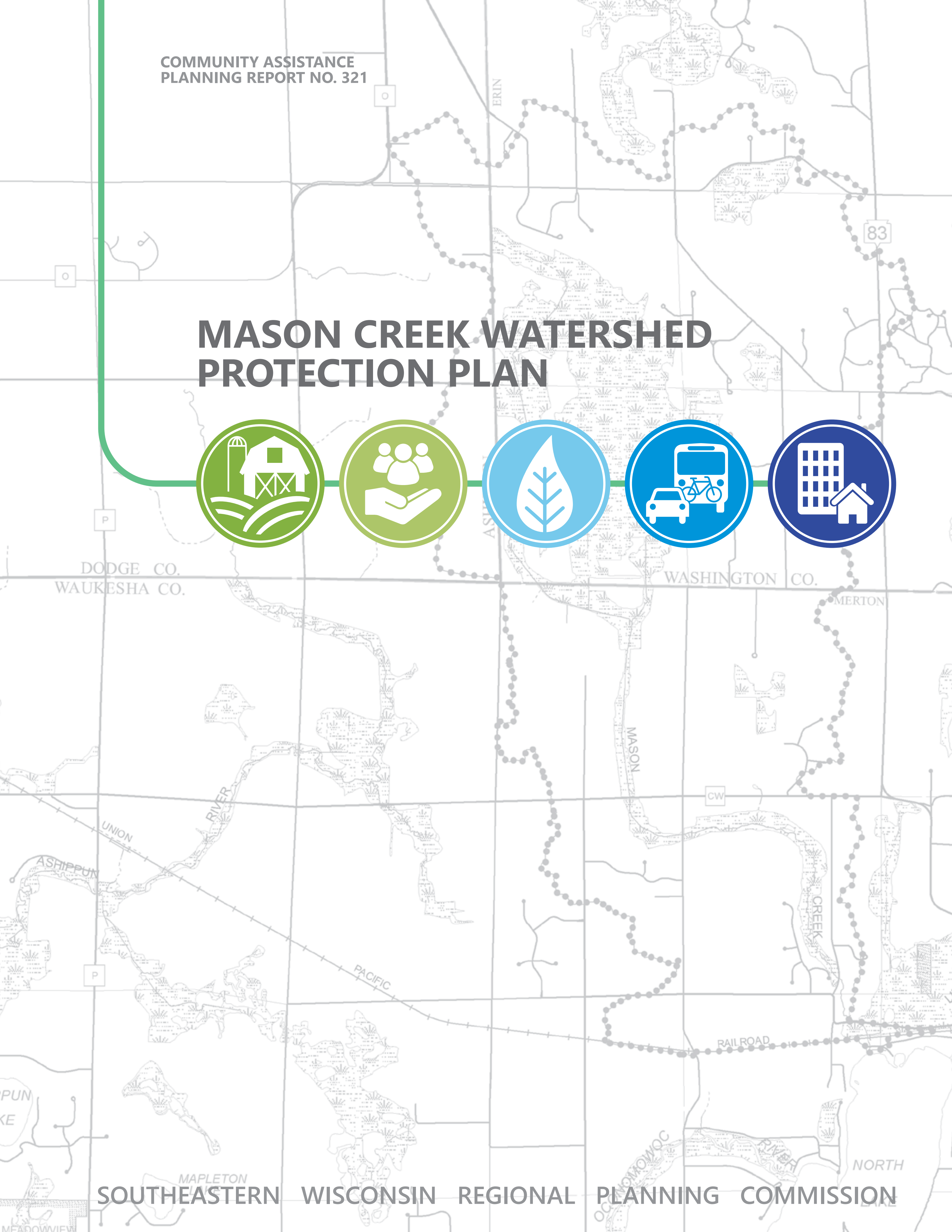
COMMUNITY ASSISTANCE
PLANNING REPORT NO. 321

MASON CREEK WATERSHED PROTECTION PLAN



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MASON CREEK WATERSHED PROTECTION PLAN

EXECUTIVE SUMMARY

The Mason Creek watershed, which is located within Washington, Waukesha, and Dodge Counties, is a 8.2-square mile subbasin within the upper part of the Oconomowoc River watershed. Mason Creek and the Oconomowoc and Little Oconomowoc Rivers discharge to North Lake. Several lakes (Friess, Loews, Keesus, Beaver, and Pine) also contribute flow to North Lake. Discharge from North Lake to the Oconomowoc River flows through Okauchee Lake, Oconomowoc Lake, Fowler Lake, and Lac La Belle before the Oconomowoc River flows into the Rock River. Historically, Native Americans were attracted to the area for its deep maple and basswood forests, wetlands, clear lakes, and wild game. Europeans began to settle in the area in the early to mid-1800s, primarily where the Towns of Erin and Merton are now located, due to the area's lakes and rivers and to experience a rural lifestyle. The settlers quickly began farming the high-quality soil, which resulted in the clearing of forests and natural areas and the building of homes along the shorelines of the lakes. Over time, farming and associated stream channelization have greatly impacted the water quality and wildlife in this ecosystem.


Adult Brook Trout

Mason Creek is home to a small population of self-sustaining brook trout.

This sensitive gamefish species is like a canary in the coal mine, so it is an indicator of good water quality & fish community conditions.

Target Annual Nonpoint Source Load Reduction Goals for Mason Creek:

92% or 5,355 (lbs)
Total Phosphorus and
93% or 883 (tons)
Total Suspended Solids

The Mason Creek watershed has been identified as an significant contributor of sediment and phosphorus to both the Oconomowoc and Rock Rivers. Mason Creek has been listed as an impaired waterway by the U.S. Environmental Protection Agency (USEPA) and Wisconsin Department of Natural Resources (WDNR). Excessive sediment and nutrient loading to North Lake have led to unnatural conditions such as increased algal blooms, deep water oxygen depletion, and water clarity issues. North Lake has been listed as impaired for high phosphorus loads.


Juvenile Brook Trout

Mason Creek serves as an important nursery area that supports the fishery within North Lake

Significant amounts of the nonpoint source loads of phosphorus and sediment to North Lake were found to be coming from the Mason Creek watershed. This fact, along with low dissolved oxygen, elevated water temperature, and degraded habitat, prompted local units of government and organizations to partner with State and Federal agencies to improve the water quality in the Lake and watershed. Although these efforts have had some success, the water quality in North Lake and Mason Creek continues to be a cause for concern. In response, the North Lake Management District and Tall Pines Conservancy worked with the Southeastern Wisconsin Regional Planning Commission to develop the Mason Creek Watershed Protection Plan in cooperation with the City of Oconomowoc, Towns of Erin and Merton, Washington and Waukesha Counties, the WDNR, USEPA, and the Natural Resources Conservation Service (NRCS).

MASON CREEK WATERSHED PROTECTION PLAN

Mason Creek high quality instream and floodplain buffer reference reach

Strategy for Improvement

In addition to establishing recommended pollutant load reductions, this plan focuses on reducing instream water temperature and protecting/preserving groundwater discharge to mitigate against a warming climate and/or reduced precipitation and to promote the "resistance" and "resilience" of the Mason Creek system. "Resistance" is the ability of a system to remain unchanged in the face of external forces. "Resilience" is the ability of a system to recover from disturbance. The overall strategy of this plan is to identify adaptation approaches that promote resistance and build ecological resilience to reduce the impacts of climate change and other stressors. More specifically, adaptation strategies can be applied in the Mason Creek watershed to increase landscape connectivity and corridors among habitats, restore degraded habitats, and remove other threats and stressors such as invasive species or upland erosion. The goals of the strategies are to enable Mason Creek to meet water quality criteria and maintain a sustainable, naturally reproducing brook trout population and the associated coldwater biotic assemblage for future generations.

The Mason Creek Watershed Protection Plan provides a framework for communities to work together on a common mission to protect and improve land and water resources and meet the state-permitted total maximum daily load (TMDL) and wasteload allocations. The protection plan is designed to be a practical guide for the improvement of water quality within the Mason Creek watershed. It addresses the management of land surfaces that drain directly and indirectly to streams—and consequently to downstream reaches including North Lake, the Oconomowoc River, the Rock River, and, ultimately, the Mississippi River.

Improving Mason Creek will improve North Lake and the Oconomowoc River too!

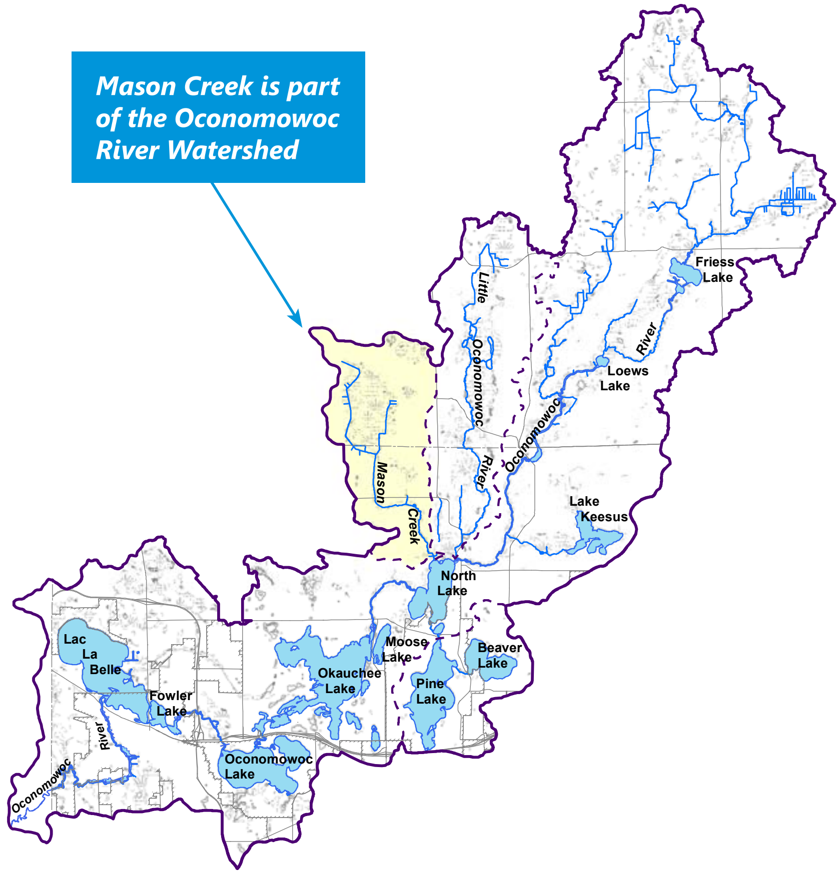
Example of flocculent sediment filling in streambed within the channelized reaches of Mason Creek. September, 2014

Challenges and Pollution Sources in the Mason Creek Watershed

Since at least the early 1900s, the Mason Creek system has been substantially altered through channelization, ditching, agricultural and urban development, road construction, placement of fill, construction of stormwater conveyance systems, and other actions related to these land use changes. These changes have physically, chemically, and hydrologically degraded aquatic habitat and impaired water quality and the associated aquatic community (particularly brook trout). As the dominant land use in the area, agriculture is responsible for nearly 82 percent of the phosphorus loading and 92 percent of the sediment loading to Mason Creek, so a major focus of the plan is to address load reductions from these areas. In addition, streambed load was found to be a significant source of sediment and impairment within Mason Creek, particularly in the channelized reaches and ditched reaches. Channelization is extensive throughout the watershed, and is a major determinant of limited instream habitat, degraded water quality, and impaired biological conditions. Therefore, a major focus of this plan is to address these problem areas through wetland restoration, improved floodplain connectivity, and/or re-meandering stream reaches.

Partnership and Participation is Key

One challenge is helping farm operators and landowners to recognize the value of Mason Creek and to become more aware of the water quality issues and the need for conservation practices and sustainable land use management. Although some of the landowners in the watershed have worked with, and are aware of, County and Federal conservation programs and best management practices (BMPs), significantly greater pollutant load reductions are still needed to meet water quality criteria. To accomplish this, implementation of BMPs needs to be expanded to address a greater proportion of the agricultural land area. The challenge in this watershed is threefold: to develop more opportunities for conservation projects, to install more BMPs, and to ensure the longevity and effectiveness of these projects and practices once they are implemented.



Mason Creek is part of the Oconomowoc River Watershed

Funding is Available

Fortunately, there is great potential for funding to implement agricultural and urban BMPs within the Mason Creek watershed, because the WDNR and USEPA have determined that this watershed-based plan is consistent with USEPA's 9-Key Elements. The agricultural and urban nonpoint source control projects within the scope of this plan meet USEPA-approved TMDL goals and are eligible for Federal and WDNR nonpoint-related activities and cost-share funding. This 9-Key Element approved plan is also consistent with the City of Oconomowoc Wastewater Utility's recently established "Adaptive Management Program (AMP)" within the Oconomowoc River watershed. Under the AMP, a total phosphorus concentration of 0.075 mg/L is to be achieved at the confluence of the Rock and Oconomowoc Rivers in the next 15 years. The Oconomowoc Watershed Protection Program (OWPP) was formerd to implement the AMP and achieve water quality criteria. This approach allows point and nonpoint sources (e.g., agricultural producers, wastewater and stormwater utilities, and developers) to work together to improve water quality in those waters not meeting phosphorus standards throughout the Oconomowoc River watershed. This partnership allows combinations of funding from the NRCS, the City of Oconomowoc, and other project partners to be used to offer incentives and matching funding for implementation actions. Hence, the Oconomowoc AMP offers a flexible and robust cost-share funding program to assist landowners with the installation of upgraded conservation practices in agricultural and urban landscapes within the Mason Creek watershed.

The challenge in this watershed is developing more opportunities for conservation projects, installing more best management practices (BMPs), and ensuring the longevity and effectiveness of practices once BMPS are installed.

Mason Creek (looking upstream, before entering North Lake) after a storm event. July, 2014

MASON CREEK WATERSHED PROTECTION PLAN

Key Management Objectives to Improve Mason Creek:

- **Reduce the loads of sediment and phosphorus from upland sources to improve water quality and enhance and restore stream form and function**
- **Reduce the volume and velocity of runoff from upland areas to streams, increase soil infiltration, and enhance groundwater recharge**
- **Maintain and expand wetland habitats and fish and wildlife habitats and populations**
- **Increase public awareness of water quality issues and participation in watershed conservation activities**

Watershed Protection Plan Elements

A 10-year implementation plan was developed to meet water quality goals for the watershed. The plan recommends best management practices, information and educational activities, restoration practices, and lists the estimated costs, potential funding sources, agencies responsible for implementation, and measures to gauge success.

Recommended Priority Management Practices

<u>Agricultural BMPs Applied to Cropland</u>

- No till
- Cover crops
- Nutrient management planning
- Grassed waterways/filter strips
- Harvestable buffers; wetland buffers; wetland restoration, including ditch plugs to stop sediments

<u>Urban BMPs</u>

- Stormwater runoff management
- Ditch checks/check dams along roadway ditches
- Green infrastructure/Low Impact Development

Instream Fish and Wildlife Habitat Recommendations

- Improve instream flows (i.e., floodwater detention, enhanced groundwater recharge)
- Protect existing high quality components (i.e., brook trout spawning areas)
- Restore degraded stream channels, wetlands, and riparian buffer areas
- Reconnect all portions of Mason Creek to North Lake by removing barriers to aquatic organism passage barriers and restoring latent ecological value to North Lake

Education and Information Recommendations

- Provide educational workshops and tours, demonstration projects, and share information on emerging crop BMPs
- Engage landowners in implementing conservation practices and provide information, technical tools, and financial support
- Promote engagement by the farming community in decision making and equip farmers with monitoring tools and methods
- Target action-oriented messages about water quality and conservation practices to key groups
- Produce and distribute newsletters, exhibits, fact sheets, and/or web content to improve communication

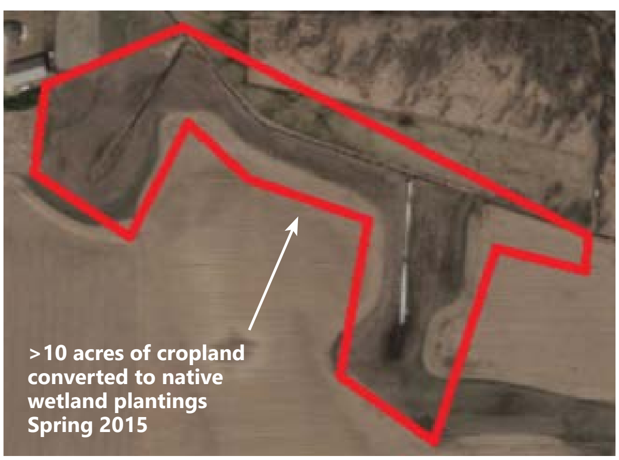
Conclusion: Mason Creek has Great Potential for Improvement

The Mason Creek watershed currently embodies significant aesthetic and ecological values and has the potential to be a more diverse and resilient aquatic and terrestrial ecosystem. The attributes that make Mason Creek and its watershed unique are the same attributes that attract residents, businesses, and supporting infrastructure to the watershed and that are necessary for a healthy local economy. Therefore, meeting the goals of the Mason Creek Watershed Protection Plan will lead to improved water quality and quantity for human needs and will help improve and preserve the hydrological and ecological integrity of the water resources. This will also lead to a healthier and more resilient local economy.

Meeting the goals for the Mason Creek watershed will be challenging. Watershed implementation is primarily a voluntary effort. The effort will need to be supported with targeted technical and financial assistance. It will require a commitment of the entire community in the Mason Creek, North Lake, and Oconomowoc River areas to improve the water quality and the condition of the watershed. The plan must be adaptable to address challenges, that will arise during implementation.

Demonstration Projects – Effectively Reduce Pollutant Loads and Improve Water Quality

(Funded in Partnership by the City of Oconomowoc Wastewater Utility
and the North Lake Management District)



Riparian buffer/filter strip BMPs are being installed to protect Mason Creek from excessive sediment and nutrient loads from cropland.

Streambank is being restored to prevent severe erosion within Mason Creek

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WATERSHED SETTING AND CHARACTERISTICS 1

Credit: SEWRPC Staff

1.1 WATERSHED SETTING

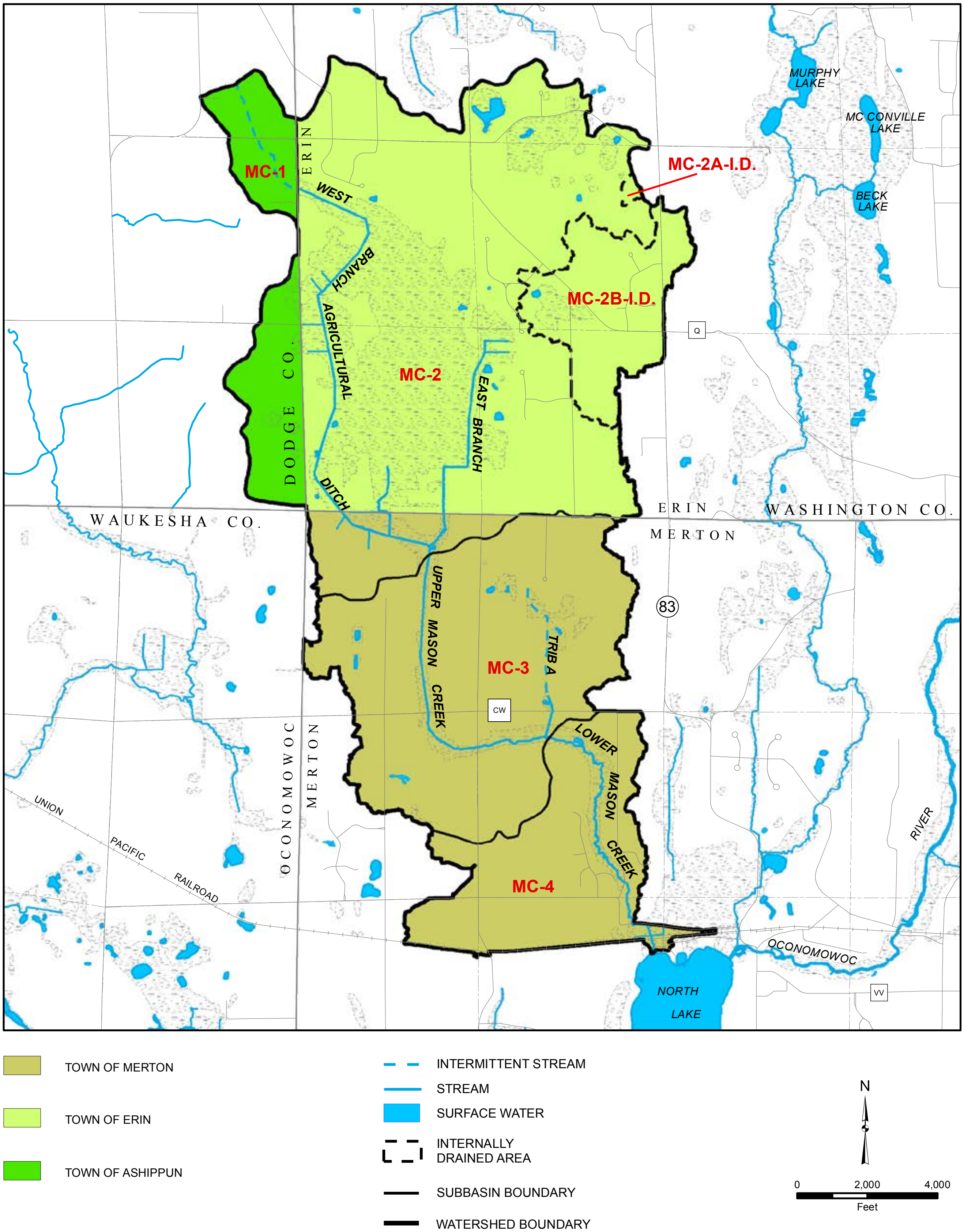
Mason Creek is an 8.2-square mile (5,275-acre) watershed situated within Washington, Waukesha, and Dodge Counties. Mason Creek discharges directly into North Lake, which is a 440-acre drainage lake, and then flows into the Oconomowoc River, which is a major subwatershed of the Rock River watershed. Mason Creek is about six miles long and has several small (perennial and intermittent) tributaries that flow into it. Due to its proximity and connection with North Lake, this watershed offers a variety of water-based recreational opportunities and has been a focus of the community surrounding the Lake. The watershed includes portions of the Towns of Ashippun, Erin, and Merton as shown on Map 1.1.

1.2 PURPOSE OF THE PLAN

The North Lake Management District received Wisconsin Department of Natural Resources (WDNR) funding through the Chapter NR 195 River Planning and Management Grant Program to complete this Protection Plan for the Mason Creek watershed. This planning effort was conducted cooperatively and involved the U.S. Environmental Protection Agency (USEPA), the Natural Resources Conservation Service (NRCS), WDNR, University of Wisconsin-Extension, Washington County Planning and Parks Department, Waukesha County Department of Parks and Land Use, City of Oconomowoc, the Towns of Erin and Merton, Tall Pines Conservancy, and the Southeastern Wisconsin Regional Planning Commission (SEWRPC).

This plan was also prepared in cooperation with representatives from the ad hoc Mason Creek Watershed Protection Plan Working Group (see Appendix A). The Working Group was comprised of self-nominated individuals representing a range of stakeholders with interests in the Mason Creek watershed who volunteered their time to meet and review portions of the plan. The Working Group represents a diversity of interests and perspectives both within and downstream of the watershed, including stream and lake residents, and County and local government staff as shown in Figure 1.1. From 2013 through 2016, participants in the Working Group either attended one or more of the several meetings or provided electronic mail correspondence to define issues, develop goals, and establish recommendations for this plan. It is important to note that the plan goals, which were based upon the feedback provided by the Working Group, form the foundation for generating and evaluating the alternative and recommended plan elements, and for establishing a sound framework within which to implement the recommendations.

Map 1.1
Civil Divisions Within the Mason Creek Watershed: 2015

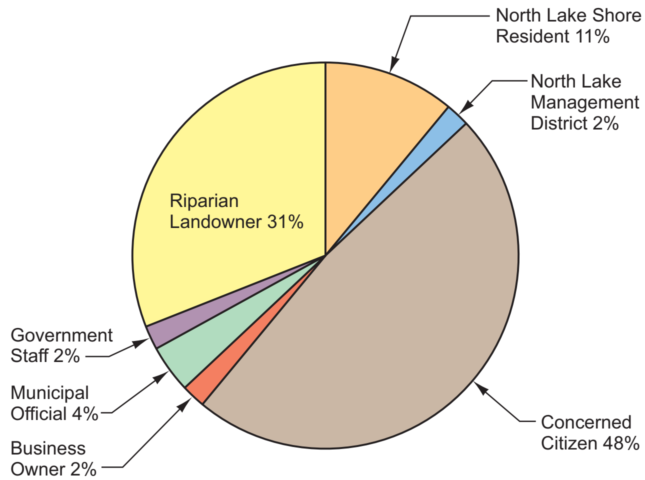


Source: SEWRPC.

The purpose of this plan is to provide a framework to enable communities in the area to work together with a common mission: *to protect and improve the land and water resources of the Mason Creek watershed*. This watershed protection plan focuses on what can be done to continue to protect the existing high-quality resources from human impacts and *prevent* future water pollution or resource degradation from occurring by implementing the following general goals:

- Minimize the further degradation of surface water and preserve, restore, and maintain the high quality of all waterbodies within the watershed.
- Identify opportunities to improve the quality of the land and water (including groundwater) resources within the watershed by reducing both nonpoint agricultural and urban runoff.
- Manage and develop lands in a manner that is consistent with the protection of living resources: avoid habitat fragmentation and encourage the preservation and enhancement of wetlands and wildlife corridors including providing and preserving connections with upland habitats and through sensitive landscaping practices.
- Promote active stewardship among residents, farmers, landowners, businesses, community associations, as well as governmental and non-governmental organizations.

Figure 1.1
Breakdown of Work Group Members Contributing to the Formulation of the Mason Creek Watershed Protection Plan: 2013 Through 2016



The composition of the work group demonstrates that the **greatest assets** to protect and improve Mason Creek **have been and continue to be the dedicated people** (individuals, organizations, and agency staff) **that live and/or work within the watershed**.

Source: SEWRPC.

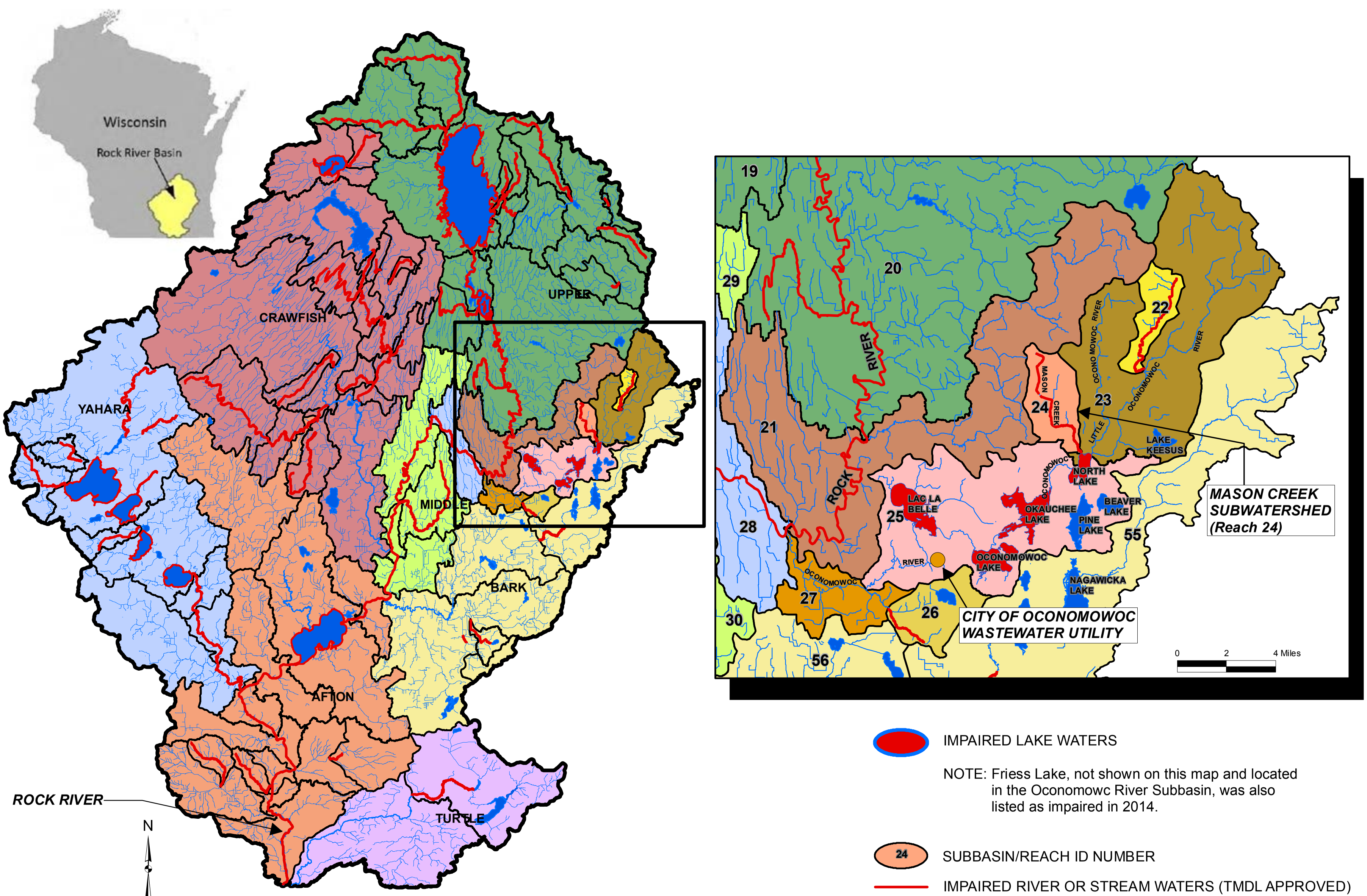
Excessive sediment and nutrient loading to North Lake has led to increased algal blooms, oxygen depletion, and water clarity issues, which have been documented since the 1970s as part of watershed planning efforts by the WDNR and SEWRPC staff. In the 1980s it was substantiated that a significant amount of the nonpoint source loads (i.e., phosphorus and sediment) to North Lake were coming from the inlets to North Lake, which included the Mason Creek subwatershed. This prompted the need for action by local units of government and organizations in partnership with State and Federal agencies to improve water quality in both North Lake and in the Mason Creek watershed. This planning effort to complete a watershed protection plan for Mason Creek was initiated as part of the ongoing efforts to identify and prioritize projects to improve water quality conditions in this basin.

More recently, excessive sediment and nutrient loading to the Rock River has led to increased algal blooms, oxygen depletion, water clarity issues, and degraded habitat. Algal blooms can be toxic to humans and costly to a local economy. Estimated annual economic losses due to eutrophication in the United States are as follows: recreation ($1 billion), waterfront property value ($0.3-2.8 million), recovery of threatened and endangered species ($44 million), and drinking water ($813 million).[1] Mason Creek was listed as an impaired waterway by the USEPA and WDNR in 2012 (see Map 1.2). In addition, North Lake was added to WDNR's year 2014 impaired waters list for excessive total phosphorus. Due to the impairments of the Rock River Basin, a TMDL (Total Maximum Daily Load) study for phosphorus and sediment was developed for the Rock River basin and its tributaries and was approved in 2011.[2] Under that study, the Mason Creek subwatershed

[1] *Dodds, W.K., W.W. Bouska, J.L. Eitzman, T.J. Pilger, K.L. Pitts, A.J. Riley, J.T. Schoesser, and D.J. Thornbrugh., Eutrophication of U. S. freshwaters: analysis of potential economic damages, Environmental Science and Technology 43: 12-19, 2009.*

[2] *USEPA and WDNR,* Total Maximum Daily Loads for Total Phosphorus and Total Suspended Solids in the Rock River Basin Columbia, Dane, Dodge, Fond du Lac, Green, Green Lake, Jefferson, Rock, Walworth, Washington, and Waukesha Counties, Wisconsin, *prepared by the CADMUS Group, July 2011.*

Map 1.2
Major Subbasins and Impaired Waters of the Rock River Watershed: 2015



Source: U.S. Environmental Protection Agency, Wisconson Department of Natural Resources, and SEWRPC.

was identified as a significant contributor of sediment and phosphorus to the Rock River. Hence, this plan is designed with a 10-year timeframe and is intended to address phosphorus and sediment load reductions consistent with the TMDL load and wasteload allocations established for Mason Creek and the Rock River. The Rock River TMDL requires that any tributaries to Mason Creek meet a median summer total phosphorus limit of 0.075 mg/l or less and a median summer total suspended solids concentration of 26 mg/l or less. According to the Rock River TMDL, achieving those instream concentrations will require substantial reductions in loading from municipal separate storm sewer systems (MS4s) and nonpoint agricultural sources. For the Mason Creek watershed, this will require average percent reductions from baseline loads of total phosphorus of 11 percent and 39 percent for MS4s and nonpoint sources, respectively. It will also require average percent reductions from baseline loads of suspended solids of 12 percent and 43 percent for MS4s and nonpoint sources, respectively.[3]

This watershed protection plan has been prepared to meet the USEPA nine minimum elements for a watershed based plan (see "USEPA Watershed Plan Requirements" section below). This protection plan is also designed to serve as a practical guide for the management of water quality within the Mason Creek watershed and for the management of the land surfaces that drain directly and indirectly to the stream, and downstream reaches including North Lake, Oconomowoc River, and, ultimately, the Rock River.

USEPA Watershed Plan Requirements

In 1987, Congress enacted the Section 319 of the Clean Water Act which established a national program to control nonpoint 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 USEPA has identified as critical for achieving improvements in water quality.[4] In addition, projects implemented using Federal funds provided under Section 319 of the Clean Water Act must directly implement a watershed-based plan that USEPA has determined to be consistent with the nine elements. Thus, a finding of consistency with the nine elements is a significant benefit to implementation of the plan in that it would make projects recommended under the plan eligible for Federal funding. The nine elements from the USEPA 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. Estimates of the load reductions expected from management measures.

3. Descriptions 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. Estimates 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. A reasonably expeditious schedule for implementing the nonpoint source management measures identified in this plan.

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

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[3] Ibid.

[4] *U.S. Environmental Protection Agency (USEPA),* Handbook for Developing Watershed Plans to Restore and Protect Our Waters*, USEPA 841-B-08-002, March 2008*.

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 eight.

1.3 PRIOR STUDIES, PROJECTS, AND EXISTING RESOURCE MANAGEMENT AND COMPREHENSIVE PLANS

Various studies have already been completed describing and analyzing conditions in the Mason Creek watershed and nearby areas, and including management and comprehensive plans and monitoring programs.

Priority Watershed Study

- ***Nonpoint Source Control Plan for the Oconomowoc River Priority Watershed Project***, WDNR, 1986

- ***Upper Rock River Basin Areawide Water Quality Management Plan***, WDNR, Wisconsin Water Quality Management Program, May 1989

- ***Upper Rock River Basin Water Quality Management Plan***, A Five-Year Plan to Protect and Enhance our Water Resources, WDNR, December 1995

- **The State of the Rock River Basin,** Your River Neighborhood – The Rock River Basin, WDNR, PUBL # WT-668-2002, April 2002

These plans identified the original goals for nutrient reduction and set the stage for implementation of management measures within the Rock River basin, which included North Lake and lands discharging to North Lake among the subwatersheds of the Oconomowoc River, Little Oconomowoc River, and Mason Creek. The highest priorities in the Rock River basin were identified as: surface water quality; groundwater aquifers; wetland, shoreland, and habitat protection; recreation, including hunting and fishing; rural development concerns; and storm water runoff.

North Lake Management Plans and Studies

- ***A Water Quality Management Plan for North Lake, Waukesha County***, Wisconsin, Community Assistance Planning Report No. 54, 1982, SEWRPC

- ***North Lake and Tributary Limnological Survey 2011-2012, prepared by*** Jerry Kaster, Aquatic Environmental Consulting, for the North Lake Management District , 2012

- ***A Water Resources Management Plan for the Village of Chenequa, Waukesha County, Wisconsin,*** Community Assistance Planning Report No. 315, 2014, SEWRPC

North Lake is the second of six major lakes in a chain connected by the Oconomowoc River. North Lake is a 440 acre lake located in Waukesha County. It has a maximum depth of 78.4 feet and over half of the Lake is more than 40 feet deep. During 1976-1977, a hydrologic budget was determined that 70 percent of the inflow came from the Oconomowoc River, which receives flow from Friess Lake, Flynn Creek, and the Little Oconomowoc River before entering North Lake. Mason Creek provides seven percent of the inflow, and the intermittent outlet from Cornell Lake provides five percent of the inflow. The remaining surface water inflow provides eight percent of the hydrologic budget to North Lake, and come from overland flow and precipitation. Groundwater accounts for 10 percent of the inflow to the lake and occurs primarily along the northern portion of the west shore, which demonstrates the importance of the Mason Creek subwatershed in protecting groundwater recharge to North Lake. The eastern shore is a groundwater flow transition zone, where flows into and out of the Lake alternate, and the south and southwest shores are areas where the groundwater is recharged from the lake. The residence time of water in the Lake is approximately 9.5 months during a year of normal precipitation, meaning that the Lake is flushed about 1.3 times per year.

North Lake has transitioned from a mesotrophic (moderately enriched) to eutrophic (highly enriched) condition over time that is consistent with decreased clarity, oxygen-depleted bottom waters during the summer, and excessive aquatic plant overgrowth.[5] Total phosphorus concentrations remain excessive and water clarity measurements are often 25 to 50 percent less than historic observations, and both conditions largely contribute to its impairment classification as described above. In addition, recent dissolved oxygen measurements taken in the lake indicate that total oxygen depletion occurs in the bottom waters during the period of summer (June-August) stratification. This condition was also recorded in the lake during the early 1900s,[6] and there appears to have been little change (i.e., no improvement) in the dissolved oxygen characteristics of North Lake over this more than 110-year period of record. This is likely also associated with the dramatic reduction in the abundance of the two-story Cisco (*Coregonus artedii* or Lake Herring) coldwater fishery in North Lake, which was observed in July 29, 2013, to be low (see "Fish Species Diversity" section in Chapter 2I of this report for more details).[7]

Concerns among lake residents also have been raised regarding the aesthetic degradation of the resource and deteriorating water quality conditions, particularly in the northern portions of North Lake, primarily related to sediment deposition from tributary streams. As previously mentioned above, North Lake was added to WDNR's year 2014 impaired waters list due to excessive total phosphorus loads. These concerns have led to a concerted effort to identify sources of sedimentation and work towards preventing or mitigating these sources with other local partners from discharging into the Lake.[8] These plans have identified that rural nonpoint source loads are the biggest sources of pollution to North Lake from the Oconomowoc River, Little Oconomowoc River, and Mason Creek subbasins. The Mason Creek subbasin has been and continues to be one of the highest priority watersheds identified (i.e., greatest potential on a per acre basis) to reduce rural nonpoint source loads for phosphorus and sediment to North Lake, which has prompted the development of this watershed protection plan by the North Lake Management District and its local partners.

Comprehensive and Land and Water Resource Management Plans

- ***Dodge County Year 2030 Comprehensive Plan Inventory and Trends Report, Prepared by Foth & Van Dyke and Assoc., Inc., Amended June 21, 2011;*** and ***Dodge County Land and Water Resource Management Plan (3rd Revision 2013-2022),*** **March 2012,** Dodge County Land Conservation Committee

- ***A Multi-Jurisdictional Comprehensive Plan for Washington County: 2035,*** Community Assistance Planning Report No. 287, April 2008, SEWRPC and Washington County Planning and Parks Department; and ***Washington County Land and Water Resource Management Plan (2nd Revision 2011-2020),*** **June 2010,** Washington County Land Conservation Committee

- ***A Comprehensive Development Plan for Waukesha County,*** Waukesha County Department of Parks and Land Use Land Resources Division, February 2009; and, ***Waukesha County Land and Water Resource Management Plan 2012 Update,*** Waukesha County Department of Parks and Land Use Land Resources Division

These plans serve a number of functions. Most importantly, they provide a basis for decision-making on land use-related matters by County and town officials and they guide the land and water quality programs, activities and priorities within Dodge, Waukesha, and Walworth Counties. In addition, the comprehensive plans serve to increase the awareness and understanding of County and town planning goals and objectives by landowners, developers, and other private interests. With the adopted comprehensive plans in place,

[5] *Wisconsin Department of Natural Resources, Citizen Lake Monitoring data, website accessed April 2016 at dnr.wi.gov/lakes/waterquality/Station.aspx?id=683137*

[6] *Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the Oconomowoc River Priority Watershed Project, *Publication WR-194-86, 1986.*

[7] *Wisconsin Department Natural Resources,* The Whitefishes Of Wisconsin's Inland Lakes: The 2011-2014 Wisconsin Department of Natural Resources Cisco and Lake Whitefish Survey, *Fisheries and Aquatic Research Section, February 2015.*

[8] *Rock River Reflections,* "The City of Oconomowoc Steps out of its Boundaries to Work in the Entire Watershed," *A publication of the Rock River Coalition in cooperation with the Rock River Stormwater Group, Volume 19, No. 1, Winter 2016.*

private sector interests and residents can proceed with greater assurance that proposals developed in accordance with these plans should receive required approvals. These Plans include current and projected land use conditions of both counties as well as natural resource base inventories to prioritize resource issues and concerns and identify opportunities to achieve land and water resource management goals.

- **Rock River Basin TMDL Study:** Total Maximum Daily Loads for Total Phosphorus and Total Suspended Solids in the Rock River Basin: Columbia, Dane, Dodge, Fond du Lac, Green, Green Lake, Jefferson, Rock, Walworth, Washington, and Waukesha Counties, Wisconsin

- **Oconomowoc Watershed Protection Program,** City Of Oconomowoc, Waukesha County, Wisconsin, prepared by Ruekert & Mielke, Inc., February 2016

The TMDL study for the Rock River Basin was prepared by the Cadmus Group for the USEPA and WDNR and was approved in 2011. This plan established TMDLs for the Rock River and certain tributaries and estimated current pollutant loadings and loading reductions needed to meet the TMDL for subwatersheds in the Rock River Basin (see "TMDL Requirements" section in Chapter 2 of this report for more details).

More recently the City of Oconomowoc is embarking on an innovative program called Adaptive Management to improve the water quality of the many lakes and rivers in the Oconomowoc River watershed. The City of Oconomowoc and its partners developed the Oconomowoc Watershed Protection Program (OWPP), which refined pollutant loads, load reduction goals, priority projects, and recommended Best Management Practices (BMPs) to achieve the load reductions throughout the entire basin.[9] This plan includes the Mason Creek subbasin area as a high priority area to achieve load reduction goals within a projected 15-year timeframe for implementation.

1.4 WATERSHED JURISDICTIONS, DEMOGRAPHICS, AND TRANSPORTATION NETWORK

Watershed Jurisdictions

The Mason Creek watershed lies almost entirely within Washington and Waukesha Counties (see Map 1.1, and Figure 1.2). The largest portion of the watershed is in the Town of Erin with 51 percent, followed by the Town of Merton with 41 percent. The remaining eight percent of the watershed lies within the Town of Ashippun in Dodge County.

Jurisdictional Roles and Responsibilities

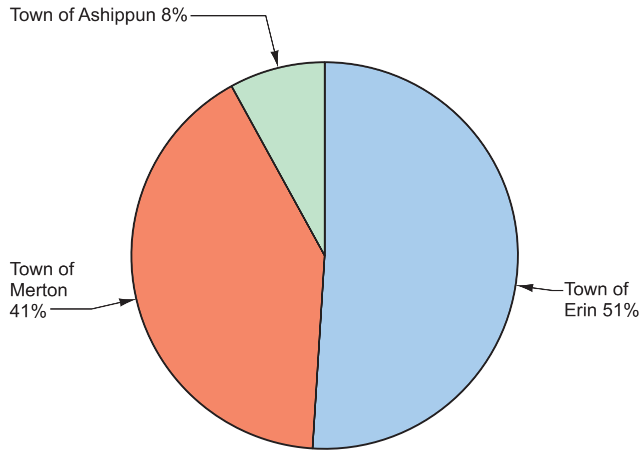
Natural resources in the United States are protected to some extent under Federal, state, and local law. The Clean Water Act regulates surface water quality at the national level. In Wisconsin, the WDNR has the authority to administer the provisions of the Clean Water Act. The US EPA, U.S. Army Corps of Engineers, Natural Resources Conservation Service, and the U.S. Fish and Wildlife Service work with the WDNR to protect natural areas, wetlands, and threatened and endangered species. The Federal Safe Drinking Water Act also protects surface and groundwater resources.

Counties and other local governments in the watershed area have ordinances regulating land development and protecting surface waters. The comprehensive zoning ordinance represents one of the most important and significant tools available to local units of government in directing the proper use of lands within their jurisdictions. Local zoning regulations include general, or comprehensive, zoning regulations and special-purpose regulations governing floodplain and shoreland areas. General zoning and special-purpose zoning regulations may be adopted as a single ordinance or as separate ordinances; they may or may not be contained in the same document. Any analysis of locally proposed land uses must take into consideration the provisions of both general and special-purpose zoning. The ordinances administered by the units of government within the watershed are summarized in Table 1.1. In addition, since State laws governing County and local zoning regulations are often revised, the SEWRPC staff provides periodic summaries of the most up-to-date changes that can be read and downloaded at the following website location: www.sewrpc.org/SEWRPCFiles/CommunityAssistance/Smartgrowth/fact_sheet_implementation_of_comp_plans.pdf.

[9] *See more details at website oconomowocwatershed.com/*

Other governmental entities with watershed jurisdictional or technical advisory roles include: the Wisconsin Department of Agriculture, Trade, and Consumer Protection; the University of Wisconsin-Extension; Dodge County Land Conservation Department, Washington County Planning and Parks Department, Waukesha County Department of Parks and Land Use; and SEWRPC.

Figure 1.2
Proportion of the Mason Creek Watershed Within each Municipality: 2014



Source: SEWRPC.

Floodland Zoning

Section 87.30 of the *Wisconsin Statutes* requires that counties, with respect to their unincorporated areas; cities; and villages adopt floodplain zoning to preserve the floodwater conveyance and storage capacity of floodplain areas and to prevent the location of new flood-damage-prone development in flood hazard areas. The minimum standards that such ordinances must meet are set forth in Chapter NR 116, "Wisconsin's Floodplain Management Program," of the *Wisconsin Administrative Code*. The required regulations govern filling and development within a regulatory floodplain, which is defined as the area that has a 1 percent annual probability of being inundated. The one-percent-annual-probability (100-year recurrence interval) floodplains within the Mason Creek watershed are shown on Map 1.3. Under Chapter NR 116, local floodland zoning regulations must prohibit nearly all forms of development within the floodway, which is that portion of the floodplain required to convey the one-percent-annual-probability peak flood flow. Local regulations must also restrict filling and development within the flood fringe, which is that portion of the floodplain located outside the floodway that would be covered by floodwater during the one-percent-annual-probability flood. Allowing the filling and development of the flood fringe area, however, reduces the floodwater storage capacity of the natural floodplain, and may, thereby, increase downstream flood flows and stages. Map 1.3 shows that there are no mapped floodplains within Dodge County. The floodplains designated as "Zone A" is where the extent of the floodplain was based upon an approximate study that did not calculate specific flood stage elevations. The majority of these areas are associated with the middle reaches of Mason Creek between CTH CW and extends northward up to the Washington and Waukesha County line as shown on Map 1.3.

The Washington and Waukesha Counties ordinances related to floodplain zoning recognize existing uses and structures and regulate them in accordance with sound floodplain management practices while protecting the overall water quality of stream systems. These ordinances are intended to: 1) regulate and diminish the proliferation of nonconforming structures and uses in floodplain areas; 2) regulate reconstruction, remodeling, conversion and repair of such nonconforming structures—with the overall intent of lessening the public responsibilities attendant to the continued and expanded development of land and structures inherently incompatible with natural floodplains; and 3) lessen the potential danger to life, safety, health, and welfare of persons whose lands are subject to the hazards of floods. Floodplain zoning is in place for each of the towns in Washington and Waukesha Counties (see Table 1.1).

1.5 TRANSPORTATION

The major road within the Mason Creek watershed is State Trunk Highway (STH) 83, which runs from north-south along the eastern edge of the basin (see Map 1.1). CTH CW/Mapleton Road crosses Mason Creek and bisects the middle of watershed runs from an east-west direction. County Trunk Highway Q is located in the northeast portion of the watershed and runs from a northwest-southeast direction. There is only one railroad line, which is part of the Canadian Pacific Railroad System that passes through the southern portion of the watershed and just north of North Lake. There are no biking or hiking recreational trails within the watershed.

Table 1.1
Land Use Regulations Applicable Within the Mason Creek Watershed by Civil Division: 2015

Community	Type of Ordinance: General Zoning	Floodplain Zoning	Shoreland Zoning	Subdivision Control	Erosion Control and Stormwater Management
Dodge County	Adopted[a]	Adopted[b]	Adopted[b]	Adopted[b]	Adopted[b]
Town of Ashippun	Regulated under County ordinance	Regulated under County ordinance	Regulated under County ordinance	Adopted[c]	Adopted[d]
Washington County	--[e]	Adopted[e]	Adopted[e]	Adopted	Adopted
Town of Erin	Adopted	Regulated under County ordinance	Regulated under County ordinance	Adopted[f]	Regulated under County ordinance[g]
Waukesha County	--[h]	Adopted[i]	Adopted[i]	Applies in shoreland areas only[j]	Adopted[i]
Town of Merton	Adopted	Regulated under County ordinance	Regulated under County ordinance	Adopted	Regulated under County ordinance

[a] *The Dodge County Land Use Code includes general zoning regulations that apply to nine of the 24 towns in the County.*

[b] *The Dodge County Land Use Code includes floodplain, shoreland, subdivision, erosion control, and stormwater management regulations that apply to all unincorporated (town) areas of the County.*

[c] *Both the Dodge County and Town of Ashippun subdivision ordinances apply within the Town. In the event of conflicting regulations in the Town and County ordinances, the more restrictive regulation applies.*

[d] *The Town of Ashippun subdivision ordinance includes erosion control and stormwater management regulations. The Town is also regulated under the Dodge County Land Use Code, which includes erosion control and stormwater management regulations. In the event of conflicting regulations in the Town and County ordinances, the more restrictive regulation applies.*

[e] *In 1986, Washington County rescinded its general zoning ordinance. All towns in the County have adopted a town zoning ordinance. County floodplain and shoreland regulations continue to apply in unincorporated (town) areas.*

[f] *Both the Washington County and Town subdivision ordinances apply within the Town of Erin. In the event of conflicting regulations, the more restrictive regulation applies.*

[g] *All towns in Washington County were given the option of being regulated under the County Erosion Control and Stormwater Management Ordinance, adopting a Town ordinance based on a model ordinance developed by the County and contracting with the County for enforcing the ordinance, or adopting a Town ordinance based on a model ordinance developed by the County with the Town taking responsibility for enforcing the ordinance. The Town of Erin chose to be regulated under the County ordinance.*

[h] *The Waukesha County Zoning Ordinance applies only in the Towns of Genesee, Oconomowoc, Ottawa, and Vernon. However, because the County has a general zoning ordinance, all zoning amendments (map and text amendments) to other town zoning ordinances within the County are subject to review and approval by the County Board.*

[i] *The Waukesha County Shoreland and Floodland Protection Ordinance and Storm Water Management and Erosion Control Ordinance apply only in unincorporated areas (towns) in the County.*

[j] *The Waukesha County subdivision ordinance applies only within shoreland areas in unincorporated (town) areas of the county. The County also reviews subdivision plats outside shoreland areas as an objecting agency under Chapter 236 of the Wisconsin Statutes.*

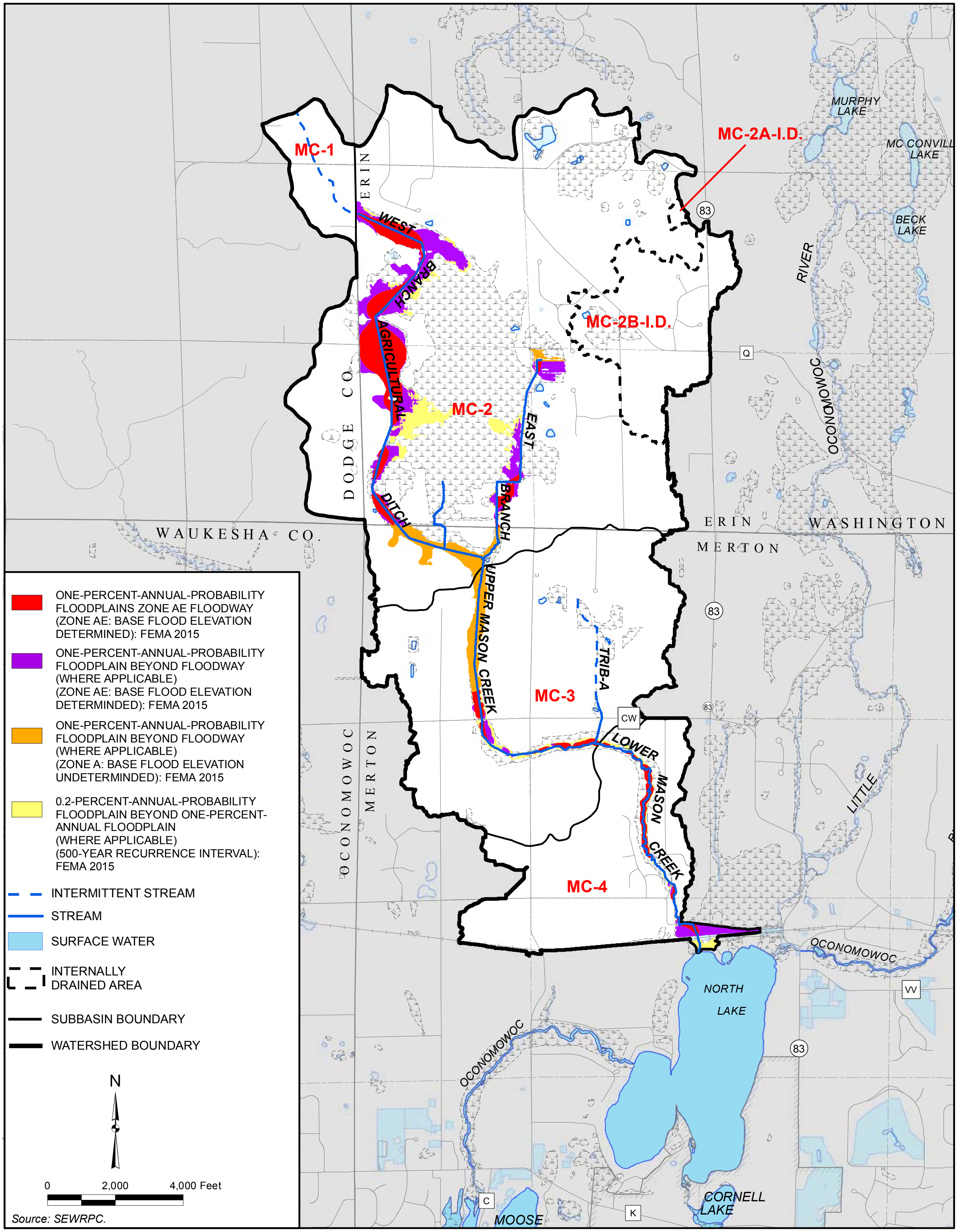
Source: SEWRPC

1.6 POPULATION AND HOUSEHOLDS

Data on population and numbers of households in the Mason Creek watershed from 1960 to 2010 is shown in Figure 1.3. Over that time period, the resident population grew from about 130 to 1,150 individuals and the number of households grew from about 40 to 420. The greatest increase in both population and the number of households occurred between 1990 and 2000, however, there has been a steady growth in both population and households since 2000 as shown in Figure 1.3. Based upon the adopted regional land use plan, the population and number of resident households in the Mason Creek watershed are projected to continue to increase through the year 2035, which is consistent with the planned land use as shown in Table 1.2.[10]

[10] *SEWRPC Planning Report No. 48,* A Regional Land Use Plan for Southeastern Wisconsin: 2035, *June 2006*.

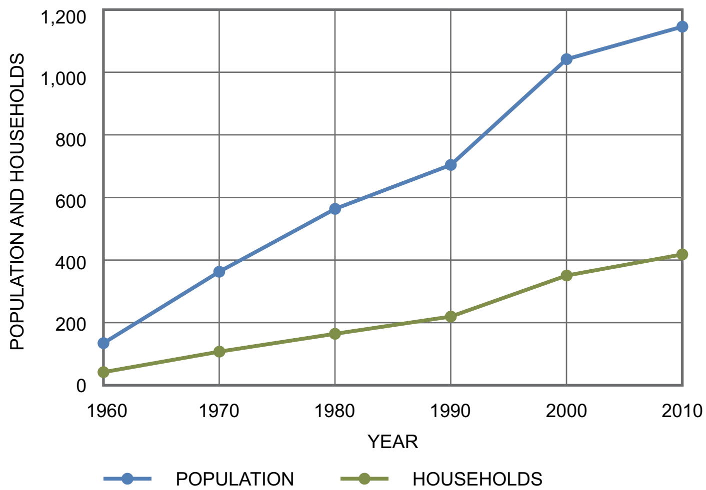
Map 1.3
Floodways and Floodplains Within the Mason Creek Watershed: 2015



1.7 HISTORICAL URBAN GROWTH

Historical urban growth within the Mason Creek watershed is summarized on Map 1.4. Much of the early growth (pre-1963) in the watershed was focused within the shoreline of North Lake. Between 1963 and 1970, growth continued to emanate from North Lake into the lower reaches of Mason Creek. In the 1980s and 1990s growth continued to expand within the lower reaches of Mason Creek as well as in the northeast portion of the watershed in the Town of Erin, Washington County. From 1995 to 2010 growth was focused in the north and northeast portion of the watershed. If population growth continues at the same rate of growth, urban runoff may have more of an impact in the watershed, and measures to mitigate that impact would need to be considered.

Figure 1.3
Population and Households Within the Mason Creek Watershed: 1960-2010



NOTE: Watershed area approximated by whole U.S. Public Land Survey quarter sections.

Source: U.S. Bureau of the Census and SEWRPC.

1.8 LAND USE

Existing year 2010 and planned year 2035 land use data for the watershed were developed by the SEWRPC staff.[11,12]

Changes in Land Use Over Time

Historically, before European settlement in the mid-1800s, the landscape within the Mason Creek watershed consisted largely of Maple - Basswood Forest, which could be characterized by continuous, often dense, canopies of deciduous trees and understories of shade adapted shrubs and herbs. Other natural habitats included large expanses of wetland and conifer swamp, with small pockets of oak forest along the northeast edge of the watershed, oak savanna (oak opening) transitional habitat between forest and grassland containing prairie grasses and forbs beneath widely spaced trees in the north, and lowland hardwood forest in the south. The extent of these natural habitat types in the Mason Creek watershed, derived from the original land survey records, is shown on Map 1.5.

Following European settlement, large portions of the landscape were converted to agricultural use. Natural vegetation was cleared to make way for crops. Efforts were made to open up wetlands to cultivation through ditching and draining of wet soils. Steeply sloped lands that were spared the plow were often opened up to grazing by livestock. This land conversion had significant consequences on water quality, water quantity, and wildlife habitat. For example, water quality has been compromised through increases in erosion leading to siltation of surface waters, particularly in North Lake. Natural waterways have been dredged and straightened to facilitate rapid runoff bypassing natural functions of adjacent wetlands including absorbing nutrients and storing flood waters.

Agricultural land use continues to dominant the landscape in the watershed, comprising about 58 percent of the watershed area under 2010 land use conditions (Map 1.6 and Table 1.2). Cultivated crops consist of about 80 percent and pasture/hay accounts for 20 percent of the agricultural land use. Urban land uses accounted for about 16 percent of the watershed area in 2010. The majority of the urban development is

[11] *Ibid.*

[12] *The existing land use data for this study area is based upon 12-inch pixel color year 2010 orthophotography and cadastral mapping. SEWRPC has over 60 land cover classifications and a spatial resolution scale of 1 inch equals 200 feet, which is equivalent to the National Map Accuracy Standards (NMAS) of 90 percent of the positions of well-defined points as determined from the orthophotographs to be within 6.6 feet of their correct position as determined by field measurement.*

Table 1.2
Land Use in the Mason Creek Watershed: 2010-2035[a]

Category[b]	2010 Acres	2010 Percent of Total	2035 Acres	2035 Percent of Total	Change: 2010-2035 Acres	Change: 2010-2035 Percent
Urban						
Residential	607	11.5	676	12.8	70	11.5
Commercial	5	0.1	6	0.1	1	17.4
Industrial	0	0.0	0	0.0	0	0.0
Governmental and Institutional	0	0.0	0	0.0	0	0.0
Transportation, Communication and Utilities	220	4.2	220	4.2	0	0.0
Recreational	6	0.1	6	0.1	0	0.0
Subtotal	837	15.9	908	17.2	71	8.4
Rural						
Agricultural and Open Lands	3,039	57.6	2,969	56.3	-71	-2.3
Wetlands	1,097	20.8	1,097	20.8	0	0.0
Woodlands	284	5.4	284	5.4	0	0.0
Water	18	0.3	18	0.3	0	0.0
Subtotal	4,438	84.1	4,367	82.8	-71	-1.6
Total	5,275	100.0	5,275	100.0	0	--

[a] *As approximated by whole U.S. Public Land Survey one-quarter sections.*

[b] *Off-street parking of more than 10 spaces is included with the associated land use.*

Source: SEWRPC

in the northeastern and southern portions of the watershed, but there are significant smaller pockets of residential lands between these areas. Wetlands comprise nearly 21 percent and forested land covers about 5 percent of the watershed, followed by surface water which covers 0.3 percent.

Under planned 2035 land use conditions (see Table 1.2 and Map 1.7), agricultural land is only expected to be reduced by about two percent, or 71 acres. Urban development, primarily residential land use, is planned to increase by about 8 percent, comprising about 17 percent of the watershed by 2035 as shown in Table 1.2. Map 1.7 graphically depicts the agricultural land, open land, and woodland that would be expected to be converted to urban uses under planned year 2035 conditions. Agricultural land will still be the largest land use overall in the watershed and will continue to be the dominant land use among each of the four main subbasins (MC-1, MC-2, MC-3, and MC-4) and the internally drained areas (MC-1B and MC-2B) as shown in Figure 1.4. Based upon this planned land use scenario urban runoff is not anticipated to have much more of an impact in the watershed in the future (see "Pollutant Loading Model" section in Chapter II of this report).

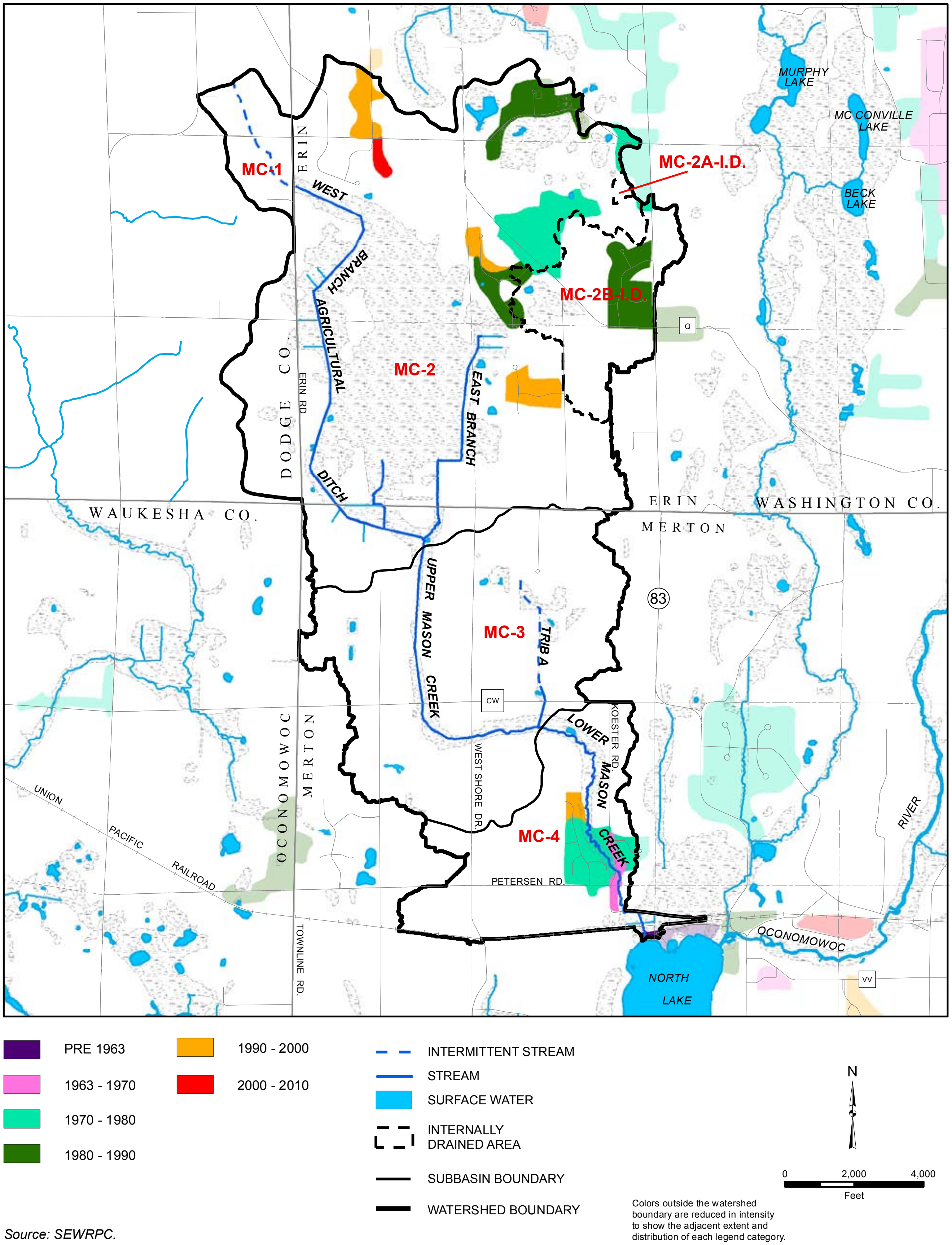
When urban development in a watershed increases, the amount of impervious surface area increases. Many researchers throughout the United States, including researchers at the WDNR, report that the amount of connected impervious surface is the best indicator of the level of urbanization in a watershed.[13] Directly connected impervious area is area that discharges directly to the stormwater drainage system, and, ultimately, to a stream without the potential for infiltration through discharge to pervious surfaces or facilities specifically designed to infiltrate runoff. Impervious surfaces:[14]

- Contribute to the hydrologic changes that degrade waterways
- Are a major component of the intensive land uses that generate pollution
- Prevent natural pollutant attenuation or removal in the soil by preventing infiltration

[13] *L. Wang, J. Lyons, P. Kanehl, and R. Bannerman, "Impacts of Urbanization on Stream Habitat and Fish across Multiple Spatial Scales,"* Environmental Management, *Vol. 28, 2001, pp. 255-266.*

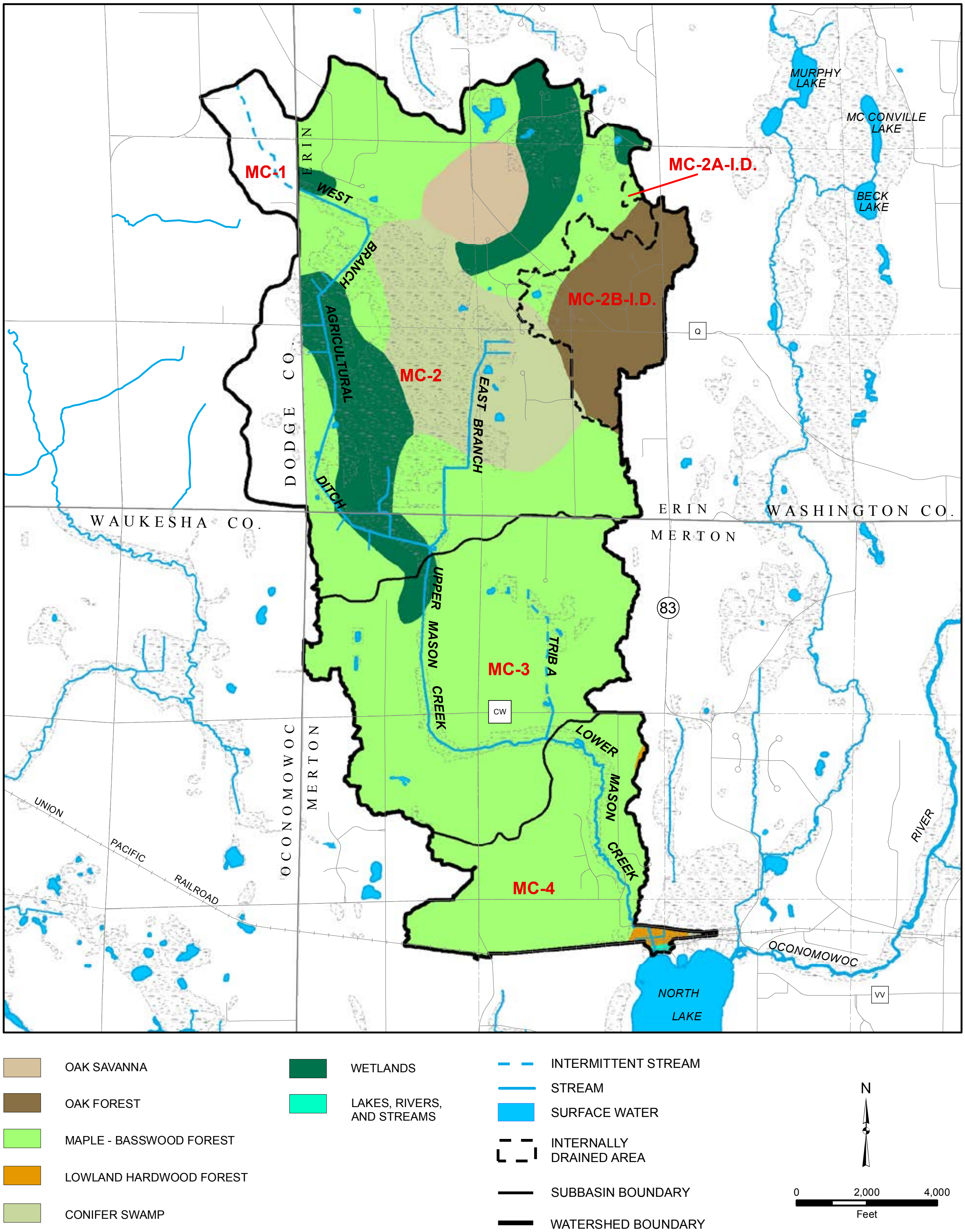
[14] *Dane County Regional Planning Commission,* Dane County Waterbody Classification Study-Phase I, *March 2007.*

Map 1.4
Historical Urban Growth Within the Mason Creek Watershed: 1850-2010



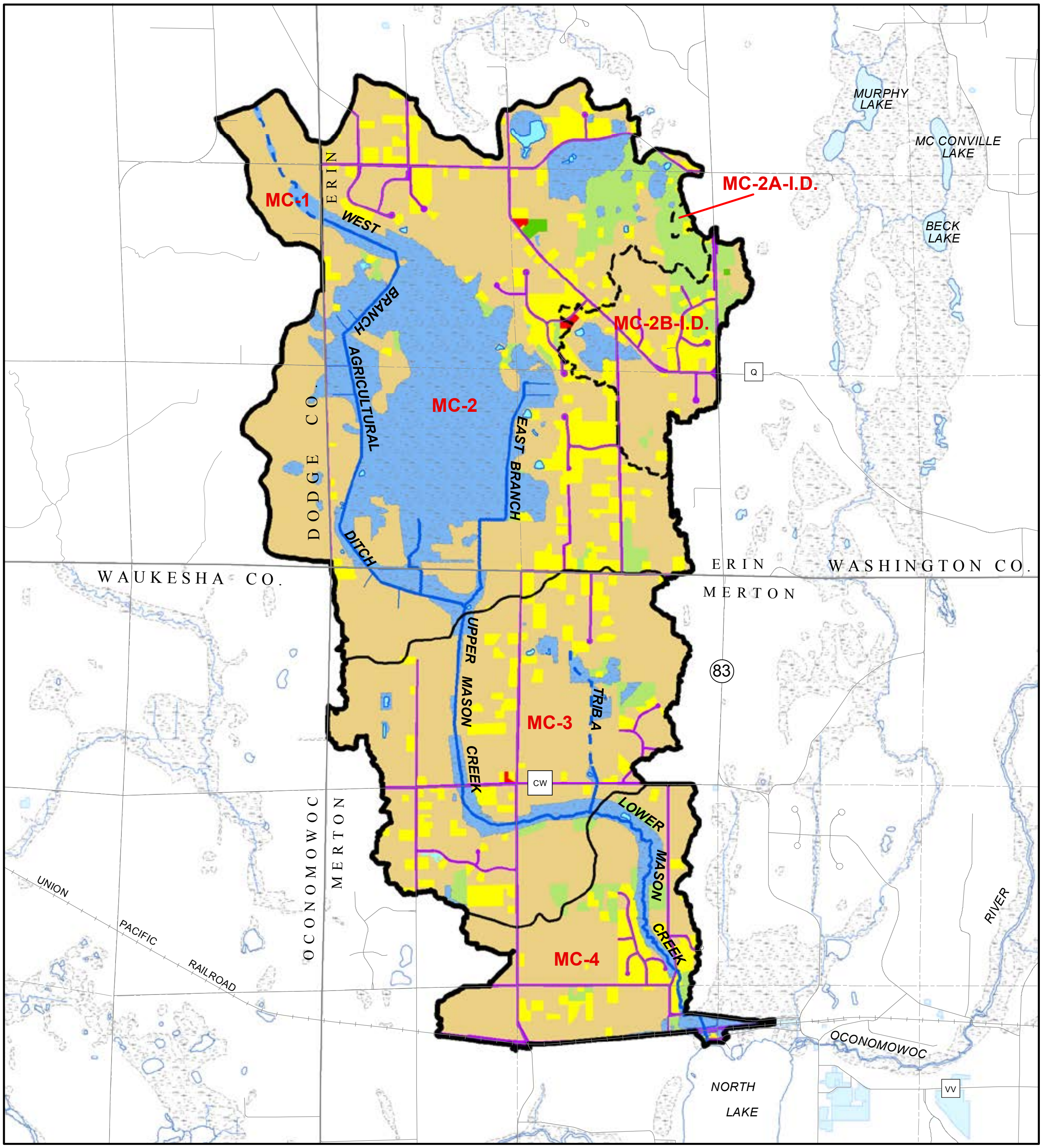
Source: SEWRPC.

Map 1.5
Presettlement Vegetation Within the Mason Creek Watershed: 1836



Source: SEWRPC.

Map 1.6
2010 Land Use Within the Mason Creek Watershed



SINGLE-FAMILY RESIDENTIAL

TRANSPORTATION, COMMUNICATIONS, AND UTILITIES

GOVERNMENT AND INSTITUTIONAL

RECREATION

WETLANDS

WOODLANDS

AGRICULTURAL, UNUSED, AND OTHER OPEN LANDS

INTERMITTENT STREAM

STREAM

SURFACE WATER

INTERNALLY DRAINED AREA

SUBBASIN BOUNDARY

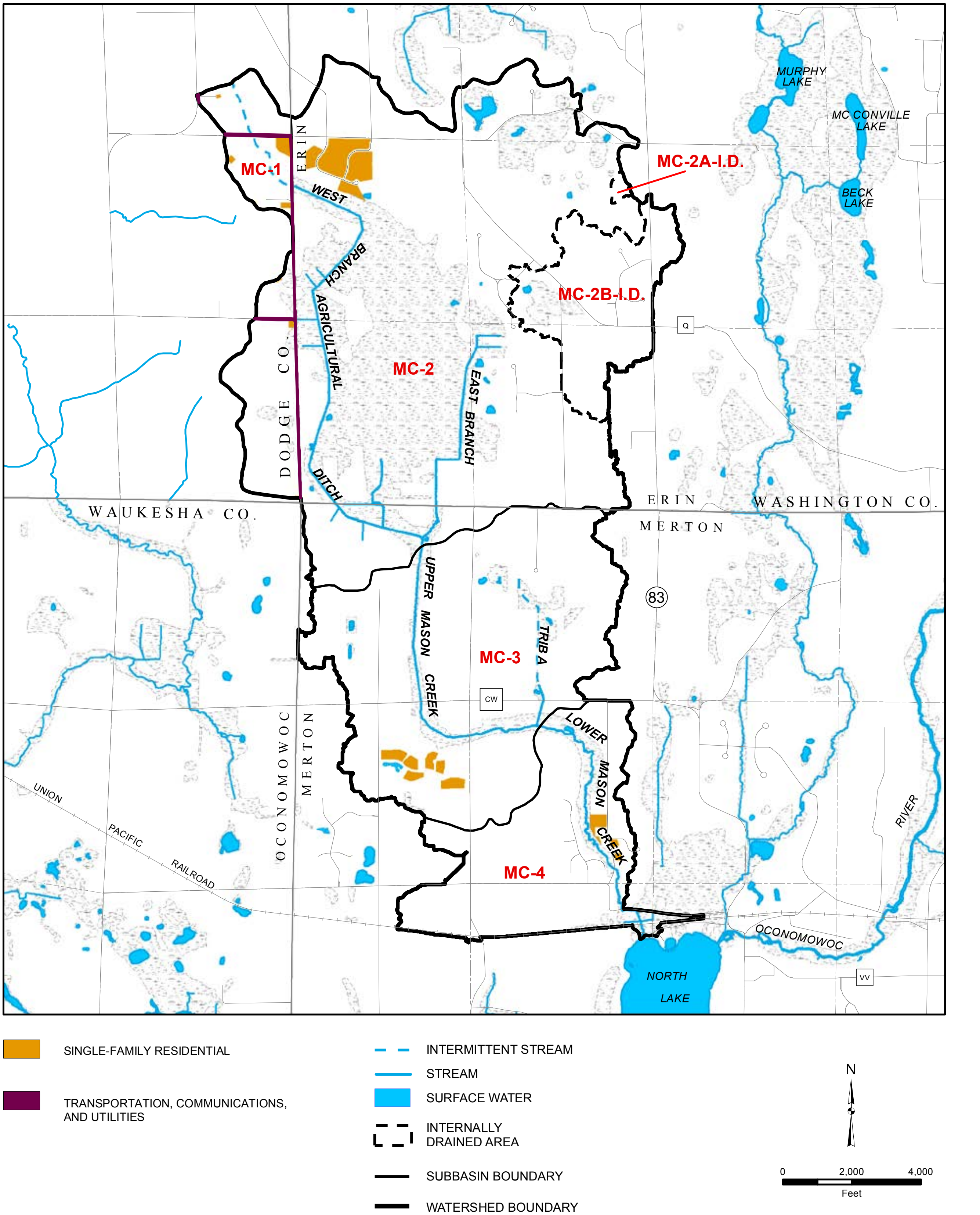
WATERSHED BOUNDARY

N

0 2,000 4,000 Feet

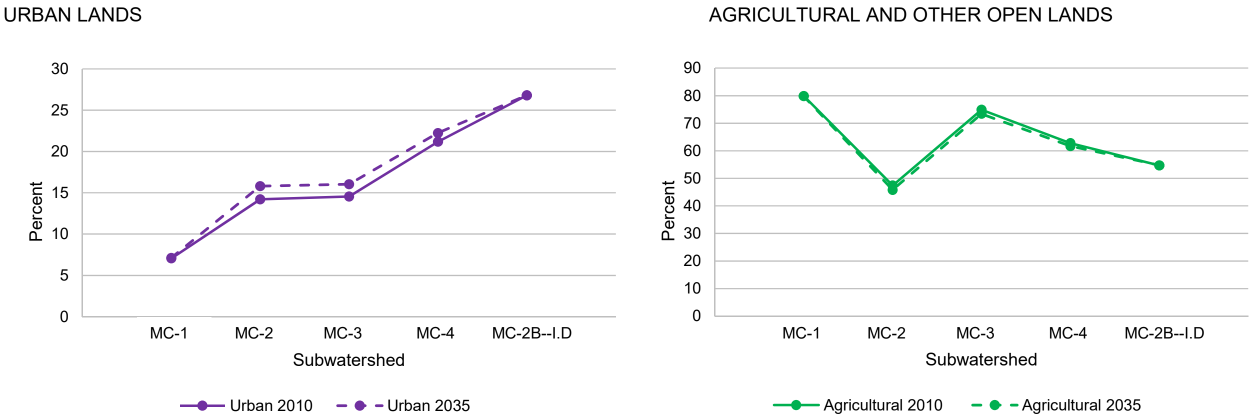
Source: SEWRPC

Map 1.7
2010 Agricultural, Open Lands, and Woodlands Lost to 2035 Urban Planned Land Use Within the Mason Creek Watershed



Source: SEWRPC.

Figure 1.4
Existing Versus Planned Urban and Agricultural Land Use Among Subbasins Within the Mason Creek Watershed: 2010 Versus 2035



NOTE: Internally drained subwatershed MC-2A—I.D. is not shown in this figure due to its small size. In 2010, the internally drained subwatershed contained about six acres of woodlands and about 1.25 acres of single family residential land use. The land use is not projected to change in 2035.

Source: SEWRPC.

- Serve as an efficient conveyance system transporting pollutants into waterways

Research over the last 20 years shows a strong relationship between the imperviousness of a drainage basin and the health of receiving streams.[15] Studies have found that relatively low levels of urbanization—8 to 12 percent connected impervious surface—can cause subtle changes in physical (increased temperature and turbidity) and chemical (reduced dissolved oxygen and increased pollutant levels) properties of a stream, leading to a decline in the biological integrity of the stream. For example, each 1 percent increase in watershed imperviousness can lead to an increase in water temperature of nearly 2.5°F.[16] While this temperature increase may appear to be small in magnitude, this small increase can have significant impacts on fish (such as trout) and other biological communities that have a low tolerance to temperature fluctuations or require specific thermal ranges.

The Mason Creek watershed overall had about 12 percent urban land use in 2010, which corresponds to about 2.5 percent directly connected imperviousness in the watershed (see Table 1.3). That level of imperviousness is below the threshold level of 6 to 11 percent at which negative biological impacts can be expected to occur, which corresponds with the high quality cold water fishery observed within the mainstem of this system. In addition, the estimated levels of imperviousness by subwatershed for year 2010 and planned year 2035, as shown in Table 1.3, are also not expected to exceed the 6 to 11 percent range. This indicates that these relatively low levels of urban development are not expected to significantly contribute to the degradation

[15] *Wang, L., J. Lyons, P. Kanehl, R. Bannerman, and E. Emmons. 2000. Watershed Urbanization and Changes in Fish Communities in Southeastern Wisconsin Streams. Journal of the American Water Resources Association 36(5):1173-1189; Wang, L., J. Lyons, P. Kanehl, and R. Gatti. 1997. Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams. Fisheries 22(6):6-12; Arnold, C., and C.J. Gibbons. 1996. Impervious Surface Coverage. The Emergence of a Key Environmental Indicator. Journal of the American Planning Association 62(2):243-258; Schueler, T. 1995. Site Planning for Urban Stream Protection. Center for Watershed Protection. Ellicot, MD; Masterson, J.P., and R.T. Bannerman. 1994. Impacts of Stormwater Runoff on Urban Streams in Milwaukee, Wisconsin. In National Symposium on Water Quality. 1994. American Water Resources Association. Middelburg, VA; and, Schueler, T. 1994. The Importance of Imperviousness. Watershed Protection Techniques 1:100-111.*

[16] *L. Wang, J. Lyons, and P. Kanehl, "Impacts of Urban Land Cover on Trout Streams in Wisconsin and Minnesota,* Transactions of the American Fisheries Society, *Vol. 132, 2003, pp. 825-839.*

of aquatic resources such as observed in other streams within southeastern Wisconsin.[17] Hence, although local stormwater management practices affecting runoff volume and quality such as promoting infiltration, green infrastructure projects, and preservation of riparian buffers will be key to mitigating the consequences of development within this watershed, agricultural land management practices should remain the priority focus to reduce pollutant loads to Mason Creek during stormwater events.

Table 1.3
Overall Estimated Percent Connected Impervious Surface for the Mason Creek Watershed

Subwatershed	2010	2035
MC-1	1.2	1.2
MC-2	2.0	2.2
MC-3	2.3	2.4
MC-4	3.7	3.8
MC-2A-Internally Drained Area	1.7	1.7
MC-2B-Internally Drained Area	4.5	4.5
Total Watershed	2.5	2.6

Source: SEWRPC

Description of the Farming Environment

Farming in the watershed is a significant economic factor with about 80 percent of the farm operations in row crop/cash grain production, and 20 percent feedlots and pasture. Loss of dairy herds over past decades has nearly eliminated hay production from the watershed. Demand for corn and soybean production, while not at an all-time high, is still good, and petroleum prices (fertilizer and fuel) are lower than in past years. Farmers continue to look for ways to increase yields by removing fence rows to increase land in production and in some cases putting land enrolled in Federal set aside programs back into production. Agricultural lands located along Mason Creek may be candidates for enrollment in Federal conservation programs.

There are approximately 170 rural properties/lots within the Mason Creek watershed. Roughly 110 of these parcels are in row crop operations and the rest are in pasture based upon the 2010 land use survey. Several of the landowners or their operators employ conservation practices such as reduced tillage and riparian buffers.

Field observations and review of data with the County conservationists identified less than five animal operations in the watershed (see Map B.1 in Appendix B-STEPL Pollutant Loading Results for the Mason Creek Watershed). Pastured beef and other livestock feeding operations, rotational grazing, and horse stables contribute to a diversity of manure management approaches within the watershed. There are no CAFO's (Concentrated Animal Feeding Operations) in the watershed.

Natural Resource Elements

Many important interlocking and interacting relationships occur between living organisms and their environment. The destruction or deterioration of any one element may lead to a chain reaction of deterioration and destruction among the others. The drainage of wetlands, for example, may have far-reaching effects. Such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater. Groundwater serves as a source of domestic, municipal, and industrial water supply and provides low flows in rivers and streams. The destruction of woodland and other upland cover types, which may have taken a century or more to develop, may result in soil erosion and stream siltation and in more rapid runoff and increased flooding, as well as destruction of wildlife habitat. Although the effects of any one of these environmental changes in isolation may not be overwhelming, the combined effects may lead eventually to the deterioration of the underlying and supporting natural resource base, and of the overall quality of the environment for life. The need to protect and preserve the environmental corridors and their associated complexes of wetland, upland, and critical species habitats within the watershed thus becomes apparent.

[17] *SEWRPC Technical Report No. 39,* Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds, *November 2007.*

Primary Environmental Corridors

Primary environmental corridors (PEC) include a wide variety of important resource and resource-related elements. By definition, they are at least 400 acres in size, two miles in length, and 200 feet in width.[18] There are two separate PECs in the watershed under existing conditions, one in the northeast and one located along the entire length of Mason Creek, which together encompass about 1,280 acres, or about 24 percent, of the Mason Creek watershed. This PEC represents a composite of the best remaining elements of the natural resource base in the watershed, and contains almost all of the best remaining uplands, wetlands, and wildlife habitat areas (see "Natural Areas and Critical Species Habitat Sites" section below). It is also important to note that these high quality corridors are a part of one much larger contiguous PEC that is shared with the neighboring North Lake, Little Oconomowoc River, and Oconomowoc River as shown on Map 1.8. Hence, North Lake and Mason Creek and its associated shorelands are part of the highest quality natural resources within the watershed as well as the neighboring watersheds. This is why management of those areas is vital to protecting and maintaining the quality and integrity of this resource (see Appendix C: Managing the Water's Edge-Riparian Buffer Guide).

Secondary Environmental Corridors

Secondary environmental corridors (SEC) are at least 100 acres in size and one mile long. In 2010, as shown on Map 1.8, there were no designated secondary environmental corridors within the Mason Creek watershed.

Isolated Natural Resource Areas

Smaller concentrations of natural resource features that have been separated physically from environmental corridors by intensive agricultural or urban land uses have also been identified. These natural resource areas, which are at least five acres in size, are referred to as isolated natural resource areas and are shown on Map 1.8. Widely scattered throughout the watershed, isolated natural resource areas covered about 137 acres, or nearly 3 percent, of the total study area in 2010. These INRAs still contain a variety of resource functions that include facilitating surface water drainage, maintaining pockets of natural resource features, and—if connected with other INRAs or PECs—enhancing the movement of wildlife and dispersal of seeds for a variety of plant species.

Natural Areas and Critical Species Habitat Sites

Natural areas, as defined by the Wisconsin Natural Areas Preservation Council, are tracts of land or water so little modified by human activity, or sufficiently recovered from the effects of such activity, that they contain intact native plant and animal communities believed to be representative of the pre-European settlement landscape (see Map 1.5). Natural areas are generally comprised of wetland or upland vegetation communities and/or complex combinations of both these fundamental ecosystem units. In fact, some of the highest quality natural areas within the Southeastern Wisconsin Region are wetland complexes that have maintained adequate or undisturbed linkages (i.e., landscape connectivity) between the upland-wetland habitats, which is consistent with research findings in other areas of the Midwest as well as in the Mason Creek watershed.[19] The extent and distribution of wetland and upland areas and their relationship to the designated natural areas and critical species habitats are shown on Map 1.9.

Natural areas have been identified for the seven-county Southeastern Wisconsin Region in SEWRPC Planning Report No. 42, A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, published in September 1997, and amended in 2010. This plan was developed to assist Federal, State, and local units and agencies of government, and nongovernmental organizations, in making environmentally sound land use decisions including acquisition of priority properties, management of public lands, and location of development in appropriate places that will protect and preserve the natural resource base of the Region. Washington and Waukesha Counties use this document to guide land use decisions.

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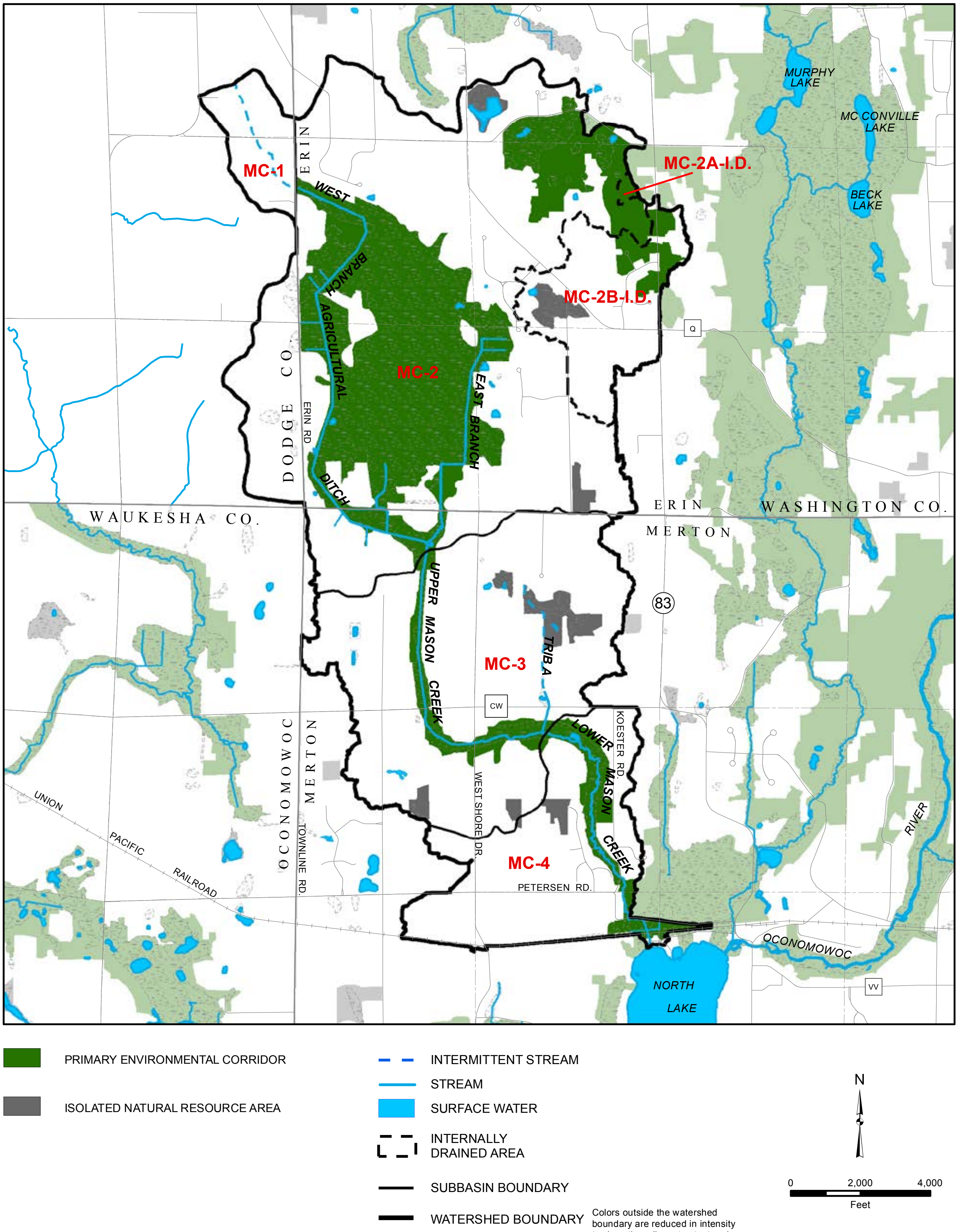
[18] *SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, Amendment, *December 2010.*

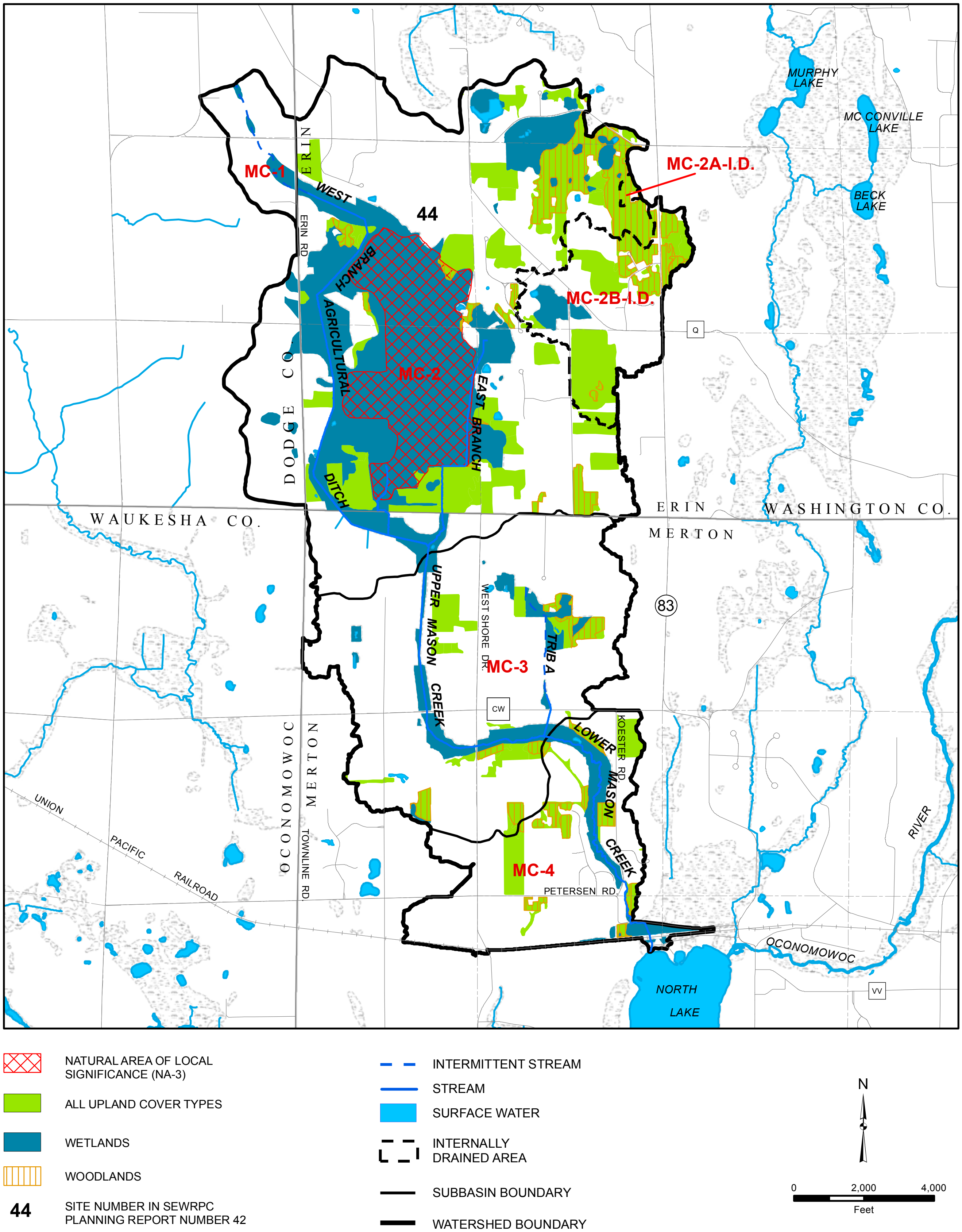
[19] *O. Attum, Y.M. Lee, J.H. Roe, and B.A. Kingsbury, "Wetland complexes and upland-wetland linkages: landscape effects on the distribution of rare and common wetland reptiles,"* Journal of Zoology, *Vol. 275, 2008, pages 245-251.*

Map 1.8
Environmental Corridors Within the Mason Creek Watershed: 2010



Source: SEWRPC.

