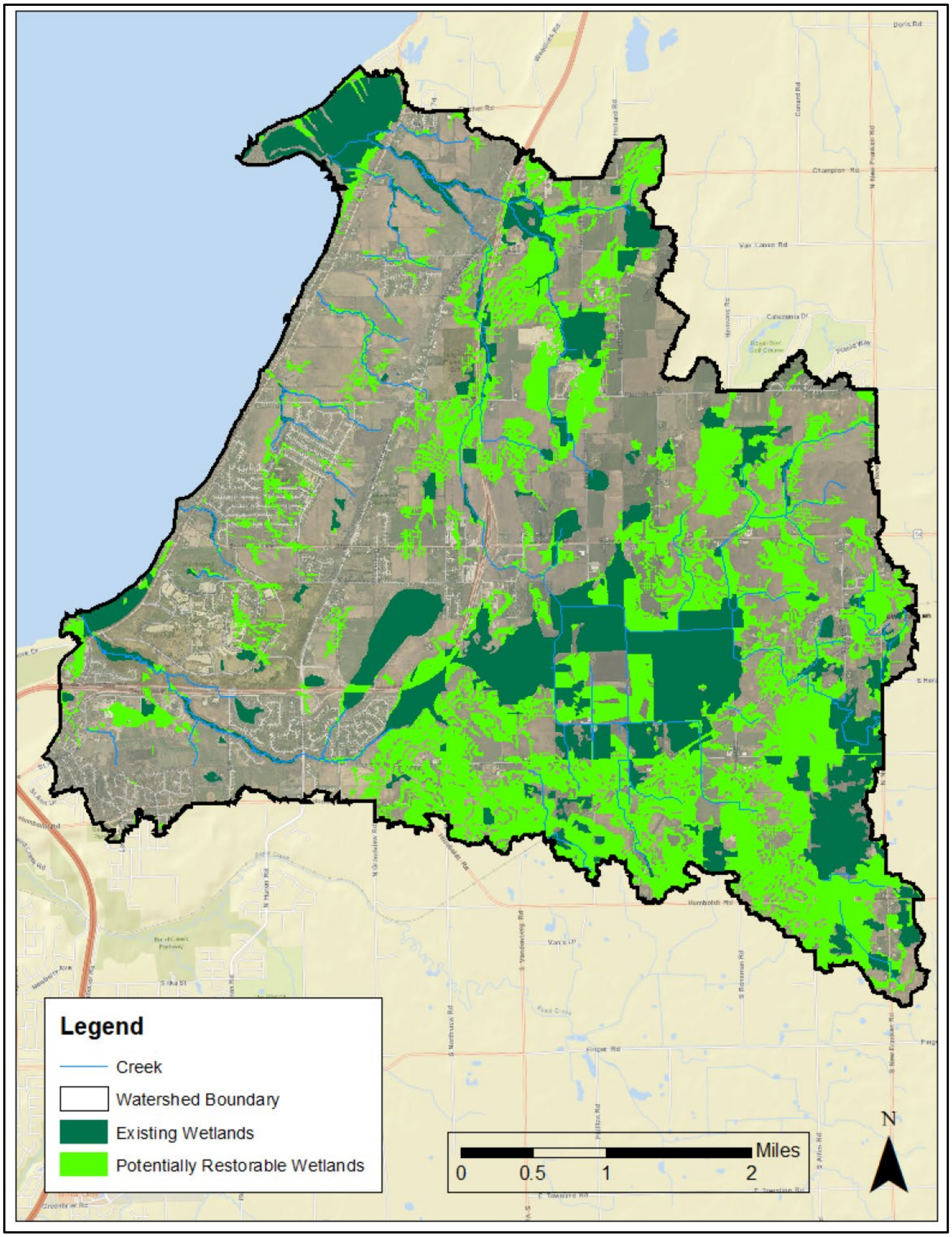

Figure C8. Map of existing wetlands and potentially restorable wetland areas in the East Shore watershed based on GIS analysis by The Nature Conservancy and Wisconsin Department of Natural Resources *Wetlands by Design* project (Miller et al. 2017). Map was generated by Hoff (2020) from The Nature Conservancy's Freshwater Network web portal, using resources from the Brown County Planning and Land Services Office, Esri, Garmin, and U.S. government agencies.

Other headwater wetland areas east of Highway 54/57 were described in 1834 land survey notes as "willow marsh," "tamarack swamp," and "black ash and alder swamp." These mostly forested wetlands today cover a significant part of the headwaters of Wequiock Creek. The land survey notes show that upland forests of sugar maple, eastern hemlock, American beech, and other climax forest species also were present throughout this region, but lowland or successional species like black ash, aspen, American elm, butternut, and black walnut were widespread, as were understory species like alder and hazelnut.

Today, most of the headwater wetlands of the Mahon and Wequiock Creek watersheds are drained by channeled watercourses or ditches (Figure C9). These modified drainage systems undoubtedly have changed the hydrology of the wetlands and lowland forests. The open willow marshes and tamarack swamps have been dried, now dominated by woodlands with early successional species like box elder, green ash, and cottonwood. Even where larger oaks, ash, American elm, and American basswood are present, the understory is quite open (Figure C10), likely reflecting seasonal flooding and intensive browsing by deer.

Restoration opportunities in the headwaters of Mahon and Wequiock Creeks begin with expanding and improving the mosaics of swamp forests and shrub-lined marshes, particularly several 100+ ac (40.5+ ha) remnants south of Algoma Road/Highway 54. Enlarging the existing habitat areas can be achieved by changing land use in the TNC-identified "potentially restorable wetlands" (Figure C8). Smaller but significant tracts of swamp forest and willow-lined wetlands also exist near Van Lanen Road and Champion Road in the northern headwaters of the Wequiock Creek watershed (Figure C8). These sites also present excellent opportunities for ecological restoration. Enlightened management of forests and wetlands in headwater regions is particularly important because these habitats provide sources of propagules (both native and unwanted invasive species) for colonizing downstream areas.

Forested areas in the headwaters provide habitat for white-tailed deer, bats, frogs and toads, breeding and migratory birds, and other animal species. The quality of these forests is generally poor, however. Restoration actions to improve forest wetlands in the upstream regions of the East Shore watershed include:

- remove buckthorn (*Rhamnus cathartica*, *Frangula alnus*) and other invasive plant species;
- re-establish native understory shrubs and forbs, such as elderberry (*Sambucus canadensis*), winterberry (*Ilex verticillata*), chokecherry (*Prunus virginiana*), hazelnut (*Corylus cornuta*), and buttonbush (*Cephalanthus occidentalis*);
- excavate or (where they already are present) protect ephemeral ponds to promote breeding habitat for woodland amphibians;
- maintain woody debris (fallen trees, brush, etc.) on the forest floor to provide habitat and promote tree regeneration;
- leave snags for bird and bat breeding and roosting habitat;
- plant and maintain native grasses and wildflowers in openings within and adjacent to remnant forest areas to provide habitat for native pollinators; and
- encourage deer population control by hunting (especially does) to prevent over-browsing of understory plants.

In addition to the degradation of forests and wetland habitats, drainage patterns and the stream channel itself have been modified severely in the headwater regions of the East Shore watershed. Restoration of meandering stream channels could slow the flow of sediments into the headwaters of Mahon Creek and Wequiock Creek and could help re-establish seasonal flooding of forested wetland habitats, benefitting many wildlife species, especially frogs, toads, fish, and aquatic macroinvertebrates. Constructed water control structures might be the best option for restoring hydrology in the remnant headwater wetlands. Designs of effective water control systems will be challenging given conflicting land use interests and the private ownership of most headwater habitats. Significant improvements undoubtedly will require creative partnerships involving private landowners, local, state, and federal government agencies, and non-profit conservation organizations.

Figure C9. Channelized branch of upper Wequiock Creek on land owned and managed by the City of Green Bay. The location is indicated by a yellow pin on the inset Google map.

Figure C10. Forest interior in tract owned by the City of Green Bay near the headwaters of Wequiock Creek. Photo credit: Dr. Robert Howe.

3.2 Riparian Corridors

Downstream from the headwater swamps, riparian corridors in the upper and middle reaches of Mahon and Wequiock Creeks are generally very narrow. In some places, only cropland or roadside ditches border the stream (Figure C11). Hoff (2020) mapped the width of vegetative buffers in all of the East Shore Lower Green Bay watersheds (Figure C12). Areas with narrow or no buffers are widespread in the upper Wequiock Creek watershed and, to a lesser extent, in the small unnamed watersheds between Mahon Creek and Wequiock Creek west of the Niagara Escarpment. Stream segments that lack adequate vegetative buffers have little wildlife habitat value, either in the stream itself or in the adjacent riparian zone. Restoration of vegetation along these stream segments should be a high priority for both wildlife habitat as well as for water quality objectives. Although vestiges of pre-colonial riparian forests and woodlands will likely never be restored along the middle reaches of the East Shore Lower Green Bay watersheds, the "willow swamps" described in 1834 land surveys do provide a viable habitat model that can provide quality native wildlife habitat and buffer the stream from excessive surface runoff. Because willows generally flower early in the season, they provide important resources for native pollinators at a time when floral resources are limited (Tumminello et al. 2018).

Figure C11. Exposed segment of Wequiock Creek near Highway 57 south of Church Road. Note willows (*Salix* sp.) in background and along right side of image.

The mid- and upper watershed sections of Wequiock Creek pose serious threats to water quality downstream because riparian vegetation is narrow or absent entirely across much of the landscape (Figures C12-C13). This also is true for Mahon Creek, although runoff comes more from residential developments than from agricultural fields. Restoration of riparian vegetation is probably the most effective strategy for improving downstream water quality in the East Shore watershed. Addition or widening of riparian corridors with willows and other native species will significantly benefit populations of native pollinators; songbirds like Yellow Warbler (*Setophaga petechia*), Common Yellowthroat (*Geothlypis trichas*), and Song Sparrow (*Melospiza melodia*); and ecologically sensitive stream invertebrates like dragonflies, mayflies, and caddisflies. Vegetated riparian corridors along Wequiock and Mahon Creeks are not especially cost prohibitive. Natural vegetation buffers as wide as 50 m (164 feet) along both sides of the exposed 3 miles of Wequiock Creek, for example, will require protection of less than 120 ac (48.6 ha) of land. Strategic plantings of native species in the riparian buffers, including willows, alder, aspen (*Populus* spp.), dogwood (e.g., *Cornus sericea*), and native grasses and forbs, can help maximize ecological services of these restored riparian buffers.