Map 1.9
Natural Areas, Wetlands, and Upland Cover Types Within the Mason Creek Watershed: 2010



Source: SEWRPC.

The identified natural areas were classified into the following three categories:

1. Natural area of statewide or greater significance (NA-1)
2. Natural area of countywide or regional significance (NA-2)
3. Natural area of local significance (NA-3)

Classification of an area into one of these three categories was based upon consideration of several factors, including the diversity of plant and animal species and community types present; the structure and integrity of the native plant or animal community; the extent of disturbance by human activity, such as logging, grazing, water level changes, and pollution; the frequency of occurrence within the Region of the plant and animal communities present; the occurrence of unique natural features within the area; the size of the area; and the educational value.

The Mason Creek watershed contains one natural area of local significance (NA-3) as shown on Map 1.9.[20] Site 44 is the Mason Creek Swamp that comprises a large proportion of the headwaters of the Mason Creek watershed. This is a large (425 acres) wetland complex that includes a variety of deep marsh, shallow marsh, and sedge meadow plant communities. This is the highest quality plant community known to exist in the watershed, and it can serve as a potential seed source for restoration in other areas (for more details see Appendix D: Mason Creek Potentially Restorable Wetland Evaluation).

Critical species are defined as those species of plants and animals that are designated by the State of Wisconsin to be endangered, threatened, or of special concern. There are five such plant and animal species known to occur in the watershed and they are listed in Table 1.4. Photos of each of these critical species and links to life history information are included in Figure 1.5.

Exotic/Invasive Species

Invasive species can have a negative impact on ecosystems. They can out compete native species that provide optimal habitats for a variety of wildlife, which causes an overall reduction in available wildlife habitat and species diversity. Invasive species such as Purple Loosestrife and Phragmites tend to populate disturbed areas such as roadside ditches and then expand into other areas. There are many exotic species located in the watershed. These species consist of reed canary grass, Purple Loosestrife, Cut Leaf Teasel, Phragmites, Garlic Mustard, Japanese Knotweed, buckthorn, and emerald ash borer to name a few. Invasive species are an important issue in this watershed and conservation practices that are implemented should be maintained to prevent establishment and spread of invasives, particularly when trying to restore native wetland habitat (see Appendix D for more details).

1.9 CLIMATE

Based on the 30-year average temperature and precipitation data from 1981-2010 for Wisconsin from the NOAA National Weather Service Forecast Office Milwaukee/Sullivan, the average annual temperature and precipitation range from about 45-48 degrees Fahrenheit and 34-36 inches, respectively, within the vicinity of the Mason Creek watershed.

However, it is also important to note that Wisconsin's climate and water resources are changing. Climate directly affects water resources and such resources can serve as indicators of climate change at various temporal and spatial scales. The Wisconsin Initiative on Climate Change Impacts (WICCI) has concluded that the projected future climate may affect the quantity and quality of the State of Wisconsin's water resources. However, WICCI also found clear evidence from analysis of past trends and probable future climate projections that there will be different hydrologic responses to climate change in different geographic regions of the State (see Figure 1.6). The differences reflect local variations in land use, soil type and surface deposits, groundwater characteristics, and runoff and seepage responses to precipitation, which illustrates the importance of considering the effects on hydrologic conditions of possible changes in those characteristics as part of a watershed protection plan strategy.

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[20] *Note: Site numbers correspond to those presented in the Regional Natural Areas Plan (SEWRPC Planning Report No. 42, Amendment December 2010).*

Table 1.4
Endangered and Threatened Species and Species of Special Concern in the Mason Creek Watershed

Common Name	Scientific Name	Status Under the U.S. Endangered Species Act	Wisconsin Status
Plants			
Pale Green Orchid[a]	*Plantanthera flava*	Not listed	Threatened
Animals			
Blanding's Turtle	*Emydoidea blandingii*	Under review	Special concern
Lake Chubsucker	*Erimyzon sucetta*	Not listed	Special concern
Slender Madtom	*Noturus exilis*	Not listed	Endangered
Veery	*Catharus fuscescens*	Not listed	Special concern

[a] *It is unlikely that suitable habitat for this species still exists where this occurrence was recorded.*

Source: Wisconsin Department of Natural Resources, Wisconsin State Herbarium, and SEWRPC

Climate change seems to be altering the availability of water (volume), the distribution of rainfall over time, and whether precipitation falls as rain or snow, each of which affects water's movement through a water cycle. As shown in Figure 1.7, most of the water entering the landscape arrives as precipitation (rain and snowfall) that falls directly on waterbodies; or runs off the land surface and enters streams, rivers, wetlands, and lakes; or percolates through the soil, recharging groundwater that flows underground and re-emerges as springs discharging into lakes, wetlands, and streams. Even in the absence of climate change, when one part of the system is affected, all other parts are affected. For example, over drafting the shallow groundwater to irrigate crops or for providing a potable water supply, can lead to a reduction or complete loss in discharge of a local stream. More important, climate change exposes the vulnerabilities of water available within a given community, and this vulnerability is proportional to how much humans have altered how water moves through the water cycle (e.g., through reducing groundwater discharge potential during land development and/or through withdrawals from aquifers). This vulnerability becomes particularly evident during periods of prolonged drought conditions.

The WICCI Water Resources Working Group (WRWG) incorporated WICCI's 1980-2055 projections for temperature, precipitation (including occurrence of events), and changes in snowfall to guide their evaluation of potential impacts to hydrologic processes and resources.[21] This team of experts prioritized the highest potential climate change impacts on water resources and proposed adaptation strategies to address impacts across the State of Wisconsin as summarized below:

- **Minimize threats to public health and safety by anticipating and managing for extreme events through effective planning—floods and droughts**
- **Increase resiliency of aquatic ecosystems to buffer the impacts of future climate changes by restoring or simulating natural processes, ensuring adequate habitat availability, and limiting human impacts on resources. Examples include limiting groundwater and surface water withdrawals, restoring or reconnecting floodplains and wetlands, and maintaining or providing migration corridors for fish and other aquatic organisms**
- **Stabilize future variations in water quantity and availability by managing water as an integrated resource, keeping water "local" and supporting sustainable and efficient water use for humans and the environment.**
- **Maintain, improve, or restore water quality under a changing climate regime by promoting actions to reduce nutrient and sediment loading**

[21] *The Water Resources Working Group (WRWG) included 25 members representing the Federal government, State government, the University of Wisconsin System, the Great Lakes Indian Fish and Wildlife Commission, and the Wisconsin Wetlands Association. For more details on climate change, impacts, adaptation, and resources visit* www.wicci.wisc.edu/water-resources-working-group.php.

Figure 1.5
State of Wisconsin Endangered, Threatened, and Special Concern Species in the Mason Creek Watershed

Blanding's Turtle

Photo by G. Knudsen

Lake Chubsucker

Photo by John Lyons

Pale Green Orchid

Photo by WDNR.

Slender Madtom

Photo by John Lyons

Veery

Photo by Laura Erickson

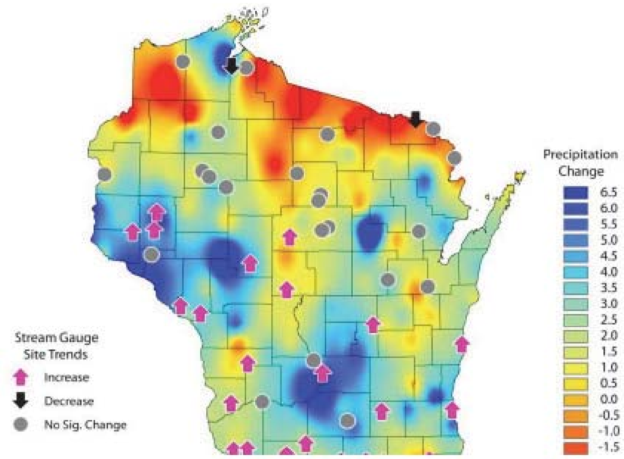
Source: Wisconsin Department of Natural Resources and SEWRPC.

Changing climatic conditions are drivers of water quality conditions within the Mason Creek system and these adaption strategies are important considerations for the protection of surface water and groundwater quality and quantity in this watershed.

1.10 TOPOGRAPHY AND GEOLOGY

The Mason Creek watershed lies in the Eastern Ridges and Lowlands geographical province of Wisconsin and was part of the glaciated portion of Wisconsin. Glaciers have greatly impacted the geology of the area. The Kankakee equivalent dolomite of the Silurian Group and the Maquoketa shale formation of the Ordovician Group are the major bedrock features within this watershed. The depth to bedrock generally ranges from 100 to 350 feet. The topography is generally smooth and gently sloping with some slopes steepened by post glacial stream erosion. The main glacial landforms are ground moraine, outwash, and lake plain. The highest point in the watershed area is in the northeast area at 1,025 feet above National Geodetic Vertical Datum, 1929 adjustment (NGVD 29) and the lowest point in the watershed is 875 feet above NGVD 29 near the confluence with North Lake. The central portion of this watershed is relatively flat while the remaining northern and southern edges contain some ridges and rolling slopes.

Figure 1.6
River Baseflow Trends and Precipitation Change in Wisconsin: 1950-2006



From 1950-2006, Wisconsin as a whole became wetter, with an increase in annual precipitation of 3.1 inches. This observed increase in annual precipitation primarily occurred in southern and western Wisconsin, while northern Wisconsin experienced some drying. The southern and western regions of the State show increases in baseflow, corresponding to the areas with greatest precipitation increases.

Source: Wisconsin Initiative on Climate Change Impacts Water Resources Working Group and SEWRPC.

1.11 GROUNDWATER RESOURCES

Groundwater not only sustains lake levels and wetlands and provides the perennial base flow of streams, but it is also a major source of water supply. In general, there is an adequate supply of groundwater within the Region to support the growing population, agriculture, commerce, and viable and diverse industry. However, overproduction and water shortages may occur in areas of concentrated development and intensive water demand.[22] The amount, recharge, movement, and discharge of groundwater is controlled by several factors, including: precipitation; topography; drainage; land use; soil; and the lithology and water-bearing properties of rock units. All of the communities within the Mason Creek watershed are dependent on groundwater for a potable water supply and for other commercial uses. Groundwater resources thus constitute an extremely valuable element of the natural resource base within the watershed. The continued growth of population and industry within the watershed necessitates the wise development and management of groundwater resources.[23]

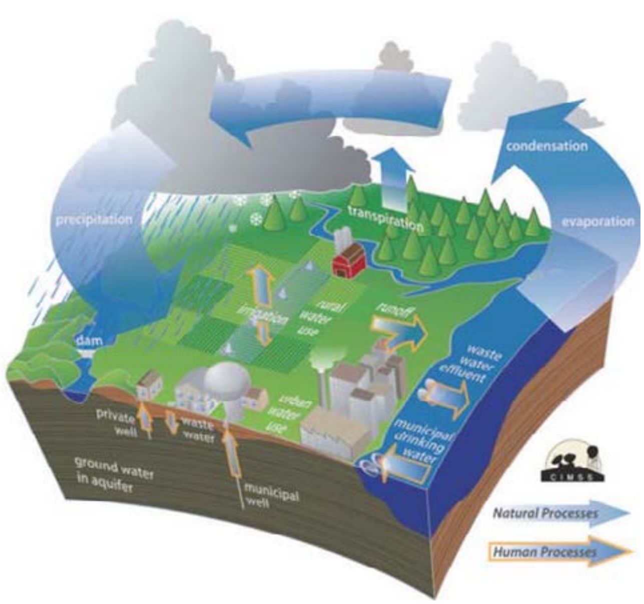
Groundwater Recharge

Recharge to groundwater is derived almost entirely from precipitation. The amount of precipitation (and snowmelt) that infiltrates at any location depends mainly on the permeability of the overlying soils, bedrock or other surface materials, including human-made surfaces. As development occurs, stormwater management practices can be instituted that encourage infiltration of runoff. However, it is important to note that such practices were generally not required to be installed prior to 1990 in the Mason Creek

[22] *SEWRPC Planning Report No. 52, A Regional Water Supply Plan For Southeastern Wisconsin, December 2010.*

[23] *Barlow, P.M., and Leake, S.A., Streamflow depletion by wells*—Understanding and managing the effects of groundwater pumping on streamflow, *U.S. Geological Survey Circular 1376, 2012, see website at pubs.usgs.gov/circ/1376/.*

Figure 1.7
Hydrologic Cycle of Water Movement



This schematic shows how human processes associated with land use development affect the natural processes of how water moves through its different states of the hydrologic cycle. Water returns to the atmosphere through evaporation (process by which water is changed from liquid to vapor), sublimation (direct evaporation by snow and ice), and transpiration (process by which plants give off water vapor through their leaves).

Source: Wisconsin Initiative on Climate Change Impacts Water Resources Working Group and SEWRPC.

watershed. So, much of the urban development was not constructed to promote such infiltration in this watershed. Ideally, practices that promote infiltration need to be located on soils with permeable subsoils and adequate groundwater separation to allow infiltration, but minimize the potential for groundwater contamination. Most of the precipitation that does infiltrate (either naturally or through a stormwater management practice) will generally only migrate within the shallow aquifer system and may discharge in a nearby wetland or stream system. This process helps support base flows, wetland vegetation, and wildlife habitat in these water resources. Therefore, as is the case for surface waters (lakes and streams), the quality of groundwater resources is clearly linked to the health and well-being of the biological communities (including humans) inhabiting those waters and their surrounding watersheds.[24]

Understanding recharge and its distribution is key to making informed land use decisions so that the groundwater needs of society and the environment can continue to be met. Fortunately, a groundwater recharge potential map derived from a soil-water balance recharge model was developed under the SEWRPC water supply planning program for the Southeastern Wisconsin Region. Groundwater recharge potential in the Mason Creek watershed is shown on Map 1.10. That map can be used for identifying and protecting recharge areas that contribute most to baseflow of the ponds, streams, springs, and wetlands in the Mason Creek watershed.[25]

Groundwater recharge potential was divided into four main categories defined as: low, moderate, high, and very high. Any areas that were not defined were placed into a fifth category as undefined. These undefined areas are most often associated with groundwater discharge, which is why they tend to be located adjacent to streams as shown on Map 1.10. Much of the Mason Creek watershed can be considered to have either moderate (1,903 acres, or 36 percent) or high (2,019 acres, or 38 percent) groundwater recharge potential, as shown on Map 1.10. In about 18 percent of the watershed the groundwater recharge potential was undefined, with those areas largely associated with the Mason Creek Swamp and associated wetlands. Less than one percent of the watershed was comprised of low and very high recharge potential combined. Hence, protecting recharge areas, particularly those located on agricultural and other open lands that have not yet been developed, is important to the goals of sustainable groundwater use and a healthy natural environment in this watershed.

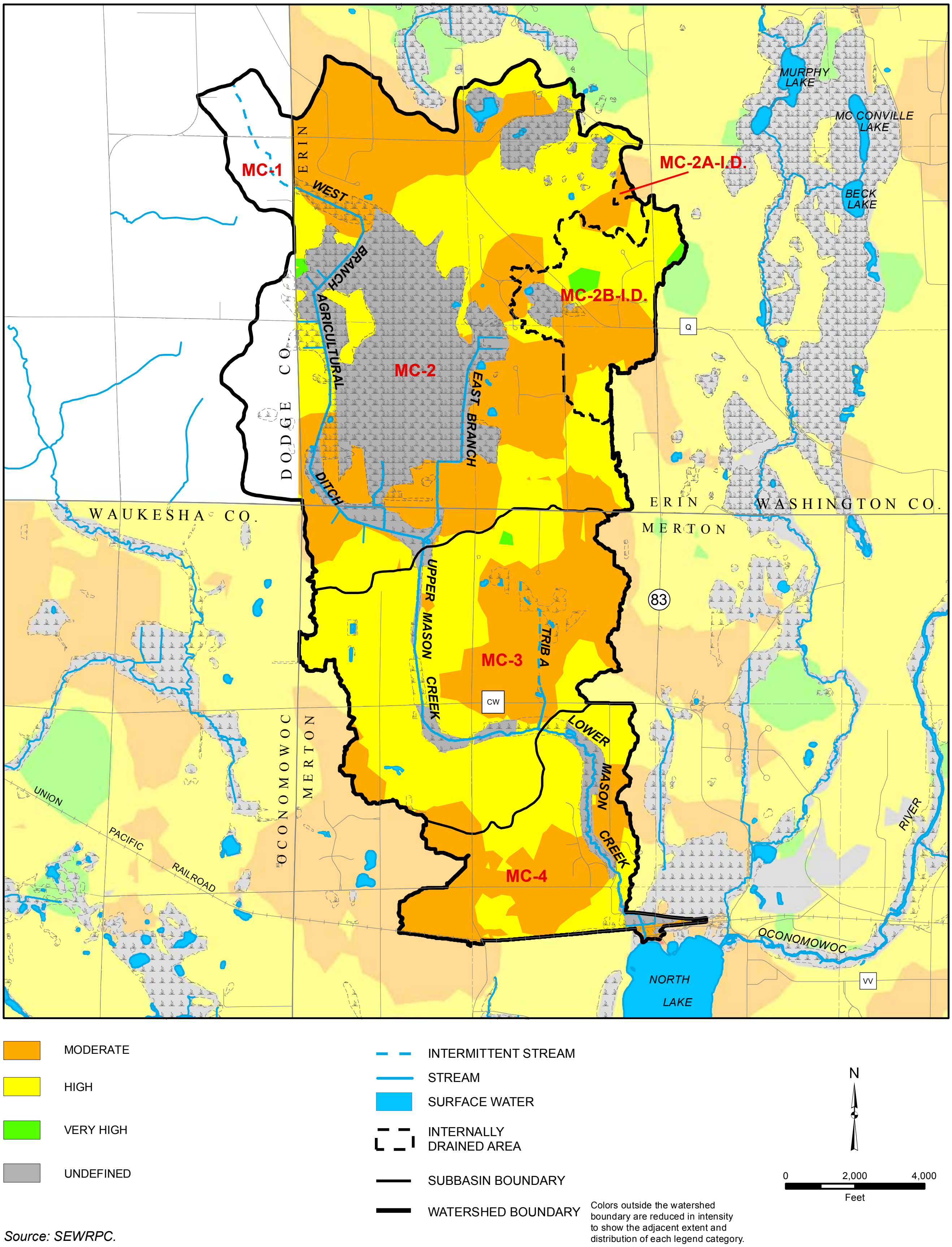
1.12 SOIL CHARACTERISTICS

Soil data for the watershed was obtained from the NRCS (SSURGO) database. Soil type and characteristics are important for planning management practices in a watershed. Factors such as erodibility, hydrologic soil group, slope, and hydric classification are important in estimating erosion and runoff in a watershed.

[24] *David Hambright, "Golden Algae & the Health of Oklahoma Lakes," LAKELINE, Volume 32(3), Fall 2012.*

[25] *SEWRPC Technical Report No. 47,* Groundwater Recharge in Southeastern Wisconsin Estimated by a GIS-Based Water-Balance Model, *July 2008.*

Map 1.10
Estimates of Groundwater Recharge Within the Mason Creek Watershed: 2000



Source: SEWRPC.

Table 1.5
Description of Hydrologic Soil Groups (HSG)

HSG	Runoff Potential	Infiltration Rate	Transmission Rate
A	Low	High	High
B	Moderately Low	Moderate	Moderate
C	Moderately High	Low	Low
D	High	Very Low	Very Low

Source: Natural Resources Conservation Service and Outagamie County Land Conservation Department

The five general soil associations found in the Mason Creek watershed include Hochheim-Theresa (53 percent), Casco-Fox-Rodman (17 percent), Houghton-Palms-Adrian (15 percent), Fox-Casco (14.7 percent), and Rodman-Casco (<1 percent). It is important to note that 71 percent of the remaining agricultural and open lands within the watershed are classified as prime agricultural soils and an additional 20 percent are considered soils of statewide importance for agriculture, which demonstrates that this is highly productive farmland.

Table 1.6
Hydrologic Soil Groups of the Mason Creek Watershed

Soil Hydrologic Group	Percent of Watershed
B	52.3
B/D	14.1
C	20.1
C/D	<1.0
A	<1.0
A/D	13.2

Source: Natural Resources Conservation Service and SEWRPC

Hydrologic Soil Group

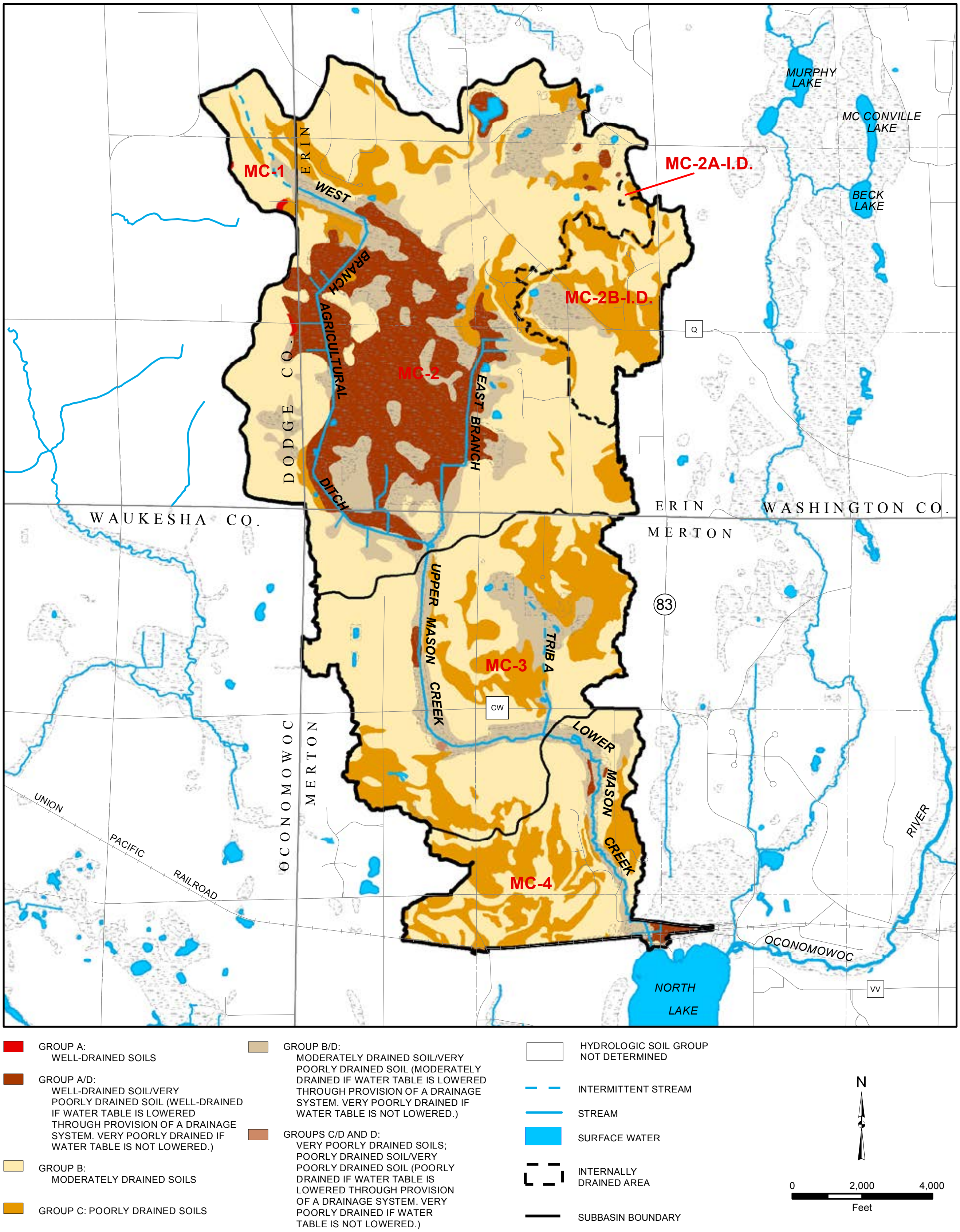
Soils are classified into hydrologic soil groups based on soil infiltration and transmission rate (permeability). Hydrologic soil group along with land use, management practices, and hydrologic condition determine a soil's runoff curve number as established by NRCS. Runoff curve numbers are used to estimate direct runoff from rainfall. There are four hydrologic soil groups: A, B, C, and D. Descriptions of Runoff Potential, Infiltration Rate, and Transmission Rate of each group are shown in Table 1.5. Some soils fall into a dual hydrologic soil group (A/D, B/D, and C/D) based on their saturated hydraulic conductivity and water table depth when drained. The first letter applies to the drained condition and the second letter applies to the undrained condition. Table 1.6 summarizes the percent of each group present in the watershed and Map 1.11 shows the location of each hydrologic soil group. The dominant hydrologic soil groups in the watershed are Group B (52.3 percent) and Group B/D (14.1 percent). The majority of the soils in the Mason Creek watershed are Group B soils that have a moderately low runoff potential. However, up to 47 percent of the soils in the watershed may have moderately high to high runoff potential, which includes Group C soils as well as Group B/D and A/D soils in the undrained condition.

Soil Erodibility

The susceptibility of a soil to wind and water erosion depends on soil type and slope. Course textured soils such as sand are more susceptible to erosion than fine textured soils such as clay. Potentially highly erodible and highly erodible soils were mapped based on a combination of hydrologic soil groups, which accounts for soil type and other key features (see above), and slope. Soils with a 2 to 6 percent slope were considered potentially highly erodible soils and soils with a 6 percent or higher slope were considered highly erodible.[26] About 57 percent of the soils for which slopes and erosion potential have been classified in the Mason Creek watershed are considered potentially highly erodible to highly erodible (see Map 1.12). There are 2,217 acres (or 42 percent) considered potentially highly erodible and 800 acres (or about 15 percent) are considered highly erodible.

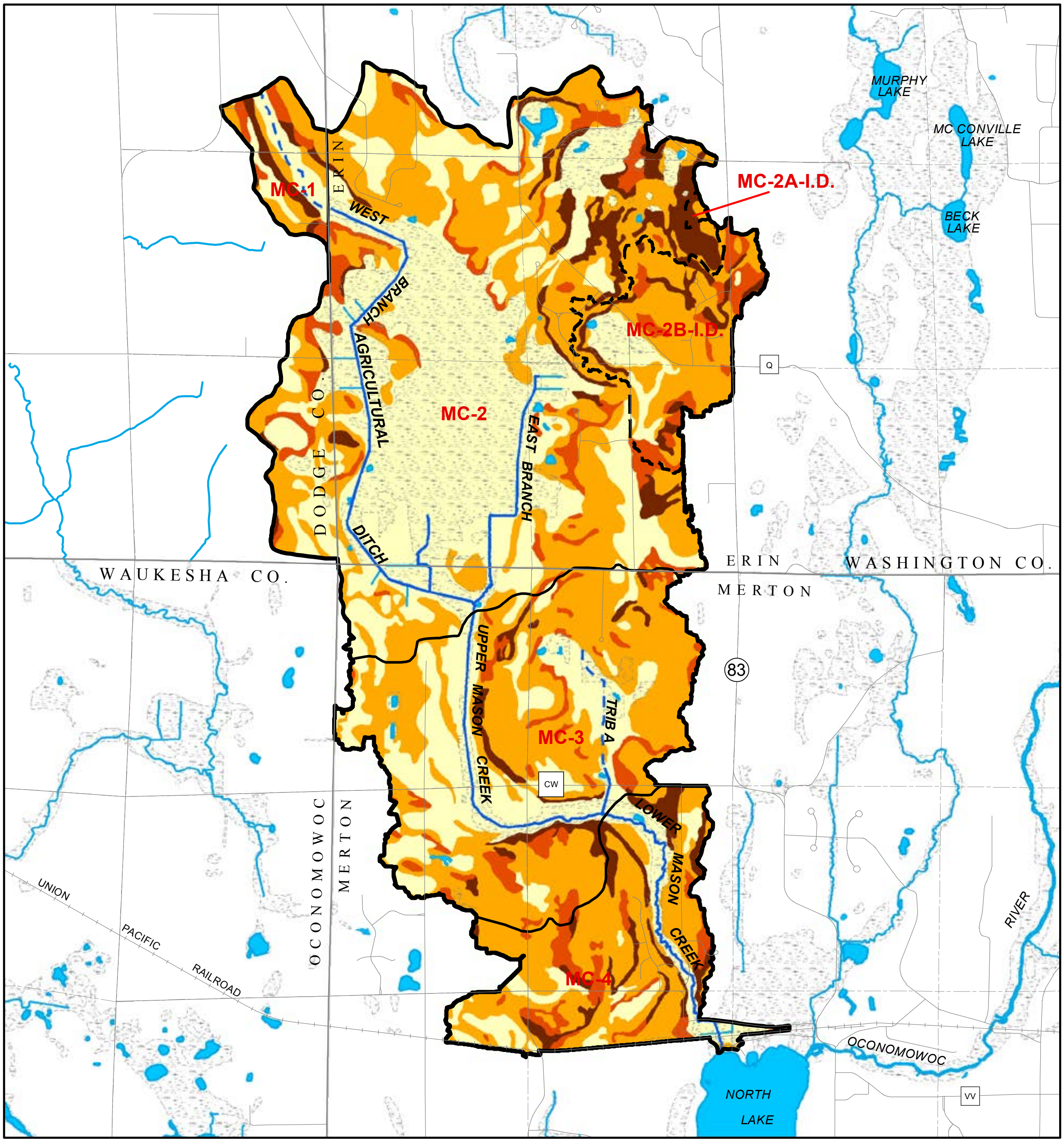
[26] *Outagamie County Land Conservation Department,* Nonpoint Source Implementation Plan for the Plum and Kankapot Creek Watersheds, *141 pages, 2014.*

Map 1.11
Hydrologic Soil Groups Within the Mason Creek Watershed: 2010



Source: Natural Resources Conservation Service and SEWRPC.

Map 1.12
Soil Slopes Within the Mason Creek Watershed: 2010



	SOILS HAVING SLOPES LESS THAN 2 PERCENT
	SOILS HAVING SLOPES RANGING FROM 2 TO 6 PERCENT POTENTIALLY HIGHLY ERODIBLE LAND
	SOILS HAVING SLOPES RANGING FROM GREATER THAN 6 TO 12 PERCENT HIGHLY ERODIBLE LAND
	SOILS HAVING SLOPES OF GREATER THAN 12 PERCENT HIGHLY ERODIBLE LAND

INTERMITTENT STREAM
STREAM
SURFACE WATER
INTERNALLY DRAINED AREA
SUBBASIN BOUNDARY
WATERSHED BOUNDARY

N

0 2,000 4,000
Feet

Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

Source: Natural Resources Conservation Service and SEWRPC.

INVENTORY FINDINGS 2

Credit: SEWRPC Staff

2.1 INTRODUCTION

The health of a stream system is a direct reflection of its watershed. More specifically, changes in land use and water resources in a watershed affect the physical or chemical properties within streams, which in turn affect water quality, habitat, and resident biological communities. Hence, a stream's health is a result of the interaction of its physical, chemical, and biological components (see Figure 2.1).

The condition of biological communities—which are collections of aquatic organisms—provides a direct measure of stream health. Reduced stream health is often associated with human-induced changes to the physical and chemical properties of streams that affect the condition of biological communities. Therefore, this chapter describes how land and water management activities within the Mason Creek watershed have influenced the physical, chemical, and biological properties of this stream system. Describing and inventorying those influences on the stream system enables development of effective management strategies aimed at restoring stream health that support the recommended management measures detailed in Chapter 3 of this report.

This chapter presents an inventory and analysis of the surface waters and related features of the Mason Creek watershed. Included is qualitative and quantitative information pertaining to 1) Physical Conditions—historical trends and current status of instream habitat quality within the Mason Creek system; 2) Chemical Conditions—historical trends and potential limitations to water quality and fishery resources; and 3) Biological Conditions—fishes and other aquatic organisms and wildlife characteristics of Mason Creek.

Environmental Factors Influenced by Agriculture and Urban Land Use

U.S. Geological Survey (USGS) scientists recently found that stream health was reduced at the vast majority of streams assessed in agricultural and urban areas across the nation.[1] The researchers found that the degree of ecological health within a stream system is directly related to the degree of human-induced changes in streamflow characteristics and water quality (nutrients and pesticides). Major findings and important implications of that study include:

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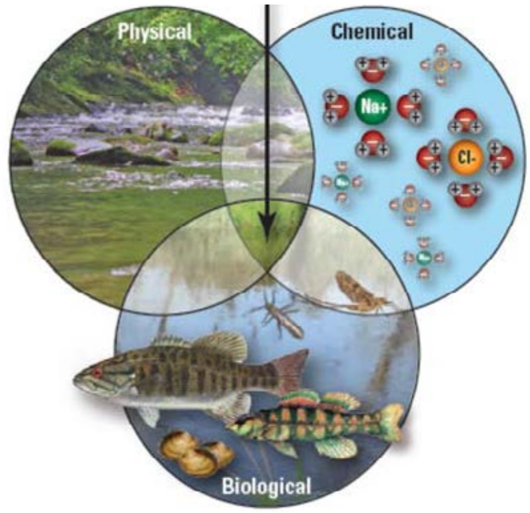
[1] *D.M. Carlisle and others,* The quality of our Nation's waters—Ecological health in the Nation's streams, *1993-2005: U.S. Geological Survey Circular 1391, 2013 (available online at: pubs.usgs.gov/circ/1391/).*

- The presence of healthy streams in watersheds with substantial human influence indicates that it is possible to maintain and restore healthy stream ecosystems.

- Water quality is not independent of water quantity because flows are a fundamental part of stream health. Because flows are modified in so many streams and rivers, there are many opportunities to enhance stream health with targeted adjustments to flow management.

- Efforts to understand the causes of reduced stream health should consider the possible effects of nutrients and pesticides, in addition to modified flows, particularly in agricultural and urban settings.

Figure 2.1
Ecological Stream Health



This simple diagram shows that a stream's ecological health (or "stream health") is the result of the interaction of its biological, physical, and chemical components. Stream health is intact if (1) its biological communities (such as algae, macroinvertebrates, and fish) are similar to what is expected in streams under minimal human influence and (2) the stream's physical attributes (such as streamflow) and chemical attributes (such as salinity or dissolved oxygen) are within the bounds of natural variation.

Source: Modified from D.M. Carlisle and others, The quality of our Nation's waters—Ecological health in the Nation's streams, 1993–2005: U.S. Geological Survey Circular 1391, *120 p.,* http://pubs.usgs.gov/circ/1391/, *2013, and SEWRPC*

More specifically, activities associated with agricultural and urban land uses have been demonstrated to influence the hydrologic, chemical, and physical factors of the streams, which are briefly described below and illustrated in Figure 2.2.[2]

Hydrologic Impacts

The natural timing, variability, and magnitudes of streamflow influence many of the key physical, chemical, and biological characteristics and processes of a healthy stream system. For example, recurring high flows from seasonal rainfall or snowmelt shape the basic structure of a river and its physical habitats, which in turn influences the types of aquatic organisms that can thrive. For many aquatic organisms, low flows impose basic constraints on the availability and suitability of habitat, such as the amount of the stream bottom that is actually submerged. The life cycles of many aquatic organisms are highly synchronized with the variation and timing of natural streamflows. For example, the reproductive period of some species like northern pike is triggered by the onset of spring runoff.

In general, human activities in agricultural settings alter the natural flow regime of streams and rivers through 1) subsurface drain tiles, which lower the water table and quickly route water to nearby streams; 2) ditching and straightening of headwater streams; and 3) irrigation, which supplements available water for crops. These changes can result in more rapid runoff, reduced streamflows during dry periods, and increased transport of sediments and pollutants. However, since there is a diversity of agricultural practices (see Figure 2.2, Agricultural Stream Ecosystem), the impacts to stream ecosystems can be highly variable.

In an urban setting, human activities change the movement of water in a watershed through introduction of increased impervious surfaces, such as buildings and pavement for roadways and parking, which restrict the infiltration of precipitation into the groundwater system, combined with construction of artificial drainage systems (e.g., storm sewer systems) that quickly move runoff to streams (see Figure 2.2, Urban Stream Ecosystem). These impervious surfaces can lead to increased stormwater runoff and higher and more variable peak streamflows (see Figure 2.3), which scour the streambed or banks and degrade the stream channel. Reduced infiltration to groundwater can lead to diminished streamflows during dry periods, particularly in stream systems where groundwater is the main source of base flow. In addition, in urban areas with a groundwater supply serving residential, industrial, and commercial land uses, increases in the withdrawal of groundwater can also affect the natural flow regime of stream systems.

[2] Ibid.

More specifically, recent research has shown that the hydrologic variables most consistently associated with changes in algal, invertebrate, and fish communities[3] are average flow magnitude; high flow magnitude, frequency and duration; and how rapidly the stream changes its width in response to changes in flow. As detailed in Chapter 1 of this report, the amount of urban development within portions of the Mason Creek watershed is at high enough levels to potentially have negative effects on water quality and water quantity, and the amount of urbanization is projected to increase.

To some degree, impervious surface impacts can be mitigated through implementation of traditional stormwater management practices and emerging green infrastructure technologies, such as pervious pavement, green roofs, rain gardens, bioretention, and infiltration facilities. Emerging technologies differ from traditional stormwater practices in that they seek to better mimic the disposition of precipitation on an undisturbed landscape by retaining and infiltrating stormwater onsite. A number of nontraditional, emerging low impact development technologies have been implemented throughout the Southeastern Wisconsin Region, including disconnecting downspouts; installing rain barrels, green roofs, and rain gardens; and constructing biofiltration swales in parking lots and along roadways. Experience has shown that these emerging technologies can be effective.

Location of impervious surfaces also determines the degree of direct impact they will have upon a stream. There is a greater impact from impervious surfaces located closer to a stream, because there is less time and distance for the polluted runoff to be naturally treated before entering the stream. A study of 47 watersheds in southeastern Wisconsin found that one acre of impervious surface located near a stream could have the same negative effect on aquatic communities as 10 acres of impervious surface located further away from the stream.[4] Because urban lands located adjacent to streams have a greater impact on the biological community, an assumption might be made that riparian buffer strips located along the stream could absorb the negative runoff effects attributed to urbanization. Yet, riparian buffers may not be the complete answer since most urban stormwater is delivered directly to the stream via a storm sewer or engineered channel and, therefore, enters the stream without first being filtered by the buffer. Riparian buffers need to be

Figure 2.2
Illustrations of the Dynamic Components of Natural, Agricultural, and Urban Stream Ecosystems

NATURAL STREAM ECOSYSTEM

AGRICULTURAL STREAM ECOSYSTEM

URBAN STREAM ECOSYSTEM

Source: Illustrations by Frank Ippolito/www.productionpost.com. Modified from D.M. Carlisle and others, The quality of our Nation's waters—Ecological health in the Nation's streams, 1993–2005: U.S. Geological Survey Circular 1391, *120 p.,* http://pubs.usgs.gov/circ/1391/, *2013, and SEWRPC*

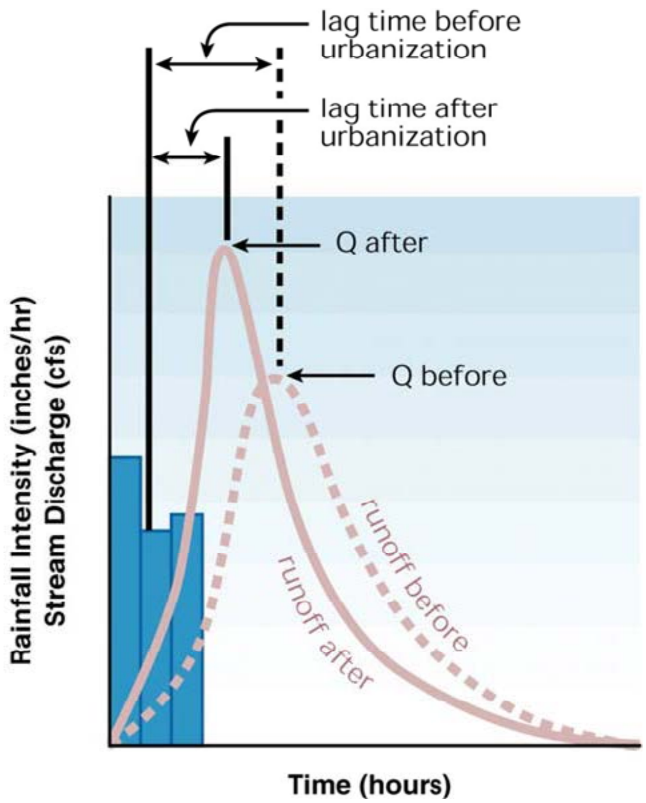
[3] *Personal Communication, Dr. Jeffrey J. Steuer, U.S. Geological Survey.*

[4] *L. Wang, J. Lyons, P. Kanehl, and R. Bannerman, "Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spatial Scales,"* Environmental Management, *Volume 28, 2001, pages 255-266.*

combined with other management practices, such as detention basins, grass swales, and infiltration facilities, to adequately mitigate the effects of urban stormwater runoff. Combining practices into such a "treatment train" can provide a higher level of pollutant removal and reduction in the volume of runoff, than can single, stand-alone practices. Stormwater and erosion treatment practices vary in their function, which influences their level of effectiveness. Location of a practice on the landscape, as well as proper construction and continued maintenance, greatly influences the level of pollutant removal and runoff volume management.

Urbanization also creates other problems. Accumulations of trash and debris in urban waterways and associated riparian lands are unsightly and can cause physical and/or chemical (i.e., toxic) damage to aquatic and terrestrial wildlife. Sometimes debris can accumulate to such an extent that it may limit recreation and the passage of aquatic organisms and/or cause streambank erosion.

Figure 2.3
A Comparison of Hydrographs Before and After Urbanization



Source: *Federal Interagency Stream Restoration Working Group (FISRWG),* Stream Corridor Restoration: Principles, Processes, and Practices, *October 1998*

Chemical Impacts

The unique water chemistry requirements and tolerances of aquatic species help to define their natural abundance in a given stream, as well as their geographic distribution. Many naturally occurring chemical substances in streams and rivers are necessary for normal growth, development, and reproduction of biological communities. For example, sufficient dissolved oxygen in water is necessary for normal respiration. Dissolved oxygen concentrations in streams and rivers are determined by the water temperature and by physical aeration processes influenced by the slope and depth of the stream. Similarly, small amounts of nutrients (nitrogen, phosphorus, and silica) are necessary for normal growth of aquatic plants.

Human activities often contribute additional amounts of these naturally occurring substances, as well as other synthetic (manmade) chemicals, to streams from point and nonpoint sources. Runoff from agricultural lands (see Agricultural Stream Ecosystem in Figure 2.2) may contain 1) sediment from soil erosion on tilled lands; 2) nutrients from the application of fertilizer and manure; and 3) pesticides used in the past and present to control insects, weeds, rodents, bacteria, or other unwanted organisms. Runoff from urban lands (see Urban Stream Ecosystem in Figure 2.2) may contain 1) sediment from construction activities; 2) nutrients and pesticides applied to lawns and recreational areas; and 3) petroleum compounds, trace metals, and deicing salts from roads and parking lots. Point sources include municipal and industrial wastewater effluent that, depending on the sources of wastewater and level of treatment, may contain different amounts of nutrients and other contaminants.

Physical Impacts

Physical habitat includes factors such as streambed substrates, water temperature, and large debris from streamside vegetation. Streambed substrates include the rocks, sediments, and submerged woody material in a stream. Streambed sediments may range in size and composition from large rocks to sand and silt that reflect the local geology. These substrates are important because they provide living space for many stream organisms. Stable substrates, such as cobbles and boulders, protect organisms from being washed downstream during high flows and, thus, generally support greater biological diversity than do less stable substrates, such as sand and silt.

Water temperature is crucial to aquatic organisms because it directly influences their metabolism, respiration, feeding rate, growth, and reproduction. Most aquatic species have an optimal temperature range for growth and reproduction. Thus, their distributions are largely determined by regional differences in climate and elevation along with more local effects from riparian (stream corridor) shading and groundwater influence. Water temperature also influences many chemical processes, such as the availability of oxygen in water for fish and other aquatic life.

The riparian zone is the land adjacent to the stream inhabited by plant and animal communities that rely on periodic or continual nourishment from the stream. The size and character of riparian zones are important to biological communities because these have a major influence on the amount of shelter and food available to aquatic organisms and the amount of sunlight reaching the stream through the tree canopy, which influences water temperature and the amount of energy available for photosynthesis. Riparian zones also influence the amount and quality of runoff that reaches the stream.

Land uses that affect streamflow, sediment availability, or riparian vegetation alter physical habitats in streams. Some agricultural practices (see Agricultural Stream Ecosystem in Figure 2.2), such as conventional tillage near streambanks and drainage modifications, lead to increased sediment erosion, channelization, or removal of riparian vegetation. Increased sediment from erosion can fill crevices between rocks and cobble in the streambed, which reduces living space for many stream organisms. As watersheds urbanize (see Urban Stream Ecosystem in Figure 2.2), some segments of streams may be cleared, ditched, straightened, and enclosed to facilitate drainage and the movement of floodwaters. These modifications increase stream velocity during storms, which can transport large amounts of sediment, scour stream channels, and remove woody debris and other natural structures that provide habitats for stream organisms. In addition, culverts and ditches can be barriers to aquatic organisms that need to migrate throughout the stream network. Humans can alter natural stream temperature through changes in the amount and density of the canopy provided by riparian trees. In some extreme cases, streams in urban areas are routed through pipes and completely buried.

Mason Creek Drainage Network

Water from rainfall and snowmelt flows into streams by one of two pathways: 1) either directly flowing overland as surface water runoff or 2) infiltrating into the soil, recharging the groundwater, and eventually reaching streams as baseflow. Ephemeral, or intermittent, streams generally flow only during the wet season or during large rainfall events. Perennial streams that flow year-round are primarily sustained by groundwater during dry periods. The surface water stream network within the Mason Creek watershed is shown on Map 2.1, where the intermittent reaches are shown as dashed lines and perennial streams are solid lines. Four subbasin areas within this watershed are designated as MC-1 through MC-4, and are numbered from upstream to downstream in the watershed. In addition, Mason Creek was further divided into several discrete reaches, which were established based on a number of considerations including gradient, sinuosity, presence of culvert crossings, and instream physical characteristics. Mason Creek originates at the confluence of its East and West Branches, which are first order headwater streams and are approximately one mile and two miles long, respectively. The East Branch has a consistent baseflow of about 1.5 cubic feet per second (cfs) based on monitoring data from 2011 through 2012, and maintained a baseflow of one cfs during the severe drought in the summer of 2012. In contrast, the West Branch, which was constructed solely as an agricultural drainage ditch (hereinafter, West Branch Agricultural Ditch), contains very limited baseflows; one measurement of 0.2 cfs was taken on June 8, 2012, and no observations could be taken later that summer due to extreme low flows. The mainstem of Mason Creek basically begins at the confluence of the East and West Branch Agricultural Ditch forming a second order stream and is nearly 3.5 miles in total length. The mainstem can be divided into two main segments. As shown in Figure 2.4 the Upper Mason Creek reach has a relatively shallow gradient (4.7 feet per mile) and baseflow discharge that ranges from about four to six cfs. In contrast, the Lower Mason Creek reach has a much steeper gradient (23.5 feet per mile) that flattens out near the railroad crossing just before it discharges into North Lake with a baseflow discharge that ranges from about eight to 16 cfs. Trib-A has a baseflow of about 0.5 cfs, and there is no discharge information for any of the other unnamed minor tributaries (see Map 2.1). The summary statistics and recommendations in this report are organized according to these reaches and subbasin areas.

Map 2.1
Stream Reaches and Subbasins Within the Mason Creek Watershed: 2015

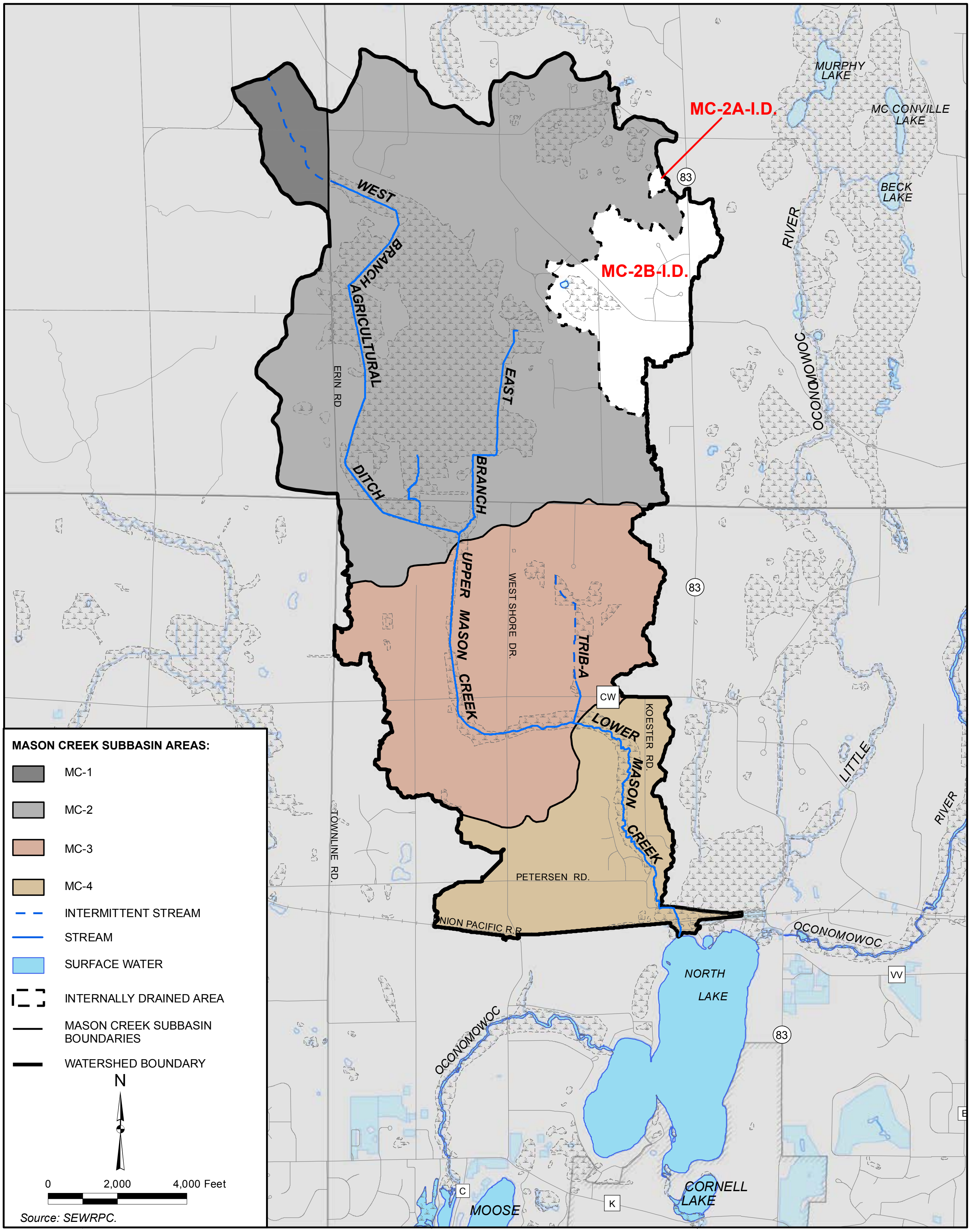
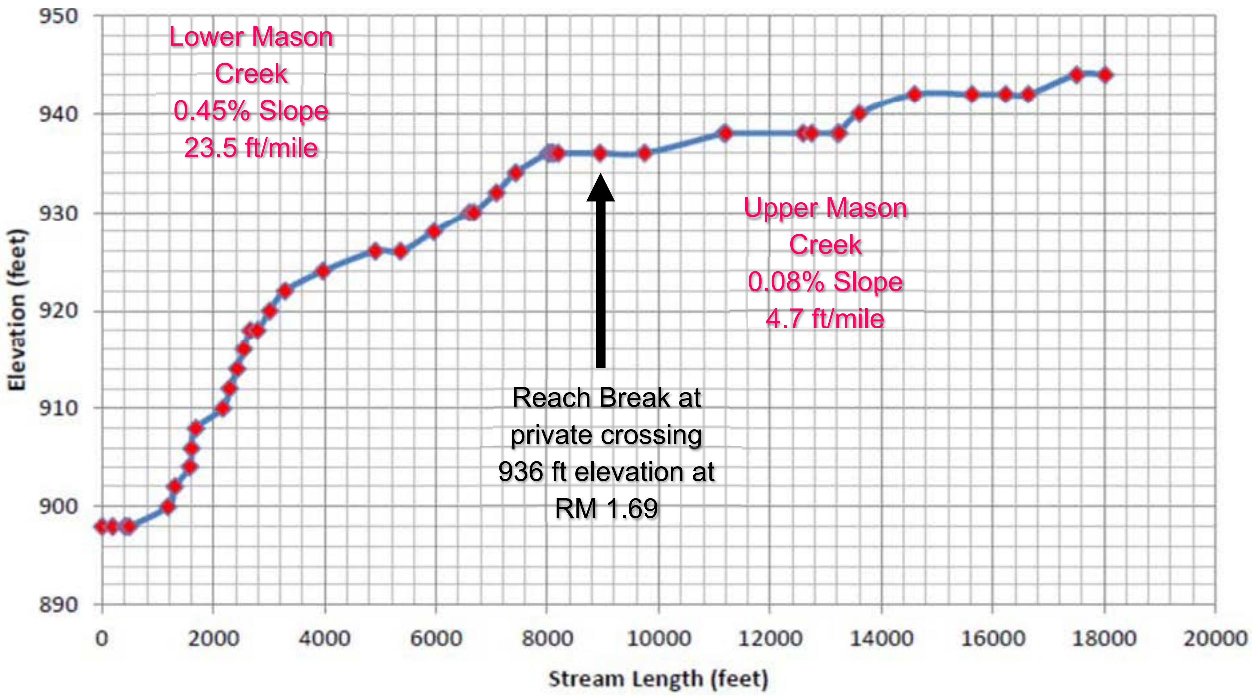


Figure 2.4
Stream Gradient Based on Surface Water Elevations Within the Upper and Lower Reaches of Mason Creek: 2010



Note: Elevation is based on National Geodetic Vertical Datum (NGVD) 1929.

Source: SEWRPC

2.2 WATER QUALITY

The Federal Clean Water Act (CWA) protects the nation's waters and requires states to 1) adopt water quality criteria that the United States Environmental Protection Agency (USEPA) publishes under 304 (a) of the Clean Water Act, 2) modify 304 (a) criteria to reflect site-specific conditions, or 3) adopt criteria based on other scientifically defensible methods. Water quality standards require assigning a designated use to the waterbody.

Clean water is vital to individual human health, healthy communities, and the economy. Having clean water upstream is essential to having healthy communities downstream. The health of rivers and lakes depend on the tributaries and wetlands where they begin. Streams and wetlands provide many benefits to communities by conveying and storing floodwaters, assimilating and filtering pollution, and providing habitat for fish and wildlife.[5]

The Clean Water Rule: Definition of "Waters of the United States"

Protection for about 60 percent of the nation's streams and millions of acres of wetlands has been confusing and complex as the result of U. S. Supreme Court decisions in 2001 and 2006. The "Clean Water Rule: Definition of 'Waters of the United States'" was published by the USEPA and the U.S. Army Corps of Engineers on June 29, 2015, pursuant to the Federal Clean Water Act, to clarify which streams and wetlands comprise "water of the United States" that are regulated under the Act.[6] The Rule protects the types of waters that have historically been covered under the Clean Water Act. The Rule does not regulate most ditches and does not regulate groundwater, shallow subsurface flows, or tile drains. It does not make changes to current

[5] *See USEPA website for more information at www2.epa.gov/cleanwaterrule*

[6] *The Rule has been subject to several legal challenges. On October 9, 2015, the United States Court of Appeals for the Sixth Circuit issued an order temporarily blocking implementation of the Rule nationwide.*

policies on irrigation or water transfers or apply to erosional features. The rule does not create any new requirements for farmers. Activities like planting, harvesting and moving livestock have long been exempt from Clean Water Act regulation, and the Clean Water Rule preserves those exemptions.[7]

Water Quality Standards

Water quality standards are the basis for protecting the quality of surface waters. The standards implement portions of the Federal Clean Water Act by specifying the designated uses of waterbodies and setting water quality criteria to protect those uses. The standards also contain policies to protect high-quality waters and to protect waters from being further degraded. Water quality standards are established to sustain public health and public enjoyment of waters and for the propagation and protection of fish, aquatic organisms, and other wildlife.

In Wisconsin, water quality standards are established and enforced by the Wisconsin Department of Natural Resources (WDNR) and are subject to approval by the USEPA. These standards consist of three elements: designated uses, water quality criteria, and an anti-degradation policy. These are set forth in Chapters NR 102, "Water Quality Standards for Wisconsin Surface Waters;" NR 103, "Water Quality Standards for Wetlands;" NR 104, "Uses and Designated Standards and Secondary Values;" NR 105, "Surface Water Quality Criteria for Toxic Substances;" and NR 207, "Water Quality Antidegradation," of the *Wisconsin Administrative Code*.

Designated Use and Impairments

The designated uses of a waterbody are a statement of the types of activities the waterbody should support—whether or not they are currently being attained. These uses establish water quality goals for the waterbody and determine the water quality criteria needed to protect the use. In Wisconsin, waterbodies are assigned four uses: fish and aquatic life, recreation, public health and welfare, and wildlife. The fish and aquatic life use is further divided into several categories:

- Coldwater community
- Warmwater sportfish community
- Warmwater forage fish community
- Limited forage fish community
- Limited aquatic life community

Coldwater communities include surface waters capable of supporting a community of coldwater fish and other aquatic organisms or serving as a spawning area for coldwater fish species. Warmwater sportfish waters include surface waters capable of supporting a community of warmwater sport fish or serving as a spawning area for warmwater sport fish. Warmwater forage fish waters include those surface waters capable of supporting an abundant diverse community of forage fish and other aquatic organisms. Because identical water quality criteria apply to them, the warmwater sportfish and warmwater forage fish categories are sometimes referred to as "warmwater fish and aquatic life (FAL)." Limited forage fish waters include surface waters of limited capacity and naturally poor water quality or habitat. These waters are capable of supporting only a limited community of forage fish and other aquatic organisms. Limited aquatic life waters include surface waters of severely limited capacity and naturally poor water quality or habitat. These waters are capable of supporting only a limited community of aquatic organisms. The latter two categories are considered variance categories. It is important to note that establishment of a stream water use objective other than coldwater or warmwater fish and aquatic life is not necessarily an indication of reduced water quality, since such streams may be limited by flow or size, but may still be performing well relative to other functions.

The WDNR also has classified some waters of the State as outstanding or exceptional resource waters. These waters, listed in Sections NR 102.10 and NR 102.11 of the *Wisconsin Administrative Code*, are not significantly

[7] *www2.epa.gov/cleanwaterrule/what-clean-water-rule-does-not-do*

impacted by human activities and are deemed to have significant value as fisheries, hydrologically or geographically unique features, outstanding recreational opportunities, and unique environmental settings. However, there are no streams with these designations in the Mason Creek watershed.

The water use objectives for fish and aquatic life for all reaches in the Mason Creek watershed are shown on Map 2.2. Both the Lower and Upper reaches of Mason Creek are designated as a coldwater Class I (naturally reproducing, not stocked) brook trout community.[8] In addition, the coldwater community designation also extends partially upstream along the West Branch Agricultural Ditch of Mason Creek to the Washington-Waukesha county line, but the remainder of the West Branch Agricultural Ditch is classified as a warmwater fish and aquatic life community. The East Branch of Mason Creek and Trib-A reaches also were classified as warmwater fish and aquatic life communities. All of the remaining stream reaches in the watershed were not classified, so they are assigned the fish and aquatic life default standard. However, all of these waters within the Mason Creek watershed were classified as meeting the full recreational use waters designation. There are no designated outstanding or exceptional resource waters within the watershed.

The water use objectives shown on Map 2.2 are regulatory designations. They serve to define the water quality criteria that apply to these waters and form the basis for determining whether the level of water quality in them meets the expectations set forth in the Federal Clean Water Act and Wisconsin law. However, it is important to note that these regulatory designations that were established in the 1980s and 1990s do not exactly match the current conditions of these reaches within this watershed.[9] For example, despite the West Branch Agricultural Ditch's regulatory warmwater and coldwater fish classifications described above, this reach is actually considered a Cool Water (Warm Transition Headwater) fishery based upon water temperature data collected as part of this planning study. In contrast, the East Branch of Mason Creek actually meets the coldwater trout stream standard, which exceeds the quality of its current designation as a warmwater fishery. These cool and cold water designations are a more accurate depiction of these reaches within this stream system and how they function, which are supported by both the biological and water quality observations. Although these revised classifications lack the regulatory significance of the designated uses shown on Map 2.2, these revised classifications will be used to guide the assessment and management recommendations in this plan (see "Biological Monitoring" section below for more details). In addition, WDNR staff identified that the lower 3.1 mile section of Mason Creek has not supported the potential coldwater community designation since 1995.[10]

Surface Water Quality Criteria

Water quality standards also specify certain criteria that must be met to ensure that the designated uses of waterbodies are supported. These water quality criteria are statements of the physical, chemical, and biological characteristics of the water that must be maintained if the water is to be suitable for the designated uses. Some criteria are limits or ranges of chemical concentrations that are not to be exceeded. Others are narrative standards that apply to all waters.

The applicable water quality criteria for all water uses designated in Southeastern Wisconsin are set forth in Tables 2.1 and 2.2. Table 2.1 shows the applicable water quality criteria for all designated uses for five water quality parameters—dissolved oxygen concentration, pH, fecal coliform bacteria concentration, total phosphorus concentration, and chloride concentration. It also shows the water quality criterion for temperature that applies to limited aquatic life communities. Table 2.2 shows the water quality criteria for temperature. All of the streams in the Mason Creek watershed have a seven-day consecutive low flow discharge of less than 200 cubic feet per second (cfs) with a 10-percent annual probability of occurrence,

[8] *The WDNR uses three categories to classify the different types of trout streams throughout Wisconsin. Class 1 indicates the highest quality trout waters that have sufficient natural reproduction to sustain populations of wild trout, at or near carry capacity. Consequently, streams in this category require no stocking of hatchery trout. These streams or stream sections are often small and may contain small or slow-growing trout, especially in the headwaters. There are 5,289 miles of Class 1 trout streams in Wisconsin and they comprise 40% of Wisconsin's total trout stream mileage. See website at dnr.wi.gov/topic/fishing/trout/streamclassification.html*

[9] *WDNR,* A Nonpoint Source Control Plan for the Oconomowoc River Priority Watershed Project, *1986; WDNR,* Upper Rock River Basin Water Quality Management Plan: A Five Year Plan to Protect and Enhance our Water Resources, *PUBL-WR-190-95REV, December 1995.*

[10] *WDNR, Upper Rock River Basin Water Quality Management Plan:* A Five-Year Plan to Protect and Enhance our Water Resources, *PUBL-WR-190-95REV, December 1995.*

Map 2.2
Current Regulatory Water Use Objectives for Surface Waters Within the Mason Creek Watershed: 2015

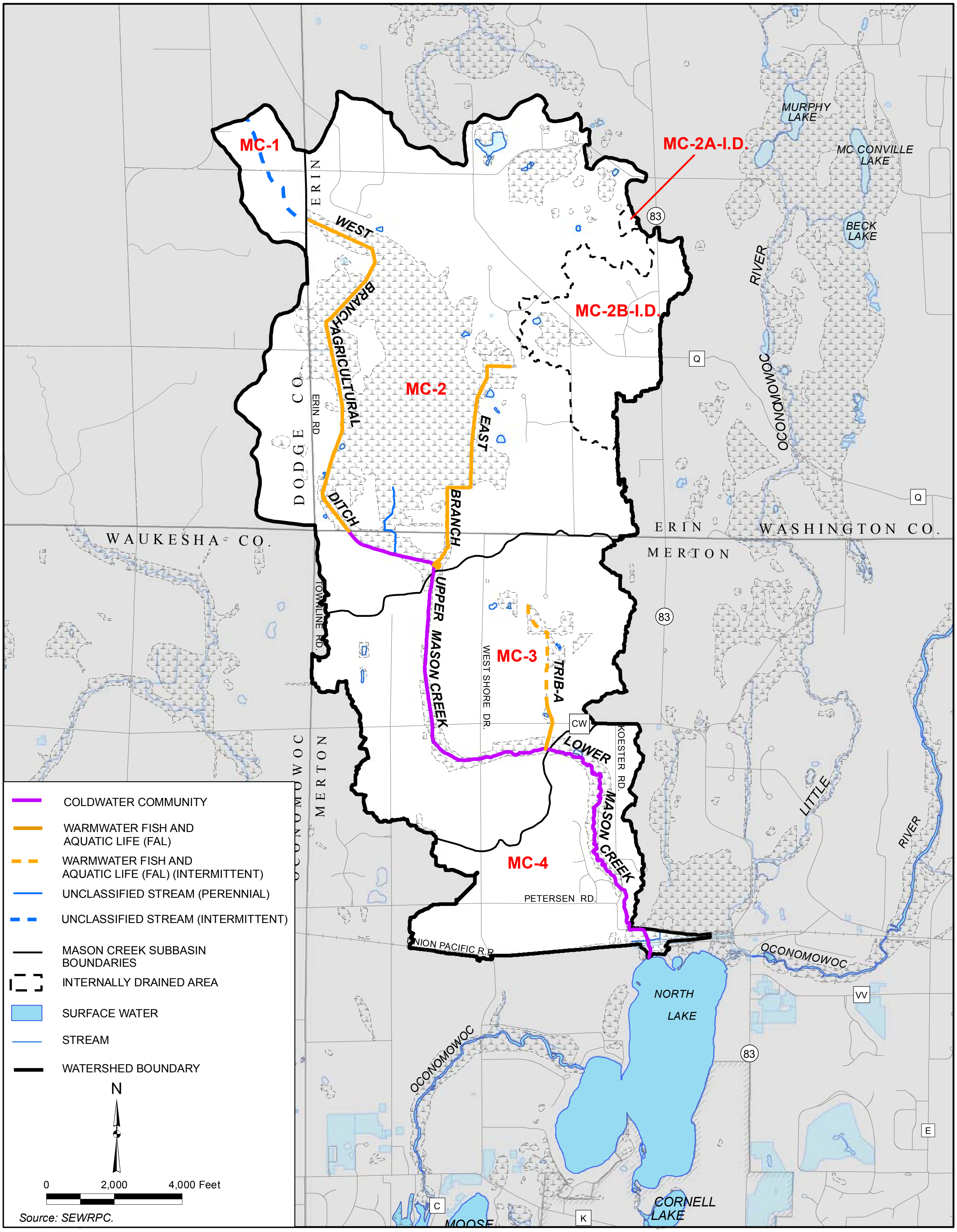


Table 2.1
Applicable Water Quality Criteria for Streams and Lakes in Southeastern Wisconsin

Water Quality Parameter	Designated Use Category[a]						Source
	Coldwater Community	Warmwater Fish and Aquatic Life	Limited Forage Fish Community (variance category)	Special Variance Category A[b]	Special Variance Category B[c]	Limited Aquatic Life Community (variance category)	
Temperature (°F)	See Table 2.2					86.0°F	NR 102 Subchapter II
Dissolved Oxygen (mg/L)	6.0 minimum 7.0 minimum during spawning	5.0 minimum	3.0 minimum	2.0 minimum	2.0 minimum	1.0 minimum	NR 102.04(4) NR 104.04(3) NR 102.06(2)
pH Range (standard units)	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	NR 102.04(4)[d]
Fecal Coliform Bacteria (MFFCC)							
Geometric Mean	200	200	200	1,000	1,000	200	NR 102.04(5)
Single Sample Maximum	400	400	400	2,000	--	400	NR104.06(2)
Total Phosphorus (mg/l)							
Designated Streams[e]	0.100	0.100	0.100	0.100	0.100	0.100	NR 102.06(3)
Other Streams	0.075	0.075	0.075	0.075	0.075	--	NR 102.06(4)
Stratified Reservoirs	0.030	0.030	0.030	0.030	0.030	--	NR 102.06(5)
Unstratified Reservoirs	0.040	0.040	0.040	0.040	0.040	--	NR 102.06(6)
Stratified Two-story Fishery Lakes	0.015	0.015	0.015	0.015	0.015	--	
Stratified Drainage Lakes	0.030	0.030	0.030	0.030	0.030	--	
Unstratified Drainage Lakes	0.040	0.040	0.040	0.040	0.040	--	
Stratified Seepage Lakes	0.020	0.020	0.020	0.020	0.020	--	
Unstratified Seepage Lakes	0.040	0.040	0.040	0.040	0.040	--	
Chloride (mg/l)							
Acute Toxicity[f]	757	757	757	757	757	757	NR 105.05(2)
Chronic Toxicity[g]	395	395	395	395	395	395	NR 105.06(5)

[a] *NR 102.04(1) All surface waters shall meet the following conditions at all times and under all flow conditions: substances that will cause objectionable deposits on the shore or in the bed of a body of water, floating or submerged debris, oil, scum, or other material, and materials producing color, odor, taste or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the State. Substances in concentrations which are toxic or harmful to humans shall not be present in amount found to be of public health significance, nor shall substances be present in amounts which are acutely harmful to animal, plant, or aquatic life.*

[b] *As set forth in Chapter NR 104.06(2)(a) of the* Wisconsin Administrative Code.

[c] *As set forth in Chapter NR 104.06(2)(b) of the* Wisconsin Administrative Code.

[d] *The pH shall be within the stated range with no change greater than 0.5 unit outside the estimated natural seasonal maximum and minimum.*

[e] *Designated in Chapter NR 102.06(3)(a) of the* Wisconsin Administrative Code. *There are no designated streams in the Jackson Creek watershed.*

[f] *The acute toxicity criterion is the maximum daily concentration of a substance which ensures adequate protection of sensitive species of aquatic life from the acute toxicity of that substance and will adequately protect the designated fish and aquatic life use of the surface water if not exceeded more than once every three years.*

[g] *The chronic toxicity criterion is the maximum four-day concentration of a substance which ensures adequate protection of sensitive species of aquatic life from the chronic toxicity of that substance and will adequately protect the designated fish and aquatic life use of the surface water if not exceeded more than once every three years.*

Source: Wisconsin Department of Natural Resources and SEWRPC

which is technically referred to as the 7Q10 low flow discharge. Thus, as indicated in Table 2.2, those streams are assigned the standards for "small warmwater communities."

In addition to the numerical criteria presented in the tables, there are narrative standards which apply to all waters. All surface waters must meet certain conditions at all times and under all flow conditions. Section NR 102.04(1) of the *Wisconsin Administrative Code* states that:

> "Practices attributable to municipal, commercial, domestic, agricultural, land development or other activities shall be controlled so that all waters including the mixing zone and the effluent channel meet the following conditions at all times and under all flow conditions:
>
> (a) Substances that will cause objectionable deposits on the shore or in the bed of a body of water shall not be present in such amounts as to interfere with public rights in the waters of the State.

Table 2.2

Ambient Temperatures and Water Quality Criteria for Temperature for Nonspecific Streams and Lakes in Southern Wisconsin[a]

Month	Cold Water Communities			Large Warmwater Communities[b]			Small Warmwater Communities[c]			Limited Forage Fish Communities[d]			Inland Lakes and Impoundments[e]		
	Ta	SL	A	Ta	SL	A	Ta	SL	A	Ta	SL	A	Ta	SL	A
January	35	47	68	33	49	76	33	49	76	37	54	78	35	49	77
February	36	47	68	33	50	76	34	50	76	39	54	79	39	52	78
March	39	51	69	36	52	76	38	52	77	43	57	80	41	55	78
April	47	57	70	46	55	79	48	55	79	50	63	81	49	60	80
May	56	63	72	60	65	82	58	65	82	59	70	84	58	68	82
June	62	67	72	71	75	85	66	76	84	64	77	85	70	75	86
July	64	67	73	75	80	86	69	81	85	69	81	86	77	80	87
August	63	65	73	74	79	86	67	81	84	68	79	86	76	80	87
September	57	60	72	65	72	84	60	73	82	63	73	85	67	73	85
October	49	53	70	52	61	80	50	61	80	55	63	83	54	61	81
November	41	48	69	39	50	77	40	49	77	46	54	80	42	50	78
December	37	47	69	33	49	76	35	49	76	40	54	79	35	49	77

Note: Acronyms for temperature criteria categories include; Ta-ambient temperature, SL-sublethal temperature, and A-acute temperature. The ambient temperature, sublethal water quality criterion, and acute water quality criterion specified for any calendar month shall be applied simultaneously to establish the protection needed for each identified fish and other aquatic life use. The sublethal criteria are to be applied as the mean daily maximum temperature over a calendar week. The acute criteria are to be applied as the daily maximum temperature. The ambient temperature is used to calculate the corresponding acute and sublethal criterial and for determining effluent limitations in discharge permits under the Wisconsin Pollutant Discharge Elimination System.

[a] *As set forth in Section NR 102.25 of the* Wisconsin Administrative Code.

[b] *Waters with a fish and aquatic life use designation of "warmwater sportfish community" or "warmwater forage fish community" and unidirectional 7Q10 flows greater than or equal to 200 cubic feet per second. The 7Q10 flow is the seven-day consecutive low flow with a 10 percent annual probability of occurrence (10-year recurrence interval).*

[c] *Waters with a fish and aquatic life use designation of "warmwater sportfish community" or "warmwater forage fish community" and unidirectional 7Q10 flows less than 200 cubic feet per second. The 7Q10 flow is the seven-day consecutive low flow with a 10 percent annual probability of occurrence (10-year recurrence interval).*

[d] *Waters with a fish and aquatic life use designation of "limited forage fish community."*

[e] *Values are applicable for those lakes and impoundments south of STH 10.*

Source: Wisconsin Department of Natural Resources

(b) Floating or submerged debris, oil, scum or other material shall not be present in such amounts as to interfere with public rights in the waters of the State.

(c) Materials producing color, odor, taste, or unsightliness shall not be present in such amounts as to interfere with public rights in the waters of the State.

(d) Substances in concentrations or combinations which are toxic or harmful shall not be present in amounts found to be of public health significance, nor shall such substances be present in such amounts as to interfere with public rights in the waters of the State."

Other Water Quality Guidelines

There are several water quality constituents for which the State of Wisconsin has not developed official water quality criteria. For many of these constituents, it would be useful to have some guidelines that could be used to evaluate what particular values of these constituents indicate regarding the quality of surface waters. Table 2.3 sets forth guidelines for several water quality constituents. These guidelines are drawn from a variety of sources including the Rock River Total Maximum Daily Load (TMDL) study,[11] studies conducted in support of the development of water quality criteria for the State of Wisconsin,[12] and studies presenting recommendations to states and tribes for water quality criteria development.[13] These sources consist of work completed by the USEPA and WDNR or studies conducted by the USGS on behalf of the WDNR. Table 2.3 combines information from all these sources to provide preferred guidelines for evaluating additional water quality constituents. These guidelines were developed specifically for Wisconsin and, in some cases, southeastern Wisconsin.

Three different types of guidelines are shown in Table 2.3: TMDL target concentrations, recommended water quality criteria, and reference values. A TMDL target concentration represents a goal set by a TMDL study. It is a concentration or value of a constituent that defines acceptable water quality. A recommended water quality criterion is a scientific assessment of the effects of a water quality constituent on human health or aquatic life. Only when a recommended criterion is adopted by a state, tribe, or territory or promulgated by USEPA does it become the relevant standard for developing permit limits, assessing waters, and developing TMDLs. Finally, a reference value is a scientific assessment of the potential level of water quality that could be achieved in the absence of human activities. Unless they are adopted by the State or promulgated by USEPA as water quality criteria, these guidelines have no regulatory impact. Instead they serve as indicators of where the division between good and poor water quality lies and can be used to serve as proxies in lieu of adopted water quality criteria to better understand water quality conditions within the Mason Creek watershed.

TMDL Requirements

Under the Federal Clean Water Act, states are required to develop Total Maximum Daily Loads (TMDLs) to address impaired waterbodies that are not meeting water quality standards. A TMDL includes both a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards and an allocation of that load among the various sources of that pollutant. The TMDL must also account for seasonal variations in water quality and include a margin of safety to account for uncertainty in predicting how well pollutant reductions will result in meeting water quality standards.

A TMDL allocates the allowable load between a wasteload allocation for point sources such as municipal wastewater treatment plants, industrial dischargers, concentrated animal feeding operations, and municipal separate storm sewer systems (MS4s); a load allocation for nonpoint sources such as agricultural sources,

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[11] *U.S. Environmental Protection Agency and Wisconsin Department of Natural Resources, Total Maximum Daily Loads for Total Phosphorus and Total Suspended Solids in the Rock River Basin: Columbia, Dane, Dodge, Fond du Lac, Green, Green Lake, Jefferson, Rock, Walworth, Washington, and Waukesha Counties, Wisconsin, July 2011.*

[12] *D.M. Robinson, D.J. Graczyk, L. Wang, G. LaLiberte, and R. Bannerman, Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin, U.S. Geological Survey Professional Paper No. 1722, 2006.*

[13] *U.S Environmental Protection Agency,* Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria: Rivers and Streams in Nutrient Ecoregion VII, *EPA 822-B-00-018, December 2000; U.S Environmental Protection Agency,* Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria: Lakes and Reservoirs in Nutrient Ecoregion VII, *EPA 822-B-00-009, December 2000.*

Table 2.3
Guidelines for Water Quality Constituents in Southeastern Wisconsin for Which Water Quality Criteria Have Not Been Promulgated

Water Quality Parameter	Stream Guideline	Lake and Reservoir Guideline	Category	Source
Total Suspended Solids (mg/l)	26	--	TMDL target concentration	Rock River TMDL[a]
Nitrogen				
Total Nitrogen (mg/l)	0.65[b]	0.66	Streams: reference value Lakes: recommended criterion	USGS/WDNR[c] USEPA[d]
Nitrate plus Nitrite (mg/l)	0.94	0.04	Reference value	USEPA[d,e]
Total Kjeldahl Nitrogen (mg/l)	0.65	0.54	Reference value	USEPA[d,e]
Chlorophyll-*a* (µg/l)	1.50[f]	2.63	Recommended criteria	USEPA[d,e]
Transparency tube (cm)[g]	> 115	--	Reference value	USGS/WDNR[c]
Secchi Depth (m)	--	3.33[h]	Recommended criterion	USEPA[d]
Turbidity (ntu)	1.70[i]	--	Recommended criterion	USEPA[e]

[a] *U.S. Environmental Protection Agency and Wisconsin Department of Natural Resources,* Total Maximum Daily Loads for Total Phosphorus and Total Suspended Solids in the Rock River Basin: Columbia, Dane, Dodge, Fond du Lac, Green, Green Lake, Jefferson, Rock, Walworth, Washington, and Waukesha Counties, Wisconsin, *July 2011.*

[b] *This is a reference value developed by USGS and WDNR for streams for this portion of Wisconsin. It should be noted that USEPA has developed a similar reference value for the southern Wisconsin till plains area of 1.30 mg/l and a recommended criterion for Nutrient Ecoregion VII (mostly glaciated dairy region) of 0.54 mg/l.*

[c] *D.M. Robertson, D J. Graczyk, L. Wang, G. LaLiberte, and R. Bannerman,* Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin, *U.S. Geological Survey Professional Paper No. 1722, 2006.*

[d] *U.S. Environmental Protection Agency,* Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria: Lakes and Reservoirs in Nutrient Ecoregion VII, *EPA 822-B-00-009, December 2000.*

[e] *U.S. Environmental Protection Agency,* Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria: Rivers and Streams in Nutrient Ecoregion VII, *EPA 822-B-00-018, December 2000.*

[f] *This is consistent with the finding by USGS and WDNR of reference values for chlorophyll-*a *in wadeable streams in Wisconsin between 1.20 and 1.70 µg/l. It should be noted that the guideline and reference values are based upon fluorometric analysis of chlorophyll-*a *concentrations. Other values may apply for chlorophyll-*a *concentrations that were determined using other techniques.*

[g] *This is based on the use of a minimum transparency tube length of 120 cm.*

[h] *For the southern Wisconsin till plains area, the USEPA found a reference value for secchi depth of 3.19 m.*

[i] *It should be noted that the guideline and recommended criterion are based upon nephelometric analysis of turbidity. Other values may apply for turbidity determined using other techniques.*

Source: U.S. Environmental Protection Agency, U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC

urban sources not covered under a discharge permit, and natural background loads; and a margin of safety. Wasteload allocations are implemented through limits established in discharge permits under the Wisconsin Pollutant Discharge Elimination System (WPDES). Load allocations are implemented through a wide variety of Federal, State, and local programs as well as voluntary action by citizens. These programs may include regulatory, non-regulatory, or incentive-based elements, depending on the program. Implementation of load allocations is typically an adaptive process, requiring the collaboration of diverse stakeholders and the prioritization and targeting of available programmatic, regulatory, financial, and technical resources.

As part of the Rock River Basin, the Mason Creek watershed is addressed in the Rock River TMDL that was approved in 2011.[14] This TMDL addresses impairments such as oxygen depletion, nuisance algae growth, reduced populations of submerged aquatic vegetation, water clarity problems, and degraded habitat

[14] Ibid.

Table 2.4
TMDL Reach 24 (Mason Creek Watershed) Baseline Median Annual Total Phosphorus (TP) and Total Suspended Solids (TSS) Loads, Annual Load Allocations, and Target Load Reductions from the Rock River TMDL Report: 2011

Pollutant	Baseline Median Annual Nonpoint Load[a]	Annual Load Allocation[b]	Target Annual Nonpoint Load Reduction	Percent Reduction
Total Phosphorus	5,821 (lbs)	466 (lbs)	5,355 (lbs)	92
Total Suspended Solids	952 (tons)	69 (tons)	883 (tons)	93

[a] *These median values were calculated using the annual modeled nonpoint source loads for TP and TSS from 1989 to 1998 that were included in Appendix L and Appendix M of the 2011 Rock River TMDL report.*

[b] *Due to an updated watershed boundary delineation by SEWRPC staff, it was determined that the nine acre portion of the watershed within the Town of Oconomowoc does not discharge into the Mason Creek watershed. Hence, the annual load allocations do not include the 9.9 lbs/year of TP and 1.16 tons/year of TSS from the Town of Oconomowoc MS4 portion of the watershed.*

Source: USEPA, WDNR, and SEWRPC

resulting from high concentrations of total phosphorus (TP) and total suspended solids (TSS). It establishes annual baseline nonpoint source loads and target load allocations for TP and TSS in 84 subbasins of the Rock River Basin, including Subbasin 24, which is the Mason Creek watershed.

As shown in Table 2.4, **the water quality targets set forth in the Rock River TMDL report will require an estimated 92 percent reduction in TP (5,355 lbs) and 93 percent reduction in TSS (883 tons) from the median annual nonpoint baseline loads for the Mason Creek watershed.**[15] The Baseline column in Table 2.4 represents the median of the ten year annual nonpoint source TP and TSS loads for the baseline period from 1989 to 1998 in the Mason Creek basin. The target column represents the annual nonpoint TP and TSS load allocation. The percent reduction column shows the TP and TSS reduction needed for the Mason Creek basin.

Under the Federal Clean Water Act, waterbodies that do not meet the applicable water quality standards are considered impaired. Section 303(d) of the Federal Clean Water Act requires that states periodically submit a list of impaired waters to the USEPA for approval. The Wisconsin Department of Natural Resources most recently submitted this list in 2016. Impaired waters in the Mason Creek watershed are shown on Map 1.2 in Chapter 1 of this report. Mason Creek and the West Branch Agricultural Ditch of Mason Creek have been listed as impaired since 1998. The Upper and Lower sections of Mason Creek downstream of the Washington-Waukesha county line is considered impaired due to elevated water temperatures and degraded habitat resulting from high concentrations of sediment and TSS and due to low concentrations of dissolved oxygen resulting from high concentrations of total phosphorus. The West Branch Agricultural Ditch of Mason Creek upstream of the Washington-Waukesha county line is considered impaired due to elevated water temperatures and low dissolved oxygen concentrations resulting from high concentrations of sediment and TSS and due to low concentrations of dissolved oxygen resulting from high concentrations of total phosphorus. These impairments are addressed in the Rock River TMDL.[16]

It should also be noted that water from Mason Creek flows into North Lake, which was listed as impaired in the year 2014. Total phosphorus concentrations in North Lake exceed the applicable water quality criterion for total phosphorus; however, no specific biological impacts have been documented. Four additional lakes within the Oconomowoc River watershed were listed as impaired in 2014 that include: Friess Lake and Okauchee Lake for high phosphorus loads; Oconomowoc Lake for high mercury levels; and, Lac LaBelle for high polychlorinated biphenyls (PCBs) contamination (See Map 1.2).

The developers of the Rock River TMDL used two models to calculate loads of TP and TSS from nonpoint sources for all the subwatersheds in the Rock River Basin. The Soil & Water Assessment Tool (SWAT Version 98.1) was used to calculate loads from agricultural and natural areas (i.e., forests and wetlands) and the

[15] *See Appendix L and Appendix M of the 2011 Rock River TMDL report.*

[16] Ibid.

Table 2.5
Daily Total Phosphorus Allocations for Rock River Watershed Subbasin 24 from the Rock River Watershed TMDL

Allocation Component	Daily Total Phosphorus Load (pounds per day)												Annual Load Allocation (pounds per year)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Wasteload Allocation													
General Permit Sources	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Municipal Separate Storm Sewer Systems (MS4)	0.49	0.56	0.41	0.31	0.32	0.47	0.49	0.46	0.37	0.32	0.33	0.36	148.23
Waste Water Treatment Facility (WWTF)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal	0.49	0.56	0.41	0.31	0.32	0.47	0.49	0.46	0.37	0.32	0.33	0.36	148.23
Load Allocation													
Background	0.00	0.01	0.02	0.03	0.03	0.04	0.03	0.05	0.03	0.04	0.01	0.01	9.16
Ag/Non-Permitted Urban	0.33	0.79	1.13	1.63	1.67	1.47	0.90	0.61	0.52	0.51	0.34	0.27	308.94
Subtotal	0.33	0.80	1.15	1.66	1.70	1.51	0.93	0.66	0.55	0.55	0.35	0.28	318.10
Total Loading Capacity	0.82	1.36	1.56	1.97	2.02	1.98	1.42	1.12	0.92	0.87	0.68	0.64	466.33

Note: The MS4 allocation component only includes pollutant loads associated with the Town of Merton, because it was established that the nine acres of the Town of Oconomowoc MS4 does not discharge into Mason Creek. The Rock River TMDL study included the nine acres in the Town of Oconomowoc in the Mason Creek watershed.

Source: U.S Environmental Protection Agency and Wisconsin Department of Natural Resources

Source Loading and Management Model (SLAMM version 9.4, PV & Associates, 2009) was used to calculate loads from urban areas. Modeled pollutant loadings indicated that over the course of an average year, agricultural lands are the source of the majority of TP and TSS in the Rock River Basin. Wastewater treatment facilities (WWTFs) contribute a significant amount of TP, but relatively little TSS. Loads of TSS and TP from natural background sources, urban areas, and facilities covered under general permits represent a small fraction of the total load. More specifically, unit-area nonpoint source loading of 1.454 pounds per acre and 0.238 tons per acre, of TP and TSS, respectively, were calculated based on SWAT for Subbasin 24. The breakdown of daily TP and TSS loading capacity and allocations for Subbasin 24 are shown in Tables 2.5 and 2.6, respectively.

The TP loading capacity for Subbasin 24 was calculated as the load that will produce the monthly target concentration of 0.075 mg/l in approximately seven out of 10 years. This target frequency was selected to ensure that loading capacity is not driven by high or low flows, but that water quality targets are met under most flow conditions. It should be noted that this monthly compliance rate will attain summer median targets in approximately 9 out of 10 years. Wasteload allocations are given for three classes of point sources: point sources covered under a Statewide WPDES general permit, MS4s, and WWTFs. The annual wasteload allocation for this subbasin is 148.23 pounds of phosphorus. Relative to the Mason Creek watershed, two aspects of the wasteload allocation should be kept in mind. First, there are currently no permitted WWTFs within the watershed. Second, there are currently no facilities that discharge to waters of the watershed under a Statewide WPDES general permit. The consequence of this is that the annual wasteload allocations for WWTFs and general permit sources are both 0 pounds of phosphorus. The Rock River TMDL report identified that there were two MS4s that discharged into waters located in the Mason Creek watershed. However, as part of the watershed boundary assessment in this study, it was determined that the nine acres of the Town of Oconomowoc MS4 does not discharge into the Mason Creek basin. Therefore, the MS4 allocation component as shown in Tables 2.5 and 2.6 for phosphorus and total suspended sediment, respectively, only includes pollutant loads associated with the Town of Merton (i.e., the Town of Oconomowoc MS4 allocation was not included). The annual wasteload allocation for the Town of Merton's MS4 is 148.23 pounds of phosphorus. Load allocations for the Mason Creek watershed are given in Table 2.5 for two

Table 2.6
Daily Total Suspended Solids Allocations for Rock River Watershed Subbasin 24 from the Rock River Watershed TMDL

Allocation Component	Daily Total Suspended Solids Load (pounds per day)												Annual Load Allocation (pounds per year)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Wasteload Allocation													
General Permit Sources	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Municipal Separate Storm Sewer Systems (MS4)	0.09	0.09	0.04	0.03	0.03	0.05	0.04	0.04	0.04	0.03	0.03	0.07	17.30
Waste Water Treatment Facility (WWTF)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal	0.09	0.09	0.04	0.03	0.03	0.05	0.04	0.04	0.04	0.03	0.03	0.07	17.30
Load Allocation													
Background	0.01	0.02	0.01	0.03	0.03	0.02	0.01	0.01	0.01	0.02	0.01	0.01	5.76
Ag/Non-Permitted Urban	0.14	0.26	0.18	0.19	0.19	0.16	0.08	0.06	0.06	0.06	0.05	0.10	46.19
Subtotal	0.15	0.28	0.19	0.22	0.22	0.18	0.09	0.07	0.07	0.08	0.06	0.11	51.95
Total Loading Capacity	0.24	0.37	0.23	0.25	0.25	0.23	0.13	0.11	0.11	0.11	0.09	0.18	69.25

Note: The MS4 allocation component only includes pollutant loads associated with the Town of Merton, because it was established that the nine acres of the Town of Oconomowoc MS4 does not discharge into Mason Creek. The Rock River TMDL study included the nine acres in the Town of Oconomowoc in the Mason Creek watershed.

Source: U.S Environmental Protection Agency and Wisconsin Department of Natural Resources

classes of nonpoint sources: an allocation for natural background sources and a combined allocation for agricultural sources and urban sources that are not required to be covered under a WPDES discharge permit. The annual load allocation for this subbasin is 318.10 pounds of phosphorus.
Table 2.6 shows the daily TSS loading capacity and allocations. The TSS loading capacity for Subbasin 24 was calculated using monthly regression equations from the Rock River Basin SWAT model to determine the TSS load that is typically associated with the total phosphorus loading capacity. The annual wasteload allocation for this subbasin is 17.30 tons of total suspended solids. Because there are currently no permitted WWTFs or dischargers permitted under a Statewide WPDES general permit located in this watershed, the annual wasteload allocations for WWTFs and general permit sources are both 0 tons of tons of suspended solids. Load allocations for Subbasin 24 are given in Table 2.6 for two classes of nonpoint sources: an allocation for natural background sources and a combined allocation for agricultural sources and urban sources that are not required to be covered under a WPDES discharge permit. The annual load allocation for this subbasin is 51.95 tons of total suspended solids.

The daily loading capacities and allocations shown in Tables 2.5 and 2.6 vary by month of the year. This reflects the fact that average total phosphorus and TSS loading varies substantially among months of the year. This variation is primarily driven by seasonal patterns in precipitation and vegetative cover that influence runoff and erosion rates. These same seasonal patterns also affect stream flow, which is the basis for pollutant assimilative capacity. To account for these patterns, calculations of loading capacity given in the tables are based on monthly patterns in stream flow, and the allocation of loads among sources is based on monthly variation in their relative contribution to current loads.

Meeting the water quality targets set in the Rock River TMDL report will require substantial reductions from the current MS4 and nonpoint source loading within the Mason Creek watershed. This will require an average monthly percent reduction from the annual baseline loads of total phosphorus of 11 percent and 39 percent for the Town of Merton MS4 and nonpoint sources, respectively.[17] It will also require an average

[17] *See Appendix H of the 2011 Rock River TMDL report.*

monthly percent reduction from the annual baseline loads of total suspended solids of 12 percent and 43 percent for the Town of Merton MS4 and nonpoint sources, respectively.[18]

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 permits with oversight from the USEPA. There are four types of WPDES permits: Individual, General, Storm water, and Agricultural.

Individual permits are issued to municipal and industrial waste water treatment facilities that discharge to surface and/or groundwater. WPDES permits include limits that are consistent with the approved TMDL wasteload allocations. Facilities are required to report phosphorus and sediment loads to the WDNR in Discharge Monitoring Reports (DMR). However, there are no WPDES permit holders that discharge in the Mason Creek watershed. Less than four percent of the watershed is located in a planned sanitary sewer service area as shown on Map 2.3. That area is directly adjacent to North Lake within the Town of Merton, but it is important to note that there is no public sanitary service currently within this area. If sanitary sewers were to be installed in this area, it would be served by the City of Oconomowoc wastewater treatment plant (see www.oconomowoc-wi.gov/271/Sanitary-Sewer-Collection-System/). The City operates and maintains the system of collection sewers and lift stations, which serves the City of Oconomowoc and seven sanitary districts. The City owns, operates, and maintains the wastewater treatment facilities and discharges into the Oconomowoc River, which, as shown on Map 1.2, are well downstream of the Mason Creek watershed.

To meet the requirements of the Federal Clean Water Act, the WDNR developed a permit program under Chapter NR 216, "Storm Water Discharge Permits," of the *Wisconsin Administrative Code*. An MS4 permit is required for a municipality that is either located within a Federally-designated urbanized area, has a population of 10,000 or more, or is designated for permit coverage by the WDNR. Municipal permits require stormwater management programs to reduce polluted stormwater runoff by implementing best management practices. Chapter NR 216 also requires certain types of industries in the State to obtain stormwater discharge permits from the WDNR, but there are no industrial stormwater permits issued in the Mason Creek watershed. The general permit requires an MS4 holder to develop, maintain, and implement stormwater management programs to prevent pollutants from the MS4 from entering State waters. Examples of stormwater best management practices used by municipalities to meet permit conditions include detention basins, street sweeping, filter strips, bioretention facilities, and rain gardens.

The Town of Merton is the only designated MS4 community in the watershed. The permit requires the Town to reduce polluted stormwater runoff by implementing stormwater management programs with best management practices. Waukesha County is currently designated as an MS4, but there are no County facilities covered under that permit that are located within the Mason Creek watershed. Nonetheless, the Town of Merton entered into an intergovernmental agreement with County for Stormwater Management Planning in March 2008. The Town and County work cooperatively to create urban storm water public education messages as well as to develop and enforce construction and post-construction site pollution control ordinances.

State and Federal laws also require that Concentrated Animal Feeding Operations (CAFOs) have Wisconsin Pollutant Discharge Elimination System (WPDES) 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 a navigable water or groundwater. Permits for CAFOs require that the production area has zero discharge. There are currently no permitted CAFOs in the watershed.