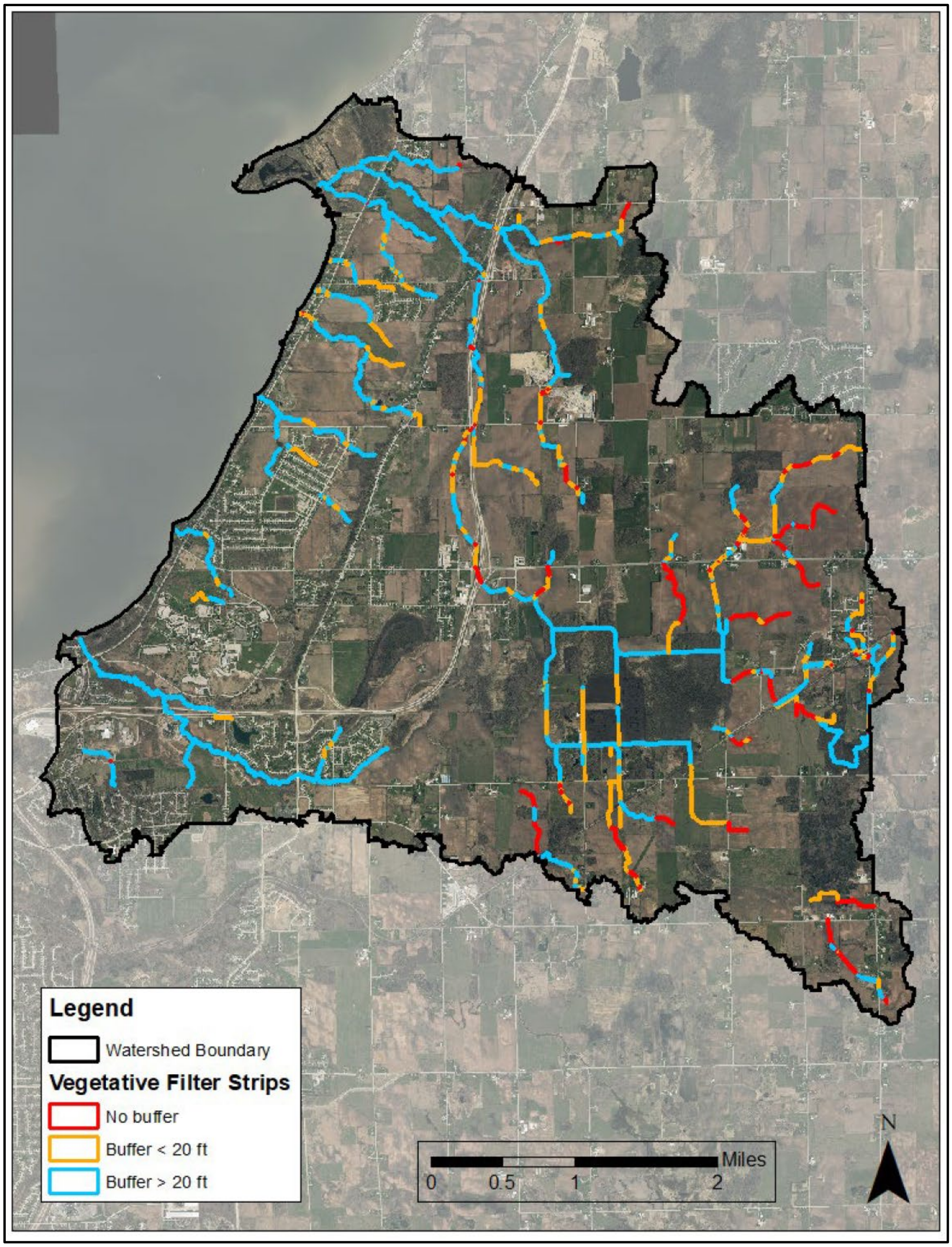

Figure C12. Width of vegetative buffers along the East Shore watershed (from Hoff 2020). Inadequate buffers (or no buffers at all) are widespread in the upper segments of the Wequiock Creek Watershed in the right half of the map.

Figure C13. Stream sections with little or no riparian buffers (yellow pointers) in middle sections of the Wequiock Creek watershed. Image is from a May 2018 NOAA satellite photograph published online by Google Earth.

Downstream riparian corridors of both Wequiock Creek and Mahon Creek are much wider and provide excellent habitat for wildlife, including several species of high conservation priority. The newly acquired Wequiock Creek Natural Area and the University of Wisconsin-Green Bay's Point au Sable Nature Preserve protect a naturally forested and wetland corridor extending approximately 1 mile (1.6 km) upstream. Large habitat trees in the forested corridor (Figure C14) provide habitat for a diverse community of native bats during summer, including the federally threatened northern long-eared bat and state threatened little brown bat and big brown bat. Other species of concern in these corridors include silver-haired bat, Red-headed Woodpecker, American Woodcock, butternut (*Juglans cinerea*), and undoubtedly others. Motion-sensitive cameras deployed during summer 2020 documented typical forest/woodland wildlife in the Mahon Creek riparian forest, including Virginia opossum (*Didelphis virginiana*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), raccoon, striped skunk (*Mephitis mephitis*), eastern gray squirrel (*Sciurus carolinensis*), eastern chipmunk (*Tamias striatus*), and white-tailed deer. Populations of these familiar urban/suburban mammals likely depend on large habitat areas like the lower Mahon Creek and Wequiock Creek river corridors for shelter and feeding during much of the year.

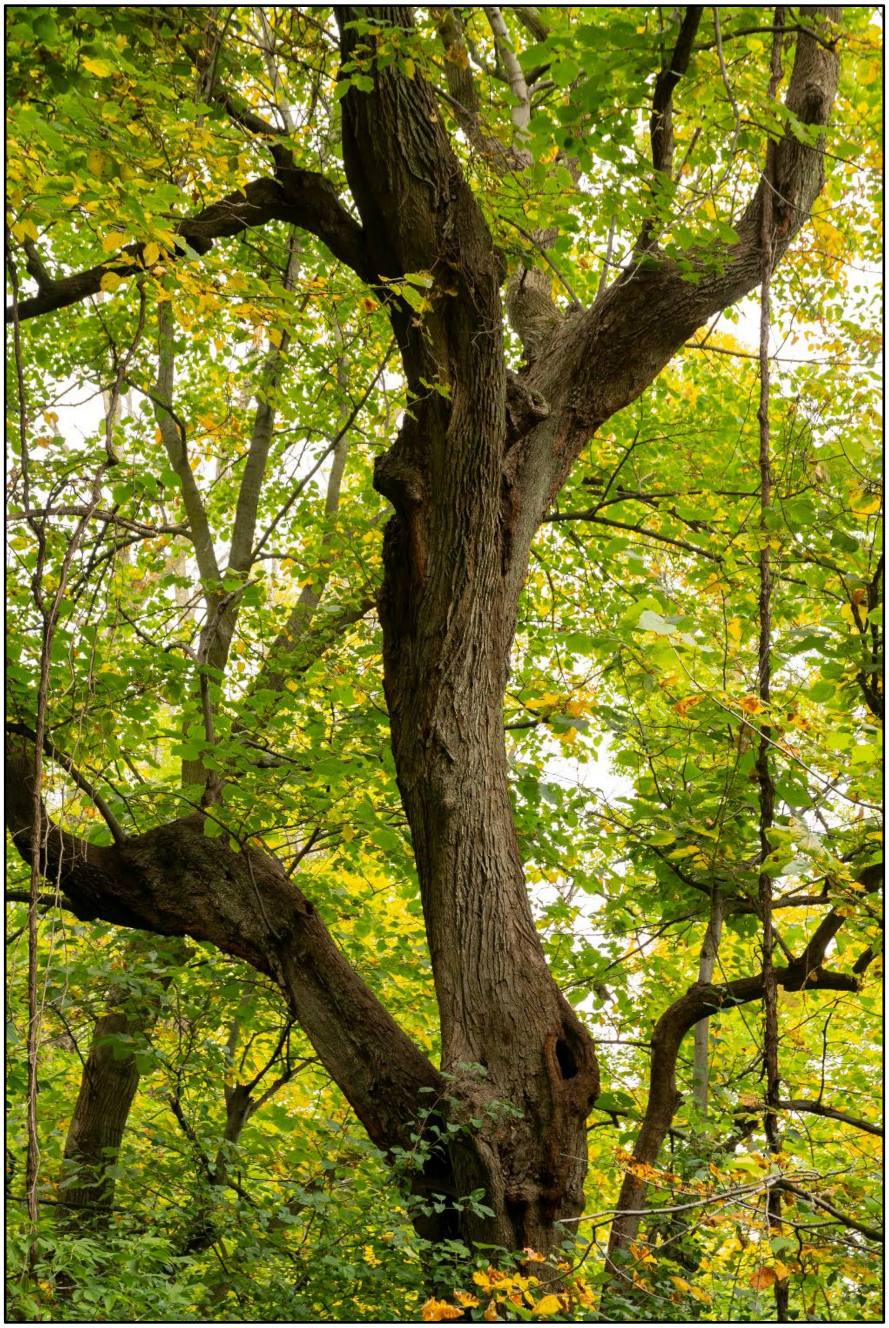

Figure C14. Large eastern cottonwood (*Populus deltoides*) in Wequiock Creek riparian forest corridor. Loose bark and cavities in these "habitat trees" provide roosting sites for several species of native bats, including the federally threatened long-eared bat (*Myotis septentrionalis*).

Width of the 1.4-mile (2.3 km) forested riparian corridor from Wequiock Falls to Pt. au Sable ranges from approximately 200 ft (61 m) to more than 500 ft (152 m). Restoration of oak savanna at the newly acquired property will increase the width of this protected buffer to more than 2,100 ft (650 m) in some areas, creating even more significant habitat for target species. The Town of Scott Comprehensive Plan Update (2017) recommends the development of a "green" parkway from Pt. au Sable to Wequiock Falls.

This proposed extension (especially if accompanied by widening of the existing natural corridor) would create the most significant remnant habitat feature in the entire area covered by this report. The Pt. au Sable to Wequiock Falls greenway also would have secondary benefits, including recreational and educational opportunities for local residents and reduction of nonpoint source pollution in Wequiock Creek.

The lower 0.9 miles (1.4 km) of Mahon Creek from the Green Bay shoreline to Highway 54/57 also is surrounded by a forested corridor, ranging from 400 ft (121.9 m) to more than 1,000 ft (304.8 m) wide in some places. Upstream from Highway 54/57, a forested corridor ranging from 350 ft (106.7 m) to approximately 800 ft (243.8 m) wide extends through Brown County land and eventually along private property for another 1.0 mile (1.6 km) to Bay Settlement Road. The forested corridors along lower reaches of both Mahon and Wequiock Creeks are protected as conservation lands owned by the University of Wisconsin-Green Bay, City of Green Bay, Brown County, Town of Scott, and Northeast Wisconsin Land Trust. Long-term management plans are needed to meet the threats of invasive species, but the ecological health and hydrological integrity of the lower portions of both Wequiock Creek and Mahon Creek seem to be secure.

The same cannot be said for smaller, unnamed watercourses in the area between Mahon and Wequiock Creeks. These small watersheds empty into Green Bay through private property or, in two cases, through narrow riparian corridors owned by the City of Green Bay. The Barina Parkway (Figure C15) provides a model for what can be done to improve these riparian corridors, with a small section (~0.3 mi; ~0.5 km) of restored native grasses and wetlands near Red Smith School. Opportunities for additional riparian habitat restoration exist downstream from the parkway and in several other unnamed drainages along the east shore of Green Bay.

Figure C15. Barina Parkway (looking south from Church Road), a restored riparian corridor along a small unnamed creek north of Red Smith School (taken by R. Howe on 9/20/2020).

Unlike Wequiock Creek, Mahon Creek is bordered largely by residential properties upstream from the University of Wisconsin-Green Bay Cofrin Memorial Arboretum and other public parcels owned by the City of Green Bay, Brown County, and Wisconsin Department of Transportation. Except for relatively short sections (e.g., between Creekside Lane and Spartan Road; south and east of Wolverine Trail, north of Luxemburg Road), adequately wide riparian buffers exist in these residential areas. Even in places where vegetated buffers are fairly wide, however, restoration opportunities are numerous, including:

- improve the quality of vegetation by controlling invasive species and, wherever possible, planting native trees, shrubs, and grasses/forbs;
- restore meanders in stream flow where channels have been artificially straightened;
- allow naturally occurring woody debris to accumulate in the stream and floodplain; and
- eliminate unimpeded drainage into the stream through culverts, drain pipes, etc.

Figure C16. Brown County Public Works Project along Lake Largo Road in the Mahon Creek watershed (2020). Although measures were implemented to reduce surface runoff of water and sediments, stream and riparian habitats have been altered significantly.

Habitat restoration opportunities in lower reaches of Mahon Creek and Wequiock Creek involve restoration of critical habitat features on public or conservation lands. Public ownership does not necessarily indicate that watershed protection and habitat preservation are adequate, however. A Brown County Public Works Project along Lake Largo during 2018-2020, for example, has been depositing soil fill (from stormwater pond excavation and a land development project) at a 25+ ac (10.1+ ha) site adjacent to a small branch of Mahon Creek (Figure C16). Although measures have been taken to minimize water and sediment runoff from this site, stream habitat in the watercourse itself and riparian vegetation have been significantly altered or degraded.

3.3 Instream Habitats

Habitats within the mainstream channel (instream habitats) include the substrates forming the stream bottom, living and dead wood, aquatic plants, and overhanging structures that affect the aquatic environment. These habitats are critical for sustaining populations of fish, invertebrates, and microorganisms. UW-Green Bay graduate students Megan Hoff and Amelia McReynolds described instream habitat (pool, riffle, or run) and dominant substrate type at approximately 40 m (50 step) intervals in Mahon and Wequiock Creeks during 2019 (Figures C18-C23). Siltation and channelization have been shown by other researchers to diminish the distinction between pool, riffle, and run microhabitats (Berkman and Rabeni 1987); this homogenization of stream morphology reduces habitat suitability for desirable fishes and macroinvertebrates (Wood and Armitage 1997). Lower reaches of Mahon Creek and (especially) Wequiock Creek (Figure C18) provide a favorable mixture of these microhabitats, but middle and upper reaches are characterized by a much more uniform lotic environment, in some cases entirely devoid of riffles or pools (Figures C19-C20).

Stream substrates are predominately sand and gravel in the lower reaches of Mahon Creek (Figure C21), but the substrates change to cobble or short stretches of clay/loam at the edge of UW-Green Bay's Cofrin Memorial Arboretum near Highway 54/57 (No substrate samples were recorded farther upstream in Mahon Creek). By contrast, sandy substrates are nearly absent from the main channel of Wequiock Creek. Cobble and gravel predominate in the lower section from Pt. au Sable (Nicolet Drive) to Wequiock Falls (Figure C21). Cobble continues to be an important substrate upstream (Figure C22) until the headwater regions (Figure C23), where silt and loamy sediments predominate. Differences in the lower portions of Wequiock and Mahon Creeks reflect the higher gradient flows and the greater incidence of bedrock outcrops in Wequiock Creek (Figure C17). Bank erosion from sandy soils below the Niagara Escarpment likely provides a source of materials for sand deposition in Mahon Creek, whereas the streambed of Wequiock Creek flows along or over bedrock outcrops, some of which contribute rocky cobble and slabs to the instream substrate.

Figure C17. Rock outcrop along bank of Wequiock Creek approximately 400 ft (121.9 m) east of Nicolet Drive.

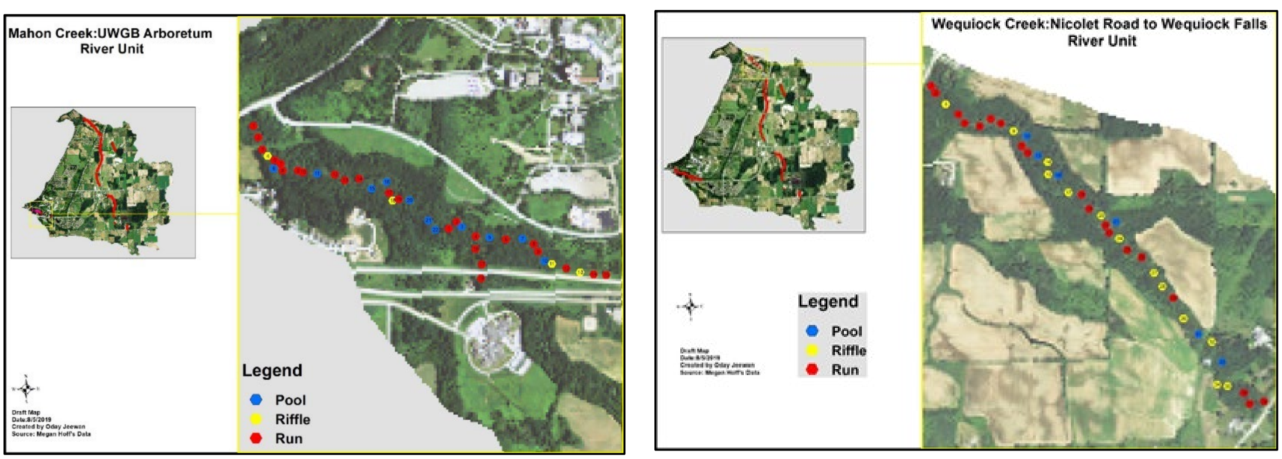

Figure C18. Categorization of stream habitat at 50 step intervals in downstream portions of Mahon Creek (left) and Wequiock Creek (right).

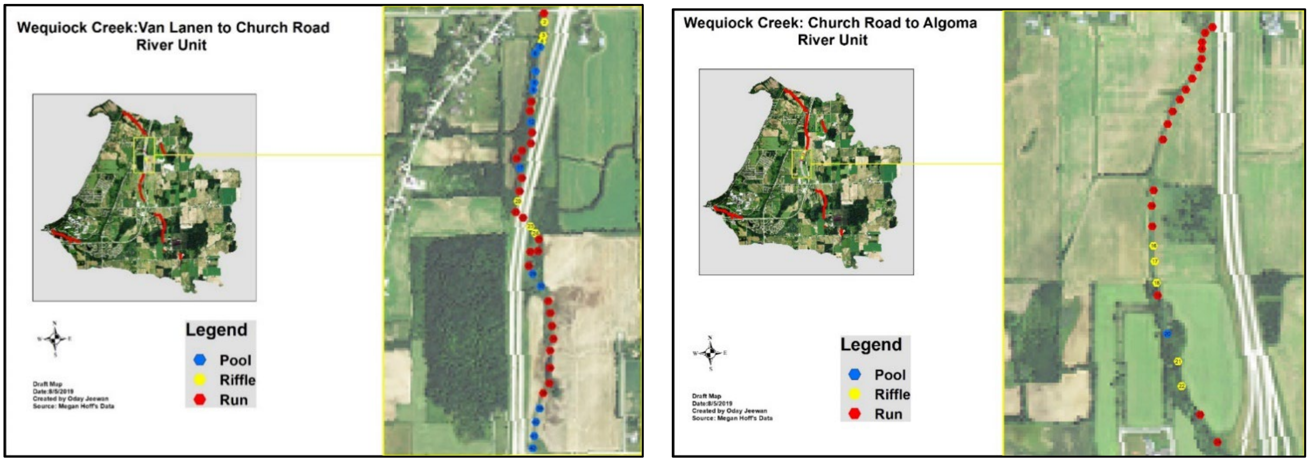

Figure C19. Categorization of stream habitat at 50 step intervals in middle segments of Wequiock Creek.