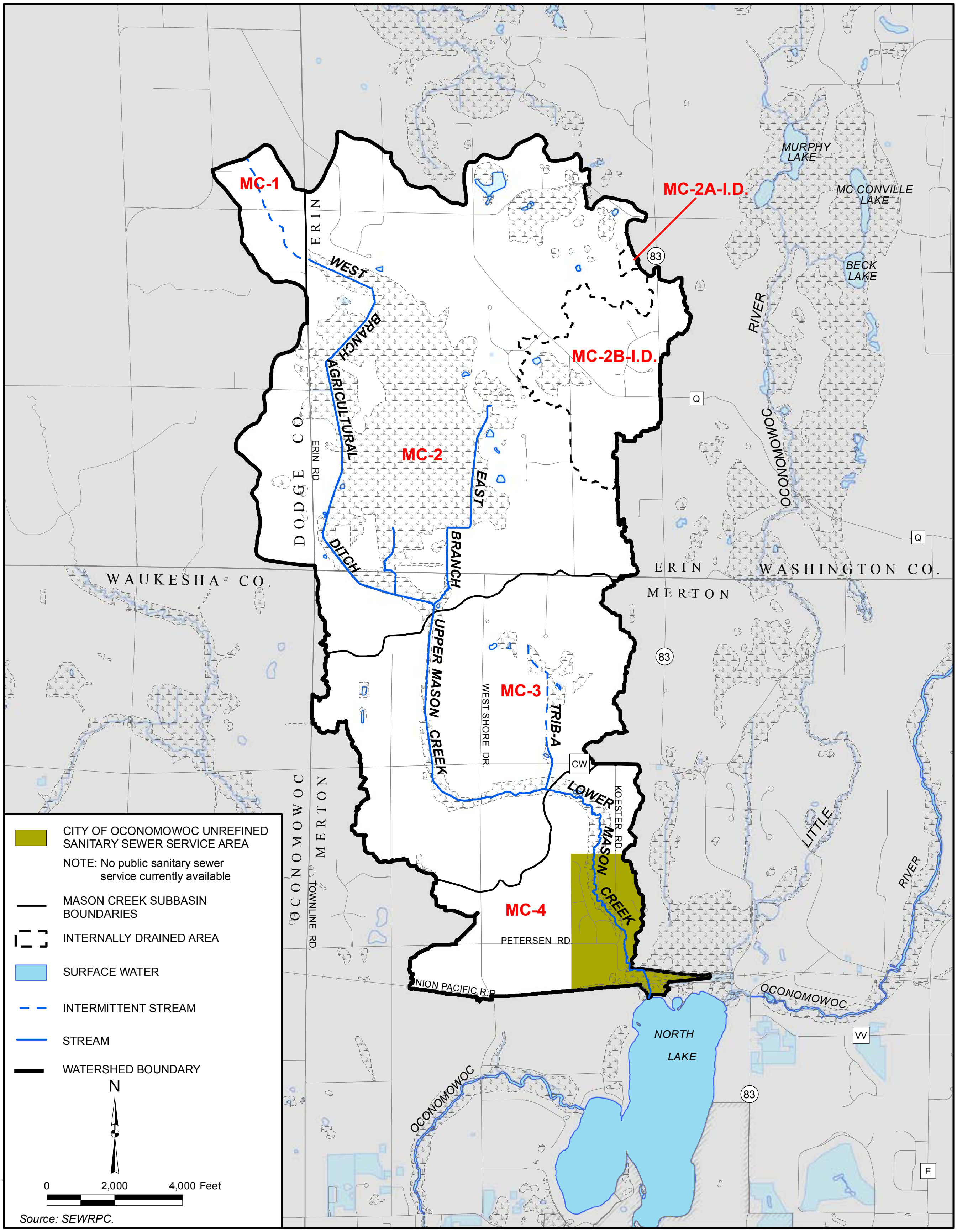
Nonpoint Sources

SEWRPC Regional Water Quality Management Plan

The initial adopted regional water quality management plan, completed in 1979 by the Southeastern Wisconsin Regional Planning Commission, identified that diffuse or nonpoint agricultural pollution, and to a lesser extent urban sources of pollution, comprised the greatest proportion of the annual load in the

[18] *See Appendix I of the 2011 Rock River TMDL report.*

Map 2.3
Planned Sanitary Sewer Service Area Within the Mason Creek Watershed: 2015



Source: SEWRPC.

Rock River Basin based upon conditions in 1975.[19] More specifically, agricultural nonpoint sources were estimated to contribute 88 percent of the total nitrogen, 55 percent of the total phosphorus, 81 percent of the biochemical oxygen demand (BOD), 96 percent of the fecal coliform, and 58 percent of the total suspended sediment annual loads. The initial plan generally recommended nonpoint source pollution control practices for both rural and urban lands designed to reduce the pollutant loadings from nonpoint sources by about 25 percent, in addition to urban construction erosion control, streambank erosion control, and onsite sewage disposal system management. Finally, this plan also recommended that detailed local-level nonpoint source control plans be developed to identity appropriate pollution control practices.

WDNR Oconomowoc River Priority Watershed Program

The Oconomowoc River watershed, which includes Mason Creek, was selected in 1983 as a priority watershed under the Wisconsin Nonpoint Source Water Pollution Abatement Program. Priority watersheds were selected because of the severity of water quality problems in the watershed, the importance of controlling nonpoint sources in order to attain water quality standards, and the capability and willingness of local government agencies to carry out the planning and implementation of projects. An Oconomowoc River Priority Watershed Plan was completed in 1986 in cooperation with local units of government, Washington and Waukesha Counties, WDNR, and SEWRPC.[20] The upland erosion inventory conducted through the Oconomowoc River Priority Watershed project showed that more than 95 percent of the soil loss occurring in this watershed was from rural lands and the estimated upland erosion load being delivered from the Mason Creek subwatershed was 2,134 tons per year based on 1980 land use conditions. Of this total load, it was estimated that approximately 50 percent of the phosphorus load were contributed directly by agricultural runoff, which was the single largest pollutant source.[21] Hence, Mason Creek was determined to be one of the major sources of pollutant loads to North Lake and it was determined that a 65 percent reduction in the total phosphorus load was needed to effect any significant change in the trophic status in North Lake.[22]

The Oconomowoc River priority watershed plan identified specific actions necessary to reduce the water quality problems related to nonpoint sources in the watershed; tasks necessary to carry out the actions presented in the plan; and the agencies responsible, and time frame, for completing those tasks.[23] The project implementation phase was carried out from 1984 through 1995 and included the following elements:[24]

- Provision of streambank erosion control practices for selected sites
- Preparation of detailed conservation plans to develop management practices on cropland with high soil losses
- Installation of facilities and management practices for problem barnyards
- Installation of facilities and management practices for selected livestock operations to change manure spreading practices

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[19] *SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan For Southeastern Wisconsin: 2000, Volumes One through Three, *1978 and 1979.*

[20] *Wisconsin Department of Natural Resources, Washington County Land Conservation Committee, Waukesha County Land Conservation Committee, Jefferson County Land Conservation Committee, in cooperation with University of Wisconsin-Extension, USDA Soil Conservation Service, USDA Agricultural Conservation and Stabilization Service, and the Southeastern Wisconsin Regional Planning Commission,* A Nonpoint Source Control Plan for the Oconomowoc River Priority Watershed Project, Publication *WR-194-86, Madison, Wisconsin, 1986.*

[21] Ibid.

[22] Ibid.

[23] *Note that pollutant loads and load reduction goals were established and specific recommendations to implement nonpoint source pollution control in both rural and urban areas were identified in the Water Quality Management Plan for North Lake (SEWRPC Community Assistance Planning Report No. 54,* A Water Quality Management Plan for North Lake, Waukesha County, Wisconsin, July 1982*); however, the contribution of the Mason Creek watershed to pollutant loads to the Lake was not included in that plan.*

[24] *Wisconsin Department of Natural Resources,* Upper Rock River Basin Water Quality Management Plan, *Publication WR-190-88, Wisconsin, May 1989; Wisconsin Department of Natural Resources,* Upper Rock River Basin Water Quality Management Plan: A Five-Year Plan to Protect and Enhance our Water Resources, *Publication WR-190-95REV, December 1995.*

- Implementation of construction site erosion controls, institution of public information and education programs on nonpoint source pollution abatement, and institution of sound urban best management practices

Since the 1980s various projects to reduce nonpoint pollution loads within the Mason Creek watershed have been implemented, including reduced tillage, nutrient management plans, grass waterways, wetland restoration, riparian buffers (see "Upland Inventory" section below), construction site erosion control, and stormwater management practices. These projects have led to a reduction in the overall pollution loads to Mason Creek and North Lake. However, as summarized above, the Rock River TMDL study verified that the majority of pollution in the Mason Creek watershed still comes from nonpoint sources. Agriculture is still the dominant land use in the Mason Creek watershed and modelling conducted for this watershed protection plan indicates that cropland accounts for 60 percent of total nitrogen, 73 percent of total phosphorus, 49 percent of BOD, and 66 percent of total suspended sediment nonpoint source loads as summarized in the STEPL load analysis documented in Appendix B. Other significant nonpoint pollutant sources in the watershed include pasture lands, feedlots, gullies, streambanks, and impervious surfaces associated with urban lands (see Appendix B for more details).

Nonpoint Source Regulations

In 2010, new State regulations went into effect in Wisconsin that restrict the use, sale, and display of turf fertilizer that is labeled as containing phosphorus or available phosphate (Wis.Stats.94.643) The law states that turf fertilizer that is labeled as containing phosphorus or available phosphate cannot be applied to residential properties, golf courses, or publicly owned land that is planted in closely mowed or managed grass. The exceptions to the rule are as follows:

- Fertilizer that is labeled as containing phosphorus or available phosphate can be used for new lawns during the growing season in which the grass is established

- Fertilizer that is labeled as containing phosphorus or available phosphate can be used if the soil is deficient in phosphorus, as shown by a soil test performed by a soil testing laboratory no more than 36 months before the fertilizer is applied

- Fertilizer that is labeled as containing phosphorus or available phosphate can be applied to pastures, land used to grow grass for sod, or any other land used for agricultural production

In 2010, the State also placed restrictions on the sale of some phosphorus-containing cleaning agents.[25] Wisconsin also has State standards pertaining to agricultural runoff. Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* describes agricultural performance standards and prohibitions. Chapter NR 151 describes regulations relating to phosphorus index, manure storage and management, nutrient management, soil erosion, and tillage setback, as well as implementation and enforcement procedures for the regulations.

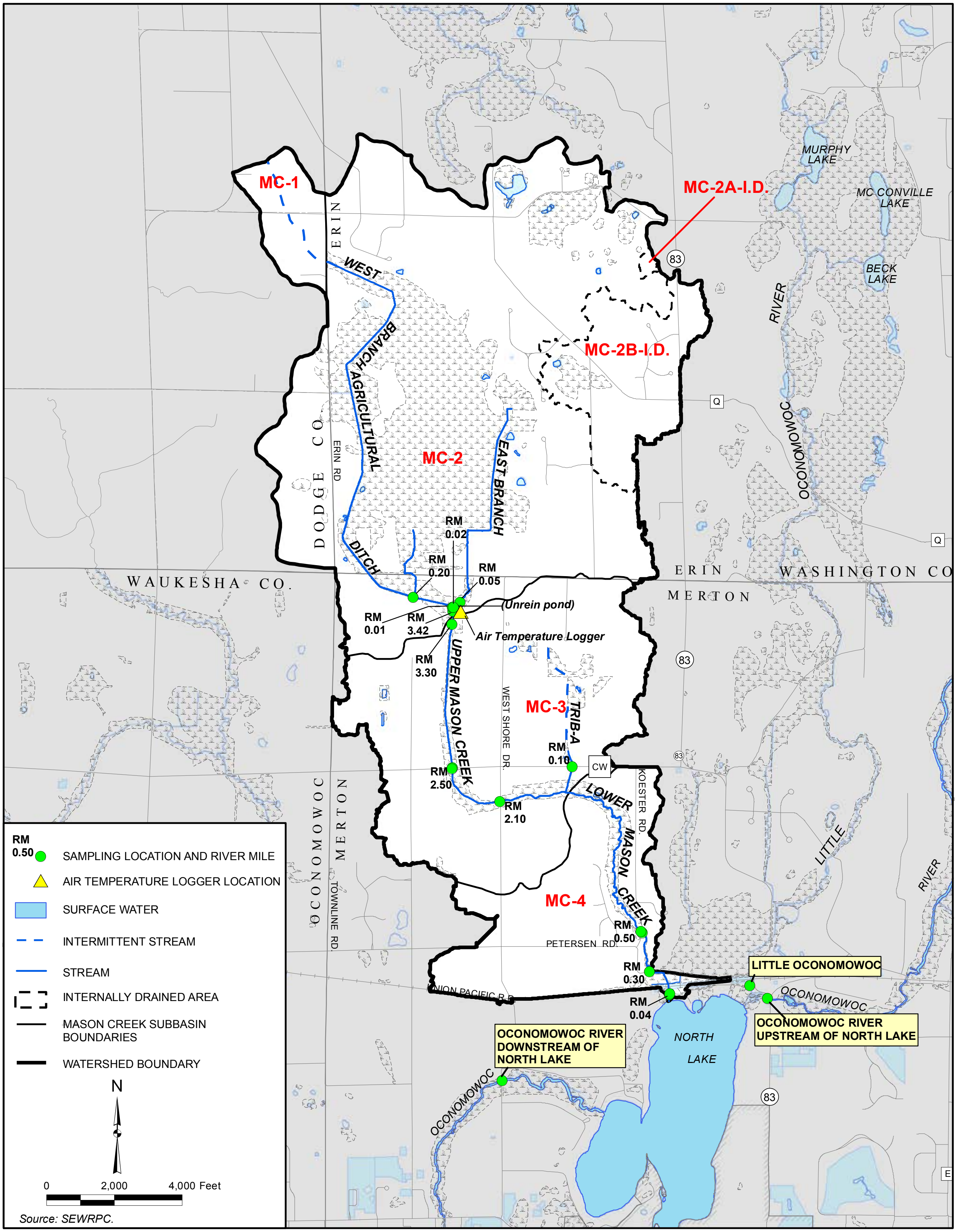
Water Quality Monitoring

Water quality information summarized in this section includes data collected at 13 sampling sites throughout the Mason Creek watershed by the WDNR, the University of Wisconsin-Milwaukee, the University of Wisconsin-Extension Water Action Volunteers Program (WAV), the City of Oconomowoc, and SEWRPC. Water quality monitoring sites in the Mason Creek watershed are shown on Map 2.4 and described in Table 2.7. The water quality monitoring efforts included several different parameters collected over the last seven years.

Several things should be kept in mind regarding the data available for evaluating water quality in the Mason Creek watershed. The data were collected by several agencies and organizations for a variety of purposes as part of a number of different studies. Each of these studies assessed a different group of water quality constituents. For some constituents, this means that data are only available for some portions of the watershed.

[25] *Section 100.28 of the* Wisconsin Statutes *bans the sale of cleaning agents for nonhousehold dishwashing machines and medical and surgical equipment that contain more than 8.7 percent phosphorus by weight. This statute also bans the sale of other cleaning agents containing more than 0.5 percent phosphorus by weight. Cleaning agents for industrial processes and dairy equipment are specifically exempted from these restrictions.*

Map 2.4
Water Chemistry and Temperature Monitoring Stations Within the Mason Creek Watershed: 2009-2014



Source: SEWRPC.

Table 2.7
Water Quality Sampling Stations Within the Mason Creek Watershed: 2009-2014

Stream	Subbasin	River Mile (see Map 2.4)[a]	Location	Source of Data	Site Identification	Period of Record
East Branch headwaters	MC-2	0.05	W. Shore Drive at farm field road	UW-Milwaukee	UWM-6	9/15/2011 – 8/17/2012
		0.01	22 feet upstream from Upper Mason Creek	SEWRPC	SEWRPC-G	5/31/2013 – 8/11/2014
West Branch drainage ditch	MC-2	0.20	Private land (Morris Farm)	UW-Milwaukee	UWM-7	6/8/2012
		0.01	22 feet upstream from Upper Mason Creek	SEWRPC	SEWRPC-E	5/31/2013 – 8/11/2014
Upper Mason Creek	MC-3	3.42	Mason Creek downstream of East Branch	SEWRPC	SEWRPC-D	5/31/2013 – 8/11/2014
		3.30	Concrete Bridge at W. Shore Drive	UW-Milwaukee	UWM-5	9/15/2011 – 8/17/2012
		2.50	CTH CW	City of Oconomowoc	Ocon-2	4/30/2014 – 8/12/2014
				SEWRPC	SEWRPC-C	5/31/2013 – 8/11/2014
				UW-Milwaukee	UWM-4	9/15/2011 – 8/17/2012
				WDNR	10016883	4/7/2014
		2.10	W. Shore Drive (south of CTH CW)	UW-Milwaukee	UWM-3	9/15/2011 – 8/17/2012
Lower Mason Creek	MC-4	0.50	Koester Road	SEWRPC	SEWRPC-B	5/31/2013 – 8/11/2014
				UW-Milwaukee	UWM-2	9/15/2011 – 8/17/2012
		0.30	Petersen Road	Water Action Volunteers	WAV-2	4/17/2009 – 7/11/2014
				WDNR	10038441	5/7/2012 – 9/9/2012
		0.04	Northwoods Drive	City of Oconomowoc	Ocon-1	4/30/2014 – 8/12/2014
				SEWRPC	SEWRPC-A	5/31/2013 – 8/11/2014
				UW-Milwaukee	UWM-1	9/15/2011 – 8/17/2012
				Water Action Volunteers	WAV-1	7/28/2011 – 8/13/2014
Trib-A	MC-3	0.10	CTH CW at Farm	UW-Milwaukee	UWM-8	9/15/2011 – 8/17/2012
Private Pond	MC-2	--	Pond	SEWRPC	SEWRPC-F	5/31/2013 – 8/11/2014

[a] *For sites on Mason Creek, the river mile is the distance upstream from the confluence with North Lake. For tributaries to Mason Creek, the river mile is the distance upstream from the confluence with Mason Creek.*

Source: SEWRPC

Each study also sampled for a different period. These periods range from a single sample collected at a site, through samples collected over a season, to long-term sampling programs that collected data for five years. Some sampling stations have been used by multiple agencies or in multiple studies (see Table 2.7). While the use of multiple data sources has extended the period of record at these stations, it should be kept in mind that differences among studies in the constituents sampled may allow for fewer time-based comparisons than would be expected based purely on the length of the period of record.

Water Quality Conditions

In the analyses that follow, distributions of water quality data are shown using box plots to illustrate changes among stations from upstream to downstream over three time periods between 2009 and 2014. Figure 2.5 shows an example of the symbols used in box plots. In this type of graph, the horizontal center line within the box marks the location of the median—the value above which and below which half the data lie. Along with the median, the two ends of the box mark the locations of the quartile divisions. These ends indicate the values of the 25th and 75th percentile of the data. These three divisions divide the distribution into four quartiles that each contain one quarter of the instances. The length of the box shows the range of the central 50 percent of the instances. This is known as the interquartile range. The "whiskers" extending from the box show the range of instances that are within 1.5 box-lengths from the 25th or 75th percentile lines of the box (*i.e.,* within lengths 1.5 times the interquartile range from the upper and lower boundaries of the box). Stars indicate outliers that are more than 1.5 box-lengths but less than three box-lengths from the box. Open circles indicate extreme values that that lie more than three box-lengths from the box.[26]

It is important to recognize that water quality monitoring has not been conducted within the Mason Creek watershed for a long enough period of time to assess long-term trends and changes in conditions. Most of the stations where water chemistry has been sampled have periods of record shorter than 16 months. The 14-month period of record for continuous monitoring of water temperature is also short. It is also important to note that collection of data for some constituents was restricted to only one or a few sampling stations. For example, the concentration of total suspended solids was assessed only at those sites monitored by the University of Wisconsin-Milwaukee (see Table 2.7). Due to these limitations, the water quality data presented in this report constitute "a snapshot in time" to define existing conditions within surface waters of the Mason Creek watershed. Due to the lack of historical data, the available water chemistry data are not sufficient to assess whether these existing conditions are similar to or different from historical conditions.

For this study, dissolved oxygen, pH, total phosphorus, total nitrogen, total suspended solids, suspended sediment concentration, specific conductance, chlorophyll-*a*, turbidity, and water temperature parameters were used to assess water quality conditions in Mason Creek and its tributary streams. These water quality constituents are defined and discussed in the subsections that follow.

Additional information regarding the levels of compliance with water quality criteria and water use objectives in the Mason Creek watershed is provided later in this section in the "Summary" subsection.

<u>Dissolved Oxygen</u>

The concentration of dissolved oxygen in water is a major determinant of the suitability of a waterbody as habitat for fish and other aquatic organisms because most aquatic organisms require oxygen to survive. Though tolerances vary by species, most aquatic organisms have minimum oxygen requirements. For example, common carp (*Cyprinus carpio*) are very tolerant of concentrations of dissolved oxygen below 2.0 mg/l and can survive at concentrations below 1.0 mg/l.[27] Bluegill, on the other hand, depend on water with dissolved oxygen concentrations above 5.0 mg/l.[28]

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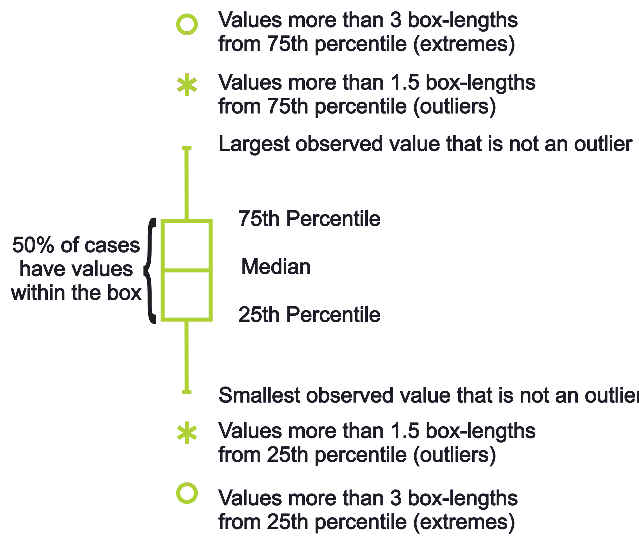
[26] *Different statistical analysis software packages and statistical graphics software packages follow different conventions in the construction of box plots. In all conventions, the ends of the box represent the values of the 25th and 75th percentile and the box itself indicates the interquartile range. The conventions differ in what is represented by the ends of the whiskers. The box plots presented in this report follow the conventions used in the SYSTAT, version 13, software package.*

[27] *U.S. Fish and Wildlife Service,* Habitat Suitability Index Models: Common Carp, *1982.*

[28] *U.S. Fish and Wildlife Service,* Habitat Suitability Index Models: Bluegill, *1982.*

Sources of dissolved oxygen in water include diffusion of oxygen from the atmosphere and photosynthesis by aquatic plants and suspended and benthic algae. Processes that remove dissolved oxygen from water include diffusion of oxygen to the atmosphere, respiration by aquatic organisms, and bacterial decomposition of organic material in the water column and sediment. Several factors can influence these processes, including the availability of light, the clarity of the water, the presence of aquatic plants, the presence of organic material in water or sediment, and the amount of water turbulence. Water temperature has a particularly strong effect for two reasons. First, the solubility of most gasses in water decreases with increasing temperature. Thus as water temperature increases, the water is able to hold less oxygen. Second, the metabolic demands of organisms and the rates of oxygen-demanding processes, such as bacterial decomposition of organic substances, increase with increasing temperature. As a result, the demands for oxygen in waterbodies tend to increase as water temperature increases.

Figure 2.5
Explanation of Symbols Used in Box-Plot Graphs



Source: SEWRPC.

Concentrations of dissolved oxygen in surface waters typically show a strong seasonal pattern that is driven by seasonal changes in water temperature. Highest concentrations usually occur during the winter. Concentrations decrease through the spring to reach a minimum during summer. Concentrations rise through the fall to reach maximum values in winter. Because the warmest water temperatures occur in the summer, this is the most important time of the year for determining physiological limitations for aquatic organisms based on dissolved oxygen concentrations. Dissolved oxygen concentrations in some waterbodies may also show daily fluctuations in which high concentrations occur during daylight due to photosynthesis and lower concentrations occur during periods of darkness when photosynthesis ceases and respiration increases.

As previously discussed, the minimum dissolved oxygen criterion for coldwater streams such as Mason Creek downstream from the Washington-Waukesha county line is 6.0 milligrams per liter (mg/l) during most of the year and 7.0 mg/l during the spawning season. For warmwater FAL streams such as Mason Creek upstream from the Washington-Waukesha county line and Mason Creek's tributaries, the minimum dissolved oxygen criterion is 5.0 mg/l (see Table 2.1).

Between 2009 and 2014, dissolved oxygen concentrations in Mason Creek ranged between 1.10 and 15.50 mg/l, with a mean value of 9.57 mg/l. Figure 2.6 shows dissolved oxygen concentrations at several sampling stations along the Creek. Dissolved oxygen concentrations were above the State water quality criterion for coldwater streams of 6.0 mg/l in almost all of samples collected. Dissolved oxygen concentrations in a few samples were below the spawning season water quality criterion of 7.0 mg/l. None of the samples in which dissolved oxygen concentrations were below 7.0 mg/l were collected during the spawning season.

Concentrations of dissolved oxygen in Mason Creek appear to be higher and more variable at downstream stations than at upstream stations (Figure 2.6). This may be an artifact of differences in the numbers of samples collected at each station. At each of the upstream stations located at the concrete bridge site, CTH CW, W. Shore Drive, and Koester Road, dissolved oxygen concentrations were assessed in only five to six samples. By contrast, over 30 samples were collected and assessed for dissolved oxygen concentrations at each of the downstream stations at Petersen Road and Northwoods Drive. This is partially related to the periods of record at these stations. Sampling was conducted at the four upstream stations over periods ranging between 11 and 15 months. The periods of record at the downstream stations were longer: 37 months at Northwoods Drive and 63 months at Petersen Road. The longer periods of record and larger numbers of samples at the downstream stations probably give a better characterization of the variability of dissolved oxygen concentrations in the stream.

Figure 2.6
Dissolved Oxygen Concentrations at Water Quality Sampling Stations Along Mason Creek: 2009-2014

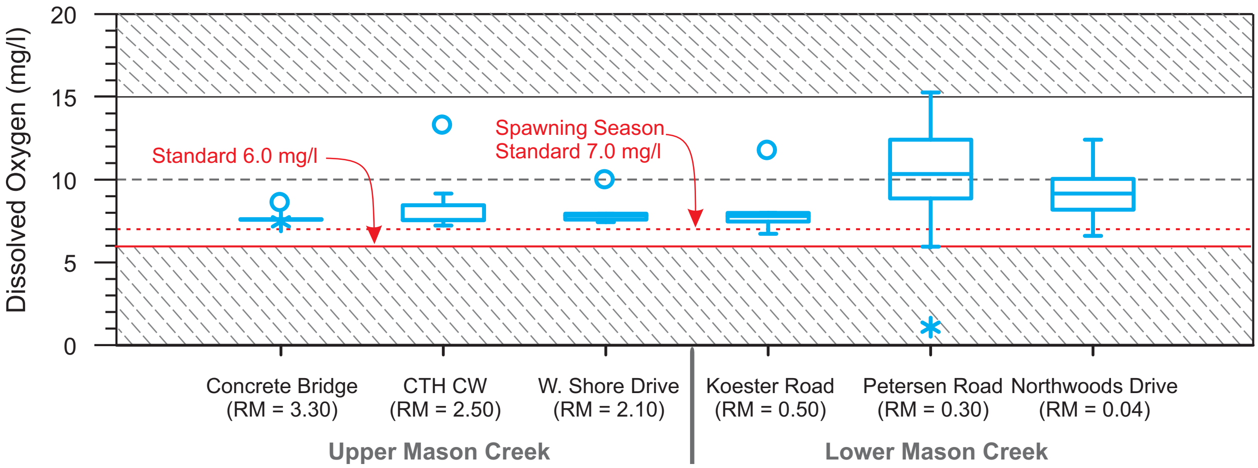
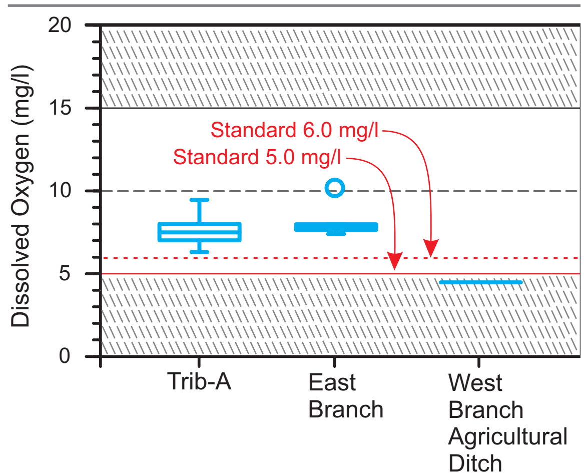


Figure 2.7 shows dissolved oxygen concentrations in three streams tributary to Mason Creek: Trib-A, which crosses CTH CW just prior to discharging into Mason Creek; the East Branch; and the West Branch Agricultural Ditch of Mason Creek. Concentrations of dissolved oxygen in Trib-A ranged between 6.30 mg/l and 9.46 mg/l with a mean value of 7.63 mg/l. Concentrations of dissolved oxygen in the East Branch ranged between 7.40 mg/l and 10.10 mg/l with an mean value of 8.12 mg/l. Dissolved oxygen concentrations in all of the samples collected from these streams were above the State's water quality criterion for warmwater streams (5.0 mg/l) and coldwater streams (6.0 mg/l), except for the West Branch Agricultural Ditch. The West Branch Agricultural Ditch only had one sample collected in June 2012, but that sample only achieved 4.5 mg/l and saturation of 52 percent. This site was not sampled again in August 2012 because there was not enough discharge to collect a proper sample.[29] This site was sampled previously in 1983. Although concentrations did not fall below 5.0 mg/l, they were never as high as the 6.0 mg/l concentration recommended for trout, and dissolved oxygen saturations were low (54-67 percent). Hence, although the number of observations are limited, dissolved oxygen concentrations in the West Branch Agricultural Ditch were at or below the applicable State water quality criterion of 5.0 mg/l for warmwater streams and never achieved the coldwater streams criterion of 6.0 mg/l. These low concentrations limit the availability of these portions of the stream for use by trout or other fish and other aquatic organisms. The low dissolved oxygen concentrations may be related to decomposition of organic matter in the sediment through chemical and biological processes, which removes oxygen from the overlying water.

Figure 2.7
Dissolved Oxygen Concentrations in Tributaries Within the Mason Creek Watershed: 2011-2014



NOTE: See Figure 2.5 for description of symbols. See Table 2.7 and Map 2.4 for locations of sample sites.

Saturation levels of dissolved oxygen of 140 percent and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: University of Wisconsin-Milwaukee and SEWRPC.

pH

The acidity of water is measured using the pH scale. This is defined as the negative logarithm of the hydrogen ion (H+) concentration, which is referred to as the standard pH unit or standard units (stu). It is important to

[29] *Personal Communication, Dr. Jerry Kaster, UW-Milwaukee faculty, June 2015.*

note that each unit of the scale represents a change of a factor of 10. Thus the hydrogen ion concentration associated with a pH of 6.0 stu is 10 times the hydrogen ion concentrations associated with a pH of 7.0 stu. A pH of 7.0 stu represents neutral water. Water with pH values lower than 7.0 stu has higher hydrogen ion concentrations and is more acidic, while water with pH values higher than 7.0 stu has lower hydrogen ion concentrations and is less acidic.

Many chemical and biological processes are affected by pH. The solubility and availability of many substances are influenced by pH. For example, many metals are more soluble in water with low pH than they are in water with high pH. In addition, the toxicity of many substances to fish and other aquatic organisms can be affected by pH. Different organisms are capable of tolerating different ranges of pH, with most preferring ranges between about 6.5 and 8.0 stu. For example, carp, suckers, and catfish generally prefer a pH range between 6.0 and 9.0 stu, although carp have been reported to tolerate water with pH values as low as 5.4 stu.[30] Sunfish, such as bass and crappies, prefer a narrower pH range between about 6.5 and 8.5 stu. Snails, clams, and mussels which incorporate calcium carbonate into their shells require higher pH values. Typically, they tolerate a range between about 7.5 and 9.0 stu. Some aquatic invertebrates prefer relatively narrow pH ranges. For example, many mayfly, stonefly, and caddisfly nymphs prefer water with pH values between 6.5 and 7.5 stu. Other aquatic invertebrates are able to tolerate much wider pH ranges. For example, mosquito larvae have been reported as living in natural waters with pH as low as 2.4 stu.[31]

Several factors influence the pH of surface waters. Because of diffusion of carbon dioxide into water and associated chemical reactions, rainfall in areas that are not impacted by air pollution has a pH of about 5.6 stu. The pH of rainfall in areas where air quality is affected by oxides of nitrogen or sulfur tends to be lower. The mineral content of the soil and bedrock underlying a waterbody has a strong influence on the waterbody's pH. Because much of the Mason Creek watershed is underlain by carbonate bedrock such as dolomite, pH in the waterbodies of the watershed tends to be between about 7.0 and 9.0 stu. Pollutants contained in discharges from point sources and in stormwater runoff can affect a waterbody's pH. Photosynthesis by aquatic plants, phytoplankton, and algae can cause pH variations both on a daily and seasonal basis.

Figure 2.8 shows pH at several sampling stations along Mason Creek. Over the period of record, the pH in the Creek ranged between 6.6 and 8.3 stu, with a mean value of 7.5 stu. Values of pH in all samples were within the range of 6.0 stu to 9.0 stu specified in Wisconsin's water quality criteria (see Table 2.1). At all of the sampling stations, most values of pH varied by less than $\pm$ 1.0 stu from the station's mean value.

Water in the Trib-A and East Branch tributaries was slightly more acidic than the samples in Mason Creek. The values of pH in Trib-A ranged between 6.5 and 7.2 stu with a mean value of 6.9 stu. The values of pH in the East Branch ranged between 6.5 and 7.9 stu with a mean value of 7.2 stu. Values of pH in all samples collected from these reaches were within the range of 6.0 stu to 9.0 stu specified in Wisconsin's water quality criteria (see Table 2.1). At all of the sampling stations, most values of pH varied by less than $\pm$ 1.0 stu from the station's mean value.

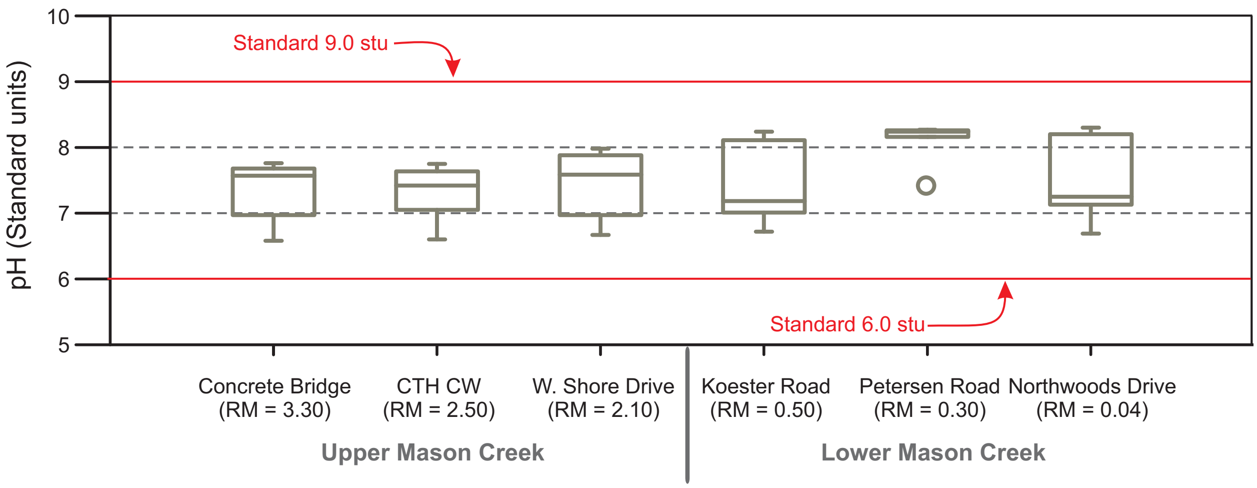
Chloride

Chlorides of commonly occurring elements are highly soluble in water and are present in some concentration in all surface waters. Chloride is not decomposed, chemically altered, or removed from the water as a result of natural processes. Natural chloride concentrations in surface water reflect the composition of the underlying bedrock and soils, and deposition from precipitation events. Waterbodies in southeastern Wisconsin typically have very low natural chloride concentrations due to the dolomite bedrock found in the Region. These rocks are rich in carbonates and contain little chloride. Because of this, the sources of chloride to surface waters in the Mason Creek watershed are largely anthropogenic, including sources such as salts used on streets, highways, and parking lots for winter snow and ice control; salts discharged from water softeners; and salts from treated wastewater and animal wastes. Because of the high solubility of chloride in water, if chloride is present, stormwater discharges are likely to transport it to receiving waters. High concentrations of chloride can affect aquatic plant growth and pose a threat to aquatic organisms. Impacts from chloride contamination

[30] *J.E. McKee and H.W. Wolf,* Water Quality Criteria (second edition), *California State Water Quality Control Board, Publication No. 3-A, 1963.*

[31] *J.B. Lackey, "The Flora and Fauna of Surface Waters Polluted by Acid Mine Drainage,"* Public Heath Reports, Washington, *Volume 53, pages 1499-1507, 1938.*

Figure 2.8
pH at Water Quality Sampling Stations Along Mason Creek: 2009-2014



NOTE: See Figure 2.5 for description of symbols. See Table 2.7 and Map 2.4 for locations of sample sites.

Source: Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, and SEWRPC.

begin to manifest at a concentration of about 250 milligrams per liter and become severe at concentrations in excess of 1,000 milligrams per liter.[32] The State of Wisconsin has promulgated two water quality criteria for chloride: an acute toxicity criterion and a chronic toxicity criterion (Table 2.1). Under the acute toxicity criterion, the maximum daily concentration of chloride is not to exceed 757 mg/l more than once every three years. Under the chronic toxicity criterion, the maximum four-day concentration of chloride is not to exceed 395 mg/l more than once every three years.

Chloride monitoring was conducted at one station in Lower Mason Creek at River Mile 0.30 at Petersen Road as part of a special study in partnership with WAV and the U.S. Geological Survey (USGS) over the period from 2012 through 2015. Five chloride measurements were taken ranging from a minimum of 16.8 mg/l to a maximum of 46.5 mg/l, with a mean of 30 mg/l. However, as part of this WAV and USGS study, 44 specific conductance measurements were taken to be used as a surrogate to infer trends in chloride concentrations in Mason Creek. The specific conductance measurements ranged from a minimum of 360 microSiemens per centimeter (μS/cm) to a maximum of 980 μS/cm and a calculated mean of 766 μS/cm. Based upon the specific conductance measurements it was estimated that there is an approximate mean chloride concentration of 150 mg/l in Mason Creek, which is below the acute and chronic state standards.

The measured and estimated concentrations of chloride reported for Mason Creek are below the applicable water quality criteria. However, the available chloride data set is not adequate for assessing trends in chloride concentrations over time in surface waters in the Mason Creek watershed. Despite this limitation it may be possible to infer likely trends in chloride concentrations from those occurring in other surface waters of the Southeastern Wisconsin Region and the Rock River Basin. Long-term trends toward increasing chloride concentrations have been documented in surface waters of the Region. These increases have been detected in several stream and river systems[33] and several lakes.[34] Long-term trends toward increasing chloride concentrations have also been documented in the Yahara Lakes, which are located in the Rock River

[32] *Frits van der Leeden, Fred L. Troise, and David Keith Todd,* The Water Encyclopedia, Second Edition, *Lewis Publishers, Inc., 1990.*

[33] *For example, see SEWRPC Technical Report No. 39,* Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds, *November 2007; SEWRPC Community Assistance Planning Report No. 316,* A Restoration Plan for the Root River Watershed, *July 2014.*

[34] *For example see SEWRPC Community Assistance Planning Report No. 315,* A Water Resources Management Plan for the Village of Chenequa, Waukesha County, Wisconsin, *June 2014.*

Basin.[35] Finally, there is some evidence that chloride concentrations may be increasing in shallow groundwater, which is the source of baseflow for streams and lakes.[36] This widespread trend toward increasing chloride concentrations in surface waters suggests that it is likely that chloride concentrations are increasing in surface waters throughout the Mason Creek watershed. As previously noted, important sources of chlorides to lakes and streams in southeastern Wisconsin are anthropogenic in origin, and include salts used on streets and highways for winter snow and ice control, salts discharged from water softeners, and salts from treated wastewater and animal wastes.

Because winter deicing activities are a major contributor of chlorides to the environment, it would be expected that chloride concentrations in streams such as Mason Creek would vary seasonally, with highest concentrations occurring during and after winter storm events and during periods of snowmelt in the winter and spring. This pattern has been observed in other streams. In two highly urbanized streams in the Menomonee River watershed, chloride concentrations as inferred from measurements of specific conductance reached levels known to be highly toxic to aquatic organisms during the winter deicing season on several occasions.[37] It should be noted that, because of its high solubility, chloride can enter, and accumulate in, groundwater. This can result in contributions of chlorides to streams through inputs of groundwater-derived baseflow. These contributions can occur throughout the year. During low streamflow periods in particular, they may cause instream chloride concentrations to be elevated.

Therefore, given these concerns and the high probability that chloride concentrations will continue to increase in both surface water and shallow groundwater within the Mason Creek watershed, the concentration of chloride in Mason Creek is an important issue of concern.

<u>Specific Conductance</u>

Conductance measures the ability of water to conduct an electric current. Because this ability is affected by water temperature, conductance values are corrected to a standard temperature of 25ºC (77º Fahrenheit). This corrected value is referred to as specific conductance. Pure water is a poor conductor of electrical currents and exhibits low values of specific conductance. For example, distilled water produced in a laboratory has a specific conductance in the range of 0.5 to 3.0 microSiemens per centimeter, a very low value. The ability of water to carry a current depends upon the presence of ions in the water, and on their chemical identities, total concentration, mobility, and electrical charge. Solutions of many inorganic compounds, such as salts, are relatively good conductors. As a result, specific conductance gives a measure of the concentration of dissolved solids in water, with higher values of specific conductance indicating higher concentrations of dissolved solids.

Under certain circumstances, measurements of specific conductance may act as a useful surrogate for measurements of the concentrations of particular dissolved materials. For example, as noted in the "Chloride" subsection above, measurements of specific conductance were used to give indications of chloride concentrations within Mason Creek as part of a special WAV and USGS study. Due to the presence of a linear relationship between specific conductance and chloride concentrations,[38] ambient chloride concentrations can be estimated using specific conductance. The advantage to this is that specific conductance can be measured inexpensively in the field using a hand-held meter. Measurements of chloride concentrations require chemical analysis. However, it should be noted that estimates from this sort of regression model should be interpreted with caution. A comparison of the chloride concentrations predicted by the USGS regression model to actual chloride concentrations in samples collected from the Root River found that the regression model usually predicted higher concentrations based upon specific conductance than were observed in the River.[39] Hence,

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[35] *Richard C. Lathrop, "Chloride and Sodium Trends in the Yahara Lakes,"* Research Management Findings, *No. 12, Wisconsin Department of Natural Resources, June 1988; Rick Wenta and Kristi Sorsa,* Road Salt – 2013*, Public Health Madison and Dane County, January 3, 2014.*

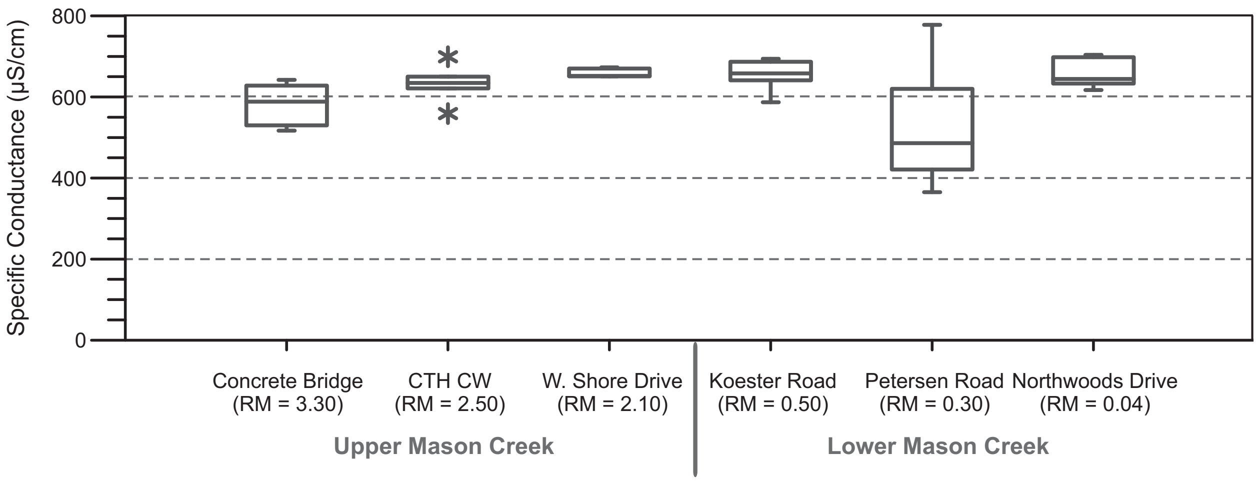
[36] *SEWRPC Community Assistance Planning Report No. 316*, op. cit.

[37] *Corsi, S.R., D.J. Graczyk, S.W. Geis, N.L. Booth, and K. D. Richards, "A Fresh Look at Road Salt: Aquatic Toxicity and Water-Quality Impacts on Local, Regional, and National Scales,"* Environmental Science & Technology, Volume 44, 2010.

[38] *Steven R. Corsi, David J. Graczyk, Steven W. Geis, Nathaniel L. Booth, and Kevin D. Richards, "A Fresh Look at Road Salt: Aquatic Toxicity and Water Quality Impacts on Local, Regional, and National Scales,"* Environmental Science & Technology, Volume 44. 2010.

[39] *SEWRPC Community Assistance Planning Report No. 316,* op. cit.

Figure 2.9
Specific Conductance at Water Sampling Stations Along Mason Creek: 2009-2014



NOTE: See Figure 2.5 for description of symbols. See Table 2.7 and Map 2.4 for locations of sample sites.

Source: University of Wisconsin-Milwaukee, University of Wisconsin-Extension, and SEWRPC.

periodic collection of chloride data along with specific conductance measurements could be helpful in refining the regression relationship.

Over the period of record from 2009 through 2014, specific conductance among sampling stations in Mason Creek ranged between 365 microSiemens per centimeter (µS/cm) and 778 µS/cm, with a median value of 628 µS/cm as shown in Figure 2.9. The values of specific conductance show a trend toward increasing from upstream to downstream between the concrete bridge (RM 3.30) and Koester Road (RM 0.50) sampling stations, with median values increasing from 588 µS/cm at the concrete bridge station to 658 µS/cm at the Koester Road station. Given that samples were generally collected at these four stations on the same dates, it is likely that this is not an artifact of sampling. This increase may reflect inputs of dissolved material from runoff or the sources along the length of the stream. Monitoring results for Trib-A, the East Branch, and the West Branch Agricultural Ditch generally showed that specific conductance was similar to the range of values observed within the mainstem of Mason Creek.

Nutrients

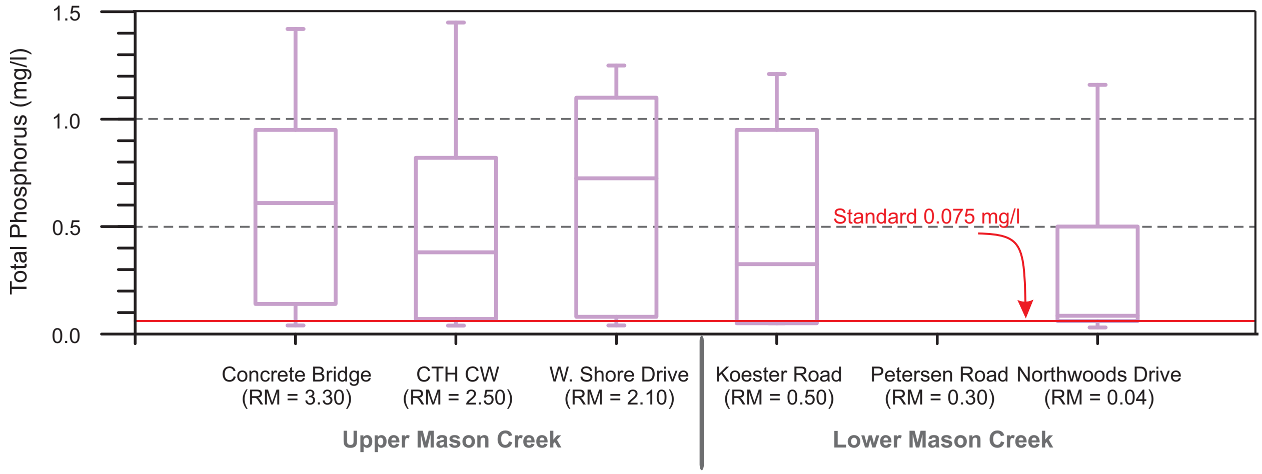
Nutrients are elements and compounds needed for plant and algal growth. They are often found in a variety of chemical forms, both inorganic and organic, which may vary in their availability to plants and algae. Typically, plant and algal growth and biomass in a waterbody are limited by the availability of the nutrient present in the lowest amount relative to the organisms' needs. This nutrient is referred to as the limiting nutrient. Additions of the limiting nutrient to the waterbody typically result in additional plant or algal growth. Phosphorus is usually, though not always, the limiting nutrient in freshwater systems. Under some circumstances nitrogen can act as the limiting nutrient.

Sources of nutrients to waterbodies include both sources within the waterbody and sources in the contributing watershed. Within a waterbody, mineralization of nutrients from sediment, resuspension of sediment in the streambed, erosion of the streambed and banks, and decomposition of organic material can contribute nutrients. Nutrients can also be contributed by point and nonpoint sources within the watershed.

Phosphorus

As noted above, phosphorus is usually, though not always, the limiting nutrient in freshwater systems. One form has been sampled in surface waters of the Mason Creek watershed: total phosphorus, which consists of all of the phosphorus contained in material dissolved or suspended in water. Total phosphorus consists of a variety of chemical forms of phosphorus that may vary in their availability to plants and algae. Because the degree of eutrophication in freshwater systems generally correlates more strongly with total phosphorus concentration than with the concentrations of other fractions such as dissolved phosphorus

Figure 2.10
Total Phosphorus Concentrations at Water Quality Sampling Stations Along Mason Creek: 2009-2014



NOTE: See Figure 2.5 for description of symbols. See Table 2.7 and Map 2.4 for locations of sample sites.

Source: University of Wisconsin-Milwaukee, City of Oconomowoc, and SEWRPC.

or orthophosphate, the State's water quality criteria are expressed in terms of total phosphorus and water quality sampling tends to focus most strongly on assessing total phosphorus concentrations.

Phosphorus can be contributed to waterbodies from a variety of point and nonpoint sources. In rural settings, phosphorus from agricultural fertilizers or animal manure spread on fields may be contributed through discharges from drain tiles or direct runoff from fields into waterbodies. Phosphorus also may be contributed by poorly maintained or failing private onsite wastewater treatment systems. In urban settings, phosphorus from eroded soil, pet waste, leaves placed in the street in fall, and other sources may be discharged through storm sewer systems and through direct runoff into streams. Cross-connections between sanitary and storm sewer systems, illicit connections to storm sewer systems, and decaying sanitary and storm sewer infrastructure may contribute sanitary wastewater to waterbodies through discharges from storm sewer systems.

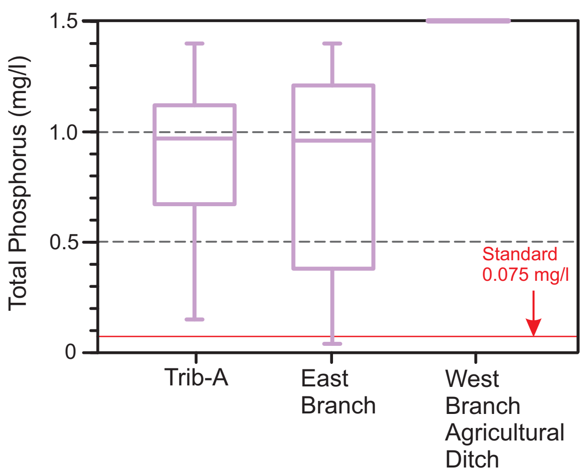
The Rock River TMDL sets a target concentration of 0.075 mg/l total phosphorus for streams in the Mason Creek watershed.[40] This reflects the fact that the applicable water quality criterion for streams of the Mason Creek watershed is that concentrations of total phosphorus are not to exceed 0.075 mg/l (see Table 2.1).

Concentrations of total phosphorus in Mason Creek ranged from 0.030 mg/l to 1.450 mg/l with median value of 0.495 mg/l. Figure 2.10 shows total phosphorus concentrations at several sampling stations along Mason Creek. Several things are evident in this figure. Concentrations of total phosphorus were high at all sampling stations. In fact, concentrations of total phosphorus in the vast majority of samples exceeded the State's water quality criterion for total phosphorus. Concentrations at the Northwoods Drive sampling station were lower than those detected at upstream stations. The median concentration at Northwoods Drive was 0.085 mg/l, while the median concentrations at the stations farther upstream ranged between 0.325 mg/l and 0.728 mg/l. This difference may reflect the difference in period of record at these stations. Alternatively, it may reflect mixing between water at the Northwoods Drive station with water from North Lake.

Figure 2.11 shows concentrations of total phosphorus in the streams tributary to Mason Creek: Trib-A, the East Branch, and the West Branch Agricultural Ditch. Concentrations of total phosphorus in Trib-A ranged from 0.150 mg/l to 1.400 mg/l with a median value of 1.070 mg/l. Concentrations of total phosphorus in the East Branch ranged from 0.040 mg/l to 1.400 mg/l with a median value of 0.960 mg/l. Although

[40] *USEPA and WDNR, T*otal Maximum Daily Loads for Total Phosphorus and Total Suspended Solids in the Rock River Basin: Columbia, Dane, Dodge, Fond du Lac, Green, Green Lake, Jefferson, Rock, Walworth, Washington, and Waukesha Counties, Wisconsin, *prepared by the CADMUS Group, July 2011.*

Figure 2.11
Total Phosphorus Concentrations in Tributaries Within the Mason Creek Watershed: 2011-2012



NOTE: See Figure 2.5 for description of symbols. See Table 2.7 and Map 2.4 for locations of sample sites.

Source: University of Wisconsin-Milwaukee and SEWRPC.

there was only one sample collected in the West Branch Agricultural Ditch, it contained the highest concentration of total phosphorus of 1.52 mg/l that was recorded in the entire Mason Creek watershed. Among these stations, concentrations in almost all samples were higher than the State's water quality criterion for total phosphorus.

The high concentrations of total phosphorus throughout the Mason Creek stream network indicate that phosphorus is a problem and an important water quality issue throughout this watershed.

Nitrogen

A variety of nitrogen compounds that act as nutrients for plants and algae are present in surface waters. Typically, only a small number of forms of nitrogen are examined and reported in water quality sampling. Total nitrogen includes all of the nitrogen compounds and ions in dissolved or particulate form in the water. It does not include nitrogen gas, which is not usable as a nutrient by most organisms. Total nitrogen is a composite of several different compounds which vary in their availability to algae and aquatic plants and in their toxicity to aquatic organisms. Common inorganic constituents of total nitrogen include ammonia, nitrate, and nitrite. These are the forms that most commonly support algal and plant growth. Total nitrogen also includes a large number of nitrogen-containing organic compounds, such as amino acids, nucleic acids, and proteins that commonly occur in natural and polluted waters. These compounds are reported as organic nitrogen.

Nitrogen compounds can be contributed to waterbodies from a variety of point and nonpoint sources. In urban settings, nitrogen compounds from lawn fertilizers and other sources may be discharged through storm sewer systems and through direct runoff into streams. Cross-connections between sanitary and storm sewer systems, illicit connections to storm sewer systems, and decaying sanitary and storm sewer infrastructure may contribute sanitary wastewater to waterbodies through discharges from storm sewer systems. In rural settings, nitrogen compounds from chemical fertilizers and animal manure that are applied to fields may be contributed through discharges from drain tiles or direct runoff from fields into waterbodies. Nitrogen compounds may also be contributed by poorly maintained or failing private onsite wastewater treatment systems.

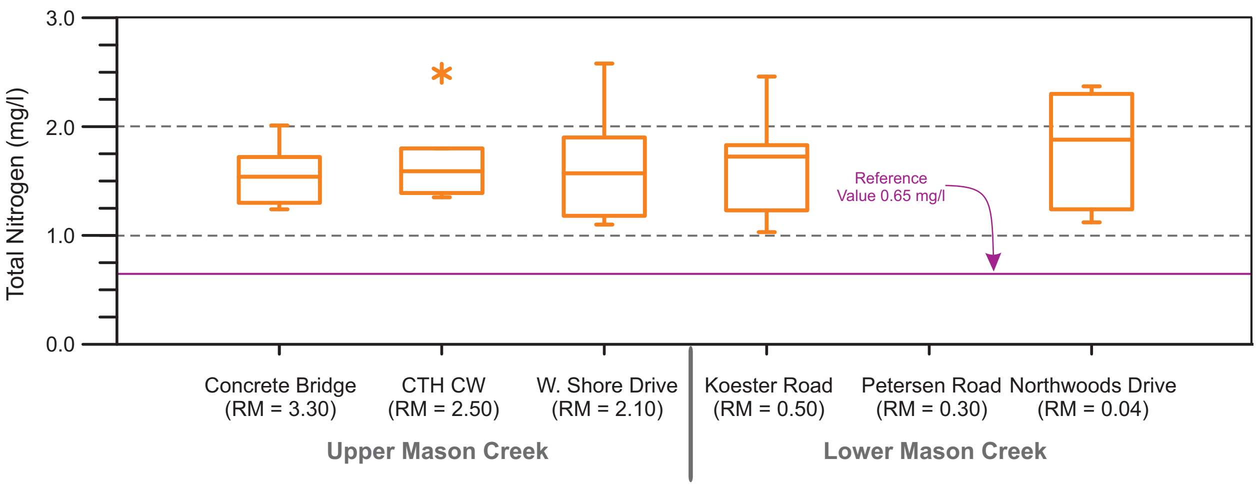
Occasionally, nitrogen acts as the limiting nutrient for algal and plant growth in freshwater systems. This usually occurs when concentrations of phosphorus are very high.

With the exception of ammonia, the State of Wisconsin has not promulgated water quality criteria for any nitrogen compounds. In the absence of specific State water quality criteria, guidelines for concentrations of total nitrogen, nitrate plus nitrite, and total Kjeldahl nitrogen that can be used to evaluate water quality conditions are shown in Table 2.3. For nitrogen compounds, these guidelines are reference values which are scientific assessments of the potential level of water quality that could be achieved in the absence of human activities. Total Kjeldahl nitrogen consists of the concentration of nitrogen in the forms of ammonia and organic nitrogen. It should be noted that Wisconsin has issued acute and chronic toxicity criteria for ammonia. The values of these criteria in any waterbody at any time depend upon the water use objective for the waterbody, the ambient temperature, and the ambient pH.

Concentrations of total nitrogen in Mason Creek ranged from 1.03 mg/l to 2.58 mg/l, with a median value of 1.71 mg/l. Figure 2.12 shows total nitrogen concentrations at sampling stations along Mason Creek. It is evident from the data that concentrations of total nitrogen in all samples collected from Mason Creek were greater than the guideline values given in Table 2.3.

Figure 2.13 shows concentrations of total nitrogen in three streams tributary to Mason Creek: Trib-A and the East and West Branch Agricultural Ditch of Mason Creek. Concentrations of total nitrogen in Trib-A ranged

Figure 2.12
Total Nitrogen Concentrations at Water Quality Sampling Stations Along Mason Creek: 2009-2014



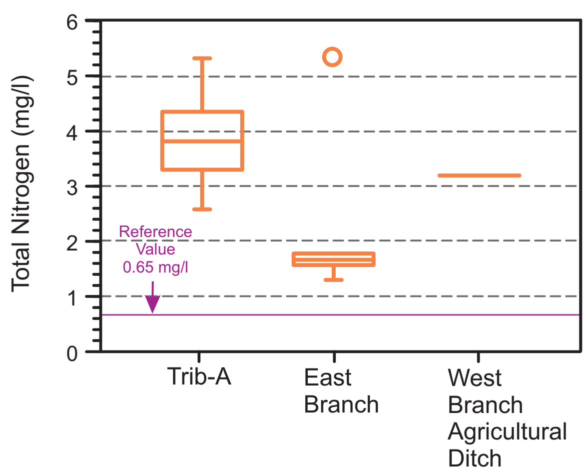
NOTE: See Figure 2.5 for description of symbols. See Table 2.7 and Map 2.4 for locations of sample sites.

Source: University of Wisconsin-Milwaukee and SEWRPC.

from 2.58 mg/l to 5.32 mg/l with a median value of 3.82 mg/l. Concentrations of total nitrogen in the East Branch ranged from 1.30 mg/l to 5.32 mg/l with a median value of 1.67 mg/l. At these stations, concentrations in all samples were higher than the guideline values given in Table 2.3. It should also be noted that concentrations of total nitrogen in Trib-A were generally higher than those found at sampling stations along the mainstem of Mason Creek (Figure 2.12).

As previously noted, total nitrogen consists of several different classes of inorganic and organic nitrogen compounds. All of these would need to be simultaneously sampled to completely characterize the existing state of nitrogen chemistry in a waterbody. This was not done for total nitrogen samples collected in the Mason Creek watershed. Because of this, nothing can be said about the relative proportions of the different chemical forms of nitrogen in samples collected from the watershed.

Figure 2.13
Total Nitrogen Concentrations in Tributaries Within the Mason Creek Watershed: 2011-2012



NOTE: See Figure 2.5 for description of symbols. See Table 2.7 and Map 2.4 for locations of sample sites.

Source: University of Wisconsin-Milwaukee and SEWRPC.

Concentrations of total nitrogen are higher in streams of the Mason Creek watershed than reference levels that indicate the potential level of water quality that could be achieved in the absence of human activities. These high concentrations indicate that nitrogen is a problem and an important water quality issue in this watershed.

Suspended Materials

Suspended material in surface waters consists of particles of sand, silt, and clay; planktonic organisms; and fine organic and inorganic debris. The composition of suspended material varies with characteristics of the watershed and pollution sources.

Energy in water motions keeps particulate material suspended in water. Because the density of these particles is greater than the density of water, they will settle out of the water in the absence of water motions such as flow or mixing. The rate at which a particle settles is a function of its size, density, and shape. In general, larger and denser particles will settle more quickly than smaller and less dense particles. Flow and mixing will keep particles suspended, with stronger flow or mixing being required to keep larger or denser particles suspended. Those properties have implications for suspended material in waterbodies. In streams, for example, higher concentrations and larger and denser particles are associated with higher water velocities—both in fast-moving sections of streams and during high flow periods. If water velocities are great enough, they may cause resuspension of sediment from the bed or erosion from the bed and banks of the stream. By contrast, deposition of suspended material may occur in slow-moving streams or during periods of low flow, with progressively smaller and lighter particles being deposited with decreasing water motions. The result of this is that concentrations of suspended material and the nature of the suspended particles in a waterbody vary, both spatially and over time.

Sources that contribute suspended material to waterbodies include sources within the waterbody and sources in the contributing watershed. Within a waterbody, resuspension of sediment in the beds of waterbodies and erosion of beds and banks can contribute suspended materials. Suspended materials can also be contributed by point and nonpoint pollution sources within the watershed. Concentrations of suspended materials in most discharges from point sources are subject to effluent limitations through the WPDES permit program that limit the concentrations and amounts of total suspended solids that can be discharged. A variety of nonpoint sources can also contribute suspended materials to waterbodies. Many BMPs for urban and rural nonpoint source pollution are geared toward reducing discharges of suspended materials.

Several different measures can be used to examine the amount of suspended materials in water. These methods differ both in the approach taken and in the characteristics actually being measured. Two measures are commonly used to assess the bulk concentration of suspended materials in water: total suspended solids (TSS) and suspended sediment concentration (SSC). Both of these are based upon weighing the amount of material retained when a sample is passed through a filter. They differ in the details of sample handling and subsampling. It is important to note that these two measures are not comparable to one another.[41] Turbidity is another measure of the amount of suspended materials in water. Turbidity measures the degree to which light is scattered as it passes through water. Higher concentrations of suspended materials in water are generally associated with greater scattering of light and have higher turbidity. A final measure is the concentration of chlorophyll-*a*, which estimates the biomass of phytoplankton suspended in the water.

Total Suspended Solids

As previously described, suspended solids consist of particles of sand, silt, and clay; planktonic organisms; and fine organic and inorganic debris suspended in the water column. High concentrations of suspended solids can cause several impacts in waterbodies. High turbidity is a result of high concentrations of suspended solids. High concentrations of suspended solids reduce the penetration of light into the water, reducing the amount of photosynthesis. In addition, suspended particles absorb more heat than water does. As a result, this can lead to an increase in water temperature in streams. Both of these effects can lead to lower concentrations of dissolved oxygen. High concentrations of suspended solids can clog the gills of fish and other aquatic organisms, stressing them physiologically—in some cases fatally. Deposition of sediments may alter the substrate, making it unsuitable as habitat for aquatic organisms, or changing channel characteristics. In addition, as a result of physical and chemical interactions, other materials may adsorb to particles suspended in water. Examples include poorly soluble organic molecules, such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and pesticides; nutrients, such as phosphate and nitrate ions; metals, such as copper and zinc ions; and microorganisms, such as bacteria and viruses. As a result, some pollutants may be carried into, or transported within, waterbodies in association with suspended material. In areas where sediment is deposited, reservoirs of these pollutants may accumulate in the sediment. While the State of Wisconsin has not promulgated water quality criteria for suspended solids, the Rock River TMDL report sets a target concentration of 26 mg/l TSS for streams in the Mason Creek watershed.[42]

Figure 2.14 shows TSS concentrations at sampling stations along Mason Creek. Concentrations of TSS in Mason Creek ranged between 4 mg/l and 509 mg/l over the period of record with a median concentration

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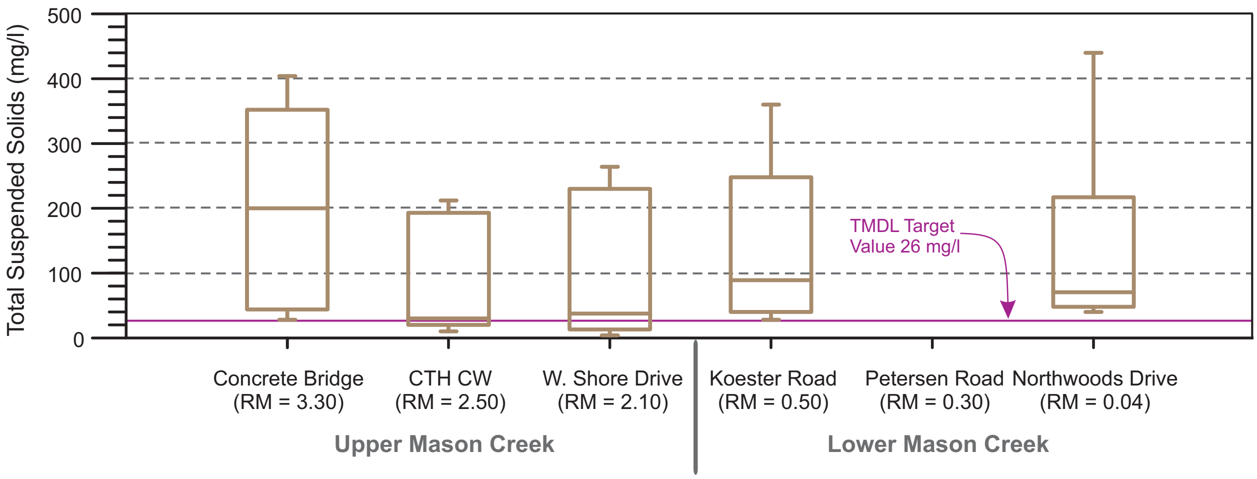
[41] *J.R. Gray, G.D. Glysson, L.M Turcios, and G.E. Schwartz,* Comparability of Suspended-Sediment Concentration and Total Suspended Solids Data, *U.S. Geological Survey Water-Resources Investigations Report No. 00-4191, 2000.*

[42] *The Cadmus Group, 2011,* op. cit.

Figure 2.14
Total Suspended Solids Concentrations at Water Quality Sampling Stations Along Mason Creek and Tributaries: 2009-2014



NOTE: See Figure 2.5 for description of symbols. See Table 2.7 and Map 2.4 for locations of sample sites.

Source: University of Wisconsin-Milwaukee and SEWRPC.

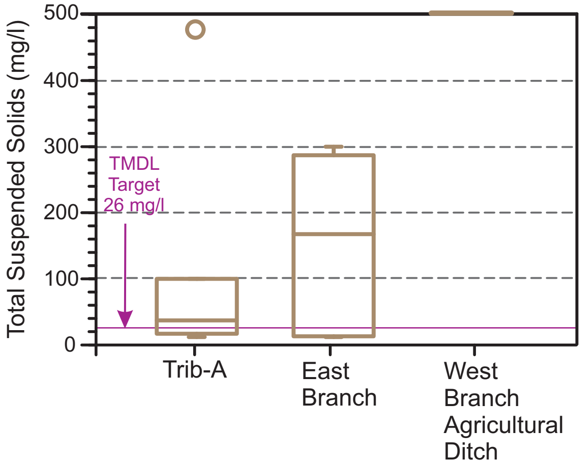
of 50 mg/l and a mean concentration of 147 mg/l. The fact that the mean concentration is higher than the median concentration indicates that the distribution of concentrations of TSS is highly skewed, with higher concentrations being relatively rare and lower concentrations being more common. When high concentrations of TSS occur, they are usually associated with high stream discharge.

Concentrations in most samples were greater than the target concentrations of 26 mg/l set by the Rock River TMDL. At most sampling stations, the Figure 2.14 shows evidence of the skewed distribution of concentrations that was discussed in the previous paragraph. The highest average and most variable concentrations of TSS were observed at the concrete bridge station (RM 3.30), which is the station farthest upstream. Lower concentrations were observed at the two stations downstream at CTH CW (RM 2.50) and W. Shore Drive (RM 2.10) from the most upstream station. These decreases in TSS are likely associated with these particles settling out of the water column in this section of the Creek. This is consistent with the sediment depth distributions observed in this reach and also consistent with the low slopes that help promote sediment deposition (see "*Stream Conditions*" section below for more details). TSS concentrations within the Lower Mason Creek reach were observed to increase downstream of the W. Shore Drive station as shown in Figure 2.14, which is consistent with an increase in channel slope and decreased sediment deposition in the stream channel.

Concentrations of TSS in nearly all samples collected from sites on Trib-A and the East and West Branch Agricultural Ditch of Mason Creek were greater than the target concentrations of 26 mg/l set under the Rock River TMDL study (see Figure 2.15). Concentrations of TSS in Trib-A ranged from 12 mg/l to 475 mg/l with a mean value of 113 mg/l and a median value of 37 mg/l. Concentrations of TSS in the East Branch ranged from 12 mg/l to 300 mg/l with a mean value of 157 mg/l and a median value of 168 mg/l. Only one sample was collected on the West Branch Agricultural Ditch of Mason Creek, but the TSS concentration was observed to be 509 mg/l. Therefore, the maximum recorded TSS concentrations observed in the Trib-A and West Branch Agricultural Ditch tributaries were the highest recorded readings in the stream network of Mason Creek.

These results help to establish that TSS is a widespread and chronic problem throughout the entire Mason Creek network, from headwaters to downstream reaches, that occurs during high discharge events as well as at baseflow conditions. These TSS observations also are consistent with the ongoing increased sediment building up at the inlet to North Lake from Mason Creek as shown in Figure 2.16.

Figure 2.15
Total Suspended Solids Concentrations in Tributaries Within the Mason Creek Watershed: 2011-2012



NOTE: See Figure 2.5 for description of symbols. See Table 2.7 and Map 2.4 for locations of sample sites.

Source: University of Wisconsin-Milwaukee and SEWRPC.

Turbidity

Turbidity is a measure of the clarity of water and is similar to TSS measurements in that high turbidity is a result of high concentrations of suspended solids. It results from light being scattered and absorbed by particles and molecules rather than being transmitted through the water. Turbid water appears cloudy. Turbidity is caused by fine material that is suspended in the water, such as particles of silt, clay, finely divided organic and inorganic material, and planktonic organisms. Colored substances that are dissolved in the water can also contribute to turbidity. There are several ways of measuring turbidity. It is often measured using a nephelometer, which is a specialized optical device that measures the amount of light scattered when a beam of light is passed through a sample. The unit of measurement for this method is called a nephelometric turbidity unit (ntu), with low values indicating high water clarity and high values indicating low water clarity. Other methods involve measuring the depth of water through which a black and white disk remains visible. For lakes and ponds, this is often done at the site using a Secchi disk. For streams this is done using a transparency tube. High turbidity can significantly reduce the aesthetic quality of lakes and streams, having a harmful impact on recreation. It reduces the penetration of light into the water, reducing the amount of photosynthesis. In addition, suspended particles absorb more heat than water does. As a result, high turbidity can lead to an increase in the water temperature in streams. Both of these effects can lead to lower concentrations of dissolved oxygen.

Turbidity can be strongly influenced by streamflow. During periods of low flow, turbidities are low, usually less than 10 ntu. During periods of high flow, water velocities are faster and water volumes are higher. This can stir up and suspend material from the streambed, causing higher turbidities. If high flows are the result of precipitation or snowmelt, particles from the surrounding land are washed into the stream. This can make the water a muddy brown color, indicating water that has higher turbidity values.

Turbidity can harm fish and other aquatic life by reducing food supplies, degrading spawning beds, and affecting gill function. It can also reduce the growth of aquatic plants. The State of Wisconsin has not promulgated water quality criteria for turbidity. For streams, the USEPA recommends that turbidity not exceed of 1.70 nephelopmetric turbidity units (ntu) (see Table 2.3).

Turbidity values at sampling stations along Mason Creek ranged from below the limit of detection to 241 ntu, with a mean value of 33.8 and a median value of 12.8 ntu. The fact that the mean concentration is higher than the median concentration indicates that the distribution turbidity is highly skewed, with higher turbidity being relatively rare and lower turbidity being more common. When high turbidity occurs, it is often associated with high stream discharge. The results from the turbidity sampling stations along Mason Creek were very similar to the TSS results as summarized above.

*Chlorophyll-*a

Chlorophyll-*a* is a pigment found in all photosynthetic organisms, including plants, algae, and photosynthetic bacteria. Measurements of chlorophyll-*a* are used to estimate the biomass of phytoplankton suspended in the water column. It is important to keep in mind that this is an estimate of the entire phytoplankton community. Chlorophyll-*a* concentration can vary depending on several factors other than the total biomass of phytoplankton present, including which species are present, the amount of light available, the ambient temperature, and nutrient availability. High concentrations of chlorophyll-*a* are indicative of poor water quality and are often associated with high turbidity, poor light penetration, and nutrient enrichment. The State of Wisconsin has not promulgated water quality criteria for chlorophyll-*a*. For streams, the USEPA recommends that chlorophyll-*a* concentrations not exceed of 1.50 micrograms per liter (μg/l) (see Table 2.3).

Figure 2.16
Mason Creek at Low Flow and High Flow Conditions at Inlet to North Lake: 2012 and 2014

LOW FLOW CONDITIONS- LOW SUSPENDED SEDIMENTS IN WATER ON SEPTEMBER 25, 2012

HIGH FLOW CONDITIONS-HIGH SUSPENDED SEDIMENTS DISCHARGING AFTER RAINFALL EVENT ON JULY 22, 2014

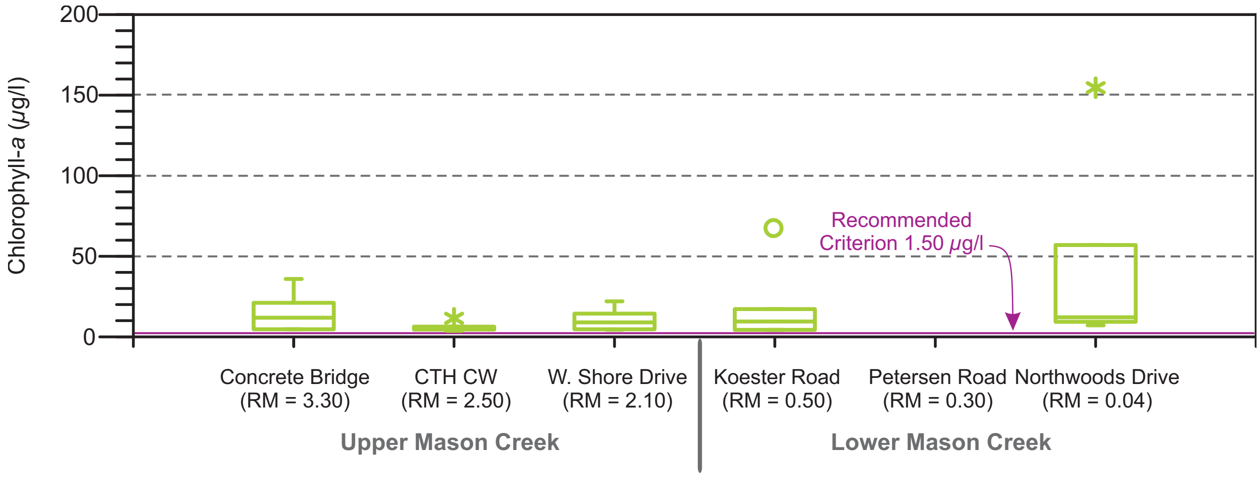
Source: North Lake Management District and SEWRPC.

Chlorophyll-*a* concentrations in Mason Creek generally ranged between 3.2 μg/l and 154.6 μg/l, with a mean value of 18.4 μg/l. Figure 2.17 shows chlorophyll-*a* concentrations at sampling stations along Mason Creek. Concentrations in all samples were greater than the guideline value given in Table 2.3. Similar concentrations and ranges of concentrations were observed at most sampling stations along the Creek. The exception to this generalization was at the Northwoods Drive station, which achieved a maximum chlorophyll-*a* concentration of 154.6 μg/l. Chlorophyll-*a* concentrations at this site were more variable and much greater than all the other sites. It is important to note that site is affected by backwater from North Lake, which likely explains the higher concentrations of chlorophyll-*a* in this portion of Mason Creek.

Similar to results above, chlorophyll-*a* concentrations in most samples collected from the tributaries to Mason Creek were greater than the guideline value given in Table 2.3. Concentrations of chlorophyll-*a* in Trib-A ranged from 3.2 μg/l to 77.4 μg/l with a mean value of 22.0 μg/l. Concentrations of chlorophyll-*a* in the East Branch of Mason Creek ranged from 1.4 μg/l to 10.9 μg/l with a mean value of 5.3 μg/l. Finally, one sample from the West Branch Agricultural Ditch was observed to have a chlorophyll-*a* concentration of 4.7 μg/l.

These high concentrations of chlorophyll-*a* are consistent with the high nutrient concentrations as summarized above and indicate a high level of eutrophication throughout the entire Mason Creek system.

Figure 2.17
Chlorophyll-*a* Concentrations at Water Quality Sampling Stations Along Mason Creek: 2009-2014



NOTE: See Figure 2.5 for description of symbols. See Table 2.7 and Map 2.4 for locations of sample sites.

Source: University of Wisconsin-Milwaukee and SEWRPC.

Water Temperature

The temperature of a waterbody is a measure of the heat energy it contains. Water temperature drives numerous physical, chemical, and biological processes in aquatic systems. Processes affected by temperature include the solubility of substances in water, the rates at which chemical reactions progress, metabolic rates of organisms, the settling rates of small particles, and the toxicity of some substances. For example, the solubility of many gases in water decreases as water temperature increases. The solubility of oxygen in water is an example of this—colder water can hold more dissolved oxygen. By contrast, the solubility of many solids in water increases as water temperature increases. Temperature is a major determinant of the suitability of waterbodies as habitat for fish and other aquatic organisms, particularly temperatures in the summer (June through August) that are the most limiting physiologically, largely due to having the highest temperatures and lowest dissolved oxygen levels than any other time period of the year. Each species has a range of temperatures that it can tolerate and a smaller range of temperatures that are optimal for growth and reproduction. These ranges are different for different species. As a result, very different biological communities may be found in similar waterbodies experiencing different temperature regimes. In Wisconsin for example, high-quality warmwater systems are characterized by many native species, including cyprinids, darters, suckers, sunfish, and percids that typically dominate the fish assemblage. In contrast to warmwater streams, coldwater systems are characterized by few native species, with salmonids (trout) and cottids (sculpin) dominating, and they lack many of the taxonomic groups that are important in high-quality warmwater streams.

Air temperatures affect water temperatures, especially in smaller waterbodies. Solar heating strongly influences water temperature and factors that affect the incidence of light on waterbodies or light penetration through waterbodies can affect temperature. The presence of suspended material or colored dissolved material in the water column can increase the absorbtion of light by the waterbody, leading to heating. Water temperature can also be affected by discharges of groundwater, stormwater runoff, and discharges from point sources.

SEWRPC staff deployed continuous monitoring devices at seven locations to measure water temperatures and one additional site to monitor air temperatures from 2013 through 2014. These devices were programmed to record temperature in hourly increments. Table 2.7 and Map 2.4 describe the locations, river miles, and collection dates for those continuous monitoring devices.

The series of plots within Figure 2.18 shows water temperatures from seven sites within, and four sites adjacent to, the Mason Creek watershed, and air temperatures from one site in the center of the Mason Creek watershed over a 438-day period running from spring 2013 to mid-summer 2014. Between May 31, 2013, and August 11, 2014, water temperatures in streams from among all sampling sites in the Mason Creek watershed ranged from about 0.0°C to 25.2°C, with a mean value of 9.5°C and a median value of 11.3°C. The data show that air temperatures are major determinants of water temperatures, which can be observed in the daily fluctuations that show the increase in temperature during the day and cooling at night. Figure 2.18 also shows that water temperatures at a particular site are dependent upon both the current and preceding daily air temperature conditions. So, as daily temperatures increase over time water temperatures within the streams tend to cumulatively get warmer or the opposite can occur as temperatures decrease, which is illustrated among the transitions from one season to the next.

Figure 2.18 also shows that the daily fluctuations and maximum temperatures overall are reduced in sections of stream with increased groundwater discharge, such as in the East Branch (average daily water temperature fluctuations of about 1.7°C) compared to the West Branch Agricultural Ditch (average daily water temperature fluctuations of about 3.5°C). Sites with greater proportions of groundwater discharge are also evident during the colder time periods, which are characterized by decreased daily fluctuations and water temperatures that consistently remain greater than zero (i.e., preventing water from freezing). Hence, groundwater discharge leads to decreased water temperatures in summer and increased water temperatures in the winter. This warmwater buffering in the winter is critical for the protection, development, and successful hatching of brook trout eggs that incubate within streambed substrates around October and emerge as fry in March. For example, the Unrein pond site is a good illustration of a site dominated by high groundwater discharge. As shown in Figure 2.18 this site contained some of the lowest daily fluctuations and lowest recorded summer water temperatures of all the sites within the Mason Creek watershed as well as warm temperatures in the winter (never decreased below 4.0°C). This pond site was observed to consistently discharge into the East Branch of Mason Creek, but it does not have any surface water inlet, so this pond's discharge is comprised solely of groundwater inputs as substantiated by the recorded temperature data. It is important note that the East Branch of Mason Creek demonstrated that it had the warmest winter temperatures of any sampling site within Mason Creek, often exceeding 5.0°C and sometimes 6.0°C. Hence, similar to the Unrein pond site, this indicates that the East Brach contains a high amount of groundwater discharge. In addition, these winter temperatures indicate that this reach has the greatest potential for successful brook trout spawning compared to all the other sites in Mason Creek. This was supported by direct observation of brook trout actively spawning within the East Branch of Mason Creek in the fall of 2014 (see Figure 2.19), which has not been observed in any other location in the watershed.

In general, summer conditions demonstrate that there is an overall decrease in water temperatures from upstream to downstream within Mason Creek as shown in Figure 2.18. The West Branch Agricultural Ditch contained the warmest temperatures of all sampled reaches or sites within the Mason Creek watershed with maximum summer daily means that ranged from 18.7°C to 21.7°C. This reach also achieved the highest maximum daily recorded temperatures within the entire river network of 23.3°C and 25.2°C in July 2013 and 2014, respectively. Although there is limited historical information on the West Branch Agricultural Ditch, it was reported that this reach achieved a maximum temperature of 23.9°C in the summer of 1983.[43] In addition, recent research has found that mean daily water temperatures above 21.0°C is considered an ecological threshold that induces an endocrine and cellular stress response by elevating plasma concentrations or cortisol, glucose, and heat shock protein.[44] Hence, above-optimum water temperatures (i.e., greater than 21.0°C) in the West Branch Agricultural Ditch likely limits the presence of brook trout in this reach, due to the negative effects of the neuroendocrine stress response on growth, reproduction, and survival.

These characteristics determine that this reach can be classified as a cool "warm transition" headwater stream, which is consistent with previous observations that this reach does not support a coldwater brook trout fishery.[45]

In contrast, the East Branch was significantly cooler than the West Branch Agricultural Ditch by an average of 4.8°C to 5.0°C in the summers of 2013 and 2014, respectively. The beneficial impact of the colder water from

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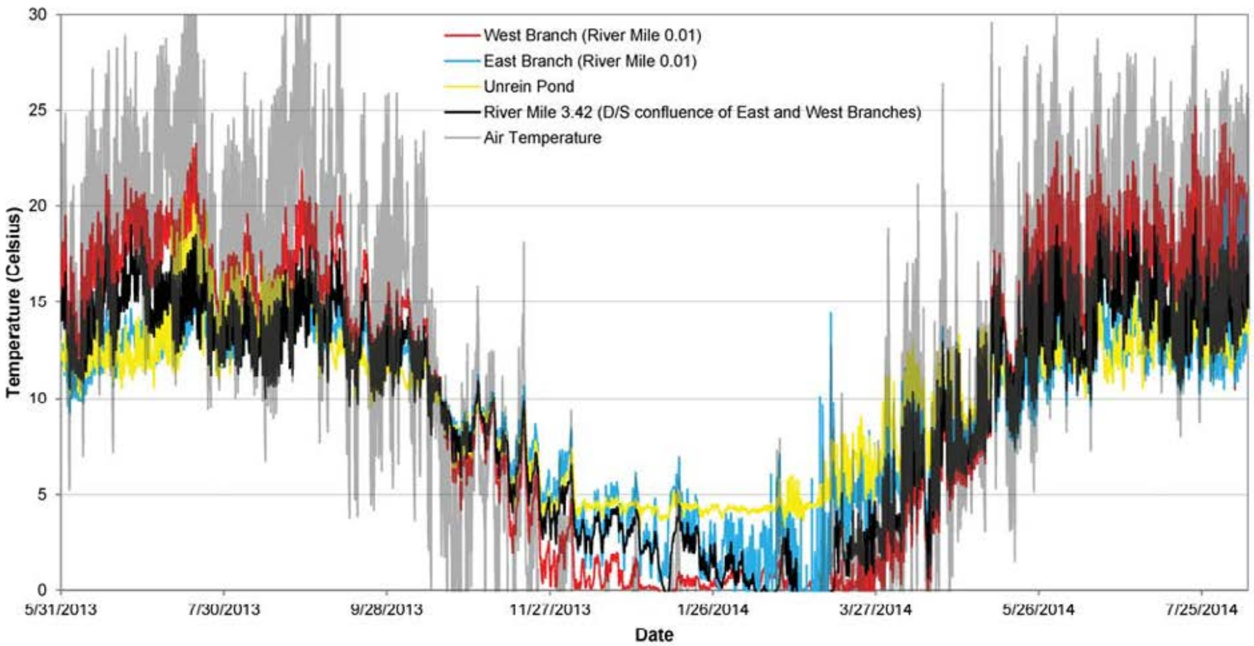
[43] *Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the Oconomowoc River Priority Watershed Project*, Publication WR-194-86, 1986.*

[44] *Chadwick, J.G., K.H. Nislow, and S.D. McCormick, "Thermal Onset of Cellular and Endocrine Stress Responses Corresponding to Ecological Limits in Brook Trout, and Iconic Cold-Water Fish,"* Conservation Physiology, *3:cov017,* 2015.

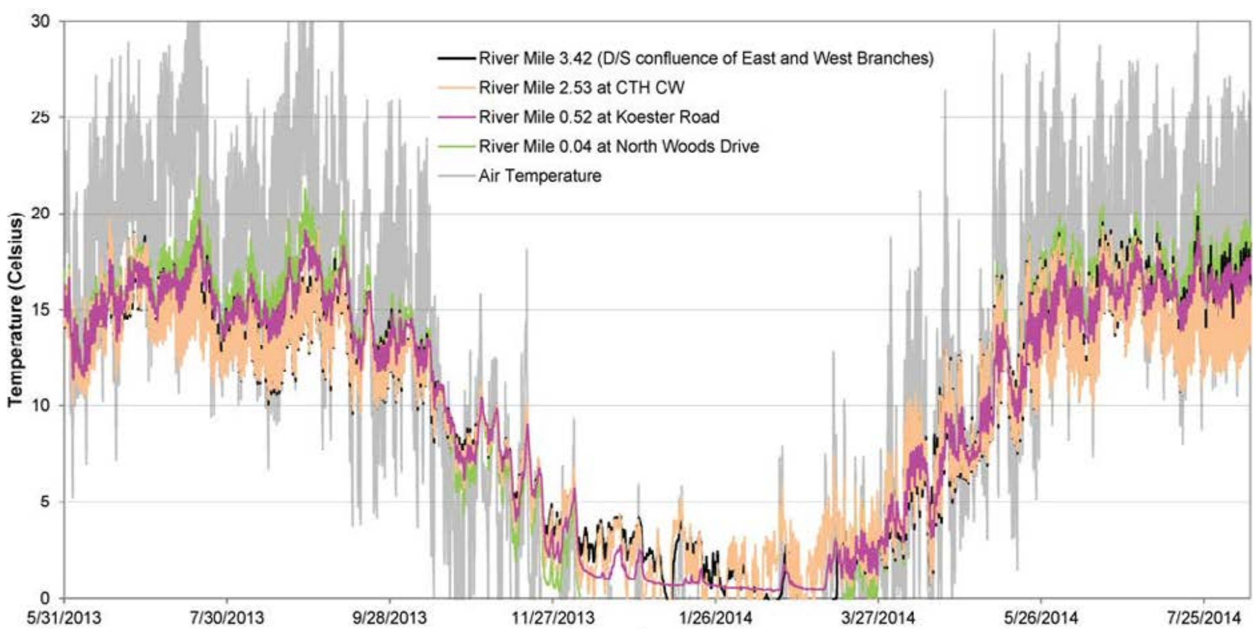
[45] *John Lyons and others, 2009, "Defining and Characterizing Coolwater Streams and Their Fish Assemblages in Michigan and Wisconsin, USA,"* North American Journal of Fisheries Management, *Vol. 29, pages 1130–1151.*

Figure 2.18
Hourly Water and Air Temperatures Among Sites and Reaches Within and Adjacent to the Mason Creek Watershed: May 31, 2013 Through August 11, 2014

EAST BRANCH VERSUS WEST BRANCH OF MASON CREEK

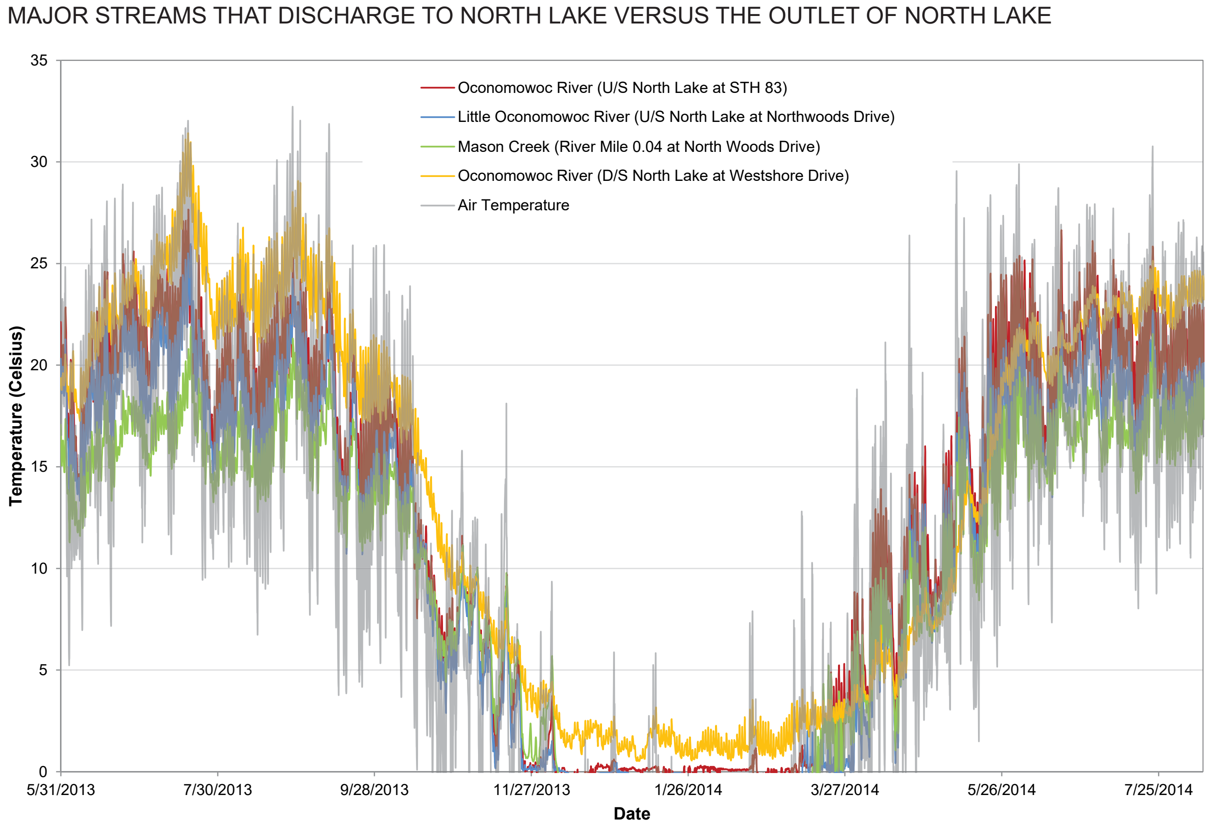


UPPER AND LOWER REACHES OF MASON CREEK



the East Branch mixing with the warmer waters of the West Branch Agricultural Ditch is evident in the Mason Creek station at RM 3.42 just downstream of the confluence of these two tributaries that form the beginning of the Upper Mason Creek reach. Summer temperatures at RM 3.42 are on average 3.1°C colder than the West Branch Agricultural Ditch site upstream. Summer water temperatures continue to decrease by about 0.5°C between RM 3.42 to CTH CW at RM 2.50. This decrease in temperature seems to reflect additional inputs of groundwater into this section of stream, which is consistent with an increase in about 2 to 4 cubic feet per second (cfs) in baseflow discharge between these stations. The East Branch and the Upper Mason

Figure 2.18 (Continued)

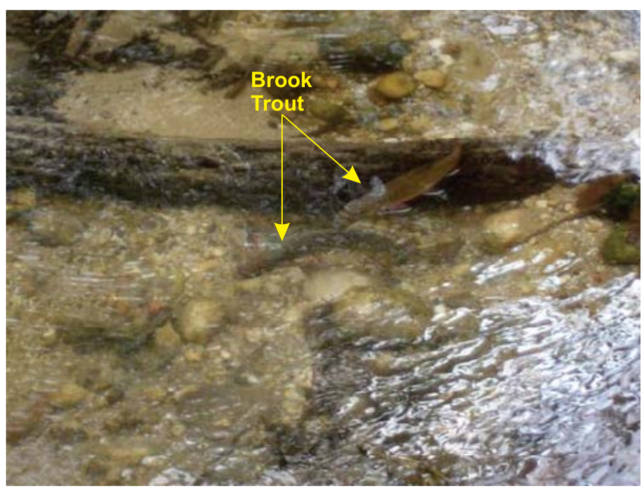


Source: SEWRPC.

Creek sites never exceeded an average maximum daily summer temperature of 15.7°C and 17.3°C, respectively, which confirms that these are high quality cold headwater trout stream reaches.[46] This is supported by the presence of adult brook trout since at least the 1970s.

In the transition from the Upper to the Lower Mason Creek stations water temperatures tend to become slightly warmer. Between RM 2.53 and Koester Road (RM 0.50) within Lower Mason Creek, summer water temperatures begin to increase on average by about 0.5°C. Then, water temperatures tend to increase by an additional 1.3°C between RM 0.5 and Northwoods Drive (RM 0.04), just upstream from the confluence with North Lake. However, it is important to note that despite this slight warming trend, neither of these two stations within the Lower Mason Creek reach ever exceeded an average maximum daily summer temperature of 17.0°C at RM 0.5 and 18.4°C at RM 0.04, which confirms that these reaches can support coldwater brook trout.[47] This is supported

Figure 2.19
Brook Trout Spawning in East Branch of Mason Creek—October 21, 2014



Source: SEWRPC.

[46] *K.E. Wehrly, L. Wang, and M. Mitro, "Field-Based Estimates of Thermal Tolerance Limits for Trout: Incorporating Exposure Time and Temperature Fluctuation,"* Transactions of the American Fisheries Society, *Volume 139, 2007, pages 365-374.*

[47] *K.E. Wehrly, L. Wang, and M. Mitro, "Field-Based Estimates of Thermal Tolerance Limits for Trout: Incorporating Exposure Time and Temperature Fluctuation,"* Transactions of the American Fisheries Society, *Volume 139, 2007, pages 365-374.*

by the periodic presence of adult brook trout since at least the 1970s. However, as shown in Figure 2.18 maximum daily temperatures at RM 0.04 has been shown to periodically exceed 21.0°C in the summer periods in both 2013 and 2014. Hence, these above-optimum water temperatures (i.e. greater than 21.0°C) in the reach may also explain that temperatures are periodically limiting the presence of brook trout in the lower portion of this reach, due to the negative effects of the neuroendocrine stress response on growth, reproduction, and survival.[48]

The ambient temperature as well as the acute and sublethal water quality criteria for temperature in warmwater streams and lakes are set forth and further described in Table 2.2. Between late spring 2013 and mid-summer 2014, daily maximum water temperatures in the East Branch, Unrein Pond, Upper and Lower Mason Creek, and Trib-A reaches never exceeded the applicable acute criterion for temperature as shown in Table 2.2. The West Branch Agricultural Ditch rarely exceeded the acute criterion, but it did exceed the sublethal criterion for temperature (i.e., calendar week average of daily maximum temperatures) about 25 percent of the time annually and about 46 percent of the time during the growing season. Most exceedances of the acute temperature criteria occurred in the West Branch Agricultural Ditch of Mason Creek during June and July. The Unrein Pond never exceeded the sublethal criteria for temperature and the East Branch rarely exceeded them. The Upper and Lower Mason Creek reaches met the applicable sublethal criteria about 92 percent and 88 percent of the time annually, respectively and slightly less than that during the growing season.