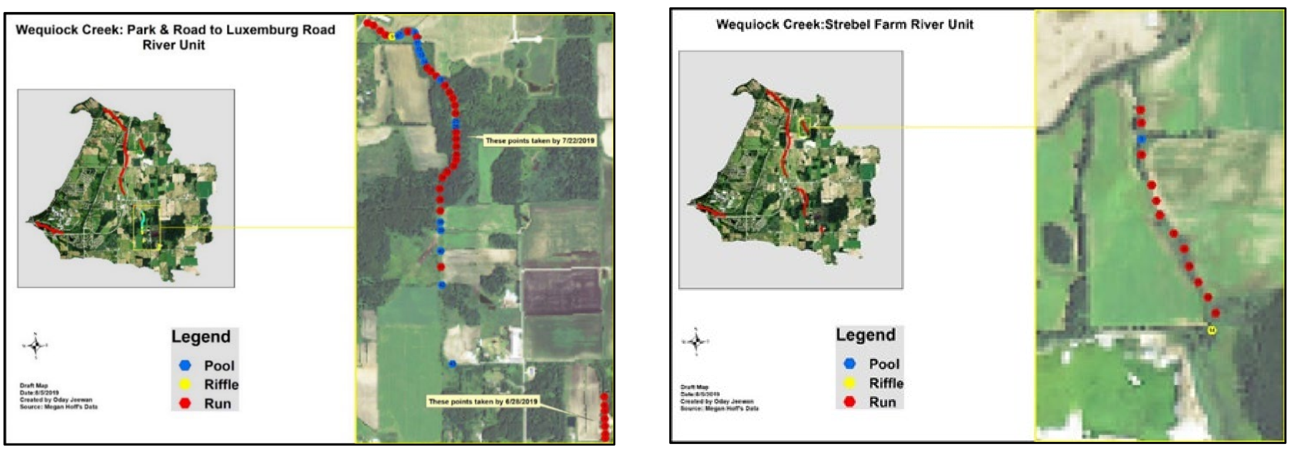

Figure C20. Categorization of stream habitat at 50 step intervals in upper (headwater) reaches of Wequiock Creek.

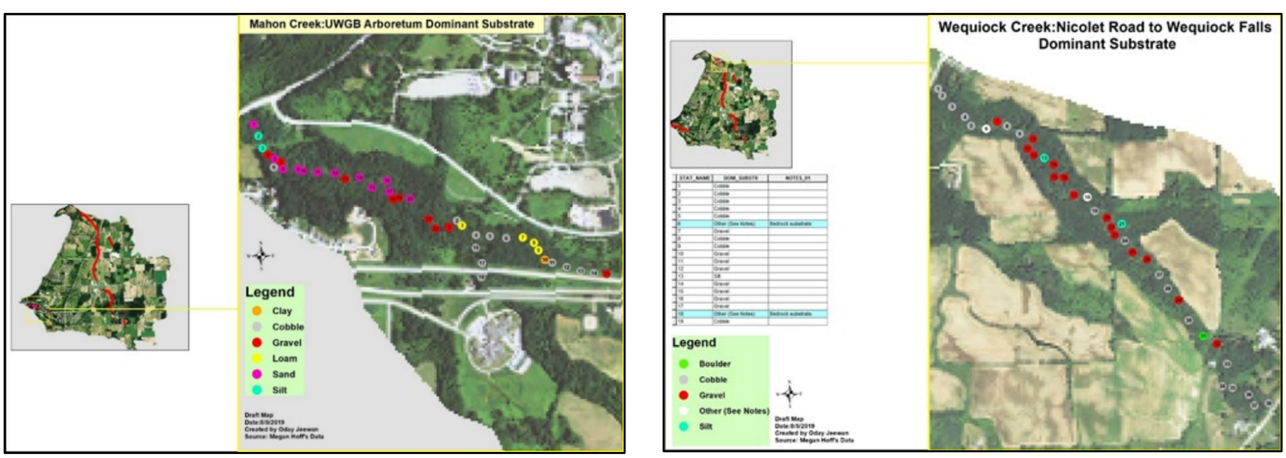

Figure C21. Categorization of dominant substrate at 50 step intervals in downstream portions of Mahon Creek (left) and Wequiock Creek (right).

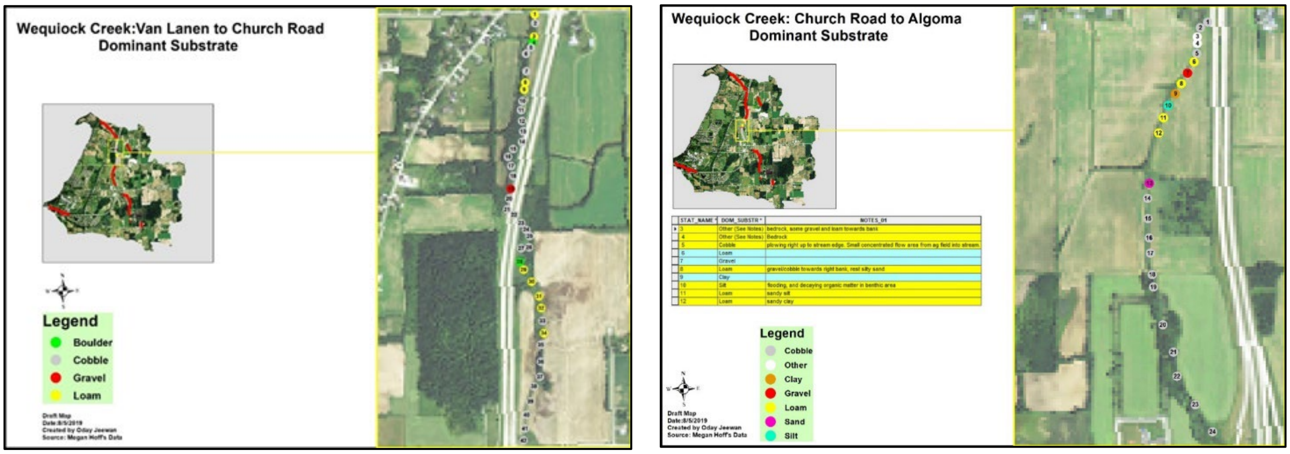

Figure C22. Categorization of dominant substrate at 50 step intervals in middle segments of Wequiock Creek.

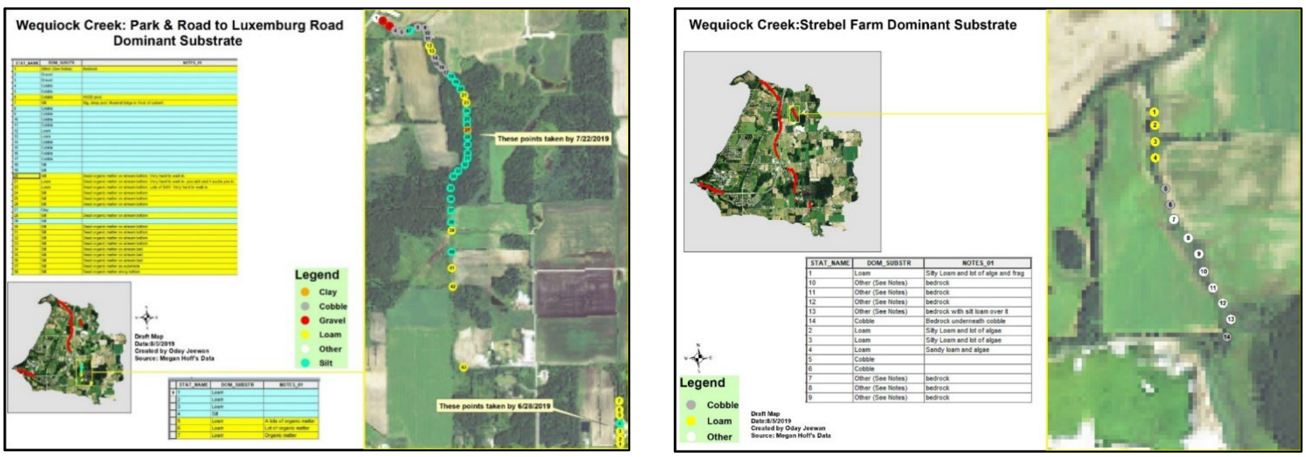

Figure C23. Categorization of dominant stream substrate at 50 step intervals in upper (headwater) reaches of Wequiock Creek.

Channelization has occurred in streams and tributaries across all the East Shore watershed. Few naturally meandering watercourses are found in the headwaters and upper reaches of any of these systems (e.g., Figure C9). Blake and Rhanor (2020) and others have shown that silt accumulation in channelized streambeds causes significant habitat degradation and negative effects on stream biota. Physical changes associated with channelization also include deepening and narrowing of the channel and floodplain, bank erosion, reduction in the width and extent of riparian vegetation, and replacement of natural streambanks with artificial materials. These changes not only affect stream hydrodynamics, but they also may destroy microhabitats that sustain healthy populations of stream organisms, including fishes and sensitive invertebrates. Lau et al. (2006) found that channelization reduced the availability of riffle and pool areas within streams in Indiana, leading to reductions in the quality of fish communities. In Finland, Laasonen et al. (1998) found that dredging and stream channelization led to increased water depth, increased stream velocity, and lower "roughness" of the streambed. These conditions were associated with lower macroinvertebrate diversity and abundance.

Restoration of instream habitats is difficult when significant lengths of the watercourse have been channelized or redirected. The challenge is exacerbated when impervious surfaces or drainage tiles accelerate the flow of water from upstream landscapes. One commonly used stream restoration measure, bank stabilization, fails to address system-wide issues like excessive flow or upstream channelization (Kondolf 1996). Bank erosion itself is a natural process, so we do not recommend expensive bank stabilization projects, especially in downstream reaches of Mahon and Wequiock Creek where natural stream morphology already exists. Upstream, bank stabilization might reduce the erosion of sediments into the watershed, but more ambitious or more comprehensive stream restoration actions like restoration of channel meanders, widening of riparian buffers, and retention of woody debris might be equally or more effective (Lammers et al. 2020).

Another common stream restoration measure, especially in Europe, is to add boulders or wood to mitigate previous streambed scouring or dredging (Turunen et al. 2017). Successful reestablishment of aquatic invertebrates is often hindered by other factors like degraded water quality, dispersal constraints, and altered stream morphology, but the addition of large substrate features is effective when combined with broader watershed restoration efforts (Pilotto et al. 2019). Lower sections of Mahon and Wequiock Creeks already contain quality stream substrates (Figure C24). Addition of substrate materials (wood or boulders) may be effective farther upstream, however, especially when combined with other measures like restoration of meanders and revegetation of stream banks. In vegetated stream corridors, boulders and woody debris increase substrate heterogeneity, reduce flow velocity, and improve the retention of leaf litter, which helps re-establish detritivore-dominated macroinvertebrate communities. Aquatic organisms that feed on leaf litter are known as "shredders"; this important functional group tends to dominate in headwater streams, where instream habitat has been most severe in the East Shore watershed.

Although watercourses in the East Shore watersheds are intermittent during most years (including Mahon and Wequiock Creeks), movements of fish and other aquatic organisms are important in maintaining the biodiversity of these aquatic ecosystems. Hooley-Underwood et al. (2019) showed that intermittent streams in Colorado play significant roles in spawning, foraging, and early life histories of several large fishes, including native suckers (*Catostomus* spp.). White suckers (*Catostomus commersoni*) undergo a major spring run in Wequiock Creek, and other fish from Green Bay also move upstream into Wequiock and Mahon Creek (Koosmann 2016). Maintaining unobstructed passages for these "potamodromous" species is an important instream restoration and management issue that should be addressed for Mahon Creek, in particular (Figure C25). Connectivity of stream habitats, including spatial relationships between seasonal refugia such as deep pools and riparian wetlands, has been shown to be important in other systems (e.g., Chester et al. 2015) and might be a critical consideration for watershed restoration strategies in East Shore watersheds.

Results from other stream restoration efforts suggest that an "all of the above" approach is most effective in restoring instream habitats: 1) re-establishing stream morphology, 2) restoring vegetation (especially trees and shrubs) along the stream corridor, 3) adding woody debris, boulders, and other instream structures that have been previously removed or buried, and 4) eliminating human-caused obstruction to fish movements and instream habitat connectivity. Many opportunities exist in the East Shore watershed to implement stream habitat restoration strategies, especially in the middle and upper reaches of Wequiock and Mahon Creeks. Evidence from restoration efforts in other systems has shown that stream restoration is especially challenging in urban areas, where impervious surfaces are extensive. Violin et al. (2011), for example, found that reach-scale restoration measures in urban environments were not successful in improving macroinvertebrate communities. Likewise, Stranko et al. (2012) reported that stream restoration in urban streams showed little or no increase in biodiversity compared with reference streams in forested regions. Streams in agricultural landscapes may respond better to restoration efforts. Miller and Kochel (2010) evaluated results from 26 stream habitat restoration studies from a variety of landscape settings. They found that additions of large woody debris yielded the largest and most consistent improvements in macroinvertebrate communities, while boulder additions and channel reconfigurations had more variable (though generally positive) effects on macroinvertebrate diversity.

Figure C24. Gravel and cobble stream bed in lower Mahon Creek at the University of Wisconsin-Green Bay's Cofrin Memorial Arboretum. Photograph by Megan Hoff in October 2019.

Figure C25. Fish passage obstruction in lower Mahon Creek in the UW-Green Bay Cofrin Arboretum. Larger concrete structure was removed during 2019, but additional materials remain and should be taken away to promote fish movement.

3.4 Downstream Wetlands and River Mouths

The most biologically diverse regions of the East Shore watershed occur at river mouths, where the stream channels empty into the waters of Green Bay. The mixing of water and deposition of sediments from both systems create unique habitat structures like deltaic sandbars, estuarine wetlands, and other distinct ecological environments. River mouths attract concentrations of potamodromous (migratory) fishes, fish-eating birds, beach-associated invertebrates, scavengers, and other species attracted by the combined resources of lentic (lake) and lotic (stream) ecosystems (Larson et al. 2013). Fisher et al. (2015) and Fujimoto et al. (2016) demonstrated that mouths of watersheds draining agricultural and urban lands also introduce distinctive microbial communities into the lake. Larson et al. (2016) provided evidence that river mouths are typically more resource-rich than both the upstream watercourse and lakes into which they flow.

Relatively few studies of river mouths have been conducted in the Great Lakes, but Makarewicz et al. (2012) showed that phytoplankton densities were higher in river mouths than in adjacent waters of Lake Ontario, while Smith and Simpkins (2018) and others have reported that fish densities in river mouths were higher than in adjacent open waters in Lake Michigan. Many Great Lakes fish species require or prefer rivers for reproduction or nursery habitats, including brook trout (*Salvelinus fontinalis*), whitefish (*Coregonus clupeaformis*), walleye (*Sander vitreus*), yellow perch (*Perca flavescens*), muskellunge (*Esox* *masquinongy*), northern pike (*Esox lucius*), and others (Becker 1983). Several of these, especially yellow perch, have been documented regularly at the river mouth of Wequiock Creek (Koosmann 2016).

The mouth of Wequiock Creek is much more ecologically diverse than the mouths of Mahon Creek and the small unnamed tributaries covered in this report. In addition to extensive hardwood swamps in the riparian floodplain and in nearby coastal lowlands, the mouth of Wequiock Creek is connected to an extensive estuarine wetland complex covering much of the Point au Sable Nature Preserve (Figure C26).

Figure C26. May 2020 air photo of the mouth of Wequiock Creek (yellow arrow) at Point au Sable. The lower section of the creek shown in the lower center of photograph was widened by private landowners in the 1950s. Most of the outer point consists of coastal wetlands and ridge/swale topography with oak woodland and shrubs on the wider ridges. Properties owned by the University of Wisconsin form the Point au Sable Nature Preserve. Image is from the Brown County interactive GIS web application.

Many of the state endangered and threatened species found in the East Shore watershed (e.g., Great Egret, Caspian Tern, Forster's Tern, Peregrine Falcon, river redhorse) are present only at or near the river mouths of Wequiock Creek and Mahon Creek. The lower Wequiock Creek floodplain and adjacent wetlands also support outstanding stopover habitats for migratory birds; more than 220 species have been recorded here by UW-Green Bay researchers since the late 1990s.

The less diverse mouth of Mahon Creek historically has been bordered by several acres of coastal wetland during low lake-level years (Figure C27). Unlike estuarine wetlands at the mouth of Wequiock Creek, these coastal wetlands are exposed to high energy waves of lower Green Bay. During high north or west winds, the shoreline is heavily impacted by waves, and during high lake-level years the coastal wetland vegetation is almost completely obliterated. No other extensive coastal wetlands occur at the mouths of smaller watercourses between Mahon Creek and (to the north) Wequiock Creek.

Figure C27. Air photos of the mouth of Mahon Creek (yellow arrow) during low lake-level years 1938 and 2014. Vegetation during 2014 consisted mainly of the introduced grass, *Phragmites australis*. Images were copied from the Brown County interactive GIS web application.

The highly dynamic character of both the Wequiock Creek and Mahon Creek river mouths leads to immense challenges for ecological restoration. Water levels at both sites change daily, seasonally, and from year to year. For example, Green Bay has seen a 6-ft (1.8-m) increase in water levels between record lows in 2013 and record high water levels in 2020. Current work at the Point au Sable Nature Preserve aims to re-establish naturally dynamic coastal wetlands like sedge meadow or wet prairie in the Wequiock Creek delta. Species characteristic of these habitats, unfortunately, have been almost completely displaced by invasive species like *Phragmites australis*, *Phalaris arundinacea* (reed canary grass), and *Typha × glauca* (hybrid cattail). The dynamic character of coastal or estuarine wetlands means that opportunities for colonization by unwanted invasive plants and animals are frequent. Restoration strategies at the Wequiock Creek and Mahon Creek river mouths therefore must begin with management of invasive species, and long-term plans will need to include repeated treatment and monitoring. Treatment measures might vary over time depending on water levels and other conditions. Local eradication of some problem species like common carp (*Cyprinus carpio*) and dreissenid mussels (Figure C27) might be impossible because efforts to eradicate them might have negative effects on other desirable species like native fish and invertebrates. Nevertheless, invasive species control is at the top of the list of actions to restore fish and wildlife habitat at the river mouths of the East Shore watershed.

Some channel modification occurred at the mouth of Wequiock Creek during the mid-20th century (Figure C26), creating deeper pools and perhaps altered flooding regime in the adjacent wetlands. Restoration of the pre-dredging substrate by adding gravel or rocks and promoting the accumulation of woody debris might improve the stream environment and promote a more natural flood regime for adjacent estuarine wetlands near the mouth of the creek. At the mouth of Mahon Creek, removal of accumulated dreissenid mussel shells (Figure C28) will enable native benthic and beach species to recolonize the estuarine ecosystem. Benefits of any engineered change to the lower channels of Mahon Creek or Wequiock Creek will likely have very limited long-term benefits unless the work is combined with comprehensive watershed restoration actions like invasive species control and restoration of wooded riparian buffers upstream.

Figure C28. Accumulation of dreissenid mussel shells at the mouth of Mahon Creek (2017).

4. Best Management Practices

The Brown County Planning Commission (2012) developed a list of general "best management practices" for reducing water pollution in environmentally sensitive areas and shoreland zones. Below, we add to that list with specific measures for ecological restoration for both private landowners and conservation land managers. Best management practices from the Brown County document are shown with an asterisk (*). Additions to these recommendations include actions that will improve habitat for fish and wildlife, often contributing simultaneously to the water quality goals outlined by Wisconsin Administrative Code NR 121, the U.S. Clean Water Act, and local zoning regulations.

1. Install rain gardens*

Rain gardens (shallow landscaped depressions that absorb water runoff from buildings and other impervious surfaces) improve filtration of rainwater and reduce surface flow into streams and rivers. This action is particularly relevant for residents along the upper reaches of Mahon Creek, where stream flows during rain events and periods of spring snowmelt are accelerated by runoff from impervious surfaces like homes and roads. While the effects of any single rain garden are relatively small, the collective impacts of many can have a significant positive effect on water quality in the watershed. This assertion is supported by literally hundreds of studies showing that water quality in urban landscapes is negatively affected by increases in the total areas of impervious surfaces.

2. Reduce impervious surfaces*

Direct flow of water from streets, driveways, parking lots, and buildings causes flash flooding during heavy rain periods. Reducing the area of these impervious surfaces will slow the flow of water and reduce nonpoint pollution in the East Shore watershed. This BMP eliminates the need for rain gardens, bioswales, etc. by reducing the sources of excessive surface runoff in the first place.