Water temperature data collected indicated that the Mason Creek and associated tributaries would be likely to support a coldwater fishery. However, in the West Branch Agricultural Ditch of Mason Creek as well as the Upper and Lower reaches of Mason Creek water temperatures sometimes exceed the applicable acute criterion during summer months and the applicable sublethal criterion during non-winter months. This indicates that temperatures are likely impacting the quality of the fishery in this stream system, and may occasionally restrict the availability of some habitat for coldwater fish species, particularly brook trout spawning or juvenile rearing.

Finally, to better understand the temperature characteristics of Mason Creek and its implications to North Lake, temperature loggers were deployed at the downstream limits of the Little Oconomowoc and Oconomowoc Rivers, and one site downstream of North Lake as shown in Figure 2.18. These results indicate that Mason Creek contains the coldest temperatures followed by the Little Oconomowoc River and the Oconomowoc River, which is the warmest system of the three. Note that, likely primarily due to discharge of heated surface waters from North Lake, the site downstream of North Lake is consistently much warmer than the other sites upstream of North Lake and often exceeds 30.0°C. The one exception to this trend is in the spring (i.e. May through June), because it takes time for the larger volumes of water and in some years ice within North Lake to warm up, causing water temperatures downstream of the Lake to be slightly colder than upstream. Although Mason Creek is only estimated to provide about seven percent of the inflow to North Lake, it can readily be seen that this discharge of very cold and well-oxygenated water is a significant benefit for the sustained protection of the diverse fishery and recreational quality within the Lake. Coldwater Class I brook trout stream systems are extremely rare in southeastern Wisconsin.

Summary

Mason Creek has a very high amount of nutrients and suspended solids in the water. A visual assessment of Mason Creek during a peak storm or runoff event clearly shows high amounts of sediment being carried as seen in both upstream areas (Figure 2.20) and downstream areas (Figure 2.16). Periodic algae blooms are also common during the summer months, particularly in the lowest reach just upstream of North Lake. Although the data are somewhat limited by the number of samples, it is apparent that the highest concentrations in suspended solids, total phosphorus, and nitrogen are associated with the greater discharges in Mason Creek, so the highest amounts of pollutant loading occurs during higher flow events. This indicates that a significant amount of the pollutants can be attributed to runoff.

Table 2.8 presents a comparison of water quality constituents among reaches of the Mason Creek watershed to applicable water quality criteria for the period beginning in 2009 and continuing through mid-2014. This comparison looks at water quality conditions throughout the year and through the examination of ambient levels of five water quality constituents: water temperature and concentrations of dissolved oxygen, chloride, and total phosphorus (no data are available for fecal indicator bacteria). In the case of water temperature and chloride concentration, ambient levels were compared to two applicable criteria—one that applies to

[48] *Chadwick, J.G., K.H. Nislow, and S.D. McCormick, "Thermal Onset of Cellular and Endocrine Stress Responses Corresponding to Ecological Limits in Brook Trout, and Iconic Cold-Water Fish,"*Conservation Physiology, *3:cov017, 2015.*

Figure 2.20
High Suspended Sediment Loads in Gully Number 7 and Concentrated Flow Coming off an Agricultural Field – December 19, 2014

Gully #7 Along Erin Road

Concentrated Flow Area Coming Off Agricultural Field

Concentrated Flow Entering Culvert Leading to Gully #7

Source: SEWRPC.

acute effects to aquatic organisms and another that applies to chronic conditions. It should be noted that these levels of compliance as shown in Table 2.8 throughout the year were compared to compliance rates specifically during the growing season between May through October among years 2009 through 2014, as recommended in the Rock River TMDL report. Comparison of the values among each of the reaches within Mason Creek shows that the levels of compliance with the applicable water quality criteria achieved during the growing season were similar to those achieved during the rest of the year for all parameters. In addition, the recommended water quality guidelines for total suspended solids, nitrogen, chlorophyll-*a*, transparency tube, and turbidity as summarized in Table 2.3 were also used to assess water quality conditions within Mason Creek. Review of the data is summarized below:

- Dissolved oxygen concentrations were above the State water quality criterion for coldwater streams of 6.0 mg/l in all of samples collected among the East Branch, Upper and Lower Mason Creek, and Trib-A reaches, except for one date at the Petersen Road station in Lower Mason Creek. Dissolved

Table 2.8
Water Quality Characteristics of Streams in the Mason Creek Watershed During the Years 2009-2014

Stream Reach (see Map 2.4)	Stream Length (miles)	Codified Water Use Objective[a]	Percent of Samples Meeting Water Quality Criteria					
			Dissolved Oxygen[b]	Temperature		Chloride		Total Phosphorus[b]
				Sublethal[b]	Acute[b]	Chronic[b]	Acute[b]	
West Branch Agricultural Ditch[c]	2.26	FAL	0.0 (1)	75.5 (53)	97.5 (438)	--	--	0.0 (1)
East Branch headwaters	1.35	FAL	100 (6)	98.4 (62)	100 (438)	--	--	16.7 (6)
Upper Mason Creek (from confluence of the East and West Branches to confluence with Tributary-A)	1.73	COLD	100 (19)	91.9 (124)	100 (876)	--	--	21.7 (23)
Lower Mason Creek (from the confluence with Tributary-A to North Lake)	1.72	COLD	98.6 (73)	87.9 (124)	100 (876)	100 (5)	100 (5)	37.5 (16)
Private Pond(Unrein Property)	--	FAL	--	100.0 (62)	100.0 (438)	--	--	--
Tributary-A	0.87	FAL	100 (6)	--	--	--	--	0.0 (6)

Note: Since there were no Fecal Coliform Bacteria or Escherichia coli data to asses water quality for these constituents, they were not reported in this table.

[a] *COLD indicates coldwater fish and aquatic life community, FAL indicates warmwater fish and aquatic life.*

[b] *Number of samples is indicated in parentheses.*

[c] *As shown on Map 2.2 the lower 0.66 miles of the West Branch drainage ditch from the Washington-Waukesha County Line to the confluence with the East Branch of Mason Creek is designated as COLD, but this agricultural ditch has never met the coldwater designation and was combined with the FAL classification for this reach.*

Source: SEWRPC

oxygen concentrations in a few samples were below the spawning season water quality criterion of 7.0 mg/l, but that did not occur during the spawning season. Although the data are limited, the West Branch Agricultural Ditch did not meet the warmwater fish and aquatic life criterion of 5.0 mg/l, which is consistent with observations that this site has not been conducive to support brook trout since at least 1983.

- Water temperature data collected indicated that the Mason Creek and associated tributaries would be likely to support a coldwater fishery. However, in the West Branch Agricultural Ditch of Mason Creek as well as the Upper and Lower reaches of Mason Creek water temperatures sometimes exceed the applicable acute criteria during summer months and the applicable sublethal criteria during non-winter months. This indicates that temperatures are likely impacting the quality of the fishery in this stream system. This suggests that temperatures may occasionally be restricting the availability of some habitat to coldwater fish species, particularly brook trout spawning or juvenile rearing, in this stream system as well as affecting the overall quality of the fishery. More specifically, chronic and periodic above-optimum water temperatures (i.e. greater than 21.0°C) in the West Branch Agricultural Ditch and Lower Mason Creek reaches, respectively, demonstrates that water temperatures are likely limiting the presence of brook trout in these reaches, due to the negative effects of the neuroendocrine stress response on growth, reproduction, and survival.[49]

- Based upon these water quality conditions, several of the reaches within Mason Creek need their designated water use objectives revised. Both the East Branch of Mason Creek and Trib-A reaches meet the coldwater fish and aquatic life community criteria for both temperature and dissolved oxygen requirements, so these should be upgraded from their current warmwater fish and aquatic life designation to a coldwater designation. In particular, the East Branch of Mason Creek is the only location where brook trout spawning has been observed in this river system, which demonstrates its critical importance to sustaining the Class I (naturally reproducing) brook trout fishery within Mason Creek. In contrast, the lower 0.66 miles of the West Branch Agricultural Ditch (i.e., from the Washington-Waukesha County Line to the confluence with the East Branch) does not have

[49] *Chadwick, J.G., K.H. Nislow, and S.D. McCormick, "Thermal Onset of Cellular and Endocrine Stress Responses Corresponding to Ecological Limits in Brook Trout, and Iconic Cold-Water Fish,"* Conservation Physiology, *3:cov017, 2015.*

enough groundwater discharge to meet the temperature and dissolved oxygen requirements for a coldwater designation, and these findings are consistent with observations that brook trout have never been observed or collected in this reach. Therefore, this portion of the West Branch Agricultural Ditch should be downgraded from a coldwater fish and aquatic life community to a warmwater designation, which is consistent with the existing designation of the upper portion of the West Branch Agricultural Ditch.

- The measured and estimated (from specific conductance) concentrations of chloride reported for Mason Creek are below the applicable water quality criteria. However, there is a known widespread regional trend toward increasing chloride concentrations in surface waters, which suggests that it is highly likely that chloride concentrations are increasing in surface waters throughout the Mason Creek watershed. Of particular concern, because of its high solubility, chloride can enter and accumulate in groundwater. This can result in contributions of chlorides to streams and North Lake through inputs of groundwater-derived baseflow. Therefore, given these surface water and shallow groundwater quality potential concerns in the concentrations of chloride in Mason Creek, continued monitoring will be important.

- High concentrations of nutrients are present in surface waters of the Mason Creek watershed. Concentrations of total phosphorus in the vast majority of samples collected from Mason Creek and in almost all of the samples collected from the tributary streams were above the State's water quality criterion of 0.075 mg/l. Depending on the reach sampled, compliance with State standards for phosphorus concentrations generally ranged from zero to less than 38 percent of the samples collected from the Creek. High concentrations of total nitrogen were also detected. While the State has not promulgated water quality criteria for nitrogen, concentrations of total nitrogen in all samples collected from Mason Creek and two tributary streams were higher than guideline values representing the potential level of water quality that could be achieved in the absence of human activities. These high levels of nutrients are also associated with high concentrations of chlorophyll-*a*, which indicates a high level of eutrophication throughout the Mason Creek system.

- Concentrations of total suspended solids (TSS), which measures the amount of material suspended in the water column, are high. TSS concentrations in most samples collected were higher that the target concentrations of 26 mg/l set under the Rock River TMDL study, which indicates that this is a chronic problem during both baseflow and higher discharge events. Similar results were observed for turbidity. These observations also are consistent with the ongoing increased sedimentation at the inlet to North Lake from Mason Creek.

Based upon the results of the water quality sampling data from 2009 through 2014 (Table 2.8), the surface waters of the Mason Creek watershed appear to be only partially achieving the recommended water use objective of coldwater community in the Upper and Lower Mason Creek, East Branch, and Trib-A reaches. The West Branch Agricultural Ditch appears to be only partially meeting its designated use objective of warmwater fish and aquatic life and cannot achieve the necessary physiological requirements to support the survival, growth, or reproduction of coldwater brook trout designated use objectives. Given that no recent sampling has been conducted for fecal coliform bacteria or *Escherichia coli*, it is not possible to assess whether surface waters of the Mason Creek watershed are achieving their designated water use objective or recreational use.

As noted previously, the Federal Clean Water Act considers waterbodies that do not meet the applicable water quality standards to be impaired and requires that states periodically submit a list of impaired waters to the USEPA for approval. It also requires the states to develop TMDLs to address impaired waters and Wisconsin most recently submitted this list in 2016. Impaired waters in the Mason Creek watershed are shown on Map 1.2 in Chapter 1 of this report. The mainstem of Mason Creek has been listed as impaired since 1998. The Upper and Lower reaches of Mason Creek and the lower portion of the West Branch Agricultural Ditch downstream of the Washington-Waukesha county line are considered impaired due to elevated water temperatures and degraded habitat resulting from high concentrations of sediment and TSS and due to low concentrations of dissolved oxygen resulting from high concentrations of total phosphorus. The West Branch Agricultural Ditch of Mason Creek upstream of the Washington-Waukesha county line is considered impaired due to elevated water temperatures and low dissolved oxygen concentrations resulting from high concentrations of sediment and TSS and due to low concentrations of dissolved oxygen resulting from high concentrations of total phosphorus. These impairments section are addressed under the Rock River TMDL study.[50] It should also be noted that water from Mason Creek flows into North Lake, which is listed as impaired on the proposed 2014 list. Total phosphorus concentrations in North Lake exceed the applicable water quality criterion for total phosphorus; however, no specific biological impacts have been documented.

As summarized in the "TMDL Requirements" subsection above, as part of the Rock River Basin, the Mason Creek watershed is addressed under the Rock River TMDL study.[51] This TMDL sets water quality targets and establishes wasteload allocations and load allocations for total phosphorus and totals suspended solids in 84 subbasins of the Rock River watershed, including a subbasin consisting of the Mason Creek watershed. Meeting the water quality targets set under the Rock River TMDL will require substantial reductions in nonpoint source loads. As shown in Table 2.4, **the water quality targets set forth in the Rock River TMDL report will require an estimated 92 percent reduction in TP (5,355 lbs) and 93 percent reduction in TSS (883 tons) from the median annual nonpoint baseline loads for the Mason Creek watershed.**[52]

Biological Conditions

The quality of streams and rivers is often assessed based on measures of the chemical or physical properties of water. However, a more comprehensive perspective includes resident biological communities. Guidelines to protect human health and aquatic life have been established for specific physical and chemical properties of water and have become useful yardsticks for assessing water quality. Biological communities provide additional crucial information because they live within streams for weeks to years and, therefore, integrate through time the effects of changes to their chemical or physical environment.[53]

In addition, biological communities are a direct measure of stream health—an indicator of the ability of a stream to support aquatic life. Thus, the condition of biological communities, integrated with key physical and chemical properties, provides a comprehensive assessment of stream health. The presence and abundance of species in a biological community are a function of the inherent requirements of each species for specific ranges of physical and chemical conditions. Therefore, when changes in land use and water management in a watershed cause physical or chemical properties of streams to exceed their natural ranges, vulnerable aquatic species are eliminated, and this ultimately impairs the biological condition and stream health.[54]

Aquatic and terrestrial wildlife communities have educational and aesthetic values, perform important functions in the ecological system, and are the basis for certain recreational activities. The location, extent, and quality of fishery and wildlife areas and the type of fish and wildlife characteristic of these areas are important determinants of the overall quality of the environment in the Mason Creek watershed.

Fisheries Classification

Based on a combination of detailed temperature data (see "Water Quality" section above),[55] fish species occurrence and abundance observations, and WDNR's natural community classification rating model, reaches within Mason Creek were classified into their appropriate biotic community and ecological

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[50] *USEPA and WDNR, 2011,* op. cit.

[51] *USEPA and WDNR, 2011,* op. cit.

[52] *See Appendix L and Appendix M of the 2011 Rock River TMDL report.*

[53] *D.M. Carlisle and others,* The Quality of Our Nation's Waters—Ecological Health in the Nation's Streams, *1993–2005: U.S. Geological Survey Circular 1391, 2013 (available online at:* pubs.usgs.gov/circ/1391/*).*

[54] Ibid.

[55] *K.E. Wehrly, L. Wang, and M. Mitro, "Field-Based Estimates of Thermal Tolerance Limits for Trout: Incorporating Exposure Time and Temperature Fluctuation,"* Transactions of the American Fisheries Society, *Volume 139, 2007, pages 365-374.*

conditions (i.e., streamflow and water temperature).[56] These results indicate that the East Branch and the Upper and Lower Mason Creek reaches meet the cold headwater fisheries classification as shown on Map 2.5. The definition of a cold headwater stream condition is:

> Small, perennial stream with cold summer temperatures. Collectively, coldwater fishes are usually abundant (catch rate of greater than 100 fish per 100 meters of stream length sampled) to common (10 to 100 fish per 100 meters), transitional fishes are common to absent, and warmwater fishes are absent. Because of the small size of the stream, trout populations often consist almost exclusively of small fish (less than five inches) with larger fish absent except perhaps during spawning periods.

Results also showed that the West Branch Agricultural Ditch of Mason Creek is a cool (warm transition) headwater stream as shown on Map 2.5.[57] The definition of a cool (warm transition) headwater stream condition is:

> Small, sometimes intermittent stream with cool to warm summer temperatures. Coldwater fishes are uncommon to absent, transitional fishes are abundant to common, and warmwater fishes are common to uncommon. Headwater species are abundant to common, mainstem species are common to absent, and river species are absent.

According to WDNR researchers, coolwater streams, which are intermediate in character between coldwater ''trout'' streams and more diverse warmwater streams, occur widely in temperate regions, including the State of Wisconsin.[58] Fish assemblages in coolwater streams tend to be variable but are generally intermediate in species richness and overlapped in composition with coldwater and warmwater streams.

Through calculation of the Index of Biotic Integrity (IBI), data on the fish community can provide insight into the overall health of the stream ecosystem. Fish catches can also reveal trends in the populations of rare and sport fish species. The overall goal of monitoring is to better document the current status of Mason Creek and its tributaries and to provide an early warning of declines in environmental quality and fisheries associated with human development in the watershed. Due to the fundamental differences among warmwater, coolwater, and coldwater streams, a separate Index of Biotic Integrity was developed to assess the health of each of these types of streams.[59] Therefore, the coldwater and coolwater indices are most appropriate for the fisheries assessment of Mason Creek.

Based upon the fisheries assessments conducted between 1975 through 2014 by WDNR among several sites within the mainstem of this system, the Upper Mason Creek seems to generally have remained as a good to excellent coldwater fishery and the Lower Mason Creek has generally ranged from a very-poor to fair coldwater fishery. Considering that this system experienced a severe drought in the summer of 2012, the continued good to excellent coldwater classification in the Upper Mason Creek from 2012 to 2014 demonstrates the resiliency of this portion of the system. In addition, although data were unpublished, 52 brook trout were recorded by WDNR in the Upper mainstem of Mason Creek (RM 3.32) just downstream the confluence of the East Branch and West Branches Agricultural Ditch,[60] which demonstrates a sustained population for more than 30 years and average catch rates of more than 50 brook trout per survey. In contrast, no brook trout have ever been recorded to be present within the West Branch Agricultural Ditch.

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[56] *John Lyons, "Patterns in the species composition of fish assemblages among Wisconsin streams,"* Environmental Biology of Fishes *Volume 45, 1996, pages 329-341; John Lyons, "Proposed temperature and flow criteria for natural communities for flowing waters," February 2008, updated October 2012; and, John Lyons, "Wisconsin Department of Natural Resources, An Overview of the Wisconsin Stream Model," January 2007.*

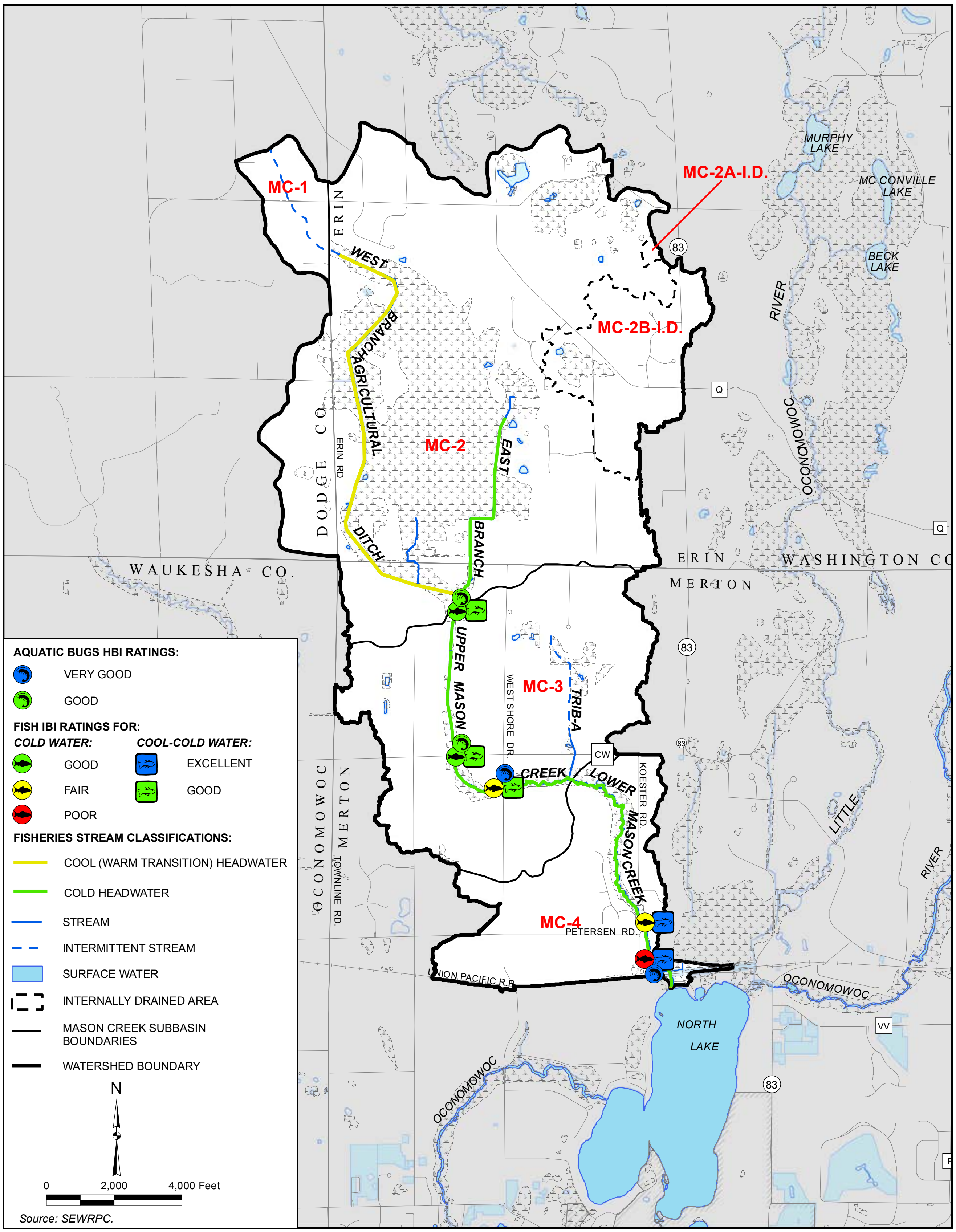
[57] *John Lyons and others, 2009, "Defining and Characterizing Coolwater Streams and Their Fish Assemblages in Michigan and Wisconsin, USA,"* North American Journal of Fisheries Management, *Vol. 29, pages 1130–1151.*

[58] *Lyons et al 2009*

[59] *John Lyons, "Development and Validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin,"* North American Journal of Fisheries Management*, Volume 16, May 1996.*

[60] *Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the Oconomowoc River Priority Watershed Project*, Publication WR-194-86, 1986.*

Map 2.5
Fish and Aquatic Bugs Sampling Locations and Fisheries Stream Classifications Within the Mason Creek Watershed: 2008, 2013, and 2014



Since 2012 there has only been one survey (conducted in 2014 at Petersen Road) within Lower Mason Creek that only achieved a poor coldwater rating. This poor rating was partly the result of no brook trout being observed in that particular survey. In fact, brook trout were only observed in five of the total nine times that the Lower Mason Creek reach was sampled as shown in Table 2.9. When brook trout were present, catch rates were consistently lower than the upper reach and averaged less than seven brook trout per survey. These results are likely related to a combination of degraded water quality, habitat conditions, and fish passage limitations (see below and "Stream Conditions" section for more details). These poor to fair coldwater ratings are also partly the result of the presence of warmwater and more tolerant fish species migrating into the lower portions of Mason Creek, which is not unexpected given its proximity to North Lake. Although this poor to fair coldwater rating is somewhat troubling, it is important to note that the Lower Mason Creek reach has been consistently functioning as an excellent coolwater fishery since 1981 as shown in Table 2.9. These results further support the evidence that the Mason Creek system is sustained by shallow groundwater inputs and that the West Branch Agricultural Ditch and Lower reach of Mason Creek are impaired, or limiting, to the brook trout fishery. This demonstrates the importance of continuing to protect groundwater recharge in this watershed.

Although the fish IBI is useful for assessing environmental quality and biotic integrity in streams, it is most effective when used in combination with additional data on physical habitat, water quality, macroinvertebrates, and other biota when evaluating a site.[61] This supplemental data is summarized below.

Fish Species Diversity

A review of the fish data collected in Mason Creek between 1975 and 2014 indicates that 35 different fish species were observed to occur within this system (see Table 2.9). Only five species of fishes were present in the Upper reach of Mason Creek, while the remaining 30 fish species were found in the Lower reach of Mason Creek. Catch rates mirrored total fish species richness, which indicated the Upper reach ranged between one and five species per survey and the Lower reach ranged between five and 18 species of fishes per survey. These differences are consistent with the high quality cold headwater fishery observed in Upper Mason Creek versus the high quality cool headwater fishery in Lower Mason Creek. However, these differences are so consistent and dramatic it seems that there may be one or more fish passage barriers at and just downstream of Koester Road that restrict fish species from migrating upstream of this road crossing (see "Stream Conditions" section below).

Coldwater systems are characterized by few native species, with salmonids (trout) and cottids (sculpin) dominating, and they lack many of the taxonomic groups that are important in high-quality warmwater streams.[62] An increase in fish species richness in coldwater fish assemblages often indicates environmental degradation. When degradation occurs, the small number of coldwater species is replaced by a larger number of more physiologically tolerant cool and warmwater species, which is the opposite of what tends to occur in warmwater fish assemblages. The Upper Mason Creek is consistently comprised of brook trout, central mudminnow, creek chub, brook stickleback, and pearl dace (Table 2.9), which is a typical cold headwater fish assemblage. One notable exception or missing species from this coldwater assemblage is mottled sculpin, which is a high quality coldwater indicator species for trout.[63]

The consistent presence of brook trout is an excellent sign of a healthy fishery, however, the exact origin or source of brook trout within Mason Creek is unclear. There is no record or mention of them within Mason Creek by WDNR in the 1963 Washington County or Waukesha County surface water resource reports.[64] These reports only note that forage fish are limited in the headwaters and common in downstream reaches. The first record of brook trout in both Mason Creek and North Lake was not until the spring of 1975. There

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[61] *John Lyons,* General Technical Report NC-149, op. cit.

[62] *John Lyons, "Development and Validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin,"* North American Journal of Fisheries Management*, Volume 16, May 1996.*

[63] *George C. Becker, Fishes of Wisconsin, University of Wisconsin Press, Madison, Wisconsin, 1983.*

[64] *Ronald J. Poff and C. W. Threinen,* Surface Water Resources of Washington County*, Lake and Stream Classification Project, Wisconsin Conservation Department, Madison, Wisconsin, 1963; and, Ronald J. Poff and C. W. Threinen,* Surface Water Resources of Waukesha *County, Lake and Stream Classification Project, Wisconsin Conservation Department, Madison, Wisconsin, 1963.*

Table 2.9
Fish Species Composition by Physiological Tolerance and Reach in the Mason Creek Watershed: 1952-2014

Species According to Their Relative Tolerance to Temperature	Stream Reach (see Map 2.5)																	
		Lower Mason Creek										Upper Mason Creek						
	North Lake	Northwoods Drive (RM 0.04)	Peterson Road (RM 0.25)					Koester Road (RM 0.50)			Westshore Drive (RM 2.12)	CTH CW (RM 2.51)						Private Farm (RM 3.32)
	1952-2012	1975	1981	1994	1995	2006[a]	2014	1975	2003	2008	2014	2008	2010	2011	2012	2013	2014	2014
Coldwater																		
Intolerant																		
Brook Trout	X	X	--	X	X	X	--	--	--	X	--	X	X	X	X	X	X	X
Intermediate																		
Brown Trout	--	--	--	--	--	--	--	--	--	X	X	--	--	--	--	--	--	--
Transitional																		
Sensitive																		
Northern Pike	X	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Intermediate																		
Johnny Darter	X	--	X	--	--	X	X	--	--	--	--	--	--	--	--	--	--	--
Pearl Dace	--	--	--	--	--	--	--	--	X	--	--	--	--	--	X	--	--	X
Walleye	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Yellow Perch	X	X	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tolerant																		
Brook Stickleback	--	--	--	--	--	--	--	--	--	X	X	X	--	--	--	--	X	X
Central Mudminnow	--	--	--	--	X	X	X	X	X	X	X	X	X	--	X	--	X	X
Creek Chub	X	X	X	X	X	X	X	X	X	X	X	--	--	X	--	--	--	X
White Sucker	X	X	X	X	X	X	X	X	X	X	--	--	--	--	--	--	--	--
Warmwater																		
Intolerant																		
Slender Madtom[b]	--	-	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--
Sensitive																		
Rainbow Darter	X	--	X	X	--	X	X	X	--	--	--	--	--	--	--	--	--	--
Rock Bass	X	X	X	--	--	X	X	X	--	--	--	--	--	--	--	--	--	--
Smallmouth Bass	X	--	X	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--
Intermediate																		
Black Crappie	X	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bluegill	X	X	--	--	--	X	X	--	--	--	--	--	--	--	--	--	--	--
Bowfin	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Brook Silverside	X	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Brown Bullhead	X	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Central Stoneroller	--		X	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--
Common Shiner	X	X	X	X	X	--	--	X	--	--	--	--	--	--	--	--	--	- -
Emerald Shiner	X	--	--	--	--	--	--	--	--	- -	--	--	--	--	--	--	--	-
Grass Pickerel	X	--	--	--	--	--	--	--	--	-	--	- -	--	--	--	--	--	--
Largescale Stoneroller	--	--	X	--	--	--	--	--	--	--	--	--	--	--	-	--	--	--
Logperch	--	--	--	--	--	--	X	--	--	--	--	-	- -	--	--	--	--	--
Fantail Darter	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--
Hornyhead Chub	--	--	X	X	X	--	X	X	--	--	--	--	--	--	--	--	--	--

Table continued on next page.

Table 2.9 (Continued)

Species According to Their Relative Tolerance to Temperature	Stream Reach (see Map 2.5)																	
		Lower Mason Creek										Upper Mason Creek						
	North Lake	Northwoods Drive (RM 0.04)	Peterson Road (RM 0.25)					Koester Road (RM 0.50)			Westshore Drive (RM 2.12)	CTH CW (RM 2.51)						Private Farm (RM 3.32)
	1952-2012	1975	1981	1994	1995	2006[a]	2014	1975	2003	2008	2014	2008	2010	2011	2012	2013	2014	2014
Warmwater (continued)																		
Intermediate (continued)																		
Lake Chubsucker[c]	X	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Largemouth Bass	X	X	X	--	--	X	X	--	--	--	--	--	--	--	--	--	--	--
Mimic Shiner	X	- -	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pumpkinseed	X	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Spotfin Shiner	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	-	--	--
Stonecat	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--
White Bass	X	--	--	--	- -	--	--	--	--	--	--	--	--	--	--	-	--	--
Tolerant																		
Black Bullhead	X	X	--	--	-	--	X	X	--	--	--	--	--	--	--	--	--	--
Bluntnose Minnow	X	--	X	--	--	X	--	X	--	--	--	--	--	--	--	--	--	--
Common Carp	X	X	X	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--
Fathead Minnow	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Green Sunfish	X	X	X	--	--	--	X	--	X	--	--	--	--	--	--	--	--	--
Yellow Bullhead	X	X	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--
Total Number of Species	28	18	17	6	6	11	12	14	5	6	5	3	2	2	3	1	3	5
Cool-Cold Transition IBI Qualitative Score	--	--	Excellent	--	--	Excellent	Excellent	Excellent	Fair	Excellent	Good	Good	Good	Good	Good	Good	Good	Good
Coldwater IBI Qualitative Score	--	--	Poor	--	--	Fair	Poor	Fair	Very Poor	Fair	Fair	Excellent	Good	Excellent	Excellent	Excellent	Good	Good

[a] *Sampling site includes 0.25 miles of Mason Creek from Peterson Road to Koester Road.*

[b] *Designated endangered species.*

[c] *Designated species of special concern.*

Source: Wisconsin Department of Natural Resources and SEWRPC

Table 2.10
Approximate Timing of the Four Major Life History Stages for Brook Trout

	Fall			Winter			Spring			Summer		
Life Stage	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Spawning Period												
Egg Incubation Period												
Summer Rearing												
Winter Rearing												

Note: Variation and overlap in timing among stages is due to variations in habitats occupied by this species.

Source: Adapted from Pauline Adams, Christopher James, and Clay Speas, Brook trout (Salvelinus fontinalis) Species and Conservation Assessment, Prepared for the Grand Mesa, Uncompahgre, and Gunnison National Forests, March 2008

are no records of brook trout stocking by WDNR staff in either Mason Creek or North Lake. It is possible that this is a relict population left over since the glaciers retreated or this could be a naturalized population that was stocked sometime near or before late 1960s to early 1970s. The lack of mottled sculpin, which is a high quality coldwater indicator species for trout, suggests that the brook trout in Mason Creek most likely became naturalized from a stocked population somewhere in the watershed, possibly from a stocked pond. For example, the only other brook trout population within the Oconomowoc River watershed is located many miles downstream in Rosenow Creek, which is a cold headwater tributary to Lac LaBelle. Historic fisheries records from WDNR files indicate that both brook trout and brown trout have been stocked within Rosenow Creek since the early 1900s.[65] Natural reproduction of both brook and brown trout were observed in the headwater areas in 1959,[66] and this coldwater fish assemblage also lacks mottled sculpin. Despite its unknown origins, this self-sustaining population of brook trout is rare in Southeastern Wisconsin and is evidence of the high quality groundwater discharges within Mason Creek that supports this fishery.

Brook trout have very unique habitat requirements throughout their life history to survive, grow, and reproduce.[67] As shown in Table 2.10 brook trout spawning occurs from mid-September through mid-November and is initiated by decreasing day length, increased late fall flows, and drops in water temperature to less than 9°C. Brook trout usually mature at age two, but males can reach maturity as early as age one. During spawning, mature females dig nests known as redds, where eggs are deposited, fertilized, and covered with gravel. Redds tend to be located in riffle habitats where velocity, depth, and bottom configuration induce water flow though stream substrates (i.e., upwelling). These redds are easy to recognize and remain visible for several weeks in the streambed after they are constructed, so these can be easy to monitor and track from year to year, which is a good way to gauge spawning activities on a river system. Incubation periods for brook trout can range from 30 days at mean water temperatures of 11.2°C to 165 days at mean water temperatures of 1.9°C, which shows that development is temperature dependent. Brook trout larvae remain in redds for several weeks after hatching as they continue to develop. Once fry emerge from the gravels, these juvenile or Young-of-Year (YOY) individuals migrate to lower velocity margins of the channel near the streambanks for protection and to feed. As both body size increases and swimming ability improves they tend to inhabit faster and deeper water habitat areas.

Despite the continued persistence of brook trout within the Mason Creek, as noted above they have never been observed within the West Branch Agricultural Ditch and are not as abundant or consistently found within the Lower Mason Creek reach, which is likely a result of the elevated temperatures and total suspended solid concentrations negatively affecting the distribution and abundance of brook trout in this system. Recent research has found that mean daily water temperatures above 21.0°C is considered an ecological threshold

[65] *SEWRPC Staff Memorandum,* Data Analysis and Recommendations Relating to the Proposed Relocation of the North Branch of Rosenow Creek for the STH 67 Oconomowoc Bypass Project—Stream Relocation Project in the Town Of Oconomowoc, Waukesha County, *July 19, 2007.*

[66] *Wisconsin Conservation Department (Wisconsin Department of Natural Resources), Intra Department Memorandum, Stocking Trout in Rosenow Creek, Waukesha County, January 26, 1959.*

[67] *Raleigh, R.F.,* Habitat suitability index models: Brook trout, United States Fish and Wildlife Service Biological Report 82 (10.24)*, Fort Collins, CO, 1982. [online] www.nwrc.usgs.gov/wdb/pub/hsi/hsi-024.pdf; Thomas Slawski,* An Analysis of Biotic and Abiotic Factors Influencing Fish Species Assemblages in a Cold-Water Stream*, PhD Dissertation, The University of Wisconsin-Milwaukee, May 1997.*

that induces an endrocrine and cellular stress response by elevating plasma concentrations or cortisol, glucose, and heat shock protein (see "Water Temperature" section above).[68] Hence, above-optimum water temperatures (i.e. greater than 21.0°C) in the West Branch Agricultural Ditch and Lower Mason Creek reaches likely limits the presence of brook trout, due to the negative effects of the neuroendocrine stress response on growth, reproduction, and survival. In addition, trout are sight feeders and nearly all of their diet comes from aquatic and terrestrial invertebrate drift within the water column, and also includes fish for the larger adults. So, the elevated total suspended solids measured at baseflow and higher flow events within Mason Creek may be limiting feeding and growth rates of brook trout. In addition, deposition of fine sediments within spawning redds can greatly reduce hatching success of the eggs. There are some potential riffle spawning habitats within the Lower Mason Creek reach, but it is unknown if spawning and successful egg hatching is actually occurring in these areas. If spawning and egg hatching is occurring in the lower portions of Mason Creek, it is likely that spawning success is being negatively impacted by the chronic sediment loads and deposition. Therefore, maintaining optimal water temperatures and achievement of the pollutant load reduction goals are a high priority concern to protect and improve the brook trout population within Mason Creek.

Optimal brook trout riverine habitat is characterized by clear, cold spring-fed water; a silt-free rocky substrate in riffle (shallow water, fast flowing)-run (deeper water, moderate flows) areas; an approximate 1:1 pool (deepest water, slow flow)-riffle ratio; well vegetated stream banks; abundant instream cover; and relatively stable water flow and temperature regimes.[69] Cover is an important feature for the survival of brook trout. Large woody debris (stumps, logs, roots), boulders, and undercut banks are key sheltering habitats for trout, but cover also can be provided by overhanging vegetation, submerged vegetation, rocky substrate, suitable water depths (greater than 0.5 feet), low current velocity (less than 0.5 feet/second), and water surface turbulence. The lack of optimal pool depth (greater than, or equal to, 3.0 feet) is a limiting factor for trout survival, particularly during low-flow conditions in late summer and throughout the winter. Therefore, adequate pool depth is critical for maintaining trout populations. Based upon the cross section survey conducted on this system it appears that pool depths—particularly within the channelized portions of both Upper and Lower Mason Creek reaches—are not adequate to support trout, since water depths rarely exceed 2.0 to 2.5 feet.

Despite monitoring since 1975, no distinction has been made between the presences of juvenile versus adult species among the recorded fish survey data, so it is unclear where juvenile or Young-of-Year (YOY) individuals are occurring in this system. As previously mentioned, undercut banks are necessary components for survival, particularly with YOY, which require habitat with cover and lower water velocities along stream margins than adult trout[70] (Raleigh 1982). Juvenile mortality in the first year of life is high and overwinter survival is greatly enhanced by warmer temperatures during the winter. Therefore, based on the temperature data among all the reaches summarized above, the East Branch contained the warmest winter temperatures and would be the most likely reach to support juvenile overwinter survival. Knowing where these areas exist is vital, so they can be protected and potentially enhanced to improve survival and abundance of brook trout in Mason Creek. Location of juveniles can also provide insights as to where successful spawning is occurring, so these areas can also be identified and protected.

The only observation of active brook trout spawning within Mason Creek was observed in the lower portion of the East Branch during the 2014 fall survey as shown in Figure 2.19. This reach contained shallow riffles with substrate sizes less than 2.0 inches in diameter, which are within the optimal range for brook trout spawning.[71] Although it was not possible to inventory very much of this reach, due to limits in property access, recent visual observations indicated that there were more riffles with appropriate substrates upstream of where the

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[68] *Chadwick, J.G., K.H. Nislow, and S.D. McCormick, "Thermal Onset of Cellular and Endocrine Stress Responses Corresponding to Ecological Limits in Brook Trout, and Iconic Cold-Water Fish,"* Conservation Physiology, *3:cov017, 2015.*

[69] *Raleigh, R.F., Habitat suitability index models: Brook trout,* United States Fish and Wildlife Service Biological Report 82 (10.24)*, Fort Collins, CO, 1982. [online] www.nwrc.usgs.gov/wdb/pub/hsi/hsi-024.pdf*

[70] Ibid.

[71] *Reiser, D. W., and T. A. Wesche,* Determination of physical and hydraulic preferences of brown and brook trout in the selection of spawning locations*, Water Resources Res. Inst., Univ. Wyo., Laramie. Water Res. Series 64. 100 pp., 1977.*

survey ended.[72] It is possible that this is the only reach where brook trout are successfully reproducing, and this is sustaining the entire population of trout within Mason Creek. Extensive ditching or channelization has removed the naturally meandering channel and associated riffle and pool habitats within Mason Creek. These ditched areas are mostly comprised of silts over clay substrates, which are not conducive to brook trout spawning or egg development. Successful spawning, egg development, and hatching is crucial to the continued existing and potential improvement of brook trout within Mason Creek. Thus, the loss of the historical pool-riffle habitat structure, due to channelization or ditching to promote agricultural production, on this system demonstrates a serious loss to the available spawning, juvenile rearing, and adult habitats within this system. Restoring the historical meandering channel patterns (see "Stream Condition" section below)—particularly in both the Upper and Lower Mason Creek reaches and their associated riffle, pool, and run habitats—exemplifies the greatest potential to improve the brook trout fishery along with reductions of nonpoint source loads as summarized above. Therefore, the continued protection and future improvement of the brook trout population and associated cold water fishery represents a major criteria assessment goal in order to demonstrate achievement of the water quality objectives in Mason Creek.[73]

In addition to brook trout, since at least the mid-1990s another excellent sign of a healthy fishery is the distribution and abundance of rainbow darter, rock bass, and smallmouth bass within the Lower Mason Creek reach (see Map 2.5 and Figure 2.21), which are all sensitive warmwater fish species. Just as described above, the Lower Mason Creek fishery contains a high quality coolwater fish assemblage that tends to be variable, but is generally intermediate in species richness and contains a variety of coldwater, coolwater, and warmwater fish species. In addition to the sensitive warmwater species mentioned above, this reach also contains bluegill, common shiner, hornyhead chub, logperch, largemouth bass, bluntnose minnow, common carp, green sunfish, and bullhead warmwater species. The coolwater species include Johnny darter, pearl dace, brook stickleback, central mudminnow, creek chub, and white sucker. Finally, the coldwater species include both brook trout and brown trout, but these species are not dominant. Brown trout are not native to Wisconsin and their recent presence in 2008 and 2014 within the Lower Mason Creek reach suggests that these are an artifact of recent brown trout stocking on the Oconomowoc River. The consistent presence of these sensitive warmwater and coldwater fishes is an indication of sustained good water quality in Mason Creek, because they have a low tolerance to pollution and silt.

Despite the continued presence of sensitive warmwater and coldwater fish species within the Lower Reach of Mason Creek, there seems to have been a loss of at least 12 fish species since 1975 or 1981 that include: northern pike, a sensitive coolwater species; slender madtom, an intolerant warmwater and a State-designated endangered fish species; lake chubsucker, a State-designated species of special concern; central and largescale stonerollers; brook silverside; fantail darter; stonecat; spotfin shiner; fathead minnow; pumpkinseed; and yellow perch. This indicates a potential loss of more than 30 percent of the fish species diversity in this reach and is indicative of degradation of this system. This may be related to the high nutrient concentrations, higher water temperatures, and/or suspended sediments within this reach and demonstrates the importance of continued monitoring on this system.

There are more species of fish observed in Mason Creek than in North Lake. However, approximately 62 percent, or 22 of the fish species found within Mason Creek, also reside within North Lake. Hence, just as there is an important linkage in water quality between Mason Creek and North Lake, there is also a vital connection between the Lake and its tributaries regarding the abundance and diversity of the fishery. The ability to migrate between a tributary and lake environment for thermal refuge, overwintering, spawning, feeding, or other essential life history requirement is what helps to sustain a healthy fishery. For example, the first ever record of logperch in the Lower Mason Creek reach was in 2014, which indicates that this species likely emigrated from either the Little Oconomowoc or Oconomowoc Rivers where it has been firmly established since at least 1975. This species requires gravel and washed sands for spawning sites, and the ability to migrate amongst each of these rivers and the Lake helps to promote establishment of new populations to expand species ranges and exchange between existing populations throughout this connected system to help ensure their overall survival. The presence of logperch in Mason Creek is indicative of the interdependence of the Little Oconomowoc River, Oconomowoc River, Mason Creek, and North Lake.

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[72] *Thomas Slawski, PhD., Chief Biologist, SEWRPC staff, June 3, 2016.*

[73] *Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the Oconomowoc River Priority Watershed Project*, Publication WR-194-86, 1986.*

Figure 2.21
WDNR Staff Electrofishing Survey Technique and Sensitive Warmwater, Coolwater, and Coldwater Fish Species Found in Mason Creek: 2014

Source: Maggie Zoellner-Kettle Moraine Land Trust, Inc. and SEWRPC.

North Lake seems to have lost a two-story fishery, due to eutrophication over the last 100 years. A "two story" fishery occurs when a lake is capable of supporting warmwater species like bass, northern pike, and muskellunge in its warm, "top story," while at the same time also supporting cold water species like cisco or whitefish in its deeper, colder, well-oxygenated "lower story."[74] For example, Lac Courte Oreilles, a 5,139-acre lake located in Sawyer County, Wisconsin, with a maximum depth of 90 feet, is a rare two-story fishery lake. This lake has smallmouth and largemouth bass, walleye, northern pike, muskies and other

[74] *Frank Pratt, WDNR, Lac Courte Oreilles – a Rare and Fragile "Two Story Fishery" see website link at cola-wi.org/fish-wildlife*

warm water species in the top story, while at the same time supports both cisco and lake whitefish in its narrow, colder layer of water in its lower story. Cisco or lake herring were first reported to occur in North Lake on August 25, 1911. In fact, from 1911 through 1927, cisco were found in high abundance in all of the deepest Oconomowoc River watershed lakes including North, Pine, Okauchee, Oconomowoc, Silver, Fowler, and LaBelle.[75] Cisco were reported to be present and afforded winter angling opportunities as recently as 1963 in North Lake and summer kills of ciscoes were reported in Pine Lake up till the early 1980s. Recent sampling in 2013 verified that cisco populations generally still persist in most of the lakes within the Oconomowoc River watershed, but their abundances are significantly reduced and they are likely extirpated from Lac LaBelle and Silver Lake. Surprisingly, small or low abundances of cisco are still found in Fowler, North, and Pine Lakes; high abundances in Oconomowoc Lake; and very high abundances in Okauchee Lake. These results generally indicate an overall loss in the extent and distribution of cold water habitat throughout the Oconomowoc River system, but some populations still thrive and this fishery has a good potential to be restored.

The greatest threat and management challenge of cisco populations in inland lakes is the enrichment of the waters, which during the summer results in the depletion of dissolved oxygen levels in the lower stratum (i.e., deep waters). This depletion forces the cisco into the upper strata or surface waters where temperatures are unfavorable for survival. Such conditions in lakes leads to significant cisco mortalities. Summer kills of ciscoes were reported in several of the chain of lakes within the Oconomowoc River system as early as 1927. It has been well established that North Lake has experienced summer total dissolved oxygen depletion in the bottom or deep waters since the early 1900s and that condition has not improved.[76] Hence, the accelerated eutrophication in North Lake has likely led to the loss of cisco and of the structure of this two story fishery, which also has been associated with a decrease in lake condition and degraded fishery quality. For example, cisco in the existing two-story fishery of Lac Courte Oreilles, as summarized above, is one reason that lake consistently produces big gamefish, including world-class muskellunge. By comparison, North Lake contains many of the same gamefish, including smallmouth and largemouth bass, walleye, and northern pike, and cisco likely made up a larger proportion of the diet of those fishes when cisco were more abundant. So, the loss of the majority of the cisco population indicates a significant loss of 1) the amount and quality of cold water habitats in North Lake and 2) access to a high quality food source for gamefish species with those two factors likely contributing to an imbalance of the fishery in this lake. **Therefore, the improvement of the cisco population in North Lake and restoration of the "two story" fishery could be a useful assessment criteria to determine whether implementation of pollutant load reductions within Mason Creek are being successful.** Using the estimated oxythermal niche boundary, which is a combination of limiting dissolved oxygen (DO) concentrations and temperatures combined, would provide a benchmark for quantifying potential refuge habitat in North Lake, potential risks of extinction, and for measuring the effectiveness of efforts in Mason Creek to protect North Lake. So, the effects of hypolimnetic oxygen changes on cisco thermal habitat could be quantified by comparing relative positions of oxythermal conditions measured with summer profiles on North Lake, without having to conduct fishery surveys. Mapped profiles of temperature and dissolved oxygen concentrations through the entire water column would probably approach the oxythermal niche boundary (e.g. lethal temperature was 23.0°C at 5.0 mg/L DO concentration, 22.0°C at 3.0 mg/L DO concentration, and 19.5°C at 1.0 mg/L DO concentration) as thermal habitat deteriorates, particularly in late summer.[77] In other words, because cisco require cold well-oxygenated waters, they are sentinels of the health of the lakes they inhabit, so increased abundance of the existing self-sustaining naturally reproducing population of cisco within North Lake would be a key indicator that the overall quality of the Lake ecosystem is improving.[78]

[75] *Alvin Robert Cahn, "An Ecological Study of Southern Wisconsin Fishes: the Brook Silversides (Labidesthes sicculus) and the Cisco (Leucichthys artedi) in Their Relations to the Region,"* Illinois Biological Monographs*, Volume XI, January 1927*.

[76] *WDNR, Oconomowoc River Priority Watershed, 1986,* op. cit.

[77] *Peter C. Jacobson and others, "Field Estimation of a Lethal Oxythermal Niche Boundary for Adult Ciscoes in Minnesota Lakes,"* Transactions of the American Fisheries Society, *Volume 137, pages 1464-1474, 2008*.

[78] *John Lyons, Jeff Kampa, Tim Parks, and Greg Sass,* The Whitefishes of Wisconsin's Inland Lakes: the 2011-2014 Wisconsin Department of Natural Resources Cisco and Lake Whitefish Survey*, Fisheries and Aquatic Research Section, WDNR, February 2015*.

Mussels

Freshwater mussels are large bivalve (two-shelled) mollusks that live in the sediments of rivers, streams, and some lakes. Mussels are considered one of the most endangered families of animals in North America. These soft-bodied animals are enclosed by two shells made mostly of calcium and connected by a hinge. Mussels can typically be found anchored in the substrate, with only their siphons occasionally exposed. They typically favor sand, gravel, and cobble substrates. They play an important role in aquatic ecosystems by helping stabilize river bottoms; serving as natural water filters; providing excellent spawning habitat for fish; and serving as food for fish, birds, and some mammals. Live mussels and relic shells provide a relatively stable substrate in dynamic riverine environments for a variety of other macroinvertebrates, such as caddis flies and mayflies, and for algae.

Mussels are viewed as important, sensitive indicators of changing environmental conditions. Water and sediment quality are important habitat criteria for mussels. Most species of freshwater mussels prefer clean running water with high oxygen content, and all species are susceptible to pollution, including pesticides, heavy metals, ammonia, and algal toxins. Mussels can be used to document changes in water quality over long periods of time since they are long-lived. Shells accumulate metals from both water and sediment, so testing heavy metal concentrations in shells can tell researchers when water in a given area was first contaminated. The presence or absence of a particular mussel species provides information about long-term water health. Because juvenile forms of mussels are more susceptible to pollution than the adult forms, finding juveniles with few adults nearby may indicate a newly colonized area. In general, having healthy diverse populations of mussels means the water quality is good.

Mussels have never been sampled for in the Mason Creek watershed, so their abundance and diversity within this system is unknown.

Benthic Macroinvertebrates

Benthic macroinvertebrates are organisms without backbones that inhabit the substrates such as sediments, debris, logs, and plant vegetation in the bottom of a stream or creek for at least part of their life cycle. Macroinvertebrates are visible to the naked eye, are abundant in freshwater systems, and include insect larvae such as leeches, worms, crayfish, shrimp, clams, mussels, and snails. Since benthic macroinvertebrates develop and grow within the water, they are affected by local changes in water quality. Just like fishes some are more tolerant to pollution and some are more sensitive, which makes them good indicators of water quality.

The majority of macroinvertebrates tend to be found within the shallow, fast flowing riffle habitats of streams compared to deeper and slower flowing pool or run habitats. Riffles can range from uneven bedrock or large boulders to sand substrates. However, the optimum riffle substrates for macroinvertebrates are characterized by particle diameters ranging from gravels (one inch) to cobbles (ten inches). Water flowing through these areas provides plentiful oxygen and food particles. Riffle-dwelling communities are made up of macroinvertebrates that generally require high dissolved oxygen levels and clean water, and most are intolerant of pollution. For example, mayflies (Ephemeroptera), stonefly larvae (Plecoptera), and caddisfly larvae (Trichoptera) tend to be found in cold, clear flowing water with a gravel or stone bottom with high dissolved oxygen concentrations. Caddisfly larvae, in particular are sensitive to pollution and oxygen depletion.[79]

Macroinvertebrate analyses were conducted by the WDNR from 1979 to 2013 at five locations on Mason Creek and in some cases on the same dates as the fisheries samples (see Map 2.5). As noted above, the number and type of macroinvertebrates present in a stream can provide an indicator of water quality. Hence, multiple indices that include the Hilsenhoff Biotic Index (HBI), Family-Level Biotic Index (FBI),[80] Index of Biotic Integrity (IBI), HBI Max 10, species richness, genera richness, and percent EPT (percent of individuals or Genera comprised of Ephemeroptera, Plecoptera, and Trichoptera) were used to classify macroinvertebrate and environmental quality in Mason Creek as shown in Table 2.11. The five sites that were surveyed on Mason Creek ranged from fair to very good quality, but the majority of the rankings indicated a good to

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[79] *Osmond, D.L., and others. 1995. WATERSHEDSS: Water, Soil and Hydro-Environmental Decision Support System, h2osparc.wq.ncsu.edu, North Carolina State University Water Quality Group, 1995, see website at www.water.ncsu.edu/watershedss/info/macroinv.html*

[80] *William L. Hilsenhoff,* Rapid Field Assessment of Organic Pollution with Family-Level Biotic Index*, University of Wisconsin- Madison, 1988.*

Table 2.11
Water Quality Ratings Using Macroinvertebrate Indices
Among Sites Within Mason Creek: 1979-2014

	Stream Sites (see Map 2.5)								
	Lower Mason Creek			Upper Mason Creek					
	Peterson Road (RM 0.25)	Koester Road (RM 0.50)		Westshore Drive (RM 2.12)	CTH CW (RM 2.51)				Private Farm (RM 3.32)
Parameters	2014	1995	2003	2014	5/12/1979	1979	1995	2014	2014
HBI (Hilsenhoff Biotic Index)	Very Good (4.37)	Good (4.99)	Good (5.38)	Very Good (4.16)	Good (4.82)	Good (4.21)	Good (4.53)	Good (5.23)	Good (4.69)
FBI (Family-Level Biotic Index)	Good (4.53)	Very Good (4.25)	Fair (5.26)	Very Good (4.17)	Good (4.66)	Very Good (3.85)	Good (4.39)	Fair (5.35)	Good (4.55)
IBI (Index of Biotic Integrity)	Fair (4.16)	Fair (4.07)	Fair (3.73)	Fair (3.99)	Fair (4.22)	Fair (4.82)	Fair (5.04)	Fair (4.85)	Fair (4.01)
HBI Max 10	Very Good (4.33)	Good (5.03)	Good (4.73)	Good (4.73)	Good (4.79)	Very Good (4.28)	Good (4.84)	Good (5.04)	Good (5.10)
Percent EPT (Ephemeroptera, Plecoptera, and Trichoptera)-Individuals	34	66	27	5	36	65	33	20	52
Percent EPT- Generas	30	37	22	23	38	39	27	29	33
Species Richness	22	20	18	16	16	19	23	27	22
Genera Richness	21	19	18	16	16	18	22	27	20

Note: Unless otherwise noted all samples were collected in the fall season.

Source: University of Wisconsin-Stevens Point, Wisconsin Department of Natural Resources, and SEWRPC

very good quality condition (see Table 2.11). This ranking was supported by a moderate to high species richness, genera richness, and percent EPT values for individuals and genera.

Comparison of the historical sample ratings to the more recent samples site collected in 2003 and 2012 indicates that the Lower Mason Creek site has retained a good to very good quality and the Upper Mason Creek maintained a good quality score (see Table 2.11).[81] In addition, the WDNR conducted a special summer assessment on Mason Creek in 1983 and identified good biotic quality ratings for sites in the Upper and Lower Mason Creek reaches,[82] which is consistent with current conditions. However, it is important to note that at the Koester Road site within the Lower Mason Creek reach, which contained some gravel substrates, significant siltation was observed. The sampling in 1983 also found that the East Branch had the highest quality score (very good), and the West Branch Agricultural Ditch had the worst score (very poor), compared to other sites in the watershed. These results are consistent with the historical and current water quality conditions within Mason Creek and confirm that the West Branch Agricultural Ditch of Mason Creek has historically contained very poor water quality and biotic community conditions. These very poor conditions have likely negatively impacted the coldwater brook trout fishery within Mason Creek since the West Branch Agricultural Ditch was channelized sometime between 1909 and 1937 (see "Stream Conditions" section below). As previously mentioned, no brook trout have ever been observed to be present within the West Branch Agricultural Ditch. In contrast, the East Branch has very good water quality, and it has been, and continues to be, a critical reach that supports the high quality brook trout fishery in Mason Creek.[83] This reach has existed since the original plat map of 1837, which confirms that this is part of the originally designated Mason Creek, and has likely been sustained by significant groundwater discharge.

Although overall benthic macroinvertebrate quality is good to very good within Mason Creek, as previously mentioned, channelization has removed the naturally meandering channel and associated riffle habitats

[81] *M.T. Barbour, J. Gerritsen, B.D. Snyder, and J.B. Stribling,* Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish*, Second Edition, EPA 841-B-99-002, U.S. Environmental Protection Agency, Office of Water, Washington, D.C., 1999.*

[82] *Hilsenhoff, W.L.,* Using a Biotic Index to Evaluate Water Quality in Streams*, WDNR Technical Bulletin No. 132, Madison, Wisconsin, 1982.*

[83] *WDNR, Oconomowoc River Priority Watershed, 1986, op. cit.*

within the Upper and Lower Mason Creek reaches. Brook trout are voracious and opportunistic feeders and will consume whatever is most readily available, but Ephemeroptera, Trichoptera, and Diptera often make up a large component of their diet.[84] Riffle habitats produce the highest abundance and diversity of macroinvertebrate food for brook trout compared to other instream habitats. Therefore, the loss of these riffle habitats significantly reduced the abundance and availability of food for brook trout in Mason Creek, which has likely limited the overall growth and/or population size throughout the watershed. Thus, restoring the historic meandering channel patterns and associated riffle and pool habitats—particularly in both the Upper and Lower Mason Creek reaches—presents the greatest potential to improve macroinvertebrate quality and the associated brook trout fishery along with reductions of nonpoint source pollution loads.

Wisconsin researchers have generally found that as the amount of human land disturbance increases, such as in the Mason Creek watershed, the subsequent macroinvertebrate community diversity and abundance decreases. Although this system has been able to maintain fair to very good macroinvertebrate community quality, there is still potential for improvement. Thus, continued monitoring of the macroinvertebrate community will be an important and effective tool, or biological indicator, to assess changes in water quality in the future, particularly as the recommendations in this plan to improve water quality are implemented.

2.3 POLLUTANT LOADING MODEL

As previously noted (see "TMDL Requirements" subsection), the most current pollution load and wasteload allocations and load and wasteload reduction goals for the impaired portion of Mason Creek (Subbasin 24) (see Tables 2.5 and 2.6) were developed under the Rock River TMDL. The SWAT model developed under the TMDL study indicated that agriculture is the main contributing source of sediment and phosphorus in the Mason Creek watershed, and all of the tributary subwatersheds draining into that waterbody. Therefore, **to be consistent with the Rock River TMDL nonpoint source load reduction requirements, load reductions for the Mason Creek watershed need to meet or exceed 92 percent for total phosphorus (5,355 lbs) and 93 percent for total suspended sediment (883 tons) from the median annual nonpoint baseline load as shown in Table 2.4.** [85]

To better refine pollutant loading and sources within the Mason Creek watershed, a separate USEPA Spreadsheet Tool for Estimating Pollutant Load (STEPL) model was applied under this study.[86] STEPL employs simple algorithms to calculate nutrient and sediment loads from different land uses and the load reductions that would result from the implementation of various best management practices (BMPs). STEPL provides a user-friendly Visual Basic (VB) interface to create a customized spreadsheet-based model in Microsoft (MS) Excel. It computes watershed surface runoff; nutrient loads, including total nitrogen, phosphorus, and 5-day biochemical oxygen demand (BOD); and sediment delivery based on various land uses and management practices. For each of the four subbasins (MC-1 through MC-4) and two additional internally drained areas (MC-2A and MC-2B) within the watershed, the annual nutrient loading was calculated based on the runoff volume and the pollutant concentrations in the runoff water as influenced by factors such as the land use distribution and management practices. The annual sediment load (sheet and rill erosion only) is calculated based on the Universal Soil Loss Equation (USLE) and the sediment delivery ratio. The sediment and pollutant load reductions that result from the implementation of BMPs are computed using generalized BMP efficiencies. STEPL model results for pollutant loading and load reductions are shown in Appendix B.
It is important to note that although it is likely that the pollutant loads estimated using the STEPL model overestimate the actual loads entering Mason Creek, based on comparison to measured instream loads summarized above and other modeling techniques such as SWAT,[87] STEPL is an effective tool to assess existing load allocations and potential reductions for planning purposes.

The pollutant modeling results from the STEPL analysis in this study and the modeling results from the aforementioned Rock River TMDL study both demonstrated that agricultural land is the main contributing source of pollutants in the Mason Creek watershed. Figure 2.22 shows that the highest loads of nitrogen, phosphorus, BOD, and sediment would be expected to come from cropland within the Mason Creek

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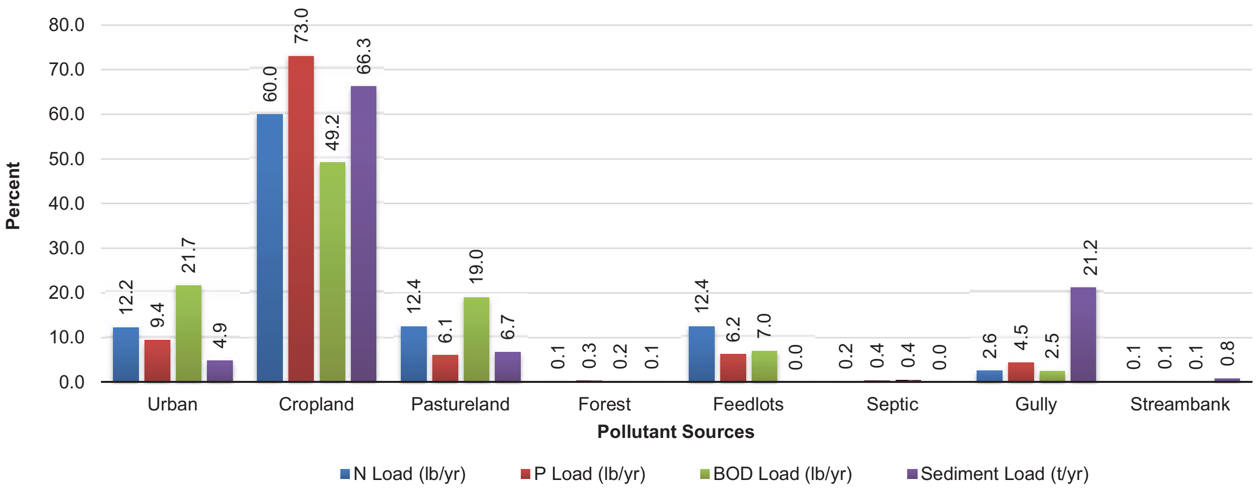
[84] *Pauline Adams, Christopher James, and Clay Speas,* Brook trout (Salvelinus fontinalis) Species and Conservation Assessment*, Prepared for the Grand Mesa, Uncompahgre, and Gunnison National Forests, March 2008.*

[85] *See Appendix L and Appendix M of the 2011 Rock River TMDL report.*

[86] *Information on the STEPL model can be found on the website* it.tetratech-ffx.com/steplweb/.

[87] *Outagamie County Land Conservation Department,* Nonpoint Source Implementation Plan for the Plum and Kankapot Creek Watersheds*, 2014.*

Figure 2.22
Proportion of Nitrogen (N), Phosphorus (P), Biological Oxygen Demand (BOD), and Sediment Loads Among Pollutant Sources Without Best Management Practices (BMPs) Within the Mason Creek Watershed: 2010



Note: this modeled data was based upon year 2010 land use and any additional known installed practices or conditions up to year 2014, where applicable.

Source: U. S. Environmental Protection Agency, Washington County, Waukesha County, Wisconsin Department of Natural Resources, and SEWRPC.

watershed. Cropland accounted for about 60 percent of total nitrogen, 73 percent of total phosphorus, 49 percent of BOD, and 66 percent of total suspended sediment annual nonpoint source loads. Thus, the majority of the targeted management measures in this plan are focused on cropland BMPs as summarized in Chapter 3 of this report. Pasture, feedlots, septic systems, gullies, and streambanks were also determined to contribute to pollutant loads, but these are much less significant than cropland sources.

Urban nonpoint source pollutant loads only accounted for a small proportion of the existing total load within the Mason Creek watershed, or about nine percent of the TP and five percent of TSS loads (Figure 2.22). Based upon the planned year 2035 levels of urban development these loads are expected to increase (see Map 1.7). Therefore, reduction of nonpoint source pollution loads from areas of existing and planned development is an important issue that needs to be addressed in this plan and a necessary component of the overall load reduction goals for this watershed.[88]

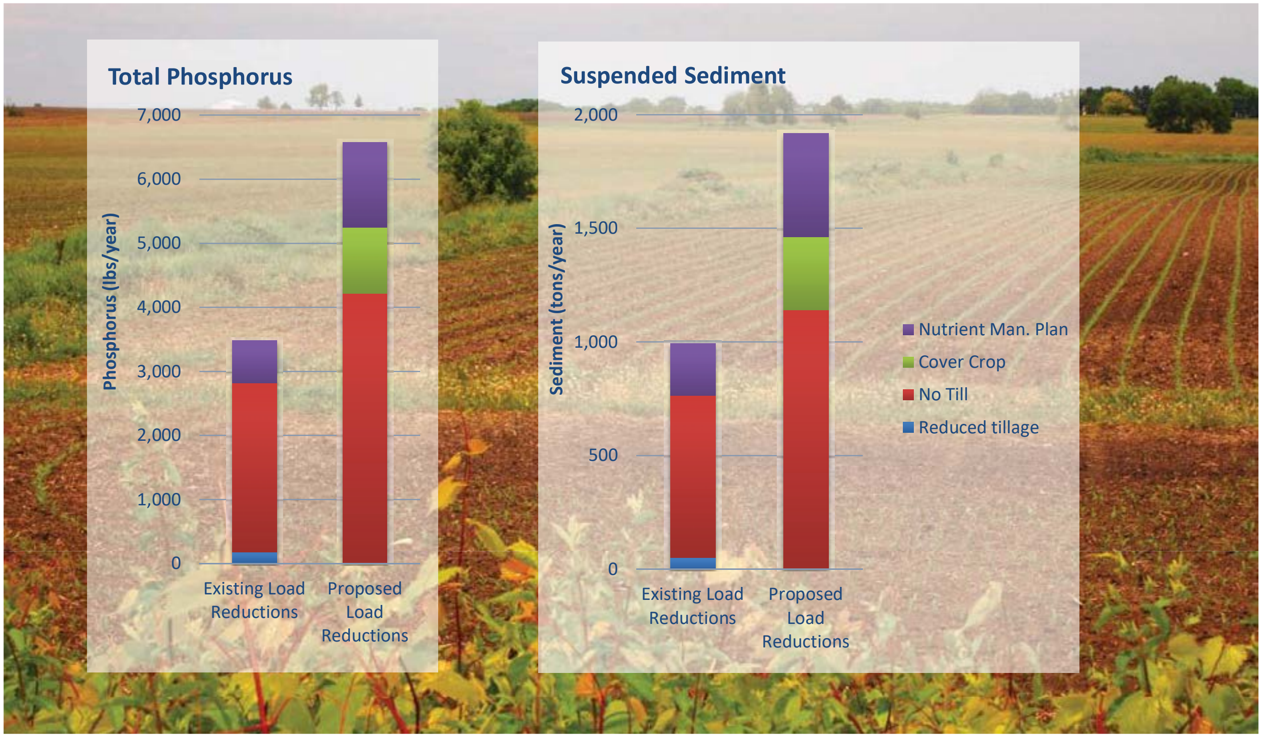
2.4 WATERSHED INVENTORY RESULTS

The staffs of the U.S. Department of Agriculture (USDA) National Resources Conservation Service (NRCS), WDNR, Washington County Planning and Parks Department, and Waukesha County Department of Parks and Land Use Land Resources Division assisted the SEWRPC staff in gathering information on livestock operations, gullies, potentially restorable wetlands, riparian buffers, and farming practices throughout the watershed.

SEWRPC staff also conducted a survey of streambank erosion conditions and instream habitat conditions for the mainstem of Mason Creek and selected tributaries from 2012 through 2015.

[88] *Performance standards for control of urban nonpoint source pollution from existing and new development are set forth in Chapter NR 151, "Runoff Management," of the* Wisconsin Administrative Code. *The Town of Merton, which has been designated as an MS4 community subject to Wisconsin Pollutant Discharge Elimination System permit requirements under Chapter NR 216, "Storm Water Discharge Permits," of the* Wisconsin Administrative Code, *is required to meet those standards.*

Figure 2.23
Existing and Proposed Annual Load Reductions Among Agricultural BMPs Applied to Cropland for Total Phosphours (lbs/year) and Suspended Sediment (tons/year) Within the Mason Creek Watershed: 2015



Note: Proposed load reductions shown in these graphs include both load reductions from existing practices and load reductions from additional proposed Agricultural BMPs. The load reductions for nitrogen and BOD are not included in this figure, but were proportionally similar to the phosphorus and sediment load reductions shown.

Current Management Practices/Projects Summary

Conservation practices installed within the Mason Creek watershed over the last 30 years, since publication of the Oconomowoc River Priority Watershed plan,[89] include:

- Conservation tillage practices on approximately five percent of the cropland in the watershed
- No till practices on approximately 50 percent of the cropland in the watershed
- Nutrient management plans for 50 percent of the cropland in the watershed
- Protection and/or establishment of 1,418 acres of riparian buffers

As shown in Figure 2.23, based on application of the USEPA STEPL model, these projects are providing significant annual pollutant load reductions to Mason Creek, and are helping the watershed to meet approximately 35 percent and 36 percent of annual pollutant load reduction goals for Total Phosphorus (TP) and Total Suspended Sediment (TSS), respectively (see Appendix B). Hence, maintenance of these practices is an important element of this plan to ensure that they are still functioning as designed. However, it is important to note that these existing practices are not enough to achieve the load reduction goals needed to meet the TMDLs for the Mason Creek watershed (Subbasin 24) as summarized above. A description of current practices and proposed projects are discussed in more detail in the following text.

[89] *WDNR, Oconomowoc River Priority Watershed, 1986, op. cit.*

Feedlot Inventory Results

Locations of current livestock operations were compiled in consultation with local NRCS staff and Washington and Waukesha County staff, and from USDA 2012 agriculture census data and 2010 and 2015 digital, color orthophotographs obtained by Washington and Waukesha Counties under a program administered by SEWRPC. It was estimated that there are approximately three active livestock operations or feedlots with an estimated 119 beef and dairy cattle, 19 swine, 10 sheep, 39 horses, 39 chickens, one turkey, and two ducks in the Mason Creek watershed. Onsite barnyard inventories were not conducted on any of these sites, so the exact number of animal units are unknown. However, none of these farms is a large enough operation to be classified as a permitted Concentrated Animal Feeding Operation or CAFO. Locations of the feedlots or livestock operations in the watershed are shown in Map B.1 of Appendix B.

Feedlot area estimates were made for the largest sites that could be identified in the watershed using geographic information system (GIS) data and tools and the 2010 and 2015 digital, color orthophotographs. Those areas were used in the STEPL model to estimate pollution loads (Appendix B). Based upon this data, as shown in Figure 2.22, it was estimated that runoff from feedlots constitutes approximately 12.4 percent of the nitrogen, 6.2 percent of the phosphorus, 7.0 percent of the BOD, and none of the sediment load from agriculture each year. Thus, feedlot runoff from livestock operations is generally not a significant source of nutrient loads in this watershed. In addition, there was no evidence of trampled streambanks or cattle observed in Mason Creek and neither Washington County nor Waukesha County staff were aware of any significant problems associated with livestock operations within the watershed.[90] It is likely that these fairly small operations can reduce any annual loads with low cost, clear water diversions and roof gutters, although more specific information would be needed to make specific recommendations. Although barnyard runoff is only contributing a small percentage of the total nutrient and sediment loading in this watershed, it is always an important issue as long as any animal units are kept within the watershed.

Upland Inventory

Agricultural uplands were inventoried using GIS data and tools, County and NRCS information, and digital, color orthophotography.

Tillage Practices and Residue Management

Crop residue levels do not remain static and often a producer's crop rotation plan will dictate changes to the tillage practice at the end of a growing season. For this reason, an annual inventory of tillage conditions is not as useful as understanding the current and recent year practices on a particular farm field. Nonetheless, estimates provided by County staff and qualitative observations indicate that a range of low to high residue practices (see Figure 2.24) are being practiced within the watershed. In addition, visible signs of erosion are prominent throughout the watershed. Rill erosion and some gullies were visible on or adjacent to several fields. A rill is a shallow channel (no more than a few inches deep) cut into soil by the erosive action of flowing water. Similar but smaller incised channels are known as microrills and larger incised channels are known as gullies. As noted above, some form of conservation tillage is practiced on approximately five percent of the cropland in the watershed, and no till cultivation is practiced on an additional 50 percent. No till is far more effective than conventional tillage in reducing nutrient and sediment runoff, and the overall goal for this watershed is for farmers to change from conventional and less effective forms of conservation tillage, increasing no till practices from being applied on 50 percent of the cropland to being applied on 75 percent. Application of STEPL indicates that implementation of 75 percent no till practices within the Mason Creek watershed could produce additional pollutant load reductions of 4,306 lbs of nitrogen, 1,319 lbs of phosphorus, 2,282 lbs of BOD, and 356 tons of sediment from croplands on an annual basis (see Figure 2.23).

<u>Cover Crops</u>

The benefits of establishing cover crops include reducing soil erosion, reducing the need for synthetic fertilizers, building organic matter in the soil, and improving local waterways. Contrary to early concerns by farmers and other conservationists, use of cover crops actually leads to increased yields, rather than a decrease.[91] Cover crops, such as winter wheat (see Figure 2.25), are planted and grown before the cash crop

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[90] *Personal Communication, Paul Sebo, Washington County, and Perry Lindquist, Waukesha County.*

[91] *2015 Cover Crop Survey Analysis, see website: www.sare.org/Learning-Center/From-the-Field/North-Central-SARE-From-the-Field/2015-Cover-Crop-Survey-Analysis*

season. According to a recent survey funded by the USDA Sustainable Agriculture Research and Education program and the American Seed Trade Association, during the 2014-15 growing season, more than 1,200 farmers found that corn yields rose on average 3.7 bushels per acre (2.1 percent) and soybean yields increased 2.2 bushels per acre (4.2 percent) when planted in fields with cover crops. This was the third year in a row where the farmers who were surveyed observed an increase in yield when cover crops were incorporated.

Cover crops are not currently being implemented within the Mason Creek watershed. Under this plan, a goal was adopted to establish cover crops on 50 percent of the cropland or about 987 acres within the watershed. The anticipated load reductions attributable to such a level of cover crop establishment are 4,243 lbs of nitrogen, 1,031 lbs of phosphorus, 2,048 lbs of BOD, and 320 tons of sediment from croplands on an annual basis (See Figure 2.23). In addition, such practices are expected to greatly improve overall soil health in the watershed.

Nutrient Management

Nutrient management plans are conservation plans designed to address concerns related to soil erosion, manure management, and nutrient applications. Nutrient management plans must meet the standards of the Wisconsin NRCS 590 Standard.

Based upon Washington County and Waukesha County records, there are currently 987 acres, or about 50 percent of the cropland in the watershed, under a nutrient management plan. All agricultural operators in the watershed should have nutrient management plans, so developing plans for the remaining 50 percent, or 987 acres, is the ultimate goal for this watershed. Implementation of nutrient management plans for all cropland within the Mason Creek watershed is expected to provide additional pollutant load reductions of 1,590 lbs. of nitrogen, 664 lbs. of phosphorus, 1,463 lbs. of BOD, and 229 tons of sediment on an annual basis (see Figure 2.23). It is important that each County monitors to insure full and effective implementation of nutrient management plans.

Figure 2.24
Examples of Typical Farming Practices Within the Mason Creek Watershed

LOW RESIDUE WITH EROSION AND CONCENTRATED FLOW

HIGH RESIDUE/NO TILL FARMING PRACTICE

Note: These photos were not taken in the Mason Creek watershed.

Source: Maggie Zellner-Kettle Moraine Land Trust, Inc. and SEWRPC.

Soil Health/Quality Indicators

The Phosphorus Index (PI) and soil phosphorus concentrations are monitored as part of nutrient management planning on farms. The PI is calculated by estimating average annual runoff phosphorus delivery from each field to the nearest surface water based on the field’s soil conditions, crops, tillage, manure and fertilizer applications, and long term weather patterns. The higher the Index number, the greater the amount that the field is contributing phosphorus to local waterbodies. Tracking of soil test phosphorus concentrations and phosphorus index (PI) in the watershed can be useful in prioritizing fields for improved management practices; however, there are many additional physical, chemical, and biological soil quality indicators available for farmers, conservationists, and soil scientists to assess and manage soil health (see Appendix E). The soil quality indicators as summarized in Appendix E directly relate soil quality with soil function, so these are more straightforward and effective parameters to assess and

Figure 2.25
One Example of Cover Crop Farming Best Management Practice

COVER CROP WINTER WHEAT NO-TILL PLANTED INTO SHREDDED CORN STALKS

Note: This photo was not taken in the Mason Creek watershed.

Source: NRCS and SEWRPC

manage soil health than the PI. Therefore, as more landowners in the watershed in both Washington County and Waukesha County sign up for nutrient management plans, more soil quality indicators will be monitored and data will become available to assess and improve soil function for this watershed.

Erosion Vulnerability

Priority fields for conservation practices were evaluated using slope, soils, and floodplain information (see Maps 1.3, 1.11, and 1.12). Cropland underlain with soil that has the potential to produce more runoff (i.e., lower infiltration rates and steep slopes) are more likely to have runoff and erosion problems. Any cropland with a mean slope of two percent or greater was considered a priority field for conservation practices (see "Soil Erodibility" section in Chapter 1 of this report). More specifically, fields with slopes of 2 to 6 percent were designated as high priority, and fields with 6 percent or higher slope were considered critical. In addition, as a general rule, effectiveness of agricultural Best Management Practices (BMPs) in improving water quality decreases with distance from a waterbody. Based upon these conditions a general parcel level agricultural priority map for BMP implementation (Map 2.6) was developed for three categories:

> ***High priority***-Agricultural lands that are intersected by waterways. This includes parcels containing waterbodies such as drainage ditches and tributaries draining directly to Mason Creek or floodways and/or floodplains of Mason Creek as designated by the Federal Emergency Management Agency (FEMA) (see Map 1.3).
>
> ***Moderate priority***-Agricultural lands that are not directly connected to Mason Creek, but still contain some portion of fields with 6 percent or higher slope, soils with higher runoff potential, and/or isolated wetlands or ponds.
>
> ***Low priority***-Agricultural lands that are not directly connected to Mason Creek. These parcels generally contain fields with less than 6 percent slope and soils with lower runoff potential.

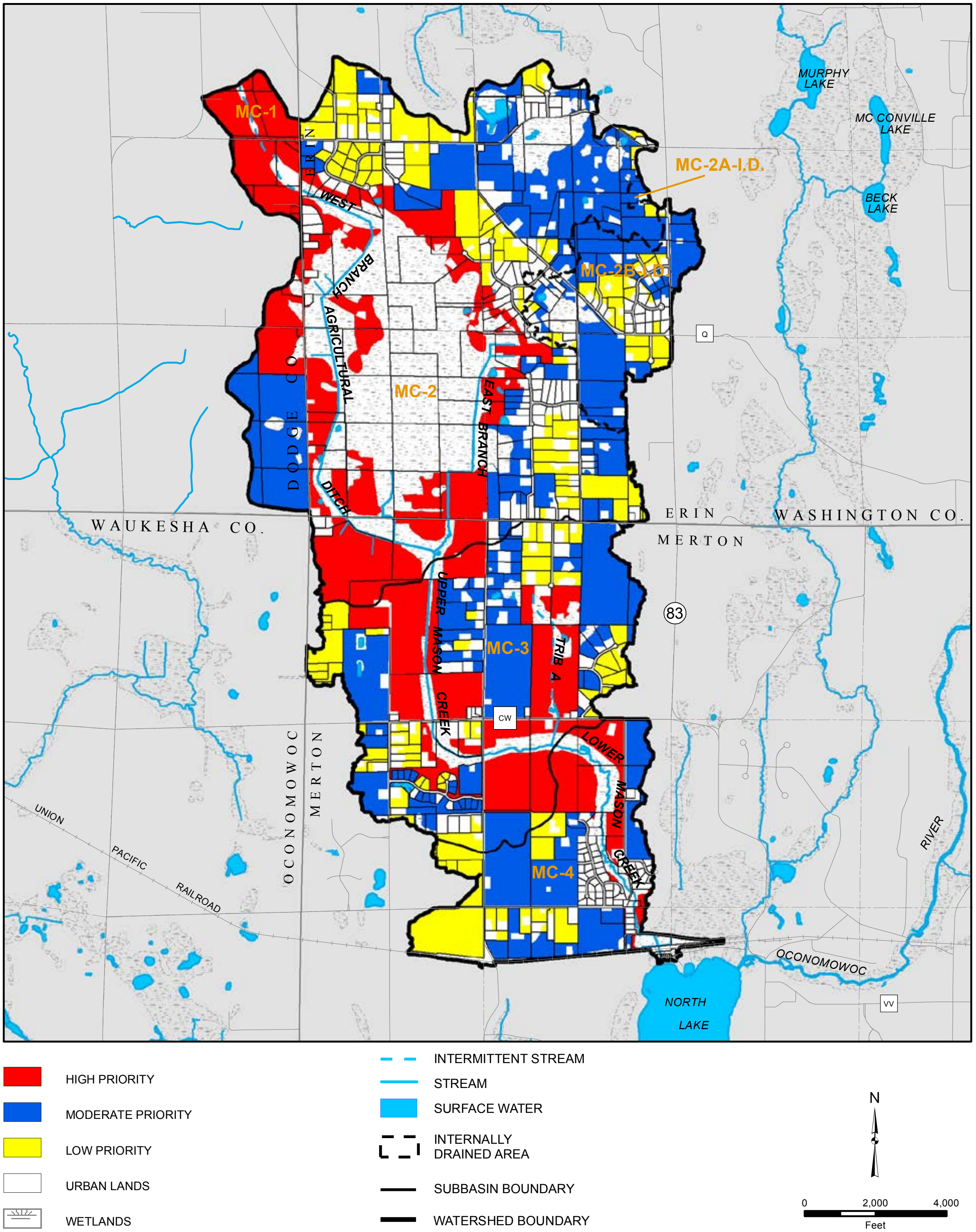
This prioritization scheme is designed to first address the highest priority or critical parcel sites for which pollutant loads can be most cost-effectively reduced. Within the Mason Creek watershed the greatest proportions of high and moderate priority fields occur within subbasins MC-3, MC-2, MC-4, and MC-1 (in descending order). The use of BMPs such as cover crops, no tillage, nutrient management plans, gully stabilization, and establishment of riparian buffers/wetland restoration practices on all priority fields will be necessary to achieve pollution load reductions.

Potential Restorable Wetlands

Wetlands provide a number of benefits such as water quality improvement, wildlife habitat, and flood mitigation. According to the USEPA a typical one-acre wetland can store about one million gallons of water.[92] Restoring wetlands in the watershed area will provide water storage and reduce sediment and phosphorus loading. Establishing restored wetlands, particularly as riparian buffers (see "Riparian Corridor Conditions" subsection below), can help reduce pollution loads from tile drains, barnyards, and upland runoff, and can be implemented in areas where frequent crop damage occurs due to flooding.

[92] *U.S. Environmental Protection Agency (USEPA),* Wetlands: Protecting Life and Property from Flooding*, May 2006, USEPA843-F-06-001, Website: water.epa.gov/type/wetlands/outreach/upload/Flooding.pdf.*

Map 2.6
Prioritization Among Parcels for Implementation of Agricultural BMPs Within the Mason Creek Watershed: 2015



NOTE: SOME AREAS PRIORITIZED FOR IMPLEMENTATION OF AGRICULTURAL BMPS CONSIST OF PLATTED LANDS THAT ARE CURRENTLY FARMED.

Source: SEWRPC

Hydric soils characteristic of wetland conditions form under settings where the ground was saturated with water for long enough periods of time to cause changes in the soil properties. These unique soils and growing conditions fostered a suite of plant species that thrive in wet, oxygen-deprived soil. The very few wetlands remaining in the Mason Creek watershed, outside of the large wetland complex associated with the Mason Creek Swamp natural area (see Map 1.9), are found along the main stem of the Creek. Pella silt loam, Pistakee silt loam, and Brookston silt loam are the predominant hydric soil types, and are very productive when the water table is lowered. Tile systems discharging to the mainstem and tributaries of the Creek are common throughout the watershed.

Under the Rock River TMDL study, each subwatershed was analyzed to identify locations of potentially restorable wetlands (PRW) using the Wisconsin Wetlands Inventory, hydric soils, and land cover data.[93] A candidate area for wetland restoration was defined as any wetland that was historically a wetland but has since been drained due to tiling and ditching or has been filled in. A wetland was considered potentially restorable if it met hydric soil criteria and was not in an urban area. The TMDL analysis estimated that there are about 329 acres of PRW in the Mason Creek watershed. The modeled load reductions also showed that if 80 percent of the potentially restorable wetlands are restored it is estimated that sediment loads would be reduced 55 percent and phosphorus loads would be reduced 44 percent in the Mason Creek watershed. Hence, according to the analysis, restoring wetlands could result in a significant reduction in pollutant loading, and would be a key component to address nonpoint source soil erosion.

Using the WDNR potentially restorable wetlands GIS layer, potential wetland restoration sites in the Mason Creek watershed were evaluated for their feasibility for restoration based on location and size. Any wetland less than five acres was considered economically infeasible and removed from consideration. Any site that was located in an area of existing or ongoing development was eliminated. After these adjustments were made, it was determined that it would be potentially feasible to restore 205 acreas of wetlands within the Mason Creek watershed, as shown on Map 2.7. Subbasin MC-2 contains 124 acres of PRW, which is more than twice the amount of PRW in any other subbasin. Subbasins MC-3 and MC-1 each contain the next highest areas of PRW with 56 acres and 14 acres, respectively. Collectively, subbasins MC-4, and MC-2B comprise the remaining 11 acres of PRW. Subbasin MC-2A does not contain any PRW.

Implementing restoration of wetlands will be difficult since it involves taking agriculture land out of production. However, these important riparian areas were considered a high priority to protect and restore physiochemical function to reduce pollution loads and improve biodiversity and landscape connectivity within this watershed.

The load reductions associated with these potential wetland restorations are shown in Figure 2.26, which also includes load reductions for high priority 75 foot riparian buffer width areas and steep slope areas (see “STEPL Load Reduction Results for Existing Riparian Buffers, 75-Foot Riparian Buffer Expansion Areas, Conversion of Farmed Potential Restorable Wetlands, and Conversion of Farmed Steep Slopes” sections and Maps B.1 and B.2 in Appendix B of this report). Potentially restorable wetland areas are also good candidate sites for constructed floodplain benches associated with remeandering the Upper and Lower Mason Creek reaches and/or opportunities to modify tile drainage to reduce pollution loads. Therefore, any PRW areas that are located within the existing floodplain boundary would be a high priority for conversion to wetland, because their location would facilitate a higher level of protection to reduce pollutants from entering into Mason Creek. Potential wetland restoration sites will have to be further evaluated onsite prior to any design and implementation.

Agricultural Tile Drainage

Tile outlets draining directly to Mason Creek or its tributaries were identified as part of the stream inventory conducted between 2012 and 2014. Locations of the tiles are shown on Maps F.1 through F.5 in Appendix F. This information, coupled with the soils information, indicates it is likely that the great majority, or all, of the fields within this watershed contain a tile drainage system. Tile drains in fields can act as a conduit for nutrient transport to streams if not managed properly. Treating tile drainage at the outlet and better management of nutrient/manure applications on fields can reduce the amount of phosphorus reaching

[93] *USEPA and WDNR, 2011,* op. cit.

Map 2.7
Potentially Restorable Wetlands Within the Mason Creek Watershed: 2015

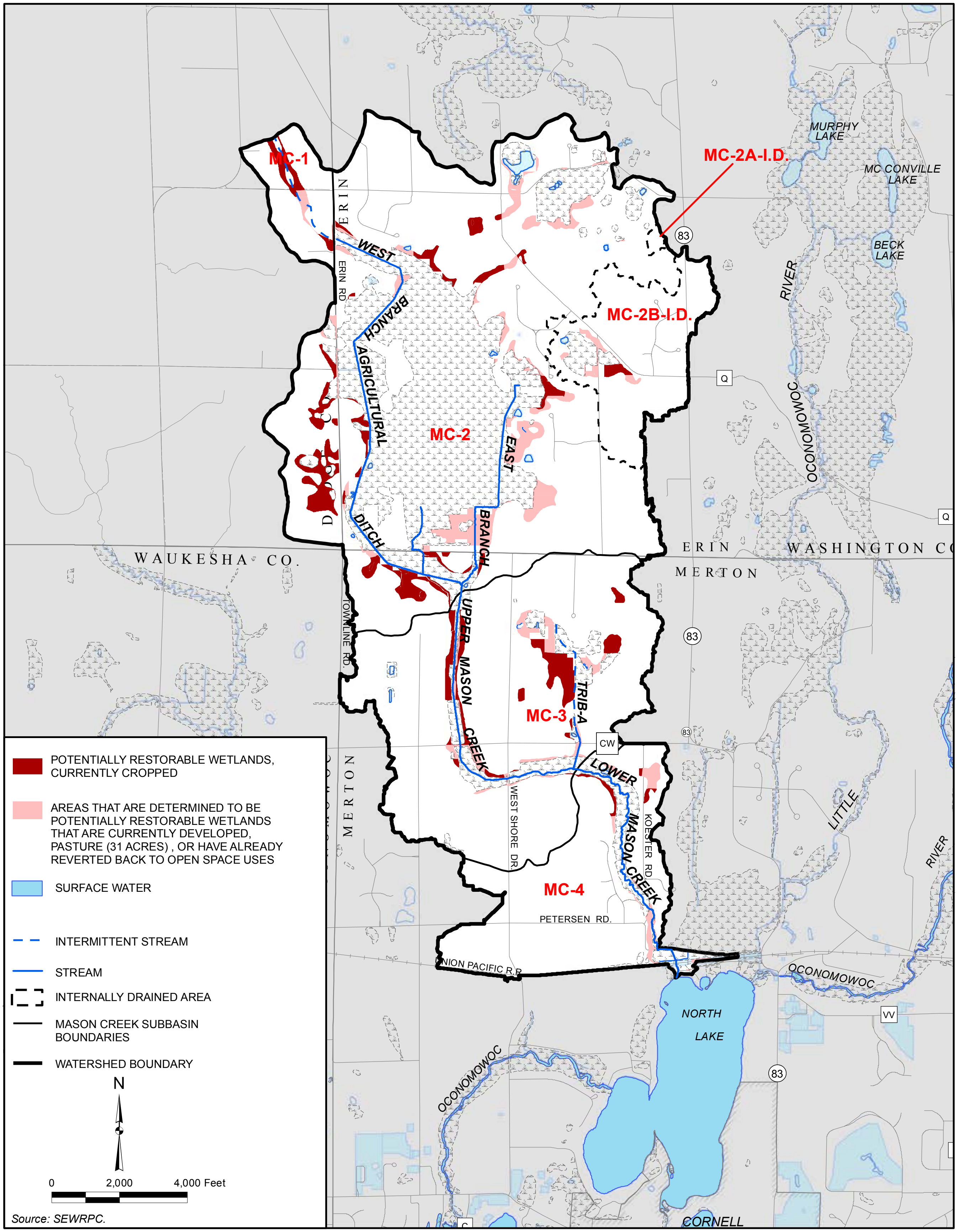
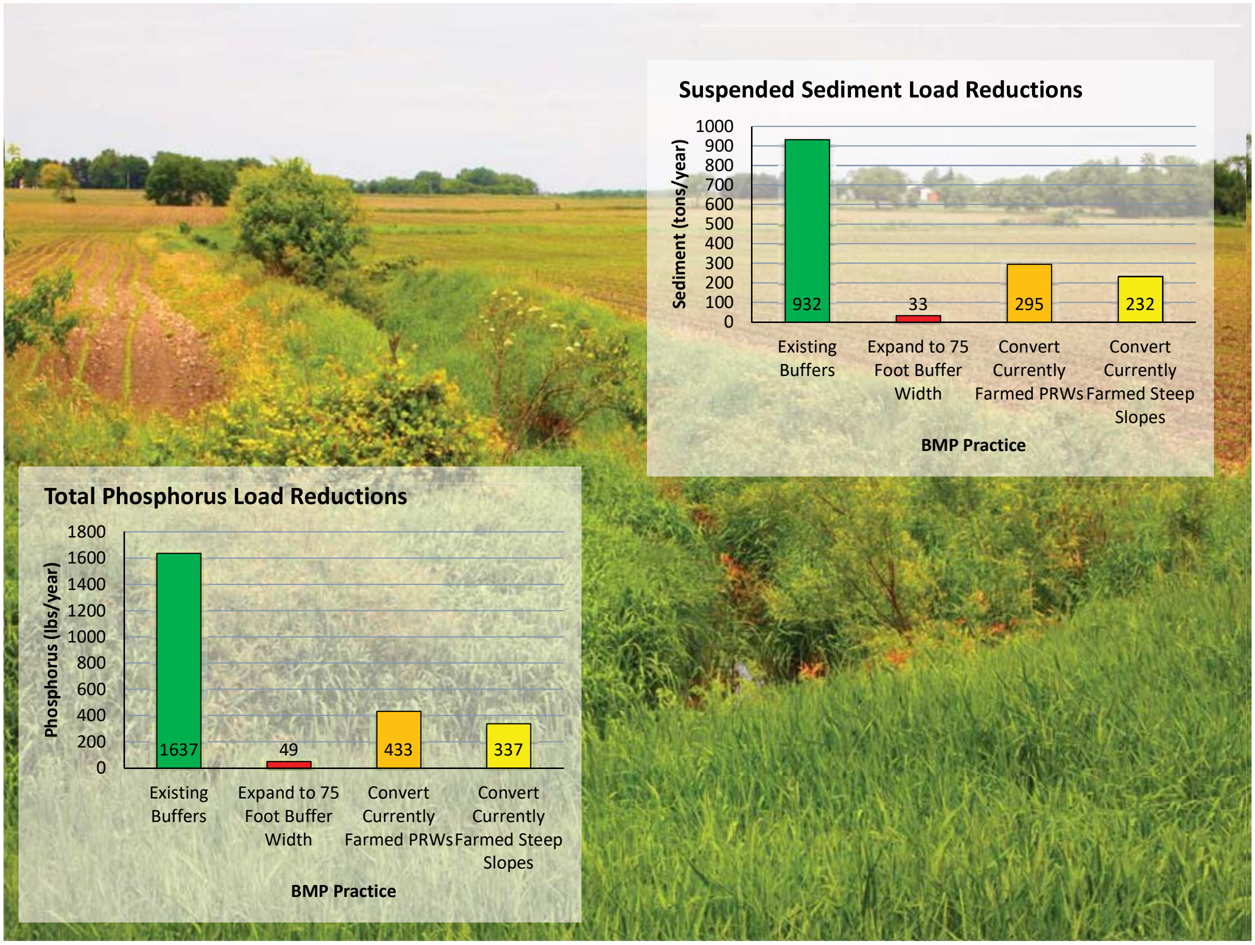


Figure 2.26
Annual Pollutant Load Reductions for Existing Riparian Buffers, Proposed 75-Foot Riparian Buffer Expansion, Proposed Conversion of Currently Farmed Potentially Restorable Wetland, and Proposed Conversion of Currently Farmed Steep Slopes Within the Mason Creek Watershed: 2015 (Areas Correspond with Maps B.1 and B.2 in Appendix B)



Notes: The load reductions for nitrogen and BOD are not included in this graph, but were proportionally similar to the phosphorus and sediment load reductions shown.

PRWs = Potentially Restorable Wetlands

Source: SEWRPC.

Mason Creek. Some options for treating tile drainage at the outlet include constructing a floodplain bench associated with remeandering the mainstem of Mason Creek and/or installation of drainage water control structures to retain water in the soil column beneath fields under certain conditions.

Riparian Corridor Conditions

Healthy riparian corridors help to protect water quality, groundwater, fisheries and wildlife, and ecological resilience to invasive species, and can reduce potential flooding of structures and harmful effects of climate change.[94] The health of riparian corridors is largely dependent upon width and continuity. Therefore, efforts to protect and expand the remaining riparian corridor width and continuity are the foundation for protecting and improving the fishery, wildlife, and potential recreation within the Mason Creek watershed.

[94] *N.E. Seavy, et al., "Why Climate Change Make Riparian Restoration More Important than Ever: Recommendations for Practice and Research,"* Ecological Restoration*, Volume 27, Number 3, September, 2009, pages 330-338; "Association of State Floodplain Managers, Natural and Beneficial Floodplain Functions: Floodplain Management—More Than Flood Loss Reduction, 2008,"* www.floods.org/NewUrgent/Other.asp.

Table 2.12
Effect of Buffer Width on Contaminant Removal

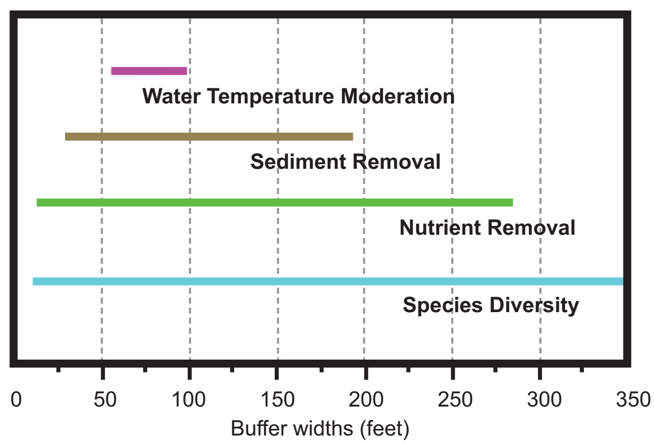
Buffer Width Categories (feet)	Contaminant Removal (percent)[a]				
	Sediment	Total Suspended Sediment	Nitrogen	Phosphorus	Nitrate-Nitrogen
1.5 to 25					
Mean	75	66	55	48	27
Range	37-91	31-87	0-95	2-99	0-68
Number of Studies	7	4	7	10	5
25 to 50					
Mean	78	65	48	49	23
Range	--	27-95	7-96	6-99	4-46
Number of Studies	1	6	10	10	4
50 to 75					
Mean	51	--	79	49	60
Range	45-90	--	62-97	0-99	--
Number of Studies	5	--	2	2	1
Greater than 75					
Mean	89	73	80	75	62
Range	55-99	23-97	31-99	29-99	--
Number of Studies	6	9	8	7	1

[a] *The percent contaminant reductions in this table are limited to surface runoff concentrations.*

Source: University of Rhode Island Sea Grant Program.

The provision of buffer strips along waterways represents an important intervention that addresses anthropogenic sources of contaminants. Even relatively small buffer strips provide a degree of environmental benefit, as suggested in Table 2.12 and Figure 2.27 and further discussed in Appendix C.[95] The Wisconsin Buffer Initiative (WBI) further developed two key concepts that are relevant to this plan: 1) riparian buffers are very effective in protecting water resources and 2) riparian buffers need to be a part of a larger conservation system to be most effective.[96] However, it is important to note that the WBI limited its assessment and recommendations to the protection of water quality, and did not consider the additional values and benefits of riparian buffers. Research clearly shows that riparian buffers can have many potential benefits, such as flood mitigation, prevention of channel erosion, provision of fish and wildlife habitat, enhancement of environmental corridors, and water temperature moderation (see Appendix C). However, the nature of the benefits and the extent to which the benefits are achieved is site-specific. Consequently, the ranges in buffer width for each of the buffer functions shown in Figure 2.27 are large. Buffer widths should be based on desired functions, as well as site conditions. For example, based upon a number of studies of sediment removal,

Figure 2.27
Range of Buffer Widths for Providing Specific Buffer Functions



Note: Site-specific evaluations are required to determine the need for buffers and specific buffer characteristics.

Source: *Adapted from A. J. Castelle and others, "Wetland and Stream Buffer Size Requirements-A Review,"* Journal of Environmental Quality, *Vol. 23.*

[95] *Data were drawn from A. Desbonnet, P. Pogue, V. Lee, and N. Wolff, "Vegetated Buffers in the Coastal Zone – A Summary Review and Bibliography," CRC Technical Report No. 2064. Coastal Resources Center, University of Rhode Island, 1994.*

[96] *University of Wisconsin-Madison, College of Agricultural and Life Sciences,* The Wisconsin Buffer Initiative, *December 2005.*

buffer widths ranging from about 25 to nearly 200 feet achieved removal efficiencies of between 33 and 92 percent, depending upon local site conditions such as soil type, slope, vegetation, contributing area, and influent concentrations, to name a few. More specifically, recent research has identified several key characteristics associated with successful buffer effectiveness to reduce pollutant loads in agricultural settings as summarized in the following text:[97]

- Field slopes should generally range between one and nine percent. Sites with high slopes are not effective, because runoff velocities are too high, which reduces trapping efficiency. Site with slopes that are too low are not as effective, because the hydraulic gradient is insufficient.

- Field soil loss rates must be less than 10 tons per acre, otherwise rate of soil deposition will exceed the buffer trapping efficiency. If soil loss rates are excessive, other agricultural BMPs should be implemented to reduce erosion rates prior to buffer installation.

- The ratio of field area to buffer area should preferably not be greater than 50:1, unless soil erosion rates are very low. Buffers need to intercept the dominant flow path that transports pollutants on the field to be effective, and it is important to promote sheet flow of field runoff through the buffer to effectively remove pollutants. So, field rill and gully erosion must be addressed with conservation tillage or plugs or some other technique prior to discharging into the buffer, so that overland flow is dispersed and not in the form of concentrated flow.

- For site conditions where precipitation intensity exceeds infiltration capacity of the field tributary to the buffer (i.e., dominant flow path is overland surface runoff), the buffer strip must allow for sediment deposition, nutrient uptake, denitrification, and/or degradation of pesticides through reduction of overland velocity, increased infiltration capacity, and increased surface roughness.

- For site conditions where precipitation intensity is less than the infiltration capacity (i.e., dominant flow path is subsurface lateral flow and/or saturation excess, tile drainage), constructed wetland buffers can provide suitable increases in nutrient uptake, infiltration capacity, retention and denitrification, and degradation of pollutants. Buffers are only effective in removing pollutants from subsurface flow when the soil root zone is deep enough to intercept shallow groundwater subsurface flows.

Figure 2.27 also shows that for any particular buffer width, for example 75 feet, the buffer can provide multiple benefits, ranging from water temperature moderation to enhancement of wildlife species diversity. A benefit not shown in the figure includes bank stabilization, which is an important concept in utilizing buffers for habitat protection (see Appendix C).

While it is clear from the literature that wider buffers can provide a greater range of values for aquatic systems, the need to balance human access and use with the environmental benefits to be achieved suggests that a 75-foot-wide riparian buffer provides a minimum width necessary to contribute to good water quality and a healthy aquatic ecosystem. In general, most pollutants are removed within a 75-foot buffer width. However, from an ecological point of view, 75-foot-wide buffers are inadequate for the protection and preservation of groundwater recharge or wildlife species. Riparian buffer strips greater than 75 feet in width provide significant additional physical protection of streamcourses, owing to their function in intercepting sediment and other contaminants mobilized from the land surface as a result of natural and anthropogenic activities. These wider buffers also serve to sustain groundwater recharge and discharge relationships, and to provide biological benefit from the habitat established within the shoreland and littoral areas associated with streams and lakes.[98]

For example, the highest quality environmental corridors, natural areas, and vegetation communities are located within and adjacent to the riparian buffer network throughout the Mason Creek watershed as

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[97] *Rebecca A. Rittenburg, and others, "Agricultural BMP Effectiveness and Dominant Hydrological Flow Paths: Concepts and a Review," Journal of the American Water Resources Association, 51(2): pages 305-329, 2015.*

[98] *See, for example, Brian M. Weigel, Edward E. Emmons, Jana S. Stewart, and Roger Bannerman, " Buffer Width and Continuity for Preserving Stream Health in Agricultural Landscapes,"* Wisconsin Department of Natural Resources Research and Management Findings*, Issue 56, December 2005.*

shown on Maps 1.9 and 2.8. In other words, riparian buffers are a vital conservation tool that provides the connectivity among landscapes to improve the viability of wildlife populations within the habitats comprising the primary environmental corridor and isolated natural resource areas.[99]

As previously mentioned, healthy and sustained aquatic and terrestrial wildlife diversity is dependent upon adequate riparian buffer width and habitat diversity. Specifically, recent research has found that the protection of wildlife species is determined by the preservation or protection of core habitat within riparian buffers with widths ranging from a minimum of 400 feet to an optimal 900 feet or greater as summarized in Appendix C. These buffer areas are essential for supporting healthy populations of multiple groups of organisms, including birds, amphibians, mammals, reptiles, and insects and their various life stages. For example, some species of birds, amphibians, turtles, snakes, and frogs have been found to need buffer widths as great as 2,300 feet, 1,500 feet, 3,700 feet, 2,300 feet, and 1,900 feet, respectively, for at least part of their life histories. Hence, preservation of riparian buffers to widths of up to 1,000 feet or greater represents the optimal condition for the protection of wildlife in the Mason Creek watershed.[100]

Map 2.8 shows the major natural cover types both within and outside of the existing riparian buffers distributed throughout the Mason Creek watershed. This inventory shows that the riparian buffers are comprised of a variety of wetland (emergent/wet meadow, flats, forested, and scrub/shrub) and upland (brush, grassland, upland conifer, and deciduous) vegetation communities. Each of these habitats is necessary to support the life history requirements of multiple wildlife species. For example, amphibians and reptiles have been reported to utilize numerous habitat types that include seasonal (ephemeral) wetlands, permanent wetlands (lakes, ponds, and marshes), wet meadows, bogs, fens, small and large streams, springs and seeps, hardwood forest, coniferous forest, woodlands, savannahs, grasslands, and prairies.[101] Hence, it is this mosaic of habitats and the ability of organisms to travel between them at the correct times in their lives to survive, grow, and reproduce, which is essential to support an abundant and diverse wildlife community throughout this watershed.

The development patterns and infrastructure that humans create on the landscape lead to a number of obstructions that can limit both the availability of wildlife habitat and the ability for organisms to travel between habitats. These obstructions are primarily a result of roadways, railways, and buildings that fragment the natural landscape. Therefore, an effective management strategy to protect wildlife abundance and diversity in the Mason Creek watershed would be to maximize critical linkages between habitat areas on the landscape, ensuring the ability of species to access these areas. Examples of critical linkages include the following:

- Water's edge (lake, pond, river, wetland) to terrestrial landscapes (i.e., riparian buffer width)
- Water's edge to water's edge (e.g., river to ephemeral pond, lake to ephemeral pond, permanent pond to ephemeral pond)
- Habitat complexes or embedded habitats – Wetland to upland (e.g., seep to prairie) and upland to upland (e.g., grassland to woodland)

In addition, connecting the multiple isolated natural resource areas (INRAs) throughout the Mason Creek watershed to the larger primary environmental corridor (PEC) area and building and expanding upon the existing protected lands, represent a sound approach to enhance the corridor system and wildlife areas within the watershed.

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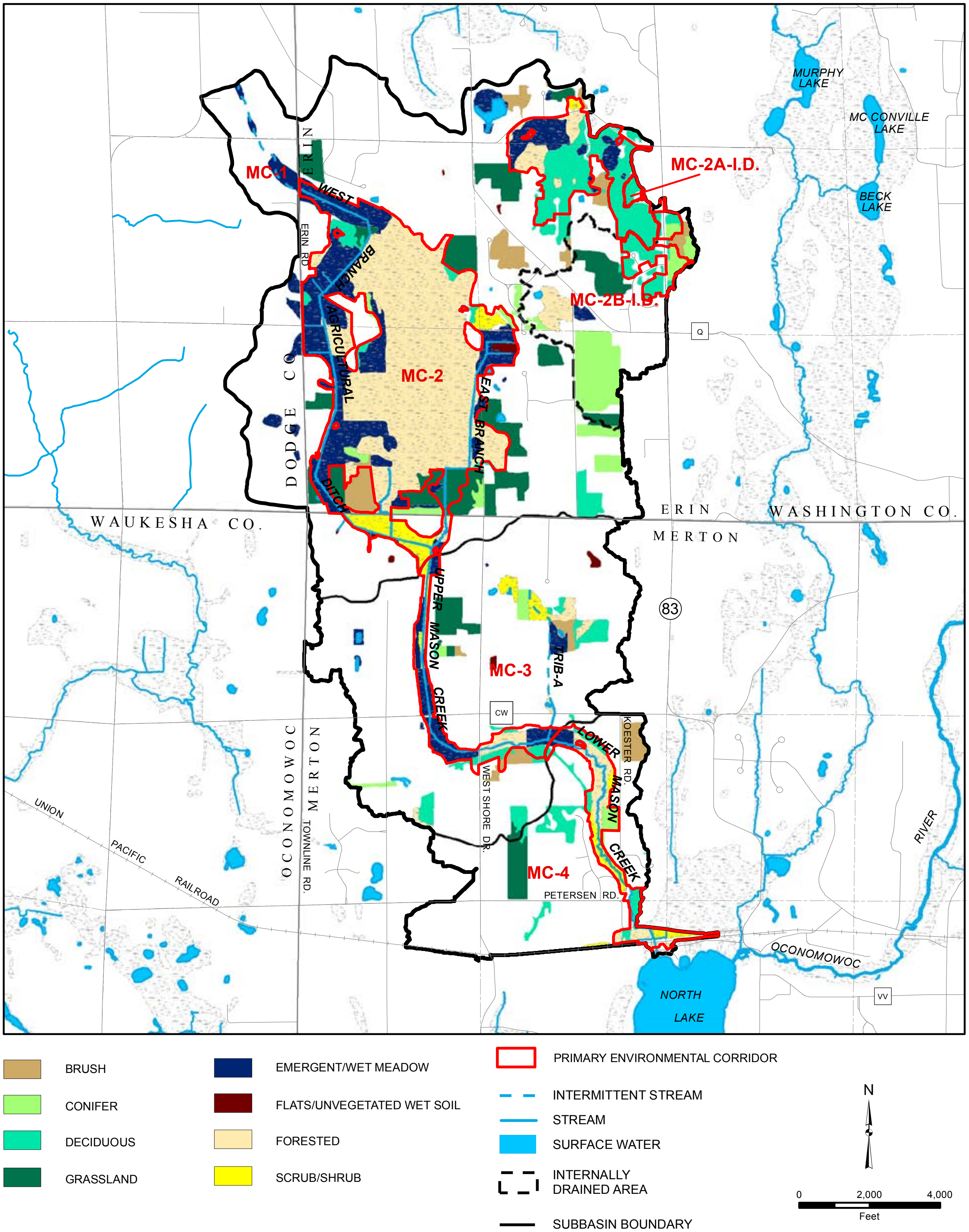
[99] *Paul Beier and Reed F. Noss, "Do Habitat Corridors Provide Connectivity?,"* Conservation Biology*, Volume 12, Number 6, December 1998.*

[100] *The shoreland zone is defined as extending 1,000 feet from the ordinary high water mark of lakes, ponds, and flowages and 300 feet from the ordinary high water mark of navigable streams, or to the outer limit of the floodplain, whichever is greater. To be consistent with this concept and to avoid confusion, the optimum buffer width for wildlife protection is defined as extending 1,000 feet from the ordinary high water mark on both sides of the lakes, ponds, and navigable streams in the watershed.*

[101] *Kingsbury, B.A. and J. Gibson (editors),* Habitat Management Guidelines for Amphibians and Reptiles of the Midwestern United States*, Partners in Amphibian and Reptile Conservation Technical Publication HMG-1. 2nd Edition, 2012, 155 pages.*

Map 2.8
Upland and Wetland Cover Types Located Inside and Outside of Primary Environmental Corridor Boundaries Within the Mason Creek Watershed: 2010



Source: SEWRPC.

Existing and Potential Riparian Buffers

Map B.2 in Appendix B shows the current status of existing and potential riparian buffers at the 75-foot, 400-foot, and 1,000-foot widths and priority PRW areas along Mason Creek and its major tributary streams. Buffers on Map 2.9 were primarily developed from 2010 digital orthophotographs and the 2010 WDNR Wisconsin Wetland Inventory, and from inventories of PEC, SEC, and INRA. Polygons were created using GIS techniques to delineate contiguous natural lands (i.e., nonurban and nonagricultural lands) comprised of wetland, woodland, and other open lands adjacent to waterbodies. Those lands comprise a total of about 1,427 acres, or about 27 percent, of the total land area within the Mason Creek watershed. As shown on Map 2.9 and in Figure 2.28, the most extensive existing buffers outside of internally drained subbasins were found within subbasin MC-2. Those buffers comprise about 40 percent (1,104 acres) of the total land area in that subbasin. In contrast, subbasins MC-1, MC-4, and MC-3 contain about 17, 15, and 11 percent buffers, respectively. Comparison between the existing buffers versus the potential buffers at the 75-foot, 400-foot, and 1,000-foot widths throughout the Mason Creek watershed indicates that the existing buffers contain some areas whose widths exceed 1,000 feet from the edge of the stream, which indicates they are providing significant water quality and wildlife protection (see Map 2.9). These extensive buffers are mostly associated with the Mason Creek Swamp natural area.

A large proportion of the agricultural areas throughout the watershed show encroachments into the 75-foot and 400- foot riparian zones as shown on Map 2.9. In particular, the most significant encroachments into the riparian zone within the 75-foot width are located within subbasins and reaches: MC-3, Upper Mason Creek and Trib-A reaches; MC-4, Lower Mason Creek; and MC-1 and MC-2, adjacent to the West Branch Agricultural Ditch. In descending order, these subbasins contain the following potential areas available to restore riparian buffers within the 75-foot width: MC-3 (7.7 acres), MC-2 (5.4 acres), MC-1 (3.8 acres), and MC-4 (2.7 acres). Therefore, although the majority of the Mason Creek stream network is fairly well buffered, these encroachments within the 75-foot width represent significant gaps in the protection of water quality for a total area of nearly 20 acres or 0.4 percent of the watershed. The analysis also shows that there is the potential to establish and expand buffers in each of the subbasins at the 400-foot and 1,000-foot widths (see Figure 2.28 and Map 2.9).

Riparian Buffer Protection and Prioritization Strategies

All riparian buffers provide some level of protection that is greater than if there were no buffer at all. However, wider buffers provide a greater number of functions (infiltration, temperature moderation, and species diversity) than narrower buffers. Therefore, it is important that existing buffers be protected and expanded where possible.

The riparian buffer network out to the 75-foot, 400-foot, and 1,000-foot widths as summarized above provides the framework upon which to protect and improve water quality and wildlife within the Mason Creek watershed. This framework can be achieved through a combination of strategies that include land acquisition, regulation, and best management practices.

<u>Land Acquisition</u>

The prioritization for acquisition of these lands (including PEC and INRA, and the natural areas (NA)) should be based upon the following order of importance (from highest to lowest priority):

1. Existing riparian buffer (protect what exists on the landscape)

2. Potential riparian buffer lands up to 75 feet wide (minimum level of protection for effective pollutant removal)

3. Potential restorable wetlands and steep slope areas (see Map B.2 in Appendix B) (priority for pollutant removal and wildlife habitat protection)

4. Potential riparian buffer lands up to 400 feet wide (minimum wildlife protection)

5. Potential riparian buffer lands up to 1,000 feet wide (optimum wildlife protection).

Map 2.9
Existing Riparian Buffer and Potential Buffer Zones Within the Mason Creek Watershed: 2010

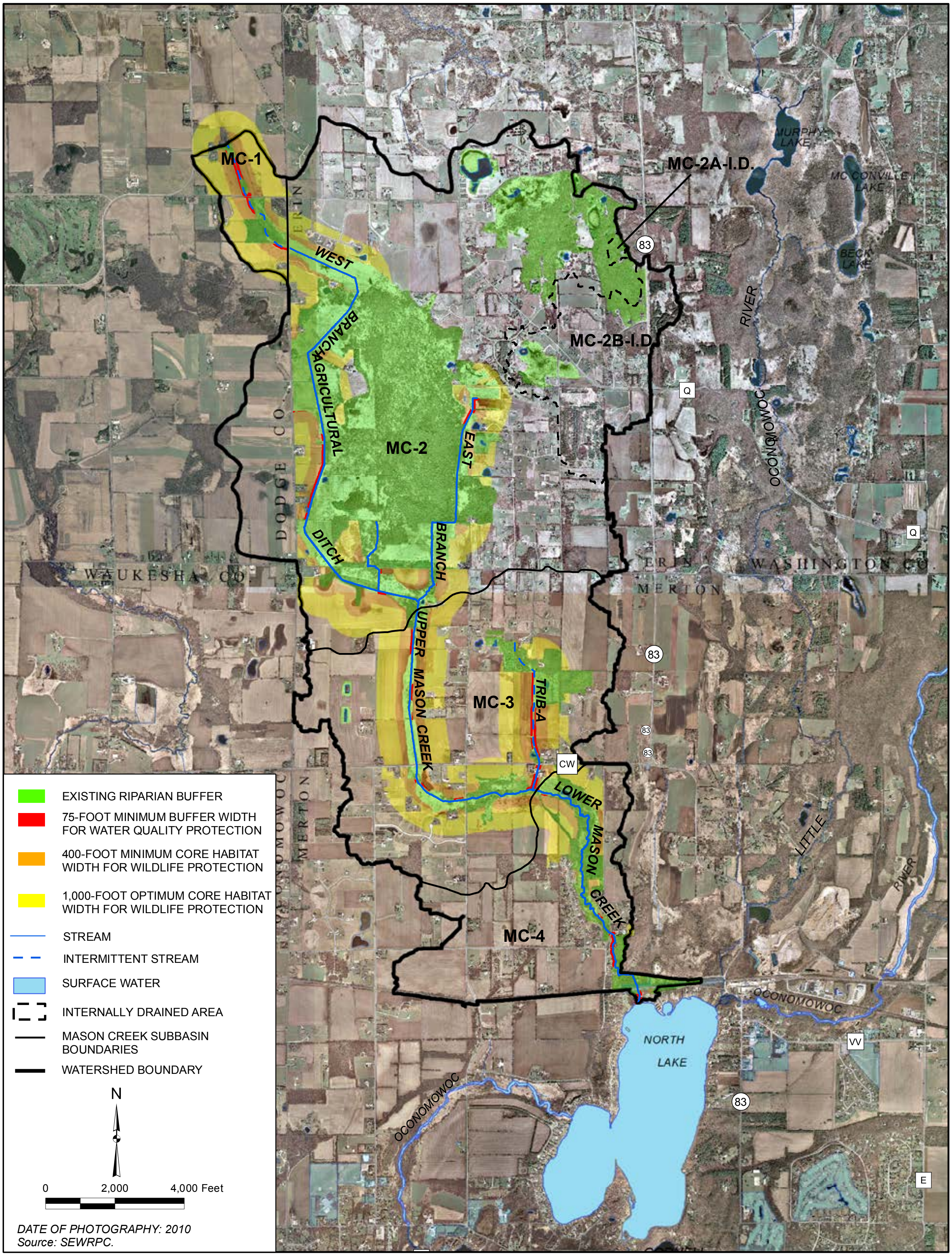
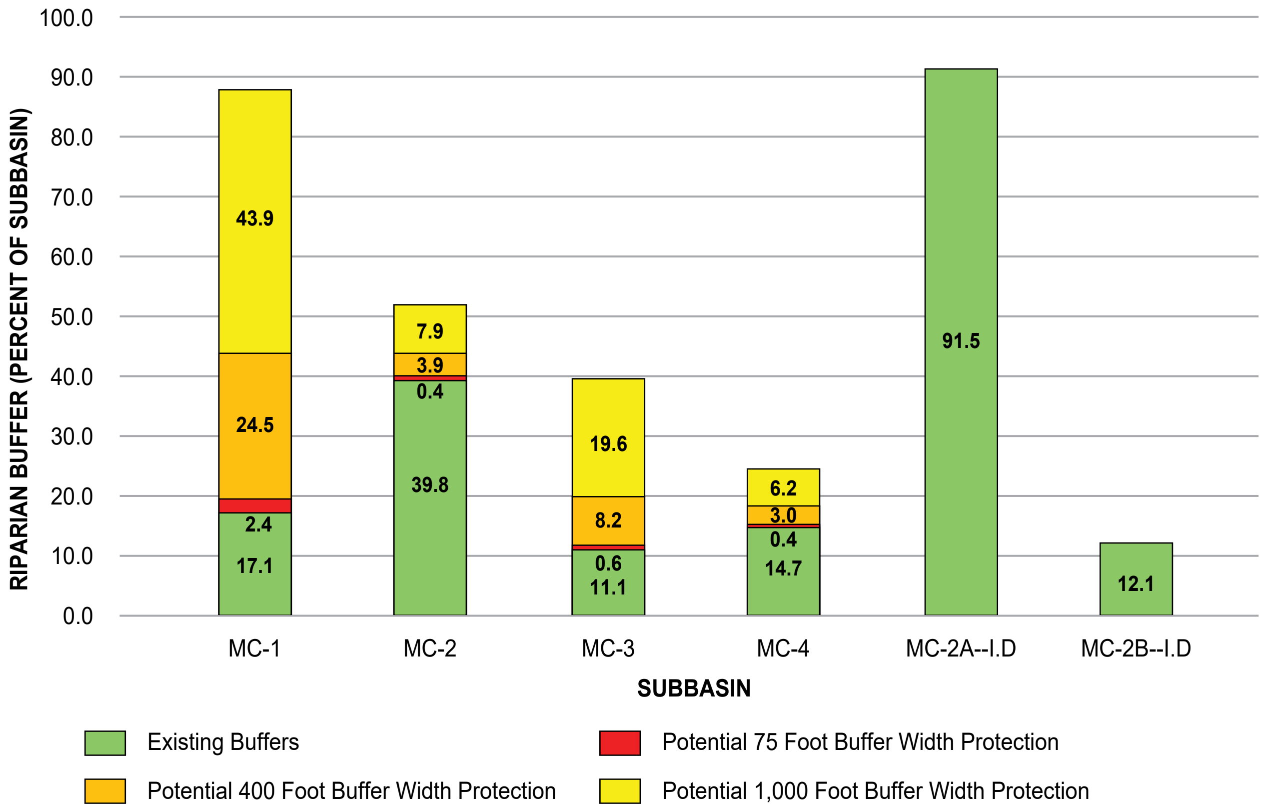


Figure 2.28
Percent Existing and Potential Riparian Buffers Within each Subbasin in the Mason Creek Watershed: 2010



Source: SEWRPC.

In addition, special consideration should be given to 1) the acquisition of riparian buffers in locations designated as having high to very high groundwater recharge potential as shown on Map 1.10 in Chapter 1 of this report and 2) connecting and expanding critical linkages among habitat complexes to protect wildlife abundance and diversity. Furthermore, connecting the multiple INRAs throughout the Mason Creek watershed to the larger PEC areas, as well as building and expanding upon the existing protected lands, represents a sound approach to enhance the corridor system and wildlife areas within the watershed.

Regulatory and Other Opportunities

Chapter NR 115, "Wisconsin's Shoreland Protection Program," of the *Wisconsin Administrative Code* establishes a minimum 35-foot development setback running parallel to the ordinary high water mark of navigable lakes, streams, and rivers. There also is a required minimum tillage setback standard of five feet from the top of the channel of surface waters in agricultural lands called for under Section NR 151.03 of the *Wisconsin Administrative Code*. Instream field observations in the watershed and orthophotograph interpretation indicate that Mason Creek and its tributaries flowing through agricultural lands meet the five-foot tillage setback. As summarized above, not having an adequate buffer between a field and a waterway can contribute to significant sediment and phosphorus loading to the waterway and can significantly limit wildlife habitat. In addition, based upon the water quality and wildlife goals for this watershed, neither the 5-foot tillage setback nor the 35-foot buffer requirement are adequate to achieve the pollutant load reduction goals and resource protection concerns.

It is important to note that crop yield losses have been found to be greatest along the edges of drainage ditches that tend to get flooded. Therefore, adding a buffer to these areas would not be taking prime production areas out of a field. Fields with high slopes (Map 1.12) and high erosion potential (Map 1.11), fields where the minimum riparian buffer width of 75 feet is not being met (Map 2.9) and/or crop land is located within the one-percent-annual-probability (100-year recurrence interval) floodplain (Map 1.3), and fields containing potentially restorable wetlands within 1,000 feet of a waterway are considered priority fields for installation of riparian buffers. In addition, in expanded riparian buffers on cropland, the 75 feet adjacent to the waterway are envisioned to be harvestable buffers, so that farmers can periodically harvest the grasses to feed livestock. Expansion of riparian buffers to the 400- and 1,000-foot widths, or greater to the extent practicable, are not likely to be achievable until such time that the agricultural land is converted to urban uses. At that time, it may be possible to design portions of the development to accommodate such buffer widths. Hence, this will likely be the last chance to establish such critical protective boundaries around waterways before urban structures and roadway networks are constructed.

Primary environmental corridors (PEC) have a greater level of land use protections compared to secondary corridors, isolated natural resource areas, or designated natural areas outside of PEC. Therefore, the regulatory strategy to expand protections for vulnerable existing and potential riparian buffers would be to increase the extent of primary environmental corridor designated lands within the Mason Creek watershed. In particular, there is only one PEC in the Mason Creek watershed (called the Mason Creek Swamp), which comprises a significant amount of the headwater area of Mason Creek and extends along the Upper and Lower Mason Creek reaches all the way downstream to North Lake (see Map 2.10). Therefore, this PEC presents the greatest opportunity to expand primary environmental corridors. Since this area already meets the minimum size requirements for designation as a PEC, any lands with sufficient natural resource features adjacent or connecting to this existing PEC could potentially be incorporated into this designation. Therefore, if buffers could be established adjacent to existing PEC, then these have the potential to be upgraded to PEC. For example, as shown in Figure 2.29 nine acres of cropland adjacent to the West Branch Agricultural Ditch were converted to buffer and restored to wetland vegetation in 2015. This expansion of buffer protection combined with addressing erosion from the concentrated flow areas/Gully 1 and 2 (see "Concentrated Flow/Gully Stabilization" section and Figure 2.30) has reduced annual pollutant loads by 116 lbs. of phosphorus and 164 tons of TSS, and has increased the PEC by an additional nine acres. This is a great example of collaboration and how shared funding among project partners (i.e., Natural Resources Conservation Service (NRCS), City of Oconomowoc, and the North Lake Management District) can be effectively used to protect water quality in Mason Creek, protect the floodplain, and expand environmental corridors for fish and other wildlife.

Wetlands located within PEC lands have been designated as Advanced Delineation and Identification (ADID) wetlands under Section 404(b)(1) of the Federal Clean Water Act and are deemed generally unsuitable for the discharge of dredge and fill material. In addition, the nonagricultural performance standards set forth in Section NR 151.125 of the Wisconsin Statutes, require establishment of a 75-foot impervious surface protective area adjacent to these higher-quality wetlands. This designated protective area boundary is measured horizontally from the delineated wetland boundary to the closest impervious surface.[102] Hence, these wetlands would have additional protections from being filled and from being encroached upon by future development, thus, they will retain their riparian buffer functions.

Best Management Practices and Programs for Riparian Buffers

A large portion of the existing and potential riparian buffers within agricultural as well as urban areas of the watershed are privately owned. It is the private landowner's choice to establish a buffer. In addition, although riparian buffers can be effective in mitigating the negative water quality effects attributed to agricultural management practices and urbanization, they alone cannot address all of the pollution problems associated with these land uses. Therefore, in agricultural settings riparian buffers need to be combined with other management practices, such as barnyard runoff controls, manure storage, filter strips, nutrient management planning, constructing grassed waterways, and reduced tillage, to mitigate the effects of agricultural runoff. In addition, riparian buffers in urban areas need to be combined with other management practices, such as infiltration facilities, wet detention basins, porous pavements, green roofs, and rain gardens to mitigate the effects of urban stormwater runoff. Therefore, the best management practices to improve and protect water quality in both agricultural and urban areas are essential elements for the protection of water quality and quantity and wildlife within the Mason Creek watershed (see Chapter 3 for more details).

Recent research has indicated that converting up to eight percent of cropland at the field edge from production to create wildlife buffer habitat leads to increased yields in the cropped areas of the fields and

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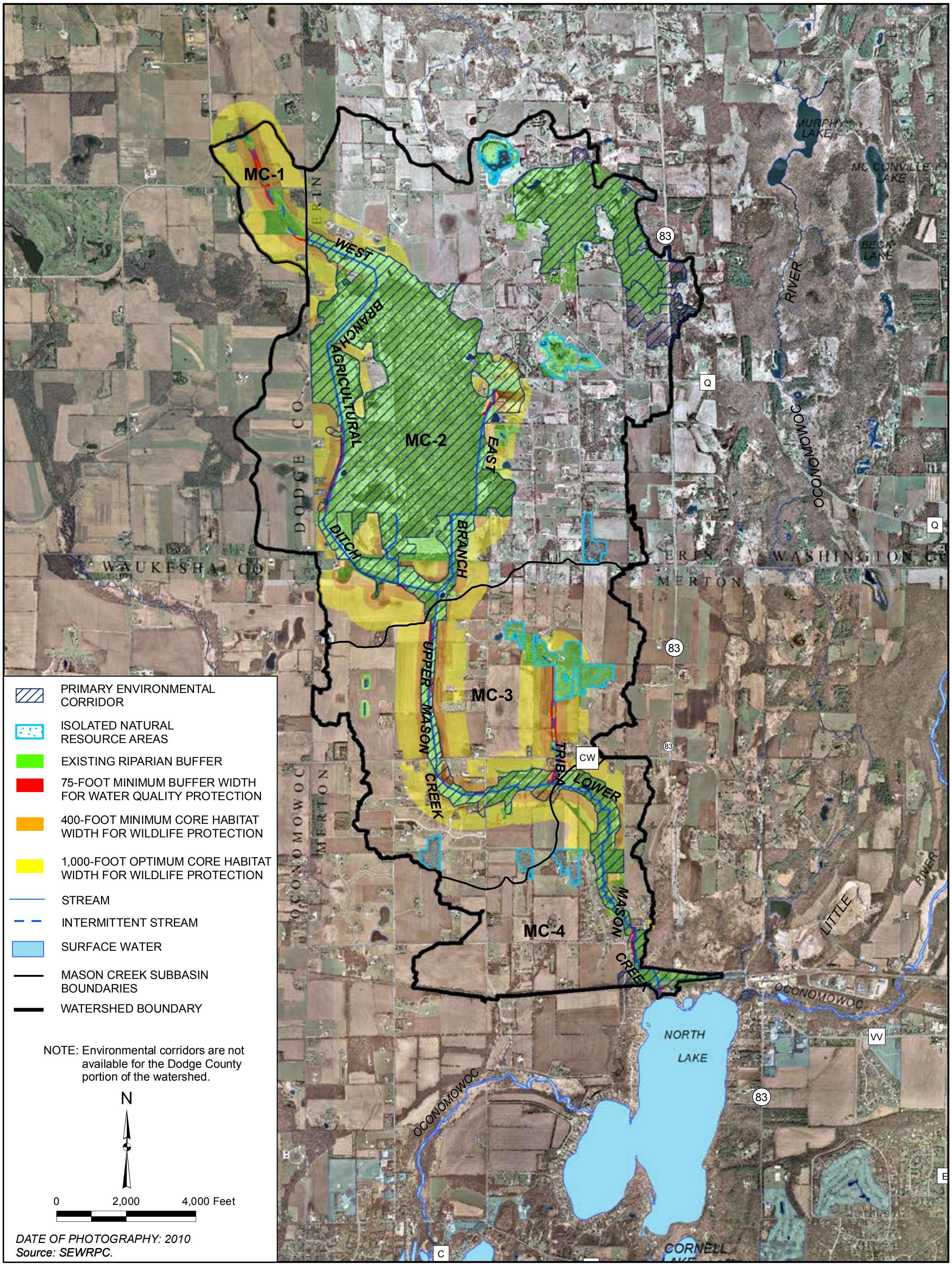
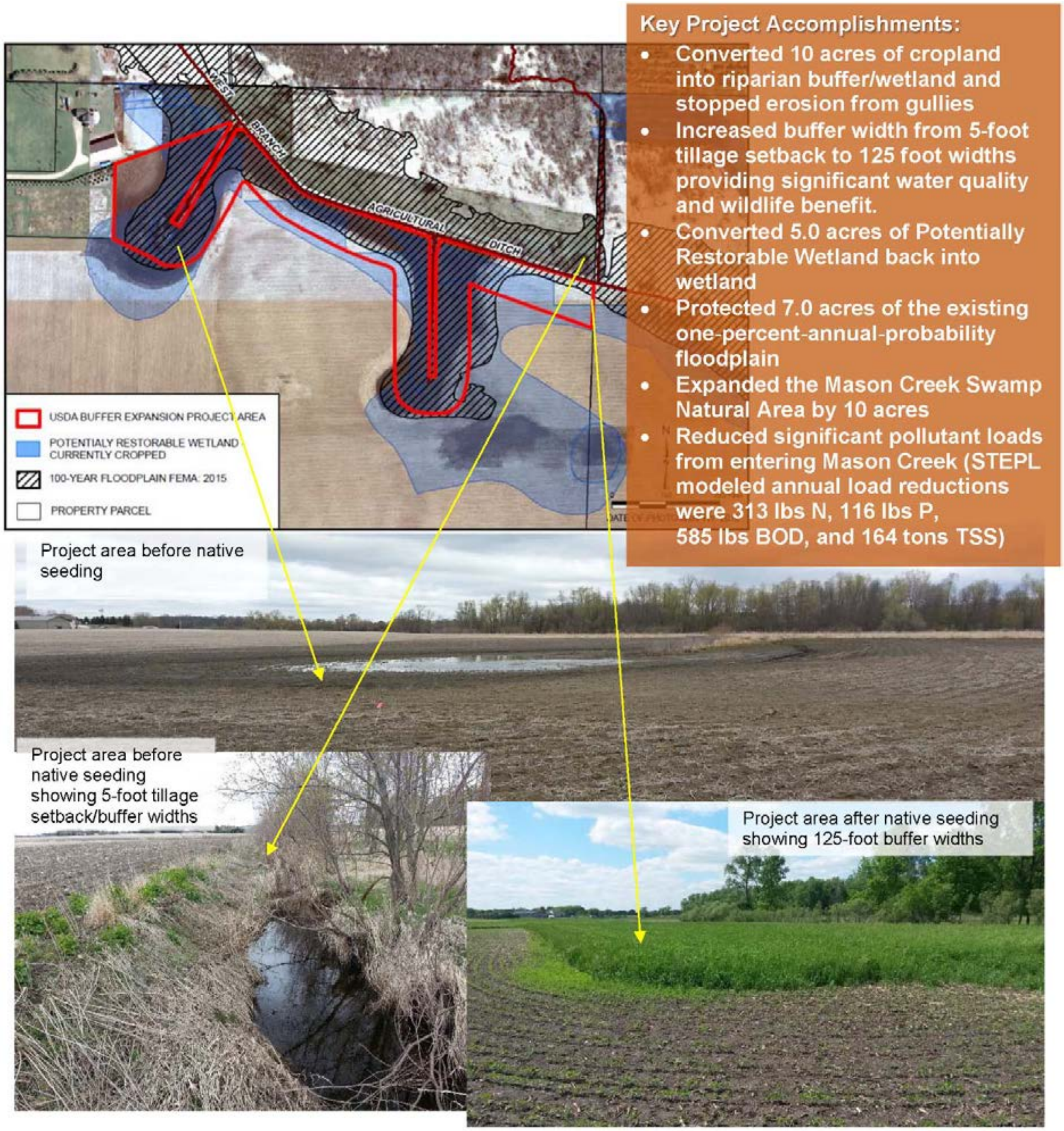
[102] *Runoff from impervious surfaces located within the protective area must be adequately treated with stormwater best management practices.*

Map 2.10
Existing Riparian Buffer and Environmental Corridors Within the Mason Creek Watershed: 2010



DATE OF PHOTOGRAPHY: 2010
Source: SEWRPC.

Figure 2.29
Example of Riparian Buffer Expansion Project Established Adjacent to the West Branch Agricultural Ditch and Concentrated Flow Areas/Gullies: 2015-2016



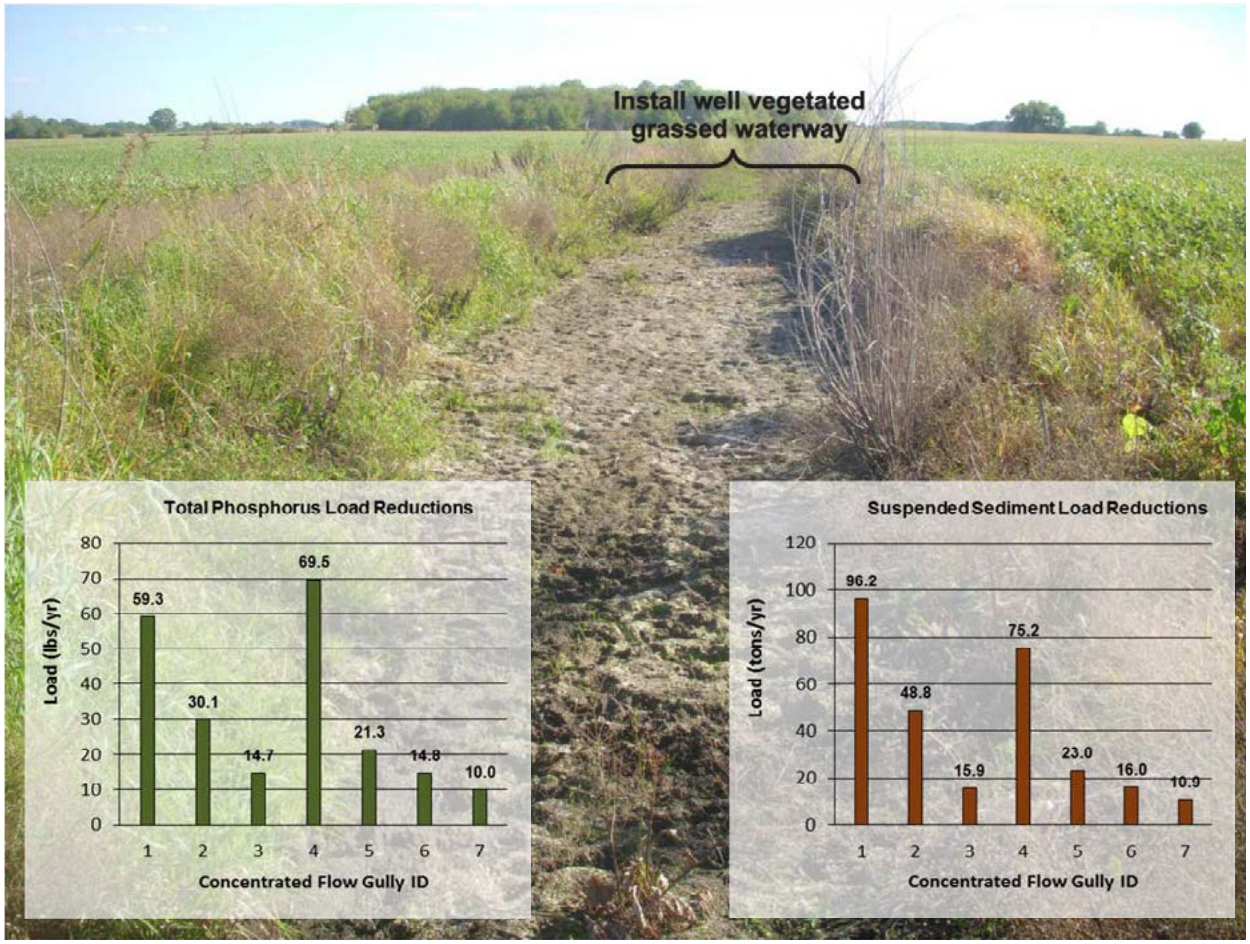
Note: This project was funded in partnership with the Natural Resources Conservation Service (NRCS), City of Oconomowoc, and the North Lake Management District.

Source: NRCS, City of Oconomowoc, North Lake Management District, and SEWRPC

that this positive effect becomes more pronounced with time.[103] As a consequence, despite the initial loss of cropland for habitat creation, overall yields for the entire field were maintained and even increased for some crops compared to the control areas. Although it took about four years for the beneficial effects on crop yield to manifest themselves in this research project, this increase in yields was largely attributed to an

[103] *Richard Pywell et. al. 2015.*

Figure 2.30
Annual Pollutant Load Reductions for Proposed Grassed Waterways Among Subbasins for Total Phosphours (lbs/year) and Suspended Sediment (tons/year) Within the Mason Creek Watershed: 2015



Notes: The load reductions for nitrogen are not included in this graph, but were proportionally similar to the phosphorus and sediment load reductions shown.

The photograph above shows Gully 1.

Source: SEWRPC.

increased abundance and diversity of crop pollinators within the wildlife habitat areas. Such results suggest that at the end of a five-year crop rotation, there would be no adverse impact on overall yield in terms of monetary value or nutritional energy, and that in subsequent years, pre-buffer yields would be maintained or increased. Hence, establishment of buffers or the sacrifice of marginal cropland edges to create wildlife buffer habitat within these riparian buffer areas within the Mason Creek watershed may actually lead to increased crop yields, so this practice may be economically feasible over the long-term for farmers. More importantly, these results also demonstrate that lower yielding field edges within Mason Creek may be better used as non-crop habitats to provide services supporting enhanced crop production, benefits for farmland biodiversity, and protection of water and soil health.[104]

In Wisconsin, the USDA offers technical assistance and funding to support installation of riparian buffers and wetlands on agricultural lands. A 14- to 15-year contract must be entered into by the landowner or operator and the land is only eligible under certain conditions. Normally the land must have recently been in agricultural production or use. Because the program requires a lengthy contract it is often difficult to

[104] *Richard Pywell et. al. 2015.*

get farmers and/or landowners to commit to installing and maintaining riparian buffer strips. To overcome this, a custom program that offers a shorter time commitment, potentially five years, with a yearly payment incentive greater than what the USDA program offers, has found favor in other counties in the State, and should be developed for the Mason Creek watershed.

Concentrated Flow/Gully Stabilization

GIS data along with digital, color orthophotographs and information from the onsite field surveys conducted as part of this study were used to estimate the location and extent of concentrated flow/gullies in fields, along field edges, and roadway ditches in the Mason Creek watershed. A total of about 4,392 linear feet, or 0.83 mile, of potential gullies/concentrated flow areas were identified as shown in Map B.3 in Appendix B. Those gullies were estimated to produce about 2.6 percent of the annual nitrogen load, 4.5 percent of the annual phosphorus load, 2.5 percent of the annual BOD load, and 21 percent of the annual sediment load from the Mason Creek watershed as shown in Figure 2.22 (see Map B.3 in Appendix B for more details). Subbasin MC-2 contains all of the concentrated flow/gullies that were observed in the watershed.

Grassed waterways are proposed to be installed in each of the seven mapped high priority sites as shown in Map B.3 in Appendix B. The potential load reductions associated with the proposed grassed waterway projects in subbasin MC-2 are shown in Figure 2.30. It may be possible to stabilize concentrated flow areas while still promoting productive agricultural practices, if the concentrated flow areas are seeded with permanent cover crops and no-till practices are followed. However, since several of these concentrated flow areas are roadway ditches or connected to roadway ditches, the use of ditch checks or some other grade control structure to temporarily impound and/or slow stormwater runoff and facilitate water quality improvement through infiltration, filtration, and sediment deposition would be effective (see Appendix G). In addition, this technique may also be used to establish/restore wetland vegetation, where appropriate (see Appendix H and "*Stream Conditions*" section below for more details). It is important to note that the pollution reduction effects of such grade control structures were not modeled, but use of such techniques in combination with grassed waterway implementation would reduce sediment and nutrient loads beyond what was modeled for grassed waterways alone.

Stream Conditions

SEWRPC staff conducted field inventories from August through November 2014 to quantitatively and qualitatively characterize the physical characteristics of streams within the Mason Creek watershed. Both quantitative and qualitative measures were largely based upon the WDNR Baseline Monitoring protocols for instream fisheries habitat assessment.[105] A total of 149 cross sections surveys were obtained throughout the watershed and the number of transects ranged from 15 to 25 per mile, depending on the reach sampled (see Maps F.1 through F.5 in Appendix F). An additional 38 and 35 maximum water depths were recorded in pool and riffle habitats, respectively, to assess habitat number and quality in order to supplement information between cross sections where the full complement of data was collected. Physical characteristics measured and/or noted included water and sediment depth, low flow and bankfull channel width and depth, substrate composition, undercut bank, bank slopes, bank erosion, and floodplain connectivity, where appropriate. The remaining cover, or cover-related, parameters that include overhanging vegetation, woody debris, macrophytes, algae, and shading were each qualitatively estimated to assess overall habitat cover quality.[106] Locations of trash and other debris in or adjacent to the stream channel were also mapped. Finally, a fish passage assessment was conducted for the mainstem of Mason Creek.

Streambank Erosion

The WDNR 24K Hydrography data set, supplemented with two-foot contour interval land surface elevation data, was used to determine the location of streams in the watershed area. Streambank erosion was inventoried by walking the streams with a handheld GPS device. Information on soil type, height,

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[105] *WDNR,* Guidelines for Evaluating Habitat of Wadable Streams, *Bureau of Fisheries Management and Habitat Protection, Monitoring and Data Assessment Section, Revised June 2000; Timothy Simonson, John Lyons, and Paul Kanehl, "Guidelines for Evaluating Fish Habitat in Wisconsin Streams,"* General Technical Report NC-164*, 1995; and Lihzu Wang, John Lyons, and Paul Kanehl, "Development and Evaluation of a Habitat Rating System for Low-Gradient Wisconsin Streams,"* North American Journal of Fisheries Management*, Volume 18, pages 775-785, 1998.*

[106] *Edward T. Rankin,* The Quality Habitat Evaluation Index [QHEI]: Rationale, Methods, and Application*, State of Ohio Environmental Protection Agency, November 1989.*

Table 2.13
Stream Erosion Lateral Recession Rate Descriptions

Lateral Recession Rate (feet per year)	Category	Description
0.01-0.05	Slight	Some bare bank but active erosion not readily apparent. Some rills but no vegetative overhang. No exposed tree roots
0.06-0.2	Moderate	Bank is predominantly bare with some rills and vegetative overhang. Some exposed tree roots but no slumps or slips
0.3-0.5	Severe	Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails. Channel cross section becomes U-shaped as opposed to V-shaped
0.5+	Very Severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross section is U-shaped and stream course may be meandering

Source: Natural Resources Conservation Service

length, and bank slope were collected and photos were taken. Lateral recession rate was determined using criteria in Table 2.13 and soil density was determined by soil type using NRCS Technical Guidance.[107] The lowest density value for the soil types and the lowest value for lateral recession were used for all calculations as summarized in Appendix B. Approximately six miles of the of Mason Creek drainage network were inventoried. Most of the streambanks within the areas surveyed, or 93.2 percent, were in fair to good or stable condition. However, about 0.4 miles, or 2,169 linear feet, of stream were actively eroding as shown on Map B.3 in Appendix B. More specifically, about 21 percent of the erosion sites or 458 linear feet were considered to have slight lateral recession rates, and 74 percent (1,598 linear feet) moderate lateral recession, and five percent (113 linear feet) severe lateral recession. This is a real improvement within the watershed, because it was determined in the mid-1980s that there were approximately 7,000 linear feet (1.3 miles) of eroding streambank, primarily due to cattle and machinery crossings.[108]

Sediment loss calculations for inventoried sites were determined using STEPL and are shown in Appendix B. Soil eroded from streambanks was estimated to account for about 0.1 percent of the annual nitrogen load, 0.1 percent of the annual phosphorus load, 0.1 percent of the annual BOD load, and 0.8 percent of the annual sediment load in the Mason Creek watershed as shown in Figure 2.22. Hence, although there was active erosion occurring among sites within Mason Creek, none of these sites were considered excessive except Site 3, which was estimated to be contributing more than 7.5 tons of sediment per year as shown in Appendix B. Therefore, this site is considered to be a high priority for mitigation of streambank erosion. This erosion site is already planned to be addressed in summer 2016, with funding provided by the North Lake Management District and the Oconomowoc Watershed Protection Program (OWPP) (see Figure 2.31 for more details). The other erosion sites should only be addressed if they become more severe.

It is important to note that, although streambank erosion is not a significant source of sediment to Mason Creek, the streambed within the channelized portions of Mason Creek contains a significant source of sediment that is negatively impacting water quality and wildlife within this system as well as in North Lake (see "Habitat Quality" section below for more details). The locations of the deepest sediments within the Mason Creek streambed, as shown on Map 2.11, correspond with the channelized reaches that have low floodplain connectivity (i.e., disconnected or partially connected areas) (see Figure 2.32). In other words, the sediment deposition is an artifact of the channelization under which the channel was likely excavated deeper and wider than necessary. Such over-excavation promotes deposition of sediment that is easily eroded when discharges increase. Such erosion will continue without intervention. Intervention in this case can range from installation of ditch plugs within the West Branch Agricultural Ditch

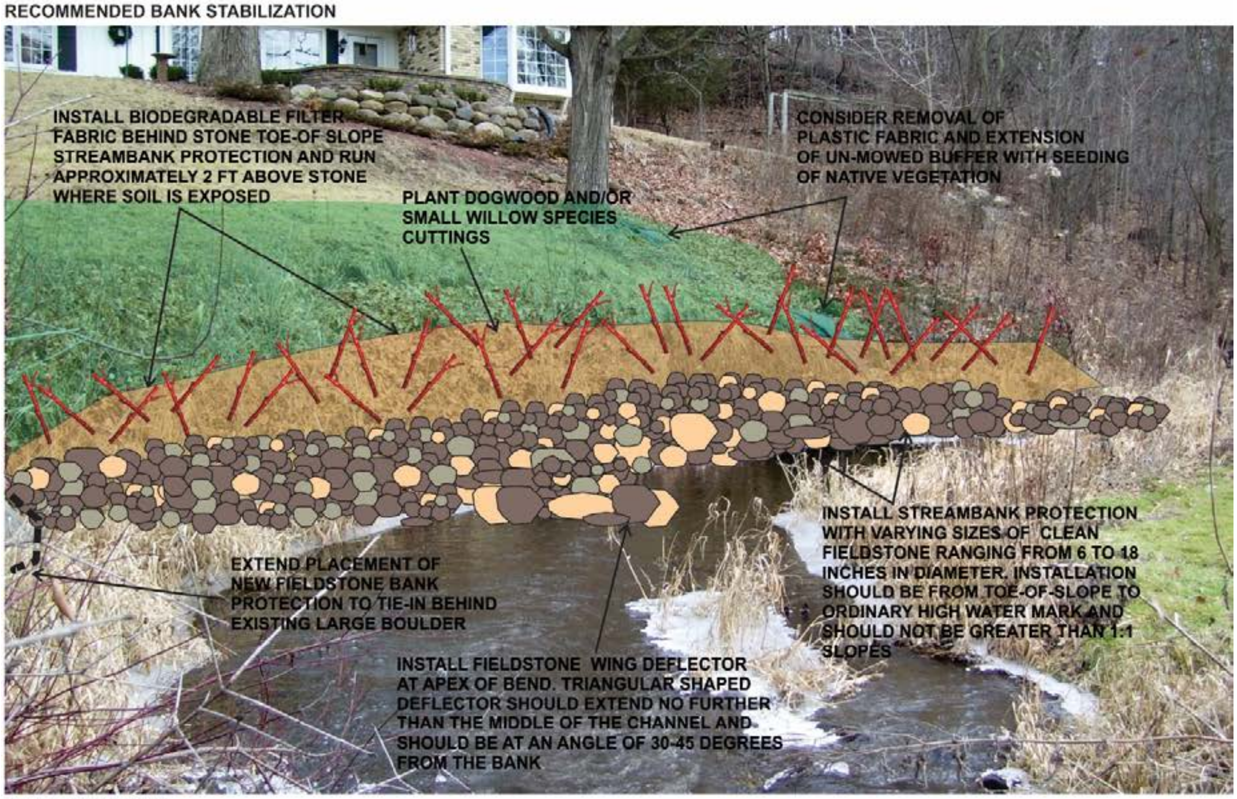
[107] *Natural Resources Conservation Services (NRCS),* Streambank Erosion. Field Office Technical Guide*, November 2003, Retrieved from: efotg.nrcs.usda.gov/references/public/WI/StreambankErosion.doc*

[108] *WDNR, Oconomowoc River Priority Watershed, 1986,* op. cit.

Figure 2.31
Existing Conditions and Recommended Bank Stabilization Actions for Erosion
Site No. 3 Just Downstream of Koester Road on Mason Creek: 2015

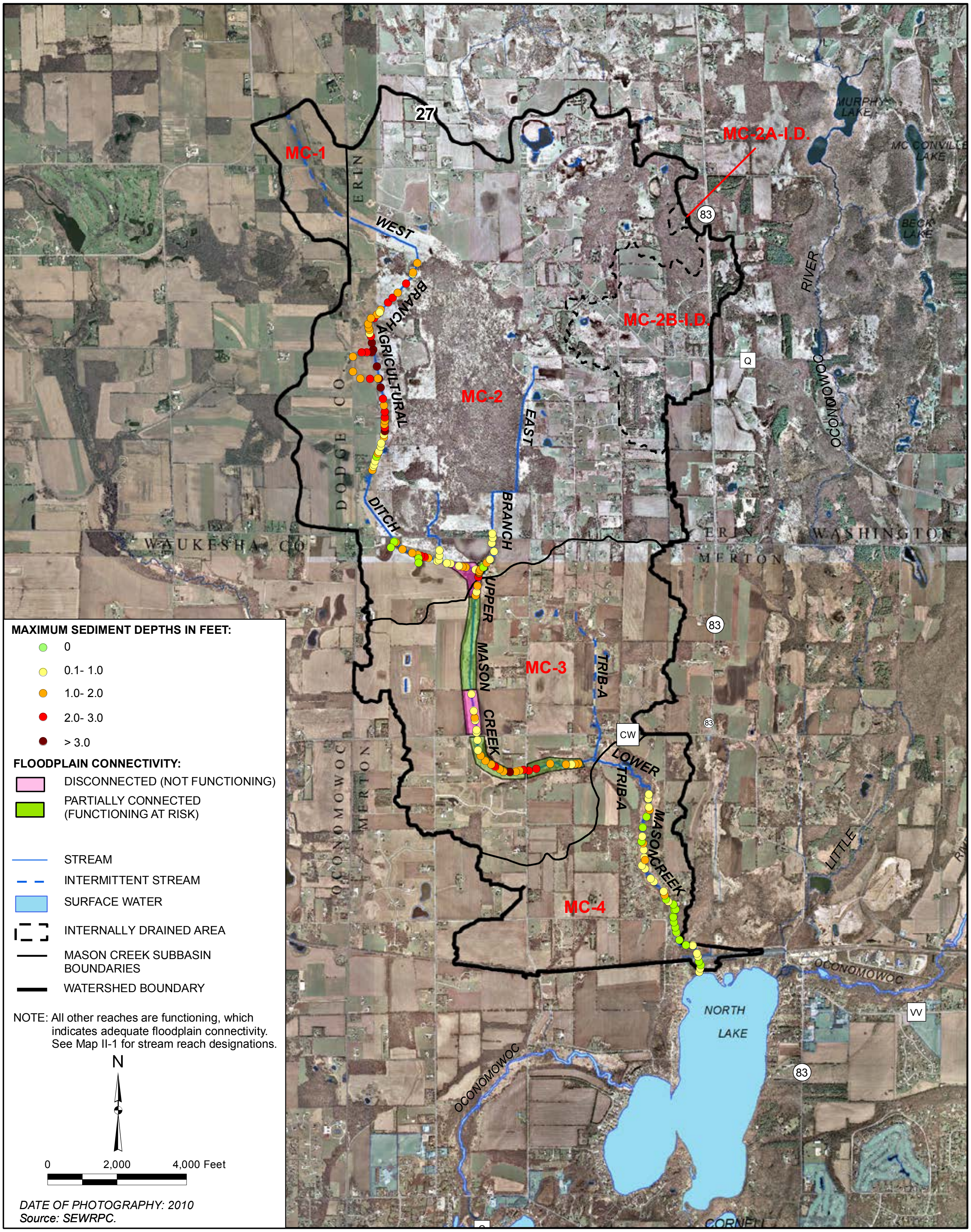
EXISTING CONDITIONS

RECOMMENDED BANK STABILIZATION



Source: SEWRPC

Map 2.11
Maximum Sediment Depths, Stream Bank Erosion Sites, and Floodplain Connectivity Within Mason Creek: 2014



(see Appendix H) to remeandering the stream to its historic condition within the Upper Reach of Mason Creek (see "Stream Restoration" section below and Chapter 3 for more details). Restoring Mason Creek to its original, or near original, highly meandering stream channel sinuosity and pool-riffle structure along with re-connecting the floodplain will restore the ability of the stream to dissipate erosive water velocities during high flow conditions as well as store and process pollutant loads (see below for more details).

Livestock can cause significant degradation to streams if not managed properly, which was an important issue in the 1980s. There were limited signs of degradation due to livestock access among stream reaches within the areas surveyed. It is important to continue to limit livestock access to waterways to protect Mason Creek from excessive erosion and nutrient loading.

Slope and Sinuosity

Stream characteristics, such as slope, length, and sinuosity are determined by a combination of geological history (i.e., glaciation) and human intervention (i.e., lake impoundments and channelization). Based upon this information, it was determined that there were two distinct stream reaches comprising the mainstem of Mason Creek (see Map 2.1 and Table 2.14). In addition, three tributaries to Mason Creek, including the West Branch Agricultural Ditch, East Branch, and Trib-A were also assessed under this project (see Map 2.1). The extent of the physical data collected within Mason Creek and other reaches within this watershed as part of this study is shown in Appendix F, and any gaps in data collection along the waterways were the result of respecting private property owners' requests to not access the stream through their properties.

The longitudinal slope of a channel is the ratio of elevation change between two points on the channel bed to the length of the channel between the same two points. Slope is an indicator of stream energy or power. The lower the slope, the lower the energy, and the slower the water flows. Stream slopes within mountainous stream systems are typically greater than 10 percent. However, slopes within the Mason Creek and tributary reaches are more indicative of lowland streams found in Southeastern Wisconsin and generally do not exceed 0.5 percent, as shown in Table 2.14. As previously mentioned in the "Mason Creek Drainage Network" section above, Figure 2.4 and Table 2.14 show that the Upper Mason Creek reach has a relatively shallow gradient of 0.08 percent (about 4.7 feet per mile). This is actually the lowest slope of all reaches in the watershed, but also very similar to the West Branch Agricultural Ditch and East Branch reach tributaries. These reaches tend to accumulate fine sediments because of their low stream slopes. In contrast, the Lower Mason Creek reach and Trib-A have steeper gradients of 0.45 percent and 0.56 percent, respectively, which is why these reaches are dominated by larger substrates such as sands, gravels, or cobbles. However, the slope of the Lower Mason Creek reach flattens out just downstream of the railroad crossing of this reach near North Lake. Hence, the backwater effect of North Lake extends almost all the way up to the railroad crossing, which means that this lowest portion of the stream has the same surface water elevation as the Lake. Therefore, water velocities are much reduced in this section compared to upstream reaches and sediments tend to accumulate in this area.

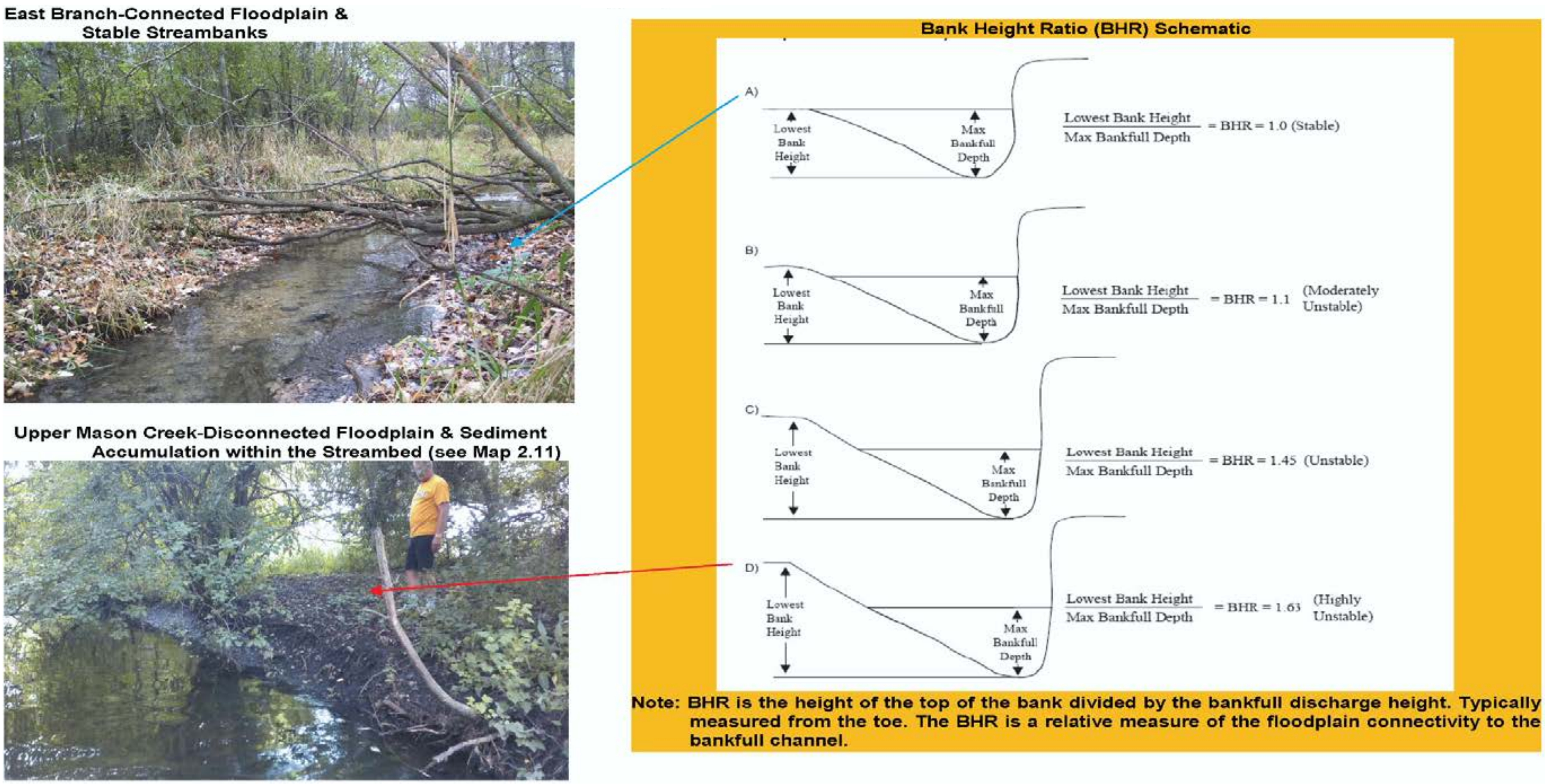
Healthy streams naturally meander or migrate across a landscape over time. Sinuosity is a measure of how much a stream meanders. It is defined as the ratio of channel length between two points on a channel to the straight-line distance between the same two points. Sinuosity or channel pattern can range from straight to a winding, or meandering, pattern. Channelized sections of streams that have been straightened typically have low sinuosity closer to one. Stream reaches within the Mason Creek that include both channelized and nonchannelized segments have sinuosities that ranged from 1.03 to 1.27 in 2010, as shown in Table 2.14.

Comparison of the original 1837 plat of survey, 1909 USGS quad map, 1937 aerial photo, and the 2010 and 2015 orthophotos demonstrate several important features of this watershed:

1. The East Branch of Mason Creek is the true headwaters of Mason Creek. As shown on Map 2.12 and extracted from notes of the 1837 survey, the East Branch was drawn in the original survey and contained a surface water width of two feet. However, by 1937 this reach was channelized/relocated and ditched to improve drainage from lands upstream of this area and the water width was about four feet and the depth was 0.5 foot at that same location. In addition, a flow-through spring pond was constructed in the lower portion of the East Branch near the confluence with the West Branch Agricultural Ditch sometime from 1941 through 1950, and then this pond was disconnected from the East Branch by 1963.

Figure 2.32

Floodplain Connectivity Comparison Among Reaches and Schematic of Bank Height Ratio (BHR) Within the Mainstem of Mason Creek: 2014



Source: W. Barry Southerland, Fluvial Geomorphologist, NRCS, http://www.ars.usda.gov/SP2UserFiles/Place/30501000/esd/talks07/geomorph_terms.pdf, and SEWRPC

Table 2.14
Physical Characteristics of Stream Reaches Within the Mason Creek Watershed: Pre-1941 Versus 2010

	Reach Length (miles)		Sinuosity		2010		
Reaches (see Map 2.1)	PRE-1941	2010	PRE-1941	2010	Minimum Elevation (feet above NGVD29)	Maximum Elevation (feet above NGVD29)	Slope (percent)
Upper Mason Creek	2.22	1.73	1.39	1.03	936	944	0.08
Lower Mason Creek	1.87	1.72	1.43	1.27	898	936	0.45
Tributaries							
East Branch headwaters	0.77[a]	1.35	1.30[a]	1.06	946	956	0.19
West Branch Agricultural Ditch	2.22	2.26	1.01	1.03	944	960	0.13
Trib-A	--	0.87	--	1.04	936	962	0.56

Note: The differences in reach lengths between years were due to limitations in the ability to discern a stream channel on the historical aerial maps and/or channel modification.

[a] *Since there were no other sources of data, these were estimated from the 1837 platted survey and recorded notes.*

Source: SEWRPC

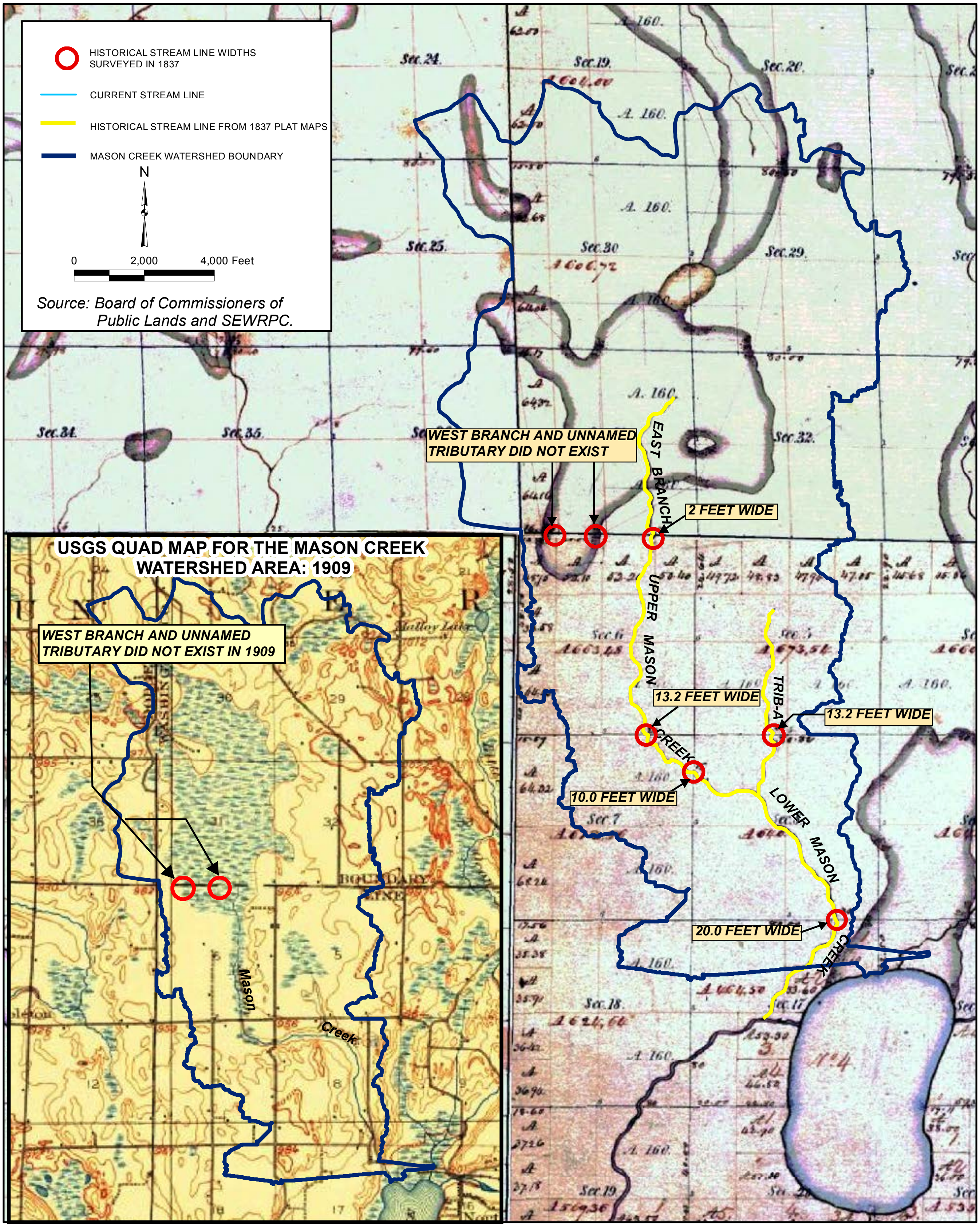
2. The West Branch Agricultural Ditch and its associated drainage ditches did not exist in 1837 nor in 1909. The West Branch Agricultural Ditch was constructed through the western edge of the Mason Creek Swamp sometime between 1909 and 1937, to improve agricultural drainage. Because this ditch was constructed mostly through highly organic and unconsolidated Houghton mucky peat soils, it has contributed significantly to degraded water quality conditions in Mason Creek. This ditch currently has an average wetted width of about four feet and a depth of 0.3 foot.

3. The upper portion (upstream of CTH CW) of the Upper Mason Creek reach was channelized sometime before 1937 and the lower portion was channelized sometime between 1937 and 1941. As a result of channelization, this historically naturally meandering stream, which could still be easily identified on both the 1937 and 1941 aerial maps, was shortened by about 0.5 mile from its original length. This ditching profoundly degraded the instream habitat quality and diversity, natural geomorphology, floodplain connectivity, and sediment transport capabilities within Mason Creek. As shown on Map 2.12 and extracted from notes of the 1837 survey, this reach had surface water widths of 13.2 feet and 10 feet where it crossed survey section lines. This reach now has an average water width of about 10 feet and depth of one foot at both of these sites.

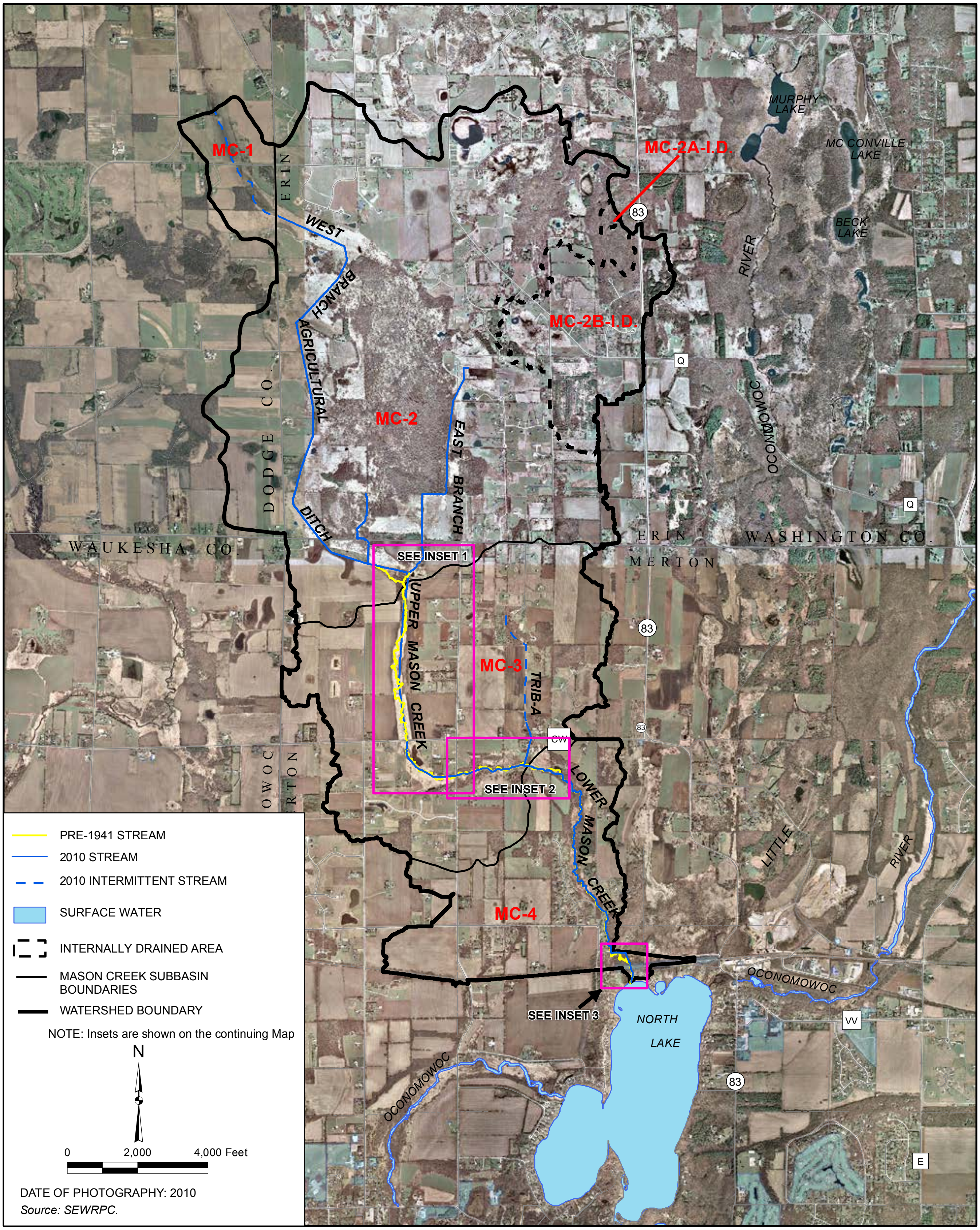
4. The Lower Mason Creek reach was the most undisturbed reach in the entire watershed, except for the lowest portion of this reach. As shown in the 1837 survey (Map 2.12), Mason Creek used to discharge directly into the Oconomowoc River downstream of North Lake. Mason Creek was shortened by about 1.2 miles and re-routed to drain directly into North Lake sometime before the year 1909 (see Map 2.12) and has continued to discharge into the Lake for at least 107 years. As shown on Map 2.12 and extracted from notes of the 1837 survey, this reach had a surface water width of 20 feet. This reach now has an average water width of about 16 feet and a depth of 0.5 foot at that site.

Comparison of the historic Pre-1941 versus 2010 stream alignments as shown on Map 2.13 shows that this system was much more sinuous under Pre-1941 conditions (see Table 2.14). As identified above, the actual distance of stream channel lost on the Upper Mason Creek reach is well established (see Map 2.13 and Table 2.14). Actual distance of stream channel lost from the pre-settlement period is likely significantly greater for the Trib-A and East Branch tributaries, but, because of a lack of aerial photography prior to 1937, it is unknown where the original stream channels were located. Examination of the 1937 and 1941 aerial photographs indicates that more than 95 percent of the stream network within the watershed had already been straightened by that time period to facilitate the intense agricultural use of the land. Most of the remaining impacts to Mason Creek that occurred after 1941 were to accommodate the construction of roads.

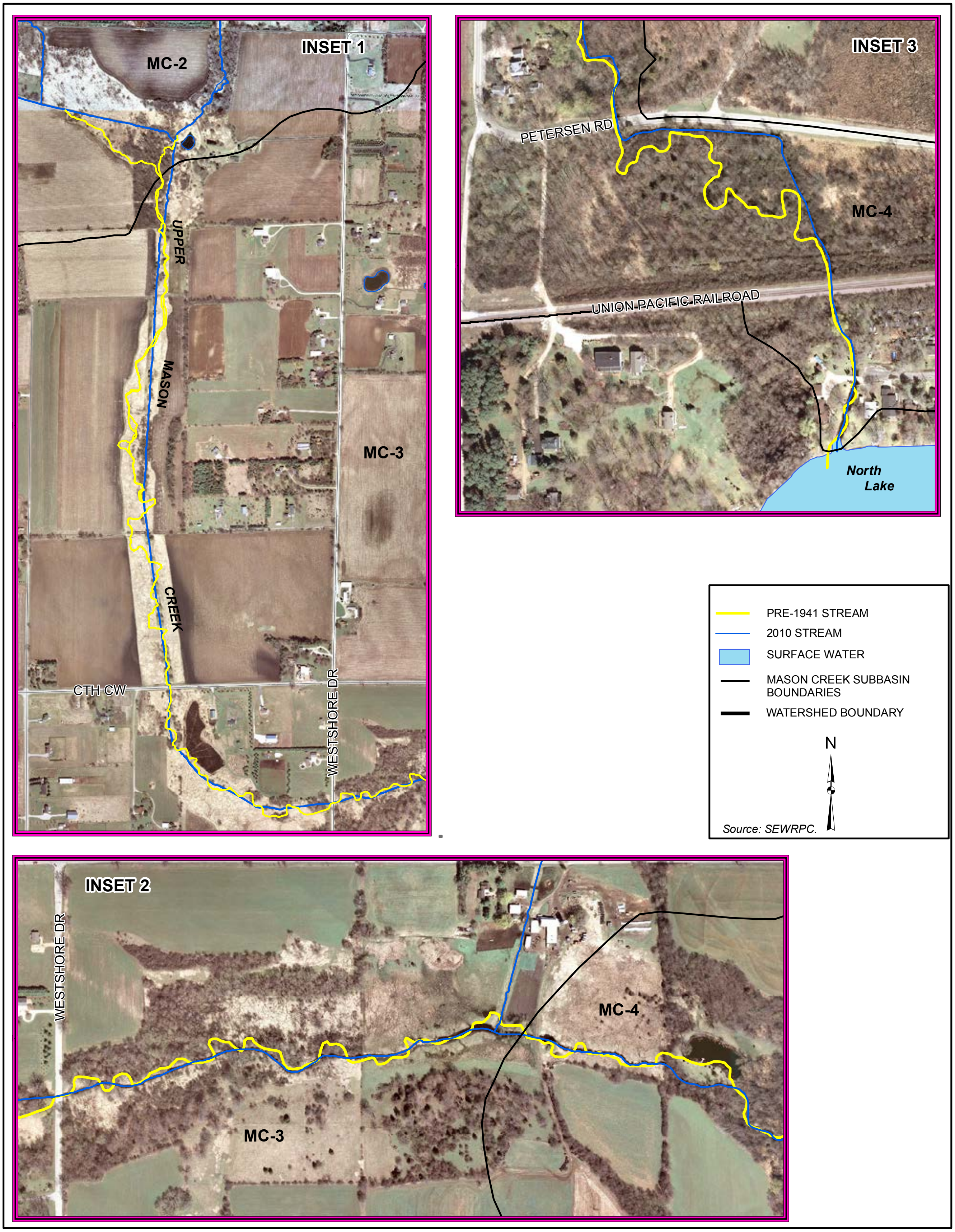
Map 2.12
Historical 1837 Plat Map and 1909 USGS Quad Map for the Mason Creek Watershed Area



Map 2.13
Comparison of Historical and Current Stream Channel Changes Within the Mason Creek Watershed: Pre-1941 Versus 2010



Map 2.13 (continued)



Straightening meandering stream channels or "channelization" was once a widely used and accepted technique in agricultural management. The U.S. Department of Agriculture NRCS (formerly Soil Conservation Service) cost shared such activities up to the early 1970s within southeastern Wisconsin.[109] The objectives of channelization were to reduce floods on lands adjacent to the channelized reaches by conveying stormwater runoff more rapidly, to facilitate drainage of low-lying agricultural land, and to allow more efficient farming in rectangular fields. In many cases channelization was likely accompanied by the installation of drain tiles within the farm fields to better facilitate water movement off the field and to lower groundwater levels. Only a few tile outlets were observed discharging to Mason Creek. Their locations are shown on Maps F.1 through F.5 in Appendix F.

Through channelization and installation of drain tiles, farmers attempted to protect their crops by lowering the groundwater table and increasing the capacity to convey water downstream. Channelization can lead to instream hydraulic changes that can decrease or interfere with the connection between the channel and overbank areas during floods. This may result in reduced filtering of nonpoint source pollutants by riparian area vegetation and soils and increased erosion of the banks. Channelization can also lead to increased water temperature, which was demonstrated in the West Branch Agricultural Ditch, due to the loss of riparian vegetation, and it can alter instream sedimentation rates and paths of sediment erosion, transport, and deposition. For example, the most heavily channelized sections of stream assessed under this study, particularly the West Branch Agricultural Ditch and the Upper Mason Creek reaches contained some of the greatest amounts of streambed deposition. In addition to the loss of stream length, channel straightening causes a major decrease in the number of pool and riffle structures within the stream system. Pool-riffle sequences are often found in meandering streams, where pools occur at meander bends and riffles at crossover stretches.[110] Therefore, channelization activities, as traditionally accomplished without mitigating features, generally lead to a diminished suitability of instream and riparian habitat for fish and wildlife, which was observed in channelized reaches of Mason Creek and its tributaries where there is a lack of riffle habitat (see Map 2.14).

Streams are transport systems for water and sediment and are continually eroding and depositing sediments, which causes the stream to migrate. When the amount of sediment load entering a stream is equal to what is being transported downstream—and stream widths, depths, and length remain consistent over time—it is common to refer to that stream as being in a state of "dynamic equilibrium." In other words, the stream retains its physical dimensions (equilibrium), but those physical features are shifted, or migrate, over time (dynamic). For example, it is not uncommon for a low-gradient stream in Southeastern Wisconsin to migrate more than one foot within a single year. Reaches in the Mason Creek watershed that were not channelized, particularly the Upper Portion of Lower Mason Creek, still exhibit healthy meanders that have migrated only slightly over the nearly 70 years between 1941 and 2010 as shown on Map 2.13. This reach also contains some of the highest quality habitat in the entire watershed (see "Habitat Quality" subsection below).

Evaluation of the channelized reaches of Mason Creek, considering channelization and floodplain connectivity along with onsite survey data and known sediment loads, generally indicates that the channelized reaches have an unstable streambed, and are not in a state of dynamic equilibrium. This instability is largely related to the channelization and floodplain connectivity. The Mason Creek system is partially-connected or disconnected from its floodplain in several areas of the watershed, particularly within the Upper Mason Creek reach, which is partially or fully disconnected over its entire length (see Map 2.11). In contrast, the Lower Mason Creek reach and the East Branch Tributary are both well-connected to the floodplain. Floodplain connectivity can be defined in several ways such as the bank height ratio, entrenchment ratio, or stage/discharge relationships. A good connection between Mason Creek and its floodplain is critical in helping to protect the streambed and streambanks by allowing flood flows to dissipate into the floodplain and reducing water velocities that would cause erosion, while at the same time allowing sediments and other pollutants to be deposited into the floodplain. In addition, in reaches with an extensive floodplain and/or riparian buffer the River system naturally makes adjustments to changes in discharge and sediment loads. It is also important to note that the extent of meandering increases with the area tributary to the stream reach, so as tributary area increases, so does the width of the meander belt (see Appendix C).

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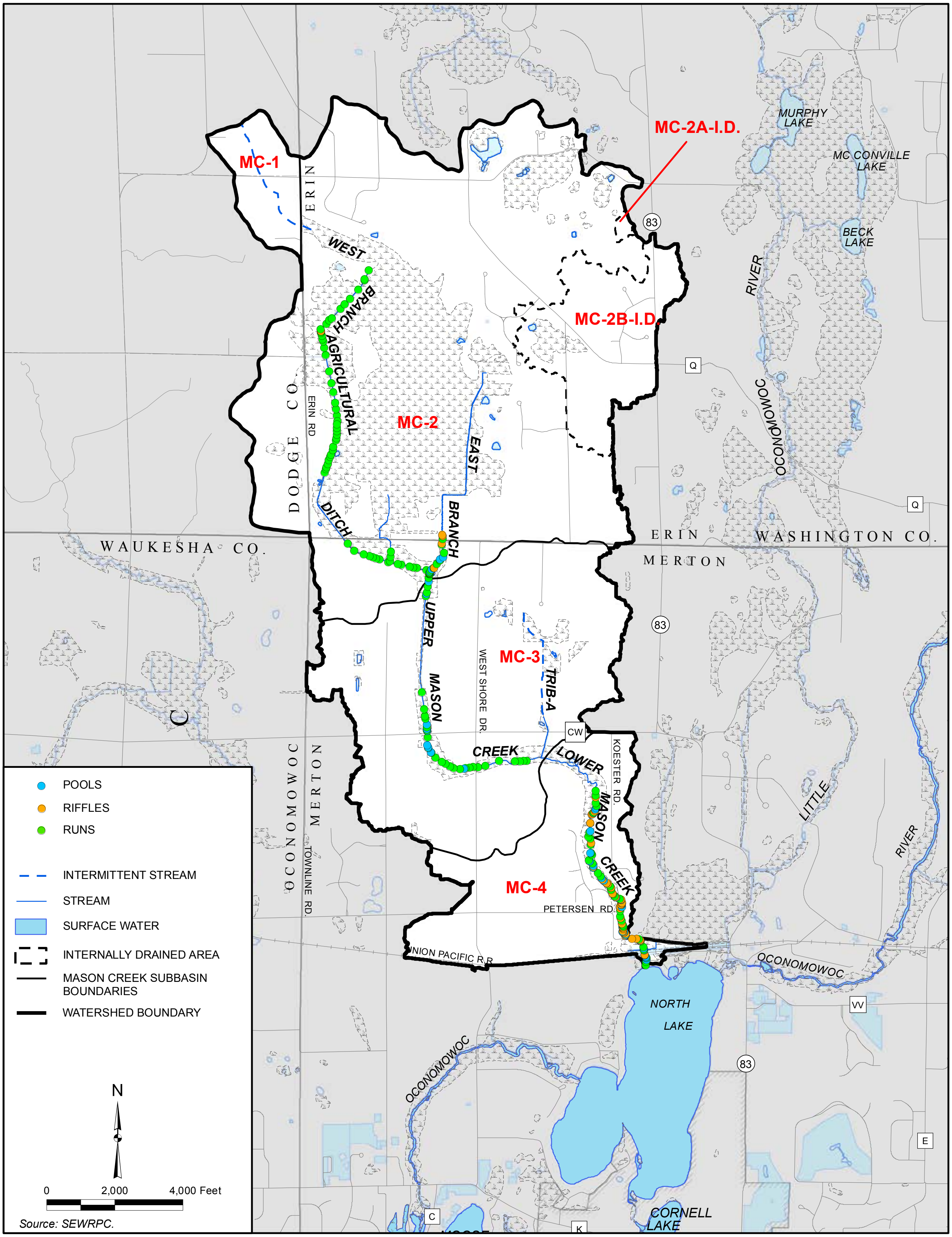
[109] *Personal Communication, Gene Nimmer, NRCS engineer.*

[110] *N.D. Gordon, et al.,* Stream Hydrology*, John Wiley and Sons, April 1993, page 318.*

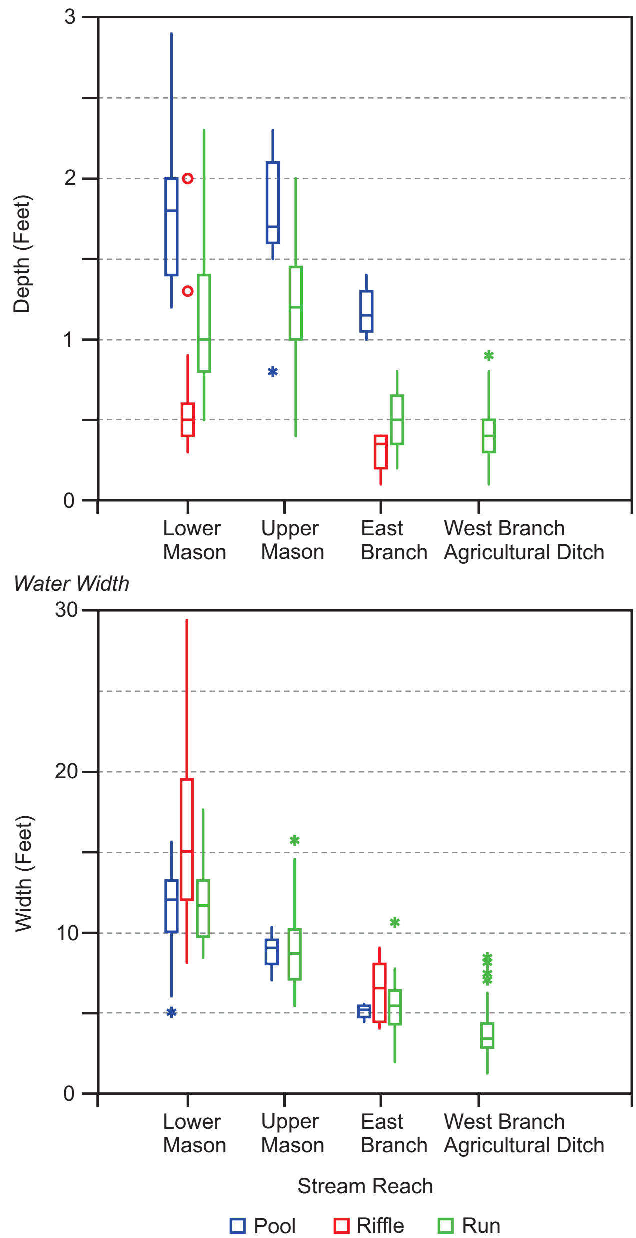
Map 2.14
Aquatic Habitat Types Within the Mason Creek Watershed: 2014



Stream Reach Dynamics

There is a general increase in stream wetted widths as well as mean and maximum water depths in Mason Creek from upstream to downstream as shown in Figure 2.33 and Map 2.15. These measurements were obtained for approximate low flow conditions for this system in late summer 2014 among pool, riffle, and run habitats (see "Habitat Quality" section below for more details). A low flow is a seasonal phenomenon that usually occurs in summer and is an important component of the flow regime regarding the ability of a river or stream to support adequate water quality and health of the aquatic community. Figure 2.33 shows increases in the highest measured width that is not an outlier for any of the pool, riffle, or run habitat types ranging from about two feet to nine feet in the East Branch, six feet to 14 feet in the Upper Reach, and six feet to nearly 30 feet in the most downstream Lower Mason Creek reach where there is a backwater effect from North Lake. Figure 2.33 also shows that depths generally range from about 0.2 to nearly three feet from upstream to downstream. Note that the West Branch Agricultural Ditch contains no pool or riffle habitats, and has the shallowest and narrowest low flow channel conditions compared to all other reaches.

Figure 2.33
Maximum Water Depth and Mean Stream Width Among Habitat Type and Reaches in the Mason Creek Watershed: 2014

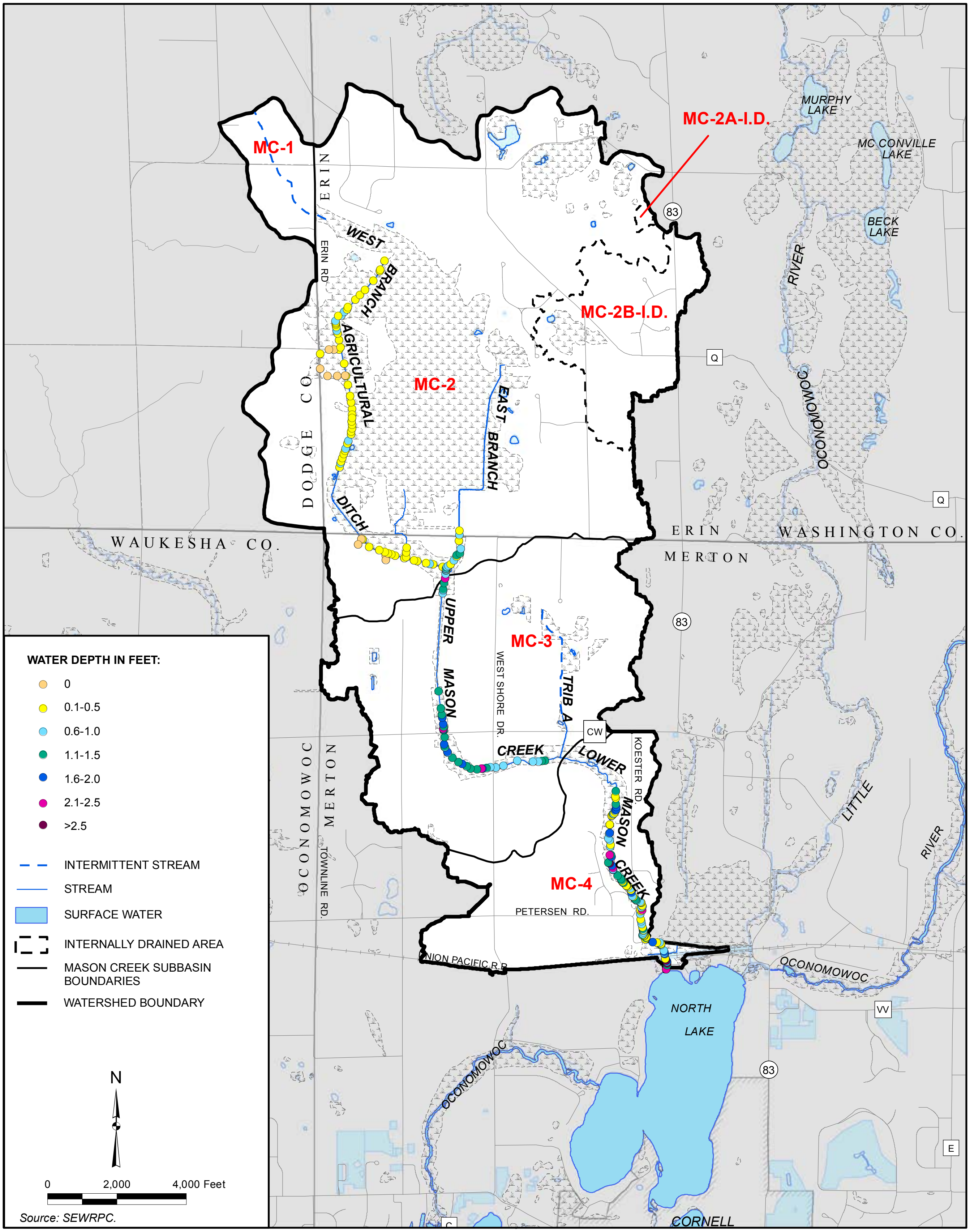


NOTE: See Figure 2.5 for description of symbols.