3. Remove/slow the spread of invasive plant species*

Property owners should plant native species in residential landscapes as much as possible. The long list of problematic non-native species includes *Phragmites australis*, garlic mustard, buckthorn, non-native honeysuckles, dame's rocket (*Hesperis matronalis*), and many others. Attractive native species are available for planting in almost every landscape. In addition to private landowners, government entities, such as the Wisconsin Department of Transportation, Brown County, City of Green Bay, UW-Green Bay, and others, should plant native grasses and forbs in road rights-of-way, around buildings, and in hedgerows or aesthetic gardens. These native species not only provide ecological services like soil stabilization and shading, but they also provide food resources for native pollinators (e.g., bumble bees and butterflies) and many other ecologically important species (Figure C29).

4. Create and widen vegetated buffer strips along waterways*

Intermittent watercourses along middle stretches of the East Shore watershed, particularly Wequiock Creek, are bordered by very narrow or, in some cases, no vegetation, exposing the stream to runoff of sediments, nutrients, and other pollutants. Vegetated buffers of less than 100 ft (30 m) can help reduce nutrient and sediment runoff, but recommended widths for viable riparian wildlife habitat are often 300 ft (91 m) or more (Lee et al. 2004, Hawes and Smith 2005). Field observations from Wequiock and Mahon Creeks illustrate the regional significance of riparian corridors for mammals and birds. Protection of wide riparian corridors clearly should be one of the most important wildlife habitat priorities in this landscape.

Figure C29. Native grasses and forbs planted along Mahon Creek riparian corridor in the University of Wisconsin-Green Bay Cofrin Memorial Arboretum.

5. Minimize the use of fertilizers and pesticides on lawns near the water's edge*

Large segments of Mahon Creek and parts of the other watercourses in the East Shore watershed pass through residential areas. Minimizing the use of chemicals for lawn care, coupled with maintenance of riparian buffers of natural vegetation, are critically important management practices for reducing pollution and thereby improving aquatic habitat for fishes and stream invertebrates.

6. Ensure that private onsite wastewater treatment systems are functioning properly*

This recommendation will contribute to improvement of water quality for stream macroinvertebrates and fish. Failed private wastewater systems may lead to surface pooling of contaminated and nutrient-rich water that may eventually flow into streams.

7. Install rain barrels to capture rainwater*

Rain barrels help store water from the roofs of buildings, reducing surface runoff from residential and commercial areas. This affects watersheds by reducing flash flooding in streams, which in turn prevents or decreases bank erosion and aquatic habitat for fish and stream invertebrates. Use of rain barrels will be especially beneficial for homes in the vicinity of Mahon Creek and smaller unnamed watersheds close to the Green Bay coastal zone. Residents can reuse the captured rainwater for gardening and other lawn maintenance tasks.

8. Install bioswales*

Like rain barrels and rain gardens, bioswales are features of developed areas designed to encourage filtration of stormwater and to filter pollutants and sediments. Plantings of native prairie grasses and wildflowers in bioswales provide habitat for pollinators and other desirable organisms. Construction of bioswales can be effective in residential neighborhoods and around parking lots or commercial buildings. Bioswales can be visualized as larger and more comprehensive versions of rain gardens, designed to improve surface water infiltration from areas larger than a single residential lot.

The following best management practices, not included in the Brown County Planning Commission document, apply mainly to forest owners, property owners whose land includes major channels or tributaries of the East Shore watershed, and managers of conservation lands.

9. Promote the retention of woody debris in stream channels

Large woody debris (fallen logs and branches) can alter flow patterns in streams, leading to an increase in pool habitats, enhancing sediment deposition, and improving habitats for fish and stream invertebrates (Cordova et al. 2007, Jones et al. 2011, and many other sources). In the East Shore watershed, woody debris is nearly absent in stream reaches of the upper watershed, where forest clearing and channel modifications are widespread. In these areas, artificial addition of logs and large branches could help slow the flow and reduce flash flooding downstream (Loperfido et al. 2014). Pool formation might lead to local widening of the stream upstream from the blockage of flow, but placement or retention of woody debris can be designed strategically to affect areas where riparian buffers are wide enough to accommodate these changes. In the larger forested riparian zones of lower Wequiock Creek and Mahon Creek, accumulation of woody debris, even if it causes bank overflow and periodic flooding, should be left undisturbed to promote natural floodplain dynamics (Figure C30).

Figure C30. Coarse woody debris in stream channel of lower Wequiock Creek.

10. Protect residual pools in intermittent streams during low water periods

Virtually all streams and tributaries in the East Shore watershed are classified as "intermittent" because flow is seasonally interrupted during dry periods. This does not mean that water is absent from the streams or tributaries, however. Typically, residual pools retain water at multiple places along the watercourse (Figure C31). These remnant pools are critical refugia for small fish and macroinvertebrates that can colonize other parts of the stream when flow is restored following rain events and spring snowmelt. Mapping and managing pools can help ensure that populations of aquatic organisms are preserved in the watershed. Management actions in the vicinity of pools include planting of native shade trees or shrubs on the adjacent banks in order to reduce evaporation and warming of the water and preventing erosion and compaction of banks by redirecting trails and stream access points away from these pools.

Figure C31. Remnant pool along lower Wequiock Creek during September 2020. Small fish and macroinvertebrates were present in this pool.

11. Maintain large "habitat trees" in floodplain and riparian corridor

Field studies during 2020 have shown that populations of state endangered/threatened bat species and the federally threatened northern long-eared bat are present in the lower Wequiock Creek floodplain and adjacent forest corridor. Several of these species use tree cavities, loose bark, and crevices found in dead or damaged trees, known as "snags" or "habitat trees" (Figure C14). The forested corridors along Wequiock and Mahon Creeks provide all three elements of productive habitat: roosting sites, foraging resources, and water (Taylor 2006). Abundant large habitat trees (mainly old oaks, hickories, and cottonwoods) are present throughout the forest. These trees should be retained and allowed to decay naturally, providing outstanding habitat for both resident and migratory bats. Breeding birds, such as woodpeckers, nuthatches, Black-capped Chickadee (*Poecile atricapillus*), and Tree Swallow (*Tachycineta bicolor*), will also benefit from snags and dead or decaying trees for nesting and foraging habitat.

12. Plant native shrubs, small trees, vines, and other native understory species in riparian corridors

Intensive grazing by livestock and clearing of land for row crops has led to severe losses of native plant diversity in the understory of forests in the East Shore watershed, even in places where forests occur today. Some species have been locally extirpated, so the only way to re-establish populations is to systematically transplant individuals of these species. Fortunately, sources of native shrubs, wildflowers, and grasses are widely available today. Desirable native shrub and understory tree species in the riparian zone of Wequiock Creek, Mahon Creek, and smaller tributaries may include black willow (*Salix nigra*), river birch (*Betula nigra*), speckled alder (*Alnus incana*), wahoo (*Euonymus atropurpureus*), buttonbush (*Cephalanthus occidentalis*), elderberry (*Sambucus canadensis*), spicebush (*Lindera benzoin*), serviceberries (*Amelanchier* spp.), hawthorn (*Crataegus* spp.), silky dogwood (*Cornus amomum*), red-osier dogwood (*Cornus sericea*), American hornbeam (*Carpinus caroliniana*), American bladdernut (*Staphylea trifolia*), steeplebush (*Spirea tomentosa*), nannyberry (*Viburnum lentago*), cherries (*Prunus* spp.) and ninebark (*Physocarpus opulifolius*). Species appropriate for a given site will depend on canopy openness, soil conditions, flood regime, and other local factors. Prickly ash (*Zanthoxylum americanum*) is an aggressive native understory shrub that is already present in the floodplain of Wequiock Creek; no planting or management is needed to promote this species, but it should be accepted as a valuable component of the understory flora due to its fruits, which are eaten by birds and mammals, and its cultural significance as a medicinal plant. Other native shrub species like American hazelnut (*Corylus americana*) and some of the species listed above can be planted along drier slopes to provide abundant food resources for wildlife and native insects.

Curtis (1959) noted that true shrubs play a relatively insignificant role in the understory vegetation of southern lowland forests in Wisconsin. On the other hand, vines or lianas are common, including wild grape (*Vitis riparia*), Virginia creeper (*Parthenocissus quinquefolia*), virgin's bower (*Clematis virginiana*), American bittersweet (*Celastrus scandens*), and others. Planting these species in forested floodplains will add to the diversity and quality of wildlife habitat in the riparian corridor.

13. Maintain closed canopy in forested riparian corridors

Removal of trees from existing forest riparian corridors provides opportunities for the establishment and spread of invasive species, including *Phragmites australis*. Numerous examples of heavily invaded openings are present in the current riparian zones of virtually every East Shore watershed (Figure C32). Planting of native grasses and forbs can help mitigate invasive species colonization, but this approach typically requires significant expense and maintenance. A better alternative is to simply retain the forested cover and, if necessary, eventually replace undesirable species with more favorable trees or shrubs.

Figure C32. Upper Mahon Creek near Spartan Road. Open areas on left side of creek are heavily invaded by the non-native common reed (*Phragmites australis*).

14. In highly disturbed or urbanized drainages, install and maintain engineered structures (e.g., detention/retention ponds, rock drainage fields, etc.) to dissipate flow and reduce sedimentation after rain events

Many studies have demonstrated that dispersed, low impact drainage schemes (Walsh et al. 2007) can help reduce flash flooding and nutrient/sediment loading in urban and agricultural watersheds. State ordinances already impose requirements for construction of engineered structures in urban areas, but additional "watershed engineering" structures (e.g., Figure C33) can have significant positive impacts on many other drainages flowing into Wequiock Creek, Mahon Creek, and several unnamed watersheds along the east shore of Green Bay.

Figure C33. Rock drainage field designed to dissipate high energy water flow from culvert along Mahon Creek.

15. Protect archeologically significant sites and work with First Nations partners to preserve the cultural heritage of lands within the East Shore Lower Green Bay watersheds

Historical evidence shows that First Nations people were well established along the east shore of lower Green Bay long before Europeans arrived in the 1600s. Numerous culturally significant sites exist in the area, and undoubtedly many others are present but unidentified. Ecological restoration activities should be conducted in concert with regional tribal representatives and officials from the Wisconsin State Archeology and Maritime Preservation Program. Wherever appropriate, cultural preservation and education should be incorporated into plans for managing riparian corridors and other public lands along Mahon Creek, Wequiock Creek, and other areas of the East Shore watershed.

16. Remove human-created barriers to instream or movements by fish and other aquatic or amphibious organisms like native macroinvertebrates, crayfish, mollusks, amphibians, and turtles.

Fishes and other aquatic organisms often move among stream segments and back and forth between connected features like wetlands and the bay of Green Bay. Unnatural obstructions that impede these movements can have significant negative impacts on the biodiversity and ecological integrity of the East Shore watershed. Dams, clogged culverts, trails (Figure C34), damaged rip-rap, and other human-created barriers should be removed to facilitate migration and recolonization dynamics of these species.

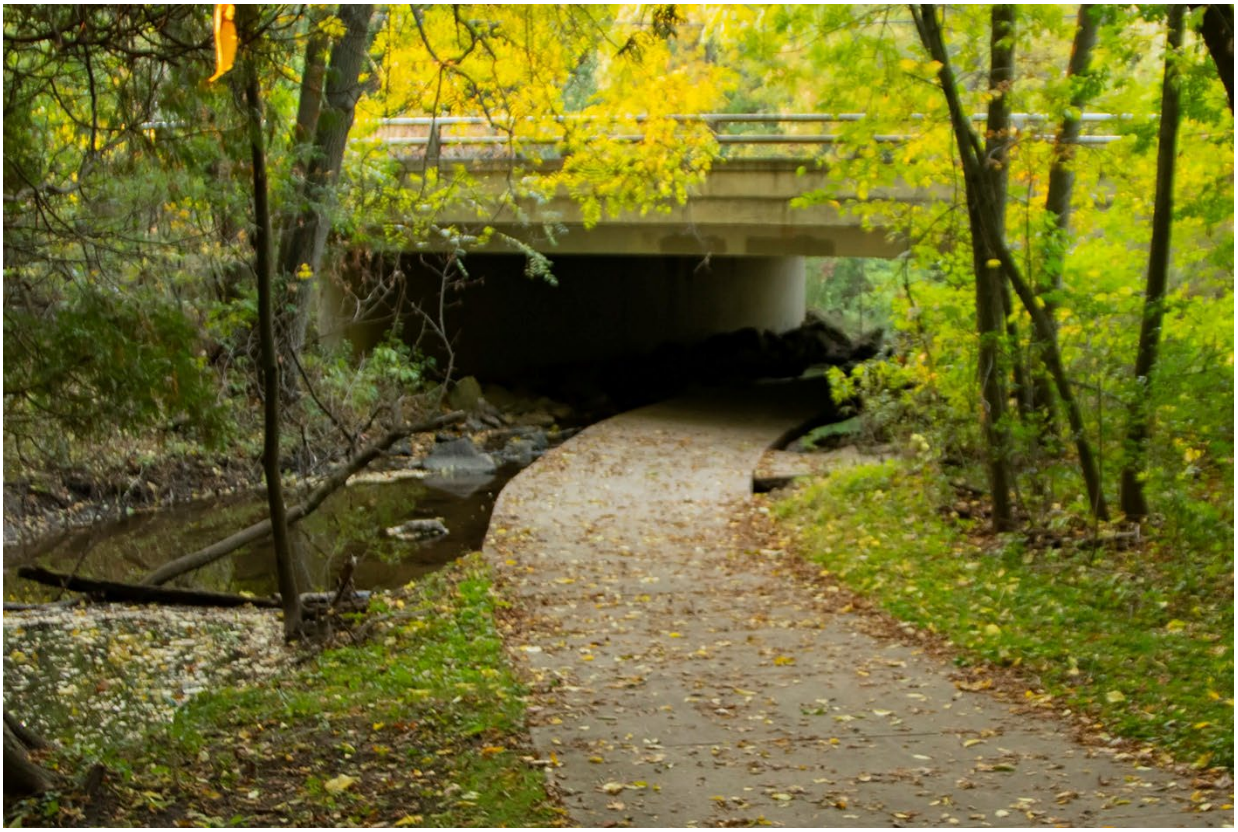

Figure C34. Concrete trail across important section of lower Mahon Creek in the University of Wisconsin-Green Bay's Cofrin Memorial Arboretum. Reconstruction of this trail may improve passage of fish from Green Bay to upstream habitats for spawning, foraging, and development of juveniles.

17. Control populations of white-tailed deer and (when necessary) other overabundant native animal species

Absence of large native predators like gray wolf and mountain lion has contributed to the well-documented overabundance of white-tailed deer in the western Great Lakes region and elsewhere (Côté et al. 2004). Overbrowsing of forest understory plants and tree seedlings is a negative consequence of deer overabundance. Population management of deer populations therefore is highly desirable to sustain a healthy understory plant community. Deer hunting in forested riparian corridors should be permitted to reduce local deer populations, which are also subsidized by crop residues and other ecological factors in today's highly altered landscape. Hunting policies must be designed to encourage culling of does, not just trophy males. Other abundant native species that might require population control include raccoon and Wild Turkey (*Meleagris gallopavo*), although native predators like coyote and red fox are present in the watersheds.

18. Strategically design trails and stream access points in riparian corridors to minimize the negative impacts of recreation

As residential development increases in the East Shore watershed, access to natural areas in the riparian corridors will be in great demand. Well-designed trails and access points will help prevent some of the problems associated with intensive recreational use of the natural areas, including soil compaction, accidental introduction of invasive species and wildlife diseases, erosion, altered hydrology, littering, poaching, disturbance of sensitive animal or plant species, and other negative ecological impacts. Evidence from other trail systems (e.g., Wimpey and Marion 2011; Meadema et al. 2020; Salesa and Cerda 2020) provides guidance that should be incorporated into trail design and maintenance in Mahon Woods in the UW-Green Bay Cofrin Memorial Arboretum, the newly acquired Wequiock Creek Natural Area, and other accessible riparian habitats in the East Shore watershed.

5. Assessment and Monitoring

Long-term protection and adaptive management of habitats in the East Shore watershed will require effective biological monitoring. Two well-studied taxa are excellent "umbrella groups" for monitoring natural communities in these watersheds: birds and stream macroinvertebrates. Birds are an informative group because they are easily recognizable, detectable by audio as well as visual cues, and well-studied. They also are found across multiple habitats and can be surveyed using relatively inexpensive, standardized field methods. Bird observers in Wisconsin can be certified for free through the Birder Certification Online program (https://www.birdercertification.org), laying the foundation for a rigorous community science opportunity. Birds are known to be responsive to environmental change and thus have been used as biological indicators for assessing the ecological condition or "health" of an ecosystem (e.g., Howe et al. 2007, Gnass Giese et al. 2015).

In the Great Lakes region, two widely accepted and related field protocols are used for monitoring breeding birds in wetlands and terrestrial habitats, respectively. Wetlands dominated by open herbaceous vegetation (e.g., emergent marsh, sedge meadow) are surveyed using the Great Lakes Coastal Wetland Monitoring Program's breeding marsh bird protocol (Uzarski et al. 2017). Certified, trained experts conduct 10-minute, unlimited-distance point count surveys at multiple locations (at least 350 m apart), in which a single observer records all birds seen or heard regardless of distance from the sample point. During the first five minutes of the count, an observer passively records all birds calling or singing. During the second five minutes, a broadcast of bird calls from secretive marsh-nesting species (e.g., rails) is played to elicit vocalizations. All species, number of individuals, and the minute and distance an individual is first detected are recorded. For ten focal species (e.g., rails, bitterns), observers also record every minute during which individuals are heard from the point. Point count locations are visited twice in the summer (last week of May through mid-July), with one survey conducted in the early morning and a second survey conducted either in the early morning or early evening with visits separated by at least 15 days. Surveys are to be conducted during relatively good weather conditions with minimal wind and precipitation. Wetland bird surveys using this protocol have been conducted in the Wequiock Creek estuary at Point au Sable for more than a decade.

A standard bird sampling protocol developed by Knutson et al. (2008) will be used to survey birds in upland and forested habitats, including riparian forest, grasslands, and oak savanna. We already have begun to monitor point count locations located at least 250 m apart in the Wequiock Creek and Mahon Creek riparian corridors. The survey method is simple. Trained observers conduct a single 10-minute, unlimited-distance point count by recording all birds seen or heard regardless of distance from the survey point. All species, number of individuals, and the minute and distance an individual is first detected are recorded. Each point count location typically is visited one time during the main avian breeding season, as early as the last week of May through early July. We also will conduct surveys during other periods to document migratory birds, which we know are numerous and diverse in the lower Mahon and Wequiock riparian forests. As with the open wetland surveys, these counts are conducted only during relatively good weather conditions with minimal wind and precipitation.

Results from both open wetland and forest/upland bird point counts provide data for application of a probability-based *Index of Ecological Condition* (IEC) described by Howe et al. (2007) and Gnass Giese et al. (2015). This metric, ranging from 0 (poorest condition) to 10 (best condition) draws from independent surveys of birds in the western Great Lakes region showing the degree of sensitivity of different species to disturbance. Only selected (sensitive) species are used for the calculations. Because locally breeding birds must integrate many environmental factors simultaneously over extended periods, an IEC based on multiple sensitive species provides an excellent indicator of habitat conditions.

Multispecies indicators using aquatic macroinvertebrates have a long history of success in describing the ecological condition of streams (Karr and Chu 1998, King et al. 2005, Friberg et al. 2010, and many others). Macroinvertebrates play an important role in stream ecology, and species exhibit different tolerances to sedimentation, nutrient pollution, storm surges, drought, and other environmental stressors (Wallace and Webster 1996). Hilsenhoff (1982), Lillie and Schlesser (1994) and others have described a variety of metrics for evaluating macroinvertebrate communities in Wisconsin streams. More recently, WDNR and University of Wisconsin Extension scientists have developed a simple Citizen Monitoring Biotic Index derived from a more detailed but widely used method developed by Hilsenhoff (1987). Field sampling consists of “kick-net” samples from different microhabitats within streams. A similar method is used by the Lower Fox River Watershed Monitoring Program. We will use this method at permanent localities established during late 2020. Baseline surveys will be conducted in spring 2021 and thereafter, enabling biologists to compare stream quality before and after watershed improvement measures.