Source: SEWRPC.

Despite this expected normal increase in water widths and depths from upstream to downstream, there is a non-uniform distribution of organic muck and silt sediments among the Mason Creek reaches as shown as in Figure 2.34 and on Map 2.11. The organic muck and silt sediments are comprised of a matrix of organic and mineral soils. Based on the level of decomposition, the organic soils are classified either as peat (slightly decomposed organic material) or muck (highly decomposed organic material). Within this watershed, the majority of muck soils forming sediments within Mason Creek are likely derived from the Houghton mucky peat, Palms mucky peat, and Ogden muck soil groups. Organic soils have lower bulk densities, in other words lower weight per unit of volume, and greater pore space than mineral soils. Consequently, organic soils are easily transported in flowing water. The mineral soils in the watershed are largely comprised of silts that are a granular material of a size somewhere between sand and clay, so these small diameter particles are also easily transported in water. Within this watershed, the majority of silts forming sediments within Mason Creek are likely derived from Pella silt loam, Theresa silt loam, Fox silt loam, Brookston silt loam, Dodge silt loam, Lamartine silt loam, Casco loam, St. Charles silt loam, and Wallkill silt soil groups. Silt may occur as a soil or as sediment mixed in suspension with water (also known as a suspended load) in a body of water such as a Mason Creek. Depending on the diameter of silt, Figure 2.35 shows that the minimum erosion velocity ranges from about 0.5 to 1.6 feet per second (15 to 50 cm/s) and the minimum transport velocity ranges from about 0.0033 to 0.02 feet per second (0.1 to 0.5 cm/s). Since these sediments within Mason Creek are a combination of organic muck and silts, the greater proportion of organic matter content amongst

Map 2.15
Maximum Water Depths Measured Within the Mason Creek Watershed: 2014



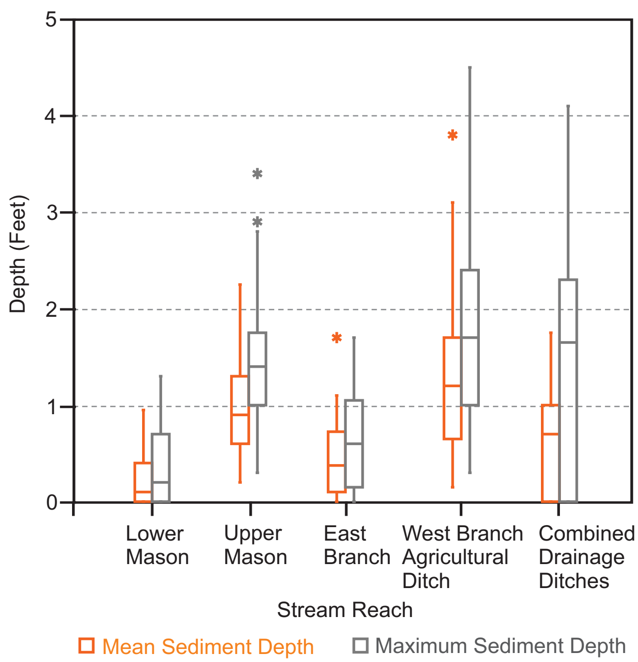
the silt sediments results in higher pore space, thereby decreasing bulk density. Consequently, the organic muck and silt sediments within Mason Creek are highly erodible and easily transported, which accounts for the high and very high suspended loads observed in both low flow and high flow conditions, respectively, contributing to impairment of water quality (see "Suspended Materials" section above).

Based on the comprehensive cross section survey results, both mean and maximum organic muck and silt sediment depths among reaches ordered from deepest to shallowest are (1) West Branch Agricultural Ditch, (2) Upper Mason Creek, (3) combined drainage ditches that drain directly to the West Branch Agricultural Ditch (see Map 2.11), (4) East Branch, and (5) Lower Mason Creek (see Figure 2.34). This uneven distribution of these organic muck and silt sediments is an artifact of several key features that include, but are not limited to:

- Nonpoint source upland erosion from agricultural lands (see "Pollutant Loading Model" section above)
- Geologic soil types within the landscape (see "Soil Characteristics" section in Chapter 1 of this report)
- Ditching or channelization
- Overall reach slope and discharge

The reaches with the greatest slopes, which include both Lower Mason Creek and the East Branch, contained the least amounts of organic muck and silt sediments. Mucks and silts are still present, but do not dominate as in the other reaches, because the steeper slopes provide overall greater water velocities and capability to transport these sediments downstream. In contrast, muck and silt sediments have accumulated to excessive amounts within the West Branch Agricultural Ditch and Upper Mason Creek reaches, which have the lowest slopes. In addition, these two reaches were entirely channelized to improve agricultural drainage, and they have no significant ability to sort sediments compared to a naturally meandering stream. These channelized ditches were likely over-excavated in width and depth, which created slow water velocity conditions suitable for deposition of these muck and silt soils that eroded from upland areas.

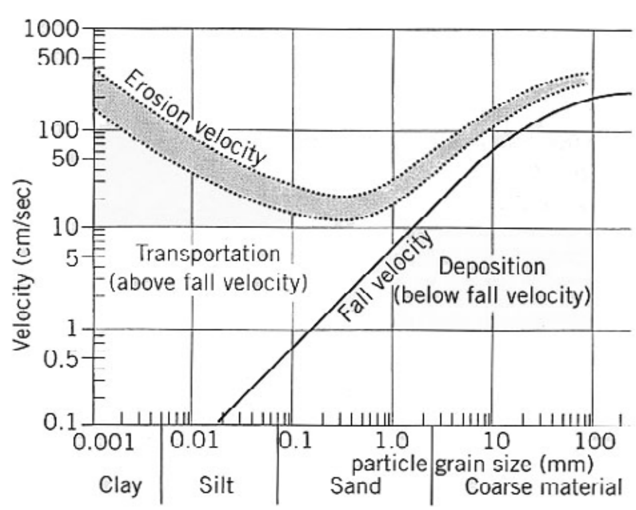
Figure 2.34
Mean and Maximum Unconsolidated Organic Muck and Silt Depth Among Reaches in the Mason Creek Watershed: 2014



NOTE: See Figure 2.5 for description of symbols.

Source: SEWRPC.

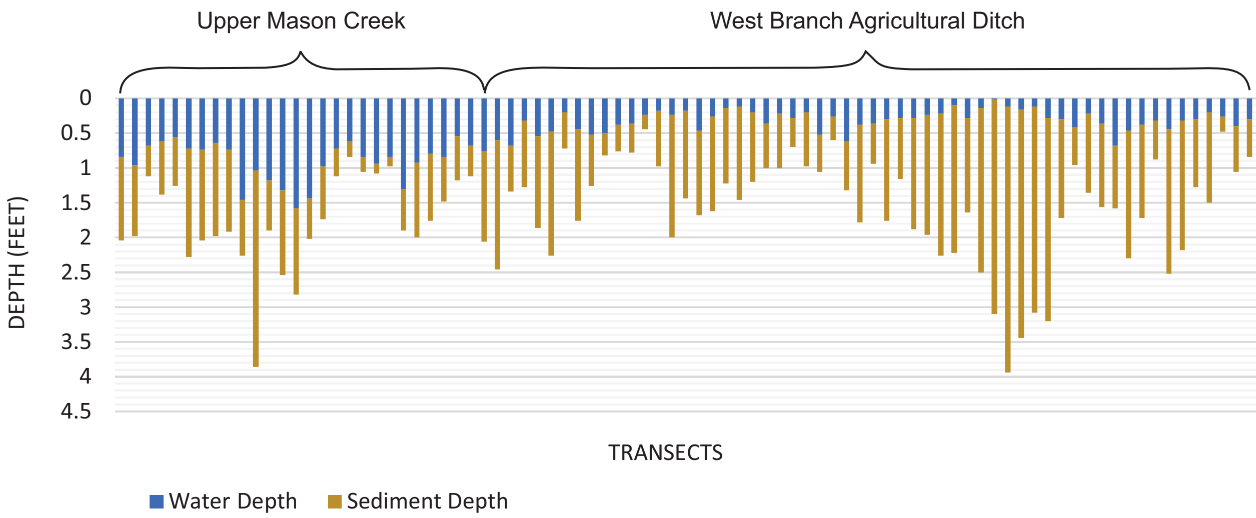
Figure 2.35
Relationship of Transported Particle Size to Water Velocity (Hjulstrom Curve)



Source: Dr Laurie's Geog Blog website at https://dlgb.files.wordpress.com/2008/09/hjulstrom_curve_task.jpg and SEWRPC.

The distribution of the mean water and sediment depths among transects within the West Branch Agricultural Ditch and Upper Mason Creek reaches are illustrated in Figure 2.36. Within the West Branch Agricultural Ditch water depths are very small and the sediment depths are greater on average than the Upper Mason Creek reach to which it discharges. In some transects, the organic muck and silt sediments were deposited

Figure 2.36
Mean Water Depth and Unconsolidated Organic Muck and Silt Depth Conditions Within the Upper Mason Creek and West Branch Agricultural Ditch Reaches: 2014



Source: SEWRPC.

on top of clay pan,[111] but in most cases survey crews could not determine the actual bottom of the channel. Cutting this drainage ditch through Houghton peaty muck established a concentrated flow path that provides a continuous supply of both organic peat and muck sediments to be transported downstream into Mason Creek. In contrast, within the Upper Mason Creek reach, all the deposited organic muck and silt sediments are sitting on top of a mixture of very firm substrates primarily composed of sand, gravel, and/or cobble.

However, it is important to note that it was not possible to know how long it may have taken to fill the West Branch Agricultural Ditch or Upper Mason Creek ditches with sediment, nor is it known how fast this sediment is being supplied into each reach or how fast this sediment is being transported downstream out of each reach and, ultimately, to North Lake. Therefore, it was not possible to establish rates of deposition within the Mason Creek reaches as part of this study. Although the tools were not available to model the pollutant loads associated with these streambed sediments, it was possible to estimate the volumes of organic muck and silt sediments among reaches as shown in Table 2.15. The greater volumes and depths of the sediment can be associated with greater impairments to water quality and fish and aquatic life because more sediments contain more pollutants, can smother or bury organisms and habitats, and have greater capacity to reduce hyporheic (the zone below the water-streambed interface) connectivity.[112]

Table 2.15 shows that that there are more than 3,700 cubic yards and 3,000 cubic yards of organic muck and silt sediments in the West Branch Agricultural Ditch and Upper Mason Creek reaches, respectfully. This illustrates that these reaches contain excessive amounts of sediments readily available for transport to downstream reaches and North Lake. In contrast, the Lower Mason Creek reach contained about 900 cubic yards of organic silt and muck sediments. Although this is about one-fourth of the sediment volume in the West Branch Agricultural Ditch and one-third the Upper Mason Creek reach sediment volume, it also demonstrates that this sediment is being transported into habitats downstream and some of it is being deposited, likely contributing to the impairment of water quality and fisheries habitat. Basically, sediments were observed to be accumulating in the deeper and slower velocity pool and run habitats, which is consistent with the high suspended sediment load concentrations observed during low flow conditions. So, the large

[111] *A claypan is a dense, compact, slowly permeable layer in the subsoil having a much higher clay content than the overlying material. Claypans are usually hard when dry, and plastic and sticky when wet and limit or slow the downward movement of water through the soil.*

[112] *Minnesota Department of Natural Resources,* Watershed Health Assessment Framework, Geomorphology - Soil Erosion Susceptibility, *www.dnr.state.mn.us/whaf/about/scores/geomorphology/soil_erodibilty.html*

Table 2.15
Estimated Surface Water Volume Versus Organic Muck and Silt Streambed Sediment Volume Among the West Branch Agricultural Ditch, Upper Mason Creek, and Lower Mason Creek Reaches: 2014

	Reach Conditions				Water Volume (length x width x water depth)		Sediment Volume (length x width x sediment depth)	
Reach	Length (feet)	Mean Water Width (feet)	Mean Water Depth (feet)	Mean Sediment Depth (feet)	Cubic Feet	Cubic Yards	Cubic Feet	Cubic Yards
West Branch Agricultural Ditch	10,560	3.7	0.3	1.2	11,722	434	100,109	3,708
Upper Mason Creek	9,134	8.9	0.9	1.0	73,163	2,710	81,293	3,011
Lower Mason Creek	9,082	13.4	0.8	0.2	97,359	3,606	24,340	902

Note: A mean bankfull width of 7.9 feet was used to calculate the average volume of sediment within the West Branch Agricultural Ditch (as opposed to water width as used in the other reaches), because that width better reflects flat banks just above water level that contain saturated organic muck and silt sediments available for transport to downstream reaches.

Source: SEWRPC

amounts of readily transportable sediment bedload within the upstream reaches (West Branch Agricultural Ditch and Upper Mason Creek) are being chronically eroded and deposited in habitats downstream as well as in North Lake, even during baseflow or low flow conditions. Because of the large sediment volumes in these reaches, during rainfall events the amounts of transported sediments are essentially limited by the depth of flow and the reach slopes, which is why all of these reaches are observed to transform to a deep chocolate brown (i.e., high sediment loads), even after the smallest rainfall events.

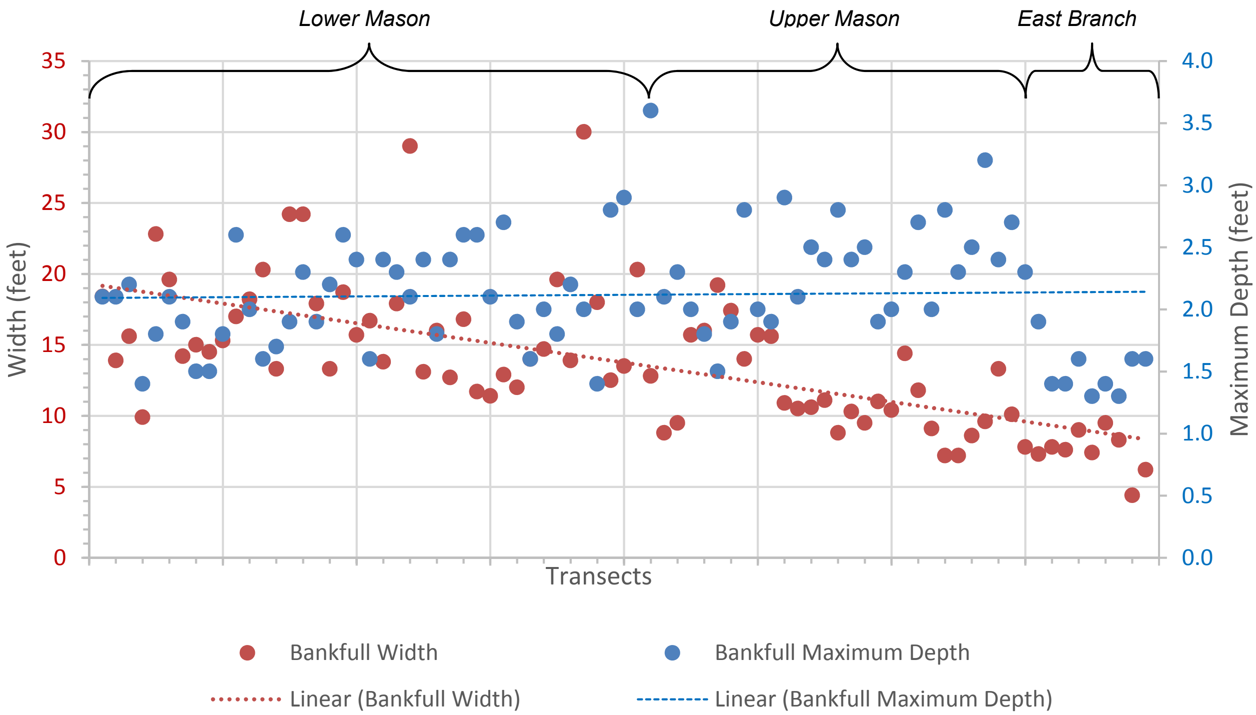
Given these large volumes of sediment in streams throughout the Mason Creek watershed, it is not possible that this accumulated sediment could have originated from streambank erosion, because there was not enough erosion to account for the large volumes of sediment deposited. This demonstrates that this sediment is likely coming from upland areas throughout the watershed, which is supported by the pollutant load modeling described above. However, this also demonstrates the significance of the existing sediment already deposited on the streambed of the Creek and its contribution to the impairments of water quality and fisheries habitat. **Therefore, it is important that reduction of the existing sediment bedload within the West Branch Agricultural Ditch and Upper Mason Creek reaches be addressed under this plan.** Since upstream reaches are loading sediment into downstream reaches, sediment bedload prevention/mitigation should be completed in the most upstream West Branch Agricultural Ditch and associated drainage ditches before the Upper Mason Creek reach can be addressed. This approach would also address the worst reach first.

There is an important difference between low flow versus bankfull channel conditions. Low flow, commonly referred to as low-water discharge, and sustained, or fair weather, runoff are not determinants of overall streambed and streambank channel shape and form. In contrast, the bankfull discharge is considered to be the channel-forming or effective discharge.[113] It is also defined by the discharge that occurs when water just begins to leave the channel and spread onto the floodplain. The quantity and movement of both water and sediment is what determines channel dimension and shape, and effective discharge is the amount of water (volume per unit time) that transports the most sediment over the long term for any given stream system (see Appendix I for more details). Therefore, bankfull channel dimensions are important characteristics of stream power or channel forming discharge, which corresponds to the highest water velocities and ability to transport sediments. The effective discharge typically occurs only a few times annually and is generally defined as the 1.5-year recurrence interval flow event.[114] As shown in Figure 2.37, the channel forming discharge or bankfull channel dimensions increase among reaches from upstream (East Branch) to downstream (Lower Mason Creek) as the drainage area increases. Mean bankfull channel width conditions

[113] *Leopold, L. B. (1994). A view of the river. Cambridge: Harvard University Press.*

[114] *V.T. Chow,* Open-Channel Hydraulics*, McGraw Hill, New York, 1988.*

Figure 2.37
Bankfull Width and Maximum Depth Conditions Among the Upper and Lower Mainstem Reaches and East Branch Tributary Reach Within the Mason Creek Watershed: 2014



Source: SEWRPC.

show an increase from about nine to 20 feet, but there is no apparent increase in depth from upstream to downstream, which ranges from about 2.0 to 2.25 feet.

Based upon the channel slope and bankfull depths of flow, the East Branch was estimated to be able to transport sediment sizes up to medium gravel (8.0 to 16.0 millimeters in diameter). Hence, this reach can easily transport all substrate particles equal to medium gravels and smaller, which includes fine gravels, course to very fine sands, course to very fine silts, and coarse to very fine clays. This is consistent with observations that this reach was dominated by sands, gravels, and cobbles amongst riffle habitats and organic silts and muck mixed with sands within the slower pool and run habitats.

Both the West Branch Agricultural Ditch and Upper Mason Creek reaches were estimated to be able to transport sediment sizes up to very fine gravels (2.0 to 4.0 millimeters in diameter) based upon the channel slope and bankfull depths of flow. Thus, during these high flow conditions these reaches are capable of eroding and transporting significant volumes of the accumulated organic muck and silt stored within the streambed sediments as noted above and on Map 2.11 and in Figure 2.36 and Table 2.15.

In comparison, the Lower Mason Creek reach was estimated to be able to transport the largest sediment sizes up to course gravels (16.0 to 32.0 millimeters in diameter) based upon the channel slope and bankfull depths of flow. The riffle habitat located within this reach, as shown in Figure 2.38, demonstrates that the particle diameter sizes on the channel bed are significantly larger than the medium sized gravels, because these substrates are more stable and less easily transported than the smaller medium sized gravels being carried downstream. However, due to the more natural sinuosities of this reach, it also contains the greatest diversity and mixture of clay, silt, sand, cobble, and boulder substrates and instream habitats (see "Habitat Quality" subsection below). Organic silt and muck sediments accumulate in the lower velocity pool and run habitats during low flow periods. Deposition of these organic sediments also dominates in the lower downstream portions of this reach where the backwater conditions created by North Lake slow water velocities and facilitate deposition of these finer substrates within the channel and inlet area of the Lake.

Figure 2.38
Examples of Instream Cover Within the Mason Creek Watershed: 2014

Source: SEWRPC.

The bankfull channel dimensions and associated discharge is critically important when considering potential projects to restore streambed and/or streambanks and to improve fisheries habitat within Mason Creek. If a newly reconstructed stream channel is improperly sized it could lead to excessive erosion of the channel bed or banks (i.e., too narrow or shallow) or aggradation (i.e., too deep or wide). Therefore, it is very important that any stream restoration within Mason Creek incorporate appropriate bankfull channel dimensions as one of the design parameters along with the associated geomorphological parameters such as slope; sinuosity; belt width; radius of curvature of the bends; substrate sizes; and low flow pool, riffle, and run habitat dimensions. The bankfull width and depth dimensions discussed above and shown in Figure 2.37 should be used as part of the stream restoration design parameters and goals within Upper Mason Creek. In addition, the historic stream channel alignment for Pre-1941 conditions (see Map 2.13) should be used to approximate the appropriate design parameters and goals for slope; sinuosity; belt width; radius of curvature of the bends; and distribution and length of low flow pool, riffle, and run habitat dimensions. However, it is important to note the channel forming discharge of bankfull channel dimension can change, particularly as a watershed becomes more urbanized. Greater urbanization is associated with greater amounts of impervious surfaces, which increases runoff that can lead to increases in discharge and stream power causing the stream to increase in size (erode its streambed or streambanks) in response. Thus, monitoring bankfull channel conditions over time is also a good way to track the health of the stream in terms of its ability to maintain its dimensions and/or whether or not it is in equilibrium with the adjacent land uses and management practices within the watershed.

Table 2.16
Low Gradient Stream Habitat Quality Criteria Scores Among Reaches Within the Mason Creek Watershed: 2014

	Mainstem Reaches		Tributary Reaches		
Habitat Criteria	Upper Mason	Lower Mason	East Branch Headwaters	West Branch Agricultural Ditch	Trib-A[a]
Channelization (percent)	61-100	1-9	61-100	61-100	61-100
Channelization (age in years)	>20	>20	>20	>20	>20
Instream Cover (percent)	5-10	11-14	5-10	<5	Not Assessed
Bank Erosion (percent)	<7	7-50	<7	7-50	Not Assessed
Sinuosity (ratio)	<1.05	1.21-1.40	1.05-1.20	<1.05	<1.05
	0.05-0.25	>0.40	0.26-0.40	<0.05	Not Assessed
Buffer Vegetation (percent)	51-90	51-90	>90	51-90	20-50

Note: The red, yellow, green, and blue fill colors are associated with poor, fair, good, and excellent habitat criteria scores, respectively.

[a] *This tributary was not assessed, because staff could not gain access to it through private properties.*

Source: Adapted from Wang et. al., Development and Evaluation of a Habitat Rating System for Low-Gradient Wisconsin Streams, North American Journal of Fisheries Management , 18:775-785, 1998, and SEWRPC

Habitat Quality

Mason Creek and its main tributaries are a low-gradient stream system, which is characterized by a gradient of about 0.005 feet/feet or lower. High quality, low gradient streams tend to lack riffles and have relatively slow currents, small substrate particle sizes, and well developed meandering (i.e., high sinuosity) channel morphology. Such systems often flow through wetlands and may have very soft, unconsolidated (i.e., organic) substrates and poorly defined channels in some cases. Such characteristics have made low-gradient streams candidates for channelization for agricultural development along with installation of tiles to improve drainage, which is what has occurred to a large extent in the Mason Creek system.

Despite the extensive channelization that has occurred in this watershed, the amount, quality, and diversity of available instream fisheries habitat ranges from poor to excellent based upon results of the low gradient stream habitat index (Table 2.16) in all areas except for the West Branch Agricultural Ditch. As shown in Table 2.16 this index incorporates several habitat variables that are well established as strongly influencing fish communities and biotic integrity.[115] Those habitat variables include channelization percent and age, instream cover, bank erosion, sinuosity, standard deviation of thalweg depth, and buffer vegetation. Instream cover can include several features such undercut banks, overhanging vegetation, woody debris, boulders, and emergent and/or submergent aquatic plants (i.e. macrophytes). The standard deviation in thalweg depth is a measurement of the variability of water depths, which is a good measure of the variability of stream channel morphology. So greater variability in water depth is reflected in greater diversity of pool, riffle, and run habitat units within a reach or stream and their associated differences in water depth, velocity, and substrate diversity. For example, channelized or straightened streams tend to have uniform conditions, whereas meandering streams tend to have a greater variety of habitats. Diverse habitat generally supports more species, a greater variety of life-stages, and higher abundance of fish.

The West Branch Agricultural Ditch contains the poorest habitat quality rating compared to the other reaches in the watershed. The best scores for this reach are for time since channelization, relatively limited erosion, and fairly good protection by riparian buffers. However, as discussed above, this reach has very poor base flows during dry periods and flashy flows during rainfall events, limited to no instream cover, no substrate diversity, no pool or riffle habitats to support trout, limited variation in water depths, and extensive streambed sediments and associated pollutants. This reach has likely not supported brook trout in the past nor does it currently support trout.

[115] *Lihzu Wang, John Lyons, and Paul Kanehl, "Development and Evaluation of a Habitat Rating System for Low-Gradient Wisconsin Streams,"* North American Journal of Fisheries Management*, Volume 18, pages 775-785, 1998.*

In contrast, the East Branch is the original/historic headwaters of Mason Creek as shown on the original 1837 plat survey (Map 2.12). It continues to provide consistent high quality groundwater discharge that is the keystone to sustaining brook trout within Mason Creek. Despite significant channelization, this reach has reestablished fair to good habitat quality, at least within its lower portion.[116] This segment contained good overall quality of instream thalweg depth diversity, stable banks, extent of protective riparian buffers, and instream cover such as woody structure and substrate diversity. Figure 2.38 shows good examples of typical instream cover variables observed within the Mason Creek watershed that includes submergent and emergent macrophytes (i.e., vegetation), overhanging vegetation, cobble and boulder substrates, and woody debris. This reach has a good pool-riffle structure. The riffle habitats contain substrate sizes conducive to brook trout spawning and egg development. The slower velocity pool and run habitats and associated depths that range from about 0.5 to 1.25 feet are also ideal for juvenile trout rearing habitat after the brook trout fry emerge from eggs, which occurs from about April to August. This is the only location where brook trout spawning was observed to occur in the entire watershed (see Figure 2.19), which demonstrates its continued capacity to support a critical life stage of this sensitive cold water species. Since it was only possible to survey the lower portion of this tributary, it is possible that there are more spawning sites upstream of the ones observed. **It is a high priority to protect the surface water and groundwater quality and discharge of this tributary, which contains vital spawning and juvenile rearing habitats that help to sustain the naturally reproducing brook trout population within Mason Creek.**

In addition, as mentioned in the "Slope and Sinuosity" section above, a flow through spring pond was constructed in the lower portion of the East Branch near the confluence with the West Branch Agricultural Ditch between the years 1941 through 1950, and then this pond was disconnected from the East Branch by 1963. This coldwater spring pond could provide important cold, deepwater habitat in the hottest summer periods and warm, deepwater habitat in the overwintering periods for brook trout and other fishes, amphibians, and reptiles, if a direct connection with Mason Creek could be restored between these habitats**.**

The Lower Mason Creek reach contains the highest quality habitat rating (good to excellent) compared to all the other reaches in the watershed for each of the habitat variables. Not surprisingly, this is also associated with the highest quality fishery observations and diversity in the watershed. This is also consistent with the highest quality in thalweg depth, instream cover, and diversity of substrates, which is characteristic of a well-balanced distribution of pool, riffle, and run habitats (see Maps 2.14 and 2.15). This reach contains the deepest and highest quality pool habitats within Mason Creek. About 50 percent of the pools had depths between 1.5 to 2.0 feet and 25 percent of the deepest pool habitats had depths ranging from about 2.0 to nearly 3.0 feet (see Figure 2.33). However, none of these achieved a maximum depth of three feet, which is considered the minimum optimal pool depth for brook trout. As a general rule of thumb, depths of three to six feet are considered necessary for quality brook trout pool habitat.[117] The lack of optimal pool depth is likely a limiting factor for trout survival within Mason Creek, particularly during low flow conditions in late summer and throughout the winter. Although this reach does not have the potential to achieve desired pool depths, due to the availability of water, hydrological soils, and geomorphological conditions within this area, this reach is connected to North Lake, which can serve as an important deep water overwintering habitat.[118] Unfortunately, fish passage seems to be limited within this reach at Koester Road and a private drive just downstream of this crossing (see "Stream Crossings" section below). Brook trout can pass downstream through these crossings, but neither brook trout nor any other fish species can pass back upstream through Koester Road. Any brook trout that pass downstream of these two road crossings would have good access to North Lake as an overwintering refuge, but would be permanently confined within the 0.5-mile-long lower section of Mason Creek. Therefore, brook trout would be unable to migrate upstream to spawn in the headwaters in spring or to feed in riffle habitats or seek cooler refuge upstream in late summer. These fish passage barriers are likely to be negatively impacting brook trout populations within Mason Creek.

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[116] *SEWRPC staff were unable to gain access to the remainder of this tributary, due to inability to obtain permissions to pass through private property.*

[117] *(USFS 1994, Raleigh et al.1986).*

[118] *David P. Boucher, Maine Department of Inland Fisheries and Wildlife,* Seasonal Movements and Habitat Use of Brook Trout in the Magalloway River, Fishery Final Report Series No. 08-01*, January 2008, see website at www1.maine.gov/ifw/fishing/reports/fishery_division/2005/seasonalmovementandhabitatuseofbrooktrout.htm*

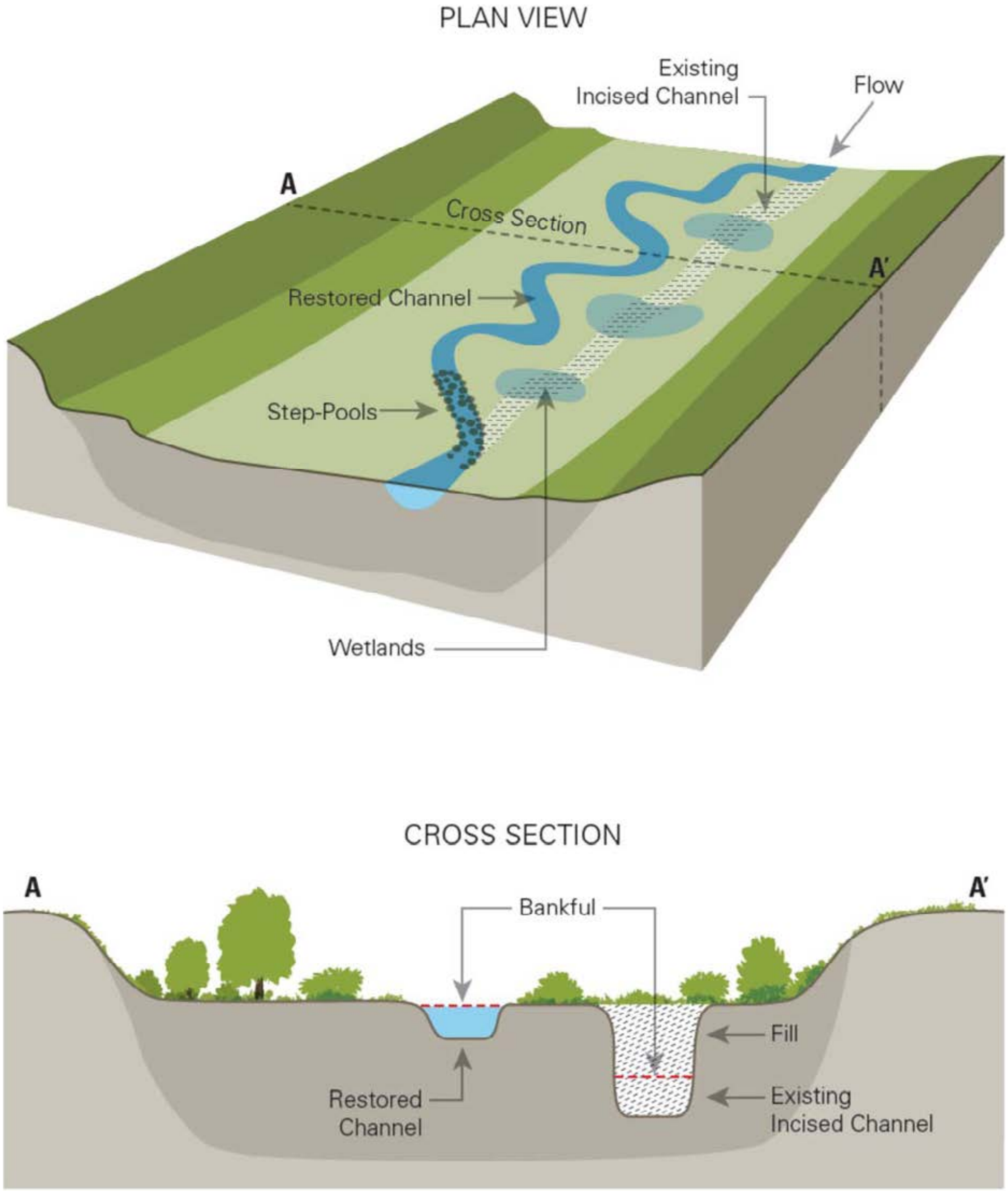
Past channelization combined with limited riparian buffer protection have occurred to a much greater degree in Upper Mason Creek than in Lower Mason Creek, and the overall quality is reduced, particularly in regards to thalweg depth diversity and instream cover. This degradation is associated with the loss of the pool-riffle habitat structure, and is a reflection of the extensive channelization that occurred within this reach prior to 1941. Riffle habitats were completely removed, which likely limited the availability of production areas for aquatic bugs/food in Mason Creek. In addition, the number and extent of pool habitats was greatly reduced, and the remaining pool habitats rarely exceed two feet in depth. Streams can recover from past channelization, which is why the criterion of channelization age is included in the habitat quality rating (i.e., more years post channelization is associated with a higher quality score). However, research has shown that there are limits to the ability of streams to recover from past channelization, particularly in low gradient streams. For example, despite channelization that has occurred 78 or more years ago in this reach, it still contains much poorer habitat diversity in terms of instream cover, substrates, habitat types, and increased sediment deposition compared to the downstream reach that was not as channelized (see "Streambank Erosion" subsection for more details). However, despite this degradation, this reach continues to be associated with a consistent abundance of adult brook trout observations, at least just upstream of the CTH CW roadway, which is likely an artifact of the exceptional ground water quality and quantity discharge in this portion of the reach. As noted above, adequate pool depth and riffle habitats are critical for maintaining trout populations, so lack of these habitats is likely limiting the existing brook trout population within this reach. However, if this section of the stream was designed and constructed to its original, or near original, pre-1941 meandering channel conditions, it may have the potential to achieve desired pool depths of up to three feet in some areas. In addition, this section of stream has a great potential to increase the number and extent of riffle habitats to improve food production and to provide potential spawning habitats.

Similar to the East Branch tributary reach, the Trib-A reach also has been significantly modified due to channelization and contains areas were riparian buffer protection needs improvement. Given the higher slope of this reach combined with channelization, it is anticipated that streambank erosion may be an issue in this reach. However, SEWRPC staff could not gain access to this tributary through private properties to assess streambank stability or instream habitats further. This tributary has been identified to be consistently discharging into Mason Creek since at least 1837. The 1837 plat of survey notes indicated Trib-A to be over six times wider (13.2 feet) than the East Branch tributary (2.0 feet) and approximately the same width as the Upper Mason Creek reach as shown on Map 2.12. This indicates that Trib-A has likely been sustained by fairly significant groundwater discharge that helps to support the coldwater brook trout fishery in Mason Creek. Hence, this tributary also may be supporting critical brook trout spawning or juvenile rearing habitats.

It is important to note that the lowest habitat scores in all cases were associated with the modified sections of streams that were highly channelized. Although the Upper Mason reach continues to recover from past channelization, it is clear that this channelized segment is limiting habitat quality for brook trout within Mason Creek and will not likely recover on its own without more intensive intervention. Hence, this channelized reach provides the greatest potential for instream habitat recovery within the Mason Creek watershed for brook trout. In addition, Mason Creek has a high potential for recovery for two key reasons. First, this riverine system contains good quality source populations of macroinvertebrate and brook trout fishery assemblages, primarily due to its high quality and quantity of groundwater discharge. Therefore, creation or rehabilitation of habitats is likely to lead to increased abundance and distribution of these key ecological indicators. Second, there are several opportunities to restore some of the most degraded reaches in this system to their original, or near original, channel configuration to restore sediment transport and floodplain connectivity, and to improve water quality and fisheries habitat (see Figure 2.39). In addition, remeandering can also help restore hyporheic (i.e., under) flow, which occurs in the subsurface area beneath and alongside a streambed where there is mixing of shallow groundwater and surface water, particularly within riffle habitats. The flow dynamics and behavior in this zone are recognized to be important for surface water/groundwater interactions to improve water quality (reduce instream water temperatures and improve dissolved oxygen), potentially attenuate contaminants,[119] and promote fish spawning and egg development habitats. Therefore, returning this stream to its original or near original channel configuration and appropriately sized pool-riffle structure would restore instream habitat and floodplain connectivity and reduce streambed deposition, and it would also reinstate the connection of the surface water in this channel

[119] *Justin E. Lawrence et. al., "Hyporheic Zone in Urban Streams: A Review and Opportunities for Enhancing Water Quality and Improving Aquatic Habitat by Active Management,"* Environmental Engineering Science*, Volume 30(8): 480-501, August 2013.*

Figure 2.39
Potential Stream Restoration Design Example for Mason Creek to Improve Stream Function Through Diverting or Reconstructing a More Natural Meandering Channel from a Channelized/Incised Condition



Source: Rosgen Priority Level 1 restoration approach adapted from Harman, W., et al. 2012. A Function-Based Framework for Stream Assessment and Restoration Projects. US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC EPA 843-K-12-006.

to the relict alluvium to restore hyporheic flows. However, it is important to note that the remeandering/reconstruction of the Upper reach of Mason Creek should not be conducted until the majority of the cropland erosion and streambed sediment loads within and adjacent to the West Branch Agricultural Ditch are addressed.

Trash and Debris

Although the accumulation of trash and debris is not part of the habitat scores as summarized above, these materials degrade the aesthetics of the stream system and can cause physical and/or chemical (i.e., toxic) damage to aquatic and terrestrial wildlife. Therefore, Commission staff recorded and mapped the significant trash and debris that was encountered during the comprehensive survey (specific details in Appendix F, Maps F.1 through F.5). There was a very limited amount of trash or debris observed within Mason Creek and its tributaries.

Stream Crossings and Dams

Culverts tend to have a destabilizing influence on stream morphology and can create selective barriers to fish migration because swimming abilities vary substantially among species and size-classes of fish, affecting their ability to traverse the altered hydrologic regime within the culverts (see Figure 2.40).[120] Fish of all ages require freedom of movement to fulfill needs for feeding, growth, and spawning. Such needs generally cannot be found in only one particular area of a stream system. These movements may be upstream or downstream and occur over an extended period of time, especially in regard to feeding. In addition, before winter freeze-up, fish tend to move downstream to deeper pools for overwintering. Fry and juvenile fish also require access up and down the stream system while seeking rearing habitat for feeding and protection from predators. The recognition that fish populations are often adversely affected by culverts has resulted in numerous designs and guidelines that have been developed to allow for better fish passage and to help ensure a healthy sustainable fisheries community.[121]

Brook trout, a highly sought gamefish species, has limited leaping and swimming abilities and is not expected to be able to traverse these structures, which is likely contributing to the impairment of this species throughout Mason Creek.[122] Given these limitations, brook trout are a good template species for structure design or modification for fish passage at critical low flow conditions. Higher flow conditions are also important to consider as part of road crossing design to accommodate for sediment transport and floodplain connectivity to the extent practicable (see Figure 2.41).

Bridges and culverts can affect stream widths, water and sediment depths, velocities, and substrates. These structures also have the potential to pose physical and/or hydrologic barriers to fish and other aquatic organisms. Therefore, SEWRPC staff conducted an inventory of 18 structures on the mainstem of Mason Creek and two crossings on the East Branch of Mason Creek (see Map J.1 in Appendix J), describing structure condition and assigning a fish passage rating as summarized in Table J.1 and the photos in Figure J.1 in Appendix J. The majority of the structures were identified to be passable, but two structures were considered complete barriers and four were considered partial barriers to passage.

Structure No. 7 at River Mile (RM) 0.41 at a private drive in Lower Mason Creek was rated as a complete barrier to fish passage (Figure 2.42). This structure is considered a complete barrier during low flow conditions, because the outlet is perched 0.6 feet above the downstream water surface. Even if fish could jump into the pipe, which is highly unlikely, water depths within the pipe are too low for passage. This elliptical pipe also is considered a barrier to fish passage at higher flows, because water velocities are likely too fast for fishes to through this narrow pipe opening. This is evidenced by a scoured pool depth of 2.7 feet just downstream

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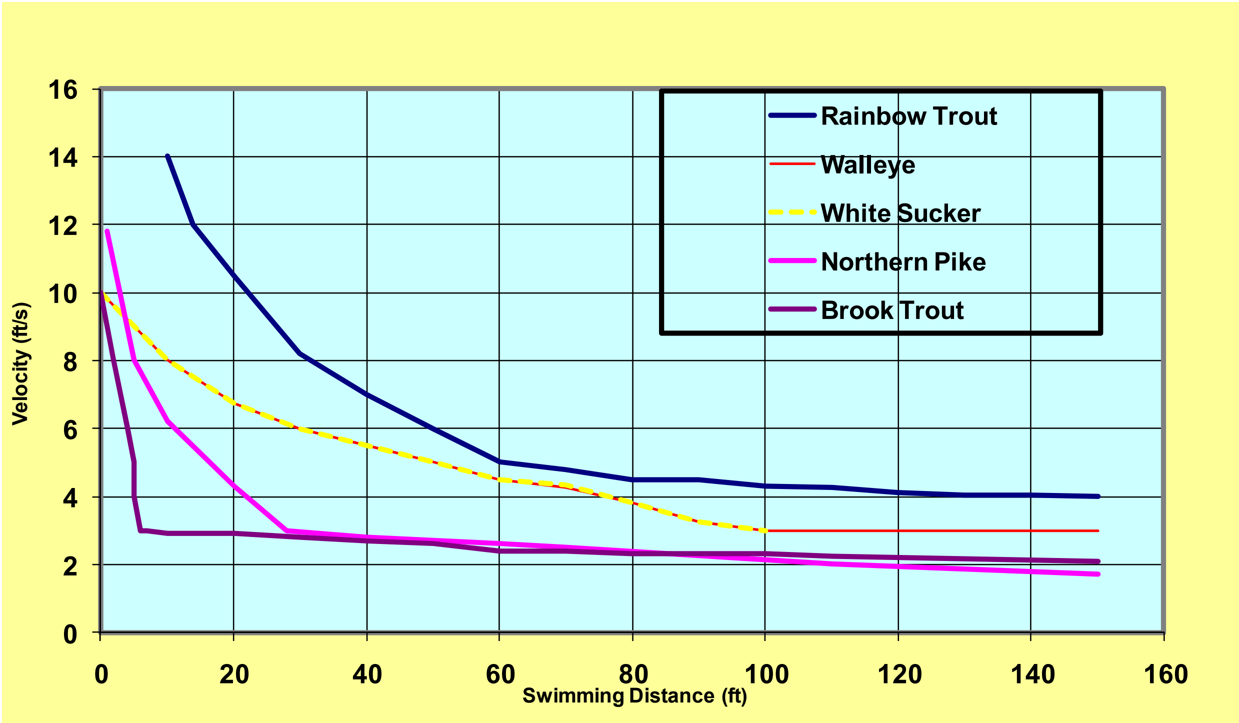
[120] *Stream Enhancement Research Committee, "Stream Enhancement Guide," Province of British of Columbia and the British Columbia Ministry of Environment, Vancouver, 1980.; and, Thomas M. Slawski and Timothy J. Ehlinger, "Fish Habitat Improvement in Box Culverts: Management in the Dark?"* North American Journal of Fisheries Management*, Volume 18, 1998, pages 676-685.*

[121] *B.G. Dane,* A Review and Resolution of Fish Passage Problems at Culvert Sites in British Columbia*, Canada Fisheries and Marine Sciences Technical Report 810, 1978. Chris Katopodis, "Introduction to Fishway Design," Freshwater Institute Central and Arctic Region Department of Fisheries and Oceans, January, 1992.*

[122] *Luther Aadland, Minnesota DNR,* Reconnecting Rivers: Natural Channel Design in Dam Removal and Fish Passage*, January 2010.*

Figure 2.40
Relationship Among Species Between Water Velocity and Fish Swimming Ability (Distance Between Resting Areas)



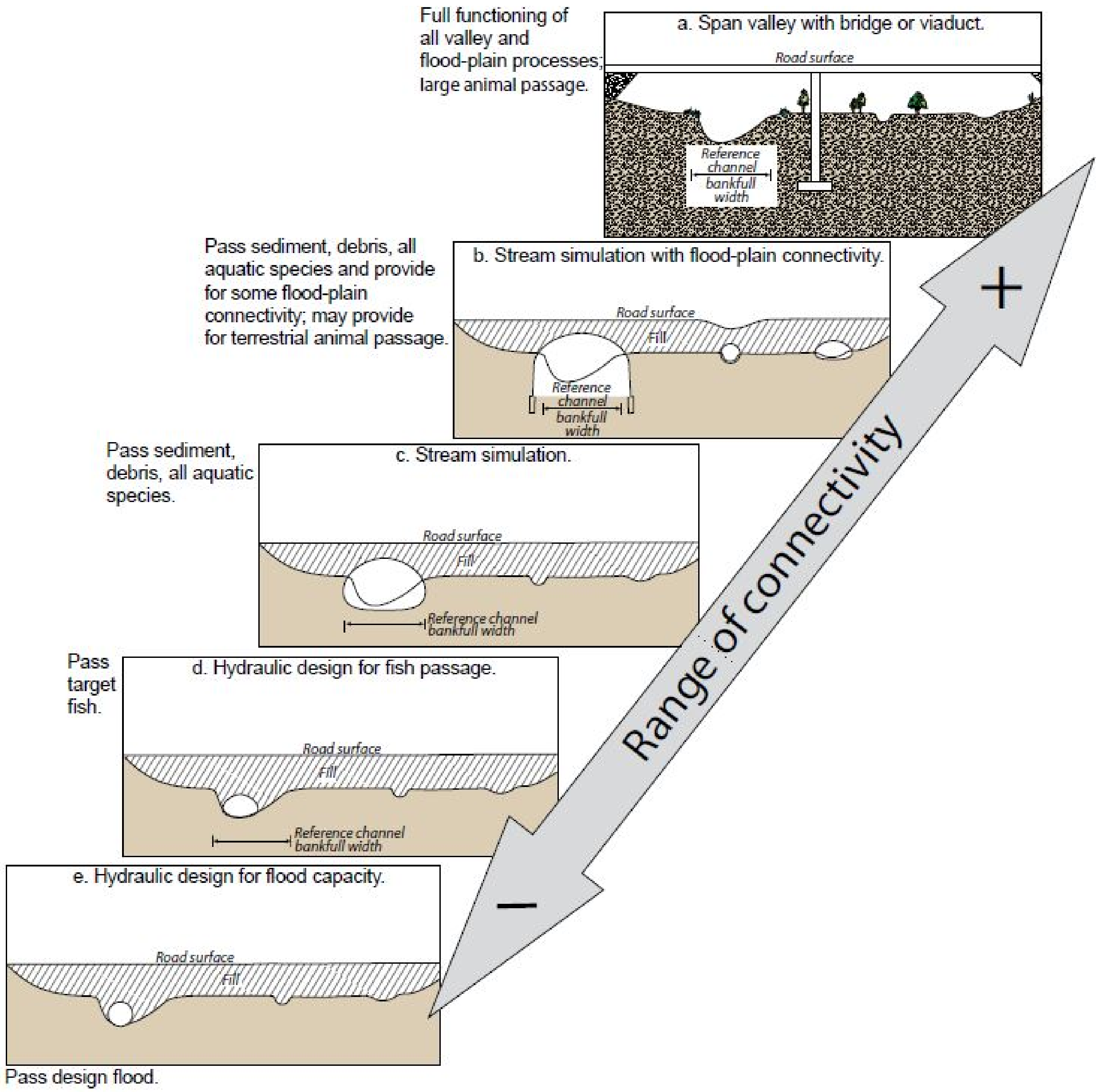
Source: Ontario Ministry of Natural Resources, Environmental Guidelines for Access Roads and Water Crossings, *Toronto, Ontario 64 p. (order from OMNR Information Centre, Toronto 1-800-667-1940), 1988, and SEWRPC.*

of the outlet. This pipe has a width of less than five feet, which is much too narrow, because bankfull widths in this area range from about 12 to 15 feet. This structure seems to show signs of instability, because culvert sections are pulling apart underneath the driveway. Based upon review of historical aerial photographs, this structure was built sometime between 1970 and 1980, which means that it is between 35 and 45 years old and may be reaching its life expectancy. Therefore, this structure is a high priority to improve fish passage for brook trout.

Structure No. 9 at RM 0.50 at Koester Road in Lower Mason Creek was also rated as a complete barrier to fish passage (Figure 2.42). This structure is considered a complete barrier during low flow conditions, because there are excessive amounts of cobble and boulder substrates blocking flows at the inlet (acting like a dam and impounding water upstream) and flows are split among three separate pipes. Consequently, water depths are too low to provide adequate fish passage. At high flows, water depths are likely to be too low and water velocities too excessive to enable fish passage. The condition of these three corrugated metal pipes is poor, with multiple locations where holes have rusted through. Based upon review of historical aerial photographs, this structure was built sometime between 1970 and 1980, which means that it is between 35 and 45 years old and has apparently exceeded its life expectancy. Therefore, this structure is a high priority to improve fish passage for brook trout.

Structure No. 19 at RM 0.05 on the East Branch of Mason Creek at a private drive was rated as a partial barrier to fish passage (see Appendix J and Figure 2.42). This structure is a ford that is located approximately 264 feet upstream from the confluence with Upper Mason Creek (see Map J.1 in Appendix J). A ford is a shallow place with good footing where the Creek may be crossed by wading, or inside a vehicle or tractor getting its wheels wet. This structure is considered a partial barrier during low flow conditions, because water depth and width is limited, which is likely limiting brook trout passage. A wood plank combined with additional stone was placed to provide a trail crossing on the downstream edge of the ford, creating the narrow water width and shallow depth and causing water to back up into the ford. In addition, one

Figure 2.41
Range of Crossing Ecological Objectives and Examples of Corresponding Design Approaches



Source: U.S. Department of Agriculture (USDA) Forest Service, Stream Simulation: An Ecological Approach To Providing Passage for Aquatic Organisms at Road Stream Crossings*, Forest Service Stream-Simulation Working Group, National Technology and Development Program, 7700—Transportation Mgmt, 0877 1801—SDTDC, August 2008.*

seven-inch diameter pipe has been installed underneath the plank crossing as shown in Figure 2.42 and two additional seven-inch diameter pipes have been installed underneath the entire length of the roadway to reduce water depths over the ford. These pipes, combined with the stone in the downstream portion of the ford which impounds water and with a poorly-graded roadway, have created excessive water widths at the ford as shown in Figure 2.42. These impounded conditions create slack water exposing this portion of the stream to increased warming, which can degrade water quality. However, it is important to note that reconstruction of this ford and associated dam stream area including pipe removal (see Figure 2.42) will likely necessitate construction of one or more instream structures to reduce overall stream slope through the ford and create deeper water to promote fish passage as well as resting areas (see Figure 43).

Figure 2.42
Fish Passage Barriers Along the Mainstem of Mason Creek: 2014

Structure No. 9 at River Mile 0.5—Koester Road,-Complete Barrier

- *Excessive amounts of cobble and boulders piled on the upstream side of culverts causing limited fish passage for native fish species for all flows except for high water events due to limited jumping ability and/or behavior*

Source: SEWRPC

There are three additional structures that are considered to be potential barriers limiting fish passage under low-flow conditions. These include Structure No. 12 at RM 1.26 in Lower Mason Creek and Structures No. 15 at RM 2.51 and No. 16 at RM 3.28 in Upper Mason Creek (see Appendix J):

- Structure No. 12 is a private road crossing that consists of one four-foot-diameter round concrete culvert that is undersized for fish passage and that is creating water velocities that prohibit the ability of many species of fish to pass through at baseflow conditions.

Figure 2.42 Continued

No. 19 at River Mile 0.05 on the East Branch of Mason Creek-Partial Barrier

- *Ford at Private driveway contains shallow water depths with obstructions combined with embedded pipes diverting flow are partially limiting fish passage for native brook trout, particularly at low flows, due to limited jumping abilities and/or swimming behavior*

Source: SEWRPC.

- Structure No. 15 at CTH CW consists of a 15-foot-wide and 3.5-foot-high corrugated metal pipe arch culvert. Roadside fencing has fallen into the stream on the downstream side of the culvert and is accumulating debris and likely impeding fish passage.

- Structure No. 16 consists of two abandoned private culverts, one a 4.2-foot-wide by 3.0-foot-high metal elliptical culvert and one 1.5-foot-diameter circular metal culvert, both of which are collecting debris and likely impeding fish passage.

Although there are only six structures considered to be either complete or partial barriers to fish passage, their combined impact on the fish communities could potentially be significant. Each of these structures, particularly the complete barriers (Structures No. 7 and 9) within Lower Mason Creek, significantly limit the

Figure 2.43
Typical Examples of Rock Vane Restoration Practices Designed to Impound Water and Protect Streambank Erosion, While Promoting Fish Passage

J-Hook Vane

A J-hook vane is an upstream pointing line of rocks that originates at one bank and terminates somewhere in the middle of the stream. The most upstream portion of the structure bends back on itself, like a "J," curving into the middle of the channel. This bent portion serves to concentrate flow and scour out a pool while the length closer to the shore deflects flow away from the bank.

Source: Minnesota River Basin Data Center, see website at http://mrbdc.mnsu.edu/.

Cross Vanes

Beaver Run Stream Restoration Project Cross-vane Structure-- A cross-vane (2-7% slope) has a vane on each side which covers 1/3 of the bankfull width and the invert portion covers the middle 1/3. They are commonly used for grade-control and to reduce nearbank stress by redirecting flow through the center of the channel. It can also considered a habitat improvement structure.

Source: USFWS.

Cross Vane Stream Deflectors within Log Frame

Wallacks Branch Habitat Project (http://fortbedfordtu.org/projects/ wallacksbranchhabitat.htm, bedfordcountyconservation.com)

Source: Trout unlimited and Bedford County Conservation District.

Series of Cross Vanes with Large Habitat Boulders

Source: NRCS, see website http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/?cid=stelprdb1043249.

ability of fish and other organisms to move between North Lake and Mason Creek and separate the deeper water habitats in the downstream reaches from shallower habitats in the upstream reaches of Mason Creek.[123]

Beaver Dams

There was no beaver activity in terms of beaver chew, felled trees, dams, or huts in the Mason Creek watershed observed during the time of this inventory. Beaver dams have the potential to limit fish passage, particularly by brook trout trying to migrate into upstream tributaries to lay their eggs. On the other hand, it is also known that beaver dams, and the wetlands that they create, add to the diversity of both instream habitat and the riparian corridor buffers for multiple wildlife species. Therefore, it is important to continue to monitor for beaver activity and take action where appropriate, but also to recognize that that there are important tradeoffs to be considered between fish passage and natural wetland creation. It is important to keep in mind that beavers are an important part of the overall native wildlife within this stream system and their associated dams are a low cost way to establish vital wetland habitat.

Habitat Quality Summary

In summary, the Lower Mason Creek reach contains the highest quality habitat (good to excellent) and the West Branch Agricultural Ditch contains the poorest habitat quality rating compared to the other reaches in the watershed. Both the East Branch and Upper Mason Creek reaches contain habitat quality that is intermediate compared to the other reaches in the watershed. The habitat impairments on this stream system are mostly due to the combination of channelization, limited riparian buffers, and fish passage barriers. This degradation is associated with the loss of the pool-riffle habitat structure and is a reflection of the extensive channelization that has occurred within this reach prior to 1941. This system has great potential for recovery and there are opportunities to improve habitat quantity and quality for brook trout (particularly in Upper Mason Creek) and the ability of fish to travel within Mason Creek and between Mason Creek and North Lake by addressing fish passage impediments (particularly in the Lower Mason Creek). However, habitat and associated water quality improvements within Mason Creek for brook trout and the associated coldwater fishery cannot be accomplished without addressing the nonpoint source pollutant loads and streambed sediment loads from the West Branch Agricultural Ditch.

[123] *M. W. Diebel, M. Fedora, S. Cogswell, and J. R. O'Hanley, "Effects of Road Crossings on Habitat Connectivity for Stream-Resident Fish, River Research and Applications", Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/rra.2822, Copyright © John Wiley & Sons, Ltd., 2014.*

PLAN RECOMMENDATIONS 3

Credit: SEWRPC Staff

3.1 WATERSHED GOALS AND MANAGEMENT OBJECTIVES, AND PLAN IMPLEMENTATION

This protection plan is designed to serve as a practical guide for the management of water quality within the Mason Creek watershed and for the management of the land surfaces that drain directly and indirectly to the stream and, consequently, to downstream waterbodies, including North Lake, the Oconomowoc River, and ultimately the Rock River. Hence, developing an approach for meeting the pollution load limits established under the Rock River Total Maximum Daily Load (TMDL) study was a major focus of this watershed plan. However, as shown in Table 3.1, that focus was only one component of the overall watershed goals and management objectives that were established to address critical issues in the watershed based on watershed inventory results and stakeholder meetings.

This watershed protection plan was prepared in the context of the Southeastern Wisconsin Regional Planning Commission's (SEWRPC) regional water quality management plan,[1] the Oconomowoc River watershed plans,[2] the North Lake management plans,[3] the County Land and Water Resources Management

[1] *SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan For Southeastern Wisconsin: 2000, Volumes One through Three, *1978-1979. SEWRPC Memorandum Report No. 93, A Regional Water Quality Management Plan For Southeastern Wisconsin: An Update and Status Report, March 1995.*

[2] *City Of Oconomowoc,* Oconomowoc Watershed Protection Program, Waukesha County, Wisconsin, *prepared by Ruekert & Mielke, Inc., February 2016; and, Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the Oconomowoc River Priority Watershed Project, *Publication WR-194-86, 1986.*

[3] *SEWRPC Community Assistance Planning Report No. 54,* A Water Quality Management Plan for North Lake, Waukesha County, Wisconsin, *1982; North Lake Management District,* North Lake and Tributary Limnological Survey 2011-2012, *prepared by Jerry Kaster, Aquatic Environmental Consulting, 2012; and, SEWRPC Community Assistance Planning Report No. 315, A* Water Resources Management Plan for the Village of Chenequa, Waukesha County, *Wisconsin, 2014.*

Table 3.1
Mason Creek Watershed Goals, Indicators, Cause or Source of Impact, and Management Objectives

Goal	Indicators	Cause or Source of Impact	Management Objective
Promote active stewardship among residents, farmers, landowners, businesses, community associations, as well as governmental and non-governmental organizations.	Dialog and Bridging Events; Network Development; Customized Information and Education; Multiple information streams/ meetings to promote Capacity and Leadership training	Lack of awareness, environmental services not given programmatic value, lack of funding,	Increase public awareness of water quality issues and participation in watershed conservation activities
Manage and develop lands in a manner that is consistent with the protection of living resources: avoid habitat fragmentation and encourage the preservation and enhancement of wetlands and wildlife corridors including providing and preserving connections with upland habitats and through sensitive landscaping practices.	Riparian buffers/ wetlands, wetland-upland complexes, streambank erosion, stream channelization/ditching, limited floodplain connectivity, macroinvertebrate quality, fishery biotic integrity, brook trout abundance and spawning redd counts, Cisco abundance in North Lake, floristic quality index	Inadequate riparian vegetation, ditching, loss of wetlands, increased fragmentation within and among natural areas and environmental corridors, excessively groomed landscapes	Maintain and expand wetland, fish, and wildlife habitats and populations
Minimize the further degradation of surface water and preserve, restore, and maintain the high quality of all waterbodies within the watershed	Surface water quality to achieve WDNR/ USEPA water quality standards including, but not limited to, total phosphorus and total suspended sediment	High phosphorus levels causing algal growth and decreased dissolved oxygen. Cropland and barnyard runoff, lack of funding	Reduce the loads of sediment and phosphorus from upland sources to improve water quality and to enhance and restore stream form and function.
Identify opportunities to improve the quality of the land and water (including groundwater) resources within the watershed by reducing both nonpoint agricultural and urban runoff.	Peak flow discharges and flooding during heavy precipitation events, groundwater recharge, streambank stability, fishery quality, macroinvertebrate quality, and improved soil health	Channelization to promote agricultural drainage and associated streambed loads, inadequate stormwater practices, lack of riparian buffers, tile drainage, poor soil health, lack of funding	Reduce the volume and velocity of runoff from upland areas to streams, increase soil infiltration, and protect groundwater recharge

Source: SEWRPC

Plans (LWRMP),[4] the County multi-jurisdictional and comprehensive development plans,[5] and the Rock River watershed plans.[6] Therefore, this plan represents a refinement of these regional, county, and watershed-scale plans and it enables successful implementation of recommendations at a smaller, 8.2-square mile (5,275-acre) watershed scale. In particular, the Washington and Waukesha County Land and Water Resource Management Plans (LWRMP) priority issues, goals, objectives, and implementation work plan

[4] *Washington County Land Conservation Committee,* Washington County Land and Water Resource Management Plan 2011-2020 (2nd Revision), *June 2010; Waukesha County Department of Parks and Land Use Land Resources Division,* Waukesha County Land and Water Resource Management Plan 2012 Update, *January 2012.*

[5] *SEWRPC Community Assistance and Planning Report No. 287,* A Multi-Jurisdictional Comprehensive Plan For Washington County: 2035, *April 2008; and, Waukesha County Department of Parks and Land Use,* A Comprehensive Development Plan for Waukesha County: Waukesha County, Wisconsin, *prepared by the Waukesha County Department of Parks and Land Use, Waukesha County University of Wisconsin-Extension, Waukesha County Municipalities, February 2009.*

[6] *WDNR,* Upper Rock River Basin Areawide Water Quality Management Plan, *Wisconsin Water Quality Management Program, May 1989; WDNR,* Upper Rock River Basin Water Quality Management Plan, A Five-Year Plan to Protect and Enhance our Water Resources, *December 1995; WDNR,* The State of the Rock River Basin, Your River Neighborhood ~ The Rock River Basin, *PUBL # WT-668-2002, April 2002; and, U. S. Environmental Protection Agency (USEPA) and Wisconsin Department of Natural Resources (WDNR),* Total Maximum Daily Loads for Total Phosphorus and Total Suspended Solids in the Rock River Basin: Columbia, Dane, Dodge, Fond du Lac, Green, Green Lake, Jefferson, Rock, Walworth, Washington, and Waukesha Counties, Wisconsin, *July 2011.*

Table 3.2
Survey Results on Ranking Current Water Quality and Quantity Issues in the Mason Creek Watershed: 2013

Water Quality and Quantity Issues	Average Score (Ranked 1-High, 5-Low)
Water Clarity	1.8
Agricultural runoff	1.9
Garbage and trash in natural areas	1.9
Invasive species	1.9
Pesticide use	1.9
Sedimentation	2.0
Urban runoff	2.0
Fishery quality	2.0
Streambed and bank erosion	2.0
Groundwater Recharge	2.1
Wetland protection	2.2
Extent of algae	2.2
Weed growth	2.3
Flooding	2.3
Water depth	2.3
Upland (prairie or woodland) protection	2.4
Water Supply	2.6
Urbanization	2.6
Big gamefish quality	2.6
Temperature	2.6
Ordinance enforcement	3.0
Bugs	3.1
Traffic noise	3.2
Development of new ordinances	3.4
Bacteria related to swimming	4.1

Source: Tall Pines Conservancy and SEWRPC

elements formed the basis of the recommendations outlined below. Hence, continued implementation and funding to support the County LWRMP work plan elements which support recommendations of this plan for the Mason Creek watershed is critical to the successful implementation of this plan.

The improvements that would result from implementing the recommendations in this plan would represent steps toward achieving the overall goal of restoring and improving the water resources of the Mason Creek watershed consistent with the goals and prioritized water quality issues identified in Table 3.1 and 3.2. However, this watershed protection plan goes beyond incorporating recent and ongoing watershed management programs and initiatives. Consequently, the successful implementation of this plan is contingent upon a strategy of community coordination, partnership among stakeholders, and development of farmer-led watershed-based improvements to develop innovative solutions (see "Engagement Strategy" section below).

Linking the TMDL to Implementation of Water Quality Improvements

The Rock River TMDL study was approved by the U.S. Environmental Protection Agency (USEPA) and the Wisconsin Department of Natural Resources (WDNR) in 2011,[7] and relied largely on modeled data to quantify pollutant loads and load (unpermitted nonpoint source) and wasteload (permitted point source) allocations. It is important to consider both the TMDL study and additional information obtained since its completion when developing the implementation actions that may improve water quality within the Mason Creek watershed. It should be noted that due to the nature of modeling uncertainty and the fact that agricultural nonpoint source loads are not regulated under the Federal Clean Water Act (CWA), achieving the wasteload allocations contained in the TMDL study would be expected to improve water quality conditions, but would not necessarily result in attainment of the phosphorus and sediment water quality standards in Mason Creek. Although TMDL load and wasteload allocations were used to establish the benchmark goals, the success of the management actions proposed under this plan will be improvements in measured ambient or instream water quality rather than attainment of load and wasteload allocations.

The City of Oconomowoc has identified adaptive management as the preferred compliance alternative to meet its Wisconsin Pollutant Discharge Elimination System (WPDES) permit requirements for its wastewater treatment facility (WWTF) and municipal separate storm sewer system (MS4) under Chapters NR 217, "Effluent Standards and Limitations for Phosphorus," and NR 216, "Storm Water Discharge Permits," respectively, of the *Wisconsin Administrative Code*. The permitted final mass-based limits for total suspended solids (TSS) and total phosphorus (TP) are derived from the Rock River TMDL approved by the USEPA and WDNR in 2011 as mentioned above.[8] The City submitted a preliminary Watershed Adaptive Management Request Form 3200-139 on February 23, 2015, and the WDNR approved their Adaptive Management Plan (AMP) on September 15, 2015. The AMP spans three WPDES permit terms or 15 years, with the understanding that progress must be demonstrated by the beginning of the third term. Under the AMP, a total phosphorus concentration of 0.075 mg/L must be achieved at the confluence of the Rock and Oconomowoc Rivers in the

[7] *USEPA and WDNR, July 2011, op. cit.*

[8] *Ibid.*

next 15 years. The City has developed the Oconomowoc Watershed Protection Program (see "Information and Education" section below for more details),[9] which includes the Mason Creek watershed, to address the AMP and achievement of water quality criteria.

Hence, it is recommended that the local partners within the Mason Creek watershed continue to participate in the ongoing Oconomowoc River watershed adaptive management program as the management actions described within this report are implemented. The management actions discussed in detail in subsequent sections were chosen because it is anticipated that they will have the greatest effect on improving water quality within the Mason Creek watershed and will promote achievement of 1) the load and wasteload allocations specified under the 2011 TMDL study and 2) the objectives of the 2016 Oconomowoc Watershed Protection Program. As actions recommended under this plan are implemented, water quality data are collected, and new information and technology become available, Washington County and Waukesha County and the City of Oconomowoc, in consultation with Federal and State agencies and municipalities and other partners, will evaluate the effectiveness of recommended actions and possibly modify or discontinue actions that are deemed ineffective and implement other actions consistent with the plan objectives.

Linking the TMDL to Stream Restoration

Restoration is not solely applicable to severely degraded streams. Although it can be used as an effective tool to return a degraded system to a pre-disturbance condition, restoration is also an important tool for preventing environmental degradation.[10]

Restoration has been defined in a number of different ways. On the most basic level, restoration is the process of returning a damaged ecosystem to its condition prior to disturbance.[11] The long-term goal of restoration is to imitate an earlier natural, self-sustaining ecosystem that is in equilibrium with the surrounding landscape.[12] A National Research Council report defines restoration as a holistic process:[13]

> *Restoration is ... the return of an ecosystem to a close approximation of its condition prior to disturbance. In restoration, ecological damage to the resource is repaired. Both the structure and the functions of the ecosystem are recreated ... The goal is to emulate a natural, functioning, self-regulating system that is integrated with the ecological landscape in which it occurs.*

As with other water resource management alternatives, restoration must address questions concerning practicality, predictability of outcomes, and overall effectiveness of specific techniques.[14] Additionally, because ecological systems are complex, and may take years to reach equilibrium or fully demonstrate the effects of restoration and other management activities, seeing or measuring results of restoration efforts may take a long time.

Therefore, under this plan, **ecological restoration is considered as an important tool for preventing environmental degradation and as a means of restoring degraded chemical, physical, and/or biological components of the Mason Creek system to an improved condition.** Strengthening structural or functional elements through restoration can help increase a stream system's tolerance to stressors which

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[9] *City Of Oconomowoc,* Oconomowoc Watershed Protection Program Report, Waukesha County, Wisconsin, *prepared by Ruekert & Mielke, Inc., February 2016.*

[10] *USEPA, Ecological Restoration - EPA 841-F-95-007, November 1995, see website water.epa.gov/type/watersheds/archives/chap1.cfm*

[11] *Cairns, John, Jr. The status of the theoretical and applied science of restoration ecology.* The Environmental Professional, *Volume 13, pp. 186-194, 1991.*

[12] *Berger, John J. The federal mandate to restore: laws and policies on environmental restoration.* The Environmental Professional, *Volume 13, pp. 195-206, 1991.*

[13] *National Research Council,* Restoration of Aquatic Systems: Science, Technology, and Public Policy, *Washington, D.C., 1992.*

[14] *Caldwell, Lynton Keith, "Restoration ecology as public policy,"* The Environmental Professional, *Volume 13, pp. 275-284, 1991.*

lead to environmental degradation. By so doing, water quality and aquatic and terrestrial habitat will be improved, which, in turn, will lead to improvements in the aquatic and terrestrial communities that depend on that water.[15]

This watershed protection plan envisions that restoration techniques be applied as a management action within the context of the Rock River TMDL pollutant load reduction goals as implemented through traditional regulatory actions (such as point source permits) and through voluntary programs (such as implementation of nonpoint source BMPs). Implementation of stream restoration techniques along with regulatory and voluntary actions would contribute to addressing the numeric or narrative water quality criteria and designated water use objectives for Mason Creek. In the context of the TMDL, stream restoration can also address nonattainment of a designated use (e.g., a coldwater fishery) or a narrative criterion that refers explicitly to habitat quality or biological diversity. The recommended management strategy would be to combine point and nonpoint source load reductions and instream ecological restoration techniques. It is important to note that stream restoration is an important and vital pollution reduction strategy to meet TMDL goals for phosphorus and sediment, but stream restoration should not be implemented for the sole purpose of nutrient or sediment reduction in this watershed.[16]

Scope of Restoration

Restoration must consider all sources of stress on a stream and is, therefore, not restricted to instream mitigation of impacts. The health and protection of a waterbody cannot be separated from the watershed ecosystem, and restoration must address all watershed processes that degrade an ecological system (e.g., sediment loading from eroding gullies or construction sites or increased polluted runoff from impervious areas). The intimate connection of rivers and watersheds is succinctly expressed by Doppelt and others:[17]

> *Most people think of rivers simply as water flowing through a channel. This narrow view fails to capture the actual complexity and diversity of riverine systems, and is one of the reasons for failed policies. In the past 15 years many scientific studies and reports have documented that riverine systems are intimately coupled with and created by the characteristics of their catchment basins, or watersheds. The concept of the watershed includes four-dimensional processes that connect the longitudinal (upstream-downstream), lateral (floodplains-upland), and vertical (hyporheic or groundwater zone-stream channel) dimensions, each differing temporally.*

Therefore, restoration is an integral part of a broad, watershed-based approach for achieving water resource goals. Specifically, restoration is the re-establishment of the chemical, physical, and biological components of an aquatic ecosystem that have been compromised by stressors such as point or nonpoint sources of pollution, habitat degradation, hydromodification (i.e., channelization), and others that are summarized above.

Restoration Techniques

This plan emphasizes and endorses the use of natural restoration techniques. Natural techniques such as stream channel remeandering that restore a system's ability to approach a pre-disturbance condition are distinct from treatment technologies or artificial structures that are inserted into the system. Natural restoration techniques also use materials indigenous to the ecosystem and apply concepts such as natural channel design into the dynamics of a river system in an attempt to create conditions in which ecosystem processes can withstand and diminish the impact of stressors that lead to environmental degradation. **Channelization has been extensive throughout the Mason Creek watershed and that is one of the major determinants of limited instream habitat, water quality, and biological condition impairments—particularly in the West Branch Agricultural Ditch and Upper Mason Creek reaches.** The extensive ditching has disabled this stream system's ability to capture, store, and process/treat sediment

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[15] *Travis T. Brown, Terry L. Derting, and Kenneth Fairbanks, "The Effects of Stream Channelization and Restoration on Mammal Species and Habitat in Riparian Corridors,"* Journal of the Kentucky Academy of Science, *69(1):37-49. 2008*

[16] *Richard Starr, Bill Stack, and Lisa Fraley-McNeal,* "Stream Restoration as a Pollutant Reduction Strategy," *Center for Watershed Protection's 2014 Watershed & Stormwater Management Webcast Series September 10, 2014.*

[17] *Doppelt, B., M. Scurlock, C. Frissell, and J. Karr.* Entering the Watershed: A New Approach to Save America's River Ecosystems, *The Pacific Rivers Council, Island Press, Washington, DC, and Covelo, CA, 1993.*

and nutrient loads. Therefore, the only way to restore this system's hydrologic and hydraulic function and associated sediment transport capacity and streambed stability is to physically reconstruct this wetland/stream complex to its historic configuration. The following two distinct areas are designated for restoration of hydrology, sediment transport, and floodplain connectivity to address the impaired water quality and excessive instream streambed loads and to improve habitat conditions for brook trout and their associated coldwater community assemblages (see Map 3.1, Priority Areas 1 through 4):

West Branch Agricultural Ditch Sediment Retention/Wetland Restoration Improvement Area-Restore this agricultural ditch and associated floodplain area to a wetland/lowland swamp with associated shallow groundwater hydrology.

It is important to note that the West Branch Agricultural Ditch is not a natural stream—it is an excavated agricultural drainage ditch. It has not supported brook trout in the past nor does it currently support trout, which means the lower portion of this reach was improperly designated by WDNR staff as a coldwater trout stream. It was constructed sometime between 1909 and 1937 solely for improvement of agricultural drainage and to collect flow from drain tiles in adjacent farmland. This ditch was primarily constructed through Houghton mucky peat soils (historically part of the Mason Creek Swamp natural area) which are very deep, anoxic, highly flocculent, and easily erodible. Hence, this ditch and associated area is largely responsible for the continued impairments and degraded water quality conditions of Mason Creek in terms of increased temperatures, low dissolved oxygen, and significant sediment and nutrient loads.

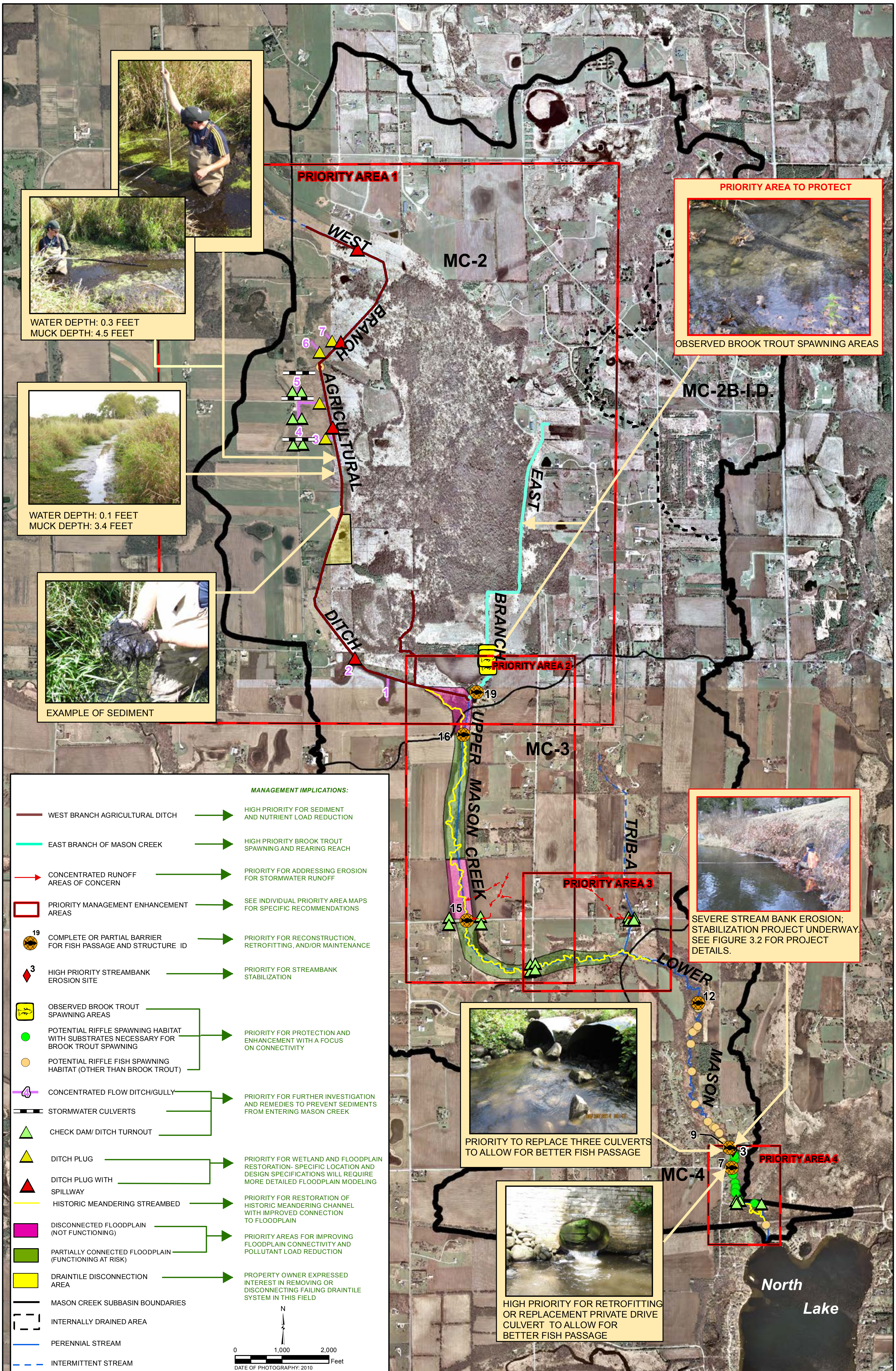
Restoration techniques in this area should focus on detaining, capturing, slowing down and/or treating stormwater runoff, increasing dry weather water levels and flow, and preventing chronic upland-sourced sediment and nutrient loads from entering Upper and Lower Mason Creek as well as North Lake. The excessive bedload sediments in the West Branch Agricultural Ditch are recommended to be addressed by installing a series of ditch plugs to restore wetland and hydrology of this area (see Appendix H). Since there is an adopted Federal Emergency Management Agency (FEMA) floodplain delineated along this ditch, it is important that construction of the ditch plugs not increase the one-percent-annual-probability flood elevation. Therefore, a floodplain modeling study would be required to ensure the design of the agricultural ditch plugs will not increase the flood elevation or flood additional existing cropland. In addition, grassed waterways and/or check dams/ditch turnouts are recommended to address bedload sediments in, and stormwater runoff from, gullies and roadway ditches that discharge directly into the West Branch Agricultural Ditch (see Appendix G).

Upper Mason Creek Brook Trout Habitat Restoration Area-Restore this stream to approximate its original channel alignment, location, slope, sinuosity, pool-riffle structure, and floodplain connectivity, including improving fish passage.

Despite having more than 70 years to recover from channelization that occurred prior to 1941, this reach has not been able to redevelop more natural or appropriate sinuosities, pool-riffle structure, or sediment transport capabilities. The ditching in this reach has created conditions for excessive sediment bedload that is contributing to the impairment of Mason Creek and North Lake. Therefore, it is obvious that, due to the low slopes or energies within this stream system, the only way to restore stream function within this system is to reconstruct it. Recent research has revealed that channelized streams have the negative effect of minimizing water residence time and biological nutrient processing, which can be mitigated by restoring floodplain connectivity to reduce pollutant loads and improve metabolism in agricultural streams. The benefits of floodplain restoration are most apparent during high flow events (during inundation) and floodplains are more effective at assimilating nutrients when the floodplains are vegetated with appropriate native plants. Hence, improving the floodplain connectivity will help Mason Creek reduce and manage pollutant runoff and be more resilient. Reconstructing meanders or restoring a more natural sinuosity, particularly in low-gradient systems like Mason Creek, is one of the most effective ways to restore instream habitat and the ability of this system to transport sediment and to function more like a healthy river system. **However, since the upstream West Branch Agricultural Ditch reach is delivering sediment into downstream reaches, it is critical to note that sediment bedload prevention/mitigation should be completed in the most upstream West Branch Agricultural Ditch and associated drainage ditches before remeandering of the Upper Mason Creek reach. This approach would also address the worst condition reach first (see "*Maintain and Restore Instream Habitat*" section below for more details).**

Map 3.1

Proposed Water Quality and Aquatic Habitat Recommendations and Priority Management Areas Within the Mason Creek Watershed: 2016



STORMWATER CULVERTS

WEST BRANCH AGRICULTURAL DITCH

EAST BRANCH OF MASON CREEK

CONCENTRATED FLOW DITCH/GULLY AND ID

CHECK DAM/DITCH TURNOUT

DITCH PLUG

DITCH PLUG WITH SPILLWAY

OBSERVED BROOK TROUT SPAWNING AREAS

ONE-PERCENT-ANNUAL-PROBABILITY FLOODPLAIN: FEMA 2015

942.3 FLOODPLAIN CROSS SECTION ALIGNMENT AND ONE-PERCENT-ANNUAL-PROBABILITY FLOOD ELEVATION IN FEET ABOUT NORTH AMERICAN VERTICAL DATUM OF 1988

DRAINTILE DISCONNECTION AREA

19 COMPLETE OR PARTIAL BARRIER FOR FISH PASSAGE AND STRUCTURE ID

PERENNIAL STREAM

INTERMITTENT STREAM

MASON CREEK WATERSHED BOUNDARY

N

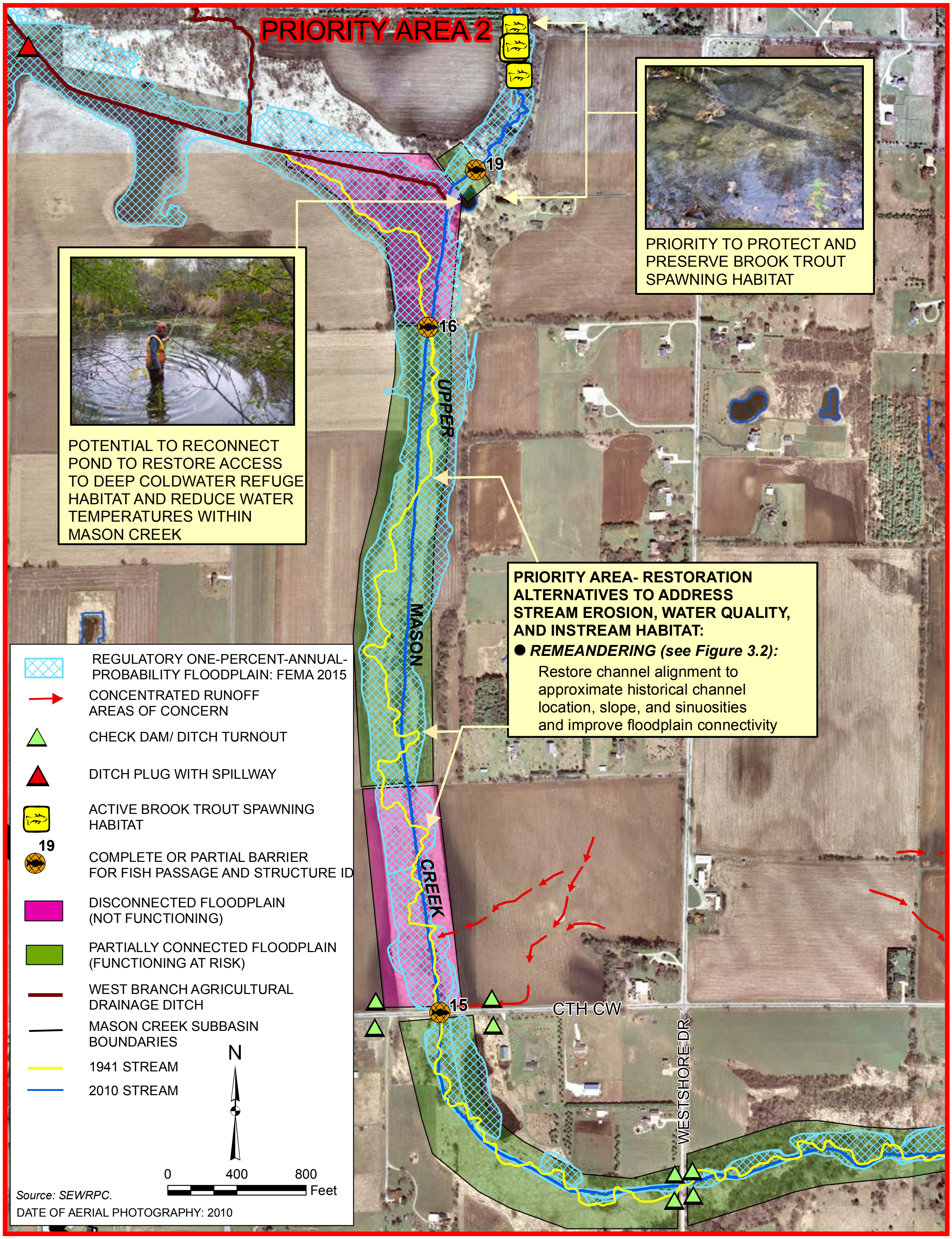
0 500 1,000 Feet

Source: SEWRPC.

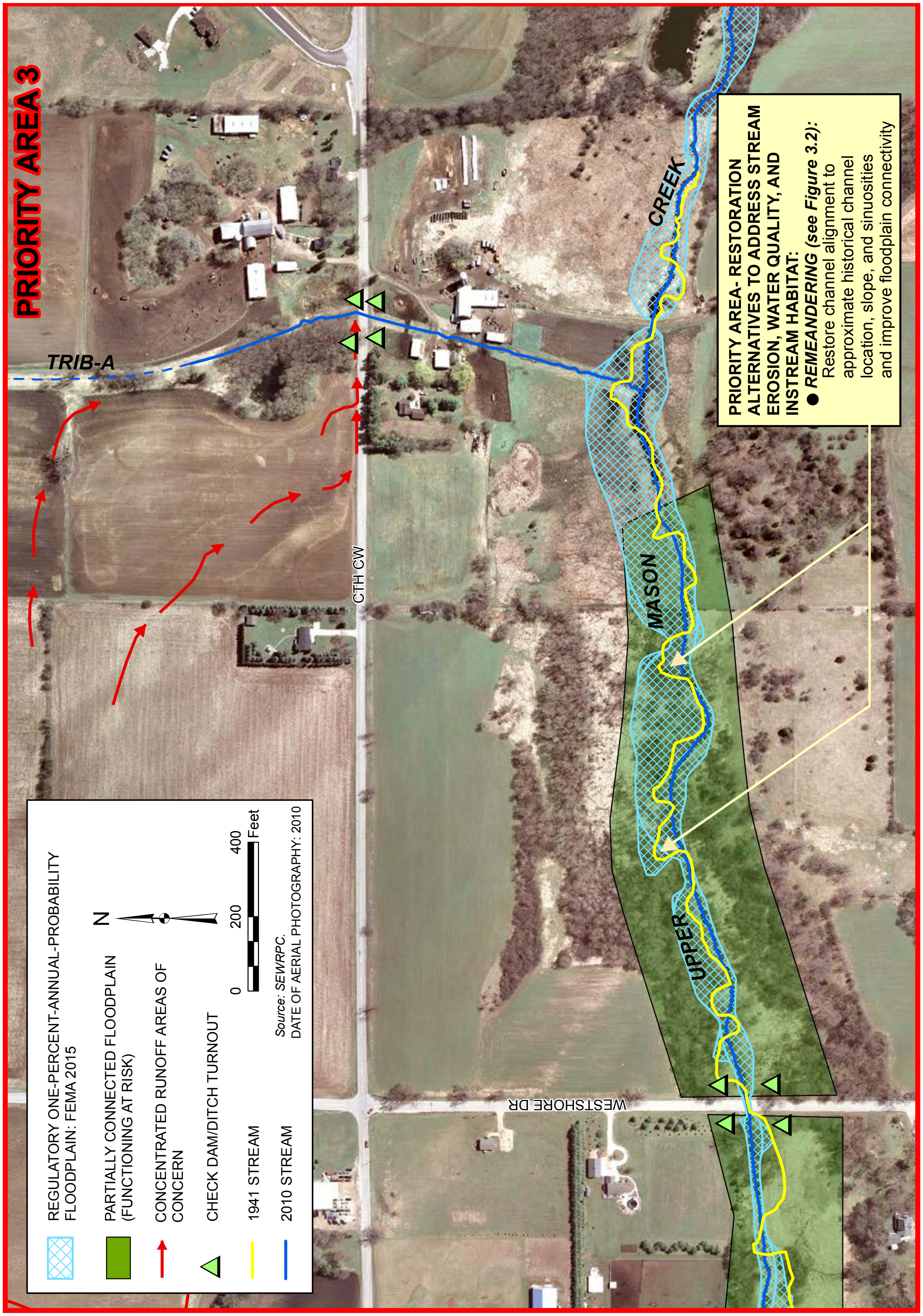
DATE OF AERIAL PHOTOGRAPHY: 2010

NOTE: Constructing a ditch plug requires specific location and design speficaions with more detailed floodplain modeling.

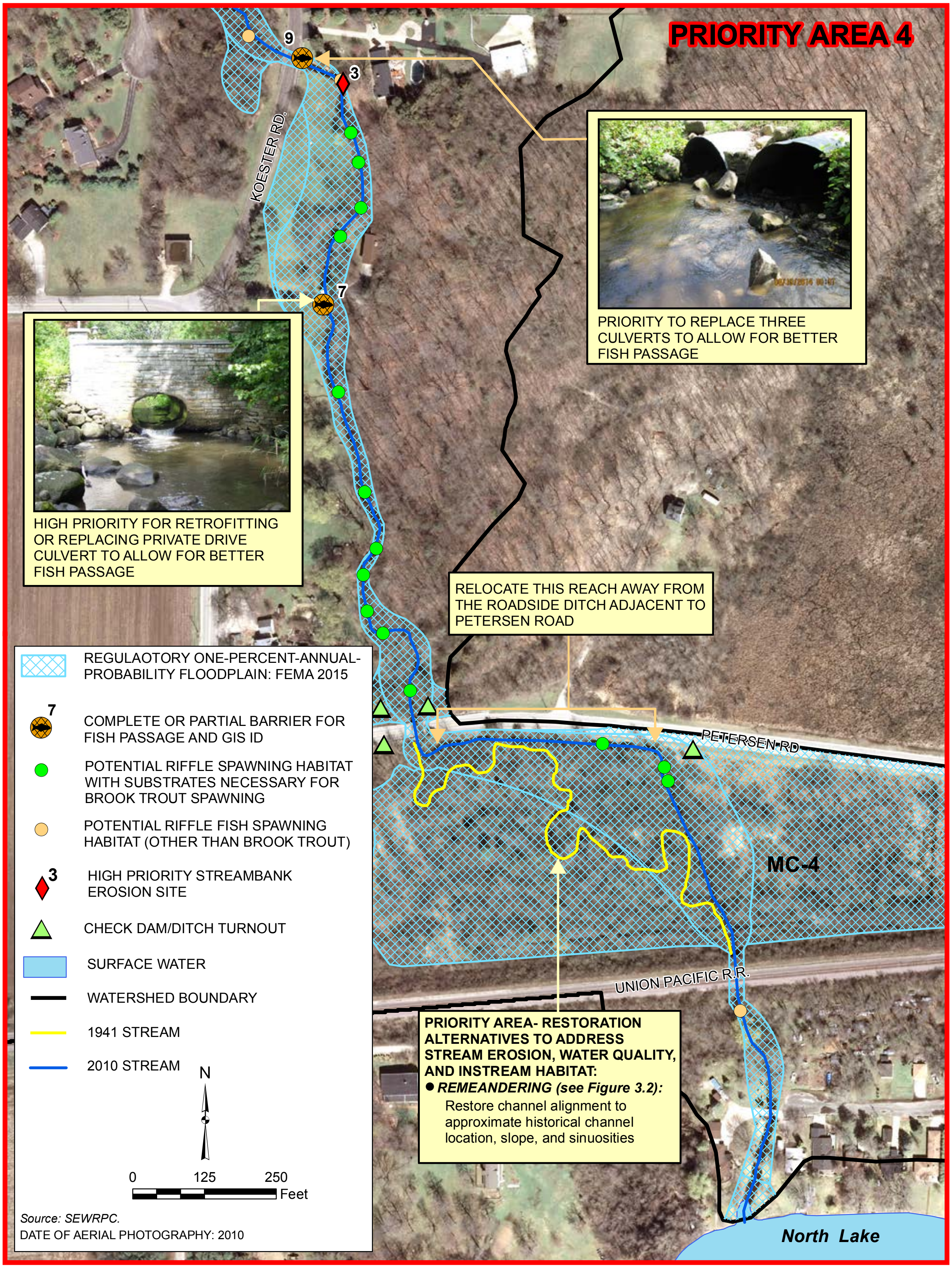
Map 3.1 (continued)



Map 3.1 (continued)



Map 3.1 (continued)



Restoration techniques in this area should focus on improving floodplain connectivity and pool-riffle structure combined with wetland restoration in an effort to capture, detain, slow down, and treat stormwater runoff; increase dry weather flow; and prevent chronic sediment and nutrient loads from entering Mason Creek. The excessive bedload sediments in this reach are recommended to be addressed by abandoning these ditched areas and reconstructing a new channel alignment (see Figure 2.39). In particular, the highest priorities or best locations to restore the historical stream alignment are where the original channel lengths that were cut off during channel straightening still exist. The bankfull width and depth dimensions discussed above and shown in Figure 2.37 should be applied as part of the stream restoration design parameters and goals for Upper Mason Creek (see also Appendix I). In addition, the historical stream channel alignment of pre-1941 conditions (see Map 3.1, Priority Areas 2 through 4) should be used to approximate the appropriate design parameters and goals for slope, sinuosity, and belt width; radius of curvature of the bends; and location and distribution of low flow pool, riffle, and run habitat dimensions.

This plan recommends a comprehensive watershed perspective for restoration that considers interactions among stressors in developing effective long-term solutions. To facilitate the assessment and development of management strategies, three zones have been identified for categorizing stressors and restoration strategies and associated management activities. In actuality, however, the zones below are broadly connected ecologically.

- The instream zone is generally the area that contains the stream's non-peak flows. Instream techniques are applied directly in the stream channel (e.g., channel reconfiguration and realignment to restore geometry, meanders, sinuosity, substrate composition, structural complexity, re-aeration, or streambank stability).

- The riparian corridor includes the stream channel and also extends some distance out from the water's edge and its extent can vary based on differences in local topography, stream bottom, soil type, water quality, ground elevation, and surrounding vegetation. Riparian techniques are applied outside of the stream channel in the riparian corridor (e.g., re-establishing vegetative canopy, increasing the width of riparian corridor, or restoring cropland to wetland and/or upland habitat).

- The upland zone consists of those areas beyond the riparian corridor within a stream's watershed that generate nonpoint source runoff to the stream and whose infiltration and topographic characteristics control stream hydrology. Upland, or surrounding watershed, techniques (e.g., agricultural and urban best management practices or BMPs) are generally related to the control of nonpoint source inputs from the watershed, including runoff characteristics from increased imperviousness of the watershed.

Stream restoration can be a mosaic of instream, riparian, and upland techniques, including BMPs, to be used in combination to eliminate or reduce the impact of stressors (both chemical and nonchemical) on aquatic ecosystems and reverse the degradation and loss of ecosystem functions. Instream restoration practices often need to be accompanied by techniques in the riparian area and/or the surrounding watershed. For example, restoration may involve rebuilding the infrastructure of a stream system (e.g., reconfiguration of channel morphology, re-establishment of riffle substrates, re-establishment of riparian vegetation, and stabilization of streambanks, accompanied by control of excess sediment and chemical loadings within the watershed) to achieve and maintain stream integrity.

Balancing and integrating instream, riparian, and surrounding watershed approaches is essential. A restoration plan could involve a combination of techniques, depending on environmental conditions and stressors to be addressed. Instream and riparian techniques directly restore the integrity of stream habitat, whereas surrounding watershed techniques focus on the elimination or mitigation of sources of stressors that cause the habitat degradation. Because techniques applied in the surrounding watershed tend to facilitate a system's ability to restore itself, instream techniques may not always be necessary. However, if instream and/or riparian techniques are selected to restore the integrity of the physical habitat, measures that eliminate or mitigate sources of stressors that caused the degradation should also be included; otherwise, the restoration effort may fail. Therefore, surrounding watershed techniques should, as a general rule, be considered prior to or in conjunction with the use of instream and riparian techniques. Because many projects need to address both causes and symptoms of stream degradation, combining instream, riparian, and surrounding watershed approaches is often appropriate and is recommended under this watershed plan for Mason Creek.

Stream Functions Pyramid - A Tool for Assessing Success of Stream Restoration Projects

The USEPA and the U.S. Fish and Wildlife Service developed a function-based framework for stream restoration goals, performance standards, and standard operating procedures.[18] The framework consists of the stream functions pyramid, a five-level, hierarchical framework that categorizes stream functions and the parameters that describe those functions as shown in Figure 3.1.

Stream restoration practitioners have long sought an adequate way to determine the success of restoration projects. Part of the problem lies in failure to link stream restoration with the restoration of stream function. For example, many restoration project goals fail to recognize the full range of stream functions and how they support each other.[19]

The difference in the pre-restoration functional condition and the post restoration functional condition is known as functional lift. The functional lift can be used to quantify the overall benefit of any proposed stream restoration project or to develop stream mitigation credits.

The stream functions pyramid provides a framework for assessing stream functions, setting design goals, and evaluating performance. The pyramid shows that restoration of functions must occur in a certain order for maximum functional lift to occur, but it is important to note that there is an iterative process among these levels over time while working towards achieving the desired goals and adjusting as necessary.

Hydrology functions create the base of the pyramid. These functions determine how much water is produced by the watershed and include measures such as the rainfall-runoff relationship and bankfull discharge determination. Hydraulic functions are shown above hydrology functions and describe the flow dynamics in the channel and floodplain where floodplain connectivity and flow dynamics are critical measures. Geomorphic functions are next and integrate the hydrology and hydraulic functions to transport sediment and create diverse bed forms.

Once this structure is in place, physiochemical functions can improve, including increased dissolved oxygen, lower stream temperature, denitrification, and organic processing. The biological functions are at the top of the pyramid because they rely on all of the other functions. The biological functions include the life cycles of fish and macroinvertebrates and riparian conditions.

The stream functions pyramid helps practitioners set goals to ensure that the design addresses the appropriate functions. Research has shown that many assessment protocols and project designs ignore the base level functions of hydrology, hydraulics, and geomorphology. Conversely, it is not always obvious or understood that land use practices or implementation of agricultural or urban BMPs are actually a form of stream restoration, which is a major component of a comprehensive approach to watershed management.

Hence, it is recommended that this hierarchical framework and associated functional lift be used to help guide project implementation in setting design goals and evaluating performance for the Mason Creek watershed. For example, as previously mentioned, two of the major goals of this watershed plan are to improve water quality by reducing phosphorus and sediment loads from adjacent land uses (i.e., functional levels 1-4) and to improve fisheries and habitat to increase the abundance and diversity of a native coldwater brook trout fishery (i.e., functional levels 1-5). In addition, the pyramid can be used to design monitoring plans that quantify functional lift by using the baseline functional capacity of the stream corridor as summarized in the sections above concerning the hydrology, hydraulics, geomorphology, physicochemical,

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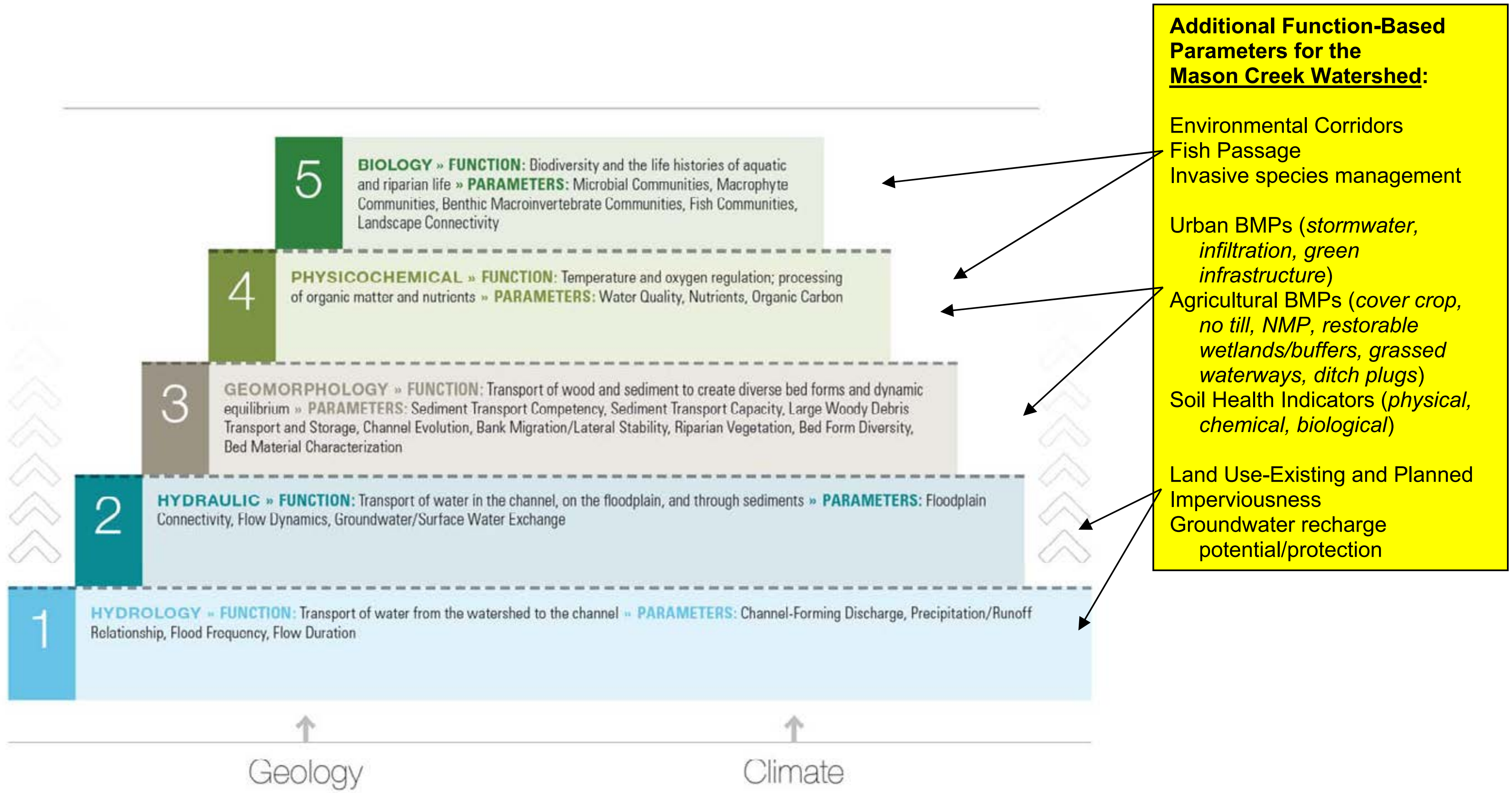
[18] *Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012.* A Function-Based Framework for Stream Assessment and Restoration Projects. *US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC EPA 843-K-12-006; Fischenich, J.C., Functional objectives for stream restoration, EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-52). Vicksburg, MS: U.S. Army Engineer Research and Development Center, 2006, www.wes.army.mil/el/emrrp*

[19] *Federal mitigation guidelines already require stream restoration practitioners to determine the functional improvement of their project.*

Figure 3.1
Schematic of Stream Functions Pyramid: A Guide for Assessing and Restoring Stream Functions and Related Parameters



Source: Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012. A Function-Based Framework for Stream Assessment and Restoration Projects. US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC EPA 843-K-12-006; Fischenich, J.C., Functional objectives for stream restoration, EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-52). Vicksburg, MS: U.S. Army Engineer Research and Development Center, 2006, www.wes.army.mil/el/emrrp; and SEWRPC..

and biological parameters and reference conditions throughout the watershed. Figure 3.1 illustrates the relationships between function-based parameters and the five levels of the functional categories and their interdependence. The design should focus on improving impaired functions, rather than just focusing on channel form (i.e., channel dimension, pattern, and profile). Monitoring can then quantify the improvement or lift in each of those functions.[20] Inherent in the achievement of these water quality and fishery goals will be a concomitant improvement in other dimensions and goals of this plan that include recreation, economic development, property values, quality of life, and aesthetics.

3.2 MANAGEMENT MEASURES IMPLEMENTATION

The Mason Creek watershed plan presents recommended management measures needed over the next 10 years to improve and/or restore the hydrologic, hydraulic, geomorphologic, physiochemical, and biological functions of this system as summarized in Table 3.1. The plan indicates 1) a timeline for when specific practices and projects, referred to as targeted management measures, should be completed; 2) estimated costs for practice and project implementation, 3) agencies responsible for implementation to meet targeted load reductions for the TMDL, and 4) general management measures to meet the goals and management objectives of this plan. This Chapter 1ncludes an information and education component to incorporate recent and ongoing watershed management programs and initiatives, information on potential funding sources, and recommendations for measuring and assessing implementation success.

Consistent with the CWA, the plan is designed to address the physical, chemical, and biological health of the watershed and its water resources. The plan recommendations are divided into four main management objectives (see Table 3.1) that include:

- To reduce the loads of sediment and phosphorus from upland sources to improve water quality and enhance and restore stream form and function
- Reduce the volume and velocity of runoff from upland areas to streams, increase soil infiltration, and protect groundwater recharge
- Maintain and expand wetland, fish, and wildlife habitats and populations
- Increase public awareness of water quality issues and participation in watershed conservation activities

These recommendations provide guidance for the management of the water resources within the watershed with respect to a variety of general and specific factors and issues that contribute to the problems related to impairing the hydrologic, hydraulic, geomorphologic, physiochemical, and biological functions of Mason Creek as detailed in Chapter 2. While the presentation of recommendations is organized according to the four main management objective sections below, the implementation of many of these recommendations will also have beneficial effects among multiple dimensions of stream function as demonstrated in Figure 3.1. Hence, it is important to keep in mind that the stream functions pyramid provides a framework to assess stream functions, set design goals, and evaluate performance. The pyramid shows that restoration of functions must occur in a certain order for maximum functional lift (improvement) to occur, and that there is an iterative process among these levels over time while working towards achieving the desired goals and adjusting management actions as necessary for the 10-year timeframe and beyond. This iterative process is described in the Information and Education and the Measuring Plan Progress and Success subsections below.

3.3 RECOMMENDED ACTIONS ASSOCIATED WITH MANAGEMENT OBJECTIVE TO REDUCE THE LOADS OF SEDIMENT AND PHOSPHORUS FROM UPLAND SOURCES TO IMPROVE WATER QUALITY AND TO ENHANCE AND RESTORE STREAM FORM AND FUNCTION

Rural nonpoint runoff is the greatest source of pollutant loads, and potential load reductions, within the Mason Creek watershed, thus, the majority of the targeted management measures are focused on

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[20] *Richard Starr, US Fish and Wildlife Service, Chesapeake Bay Field Office, see website www.fws.gov/chesapeakebay/Newsletter/Fall11/Pyramid/Pyramid.html*

cropland best management practices (BMPs) as shown in Table 3.3. Specifically, targeted cropland BMPs recommended in this watershed include use of cover crops and no till practices, increased implementation of nutrient management plans, and expansion of potentially restorable wetlands and riparian buffers. Installation of grassed waterways was also identified as having potential to reduce pollutant loads in this system. Streambank erosion sites were identified and prioritized, but not determined to be a significant source of pollutants to Mason Creek. However, one severe streambank erosion site was recommended to be addressed and other sites were recommended to be monitored and addressed if they become worse. In contrast, streambed load was found to be a significant source of sediment and impairment within Mason Creek, particularly in the West Branch Agricultural Ditch and Upper Mason Creek reaches, and addressing these problems areas would immediately improve water quality as well as enhance instream fisheries habitat and wildlife (see "Maintain and Restore Instream Habitat" section below for more details).

Existing runoff management standards have been established by the State of Wisconsin. Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* provides runoff management standards and prohibitions for agriculture. However, experience in the State has indicated that a combination of regulation and informed local decision making by landowners/operators is needed to achieve water quality improvements consistent with the attainment of water quality standards and criteria.[21] Although this plan recognizes the importance of continued funding and staff to ensure adherence to State and local standards, it goes beyond reliance on regulation and enforcement. This plan's focused strategy is to rely on empowered local decision makers crafting unique solutions that work for the Mason Creek watershed in an effort to ultimately exceed compliance standards. This strategy is designed to augment ongoing programs such as the City of Oconomowoc's Adaptive Management Program and the work of Washington County and Waukesha County staff in working with landowners and operators to implement innovative and effective conservation practices continued through collaboration amongst the County, State, and Federal agen*cies* (see Information and Education section below). Implementation of practices that promote improved nutrient management and BMPs to reduce runoff and soil loss, that promote improved soil health, and that provide and protect natural habitats for wildlife, will insure that farming will remain a viable way of life for many years to come within this watershed.

Point Source Pollution

As summarized in Chapter 2, the Town of Merton is the only designated MS4 community in the watershed. The permit requires the Town to reduce polluted stormwater runoff to meet the targeted TMDL wasteload allocations by implementing stormwater management programs with best management practices. Waukesha County is currently designated as an MS4, but there are no County facilities covered under that permit that are located within the Mason Creek watershed. Nonetheless, the Town of Merton entered into an intergovernmental agreement with the County for stormwater management planning in March 2008. The Town and County work cooperatively to create urban stormwater public education messages, and to develop and enforce construction and post-construction site pollution control ordinances.

Targeted Load Reductions

Pollution load reductions for upland BMPs, gullies, and streambanks were estimated using the USEPA Spreadsheet Tool for Estimating Pollutant Loading (STEPL) as shown in Table 3.4. Based upon the Rock River TMDL model agricultural baseline loading for Mason Creek (model Reach 24), **load reductions for the Mason Creek watershed need to meet or exceed 92 percent (5,355 lbs) for Total Phosphorus (TP) and 93 percent (883 tons) for Total Suspended Sediment (TSS) from the median annual nonpoint baseline load as shown in Table 2.4.**

Based upon prior agricultural BMPs applied to cropland, gully stabilization, and riparian buffers implemented throughout the watershed as summarized in Chapter 2, it is estimated that the Mason Creek watershed is already achieving 35 percent and 36 percent pollutant load reductions in TP and TSS, respectively, as noted in Table 3.4.

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[21] *The Minnesota Pollution Control, Wisconsin Department of Natural Resources, and The St. Croix Basin Water Resources Planning Team,* Implementation Plan for the Lake St. Croix Nutrient Total Maximum Daily Load, *prepared by LimnoTech, February 2013.*

Table 3.3
10-Year Targeted Management Measures Plan Matrix for the Mason Creek Watershed: 2015

Recommendations	Indicators	Milestones			Timeline	Funding Sources[a]	Implementation[b]
		0 to 3 Years	3 to 7 Years	7 to 10 Years			
1) **Agricultural BMPs:** Reduce the amount of sediment and phosphorus loading from agricultural fields and uplands							
a) Increase use of no till in watershed area from 50 to 75 percent (promote transition of conservation tillage to no till practices)	Number of acres cropland with conservation practice applied	124	246	124	0-10 years	EQIP, TRM, CSP, AM, NLMD	NRCS; Dodge, Washington, and Waukesha Counties; Local Partners
b) Increase use of cover crops in watershed area from 0 to 50 percent	Number of acres cropland with conservation practice applied	247	493	247	0-10 years	EQIP, TRM, CSP, AM, NLMD	NRCS; Dodge, Washington, and Waukesha Counties; Local Partners
c) Increase implementation of land under nutrient management plans from 50 to 100 percent	Number of acres cropland with conservation practice applied	247	493	247	0-10 years	EQIP, TRM, CSP, AM, NLMD	NRCS; Dodge, Washington, and Waukesha Counties; Local Partners
d) Installation of grassed waterways in priority areas	Number of linear feet of grassed waterways installed	1,098	2,196	1,098	0-10 years	EQIP, CREP, AM, NLMD	NRCS; Dodge, Washington, and Waukesha Counties; Local Partners
2) **Riparian Buffers/Wetland Restoration/Filter Strip Installation:** Convert cropped wetland back to wetland and cropped steep slopes to filter strips							
a) Installation of 75 foot wide minimum riparian buffers/harvestable buffers	Number of acres of riparian buffers installed	6	13	6	0-10 years	CREP/CRP, EQIP, AM, NLMD	NRCS; Dodge, Washington, and Waukesha Counties; Local Partners
b) Conversion of Currently Farmed Potentially Restorable Wetland Back to Wetland	Number of acres of restored wetland	51	103	51	0-10 years	CREP/CRP, EQIP, AM, NLMD	NRCS; Dodge, Washington, and Waukesha Counties; Local Partners
c) Conversion of Currently Farmed Steep Sloped Lands to Filter Strips	Number of acres of riparian buffers installed	31	63	31	0-10 years	CREP/CRP, EQIP, AM, NLMD	NRCS; Dodge, Washington, and Waukesha Counties; Local Partners
d) Document decrease in surface water runoff by evaluating soil infiltration rates on select projects above	Number of farms/agricultural landowners checked	5	7	3	0-10 years	N/A	NRCS; Washington and Waukesha Counties; Local Partners
3) **Restore and Stabilize Degraded Streambanks**							
a) Restore high priority eroded stream banks	Number of linear feet of streambank stabilized	114	0	0	0-10 years	NLMD	NRCS; Washington and Waukesha Counties; WDNR; Local Partners

Note: A combination of the listed practices will be applied to agricultural fields to get the desired reductions required by the Rock River TMDL. Not all practices listed will be applied to each field. The combinations of practices applied will vary by field. In most cases just applying one practice to a field will not get desired reductions and a combination of two to three practices will be necessary to get desired reductions.

[a] *Funding sources include Adaptive Management (AM) administered through the City of Oconomowoc Wastewater Utility, the Conservation Reserve Enhancement Program (CREP), the Conservation Reserve Program (CRP), the Environmental Quality Incentives Program (EQUIP), and North Lake Management District (NLMD).*

[b] *Local Partners include the following: Townships of Ashippun, Erin, and Merton; City of Oconomowoc Wastewater Utility; North Lake Management District; Tall Pines Conservancy; and Rock River Coalition.*

Source: NRCS and SEWRPC

Table 3.4
Estimated Load Reductions for Watershedwide Management Measures for the Mason Creek Watershed: 2015[a] (percent reduction calculated from STEPL modeling)

Management Measure Category	Total Units (size/length)	Total Cost[b] ($ dollars)	Estimated Load Reduction[a] TP (pounds per year)	Percent	TSS (tons per year)	Percent
Agricultural BMPs Applied to Cropland[c]						
No Till	494 acres	9,702	1,319	13.10	356	12.90
Cover Crops	987 acres	59,368	1,031	10.24	320	11.60
Nutrient Management Plans	987 acres	52,311	664	6.60	229	8.30
Gully Stabilization						
Grassed Waterways	4,392 feet	19,500	314	3.12	409	14.82
Riparian Buffers/Wetland Restoration/Filter Strips						
Restore 75 Foot Wide Minimum Riparian Buffers	25 acres		49	0.49	33	1.20
Restore Farmed Potentially Restorable Wetlands	205 acres	1,420,000	433	4.30	295	10.69
Convert Farmed Steep Sloped Lands to Filter Strips	125 acres		337	3.35	232	8.41
Streambank Restoration						
High Priority Site	114 feet	7,000	3.6	<0.1	5.8	0.3
Total	--	1,567,881	4,151	41	1,880	68

Note: This table only shows the pollutant reductions for Total Phosphorus (TP) and Total Suspended Sediment (TSS) as required under the Rock River TMDL, but nitrogen and BOD were also modeled as summarized in Appendix B.

[a] *Based upon past Agricultural BMPs applied to cropland, gully stabilization, and riparian buffers implemented throughout the watershed, it is estimated that the Mason Creek watershed is already achieving a 35 percent and 36 percent pollutant load reduction in Total Phosphorus (TP) and Total Suspended Sediment (TSS), respectively. Therefore, the existing load reductions combined with the proposed pollutant load reductions would achieve approximately 76 percent TP reduction and meet the TSS reduction recommended by the TMDL.*

[b] *See Table 3.8.*

[c] *In reality a combination of practices will likely be applied to the majority of the crop fields in the watershed, but it is difficult to know who or where such practices would be adopted. So, the upland practices have separate existing levels of implementation and target goals and were modelled individually. However, it is important to note that when multiple practices are installed/implemented simultaneously, they are much more effective than if they were implemented separately. Therefore, the modelled load reductions calculated within Appendix B are likely a conservative estimate of potential load reductions in this watershed, which should be kept in mind when implementing and tracking progress in this planning effort.*

Source: Washington County, Waukesha County, and SEWRPC

The load reductions anticipated through implementation of the targeted management measures recommended under this plan are estimated to be 4,151 pounds (41 percent) of TP per year and 1,880 tons (68 percent) of TSS per year (see Table 3.4). Therefore, the existing load reductions combined with the proposed pollutant load reductions in this plan would achieve approximately 76 percent TP reduction and meet the TSS reduction called for under the TMDL study for the Mason Creek watershed.

Agricultural Best Management Practices (BMPs) - (Table 3.3, Part 1)

Although it is difficult to specify at the watershed planning level where agricultural BMPs will be implemented within the Mason Creek watershed, since such specification depends on factors such as the receptiveness of landowners to such installations, the availability of adequate cost share funding, and technical assistance, this section is intended to provide some guidance for prioritizing projects. As a general rule, effectiveness of BMPs in improving water quality decreases with distance from a waterbody. **Therefore, it is recommended that the prioritization scheme as illustrated on Map 2.6 be used to guide implementation of agricultural BMPs by landowners and farmers within the Mason Creek watershed to address the highest priority or critical parcel sites for which pollutant loads can be most cost-effectively reduced.** However, it is also important to note that in order to reach the watershed-wide target load reductions, it will require implementing BMPs among high, moderate, and low priority agricultural areas throughout the watershed.

Increase No-Till from 50 to 75 Percent

Removing crop residue through tillage operations leads to soil erosion. When soil is tilled, more soil is exposed to erosive forces, leading to nutrient- and sediment-laden surface runoff. No-till farming is the practice where the soil is undisturbed except for where the seed is placed in the soil. No-till planters disturb less than 15 percent of the row width. The combination of minimal ground disturbance and minimal removal of crop residue contribute to a more stable soil surface that is less susceptible to erosion and the accompanying washoff of nonpoint source pollutants. No-till benefits are recognized in several areas.

By not turning soil over to prepare a seed bed, the soil structure of pores and channels formed throughout the soil surface layers remains intact and does not become compacted, allowing precipitation to effectively infiltrate and resulting in less surface runoff. The residue left behind after crop harvest is left to breakdown naturally, increasing the amount of organic matter in the soil. Decaying residue cycles nutrients back into the soil, decreasing reliance on fertilizers. Soil with higher organic matter generally has the capacity to absorb and hold more water, and then release it to crops during the growing season.

Some soils are better suited to no till than others. Soil warming and drying may be slower in the spring especially on poorly drained soils causing plants to germinate more slowly. Since the soil is not turned over, undesirable weeds may be harder to control and herbicide use could increase. The benefits of no-till are not realized until the practice has been in place for many consecutive years. To be effective, no-till must be done as part of a system of crop rotation, nutrient management, and integrated pest management. Managing weeds and the residue resulting from no-till requires the farmer to be committed to changing additional interdependent farming practices, and will likely require purchasing new equipment or modifying existing equipment.

Increase Cover Crops from 0 to 50 percent

The establishment of cover crops is the practice of planting grasses, legumes, forbs or other herbaceous plants for seasonal cover and conservation purposes. Common cover crops used in Wisconsin include winter hardy plants such as barley, rye and wheat. Other less common, but also effective cover crops include oats, spring wheat, hairy vetch, red clover, turnips, canola, radishes, and triticale.[22]

Cover crops can help reduce phosphorus and sediment loads by reducing erosion and improving infiltration. Cover crops grow and remain during the fallow months when corn and soybean fields would be bare. The use of cover crops for erosion control requires maintaining nearly continuous ground cover to protect the soil against raindrop impact. Having continuous plant cover increases infiltration, reduces flow and runoff across the soil surface, and binds soil particles to plant roots.

A cover crop slows the velocity of runoff from rainfall and snowmelt, reducing soil loss due to sheet and rill erosion. Decreased soil loss and runoff translates to reduced transport from farmland of nutrients, pesticides, herbicides, and harmful pathogens associated with manure that degrade the quality of surface waters, and could pose a threat to human health. Over time, a cover crop regimen will increase organic matter in the soil, leading to improvements in soil structure, stability, and increased moisture and nutrient holding capacity for plant growth.

Recent findings based on an annual cover crop survey by the U.S. Department of Agriculture (USDA) Sustainable Agriculture Research and Education program, recommend that a variety of strategies be employed to promote planting of cover crops. Education, sharing new research results, appropriate technical assistance, low-cost seed, and in some cases, financial incentives will be necessary to encourage more farmers to adopt cover crops.[23]

Increase Land Under Nutrient Management Plans from 50 to 100 percent

The goal of a nutrient management plan is to reduce excess nutrient applications to cropland and to thereby reduce nutrient runoff to lakes, streams, and groundwater. Nutrient management plans consider

[22] *See UW-Extension website for more information at fyi.uwex.edu/covercrop/*

[23] *Download USDA report at website www.sare.org/Learning-Center/From-the-Field/North-Central-SARE-From-the-Field/2015-Cover-Crop-Survey-Analysis*

the amounts and types of nutrients, and timing of nutrient application, to obtain desired yields while minimizing the risk of surface water and groundwater contamination. Plans must be prepared by a qualified planner, which may be the farmer or a certified crop adviser. Soil testing is done on each field so the farmer knows where nutrients are needed and where they are not, and also takes into account tillage and residue management practices. Plans help farmers allocate nutrients economically while also helping to ensure they are not over-applying nutrients, which could cause water quality impacts.

Install Additional Grass Waterways

A grassed waterway is used to carry runoff water from the field. Grassed waterways are constructed in natural drainage ways by grading a wide, shallow channel and planting the area in sod-forming grasses. When needed to help or keep vegetation established on sites having prolonged flows, high water tables, or seepage problems, the installation of subsurface drains, underground outlets, or other hard engineered components may be necessary. An effective grass waterway carries runoff water from the field and the grass prevents the water from forming a gulley. The vegetation may also trap some sediment washed from cropland, absorb some chemicals and nutrients in the runoff water, and provide cover for small birds and animals. Grass waterways fill with sediment over time and need to be rejuvenated by removing sediments, regrading, and planting.

A total of seven high priority gullies/concentrated flow areas (4,392 linear feet or 0.83 miles) are proposed to be addressed by installing grassed waterways in these locations as shown on Map B.3 in Appendix B. As indicated in Figure 2.29 two of the priority gullies/concentrated flow areas were stabilized while still promoting productive agricultural practices. Hence, five high priority gullies/concentrated flow areas remain. **Since several of these concentrated flow areas are roadway ditches or connected to roadway ditches, the use of check dams/ditch turnouts or some other grade control structure to temporarily impound and/or slow stormwater down and facilitate water quality improvement through infiltration, filtration, and sediment deposition is recommended (see Appendix G)**.

Initiate Assessment and Evaluation of BMPs

The 10-year targeted management measures matrix in Table 3.3 details the milestones and indicators for each practice. **It also is recommended that installed BMPs be inspected at least annually to ensure that they are functioning as designed or are not deteriorating.** In addition, as described below, the assessment of the health of the soil in fields where management recommendations are implemented will foster dialog and action applicable to multiple objectives of this plan that goes beyond only making recommendations regarding improving surface water quality.

Soil Health Indicator

Soil is made up of different sized mineral particles (sand, silt, and clay), organic matter, and numerous species of living organisms. Soil health is the capacity of soil to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation. Soil properties can change in response to management or climate impacts. Various soil properties can be measured and thus make good indicators of soil quality.

Indicators can be physical, chemical, or biological properties, processes, or characteristics of soils. One physical indicator useful for assessing soil health is the rate at which water infiltrates. The infiltration rate is the time it takes a given amount of water to enter the soil and is expressed as inches per hour. Infiltration will vary depending upon the amount of sand, silt, and clay that makes up a particular soil type. Infiltration rate is also dependent upon how intact the structure and system of pores and channels are within the soil. Soils with well-developed structure and continuous channels infiltrate water quickly and less runoff occurs. Some management practices such as no-till and the use of cover crops, increase organic matter and have a positive effect on soil quality and infiltration rates. No-till also improves soil health by minimizing compaction and breaking of soil pores and channels. This in turn increases the amount of water that soils can absorb. Other management practices, such as tilling the soil when wet, adversely affect soil quality by increasing compaction. Sufficient water must infiltrate the soil profile for optimum crop production. Water that infiltrates through porous soils recharges groundwater aquifers and helps to sustain the baseflow in streams.

It is recommended that, as part of the implementation plan, soil health be monitored on properties where agricultural BMPs are implemented by using the physical, chemical, and/or biological indicators of soil health as summarized in Appendix E. For example, documenting that water infiltration rates improve over time, or is sustained at rates indicating healthy soil structure, will validate the continued use of the particular BMPs.

Convert 6.4 Percent of the Watershed Area to Riparian Buffers/ Restored Wetland/Filter Strip (Table 3.3, Part 2)

The few existing wetlands in the watershed are found along the main stem of the Creek. The predominant hydric soils in the watershed are very productive when the water table is lowered. The water table has been lowered by tile systems that are installed below the ground surface for the purpose of draining water from the soils and conveying it to Mason Creek or a tributary to the Creek, although the exact extent and distribution of tile systems is unknown.

As summarized in Chapter 1 of this report, the pre-settlement wetlands in the Mason Creek watershed likely contained prairie elements, particularly wetlands that were not seasonally inundated for prolonged periods (see restoration Appendix D). Areas in permanent vegetation, some wetlands, and native grassland habitats in particular, also infiltrate water and reduce polluted runoff. Restoration of wetland and associated upland prairie habitats, particularly within the 1,000-foot optimal wildlife habitat riparian buffer zone, is an important recommendation to achieve the water quality and wildlife goals of this plan. Wetland restoration can be done by disabling drain tile, installing water control structures, and establishing embankments to settle out sediment and associated nutrient loads.

Restoring wetlands will increase the diversity of native plants, provide wildlife habitat for species of concern, and improve both the biological and hydrological connectivity of the watershed, which is further described in the "Protect and Expand Riparian Buffers" section below.

However, implementing restoration of wetlands will be difficult since it involves taking agricultural land out of production (see "Riparian Corridor Conditions" section in Chapter 2 of this report). More specifically, **it is recommended to restore a total of 345 acres of wetland/riparian buffers/filter strips (25 acres within the 75-foot wide zone adjacent to the stream, 205 acres of currently farmed potentially restorable wetlands back to wetland, and 125 acres of currently farmed steep sloped lands to filter strips) along Mason Creek and its associated tributaries (as shown on Map B.2 in Appendix B) to help meet the pollutant load reduction goals for this watershed.**[24]

Harvestable Buffers

Although converting cropland to restored wetland within 1,000 feet of a waterway is considered a high priority, expansion of riparian buffers to a minimum width of 75 feet on each side adjacent to all waterways as shown on Map B.2 in Appendix B is considered the highest priority in terms of pollutant load reduction in the Mason Creek watershed. In addition, 75-foot-wide riparian buffers are envisioned to be harvestable, so that farmers can periodically harvest the grasses to feed livestock. Expansions of restored wetland/ riparian buffers to the 400 and 1,000 foot widths are most likely to be located where crop yield losses have been found to be greatest, such as in fields with steep slopes or high erosion scores or fields within the one-percent-annual-probability (100-year recurrence interval) floodplain. As described in Chapter 2, crop yield losses have been found to be greatest along the edges of drainage ditches that tend to get flooded. Therefore, converting such marginal, relatively low-yield cropland to a buffer may not necessarily reduce overall yields as summarized in the "Best Management Practices/Programs for Riparian Buffers" section in Chapter 2 of this report. In addition, restoration of wetlands within riparian buffers out to the 400- and 1,000-foot widths is most likely to be achievable when agricultural land is converted to urban uses. Such fields where this is planned to occur are shown on Map 1.6 in Chapter 1 of this report. The plan implementation period will likely be the last opportunity to establish such critical protective boundaries around waterways before urban structures and roadway networks are constructed (see the "Maintain and Expand Wetland, Fish, and Wildlife Habitat" section below for more details).

[24] *Note that the targeted total acreage indicated in Tables 3.3 and 3.4 can be reduced, due to the recent ten acres of cropland that was converted to approximately five acres of riparian buffer and five acres of potentially restorable wetland as summarized in Figure 2.29.*

Restore and Stabilize Degraded Streambanks (Table 3.3, Part 3)

The survey conducted by SEWRPC staff assessed erosion sites based on bank slope, length, and height of active erosion at each site. To rank priority streambank stabilization sites, the SEWRPC staff estimated the annual load of sediment contributed to the Creek by each site. Results of these surveys are summarized in Figure 2.22 in Chapter 2 of this report and shown on Map B.3 in Appendix B. All the erosion sites and their associated severity are detailed in the "STEPL Load Reduction Results for Streambank Restoration Practices" section in Appendix B.

The estimated costs for recommended streambank stabilization projects within the Mason Creek watershed are set forth in Table 3.4. The costs were estimated based on an assumed typical stabilization approach and they include mobilization, regrading and revegetating banks, and rock toe stabilization (see the constructed project shown in Figure 2.31). In the case of that project, preliminary plan, profile, and cross section details were provided by SEWRPC staff. Additional costs of permitting, inspection, and other contingency costs were not included. **Note that revegetation of the banks using bioengineering techniques and expansion of the vegetative buffer slopes was an important component of the stabilization of this streambank and revegetation, which also provides wildlife habitat. The project shown in Figure 2.31, can be used as a demonstration project for future projects in this watershed.**

Based on the results of the surveys conducted within the Mason Creek watershed, this plan makes the following recommendations regarding streambank erosion:

1. Since the highest priority eroding site was recently addressed (see Figure 2.31), it is recommended that the remaining 27 low priority erosion sites totaling approximately 2,055 lineal feet as identified on Map B.2 in Appendix B be monitored and addressed if they become worse or more severe.

2. That the design and implementation of the streambank stabilization projects ensure that the stream is reconnected to its floodplain when practicable, and that consideration be given to restoring stream reaches to their historical channel alignment prior to channelization (see "Streambank Erosion and Restoration Priorities" section below).[25]

3.4 RECOMMENDED ACTIONS TO REDUCE THE VOLUME AND VELOCITY OF RUNOFF FROM UPLAND AREAS TO STREAMS, INCREASE SOIL INFILTRATION, AND PROTECT GROUNDWATER RECHARGE

> In some cases, load reductions and/or specific targeted goals associated with recommendations within this section have been addressed under management measures described above (e.g., riparian buffers). In other cases, load reduction goals were either not quantified due to them being outside the scope of this project (e.g., green infrastructure projects) or not lending themselves to quantification (e.g., protection of groundwater recharge areas). However, implementation of those recommendations would lead to pollutant load reductions beyond what was modeled and will be vital to the long-term protection of Mason Creek within the 10-year timeframe and beyond. Implementation of these recommendations would contribute to improving the hydrologic, hydraulic, geomorphology, physiochemical, and biological functions of this stream system to achieve the water quality (Tables 2.1 though 2.6), biological quality (Tables 2.9 and 2.11), and habitat quality (Table 2.16) criteria and/or targets for the Mason Creek watershed.

Agricultural and, to a lesser extent, urban development have brought significant changes to the landscape and have produced profound effects on the surface water hydrology within the Mason Creek watershed. These landscape changes historically have included modification of the drainage patterns, hardening of surfaces, alteration of groundwater infiltration within urbanized areas, straightening and ditching of streams, and installation of drain tile systems in agricultural areas. These changes to the landscape generally

[25] *If restoration of floodplain connectivity and/or addressing channelization were incorporated into the pollutant reduction estimates for the severe and moderate eroding streambank sites within the Mason Creek watershed, the pollutant load reductions would be significantly higher than what was modeled using STEPL.*

act to increase the volume and rate of runoff from precipitation events, leading to flashiness in stream flow. This flashiness reduces streambank and streambed stability, increases pollutant loading, and changes the sediment dynamics within the stream system. These changes in turn reduce the availability of habitat and degrade its quality.

The objective of the recommendations set forth below is to promote restoration of the hydrologic and hydraulic function of Mason Creek and its associated watershed so that stream discharges more closely emulate the levels that are thought to have occurred prior to agricultural or urban development. Specifically, decreases in average flow magnitude, high flow magnitude, high flow frequency, and/or high flow duration are sought to provide potential improvements to the algal, invertebrate, and fish communities within the Mason Creek watershed.

Agricultural Surface Water Hydrology

Drain tiles have been installed within agricultural lands to clear fields of rainwater as rapidly as possible and keep them productive. Most stream channels located in agricultural areas of the watershed have been deepened and straightened to facilitate the flow of water from agricultural subsurface drainage outlets, to maximize conveyance of agricultural drain water, to maximize the amount of land available for cultivation, and to make the land easier to cultivate. The following recommendations are intended to mitigate the impacts of channelization and installation of drain tile on the surface water hydrology:

1. **It is recommended that natural surface hydrology be restored by reducing, to the extent feasible, unnecessary drain tile systems and retrofitting needed systems.** Specific measures that can be taken to accomplish this recommendation include:

    - Working with landowners to remove or disconnect any unneeded or unwanted tile systems (see Map 3.1, Priority Area 1).

    - Working with landowners to integrate water control structures within drain tile systems to reduce tile flow during periods when a higher water table would not present a problem for crop production. (See **"***General Rural Nonpoint Source Pollution Control Measures*" section below for information on drainage water management.)

1. **It is recommended that natural landscape elements be restored to slow down water and reduce flashiness and its negative effects on aquatic habitat quality.** Specific measures that can be taken to accomplish this recommendation include:

    - Improving the connectivity of Mason Creek to its floodplain, improving instream habitat, and reducing streambed erosion within the following priority reaches:

        - **West Branch Agricultural Ditch-Install a series of ditch plugs to promote wetland restoration and prevent bedload sediment transport (see Appendix H, and Map 3.1, Priority Area 1), and install series of check dams/ditch turnouts within gullies/ concentrated flow areas/roadside ditches to capture sediment and reduce water velocities (see Appendix G, Map 3.1, Priority Area 1).**

        - **Upper Mason Creek-Reconnect and/or reconstruct historical stream channels (i.e., remeandering) to promote wetland restoration, reduce water velocities, and prevent bedload sediment transport (see Map 3.1, Priority Area 2).**

    - Considering expanding buffers to include areas of high and very high groundwater recharge potential.

    - Considering installing saturated buffers in agricultural areas of the watershed, where feasible (See "Saturated Buffers" below for more information).

General Rural Nonpoint Source Pollution Control Measures

Nonpoint source pollution contributed by rural stormwater runoff constitutes the major source of water pollution in the Mason Creek watershed. Therefore, in addition to the targeted management measures summarized above, the following additional strategies are also recommended.

1. **Continue to support the ongoing Farmer Leadership Group established as part of the Oconomowoc Watershed Protection Program (OWPP) and Adaptive Management Programs administered through the City of Oconomowoc, and expand this collaborative model of water quality improvement through farmer engagement among the priority parcel areas in the Mason Creek watershed (see Map 2.6).**[26] This program should be designed to improve water quality in Mason Creek through reduced pollutant loads; to increase knowledge about, and engagement with, water quality issues, including the adoption of conservation practices; and to develop leadership around water quality issues among farmers in the watershed.

2. **That implementation of the agricultural BMPs summarized above (see "Targeted Load Reductions" section above) be a higher priority on agricultural fields that are located in areas of high and very high groundwater recharge** (see Map 1.9).

3. **That the application of practices to reduce soil loss from cropland be expanded to attain erosion rates less than "T," the tolerable soil loss rate.**[27] This is envisioned to be accomplished through a combination of practices including, but not limited to, expanded no till, grassed waterways, use of cover crops, and riparian buffers (see targeted management measures in Table 3.3 and 3.4). The applicable measures should be determined by the development of farm management plans which are consistent with the County land and water resource management plans.

4. **That nutrient management plans be prepared for all agricultural operations in the watershed that do not currently have them, and that manure and other nutrients be applied to fields in accordance with nutrient management plans** (see targeted management measures in Table 3.3 and 3.4). **The provision of barnyard runoff control systems and six months of manure storage are also recommended for all livestock operations in the watershed as well as maintaining exclusion of livestock from waterbodies and adjacent riparian areas.** To facilitate this, **it is recommended that the WDNR consider increasing levels of cost-share funding to enable a higher level of implementation of the best management practices needed to meet the NR 151 performance standards.**

5. **That pilot projects be conducted under field conditions in the watershed to evaluate the performance of two potential strategies for treating tile drainage—drain water management and saturated buffers. Those pilot projects would help determine whether these practices would be useful in reducing contributions of pollutants, especially nutrients, from agricultural fields with tile drainage.**

   Because of the nature of the soils present in portions of the watershed, much of the agricultural land is artificially drained through the use of subsurface drain tile. These tiles often discharge directly into streams, or into ditches that discharge into streams. Because they provide a direct pathway from fields to surface waterbodies, drain tiles can allow water and pollutants to bypass agricultural BMPs, especially riparian buffers, reducing their effectiveness. Research conducted at the University of Wisconsin Discovery Farms illustrates this bypass effect.[28] In fields with intact drain tile, between 15 to 34 percent of the total phosphorus, 78 to 87 percent of the nitrogen, and about 25 percent of the

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[26] *City Of Oconomowoc,* Oconomowoc Watershed Protection Program, Waukesha County, Wisconsin, *prepared by Ruekert & Mielke, Inc., February 2016; see more details at website at oconomowocwatershed.com/*

[27] *"T-value" is the tolerable soil loss rate—the maximum level of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely, as determined by the U.S. Natural Resource Conservation Service. "Excessive" cropland erosion refers to erosion in excess of the tolerable rate, or T-value.*

[28] *Eric Cooley, "Nutrients Discharging from Drain Tiles in Eastern Wisconsin," Presentation at the Eighth Annual Clean Rivers, Clean Lake Conference, Milwaukee, Wisconsin, April 30, 2012.*

sediment leaving the field moved through the drain tile system. In fields with damaged drain tile (i.e., tile blow outs), about 65 percent of the total phosphorus and the majority of sediment leaving the fields traveled through drain tile. These results show that drain tiles can constitute a major pathway through which sediment and nutrients travel from agricultural fields to surface waters.

Because the performance of drainage water management and saturated buffers with respect to removing phosphorus and with respect to the types of conditions present within the Mason Creek watershed are not well understood, it would be desirable to conduct pilot projects in the watershed under which these practices could be installed and their performance evaluated. County conservation staff could use the results of such pilot projects to devise strategies for addressing the "bypassing effect" of drain tiles for each of these practices as summarized below.

a. Drainage water management is the practice of using a water control structure in a main, submain, or lateral drain to vary the depth of water at the drain outlet. When this is done, the water table must rise above the invert elevation of the outlet for drainage to occur. This allows the minimum depth of the water table under the field to be controlled to reduce flow from the tile during periods when a higher water table would not present a problem for crop production. For example, for a field managed using a corn-soybean rotation, the outlet water depth, as determined by the control structure, would be:

    - Raised after harvest to limit drainage outflow and reduce the delivery of nutrients to ditches and streams during the off-season

    - Lowered in early spring and again in the fall so the drain can flow freely before field operations such as planting or harvesting

    - Raised again after planting and spring field operations to create the potential to store water for the crop to use during the summer

    Drainage water management can reduce nutrient loads to receiving streams. Studies have found reductions in annual nitrate loads ranging between 15 percent and 75 percent, depending upon location, climate, soil type, and cropping practice.[29] Few data are available regarding the performance of this practice with respect to phosphorus.

b. Saturated buffers, unlike ordinary riparian buffers, capture and treat water from tile drainage. A saturated buffer has a control structure that redirects flow from a main tile line through a lateral distribution line into the buffer. Once within the buffer soils, the water redirected from the tile percolates deeper into the soil or gets taken up by vegetation. In its study at Bear Creek in Iowa, the Leopold Center for Sustainable Agriculture at Iowa State University found that the use of a saturated buffer reduced annual nitrate loads by about 55 percent. While no data have yet been collected regarding the performance of saturated buffers with respect to phosphorus, it would be expected that uptake by plants growing within the buffers would reduce the amount of phosphorus contributed to streams.

Urban Surface Water Hydrology

Historically, the approach to managing increases in rates and volumes of runoff within urbanized areas often involved the construction of storm sewer and/or open channel systems to convey stormwater to streams as quickly and efficiently as possible. In recent years, flooding, water quality impairment, and environmental degradation have demonstrated the need for an alternative approach to urban stormwater management. Consequently, current approaches to stormwater management seek to manage runoff using a variety of measures, including detention, retention, infiltration, and filtration, better mimicking the disposition of precipitation on an undisturbed landscape.

[29] *University Cooperative Extension Service Publication No. WQ-44, August, 2006.*

1. **It is recommended that natural surface hydrology be restored to the degree practicable by reducing impervious cover and associated runoff in urbanized areas.** Specific measures that can be taken to accomplish this recommendation include:

    - In addition to implementing the recommendations described in the "Protect Areas of High Groundwater Recharge Potential" section below, it is recommended that new urban development be accomplished to minimize impacts on areas of high groundwater recharge potential and that infiltration practices be installed in cases where development affecting areas of high groundwater recharge potential cannot reasonably be avoided or in areas where development already exists. If new urban development is to take place in areas of high recharge potential, it is recommended that this development incorporate green technologies designed to maintain infiltration functions consistent with high groundwater recharge potential.

2. **It is recommended that natural landscape elements be restored to "slow down water" and reduce the magnitude of flashiness in streamflow and its negative effects on aquatic habitat quality.** Specific measures that can be taken to accomplish this recommendation include:

    - **It is recommended that riparian buffers and environmental corridors be established, expanded, or protected from development[30] to allow the capture of significant rainfall (see Map B.2 in Appendix B).** As noted in Chapter 2, when impervious surfaces increase, there are often negative changes to streams. If steps are not taken to mitigate these negative effects, Mason Creek will lose biological integrity with continued urban growth over time.

    - **The use of green infrastructure to manage stormwater in the Mason Creek watershed is recommended.** The USEPA defines green infrastructure as follows (see www.epa.gov/green-infrastructure/what-green-infrastructure):

      "Green infrastructure uses vegetation, soils, and other elements and practices to restore some of the natural processes required to manage water and create healthier urban environments. At the city or county scale, green infrastructure is a patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the neighborhood or site scale, stormwater management systems that mimic nature soak up and store water. ...an approach to wet weather management that is cost-effective, sustainable, and environmentally friendly. Green infrastructure management approaches and technologies infiltrate, evapotranspire, capture, and reuse stormwater to maintain or restore natural hydrologies."[31] This is an approach that helps infiltrate and store rainwater in more natural ways. Green infrastructure complements the gray infrastructure, such as sanitary sewer pipes, storm sewers, and water reclamation facilities that have been, and will continue to be, the backbone for meeting water quality and stormwater management goals. While green infrastructure cannot entirely replace the capacity of gray infrastructure in urban areas, it can improve water quality through treatment of stormwater runoff and reduce the volume of stormwater runoff to Mason Creek during small storms.

    - **It is recommended that the counties and municipalities in the Mason Creek watershed review their municipal codes to identify barriers to the implementation of green infrastructure practices within their jurisdictions.** Municipal codes and ordinances have a broad impact on the use of green infrastructure. Depending on their specifics, they can provide incentives for, or present barriers to, the implementation of green infrastructure by the private and public sectors. Modifications to local codes, ordinances, and review processes can

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[30] *Restrictions on development in primary environmental corridors, and certain secondary environmental corridors, are already applied throughout the Southeastern Wisconsin Region under the sanitary sewer service area planning process conducted by the Regional Planning Commission in its role as the designated areawide water quality planning agency for the Region. However, the Mason Creek watershed lies outside of a sanitary sewer service area. Thus, urban development in the watershed would be subject to municipal and/or County review, but, at present, not to review through the sewer service area planning process.*

[31] *U.S. Environmental Protection Agency,* Reducing Stormwater Costs through Low Impact Development Strategies and Practices, *2007.*

encourage municipalities, builders, and developers as well as property owners to implement green infrastructure practices.

- **It is recommended that developers be encouraged to incorporate infiltration in stormwater management designs and that local government consider groundwater recharge as an integral part of new development proposals.** Some Southeastern Wisconsin communities have integrated analysis of groundwater and surface water impact into the process through which developers obtain permission to build new buildings and subdivisions.[32]

Urban Stormwater Runoff Pollution Control Measures

Although rural nonpoint source loads are currently substantially greater than urban nonpoint source loads in the watershed, a review of planned land use conditions indicates that urban loads would be expected to increase. Therefore, addressing urban stormwater runoff is an important element that needs to be included in this plan. The following recommendations are targeted at reducing the contributions of pollutants from these sources through a variety of strategies:

1. **It is recommended that urban nonpoint source controls be implemented that are consistent with the standards set forth in Chapter NR 151 of the *Wisconsin Administrative Code*.** By implementing controls to meet or exceed the standards of Chapter NR 151, municipalities will address the control of construction site erosion; the control of stormwater pollution from areas of existing and planned urban development, redevelopment, and infill; and infiltration of stormwater runoff from areas of new development.

2. **It is recommended that the Town of Merton design its illicit discharge detection and elimination (IDDE) program developed under the MS4 permit to monitor outfalls to reduce pathogens and fecal indicator bacteria.**

3. **It is recommended that Waukesha County continue to work closely with the Town of Merton in the development of its permit, information and education program, and stormwater infrastructure mapping.**

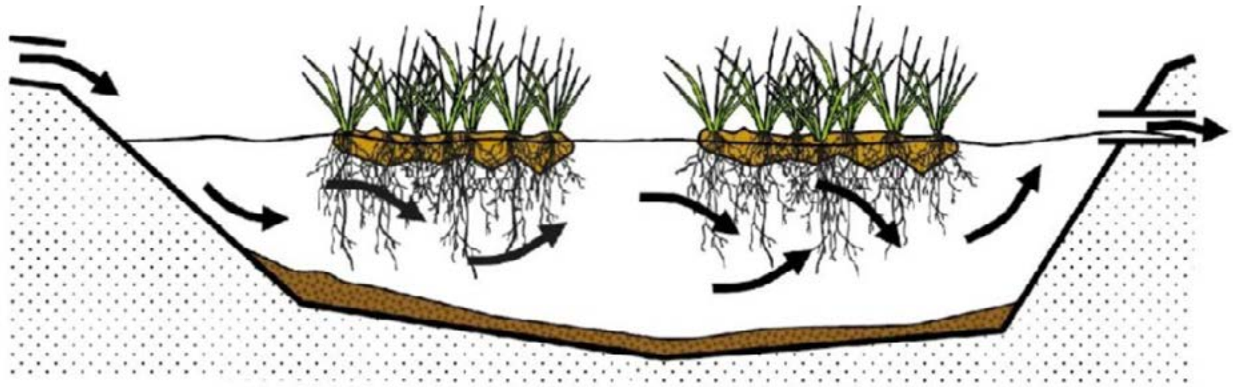
   - **It is recommended that the Town of Merton and Waukesha County develop a standard digital format, labeling, and coordinate system for mapping stormwater infrastructure** to establish a model format that can be applied by other municipalities in the future, enabling inventories among municipalities to be readily compared and merged at the scale of watersheds.

   - **It is recommended that consideration be given to installing floating islands or floating treatment wetland technologies in existing and/or planned wet stormwater detention basins or stormwater wetlands**, where applicable, as shown in Figure 3.2, to reduce nutrient and other pollutant loads to Mason Creek.

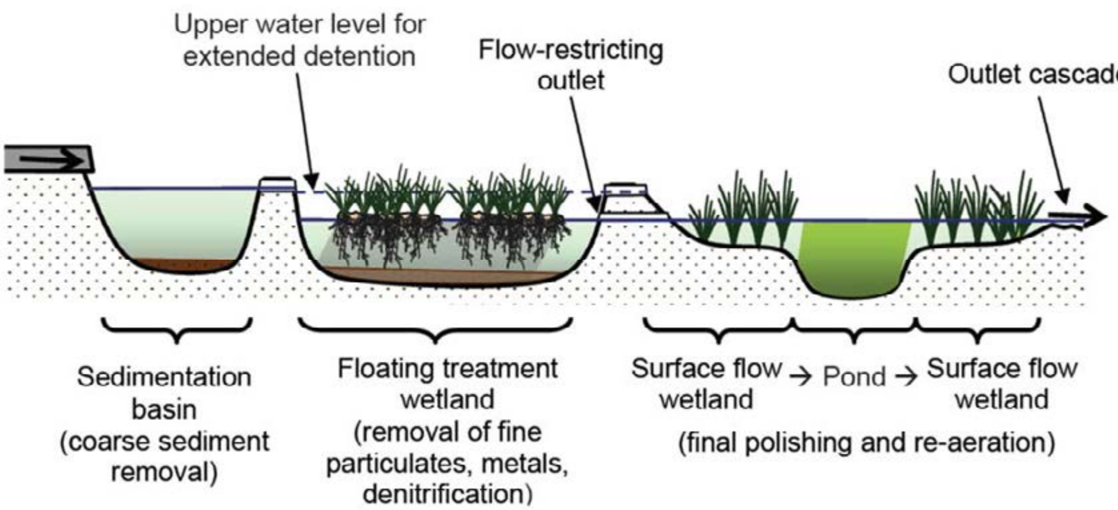
4. **It is recommended that, at a minimum, County-enforced inspection and maintenance programs be implemented for all new or replacement private onsite wastewater treatment systems (POWTS) constructed after the date on which the County adopted private sewage system programs, that voluntary County programs be instituted to inventory and inspect POWTS that were constructed prior to the dates on which the County adopted private sewage system programs, and that the WDNR and the County work together to strengthen oversight and enforcement of regulations for disposal of septage and to increase funding to adequately staff and implement such programs.** Regulations regarding POWTS set forth by the Wisconsin Department of Safety and Professional Services in Section SPS 383.255 of the *Wisconsin Administrative Code* mandate an expansion of county and municipal POWTS programs. Under the current rules, units of government are required to complete inventories of POWTS in their jurisdictions by October 1, 2017, and have the other elements of the program in place by October 1, 2019. Thus, **it is recommended that the county and municipalities in the watershed implement expanded POWTS programs in accordance with the deadlines given in SPS 383.255**.

[32] *The Village of Richfield in Washington County is such an example. More information may be found at the Village's website: www.richfieldwi.gov/index.aspx?NID=300*

Figure 3.2
Schematic of Floating Treatment Wetland (FTW) Design Applications



Emergent plants are grown within a floating artificially constructed material within a wet detention stormwater basin. The roots are directly in contact with the water column and can intercept suspended particles. The roots also provide a high surface area for microbiological activity that aid in adsorbing pollutants



Conceptual longitudinal cross-section through a "newly designed" stormwater treatment system incorporating floating wetlands, ponds, and surface flow wetlands (not to scale).

Source: *Ian Dodkins; Anouska Mendzil; and Leela O'Dea, Floating Treatment Wetlands (FTWs) in Water Treatment: Treatment efficiency and potential benefits of activated carbon, Prepared for: FROG Environmental Ltd, March 2014;* Headley, T.R. and C.C. Tanner, Constructed Wetlands With Floating Emergent Macrophytes: An Innovative Stormwater Treatment Technology, Critical Reviews in Environmental Science and Technology, 42:2261–2310, 2012.

5. **Should any CAFOs be established within the watershed, it is recommended that nutrient management requirements for such operations be based upon the conditions given in their WPDES permits.**

Protect Areas of High Groundwater Recharge Potential

Groundwater recharge within the Mason Creek watershed supplies water to the shallow aquifers, which, in turn, provide the baseflow to the Creek and its tributaries. Baseflow is essential to maintaining the natural hydrology, instream habitat, and the overall health of the Creek, particularly during the droughts and low flow periods which may occur more frequently as climate change occurs. Thus, the maintenance and improvement of groundwater recharge is a crucial part of any plan that hopes to maintain or improve water quality and instream habitat conditions within the watershed.

Traditional urban development increases the area of impervious surfaces which, in the absence of green infrastructure or other land development measures to promote infiltration of runoff, reduces infiltration volumes into the shallow aquifer. This reduction in infiltration reduces the baseflows provided by the shallow groundwater system. This loss of baseflow can lead to substantial loss in stream depth and volume, increased water temperatures, loss of critical fish and other aquatic organism habitat, increased potential for summer fish kills caused by low dissolved oxygen concentrations, and loss or degradation of the coldwater fishery. The 2035 planned land use data presented in Chapter 1 of this report show that some planned land use changes are located in areas that have been identified as having high and very high groundwater recharge potential (see Maps I 6 and I 9 in Chapter 1 of this report). Maintaining the groundwater recharge provided by these areas is important to preserve baseflows to the surface water system of the watershed.

1. **Specific recommended management measures to protect groundwater recharge potential include:**

   - During local government consideration of new development plans, examine the regional groundwater recharge potential maps[33] to identify and, where practicable, avoid installing impervious surfaces in areas of high and very high groundwater recharge potential areas and during the siting, design, and installation of sewers, water lines, and other buried utilities which could intercept groundwater flows.;

   - Protection and preservation of areas classified as high and very high groundwater recharge through conservation easements, land purchases, or voluntary incentive-based measures. Such protection should also incorporate preservation of environmental corridors, isolated natural resource areas, prime and other agricultural areas, and open lands that are associated with cluster, or open space, developments that facilitate groundwater recharge;

   It is recognized that in some cases, it will not be possible to avoid locating urban development on or near areas of high groundwater recharge. In these cases, it is even more crucial to implement supplemental measures to maintain both groundwater levels and groundwater quality.

2. **It is recommended that mitigation measures be implemented to reduce the impacts of any future urban development on groundwater recharge quality and quantity.** Specific measures that can be taken to accomplish this recommendation include:

   - Reviewing and updating as necessary, local and county land use regulations to promote where appropriate, cluster, or open space, development practices that provide for the clustering of new development so as to minimize potential reductions in groundwater recharge.

   - **Maintaining infiltration and recharge rates as close to existing rates as practicable by incorporating runoff management recommendations for enhancing infiltration using low-impact design standards in accordance with the regional water supply plan.** Some examples of infiltration techniques and low-impact design include:

     - Bioretention cells
     - Elimination of curb and gutter street cross sections
     - Grassed swales
     - Green parking design
     - Infiltration trenches
     - Permeable pavement
     - Rain barrels and cisterns
     - Rain gardens

[33] *SEWRPC Planning Report No. 52,* A Regional Water Supply Plan for Southeastern Wisconsin, *December 2010.*

- Riparian buffers
- Sand and organic filters
- Soil amendments
- Tree boxes
- Vegetated filter strips
- Vegetated roofs

Under current conditions, the extent of urban development within the Mason Creek watershed is potentially sufficient to negatively affect the groundwater quantity and quality in shallow aquifers, and in turn water quantity and water quality within Mason Creek and its tributaries. Implementing projects that seek to restore the natural precipitation infiltration characteristics have the potential to mitigate these effects.

3. **It is recommended that measures be taken to reduce the impact of existing urban development on groundwater recharge and groundwater quality.** Specific measures that can be taken to accomplish this recommendation include:

    - Increasing the infiltration of urban runoff at those sites where it can be achieved without degrading groundwater quality; Retrofitting current urban development to improve infiltration of rainfall and snowmelt using innovative BMPs that are associated with low-impact development including bioretention and rain garden projects,[34] disconnection of downspouts from sewer systems, installation of porous pavement, and other green infrastructure practices, as recommended above (also see the information on green infrastructure provided in the preceding "Urban Surface Water Hydrology" section); and

    - Applying the stormwater management technical standards developed by the WDNR in the design of stormwater management facilities. In particular, the potential for pollutants to enter groundwater through infiltration should be considered in the design of infiltration facilities such as, infiltration trenches, infiltration basins, bioretention facilities, rain gardens, grassed swales, and stormwater detention basins. This consideration is especially important in areas with shallow depths to groundwater and in areas where chloride compounds may be used for winter road and parking area maintenance.

      Although infiltration into soils provides some level of pollution reduction, shallow aquifers can be vulnerable to pollution. Within the Mason Creek watershed, there are specific areas associated with particular land uses that could potentially contribute pollutants to groundwater. These areas include agricultural fields and areas of urban land use located in high groundwater recharge areas which could act as sources of pollution due to over-fertilization and pesticide use. Pollutants contributed by these areas can infiltrate into groundwater during rain events. This pollution needs to be prevented to the greatest extent practicable to avoid contaminating the groundwater and the baseflow of Mason Creek and its tributaries. It also is important that nutrient and chemical applications not occur during periods when groundwater levels are known to be high.

[34] *Roger Bannerman, WDNR and partners; Menasha Biofiltration Retention Research Project, Middleton, WI, 2008; N.J. LeFevre, J.D. Davidson, and G.L. Oberts,* Bioretention of Simulated Snowmelt: Cold Climate Performance and Design Criteria, *Water Environment Research Foundation (WERF), 2008; William R. Selbig and Nicholas Balster,* Evaluation of Turf Grass and Prairie Vegetated Rain Gardens in a Clay and Sand Soil: Madison, Wisconsin, Water Years 2004-2008, *In cooperation with the City of Madison and Wisconsin Department of Natural Resources, USGS Scientific Investigations Report, in draft.*

3.5 RECOMMENDED ACTIONS ASSOCIATED WITH MANAGEMENT OBJECTIVE TO MAINTAIN AND EXPAND WETLAND, FISH, AND WILDLIFE HABITATS

Implementation of plan recommendations related to habitat would lead to further pollutant load reductions beyond what was modeled under this study and will be vital to the long-term protection of Mason Creek within the 10-year plan timeframe and beyond. Implementation of these recommendations would contribute to improving the hydrologic, hydraulic, geomorphology, physiochemical, and biological functions of this stream system to achieve the water quality (Table 2.1 though 2.6), biological quality (Tables 2.9 and 2.11), and habitat quality (Table 2.16) criteria and/or targets for the Mason Creek watershed.

The presence of healthy wildlife communities, including populations of animals such as deer, fish, amphibians, reptiles, birds, and small mammals, is a significant indicator of a healthy watershed. This is largely because wildlife populations require large, well-connected natural areas, which are associated with good water quality and good aquatic and terrestrial habitat. The presence of healthy wildlife populations provides recreational opportunities, such as bird watching, hunting, fishing, and nature hiking.

Maintain and Improve Wildlife Habitat

The environmental corridors and isolated natural resource areas (Map 1.7), as well as the Mason Creek Swamp designated natural area (Map 1.8) contain the most pristine lands in the watershed. These areas are crucial to wildlife maintenance and enhancement due to their continuity, size, and proximity to Mason Creek and its associated tributaries. Maps 2.9 and 2.10 indicate the extent and distribution of existing and potential riparian buffers and their relationship with the location of primary environmental corridor and isolated natural resource areas within the Mason Creek watershed. Map 3.2 is provided to guide wildlife enhancement activities toward protecting, enhancing, and connecting these resources. It also indicates the existing and potential buffer areas in the watershed, which are identified to provide guidance as to where buffer development and land purchase and easements should be focused when attempting to enhance wildlife. As summarized above within the "Targeted Load Reductions" section, increasing the amount of riparian buffers/restored wetland by 6.4 percent to meet pollutant load reductions within the priority areas as shown in Map B.2 in Appendix B will also help to achieve significant improvements to fish and wildlife habitat within the Mason Creek watershed. This would double the amount of existing wetland/riparian buffers within the Mason Creek watershed from about 27 to 33.6 percent, an amount of buffered lands that is consistent with goals to protect and restore wildlife in other watersheds.[35] Therefore, these important riparian areas are considered a high priority for buffer establishment to reduce pollutant loads and to protect and restore hydrological function and improve wildlife within this watershed. In addition, consideration should also be given to protecting networks of wetland and upland habitat communities in both rural and urban settings.

In general, the goals of the recommendations included on Map 3.2 are to protect and expand primary environmental corridors to the extent feasible while maximizing connections between isolated natural areas and the corridors. These connections can be prioritized for expansion by establishing buffers out to the 75-foot, 400-foot, and 1,000-foot distances as shown on Map 2.9. Measures taken to carry out these recommendations will ultimately significantly benefit the wildlife in the Mason Creek watershed.

To maintain and improve wildlife populations in the Mason Creek watershed, the following recommendations have been developed:

1. **It is recommended that wildlife habitat be preserved and expanded through protection of primary environmental corridors and isolated natural resources areas (Map 1.7) where feasible; natural areas and critical species habitats (Map 1.8); and through establishment of additional riparian buffers** (see Map 3.2 and Map B.2 in Appendix B). Establishment of riparian buffers should occur particularly at those sites where development of a buffer can be located contiguous with an environmental corridor or natural area and may result in a potential expansion and/or protection of such areas (see Figure 2.29 for demonstration of this concept). Specific measures that can be taken to accomplish this recommendation include:

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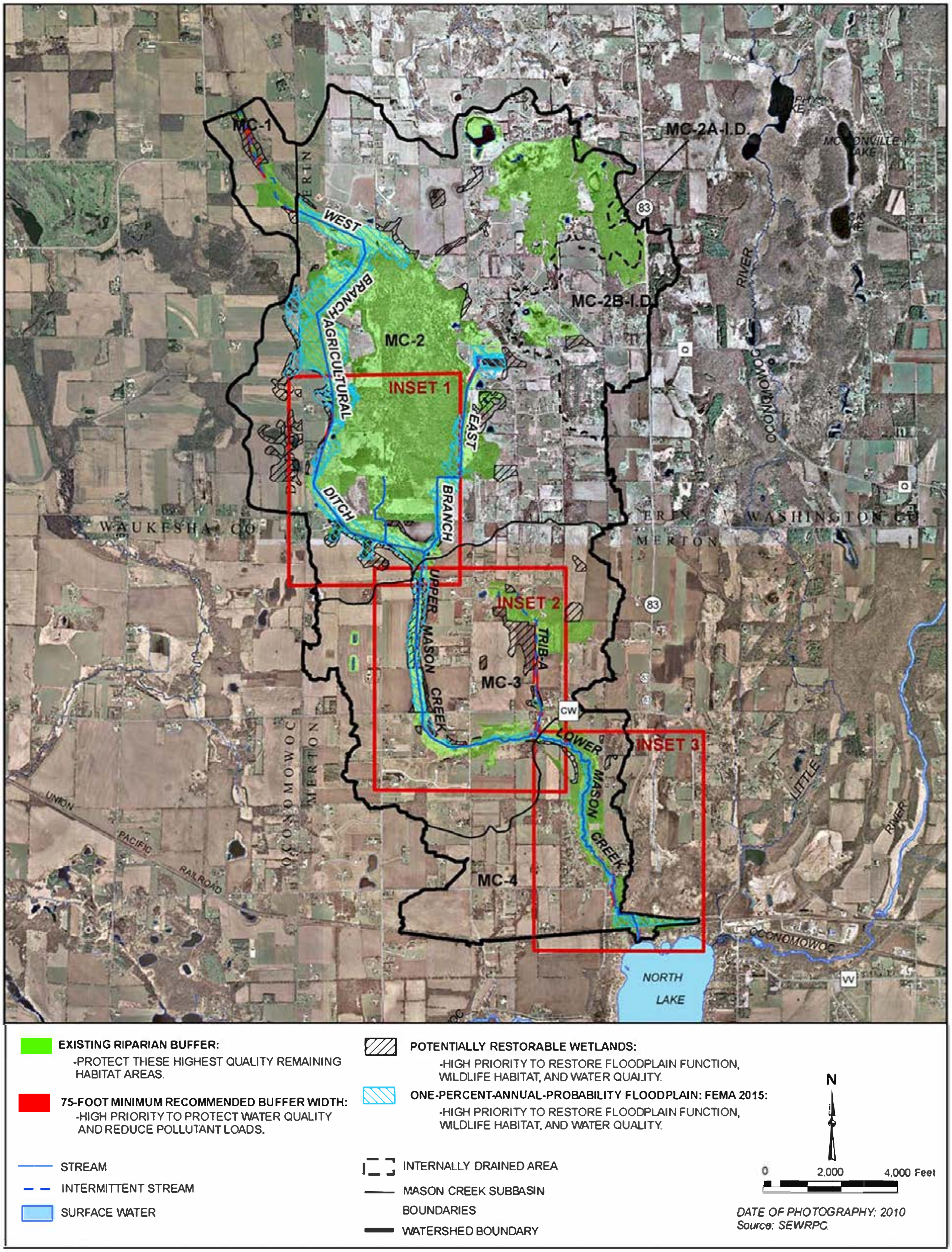
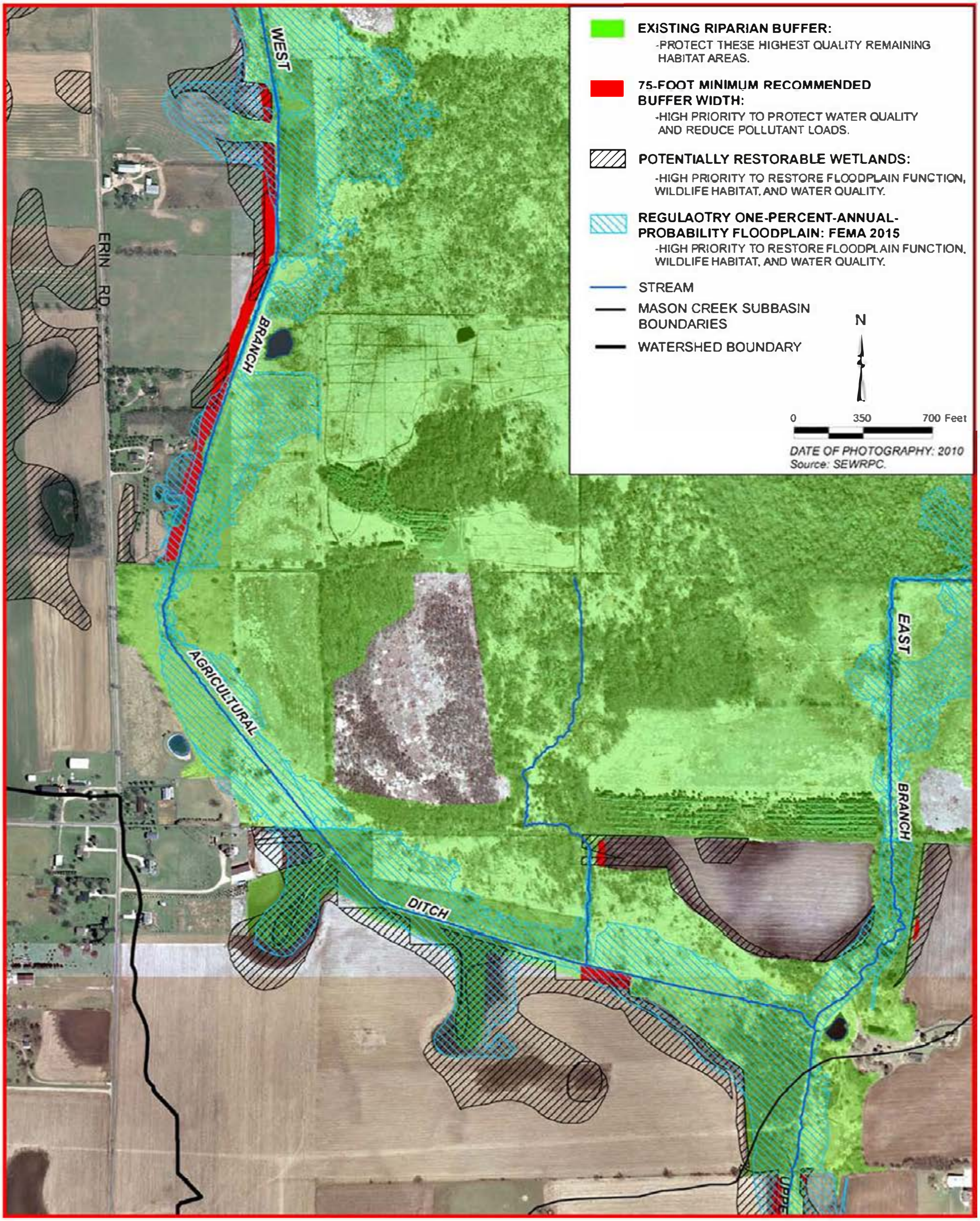
[35] *Environment Canada,* How Much Habitat is Enough? *Third Edition, Environment Canada, Toronto, Ontario, 2013*

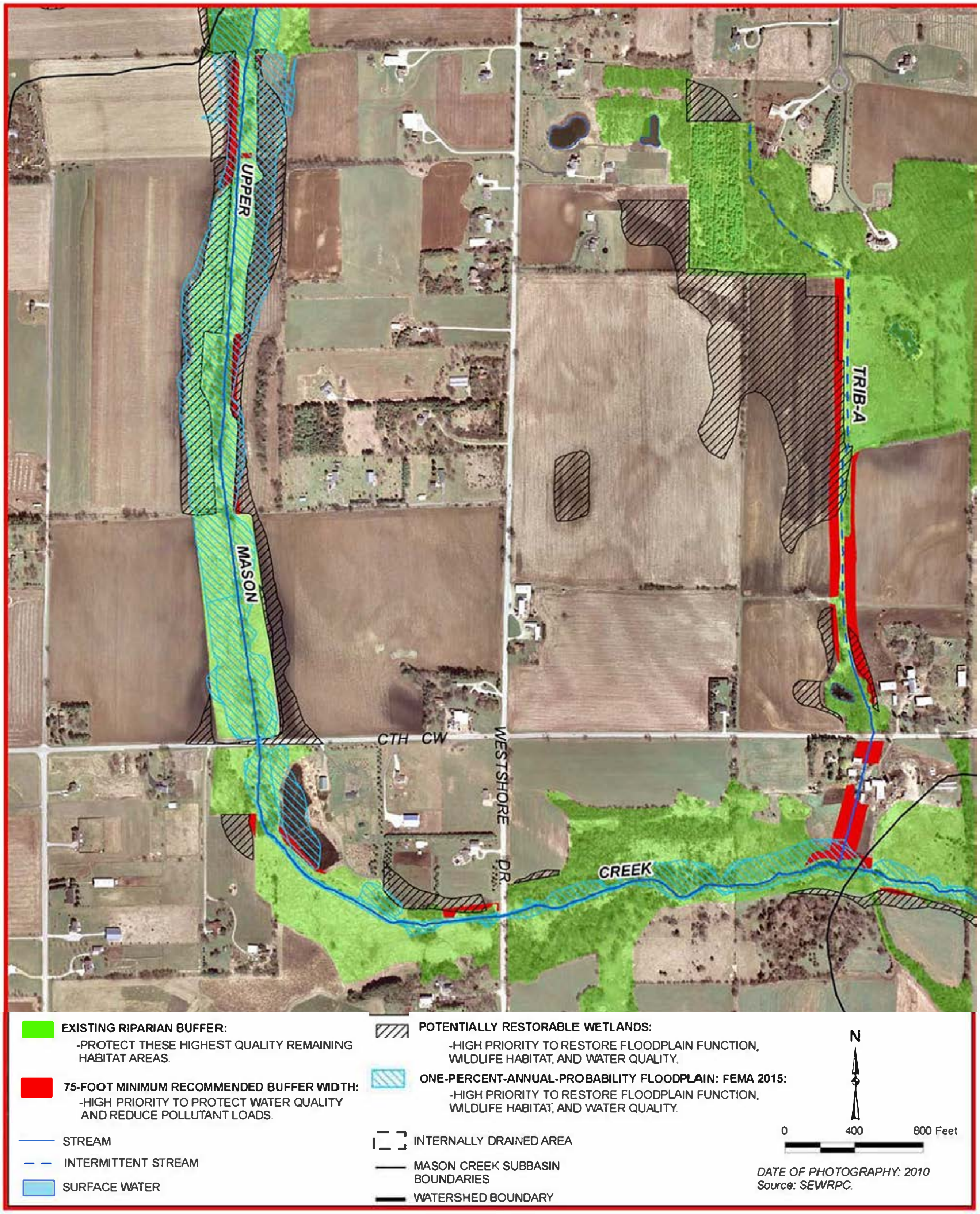
Map 3.2
High Priority Riparian Buffer Protection Areas to Improve Water Quality and Wildlife Within the Mason Creek Watershed: 2016



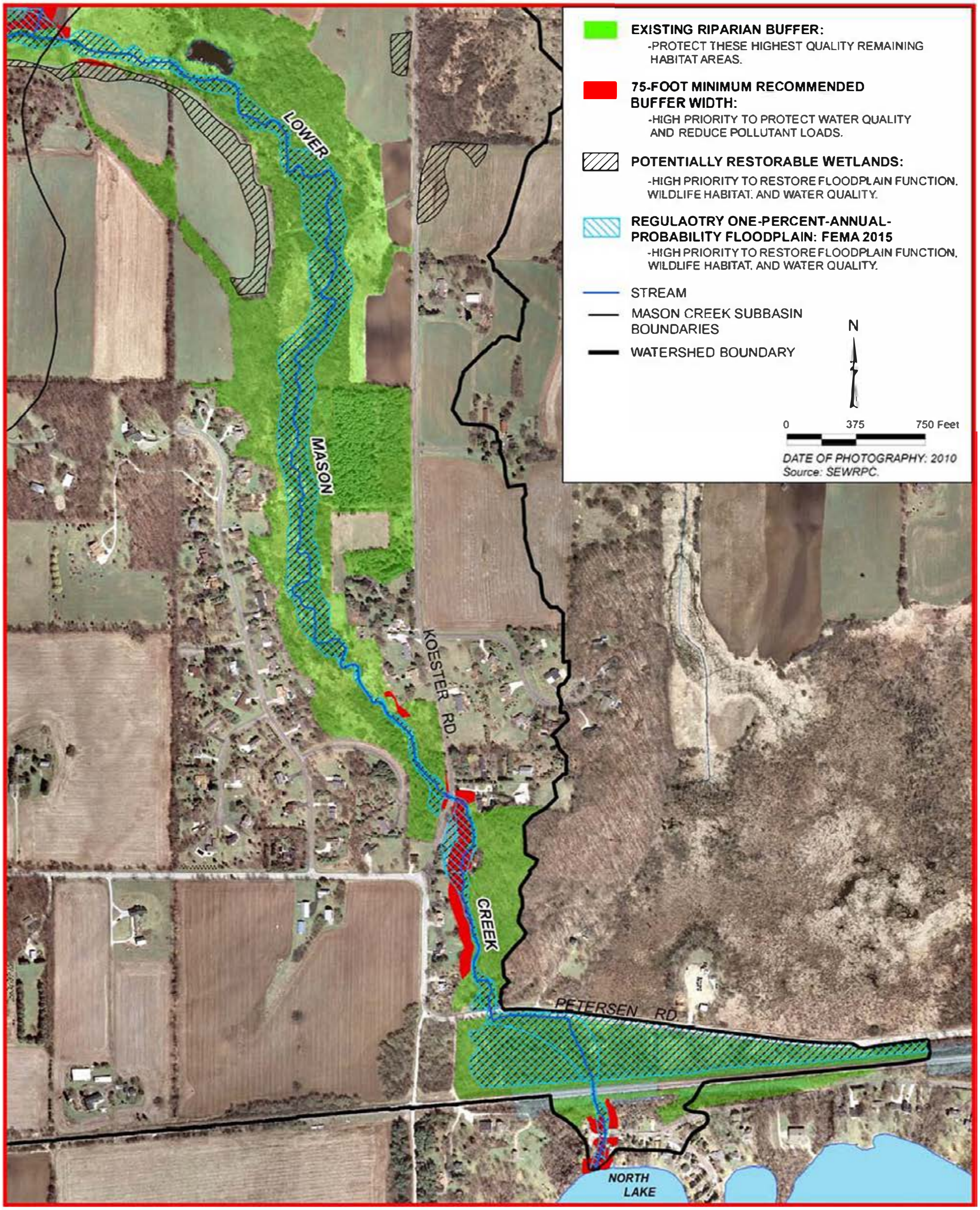
Map 3.2 (continued)



Map 3.2 (continued)



Map 3.2 (continued)



- Implementing recommendations for the acquisition and protection of wetland and woodland/upland areas that have been identified for acquisition in the adopted regional natural areas and critical species habitat protection and management plan.[36] Implementation of these recommendations, in addition to those set forth in the adopted park and open space plans for Washington and Waukesha Counties,[37] would complement the protection and preservation of environmentally sensitive lands.

- The management and restoration of wetlands and upland buffers should be prioritized near and within existing natural areas. In particular, installation of grassland buffers upslope from the Mason Creek Swamp and restoration of potentially restorable wetland adjacent to the Mason Creek Swamp would alleviate further degradation to the remaining high quality natural communities within these natural areas.

- Conducting targeted vegetation inventories to assess floristic quality as well as invasive species presence and abundance to guide management of existing natural areas and newly restored riparian buffers/wetland and upland habitat areas.

- Conserving and managing wooded areas that contain oak or hickory for future oak and hickory recruitment.

- Conserving and managing areas with excessive non-native invasive plant species to promote native vegetation, particularly adjacent to riparian waterways.

2. **It is recommended that habitat fragmentation be reduced by preserving and further enhancing connections between riparian buffer areas, open spaces, critical species habitat sites, and natural areas.** Specific measures that can be taken to accomplish this recommendation include:

   - Establishing corridors and buffers of natural habitat connecting isolated wetlands to nearby upland areas to allow reptiles and amphibians safe access to upland habitats necessary for certain life history stages. In general, priority should be given to the restoration of wetlands and upland buffers that enhance or create upland-wetland habitat complexes or increase connectivity between Mason Creek, its associated natural areas and other wetlands, and nearby stands of existing woodland;

   - Maintaining connections between streams and overbank floodplains so as to continue to protect and preserve fish and wildlife habitat and water quality benefits, making use of open lands, riparian corridors, and park lands in floodprone areas, as appropriate;

   - Maintaining connections between streams and wetlands, wetland and upland complexes, wetlands and ephemeral and/or perennial ponds, and multiple ponds, all of which provide redundancy in available habitat quality and quantity necessary to help ensure wildlife diversity; and,

   - For existing and future roadway projects, considering various pre- and post-construction measures to prevent, mitigate, or compensate for road impacts on surrounding habitats and wildlife, particularly when crossing waterways.[38] The expansion of the road network contributes to landscape fragmentation, which is recognized as one of the major threats to biodiversity

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[36] *SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, *September 1997; SEWRPC,* Amendment to the Natural Areas and Critical Species Habitat Protection and Management Plan for the Southeastern Wisconsin Region, *December 2010.*

[37] *SEWRPC Community Assistance Planning Report No. 136,* A Park and Open Space Plan for Washington County, *March 2004, see website at www.co.washington.wi.us/departments.iml?mdl=departments.mdl&ID=POS; and, Waukesha County Parks and Land Use,* Park and Open Space Acquisition Plan for Waukesha County, *Updated May 2012, see website at www.waukeshacounty.gov/uploadedFiles/Media/PDF/Parks_and_Land_Use/Planning_and_Zoning/Open_Space_Maps/OpenSpace%20Entire%20County.pdf*

[38] *Forman, R. T. T., et al.,* Road Ecology: Science and Solutions, *Island Press, Washington, D.C. 481 pp., 2003.*

for amphibians, reptiles, and mammals. In addition to reduction of road casualties for wildlife, project success should also be based upon restoring ecological processes. Goals of a successful mitigation project should include the following six elements.[39] Actions to implement projects would have to be coordinated with the WDNR, the Dodge and Washington County Highway Departments, the Waukesha County Public Works Department, local public works departments, and/or the Wisconsin Department of Transportation (WisDOT):

- Reduction of roadkill rates following mitigation
- Maintenance of habitat connectivity
- Promotion of gene flow among populations
- Confirmation that biological requirements are met
- Allowance for dispersal and recolonization
- Maintenance of processes and ecosystem function to support sustainable populations of target organisms

3. **It is recommended that best management practices aimed at maintaining wildlife be implemented. These practices should consist of voluntary, educational, or incentive-based programs.** Specific measures that can be taken to accomplish this recommendation include:

   - Encouraging agricultural landowners to enroll in Federal programs which provide incentives to restore habitats on agricultural lands such as the Conservation Reserve Program, the Wetland Reserve Program, the Wildlife Habitat Incentives Program, or the Landowner Incentive Program; and,
   - Encouraging homeowners and businesses within the 1,000-foot optimal habitat zone to consider landscaping that would enhance wildlife by providing connections (see Appendix C) or lanes through the properties. These programs should encourage the use of native plants that provide cover and food for wildlife.

Protect and Expand Riparian Buffers

As discussed above, protection and expansion of riparian buffers is an essential component to address both pollutant load reductions (see "Targeted Load Reductions" section above) and protection of wildlife. Riparian buffers protect water quality, groundwater quality and recharge, fisheries, wildlife, and ecological resilience to invasive species, and they may reduce potential flooding of structures and harmful effects of climate change (see Appendix C). Hence, preservation and development of riparian buffers are key to the existing and future economic, social, and recreational well-being of the Mason Creek watershed.

As noted above and identified in Map 3.2, while this plan recommends protecting and expanding riparian buffer regions to a minimum 75-foot width for water quality protection and, where feasible, an optimum 1,000-foot width for wildlife protection, it is important to note that, for water quality and wildlife protection, the presence of a buffer is always better than the absence of one, even if only to prevent some pollution or allow for better aquatic habitat. Therefore, **it is recommended that efforts be made to establish buffered areas, to the maximum extent practicable up to the optimum width of 1,000 feet and beyond that width in special cases where feasible.**

Specifically land managers and policy makers should focus on the following recommendations in regards to riparian buffers:

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[39] *Kimberly M. Andrews, J. Whitfield Gibbons, and Denim M. Jochimsen,* Literature Synthesis of the Effects of Roads and Vehicles on Amphibians and Reptiles, *Federal Highway Administration (FHWA), U.S. Department of Transportation, Report No. FHWA-HEP-08-005, Washington, D.C., 151 pp., October 2006.*

1. **It is recommended that existing buffers (see Map 3.2) be managed and preserved to the degree practicable. Specific measures that can be taken to accomplish this include:**

   - Eradicating invasive species to the extent practical to allow native plant species to become established. Partnerships between landowners, communities, schools, volunteer groups, service organizations, local governments, and through participation in programs offered by the WDNR are critical in such an effort (see Appendices C and D).

   - Restoring and establishing native vegetation where needed. Vegetation with a high capability to sequester nitrogen and phosphorous should be considered.

   - Conducting educational campaigns and generally promoting low-impact use of existing buffer areas. For example, in some areas row cropping is occurring too close to the roadway ditches, which is a significant source of sediment that discharges directly into Mason Creek during rainfall events.

2. **It is recommended that existing riparian buffers be protected through acquisition, purchase, easements, and regulation (See Map B.2 in Appendix B to implement this recommendation). Specific measures that can be taken to accomplish this recommendation include:**

   - Acquiring public land via donation or purchase and establishing public or private conservation easements on critical lands;

   - Applying limits on development within SEWRPC-delineated primary environmental corridors and connecting "vulnerable" existing and potential buffer lands to primary environmental corridors (PEC), secondary environmental corridors (SEC), and isolated natural resource areas (INRA) where feasible. Additional buffer lands may be added to primary environmental corridors if they meet the criteria for inclusion in a corridor, thus extending the restrictions on development that are inherent to primary environmental corridors;[40] and

     - Conservancy Districts: Each community's zoning ordinance and attendant "Lowland Conservancy" and "Upland Conservancy" district boundaries and associate maps should be based upon the most up-to-date year 2015 PEC, SEC, and INRAs as well as Wisconsin Wetland Inventory (WWI) data and be updated annually or at least every five years.

   - Enforcing local zoning regulations to encourage establishment of riparian buffers within the 1-percent-annual-probability floodplain, particularly when the zoning of land changes from agricultural to urban uses.

3. **It is recommended that riparian buffers be established to the extent practicable throughout the watershed with a minimum goal of a 75-foot width and an optimal goal of a 1,000-foot width (Map 3.2), to meet pollution load reduction goals through establishment of 345 acres of riparian buffers/restored wetlands/filter strips as shown on Map B.2 in Appendix B** (see "Targeted Load Reductions" section). These important riparian areas are considered a high priority to protect and restore hydraulic and hydrologic function, reduce pollutant loads, and improve wildlife within this watershed. Specific measures that can be taken to accomplish this recommendation include:

   - Establishing undisturbed vegetation along perennial, intermittent, and ephemeral waterways in both urban and rural areas to the extent practicable. The use of native species should be considered where possible;

   - Considering installation of harvestable riparian buffers where practicable while the lands remain in agricultural uses; and,

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[40] *The Town of Merton does not have an upland conservancy zoning district, but this is regulated under Waukesha County ordinance.*

- When lands are converted from agricultural to urban uses, considering establishing larger buffers widths for Mason Creek and its associated tributaries at the 400-foot and 1,000-foot optimal widths or to the 1-percent-annual-probability floodplain boundary, whichever is greater.

4. **It is recommended that connections and pathways be established between riparian buffer areas to ensure connectivity and continuity of buffers, environmental corridors, and natural areas. Specific measures that can be taken to accomplish this recommendation include:**

   - Creative landscaping to promote safe travel corridors and creating essential habitat features within and adjacent to corridors in either urban or agricultural landscapes such as shown in Figure 3.3 (e.g., creating ephemeral wetlands or naturalizing stormwater detention basins from mowed grass to natural plant communities using native species);

   - Where possible, protecting against fragmentation of riparian buffers by limiting both creation of new road crossings of the mainstem of Mason Creek and tributary streams and encroachment by development and other infrastructure that impacts the structure and function of these riparian areas and reduces their ability to adequately protect waterways and wildlife habitat; and

   - Removing abandoned or nonessential roads and other stream crossings where appropriate (see “Reconnect Aquatic Organism Passage” section below for more details)

Maintain and Restore Instream Habitat

Since at least the early 1900s, the Mason Creek system has been substantially altered through channelization, agricultural and urban development, road construction, placement of fill, construction of stormwater conveyance systems, and other actions related to agricultural and urban development. These changes have physically, chemically, and hydrologically degraded aquatic habitat and impaired the health of the cold water trout fishery and associated aquatic community. Therefore, the general approach to conserve and protect instream fish and wildlife habitat within the Mason Creek watershed includes four main elements (see below for more details):[41]

- Protect existing high quality components

- Improve instream flows

- Restore degraded stream channels, wetlands, and riparian areas

- Reconnect mainstream and tributary components of Mason Creek to North Lake by removal of aquatic organism passage barriers

It will be important to maintain and improve, to the extent practical, the physical, chemical, and hydrologic characteristics within the Mason Creek watershed, as well as the habitat integrity, through invasive species management, preservation of riparian buffers, protection of groundwater recharge, preservation and protection of spawning areas and riffles, and restoration of streambeds and banks where appropriate. As habitat among reaches and the connectedness of the stream system are improved over time, there will be improved aquatic organism populations and overall health. Hence, these recommendations are designed to restore natural functions in the Mason Creek watershed, to mitigate the negative impacts of alteration, and to provide essential habitat for fish and wildlife.

Modeling results based upon the overall state of Wisconsin indicated that climate change has the potential to cause the possible extirpation of coldwater brook trout within Mason Creek. This does not mean that Mason Creek will inevitably become unsuitable for brook trout, but it does indicate that it is a likely scenario and that this stream is sensitive to changing air and water temperatures, precipitation, and groundwater discharge. However, climate change stressors are difficult to differentiate from other anthropogenic (i.e., human induced) stressors such as summarized above that include land use changes,

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[41] *Jack E. Williams, and others, Adaptation and Restoration of Western Trout Streams: Opportunities and Strategies, Fisheries, Vol. 40, No. 7, pages 304-317, July 2015.*

Figure 3.3
Examples of Habitat Improvement Projects in Agricultural and Urban Landscapes for Amphibians and Reptiles

Recreation or reconnection of wetland and upland habitats

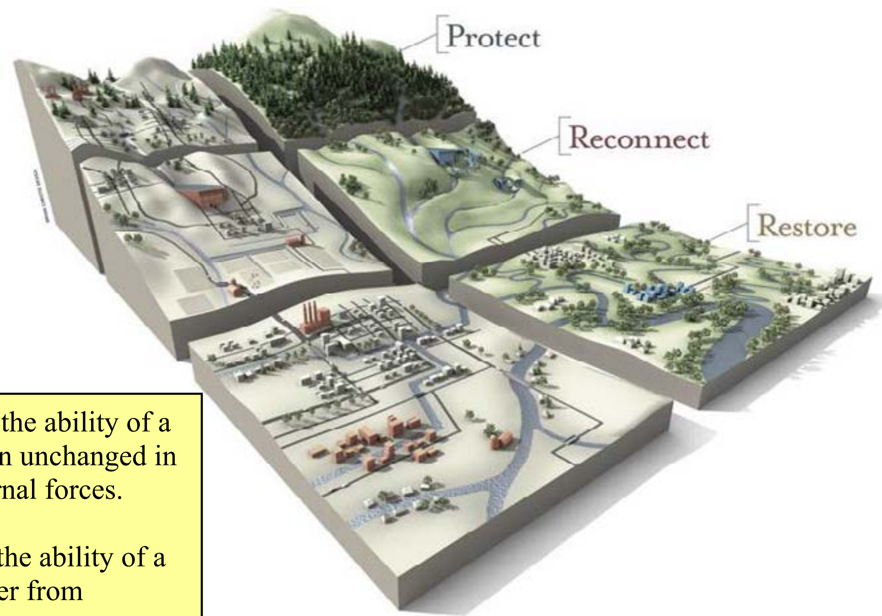
Removing obstacles and signage can improve safety and effectiveness of travel between habitats

Burning can be an effective management tool

Roadside fences can reduce mortality

Source: Partners in Amphibian and Reptile Conservation (PARC), Habitat Management Guidelines for Amphibians and Reptiles of the Midwestern United States, Technical Publication HMG-1, 2nd Edition. 2012.

Figure 3.4
Watershed-Scale Adaptation Strategies to Promote Ecological Resistance and Resilience



"***Resistance***" is the ability of a system to remain unchanged in the face of external forces.

"***Resilience***" is the ability of a system to recover from disturbance.

This graphic depicts several strategies that include: protecting the highest quality remaining habitats; increasing landscape connectivity and corridors among occupied habitat patches among water and land features; reconnecting mainstem with tributary reaches through fish passage enhancements and improving instream flows; and, restoring degraded habitats within intensive land use development areas. **This graphic was provided courtesy of Bryan Christie Design and Trout Unlimited.**

Source: Source: Adapted from Jack E. Williams and other, "Climate Change Adaptation and Restoration of Western Trout Streams: Opportunities and Strategies," Fisheries, Volume 40(No. 7), pages 306-317, July 2015; and SEWRPC

hydrologic alteration, invasive species impacts, and riparian buffer clearing, which can have complex and compounded negative effects on inland fisheries.[42] Fortunately, the occurrence of compounded effects indicate that actions to lesson other anthropogenic stressors can mitigate climate change impacts to protect and sustain the fishery.[43] Therefore, in addition to the pollutant load reductions summarized above, to promote the resistance and resilience of the Mason Creek system (see Figure 3.4),[44] this plan focuses on reducing instream water temperature and protecting/preserving groundwater discharge (to mitigate against a warming climate and/or reduced precipitation). More specifically, adaptation strategies targeted to increase landscape connectivity such as idealized in Figure 3.4 and corridors among habitats, restoring degraded habitats, and removing other threats and stressors such as invasive species or upland erosion are examples of how these strategies can be applied in the context of climate adaptation in the Mason Creek watershed (see Table 3.5 for more details). **Therefore, adaptation strategies that promote resistance and build ecological resilience to reduce the impacts of climate change and other stressors in the Mason Creek watershed is the overall strategy in this plan.** That strategy will enable Mason Creek to maintain a sustainable, naturally reproducing population of brook trout and the associated coldwater biotic assemblage for future generations.