A third avenue of habitat monitoring will assess understory shrubs and non-woody plants in riparian corridors of Wequiock Creek, Mahon Creek, and perhaps other smaller watersheds. The field sampling protocol will be developed during 2020-2022 as part of a UW-Green Bay restoration project funded by a grant from the Fox River Natural Resource Trustee Council’s Natural Resources Damage Assessment (NRDA) program. The resulting environmental indicator will draw from the database of expert-designated “coefficients of conservatism” (Wilhelm and Ladd 1988, Bernthal 2003) for Wisconsin plant species. Application of this methodology may use a simple average or weighted average of the coefficients of conservatism for all plant species recorded in field samples. More sophisticated metrics using the IEC approach to coefficients of conservatism for individuals in standard field samples also will be explored.

These three monitoring efforts (birds, stream macroinvertebrates, and understory vascular plants) will provide a strong signal of habitat quality that can be tracked over space and time. Successful ecological restoration measures should lead to an increase in one or all three of these multispecies metrics. Additional monitoring of high priority species like bats, bumblebees, and perhaps selected stream fishes will be conducted at sites where management activities occur. In these cases, quantitative metrics can be simply presence/absence or an index of relative abundance for the targeted species.

6. Conclusions

Watersheds flowing into the east shore of lower Green Bay drain relatively small catchments and deliver only modest volumes of water compared with other watersheds in the Green Bay basin. Nevertheless, the two largest streams, Wequiock Creek and Mahon Creek, are significant because they are imbedded in a rapidly expanding suburban landscape, and the lower portions contain some of northeastern Wisconsin's best natural areas. This document identifies key opportunities and challenges for improving the quality of fish and wildlife habitats in these landscapes. In some cases, meaningful ecological restoration can be achieved by simply managing invasive species in protected conservation areas. In other cases, restoration of quality habitats will require widening of vegetated buffers on private lands or planting of native vegetation where it has previously been displaced by agriculture or urbanization. In extreme cases near the headwaters of both Mahon and Wequiock Creek (and perhaps in smaller, unnamed watersheds closer to the Green Bay coastal zone), restoration of stream morphology through "watercourse engineering" will be necessary to restore fully functional instream and riparian habitats.

Although road construction, residential development, and agricultural activities have permanently altered significant parts of the East Shore watershed, outstanding opportunities still exist for improving fish and wildlife habitats in this area. Hoff (2020) mapped existing conservation lands and recreational areas (Figure C33), revealing large areas of habitat across the region. Recent history has shown that partnerships involving private landowners, government agencies (at all levels), university scientists and students, non-profit conservation organizations, private companies, and highly motivated community members are particularly effective in implementing ambitious habitat improvement projects. Hoff (2020) further emphasizes the important role of education and landowner assistance programs in mobilizing local support for habitat improvement projects. The benefits of investments in these actions is great. Habitat restoration measures along Mahon Creek, Wequiock Creek, and smaller East Shore watersheds lead to new recreational opportunities, increased property values, and improved quality of life for people living in the watersheds. Our goal here is to help guide future projects that achieve all these benefits. In light of increased residential development in the Town of Scott and the expected impact of climate change on the local environment (Wang et al. 2017), protection and restoration of quality wildlife habitats in the East Shore watersheds is more important than ever.

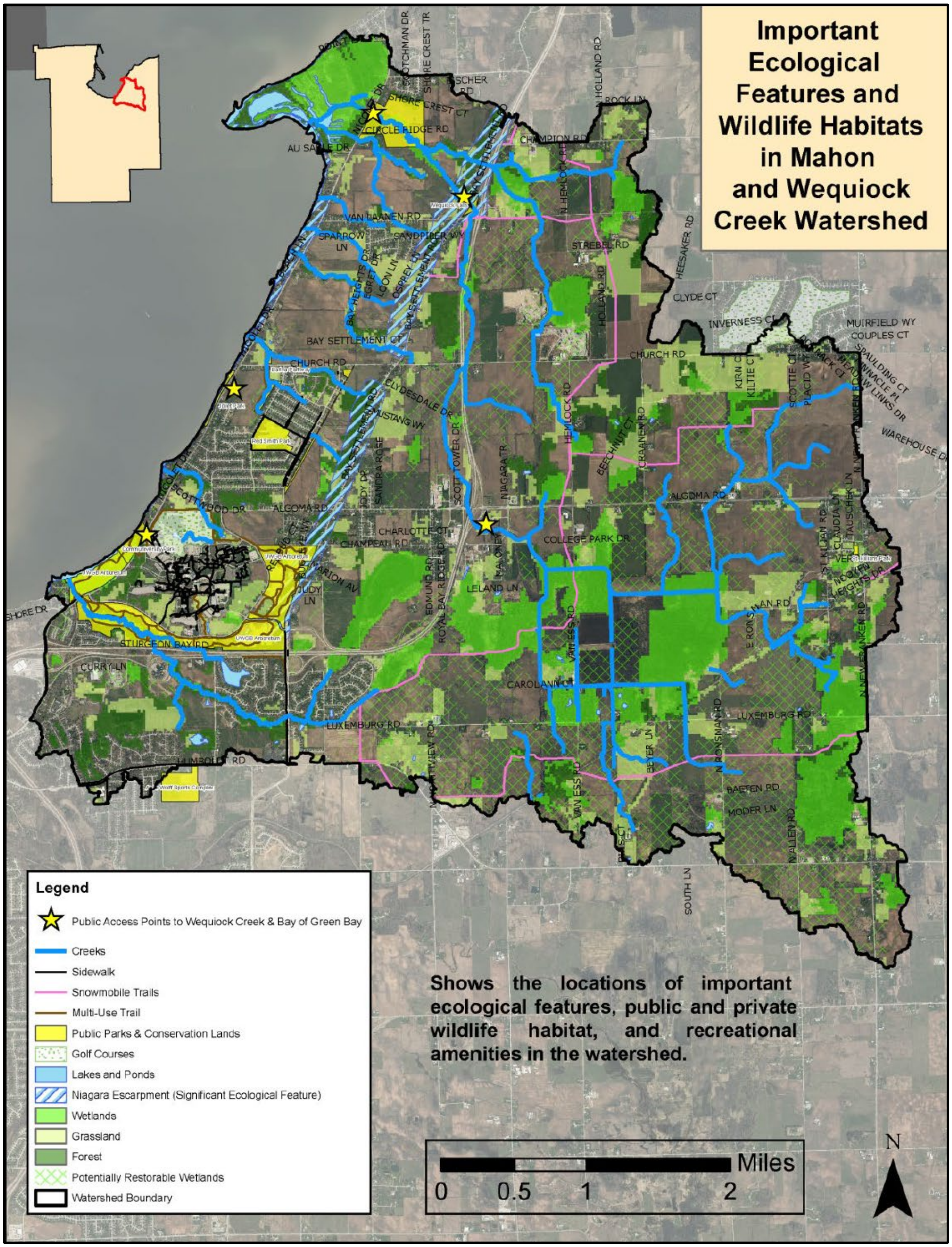

Figure C35. Public access, recreation, and conservation lands within the East Shore watershed. Map was developed by Hoff (2020).

7. Acknowledgements

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Appendix D. Load Allocation for East Shore Watershed.

The published Lower Fox River and Lower Green Bay TMDL (WDNR 2012) did not separate East Shore and West Shore watersheds to create separate load allocations; rather, the load allocations were combined. Therefore, two separation methods were evaluated to determine which was the most appropriate to use for the East Shore watershed load allocation. The following TSS and TP load allocation spreadsheets were created by Cadmus for developing the TMDL, and these spreadsheets were utilized to assist in this task.

“LFR TMDL TSS (final EPA approval 03-09-12).xlsx” and “LFR TMDL TP (final EPA approval 03-09-12).xlsx”

Briefly, the differences between the two separation methods can be explained by how the required allocations and reductions are derived: (A) uses the allocation spreadsheets developed by Laura Blake of Cadmus which separates out the source loads by sub-watershed (LFS7-1 to 3 in East Shore, and LFS8-1 in West shore) along with the required total allocation from each sub-watershed to derive agricultural allocations and associated reductions of 723 tons of TSS and 5,548 lbs of TP from the East Shore watershed (after accounting for non-agricultural reductions from other sources); and (B) uses these same allocation spreadsheet values, except it utilizes the agricultural reductions that are listed in the published TMDL summary table for the combined East and West shore watersheds (633 tons of TSS and 5,261 lbs of TP, pages 86-87).

Method B was initially used in a Draft East Shore Plan; however, Method A was selected for the Final Plan after consulting with WDNR Kevin Kirsch (Water Resource Engineer – Bureau of Water Quality) in a July 30, 2021 video discussion. Method A is consistent with meeting water quality objectives, so this method was utilized to derive load allocations for the East Shore Watershed. It is expected that the TMDL will be amended to reflect this modification when other amendments are made within one to two years of approval of the East Shore watershed Plan.

A) With this method, the reductions required to meet water quality objectives (0.1 mg/L TP) are derived directly from the allocation spreadsheets created by Cadmus which separates out the sub-watershed units in the “Load Subwatershed-R” TAB (versus the numbers obtained from combining both East and West shore watersheds as in the Summary Table in the TMDL). If it is assumed that the required reductions for MS-4’s, construction sites, etc. are accounted for in the allocation, and these are then subtracted from the total allocation that Cadmus had in the “Allocation” Tab, then the reductions required from agriculture, as well as the total reductions from the East Shore watershed can be derived (combining LFS-7-1 to 7-3). The resulting required total reductions are 723 tons of TSS and 5,548 lbs of TP. Note that agricultural sources were separated into direct agricultural sources and stream bank sources because these sources had previously been combined in the TMDL SWAT model framework.

Note, that in the calculations shown in the TSS and TP Allocation spreadsheets, no reductions are required from the West shore sources (however, they are required from permitted sources).

B) This method is based directly on the data from the 2012 published TMDL. It reflects the load allocations and reductions that would be obtained if the mass reductions listed in the TMDL combined East and West shore watershed summary tables for agricultural sources (633 tons of TSS, and 5,261 lb of TP, pages 86-87), were applied in combination with the required reductions from the other sources in the East Shore watershed. With this method, no reductions are required in the West Shore watershed because it seemed to meet the water quality objective of 0.1 mg/L TP when the TMDL was published in 2012. However, the calculated allocations from agriculture and other sources does not appear to be sufficient to meet the water quality objectives for the East Shore sub-watersheds with this method.

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