[42] *Abigail J. Lynch, and others, "Climate Change Effects on North American Inland Fish Populations and Assemblages," Fisheries, Volume 41(7), July 2016.*

[43] *Ibid.*

[44] *Jack E. Williams, and others, Adaptation and Restoration of Western Trout Streams: Opportunities and Strategies, Fisheries, Vol. 40, No. 7, pages 304-317, July 2015; and, James E. Whitney, and others, Physiological Basis of Climate Change Impacts on North American Inland Fisheries, Fisheries, Vol. 41, No. 7, pages 333-345, July 2016.*

Table 3.5
Comparisons of Potential Climate Effects, Corresponding Adaptation Strategies, and Restoration Actions Within the Mason Creek Watershed: 2016

Climate Effects	Adaptation Strategy	Restoration Actions
Warmer Summer Temperatures	Increase stream shading and increase cool water habitat and refuge areas; maintain or increase direct groundwater discharge to stream; minimize water surface area	Restore native riparian vegetation and improve overhead cover to increase shading; increase stream meanders to promote deep water habitats; protect groundwater recharge areas; promote access to critical habitat through improved instream connectivity
Earlier peak flows in spring, reduced summer flows, and more drought-like occurrences	Increase capacity to detain runoff on a landscape scale (e.g., minimize artificial drainage features such as ditches and tile lines); recharge aquifers; increase in-stream and riparian refuge habitats	Restore wetlands; increase buffer width; protect groundwater recharge; increase channel meanders and enhance hyporheic flows; restore instream flows; increase number and size of deep pool habitats; improve access to critical refuge habitats for fishes
Increased flooding with greater intensity storm events and higher flows, increased flashiness, and higher flows in winter	Increase time of concentration by increasing capacity of the landscape to detain water; increase flood conveyance capacity and floodplain connectivity to absorb and dissipate flow energy	Reconnect and restore floodplain connectivity; expand and revegetate riparian areas; improve overall system connectivity including fish passage
Increased cumulative stress to stream systems	Reduce other sources of stress to minimize cumulative impact of increased climate stressors	Reduce pollutant sources throughout watershed, particularly from agriculture; mitigate impervious surfaces and stormwater impacts; actively manage natural areas to retain habitat value and stormwater detention benefits (e.g., manage invasive species); develop ordinances that protect key resource features (e.g., groundwater).

Note: The adaptation strategies and restoration actions can often mitigate one or more climate effects simultaneously.

Source: Adapted from Jack E. Williams, and others, Adaptation and Restoration of Western Trout Streams: Opportunities and Strategies, Fisheries, Vol. 40, No. 7, pages 304-317, July 2015, and SEWRPC.

Protect Existing High Quality Components

As described in Chapter 2 of this report (see Map 2.5 and Table 2.16), the existing highest quality fishery and aquatic habitat within the Mason Creek watershed is located within the East Branch and Lower Mason Creek reaches:

> East Branch brook trout spawning and rearing habitat protection area-Protect this area by establishing buffers and improving groundwater supply to the Creek (particularly dry weather flow) and by disabling any drain tiles, refilling any drainage ditches, and enhancing coldwater spawning and rearing habitats (see Priority Area 2 on Map 3.1). Consider drainage effects on upstream property owners.
>
> Lower Mason Creek brook trout habitat protection area-Protect this area by establishing buffers and improving groundwater supply to the Creek (particularly dry weather flow), disabling any drain tiles, refilling any drainage ditches, and enhancing potential spawning areas as well as deep coldwater pool habitats (see Priority Area 3 on Map 3.1).

Branches, tree limbs, root wads, and entire trees that fall into, and collect along, streams are commonly referred to as large woody structure (LWS). LWS plays a vital role in the hydraulic, geomorphic, and biological function of the streams and floodplains within the Mason Creek watershed, which includes wetlands, ponds, creeks, and North Lake.[45] LWS helps control the shape of the channel and provides cover, shelter, resting

[45] *Kingsbury, B.A. and J. Gibson, Habitat Management Guidelines for Amphibians and Reptiles of the Midwestern United States, Partners in Amphibian and Reptile Conservation (PARC), Technical Publication HMG-1, 2nd Edition, 2012.*

areas, and feeding opportunities for aquatic organisms over the course of their complex life histories. In addition, the interaction between LWS, water, and sediment has a significant effect on channel form and process, increasing geomorphic complexity and the quality of aquatic habitat.[46] In general, the amount and character of large woody debris was adequate within the Lower Mason Creek, but LWS was absent or only present in limited amounts within the channelized Upper Mason Creek.

- It is recommended that, removal of LWS from streams within the Mason Creek watershed be discouraged, unless it becomes a barrier to fish passage, is causing streambank erosion, or is creating upstream flooding. It is recognized that this will need to be balanced with reasonable removal efforts that are required to reduce the risk of property damage and maintain aquatic organism passage.

- Similarly, it is recommended that both submerged and floating trees be introduced into riparian wetlands and waterways such as the Spring Pond area to enhance fish, amphibian, and reptile habitats.

- It is recommended to periodically monitor for woody debris accumulations within the watershed, particularly at road crossings or associated with streambank erosion, and to dismantle and/or remove them if they become a problem.

- It is also recommended that overall wildlife habitat be enhanced by adding features such as strategically-placed downed trees, brush, rock, or ephemeral wetlands in riparian areas throughout the floodplain (see *"Maintain and Improve Wildlife Habitat"* section above).

- Although there was limited trash and other debris observed within the Mason Creek system, it is recommended that annual or semi-annual surveys be conducted in riparian and instream areas and all trash and debris identified be removed to improve aesthetics and to protect wildlife.

Improve Instream Flows

In addition to the recommendations set forth in the "Reduce the Volume and Velocity of Runoff from Upland Areas to Streams, Increase Soil Infiltration, and Protect Groundwater Recharge" section above, the following recommendations are made:

- Identify opportunities to protect and enhance groundwater recharge, particularly within the headwater areas of this watershed.

- Work with local municipalities to consider establishing ordinances that require consideration of groundwater and groundwater/surface-water interaction effects when issuing permits.

- Work with landowners and farmers in priority areas to encourage implementation of the agricultural BMPs within critical floodplain areas with emphasis on buffer establishment.

Restore Degraded Stream Channels, Wetlands, and Riparian Areas

Restoration of natural conditions within failed wetland drainage projects was also identified as having a high potential to reduce pollutant loads in this system. In such areas, ditch plugs and wetland restorations are recommended to naturalize water flow as detailed in the "Protect and Expand Riparian Buffers" sections above. Streambank erosion sites were identified and prioritized. However, it is important to note that streambank erosion is only a small fraction of the overall pollutant load to Mason Creek and the worst eroding site depicted in Figure 2.31 has recently been addressed with funding from the North Lake Management District and the OWPP. There are additional moderate and low streambank erosion sites (see Map B.2 in Appendix B), but these are not considered a problem at this time. Some of these sites are located within the Upper Mason Creek reach, but it is anticipated that those will be addressed when the stream remeandering and floodplain connectivity is restored in this reach (see below). There also were some erosion sites located within the Lower Mason Creek, and these streambank sites are recommended to be monitored at least annually and addressed only if they become worse.

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[46] *C.J. Brummer, T.B. Abbe, J.R. Sampson, and D.R. Montgomery, "Influence of Vertical Channel Change Associated with Wood Accumulations on Delineating Channel Migration Zones,"* Geomorphology, *Volume 80, pp. 295-309, 2006.*

The extensive ditching within the West Branch Agricultural Ditch and Upper Mason Creek reaches has disabled this stream system's ability to capture, store, and process/treat sediment and nutrient loads. Therefore, the only way to restore this system's hydrologic and hydraulic function and associated sediment transport capacity and streambank and streambed stability is to physically reconstruct this wetland/stream complex to its historic configuration as described below:

1. **West Branch Agricultural Ditch Sediment Retention/Wetland Restoration Improvement Area** – Restore this agricultural ditch and associated floodplain area to a wetland/lowland swamp with associated shallow groundwater hydrology to emulate historic hydrological and ecological conditions, reduce flashiness, and prevent bedload sediments and associated pollutants from being transported downstream. Most of the recommended actions below are potentially eligible for cost sharing, particularly if combined with wetland restoration. This will require cooperation and coordination with the County, Town, and local landowners. More importantly, all of the recommendations below will require cooperation and permission from the local landowner(s) and farmer(s) as well as coordination with the relevant Federal, State, county, and town staffs.

   - *Objective*-Detain, capture, slow down, and/or treat stormwater runoff, increase dry weather water levels and flow, and prevent chronic upland-sourced sediment and nutrient loads from entering Mason Creek by installing a series of ditch plugs (see Appendix H) combined with check dams and/or wetland restoration in gullies discharging to the West Branch agricultural ditch (see Map 3.1 and Priority Area 1).

     Short term strategy:

     - Purchase all the land and/or obtain appropriate conservation easements within the floodplain area. Discontinue agricultural production in the floodplain or convert to a harvestable buffer within the minimum buffer distance of 75 feet from the edge of the stream, whichever is greater, and disable drain tiles (see Map 3.2). Consider the effects of these actions on upstream property owners.

     - Work with landowners and farmers in the floodplain to encourage implementation of agricultural BMPs within this critical floodplain area with emphasis on buffer establishment.

     - Install and maintain check dams/ditch turnouts (see Appendix G) or equivalent BMPs within the roadside ditches adjacent to Erin Road/Townline Road, as appropriate to reduce sediment loads to the West Branch Agricultural Ditch and Mason Creek (see approximate locations on Map 3.1, Priority Area 1). In addition, work with landowners and farmers to encourage greater setbacks adjacent to roadside ditches with emphasis on buffer establishment.

     - Install and maintain agricultural ditch plugs (see Appendix H), partial ditch fill, or equivalent BMPs within the minor drainages/concentrated flow areas (see concentrated flow ditch/gullies on Map 3.1, Priority Area 1) tributary to the West Branch Agricultural Ditch. These drainages are very flashy and deliver high loads of sediment-laden water to the West Branch Agricultural Ditch and Mason Creek.

     - There are design opportunities on the west side and east side of Erin Road/Townline Road (particularly where there are existing culverts, see Map 3.1, Priority Area 1), to store and slow water down during rainfall events to reduce pollutant loads entering Mason Creek. It is recommended to work with the municipalities and landowners to modify or replace existing culverts or construct additional stormwater detention ponds or other BMPs to detain and temporarily store stormwater runoff from fields and the roadway.

     - Work with landowners to restore groundwater hydrology by disconnecting drain tiles. More specifically, one landowner who was contacted at the time of the stream survey was interested in disabling tiles on his property, which was shown on Map 3.1, Priority Area 1 as "Drain Tile Disconnection Area".

Long term strategy—Challenges associated with this recommendation

- Install a series of ditch plugs (see Appendix H) and/or partial ditch fills using spoil piles from past channelization within the West Branch Agricultural Ditch (see Map 3.1, Priority Area 1). This will require cooperation and permission from the local landowner(s) as well as coordination with the relevant Federal, State, County, and Town staff.

  Because this project is located within an agricultural setting (i.e., zoned agricultural land), it does qualify for one or more government wetland restoration programs such as the Conservation Reserve Program (CRP) or Wetland Reserve Program (WRP) (see "Funding Sources" section below for further details). This proposed project would likely meet the eligibility requirements for sound wetland restoration as set forth within Chapter NR 353, "Wetland Conservation Activities," of the *Wisconsin Administrative Code*. Hence, this proposed restoration project may be eligible for the NR 353 general permit, because it would likely meet each of the eligibility requirements listed/described below in question/answer format, along with supplementary recommendations:[47]

  Question*: Is your project sponsored by the Natural Resources Conservation Service (NRCS), the US Fish and Wildlife Service (FWS) or the Wisconsin Department of Natural Resources (WDNR)?*

  Response: Yes—It is recommended that this project be sponsored by the NRCS and/or WDNR through the OWPP in partnership with the City of Oconomowoc's Adaptive Management Program, which will help with design and implementation cost share funding (see "Funding Sources" section below for further details).

  Question*: Is the purpose of the project wetland conservation? In other words will the project result in the re-establishment or restoration of drained wetlands, enhancement of existing degraded wetlands or creation of new wetlands?*

  Response: Yes—This project will re-establish drained wetlands and enhance degraded wetlands. The proposed ditch plugs and/or partial ditch fills are designed to reverse the impacts to this wetland and restore groundwater hydrology.

  Question*: Will the project include one or more activities that are eligible for the general permit and that are consistent with design and construction according to NRCS Field Office Technical Practice Standard 657-"Wetland Restoration"?*

  This project potentially includes one or more of the following activities:

  » Drain tile alteration or removal by disabling a section of drain tile in the project area.

  » Disabling artificial surface drains by filling lengths of the ditch downstream of the drainage system to be altered or installation one or more ditch plugs. Ditch fills may be added upstream of ditch plugs or ditch fills may extend for the entire length of the ditch. Ditch plugs may be eliminated if the proposed ditch is completely filled with earth.

  » Introducing native plants and managing existing exotic or invasive plant species.

  Response: Yes—The potential activities listed above are eligible for the general permit and also are eligible for cost share through the OWPP as an approved wetland restoration technique (see "*Funding Sources*" section below). In addition, **it is recommended that a management plan be included with the permit application,** because maintenance that is described in the project proposal will not require additional WDNR permits in the future. For example, if the management plan includes maintenance of a ditch plug, the

[47] *Alice L. Thompson and Charles S. Luthin, Wetland Restoration Handbook for Wisconsin Landowners, 2nd Edition, 2010; and WDNR Wetland Regulations website at dnr.wi.gov/topic/wetlands/restorationpermits.html*

project team will be allowed to repair the plug to the original specifications at a later date without needing to obtain another permit. **It also is recommended that re-seeding and planting, burning, herbicide use, and mowing, along with any other future maintenance activities to promote native vegetation and control invasive species, be included in the permit,** which will allow such actions to occur without further WDNR permitting. However, Federal or local permits may be needed for continued maintenance.

Question: Does the project involve activities in navigable waters with prior stream history?

Response: No—There is no stream history associated with the West Branch Agricultural Ditch. More specifically, there was no natural stream within the vicinity of this Ditch prior to its construction sometime between 1909 and 1939. This is based upon information from the 1909 and 1836 plat maps and associated notes as well as the 1892 and 1909 U.S. Geological Survey quadrangle maps (see Chapter 2).

Question: Will the project include the construction of a dam, dike, embankment, or low berm that is: less than or equal to 6 feet in height as measured from the natural ground level; or, less than 25 feet in height as measured from the natural ground level with a maximum storage capacity of less than 50 acre-feet?

Response: Yes—It is estimated that the ditch plugs or partial ditch fills will not exceed three to four feet in height, which is the approximate maximum height of the stream banks within the West Branch Agricultural Ditch. In addition, since there is an adopted FEMA floodplain delineated along the Ditch, it is important that construction of the ditch plugs not increase the one-percent-annual-probability flood elevation. Therefore, **completion of a floodplain modeling study is recommended to ensure the location, number, and design details of each agricultural ditch plug or partial ditch fills will not increase the flood elevation or flood additional existing cropland.** The ditch system was designed to reduce water elevations during fair weather periods to promote farming of these lands. The additional stormwater conveyance capacity offered by the relatively small artificial ditch is likely negligible. Therefore, it may be possible to install ditch plugs without raising regulatory floodplain elevations. The ditch plug locations identified on Map 3.1 inset Area 1 were placed at two foot elevation intervals to approximate the potential location of a series of ditch plugs, but the exact location and number would have to be verified by modeling, onsite conditions, and permission from landowners. Implementing this project may require moving or retrofitting drain tiles in some areas.

Question: Will the project result in significant adverse impacts to endangered or threatened species, or to historical or cultural resources?

Response: No—This Ditch and the adjacent wetland do not contain any known endangered or threatened species, or impact any historical or cultural resources.

Therefore, based upon the scenario outlined above, it is expected that this proposed wetland restoration project would qualify for the Statewide wetland conservation general permit. However, **it is recommended that the project partners consult with WDNR prior to proceeding with such a project.** It is important to note that these proposed wetland restoration actions would help to reduce the sediment and phosphorus loads, beyond what was modeled under this plan.

2. **Mason Creek Brook Trout Habitat Restoration** – Restore and/or rehabilitate the degraded channelized reaches and their associated wetlands and riparian areas to improve water quality and brook trout habitat by addressing streambank and streambed sediment loads, recreating pool-riffle structure, and providing floodplain connectivity (see Map 3.1, Priority Areas 2 through 4).

   Restoring channelized reaches to a more natural state will decrease the pollutant loads beyond what was modeled under this study. The stream will also be able to remove pollutants by increasing 1) water residence time (longer meandering stream length), 2) biological nutrient processing (connected floodplain), 3) sediment transport and storage capabilities, and 4) metabolism.[48] The benefits of floodplain restoration are most apparent during high flow events (during inundation). Floodplains are more effective at assimilating nutrients when they are vegetated with appropriate native plants, so invasive species management is also important (see "Maintain and Improve Wildlife Habitat" section above). Restoring natural meanders also has the added benefit of dramatically improving the number and diversity of essential deep pool and shallow riffle habitats that will improve the quality and diversity of the biological community, particularly for brook trout life history requirements. Therefore, this plan makes the following short-term and long-term recommendations to work towards achieving this restoration goal:

- *Objective*-Capture, detain, slow down, and treat stormwater runoff; increase dry weather flow; and prevent chronic sediment and nutrient loads from entering Mason Creek by improving floodplain connectivity and pool-riffle structure (see Figure 2.39) combined with wetland restoration (see Map 3.1, Priority Areas 2 through 4).

  Short term strategies/alternatives:

  - Purchase all the land and/or obtain appropriate conservation easements within the floodplain area or a minimum distance of 75 feet from the edge of the stream, whichever is greater. Discontinue agricultural production in the floodplain or 75-foot buffer area or manage that area as harvestable buffer and disconnect or modify drain tiles to promote vegetative uptake of nutrients prior to discharge to the stream (see Map 3.1, Priority Areas 2 through 4).

  - Work with landowners and farmers with property in the floodplain to encourage implementation of the agricultural BMPs within this critical floodplain area with emphasis on buffer establishment.

  - Work to reduce pollutant loads from all roadway ditches. This will require cooperation and coordination with the County, Town, and local landowners. The drainage ditches associated with these roads are very flashy and deliver high loads of sediment-laden water that discharge to Mason Creek, so the goal is to look for design opportunities on all roadways—with a priority on the north side and south side of CTH CW and the east and west sides of Westshore Drive—to store and slow water down during rainfall events to reduce pollutant loads to Mason Creek.

  - Work with landowners and other partners to incorporate their needs in a conceptual plan for the proposed stream channel remeandering in the Upper and Lower reaches of Mason Creek (see Priority Areas 2 and 3 as shown in Map 3.1). Once preliminary agreements are reached, it will be necessary to conduct a floodplain study to verify that the proposed conceptual remeandering projects will not increase the regulatory floodplain elevations.

    » Relocate the channelized portion of the Lower Mason Creek reach that parallels Petersen Road into its historical channel configuration between Petersen Road and the Union Pacific Railroad bridge (see Map 3.1, Priority Area 4). This will simultaneously move the stream channel away from the existing road ditch and increase the number and quality of pool and riffle habitats, improve floodplain connectivity, and increase stream length by 100 feet. This historical channel is still present and this relocation could easily be achieved with construction of simple channel blocks to divert flows back into the old channel. Once flow is diverted, the channelized portion is recommended to remain as deepwater marsh wetland habitat for amphibians and reptiles, which will also function to naturally capture sediments during high flows, thereby reducing loads to the downstream portion of this

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[48] *Sarah S. Roley, et al., "Floodplain restoration enhance denitrification and reach-scale nitrogen removal in an agricultural stream", Ecological Applications, Volume 22(1), pages 281-297, 2012; Sarah S. Roley, et al., "The influence of floodplain restoration on whole-stream metabolism in an agricultural stream: insights from a 5-year continuous dataset; and, Sarah S. Roley, Jennifer L. Tank, and Maureen A. Williams, "Hydrologic connectivity increases denitrification in the hyporheic zone and restored floodplains of an agricultural stream", Journal of Geophysical Research, Volume 117, pages 1-16, 2012.*

reach and North Lake. This stream and wetland restoration will require permits and it is recommended that the project partners consult with WDNR prior to proceeding with this project. It is important to note that these proposed stream and wetland restoration actions would help to reduce the sediment and phosphorus loads below what was modeled under this plan.

- It is recommended that a streambank/streambed survey be conducted on the remaining unassessed portion of the East Branch of Mason Creek to identify opportunities to reduce pollutant loads and improve surface water and groundwater quality and quantity. While a large portion of the stream network in the Mason Creek watershed has been surveyed for streambank erosion and streambed deposition as part of this study, the majority of the East Branch remains unassessed. Since this is the only reach where brook trout were observed to be spawning, it is important to identify potentially eroding streambank or streambed sites that could be affecting downstream aquatic habitat in this reach as well as in areas downstream.

Long-term strategy:

- It is recommended that excessive streambed sediments be addressed through creation of a more natural stream system in the impaired Upper Mason Creek reach. This would involve restoring or reconstructing the historical stream sinuosity, pool-riffle habitats, and floodplain connectivity of the Creek. This is a long-term project because remeandering of this reach should not be conducted until sediment bedload prevention/mitigation be completed in the West Branch Agricultural Ditch and associated drainage ditches directly upstream of this reach. Although the location and characteristics of the historical channel within the Upper Mason Creek is known from historical aerial maps, due to many years of agricultural management, this channel no longer exists on the landscape and will have to be reconstructed. It is recommended that this reach be restored to approximate its original (i.e., historical) channel alignment, location, slope, sinuosity, and floodplain connectivity (see Map 3.1) within the confines of the needs of stakeholders and landowners. The stream channel design dimensions should be based upon the template or reference low flow and bankfull (i.e., channel forming discharges, see Appendix I) reach conditions in this portion of the Upper Mason Creek reach.

Re-Establish Aquatic Organism Passage

Recreational fishing is an important economic activity in the Southeastern Wisconsin Region and North Lake. The maintenance and continuity of the species of economic importance (i.e., gamefish species) and those species on which they depend is associated to a large degree with the protection and restoration of appropriate habitat. To this end, efforts to remove obstructions to fish migration from the mainstem and tributaries of Mason Creek to North Lake are key considerations for the long-term restoration of the fishery, particularly brook trout. Examples of these obstructions are shown in Figure 2.40 and further summarized in Appendix J. Removal, replacement, and/or retrofitting of these obstructions should be accompanied by the restoration or re-creation of habitat within the stream and riparian corridor. Such habitat is essential for refuge, rearing, feeding, and spawning of fishes and other organisms. Therefore, designs to improve fish passage through replacement or modification of hydraulic structures should use brook trout swimming abilities as a guide template for passage at critical low flow and bankfull conditions in Mason Creek and should accommodate sediment transport and floodplain connectivity to the extent practicable as illustrated in Figure 2.41 (also see fish passage criteria in Appendix J). This will help to improve the biotic integrity of both the streams within the Mason Creek watershed and North Lake. To maintain and restore fish and aquatic organism passage throughout the Mason Creek watershed, the following recommendations have been developed:

1. Removal, replacement, and/or retrofitting of obstructions identified on Map 3.1, accompanied by the restoration or re-creation of habitat within the stream and riparian corridor, is essential for refuge, rearing, feeding, and spawning of fishes and other organisms. **Priority for improving passage should be given to restoring connectivity and habitat quality between the mainstem of Mason Creek and North Lake and between the mainstem of the Creek (Upper and Lower reaches) and the East Branch.**

The description and recommended actions for each of these structures are summarized below:

- **Lower Mason Creek**

  - **Private drive (Structure No. 7, see Priority Area 4 of Map 3.1) at River Mile 0.41** – It is recommended that modification of this structure be a high priority to improve fish passage for brook trout. Replace the existing structure with a single cell structure with a minimum width of 1.2 times the reference reach bankfull conditions (e.g., open bottom box culvert, embedded closed bottom box, or equivalent pipe, see fish passage structure guidance in Appendix J for more details) along with one or more floodplain relief/overbank culverts (see Figure 2.41).[49] Modeling will need to be conducted to ensure that the regulatory flood elevation is not increased.[50]

  - **Koester Road (Structure No. 9, see Priority Area 4 of Map 3.1) at River Mile 0.5** – it is recommended that modification of this structure be a high priority to improve fish passage for brook trout. Replace the three corrugated metal pipes with a single cell structure with a minimum width of 1.2 times the reference reach bankfull conditions (e.g., open bottom box culvert, embedded closed bottom box, or equivalent pipe, see Appendix J) along with one or more floodplain relief/overbank culverts (see Figure 2.41). Given the length of this structure, resting areas are recommended to be incorporated within the bankfull culvert to ensure adequate passage, particularly for brook trout (see Appendix J for more details). Modeling will need to be conducted to ensure that the regulatory flood elevation is not increased.[51]

  - Private drive (Structure No. 12) RM 1.26 – Remove or replace this structure with an appropriately sized culvert or install rock vane(s) in the culvert to raise water levels, reducing water velocity and increasing water depth. If the culvert is replaced, it should be replaced by a single structure that has a minimum width of 1.2 times the reference reach bankfull dimensions and that meets other criteria to ensure adequate fish passage as summarized in Appendix J.

- **Upper Mason Creek**

  - **CTH CW (Structure No. 15, see Priority Area 2 of Map 3.1) at RM 2.51** – Remove the roadway fencing and debris accumulated in the channel at the downstream side of the culvert.

  - **Private culverts (Structure No. 16, see Priority Area 2 of Map 3.1) at RM 3.28** – Remove both culverts and accumulated debris in the channel.

  - **Private Spring Pond near confluence with East Branch of Mason Creek** – Restore the hydrological connection between the spring pond outlet to Upper Mason Creek by removing the outlet standpipe and associated earthen berm. This connection would restore access to important cold, deepwater habitat in the hottest summer periods and warm, deepwater habitat in the overwintering periods for brook trout and other fishes, amphibians, and reptiles.

- **East Branch of Mason Creek**

  - **Private drive (Structure No. 19, see Priority Area 2 of Map 3.1) at RM 0.05** – Remove all three of the embedded pipes from underneath this ford crossing to enable the previously diverted water to flow over the ford, which will improve water depth for passage, particularly in low-flow time periods. Regrade/reconstruct the downstream edge of the ford as well as the roadway to a more appropriate slope. It is recommended that target water depths of the

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[49] *See U.S. Fish and Wildlife Service at www.fws.gov/northeast/mainefisheries/projects/connectivity.html*

[50] *Federal Emergency Management Agency (FEMA), Flood Insurance Study (numbers 55133CV002C and 55133CV003C), Waukesha County, Wisconsin, and Incorporated Areas, Volumes 2 and 3, November 5, 2014, Contact WDNR to obtain copy of Hydraulic/Floodplain Model.*

[51] *Ibid.*

completed ford be not less than 0.5 foot and water widths be not less than four feet or greater than 10 feet at low flow conditions, and that streambed slopes of this entire ford structure not exceed 2 percent. It may be necessary to install one or more rock vanes (see Figure 2.43) to reduce the overall stream slope through the ford and create deeper water to promote fish passage as well as resting areas.

2. Stream crossings tend to have a cumulative impact on the stream and adjacent lands, as well as an impact on the quality of the water and the fishery. Therefore, it is important to reduce the linear fragmentation of the existing riparian buffers by either removing crossings where possible or by not increasing the number of crossings where practical. It is recognized that access by police, fire protection, and emergency medical services are overriding considerations that must be applied in determining whether the objective of removing a crossing is feasible. This recommendation is only meant to apply to situations where there are more road crossings than necessary to ensure adequate traffic carrying capacity and adequate access for emergency services.

3. Encourage development of plans for replacement and/or retrofitting of obstructions at all mainstem and tributary road crossings to incorporate improvements to aquatic and other organism passage over time as opportunities present themselves (e.g., structure failure, major blockage, or bridge reconstruction or replacement). The recognition that fish populations and other wildlife are often adversely affected by culverts has resulted in numerous designs and guidelines to allow for better fish passage and to help ensure a healthy sustainable fisheries community (see Appendix J).[52]

   - These plans should be developed in partnership with the relevant municipality and the County Highway or Public Works Departments. Actions to improve passage would have to be coordinated with the WDNR, County Highway or Public Works Departments, local public works departments, and/or the Wisconsin Department of Transportation.

   - Consider annual or biannual surveys of the Mason Creek system to assess capabilities to maintain fish passage at all road or railway crossings, particularly identifying obstructions due to debris accumulation or beaver dams, and to identify where actions need to be taken to improve passage.

3.6 RECOMMENDED ACTIONS ASSOCIATED WITH MANAGEMENT OBJECTIVE TO INCREASE PUBLIC AWARENESS OF WATER QUALITY ISSUES AND PARTICIPATION IN WATERSHED CONSERVATION ACTIVITIES

The recommendations presented within this section are designed to enhance both public understanding of the plan and participation to implement plan recommendations. More specifically, this section contains 1) recommendations related to an information and education component, 2) details on how to measure and track plan implementation progress and success, and 3) interim measurable milestones and established criteria.

Information and Education

The information and education component of this plan is designed to increase participation in conservation programs and implementation of conservation practices by informing the landowners and farm operators of assistance and tools available to them and providing emerging information on cover crop, no-till implementation strategies, and other recommended BMPs. Creating education and partnership opportunities for elected officials and representatives of organizations active in the watershed are also integral to the information and education plan. Riparian landowners and the general public will need to be informed of the importance of land and water connections and the necessity of improving in-stream and wildlife habitat and water quality.

[52] *B.G. Dane,* "A Review and Resolution of Fish Passage Problems at Culvert Sites in British Columbia," *Canada Fisheries and Marine Sciences Technical Report 810, 1978. Chris Katopodis,* "Introduction to Fishway Design," *Freshwater Institute Central and Arctic Region Department of Fisheries and Oceans, January, 1992.*

Civic Engagement

Civic engagement is essential to the implementation of watershed plans. Technical advisors and funding agencies are key to successfully completing watershed projects, but having an engaged core of committed municipalities, citizens, business leaders, grassroots organizations, and local agencies is paramount. When the entire group is willing and able to understand each other's goals and are committed to work together, implementation plans lead to successful on the ground projects. Stakeholders who are affected by the watershed plan, who can provide information on the issues in the watershed, and who work to implement existing programs or plans that incorporate similar goals should actively participate.

Driving Forces

Within the watershed, stakeholders have worked together at varying scales to improve water quality for many decades. In the 1980s, the watershed was part of the Oconomowoc River Priority Watershed Project that facilitated the implementation of agricultural BMPs through joint efforts of the Counties, WDNR, and NRCS.[53] More recently, interest in improving the quality of water in the Oconomowoc River watershed led to the formation of the Oconomowoc Watershed Protection Program (OWPP) and Adaptive Management Program administered through the City of Oconomowoc. The mission of the OWPP is stated as "Working in Partnership to Protect and Improve Soil and Water Quality in the Oconomowoc River Watershed" (see Figure 3.5). The OWPP is composed of community groups, State and Federal agencies, nonprofit organizations, and other local interest groups. The diverse membership works collaboratively to implement recommendations established under the WDNR-approved Adaptive Management Program by organizing, prioritizing, and coordinating land management and outreach activities.[54] The NRCS, Washington County, and Waukesha County have provided technical guidance to farmers and the OWPP to help implement agricultural management improvement projects to improve water quality.

Additional funds became available from the USDA in 2015 through successful acquisition by the City of Oconomowoc of a Regional Conservation Partnership Program (RCPP) grant (see "Funding Sources" for more details). The main goal of this RCPP grant/project is to improve water quality within and downstream of the Oconomowoc River watershed. The City of Oconomowoc is leading this project by working with producers and many other partners to improve water quality. A secondary objective is working with agricultural producers to improve water quality by reducing soil loss and nutrients within the watershed. [55] There are 21 potential agricultural sites currently involved with this program and project partners are able to provide up to $500,000 toward conservation efforts within the Oconomowoc River watershed.[56] The program includes two recent projects to improve water quality by increasing stream side buffer strips and addressing streambank erosion as shown in Figures 2.29 and 2.31, respectively, within the Mason Creek watershed.

In 2014, the USEPA directed that the majority of funds available through the Clean Water Act for pollution abatement projects for waters that are designated as being impaired are to be used in watersheds with a WDNR- and USEPA-approved plan that meets the USEPA nine key elements of a watershed-based plan. Since Mason Creek is located within the Rock River basin, and the basin has been designated as impaired by excess phosphorus and sediment, it is necessary to establish and implement a plan that meets the USEPA nine key elements.

Stakeholders

Efforts to educate, inform, and engage Mason Creek watershed stakeholders about the watershed protection plan process has been accomplished through the convening of stakeholder and community meetings. Stakeholder input has been a key factor in developing objectives, and refining priority projects and programs. Community input about issues of concern is reflected in the results of a questionnaire that

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[53] *WDNR,* Oconomowoc River Priority Watershed Project, *1986.*

[54] *Op. cit., City Of Oconomowoc, February 2016.*

[55] *See www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/farmbill/rcpp/?cid=stelprdb1267*903

[56] *Tyler Langan, "Oconomowoc Watershed Program Embraced by Area Farmers", Lake County Now, June 29, 2016, archive.lakecountrynow.com/news/oconomowocfocus/oconomowoc-watershed-program-embraced-by-area-farmers-b99753337z1-384897571.html*

Figure 3.5
Community Engagement Strategy Within the Mason Creek Watershed

Oconomowoc Watershed Protection Program (OWPP)

Mission: Working in Partnership to Protect and Improve Soil and Water Quality in the Oconomowoc River Watershed

About the Program	The **City of Oconomowoc** is embarking on an innovative program called **Adaptive Management** to improve the water quality of the many lakes and rivers in the Oconomowoc River watershed.
Goal	To **reduce non-point source pollution** from urban storm water, construction sites, and agricultural land to improve water quality, thus enabling the City to **reach compliance** with the Department of Natural Resources wastewater and storm water permit requirements in a cost-effective manner.
Benefits	Since the Oconomowoc River is upstream of the Rock River, the program will also **improve the water quality** of the Rock River and aid in the objectives of the Rock River Total Maximum Daily Load rule. The specific pollutants to be reduced are phosphorus and total suspended solids. In addition to improving surface water quality in area streams and lakes, the program will **enhance local wildlife habitat and ecology, control excessive aquatic plant growth and reduce algal blooms.**

Leading the Effort

City of Oconomowoc Wastewater Utility

Other lead partners: Tall Pines Conservancy and Ruekert & Mielke, Inc.

OCONOMOWOC WASTEWATER UTILITY

Other partners:

- American Farmland Trust
- Camp Whitcomb/Mason
- Carmelites of Holy Hill
- Clean Water Association
- Clean Wisconsin
- Erin Meadows Farms
- Greener Oconomowoc
- Jefferson County Land and Water Conservation Department
- Local Engineering Firms
- Local Farmer Leadership Group
- Local Lake Management Districts
- Local Municipalities
- Mid-Kettle Moraine
- National Resource Conservation Service
- Pabst Farms
- Rock River Coalition
- Sand County Foundation
- Southeastern Wisconsin Regional Planning Commission
- Town & Country Resource Conservation & Development, Inc.
- University of Wisconsin - Extension
- UWM School of Freshwater Sciences
- Washington County Land and Water Conservation Department
- Waukesha County Land Resources Divsion of Parks and Land Uses Department
- Wisconsin Department of Agriculture, Trade and Consumer Protection
- Wisconsin Department of Natural Resources

Oconomowoc River Watershed

Healthy Soils
Clean Water
Happy People

If you would like to learn more, please contact Tom Steinbach at 262-569-2192 or tsteinbach@oconomowoc-wi.gov

Note: The community engagement among local partners and commitment to implementing projects within the Mason Creek watershed is already occurring within the context of the larger ongoing OWPP efforts.

Source: City of Oconomowoc Wastewater Utility and SEWRPC.

was distributed early in the outreach effort. Community meetings have also provided a means to develop goals, share progress on the development of the protection plan, and receive input from the public. The questionnaire results established that water clarity, agricultural runoff, garbage and trash in natural areas, invasive species, and pesticide use topped the list of water concerns (see Table 3.2).

The following stakeholders were identified during the information and education process:

- Agricultural Producers
- Businesses
- City of Oconomowoc Wastewater Utility
- Clean Water Association
- Crop Advisors
- Farmers
- Landowners
- North Lake Management District
- Rock River Coalition
- Ruekert & Mielke, consulting engineers
- School Districts
- Southeastern Wisconsin Regional Planning Commission
- Tall Pines Conservancy
- Towns of Merton and Erin
- Universities and Colleges
- University of Wisconsin Extension Service
- USDA - Farm Service Agency
- USDA - Natural Resources Conservation Service
- Washington County
- Waukesha County
- Wisconsin Department of Natural Resources

Goals

The goals and recommended actions for this information and education plan are based on the USEPA 2008 effective information and education watershed plan components as well as questionnaire results, work group meetings, and stakeholders.[57] The plan addresses elements such as creating appropriate messages to targeted audiences, distributing the message, and periodic evaluation of the information and education program. Most importantly, it is envisioned that the identified stakeholders within and adjacent to the Mason Creek watershed will continue to partner and work together to implement the plan.

The goal of the Mason Creek watershed protection plan is to provide information that local decision makers, farmers and landowners, and watershed residents can use to improve and protect the natural resources of the Mason Creek watershed. More specifically, the goal is to promote active stewardship among residents, farmers, landowners, businesses, community associations, as well as governmental and non-governmental organizations.

To increase public awareness of water quality issues and increase participation in watershed conservation activities, the education and information plan includes the following elements and specific actions (proposed timelines are summarized in Table 3.6):

- Inform the general public about the fish and wildlife species known to reside in the watershed, their habitat requirements, and management practices required to sustain them.

- Inform agricultural landowners and operators about the plan, its recommended BMPs, and technical and funding assistance available.

- Inform nonresident agricultural landowners about local, State and Federal opportunities for funding and technical assistance.

- Inform riparian landowners about opportunities to improve wildlife habitat, and provide information about programs to fund expanding riparian buffers and restoring wetlands.

- Inform local officials about the protection plan and its goals, and work with them to adopt this plan through partnership building (see "Measuring Plan Progress and Success" section below).

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[57] *U.S. Environmental Protection Agency (USEPA),* Handbook for Developing Watershed Plans to Restore and Protect Our Waters, *USEPA 841-B-08-002, March 2008.*

Table 3.6
Information and Education Plan Implementation Matrix

Information and Education Plan Implementation Matrix							
		Schedule					
Target Audience	Actions	0–2 Years	2–5 Years	5–10 Years	Cost	**Implementation**	**Outcome/Evaluation Metric**
General Public	Media notices in newspapers and community newsletters & public presentations	Notice in 2 local newspapers about completion of Mason Creek Protection Plan.	--	Drivers see watershed signs when entering watershed. Signs create interest to see what watershed project is about		Local Partners	General public is aware of protection plan, understand how the Plan is relevant to them.
		At least 1 presentation to municipal representatives, landowners, and general public.	--	--	$1,000	Local Partners	
	Create educational display for County Fair, local libraries, and government offices	At least 1 educational display exhibited at County Fair and 2 other venues.	At least 2 educational displays exhibited at government offices, and local events.	--	$3,600	Local Partners	People who live, work and recreate in the watershed will understand how the plan improves their community and life, and have a better understanding of how they impact the resources in the watershed. They will be informed of progress and new recommendations for improvements and protections.
	Utilize municipal and community organization websites to post watershed project information	2 Stakeholder groups develop a website page or social media site for watershed plan news and activities.	--	--	$2,200	Local Partners	
	Distribute information to watershed residents about Mason Creek Protection Plan goals and recommended actions.	A fact sheet or publication is created about the Plan goals, recommended actions and opportunities for civic involvement and is mailed to residents.	The fact sheet or publication is updated about the Plan goals, recommended actions and opportunities for civic involvement, and is distributed to residents.	The fact sheet or publication is updated to reflect Plan goals, recommended actions and opportunities for civic involvement, and is distributed to residents.	$6,000	Local Partners	
Riparian Landowners	Distribute information to riparian landowners about management actions to protect and promote wildlife habitat, and information about programs to fund riparian buffers and wetlands.	A fact sheet is developed and distributed to riparian landowners about Plan goals, recommended BMP's and available resources.	At least 5 site meetings are held with riparian landowners.	--	$2,500	NRCS, UWEX, Washington County, Waukesha County, Dodge County, and Local Partners	Riparian landowners will recognize the unique multipurpose functions of the riparian corridor, and learn about resources available to help them improve management of their lands, and restore/improve in stream conditions.

Table continued on next page.

Table 3.6 (continued)

Information and Education Plan Implementation Matrix							
		Schedule					
Target Audience	Actions	0–2 Years	2–5 Years	5–10 Years	Cost	**Implementation**	**Outcome/Evaluation Metric**
Agricultural Landowners and Operators	Distribute educational information materials about BMP's, and available resources to support implementation.	A fact sheet is developed and distributed to agricultural landowners and operators about Plan goals, recommended BMP's and available resources.	--	--	$1,500	NRCS, UWEX, Washington County, Waukesha County, Dodge County, and Local Partners	Agricultural landowners and operators will be informed about recommended BMP's, funding, and technical assistance resources.
	Individual meetings with landowners and operators to provide information and offer technical assistance.	At least 5 personal contacts are made with landowners, and 5 personal contacts are made with operators.	At least 5 personal contacts are made with landowners, and 5 personal contacts are made with operators.	At least 5 personal contacts are made with landowners, and 5 personal contacts are made with operators.	$3,000	NRCS, UWEX, Washington County, Waukesha County, Dodge County, and Local Partners	The interest in BMP's will increase among agricultural landowners and operators.
	Create opportunities for agricultural landowners and operators to share information and build strong connections with other stakeholders through field meetings, workshops.	At least 2 group meetings are held.	At least 2 workshops or tours are held at a demonstration site.	--	$3,000	NRCS, UWEX, Washington County, Waukesha County, Dodge County, and Local Partners	Agricultural landowners and operators will see successful BMP's and gain knowledge needed to implement similar practices.
		At least 1 educational meeting is held to share information on integrating recommended BMP's effectively.	--	--	$1,000	NRCS, UWEX, Washington County, Waukesha County, Dodge County, and Local Partners	Agricultural landowners and operators will learn emerging strategies in cover crop rotations, reduced tillage and nutrient management.
Non Resident Agricultural Landowners	Convene a webinar designed for absent agricultural property owners informing them of the watershed plan, recommendations and available resources.	At least one webinar is held for landowners who lease agriculture lands.	--	--	$1,000	NRCS, UWEX, Washington County, Waukesha County, Dodge County, and Local Partners	Nonresident landowners will understand the various strategies available to implement BMP's when working with a lease.
Elected Officials	Convene meetings with local officials and community group representatives to encourage new community connections to foster customized solutions to implementation obstacles.	Presentations are given to at least 2 municipal boards.	At least one workshops is held for local officials.	--	$2,400	Local Partners	Increased interest among municipalities to restore and improve the natural hydrological functions of Mason Creek, and partner on recommended projects and programs.
				Total Materials Cost	$27,200[a]	--	--

Note: Local Partners include the following: Towns of Ashippun, Erin, and Merton; North Lake Management District; City of Oconomowoc Wastewater Utility; Tall Pines Conservancy; Rock River Coalition.

[a] *These costs are likely to be offset by the ongoing City of Oconomowoc's Adaptive Management Program, Washington County Land & Water Conservation Division, and Waukesha County Parks and Land Use education and outreach programming activities.*

Source: SEWRPC

- Promote increased stewardship through enhancements of recreational use and access, where practicable.

- Host workshops, meetings, and events that landowners can attend to learn about conservation practices. More specifically, the OWPP should continue to host events such as the 2nd Annual Watershed Paddle and Protect the Monarchs Workshop and the 1st Annual Healthy Lake Conference.

Engagement Strategy

Different target audiences require different educational messages delivered in a customized fashion. The agricultural landowners are the audience with the greatest potential to reduce pollutant loads and to partner to expand wetland and wildlife habitat. It is estimated that a large proportion of the lands in agricultural row crop production are farmed through lease agreements. The landowners who lease their properties often plan to sell their land when development pressure creates a favorable market. Engaging both the landowner and operator requires understanding their perspectives and goals. This will require a greater amount of effort and resources than the other defined target audiences. Farmer-led watershed improvement efforts are working effectively in several locations in the Midwest. **It is recommended that the plan implementing organizations continue to work with stakeholders in the Mason Creek watershed to encourage participation in the Farmer Leadership Group (see Appendix K regarding farmer-led models) established as part of the Oconomowoc Watershed Protection Program (OWPP).**

Other Watershed Initiatives

The Rock River Coalition is a nonprofit organization founded in 1994 that works to build alliances and consensus among all stakeholders to protect the Rock River watershed. Its members are private citizens, businesses, conservation and historic organizations, Chambers of Commerce, and local and State agency staff. Their mission is to educate and provide opportunities for people of diverse interests to work together to improve the environmental, recreational, cultural, and economic resources of the Rock River Basin. The Coalition addresses issues related to the water quality of the Rock River by developing programs such as stream and wetland monitoring programs and convening a task force to improve urban stormwater runoff.

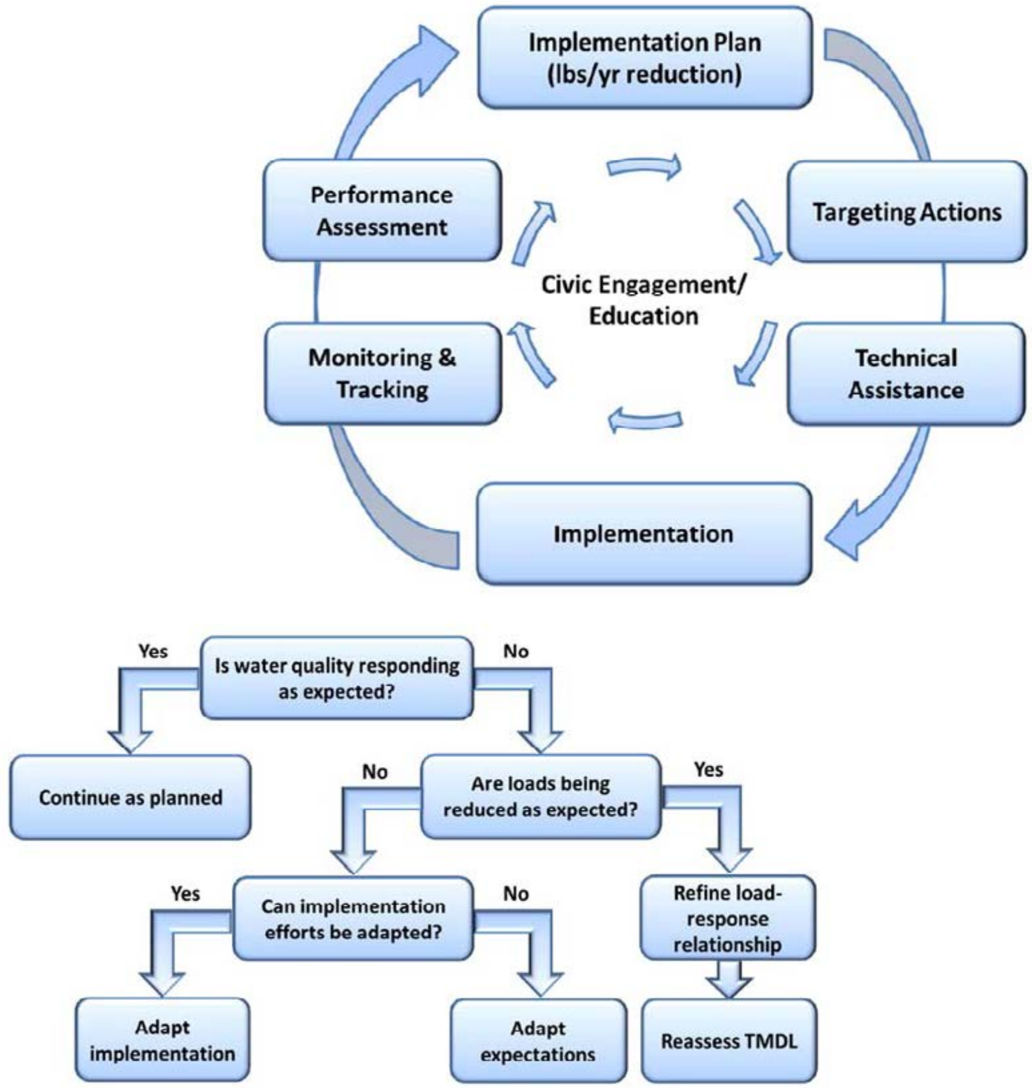
Measuring Plan Progress and Success

Monitoring of plan progress will be an essential component of achieving the desired water quality goals. Plan progress and success will be measured by water quality improvement, progress of best management practice implementation, and by participation rates in public awareness and education efforts.

Adoption of the watershed protection plan by the local legislative bodies and the existing local, county, State, and Federal agencies concerned is recommended and also an essential component of tracking progress and success as well as highly desirable to assure a common understanding among these various entities. In addition, formal plan adoption may also be required for some State and Federal financial aid eligibility. Adoption of the recommended watershed protection plan will assist a unit or agency of government to more fully integrate the protection plan elements into existing work plans and enable staffs to program the necessary implementation work.

Due to the uncertainty of water quality and varied reduction efficiency of the best management practices in this plan, it is recommended that an adaptive management approach be followed in the Mason Creek watershed (see Figure 3.6). Management measures and interim milestones for this watershed plan are summarized in Tables 3.3, 3.4, and 3.6. After the implementation of practices (and monitoring of water quality within Mason Creek) the effectiveness of the plan should be evaluated annually as part of the ongoing OWPP and Adaptive Management Programs as well as every five to ten years coincident with the Washington County and Waukesha County Land and Water Resource Management Plan (LWRMP) updates (see "Tracking of Progress and Success of Plan" section below). If minimum progress is not being made, the plan will be reevaluated and revised with new interim milestones. For purposes of this plan minimum progress means: less than 20 percent of the 0-three year practice milestones are implemented and/or less than 20 percent of required funding is available to implement the 0-th year cost/unit milestones shown within Tables 3.3 and 3.4. Adjustments to this plan will be made based on measured progress towards plan interim milestones and also after any additional new water quality monitoring data, management tools, and/or BMPs are implemented or obtained over time. See "Evaluating the State of Plan Implementation" section below for additional information on tracking progress against this plan's interim milestones.

Figure 3.6
Adaptive Management Implementation Framework and Evaluation Process



Source: Adapted from the Implementation Plan for Lake St. Croix and SEWRPC.

Evaluation of Existing Water Quality Monitoring and Data Collection Programs

Due to ongoing monitoring by the City of Oconomowoc, Water Action Volunteers in partnership with Waukesha County and the North Lake Management District, and special assessment by the University of Wisconsin-Milwaukee, there is a good baseline to assess water quality conditions mostly within the lower and middle portions of Mason Creek. Therefore, continued monitoring at stations and establishing at least two additional stations in upstream reaches in the West Branch Agricultural Ditch and East Branch of Mason Creek (see Map 2.5) will be instrumental in detecting changing trends in the future. More specifically, continued monitoring at these stations may also be used in the future to support the following objectives:

- Determining water quality standards attainment
- Identifying causes and sources of water quality impairments
- Supporting the implementation of water management programs
- Supporting the evaluation of program effectiveness.

The WDNR periodically conducts biological sampling in the watershed. Most recently, in 2014 it conducted fishery and macroinvertebrate surveys at three sampling stations in the mainstem of Mason Creek, which largely indicated that the biological community is meeting fair to good quality standards, but no mussel survey has ever been conducted in this river system. Hence, it is recommended that local partners work with WDNR to conduct surveys on Mason Creek as part of the WDNR Mussel Monitoring Program of Wisconsin.[58]

The North Lake Management District conducts regular water quality monitoring within North Lake, including participation in the WDNR Citizen Lake Monitoring program.

Identification of Additional Monitoring Needs

There are adequate data available to assess the majority of physical, chemical, and biological water quality and designated use standards that need to be assessed to measure the progress and effectiveness of the watershed plan. However, most of this data is focused within the lower portions of the watershed. So, adding at least two monitoring stations in the upper parts of the watershed, one in the West Branch Agricultural Ditch and one in the East Branch of Mason Creek, would greatly assist in determining improvements in water quality as projects are implemented. No recent sampling has been conducted on fecal coliform bacteria or *Escherichia coli* to be able to adequately determine if water use objectives related to these parameters are being met.

Stream Water Quality Monitoring Recommendations

It is important to assess the condition of water quality, biological communities, and habitat in the watershed and determine whether these conditions are improving or deteriorating. It is, therefore, important to establish and maintain a robust program to monitor and assess conditions within the watershed. Such a monitoring program should integrate and coordinate the use of the monitoring resources of multiple agencies and groups, generate monitoring data that are scientifically defensible and relevant to the decision-making process, and manage and report data in ways that are meaningful and understandable to decision makers and other affected parties. This watershed protection plan recommends maintaining the existing monitoring network and expanding monitoring in the watershed to continue to fill data gaps. Toward these ends, the plan includes the following recommendations for water quality monitoring:

1. **That current water quality monitoring program activities in the Mason Creek watershed continue, and the efforts of the local units of government, organizations, and agencies conducting these activities be supported and maintained.**

2. **That the water quality monitoring network in the Mason Creek watershed be expanded and modified as recommended below. It is envisioned that this would be accomplished through the Water Action Volunteers Program (WAV) administered through Waukesha County in collaboration with the WDNR and the University of Wisconsin-Cooperative Extension (UWEX).**[59]

    - **That up to three Level 1 WAV monitoring stations be established during the growing season from May to October, at each of the locations described below.**

        - *Upper Mason Creek at CTH CW (RM 2.5)* – The City of Oconomowoc already monitors for total phosphorus at this location, so additional Level 1 monitoring will add important supplemental information to assess this portion of the mainstem of Mason Creek.[60]

        - The *West Branch Agricultural Ditch site* just upstream of the confluence with the East Branch can be used to monitor that entire subbasin. Permission would need to be obtained from the landowner to access this site.

[58] *Heather Kaarakka, Wisconsin Department of Natural Resources, "Several paths to build up mussels,"* Wisconsin Natural Resources Magazine, *June 2010 (dnr.wi.gov/wnrmag/2010/06/mussels.htm).*

[59] *Water Action Volunteer (WAV) Citizen Stream Monitoring Program, watermonitoring.uwex.edu/wav/monitoring/.*

[60] *Level 1 volunteers monitor dissolved oxygen, temperature, transparency, streamflow, habitat, and macroinvertebrates at each stream site each month from May through October.*

- *The East Branch site* just upstream of the confluence with the West Branch Agricultural Ditch can be used to monitor that entire subbasin. Permission would need to be obtained from the landowner to access this site.

- That the two existing and three proposed WAV sites be upgraded to Level 2 monitoring sites, if funding opportunities are found. This level of WAV monitoring includes deployment of continuous temperature monitoring devices, called thermistors (e.g., HOBOs or TidBits) that are placed in the stream and record temperature every hour until they are removed from the stream and data are downloaded to a computer. In addition, volunteers use meters to monitor pH and dissolved oxygen. The downside is that this level of monitoring will have higher equipment costs. **However, high resolution (i.e., hourly records) water temperature monitoring at these sites is recommended.** In addition to tracking improvements in water quality as BMPs are implemented, this detailed temperature monitoring (along with chemical and biological monitoring) will help distinguish between climate change-related stressors and other anthropogenic (i.e., human induced) stressors, which will provide better understanding and decision-support tools among reaches in this watershed. For example, such detailed monitoring will allow real time tracking of daily maximum temperature extremes within and among reaches, seasonal changes, and year to year changes that could reflect climate change.

- That the two proposed WAV sites in the West Branch Agricultural Ditch and East Branch of Mason Creek be upgraded to Level 3 monitoring sites, at least periodically, particularly to obtain data on total phosphorus concentrations. Since the City of Oconomowoc is already monitoring for total phosphorus at Northwoods Drive (RM 0.04) and CTH CW (RM 2.5), capturing total phosphorus concentrations at each of the suggested stations located farther upstream would help to further refine existing loads/baseline conditions and assess improvements in load reductions in the future, once agricultural BMPs are implemented.

- Encourage the public to volunteer to become “Mud Chasers” as part of a new monitoring program being organized by the City of Oconomowoc. These volunteers will go out in storms and look for areas where sediment is flowing off the land and into waterways.[61] However, it is important to note that permission to monitor runoff will be sought from private landowners. Using rain gauges, cameras, and sampling bottles, the Mud Chasers will focus on specific impaired streams, helping to determine where total suspended sediment/ nonpoint source runoff is coming from within the Mason Creek watershed.

3. **That the WDNR continue to conduct biological monitoring of fishes and macroinvertebrates at the three stations previously sampled, as indicated on Map 2.5, at a minimum of once every three to five years.**

   - That local partners consider conducting wildlife surveys for fishes and other organisms such as mussels, amphibians, and reptiles within the Mason Creek watershed with WDNR staff and/or other wildlife experts. For example, **it is recommended that annual spawning count surveys be conducted in the fall season on the East Branch of Mason Creek, Trib-A, and Lower Mason Creek reaches to identify the number of spawning adult brook trout as well as the location and distribution of redds (i.e., shallow, excavated nests in gravel substrates) among riffle habitats.** However, it is important to note that permission to monitor will need to be obtained from private landowners.

   - **That local partners consider coordinating data collection in the Mason Creek watershed with monitoring in North Lake.** Greater coordination among the time and date of sample collections between these two systems will allow greater interpretation and understanding of realtime conditions and potential linkages or responses between these systems.

All water chemistry samples from the sites should continue to be analyzed by a State-certified lab to analyze trends and gauge the impact of watershed management practices. The monitoring program should continue

[61] *See website for volunteer information, www.oconomowoc-wi.gov/DocumentCenter/View/3470*

to follow the guidance set forth in WDNR protocols and laboratory analysis should follow standards as applicable for stream monitoring.[62] In addition, to assist data reporting and to ensure that data is preserved in a safe and reliable source and is publicly available, **it is recommended that all water quality monitoring continue to be conducted as part of a managed and publicly available (through the WDNR Surface Water Integrated Monitoring System (volunteer access) (SWIMS) database or equivalent) program.**

It is anticipated that the City of Oconomowoc will continue to collect total phosphorus monitoring data on the two stations in Mason Creek on a monthly basis from May through October for at least the next 10 years. Since this monitoring is part of the ongoing compliance for the City of Oconomowoc's WPDES permit and its adaptive management program, the costs for this monitoring are not included under this plan.

It also is anticipated that volunteers will continue to collect monitoring data on a monthly basis in Mason Creek from May through October for the existing two WAV stream sites. It will cost Waukesha County approximately $1,000 over 10 years ($200 per site for laboratory analysis costs for Level 1 monitoring plus $40 per year to cover all five watershed sites for equipment, supplies, shipping and replacement parts) (see Table 3.7) to support monitoring at the three recommended additional sites, assuming volunteer monitoring. However, additional monitoring for nutrients and total suspended solids, should be considered for these sites in Mason Creek.[63] It is anticipated that recruitment, training, and volunteer support costs will be incorporated as part of the ongoing technical services staff support provided by Waukesha County. It is also estimated that upgrading to Level 2 monitoring for all five sites would cost an additional $3,600 over ten years. As shown in Table 3.7, these costs are mostly associated with equipment upgrades. It is anticipated that the City of Oconomowoc Water Utility will continue monitoring for total phosphorus at two of the five recommended monitoring sites. Therefore, it is estimated that Level 3 total phosphorus monitoring at three sites would cost $513 per year and up to $5,130 over ten years. The total cost of water quality monitoring over the 10 year period is estimated to range from $0 (Level 1 monitoring) to up to $8,730 (includes annual Level 2 and 3 monitoring) (see Table 3.7).

Periodically Analyze Monitoring Data and Report Results

Data analysis is an integral component of the water quality management process. For monitoring programs to be useful in guiding management decisions, generating good data is not enough. The data must be processed and presented in a manner that aids understanding of the spatial and temporal patterns in water quality. The data must be placed into a context that reveals the existing state of water quality conditions and any changes or trends occurring in those conditions. This should be a context that takes the natural processes and characteristics of the watershed into account, that allows the impact of human activities upon the watershed to be understood, and that enables the consequences of management action to be predicted. Establishing such a context requires that monitoring data be periodically analyzed, interpreted, and summarized. This should be done at a frequency that provides decision makers and managers with reasonably current information while recognizing the substantial effort that is required to analyze and interpret data from all the sites within the watershed.

Therefore, to assist data reporting, **it is recommended that all existing and any future water quality monitoring data for Mason Creek be preserved in a safe and reliable source, and that the data be publicly available.**

It is recommended that monitoring data for the Mason Creek watershed be collated, analyzed, and reported at one-year intervals by the City of Oconomowoc, and incorporated in the relevant County land and water resource management plan at five-year intervals. The analyses, results, and conclusions of those reports should be published and made available to the public and to the agencies and organizations involved in the management of the Mason Creek watershed.

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[62] *Wisconsin State Laboratory of Hygiene, see website at www.slh.wisc.edu/research/capabilities/*

[63] *For about $90 per sample, the University of Wisconsin-Steven Point lab can analyze total suspended solids, chloride, ammonium nitrogen, nitrate + nitrite, reactive and total phosphorus, and total Kjeldahl nitrogen.*

Table 3.7
Estimated Costs for Water Quality Monitoring Recommendations: 2015

Water Quality Monitoring	Level 1 Cost[a] ($ dollars)	Level 2 Cost[b] ($ dollars)	Level 3 Cost[c] ($ dollars)
East Branch headwaters of Mason Creek – **Proposed New Site**	0 (200 per sampling kit)	400 ($200 tidbit meter/5 years) 0 (YSI meter shared)	2,400 (40 per sample x 6 samples/year x 10 years)
West Branch Agricultural Ditch – **Proposed New Site**	0 (200 per sampling kit)	400 (200 tidbit meter/5 years) 0 (YSI meter shared)	2,400 (40 per sample x 6 samples/year x 10 years)
Upper Mason Creek at CTH CW (RM 2.50) – **Proposed New Site**	0 (200 per sampling kit)	400 (200 tidbit meter/5 years) 0 (YSI meter shared)	0[d]
Lower Mason Creek at Petersen Road (RM 0.30) – *Existing Monitoring Site*	0	400 (200 tidbit meter/5 years) 0 (YSI meter shared)	Not recommended
Lower Mason Creek at Northwoods Drive (RM 0.10) – *Existing Monitoring Site*	0	400 (200 tidbit meter/5 years) 1,000 (YSI meter shared among all sites)	0[d]
Supplies and replacement parts for all sites	0 (40/year x 10 years)	250 (25/year x 10 years) 100 (software) 250 (data shuttle)	330 (11/sampling year x 3 sites x 10 years)
Total Cost	0	3,600	5,130

Note: It is anticipated that all monitoring be conducted as part of ongoing Waukesha County Water Action Volunteer (WAV) stream monitoring program, which will provide recruitment, training, and volunteer support services for all (Level 1 through 3) monitoring.

[a] *If the volunteer monitors are trained and run through the Waukesha County WAV program, monitoring equipment kits and supplies estimated to cost about $1,000 over ten years, will be provided. Volunteers are expected to collect monitoring data monthly from May – October.*

[b] Due to limited availability of tidbit programmable temperature dataloggers and YSI meters, Waukesha County cannot guarantee availability of this equipment, so purchase of this equipment is necessary. The battery in the Tidbit meter is non-replaceable and designed to last five years. A one-time purchase for software and data shuttle totaling $350 to manage, program, and download data from the loggers is included.

[c] These are based upon year 2015 cost estimates and sample laboratory costs include shipping.

[d] It is anticipated that the City of Oconomowoc Water Utility will continue monitoring for total phosphorus monthly from May to October at this site.

Source: WDNR, Waukesha County, City of Oconomowoc Water Utility, and SEWRPC

Implementation Tracking Mechanism

For this plan to be most effective, it is important to track the projects and recommendations that are implemented. This could be best accomplished by having a reporting mechanism through which the organizations implementing recommendations of this plan report the initiation and completion of projects to some agency or agencies that would oversee the monitoring of implementation. The role of the overseeing agency or agencies would be to receive these reports, periodically compile this information, and evaluate the status of the implementation of the watershed restoration plan.

As described in more detail in the "Tracking of Progress and Success of Plan" section below, **it is recommended that all organizations acting to implement this plan report the initiation and completion of projects implementing plan recommendations to the City of Oconomowoc and That the City work with Washington and Waukesha County staff to identify ongoing and completed implementation projects.**

Evaluating the State of Plan Implementation

It is recommended that the Mason Creek Watershed Plan Advisory Group be maintained as a continuing committee to provide advice and coordination for plan implementation and to evaluate the state of implementation of this plan. Consideration should be given to adding members to this Group as needed, with these additional members being drawn primarily from local units of governments and private organizations that are actively implementing plan recommendations.

It is recommended that the Advisory Group meet annually (at a minimum) to evaluate the status of plan implementation. This evaluation will include review of the project reports from all group members as well as other available information relevant to evaluating plan implementation.

The Advisory Group will evaluate progress in plan implementation against the milestones set forth in Table 3.3. These milestones reflect the land areas affected, load reductions, and schedule for plan implementation set forth in Table 3.4 and 3.6. In addition, it is also recommended that the EPA technical memorandum on agricultural BMP depreciation be reviewed and used to determine whether this plan's estimated load reductions are being achieved/maintained over time or need to be revised based upon actual performance or depreciation.[64] Based upon its evaluation, the Advisory Group will make a determination as to whether plan implementation is proceeding in accordance with the schedule. Based upon this determination, it will provide advice to organizations implementing the plan regarding implementation strategies.

As part of its review process, and consistent with the adaptive management approach as shown in Figure 3.6, the Advisory Group will examine the plan and efforts to implement it to determine whether any adjustments or modifications in plan recommendations or priorities are warranted. The issues that should be addressed in this review include, but are not limited to:

- Whether conditions within the watershed have changed in ways that require adjustment of the plan
- Whether public priorities with respect to the focus areas of the plan have changed
- Whether the regulatory environment with respect to the focus areas of the plan has changed
- The degree and extent of progress made in implementing recommended actions
- Whether the elements and priorities of the plan need modification
- Whether new plan elements are needed
- Whether applicable funding programs and levels of funding have changed

Tracking of Progress and Success of Plan

As summarized in the "Driving Forces" section above, the City of Oconomowoc has developed the Oconomowoc watershed program to monitor and curtail nutrient pollution throughout the entire Oconomowoc River watershed. The City has established and implemented a comprehensive monitoring program and appointed a part-time administrator to facilitate and implement improvement projects and information and education programming throughout the Oconomowoc River watershed, which includes the Mason Creek watershed. Hence, the City and its partners, through the Oconomowoc watershed program group, are already implementing a range of agricultural projects and educational programs, as well as monitoring some 30 sites around the watershed.

The State also requires that Counties administer a variety of programs and regulations related to the protection of land and water resources. Hence, both Washington County and Waukesha County are already committed to monitoring, tracking, and evaluating conservation activities, actions, policies, and programs to address land and water resources management concerns and issues as part of their five-year workplan (i.e., Land and Water Resources Management Plan).

Therefore, **it is recommended that the City of Oconomowoc be the lead entity responsible for tracking progress of this plan and that the city work with Washington and Waukesha Counties ion that effort. The extent of this tracking is largely contingent upon continued collaboration and support of local partners. Hence, City of Oconomowoc staff may need to increase communication and coordination among County staff along with NRCS, WDNR, and other local partners to track**

[64] *Donald W. Meals and Steven A. Dressing.* Technical Memorandum #1: Adjusting for Depreciation of Land Treatment When Planning Watershed Projects, *October 2015. Developed for U.S. Environmental Protection Agency by Tetra Tech, Inc., Fairfax, VA, 16 p. Available online at www.epa.gov/sites/production/files/2015-10/documents/tech_memo_1_oct15.pdf*

progress, report implementation of practices, and improvements in water quality over time. Reports should be completed annually by the City of Oconomowoc, and an intensive review and analysis of plan implementation success should be conducted at five to ten-year intervals, incorporating information from the Washington County and Waukesha County Land and Water Resources Management Work Plans.

Progress and success of implementation of the Mason Creek watershed protection plan should be tracked based on the following four metrics: 1) Information and education activities and participation, 2) Pollution reduction evaluation based on BMPs installed, 3) Water quality monitoring, and 4) Administrative review (see below for more details).

Nearly all the local partners or Advisory Group members implement information and education activities throughout the watershed, so **it is important that each of these agencies and/or organizations provide a brief summary update of activities to the City of Oconomowoc for inclusion in the annual watershed report. The Advisory Group should consider designating a member to attend the annual Rock River Coalition (RRC) meeting to stay informed regarding ongoing progress and activities in the larger Rock River basin.**

1. Information and education reports should include:
    a. Number of landowners/operators in the watershed
    b. Number of eligible landowners/operators in the watershed
    c. Number of landowners/operators contacted
    d. Number of cost-share agreements signed
    e. Number and type of information and education (I&E) activities held, who led the activity, how many were invited, how many attended, and any measurable results of I&E activities
    f. Number of informational flyers/brochures distributed per given time period
    g. Number of individual contacts with landowners in the watershed
    h. Comments or suggestions for future activities
2. Pollution reduction management measures reporting should consider the following elements:
    a. Planned and completed BMPs
    b. Pollutant load reductions and percent of goal planned and achieved
    c. Cost-share funding source of planned and installed BMPs
    d. Numbers of field checks to make sure nutrient management plans are being followed by landowners
    e. Number of field checks to make sure practices are being operated and maintained properly
    f. Tracking of the agricultural fields and practices selected and funded by a point source to meet permit compliance requirements through adaptive management or water quality trading to assure that Section 319 funds are not being used to implement practices that are part of a point source permit compliance strategy
    g. Number of new and alternative technologies and management measures used and incorporated into the plan

3. Water Quality Monitoring Reporting Parameters:

    a. Annual summer and monthly mean total phosphorus concentrations from City of Oconomowoc stream monitoring stations

    b. Total phosphorus, dissolved reactive phosphorus, total suspended solids, temperatures, and clarity data from volunteer sampling (Water Action Volunteer Monitoring Program and Citizen Lake Monitoring on North Lake)

    c. Macroinvertebrate Index of Biotic Integrity (WDNR and Water Action Volunteer Monitoring Program)

    d. Fishery Index of Biotic Integrity and species abundance and diversity; brook trout abundance, including improvements in spawning, juvenile, and adults; and improvements in fish species diversity and abundance in North Lake, particularly improvements in the abundance of the two-story (Cisco Coregonus artedii or Lake Herring) coldwater fishery, (WDNR or University staff)

4. Administrative Review tracking and reporting should include:

    a. Status of grants relating to project

    b. Status of project administration including data management, staff training, and BMP monitoring

    c. Status of nutrient management planning and easement acquisition and development

    d. Number of cost-share agreements

    e. Total amount of money spent on cost-share agreements

    f. Total amount of landowner reimbursements

    g. Staff salary and fringe benefits expenditures

    h. Staff travel expenditures

    i. Information and education expenditures

    j. Equipment, materials, and supply expenses

    k. Professional services and staff support costs

    l. Total expenditures among Counties

    m. Number of adaptive management contracts

Information and Education Indicators of Success

The indicators of success and targeted schedule of completion are provided in Table 3.6.

Water Quality Monitoring Indicators of Success

Water quality monitoring indicators of success for the Mason Creek watershed would include achievement of applicable water quality criteria for coldwater streams including temperature, non-regulatory water quality guidelines, and progress toward annual and daily load and wasteload allocation reduction goals for phosphorus and sediment (see Table 2.1 through 2.6 in Chapter 2 of this report). Water quality indicators should also include biological quality (e.g., improvement of the fishery community coldwater IBI classification) and habitat quality criteria and/or targets for the Mason Creek watershed (see Tables 2.9, 2.11, and 2.16 in Chapter 2 of this report). Other plan recommendations, particularly some of those focused on habitat improvement, may produce ancillary water quality benefits, but such benefits were not directly quantifiable in terms of a pollutant load reduction (e.g., floodplain connectivity or fish passage improvements). Indicators of success for management measures are set forth in Table 3.1 and additional hydrologic, hydraulic, geomorphologic, physiochemical, and biological functional parameters to monitor are listed in Figure 3.1 (see "Stream Functions Pyramid - A Tool for Assessing Success of Stream Restoration Projects" section above).

Any improvements in the abundance, distribution, and population size structure (i.e., survival, growth, and reproduction) of brook trout within Mason Creek also would be an indicator of water quality success. Such an assessment would consider expansion of spawning areas, number of spawning adults, number of spawning redds, hatching success, overwintering juvenile abundance, and increases in the number of juvenile and adult fishes. Improvement of the fishery community IBI coldwater classification and in macroinvertebrate indices, including mussel species diversity and abundance, are another key water quality indicators of success in the Mason Creek watershed.

Improvements in water quality indicators in North Lake should also be considered as indicators of success. More specifically, reduced pollutant loads to surface waters within the Mason Creek watershed should produce improvements in water quality constituents in North Lake such as total phosphorus, secchi depth, chlorophyll-*a*, water temperature, and dissolved oxygen, and in the fishery community abundance and diversity. **It is recommended that improvement of the cisco population in North Lake and restoration of the "two story" fishery be used as assessment criteria to determine whether implementation of pollutant load reductions within the Mason Creek watershed are successful.** Using the estimated oxythermal niche boundary, which is a combination of limiting dissolved oxygen (DO) concentrations and temperatures, would provide a benchmark for quantifying potential refuge habitat in North Lake and potential risks of extinction and for measuring the effectiveness of efforts in the Mason Creek watershed in protecting North Lake. Hence, the effects of hypolimnetic oxygen changes on cisco thermal habitat could be quantified without having to conduct fishery surveys by comparing relative positions of oxythermal conditions measured with ongoing summer profiles collected on North Lake. Mapped profiles of temperature and DO concentrations through the entire water column would probably approach the oxythermal niche boundary (e.g., lethal temperature is 23.0°C at 5.0 mg/L DO concentration, 22.0°C at 3.0 mg/L DO concentration, and 19.5°C at 1.0 mg/L DO concentration) as thermal habitat deteriorates, particularly in late summer.[65] In other words, because cisco require cold well-oxygenated waters, they are sentinels of the health of the lakes they inhabit, so increased abundance of the existing self-sustaining naturally reproducing population of cisco within North Lake would be a key indicator that the overall quality of the Lake ecosystem is improving. This should be considered as part of the evaluation of the overall effectiveness of plan implementation.

In addition, continuous long-term temperature monitoring can help distinguish climate-induced environmental changes from other anthropogenic alternations or stressors such as pollutant loads, non-native species, or habitat degradation.[66] For example, establishing that mean or maximum daily water temperatures do not exceed or continue to not exceed 21.0°C among reaches, which is the ecological temperature threshold for brook trout,[67] would be an indicator of water quality success. Such improvements would also be key indicators of sustained and/or improvements in groundwater discharge or stream shading habitat enhancements. In contrast, a documented trend of increases in mean or maximum daily temperatures over time would be an indicator of global climate warming impacts or stressors within Mason Creek, which would allow more informed decision making and adjustment of management strategies.

3.7 COST ANALYSIS

Cost estimates based on current USDA NRCS payment rates for adoption of conservation practices, incentives payments to attain necessary farmer participation, and installation rates for conservation projects are summarized in Table 3.8. Current conservation project installation rates were obtained through

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[65] *Peter C. Jacobson and others, "Field Estimation of a Lethal Oxythermal Niche Boundary for Adult Ciscoes in Minnesota Lakes," Transactions of the American Fisheries Society, Volume 137, pages 1464-1474, 2008.*

[66] *James E. Whitney and others, "Physiological Basis of Climate Change Impacts on North American Inland Fishes," Fisheries, Volume 41(No.7), pages 333-345, July 2016.*

[67] *Chadwick, J.G., K.H. Nislow, and S.D. McCormick, "Thermal Onset of Cellular and Endocrine Stress Responses Corresponding to Ecological Limits in Brook Trout, and Iconic Cold-Water Fish," Conservation Physiology, 3:cov017, 2015.*

Table 3.8
Typical Costs for Management Measures

BMP	Quantity[a]	Cost per Unit (dollars)	Total Cost (dollars)
Upland Control			
No Till[b] (acres)	494	19.64	9,702
Cover Crops[b] (acres)	987	60.15	59,368
Nutrient Management[b] (acres)	987	53.00	52,311
Grass Waterways (linear feet)	4,392	4.44	19,500
Riparian Buffers/Wetland Restoration/Filter Strips (acres)	355	4,000.00	1,420,000
Streambank Erosion Control			
Bank Stabilization, High Priority[c] (linear feet)	114	61.4	7,000
Technical Assistance			
Conservation/Project Coordinator	--[d]	--[d]	--[d]
Additional Wetland and Stream Measures (see Map 3.1 for locations)			
Hydrologic Restoration with Ditch Plug (see Appendix H)	100 foot long embankment example	6,299.78	--[e]
Grade Control Structures			
Sedimentation Basin	900 cubic yards example size	4,106.81	--[e]
Ditch Check/Check dams (see Appendix G)	10 foot width typical roadside ditch	200	--[e]
Stream Remeandering	One linear foot of restored stream	100.00	--[e]
Riverine Channel and Floodplain Restoration	15 acres (scenario typical size)	8,252.34	--[e]

[a] *See Table 3.4.*

[b] *Estimated costs based on cost-sharing for three years.*

[c] *Locations of all streambank erosion sites are identified on Map B.3 in Appendix B. Low priority sites are not represented in this table and are not recommended to be addressed at this time.*

[d] *It is assumed that the City of Oconomowoc's Adaptive Management Program/Oconomowoc Watershed Protection Program (OWPP) Coordinator will continue to be funded along with NRCS staff and* ongoing Washington County Land & Water Conservation Division staff and Waukesha County Parks and Land Use staff *to implement projects over the next 10 year time period. Financial packages are available for farmers to implement agricultural BMPs through the OWPP. In addition, the OWPP will pay farmers up to $250/acre/year for any agricultural land taken out of crop production. Contact Darrell Smith, Watershed Agriculture Coordinator (phone: 414-313-4323, email: natural@sbcglobal.net), or Thomas Steinbach, Watershed Director (phone: 262-569-2192, email: tsteinbach@oconomowoc-wi.gov), from the OWPP for more information.*

[e] *Due to the uncertainty of the number and/or size of these potential BMPs, permitting issues, design costs, and willingness of landowners, it was not feasible to calculate a total project cost for these practices.*

Source: Natural Resource Conservation Service and SEWRPC

conversations with county conservation technicians, UW-Extension, and NRCS staff. The total cost to implement the watershed plan over 10 years is estimated to be **$1,603,811**, as shown below.

- **$1,567,881 to** implement best management practices (see Tables 3.4 and 3.8)
- **$27,200** needed for Information and Education (see Table 3.6)
- From **$0** (Level 1 monitoring) to **$8,730** (Level 2 and 3 monitoring, rather than Level 1) needed for Water Quality Monitoring (see Table 3.7)
- Technical assistance will continue to be provided through ongoing programs

Table 3.9
Comparison of Adaptive Management and Water Quality Trading

Adaptive Management	Water Quality Trading
Receiving water is exceeding phosphorous loading criteria	The end of pipe discharge is exceeding the allowable limit
More flexible and adaptive to allow cropland practices to show reductions over extended time period	Not as flexible, needs to show stable reductions year to year
Does not use "trade ratios" as modeling factor	Uses "trade ratios" as margin of error factor
Uses stream monitoring to show compliance	Uses models such as SNAP+ or BARNY to show compliance with reduction in loading
Typically used for phosphorus compliance only	Can be used for a variety of pollutants, not just phosphorus
Can be used to quantify phosphorus reductions for up to 15 years	Can be used to demonstrate compliance indefinitely as long as credits are generated

Source: Outagamie County Land Conservation Department, Nonpoint Source Implementation Plan for the Plum and Kankapot Creek Watersheds, *2014*

The City of Oconomowoc's Adaptive Management Program/Oconomowoc Watershed Protection Program (OWPP) Coordinator will continue to be funded by the City of Oconomowoc along with NRCS staff and ongoing Washington County Land & Water Conservation Division staff and Waukesha County Parks and Land Use staff to provide technical assistance to implement projects over the next 10 year time period.

It is also important to note that the summary of total project costs above does not include several additional wetland and stream restoration practices that include: ditch plugs, grade control structures (sedimentation basins and check dams), stream remeandering, and riverine channel and floodplain restoration (see Table 3.8). Due to the uncertainty of the number and/or size of these potential BMPs, permitting issues, and willingness of landowners to implement the projects, it was not feasible to calculate a total cost for these practices. However, approximate unit area costs were provided for each of these practices as shown in Table 3.8 to help develop cost estimates to implement these projects in the future. In addition, all of these practices are cost sharable through the OWPP and/or NRCS programs, which means that technical assistance for design and permitting costs are also supported.

Operation and Maintenance

This plan will require a landowner to agree to a five or 10-year maintenance period for practices such as vegetated buffers/wetland restoration, grassed waterways, and streambank stabilization. For practices such as no till, cover crops, and nutrient management, landowners are required to maintain the practice for each period that cost sharing is available.

3.8 FUNDING SOURCES

There are several State and Federal programs as well as local entities that currently provide funding for conservation practices as listed and briefly described below. However, as previously noted, the greatest potential for funding projects within the Mason Creek watershed is through the City of Oconomowoc Wastewater Utility's recently established "Adaptive Management Program" to address its permitted phosphorus point source loads.[68]

The Adaptive management approach was determined to provide the most economically feasible option for the City of Oconomowoc Wastewater Utility to meet their wasteload allocation. Under that approach, point sources (i.e., City of Oconomowoc) provide funding for best management practices to be applied in the Oconomowoc River watershed and receive credit for the pollution load reductions from those practices. Federal Clean Water Act Section 319 nonpoint source management funds cannot be used implement practices that are part of a point source permit compliance strategy. Adaptive management focuses on compliance with phosphorus criteria, as opposed to the water quality trading option, which focuses on compliance with a discharge limit (see Table 3.9).

[68] *The WDNR approved the City of Oconomowoc's Adaptive Management Plan (AMP) for the Oconomowoc River watershed on September 15, 2015 (see "Linking the TMDL to Implementation" section above for more details).*

Adaptive management is a phosphorus compliance option that allows point and nonpoint sources (e.g., agricultural producers, stormwater utilities, wastewater treatment plants, and developers) to work together to improve water quality in those waters not meeting phosphorus water quality standards. This option recognizes that the excess phosphorus accumulating in lakes and streams comes from a variety of sources, and that reductions in both point and nonpoint sources are frequently needed to achieve water quality goals. By working in their watershed with landowners, municipalities, and counties to target sources of phosphorus runoff, point source dischargers can minimize their overall investment while helping achieve compliance with water quality-based criteria and improving water quality. Guidance is available from the WDNR that describes adaptive management and how to develop a successful adaptive management strategy.[69] Adaptive management is only applicable to phosphorus discharges.

The Oconomowoc Watershed Protection Program (OWPP) was the first adaptive management program of its kind in the State and in the nation. The OWPP, which included a partnership with the NCRS, was awarded a Regional Conservation Partnership Program (RCPP) grant in 2015 (see "Driving Forces" section above for more details). This partnership allows funding from the NRCS, the City of Oconomowoc, and other project partners to be used to offer incentives and matching funding for projects and practices to reduce phosphorus loads to the streams of the Oconomowoc River watershed, including Mason Creek. Hence, the Oconomowoc Adaptive Management program offers a flexible and robust cost share funding program to assist landowners/farmers with the installation of upgraded conservation practices in agricultural and urban landscapes. For example, financial packages are currently available for farmers to implement agricultural BMPs through the OWPP and/or the NRCS programs. In addition, the OWPP will pay farmers up to $250/acre/year for any agricultural land taken out of crop production.[70]

Through these efforts, a significant reduction in phosphorus-laden runoff entering the lakes and streams of the Oconomowoc River watershed (including Mason Creek) is anticipated within the next 10 years. Other benefits of the OWPP in addition to improving surface water quality will be enhanced habitat and wildlife, reduced aquatic weed growth and algal blooms, and, removal of currently-impaired waters from the Federal Clean Water Act Section 303(d) impaired waters list.

Federal and State Funding Sources

Brief descriptions of available funding programs are set forth below:

- **Environmental Quality Incentives Program (EQIP)—**Federal program that provides financial and technical assistance to implement conservation practices that address resource concerns. Farmers receive flat rate payments for installing and implementing runoff management practices. It is important to note that the current Regional Conservation Partnership Program (RCPP) grant for the Oconomowoc River watershed is provided through EQIP, so landowners in the Mason Creek watershed should contact the City of Oconomowoc to participate in this program. The following agricultural practices are eligible for cost sharing (see also documents posted on the Wisconsin NRCS website and payment rates for the Oconomowoc River RCPP-EQIP):

    - Access Control
    - Access Road
    - Composting Facility
    - Conservation Cover
    - Contour Buffer Strips
    - Contour Farming
    - Residue Management/No-Till
    - Riparian Forest Buffer
    - Roof Runoff Structure
    - Sediment Basin
    - Spoil Spreading
    - Stream Crossing

[69] *Wisconsin Department of Natural Resources,* Adaptive Management Technical Handbook: A Guidance Document for Stakeholders*, Guidance Number 3800-2013-01, January 7, 2013.*

[70] *Contact Darrell Smith, Watershed Agriculture Coordinator (phone: 414-313-4323, email: natural@sbcglobal.net), or Thomas Steinbach, Watershed Director (phone: 262-569-2192, email: tsteinbach@oconomowoc-wi.gov), from the OWPP for more information.*

- Cover Crop
- Critical Area Planting
- Diversion
- Fence
- Field Border
- Filter Strip
- Forage and Biomass Planting
- Grade Stabilization Structure
- Grassed Waterway
- Heavy Use Area Protection
- Lined Waterway or Outlet
- Livestock Pipeline
- Mulching
- Obstruction Removal
- Prescribed Grazing
- Streambank and Shoreline Protection
- Strip cropping
- Structure for Water Control
- Subsurface Drain
- Terrace
- Trails and Walkways
- Tree/Shrub Establishment
- Tree/Shrub Site Preparation
- Underground Outlet
- Vegetated Treatment Area
- Water and Sediment Control Basin
- Water Well
- Watering Facility
- Wetland Restoration

- **Conservation Reserve Program (CRP)—**A Federal land conservation program administered by the Farm Service Agency. Farmers enrolled in the program receive a yearly rental payment for environmentally sensitive land that they agree to remove from production. Contracts are 10 to 15 years in length. Eligible practices include buffers for wildlife habitat, wetland buffers, riparian buffers, wetland restoration, filter strips, grass waterways, shelter belts, living snow fences, contour grass strips, and shallow water areas for wildlife.

- **Conservation Reserve Enhancement Program (CREP)—**Federal program provides funding for practice installation, rental payments, and an installation incentive. A 15-year contract or perpetual contract conservation easement can be entered into. Eligible practices include filter strips, buffer strips, wetland restoration, tall grass prairie and oak savanna restoration, grassed waterway, and permanent native grasses.

- **Agricultural Conservation Easement Program (ACEP)—**New Federal program that consolidates three former programs (Wetlands Reserve Program, Grassland Reserve Program, and Farm and Ranchlands Protection Program). Under this program, NRCS provides financial assistance to eligible partners for purchasing Agricultural Land Easements that protect the agricultural use and conservation values of eligible land.

- **Targeted Runoff Management (TRM) Grant Program—**State program that offers competitive grants for local governments for controlling nonpoint source pollution. Grants reimburse costs for agricultural or urban runoff management practices in critical areas with surface water or groundwater quality concerns. The cost-share rate for TRM projects is up to 70 percent of eligible costs.

- **Conservation Stewardship Program (CSP)—**Federal program that offers funding for participants that take additional steps to improve resource condition. Program provides two types of funding through five-year contracts: 1) annual payments for installing new practices and maintaining existing practices and 2) supplemental payments for adopting a resource-conserving crop rotation.

- **Farmable Wetlands Program (FWP)—**Federal program designed to restore previously farmed wetlands and wetland buffer to improve both vegetation and water flow. The Farm Service Agency runs the program through the Conservation Reserve Program with assistance from other government agencies and local conservation groups.

- **Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP)—**Beginning in 2016, grants will become available for farmer-led projects to protect water quality in Wisconsin. DATCP will administer this program. Grant funding will be available for farmer-led activities to reduce nonpoint source pollution in their watersheds.[71] Farmer-led groups must:
    - Include at least five eligible farmers who form a group in collaboration with a government agency, an educational organization, or a nonprofit conservation group
    - Help other farmers in the watershed voluntarily work to reduce nonpoint source pollution
    - Contribute at least 50 percent of the costs that are eligible for grant funds
- **Wisconsin Department of Natural Resources (WDNR)—**Beginning in 2016, grants are available to establish streambank easements along Mason Creek.[72] The Knowles-Nelson Stewardship - Stream Bank Protection Program (SBP) aims to provide public access for angling and protect water quality and fish habitat along quality streams threatened by agricultural and urban runoff.

    The SBP purchases easements directly from landowners. In return for payment, the landowner allows public fishing and WDNR management activities along the stream corridor on his or her property. The easement area is generally 66 feet of land from the streambank on either side of the stream. Easements are perpetual and remain on the land even if it sold or deeded to an heir. The SBP program has been popular with landowners and anglers. Landowners enjoy the ability to sell part of their rights in their property and in some cases get assistance in restoring the stream corridor from WDNR or local conservation clubs, while anglers enjoy access to streams that provide high quality recreational experiences.

Local Funding Sources
Brief descriptions of available funding organizations are set forth below:

Land Trusts
Landowners also have the option of working with a land trust to preserve land. Land trusts preserve private land through conservation easements, purchase land from owners, and accept donated land. Tall Pines Conservancy is a very active land trust working within the Mason Creek watershed and a key partner of the Oconomowoc Watershed Protection Program (OWPP).[73]

North Lake Management District
Landowners also have the option of working with the North Lake Management District to implement projects.[74] The North Lake Management District has provided funding to reduce pollutant loads entering Mason Creek through establishing riparian buffers adjacent to cropland and reducing streambank erosion (see Figures 2.29 and 2.31).

Trout Unlimited
Landowners could partner with the Southeast Wisconsin Chapter of Trout Unlimited (TU) to help fund projects, because Mason Creek is a trout stream. TU is a national organization dedicated to conserve, protect, and restore North America's coldwater fisheries and their watersheds.[75] TU has been involved in many fisheries restoration projects with experience in collaborative work at the local, state and national levels.

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[71] *See website at datcp.wi.gov/Environment/Land_and_Water_Conservation/index.aspx?Id=237*

[72] *See website for more details at dnr.wi.gov/topic/fishing/streambank/*

[73] *See website for contacts and information at tallpinesconservancy.org/*

[74] *See website for contacts at nlmd.org/*

[75] *See Southeast Wisconsin Chapter website for contacts at www.tu.org/conservation/conservation-issues*

APPENDIX A

INFORMATIONAL MEETING ATTENDEES, WORK GROUP MEMBERS, AND PARTNERS

Figure A.1
Informational Meeting Attendees, Work Group Members, Technical Assistance, and Grant Partners Contributing to Development of the Mason Creek Watershed Protection Plan

INFORMATIONAL/COMMUNITY MEETING DATES AND LOCATIONS:

March 19, 2013	**Town Hall Library, North Lake** N76 W1429 HWY VV North Lake, WI 53064
July 23, 2013	**Town Hall Library, North Lake** N76 W1429 HWY VV North Lake, WI 53064
April 28, 2014	**Tall Pines Conservancy Office** N44 W32882 Watertown Plank Road Nashotah, WI 53058
September 29, 2014	**Southeastern Wisconsin Regional Planning Commission** W239 N1812 Rockwood Drive Waukesha, WI 53187
July 28, 2015	**Merton Town Hall** W314 N7624 HWY 83 North Lake, WI 53064

INFORMATIONAL MEETING ATTENDEES AND WORK GROUP PLAN CONTRIBUTORS

Name	Affiliation
Dave Arnot	Ruekert & Mielke, Inc.
Megan Beauchaine	Southeastern Wisconsin Regional Planning Commission
Jill Bedford	Tall Pines Conservancy
Ben Benninghoff	Wisconsin Department of Natural Resources
Nick Besasie	USDA Natural Resources Conservation Services
Susan Buchanan	Tall Pines Conservancy
Lisa Conley	Rock River Coalition
Dave Cox	Village of Hartland
Andrew Craig	Wisconsin Department of Natural Resources
Kenneth Denow	Consultant for Oconomowoc Watershed Protection Program
Karen Doyle	Waukesha County
Jason Freund	Carroll University
Don Gallo	Reinhart Law
Amy Garbe	Faye Gehl Foundation
John Gehl	Wisconsin Department of Natural Resources
Ellen Gennrich	Waukesha County Land Conservation
Marilyn Haroldson	Town of Merton
Lori Hazel	Concerned Citizen
Mike Hazel	Concerned Citizen
Don Heilman	Concerned Citizen
Jerry Heine	North Lake Management District
Eric Hyde	Washington County
Ken Lane	Concerned Citizen
James Jackley	Wisconsin Department of Natural Resources
Ben Johnson	Concerned Citizen
Marlin Johnson	Waukesha County Land Conservation

INFORMATIONAL MEETING ATTENDEES AND WORK GROUP PLAN CONTRIBUTORS (continued)

Name	Affiliation
Mike Lawton	Concerned Citizen
Perry Lindquist	Waukesha County
Michelle Lehner	Wisconsin Department of Natural Resources
Jon McAnolly	Concerned Citizen
Maureen McBroom	Wisconsin Department of Natural Resources
John Muehl	North Lake Management District
Zofia Noe	Southeastern Wisconsin Regional Planning Commission
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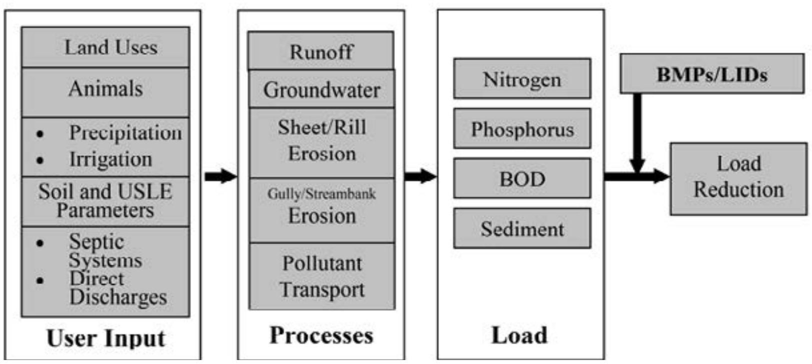
Southeastern Wisconsin Regional Planning Commission
Tall Pines Conservancy
University of Wisconsin-Extension
Washington County
Waukesha County
Wisconsin Department of Natural Resources

APPENDIX B

STEPL LOADING RESULTS FOR THE MASON CREEK WATERSHED

Spreadsheet Tool for the Estimation of Pollutant Load *(excerpt from STEPL 4.1 User's Guide*):
The Spreadsheet Tool for the Estimation of Pollutant Load (STEPL) employs simple algorithms to calculate nutrient and sediment loads from different land uses and the load reductions that would result from the implementation of various best management practices (BMPs). It computes surface runoff; nutrient loads, including nitrogen, phosphorus, and 5-day biological oxygen demand (BOD5); and sediment delivery based on various land uses and management practices. The land uses considered are urban land, cropland, pastureland, feedlot, forest, and a user-defined type. The pollutant sources include major nonpoint sources such as cropland, pastureland, farm animals, feedlots, urban runoff, and failing septic systems. The types of animals considered in the calculation are beef cattle, dairy cattle, swine, horses, sheep, chickens, turkeys, and ducks. For each watershed, the annual nutrient loading is calculated based on the runoff volume and the pollutant concentrations in the runoff water as influenced by factors such as the land use distribution and management practices. The annual sediment load (from sheet and rill erosion only) is calculated based on the Universal Soil Loss Equation (USLE) and the sediment delivery ratio. The sediment and pollutant load reductions that result from the implementation of BMPs are computed using the known BMP efficiencies.

The input data include state name, county name, weather station, land use areas, agricultural animal numbers, manure application months, population using septic tanks, septic tank failure rate, direct wastewater discharges, irrigation amount/frequency, and BMPs for simulated watersheds. When local data are available, users may choose to modify the default values for USLE parameters, soil hydrologic group, nutrient concentrations in soil and runoff, runoff curve numbers, and detailed urban land use distribution. Pollutant loads and load reductions are automatically calculated for total nitrogen, total phosphorus, BOD5, and sediment.



STEPL is designed for the Grants Reporting and tracking System of the U.S. Environmental Protection Agency.

STEPL Version 4.2 released in April 2013 was used to model the pollutant loads (see website at it.tetratech-ffx.com/steplweb/)

STEPL Data Inputs:
State: Wisconsin
County: Waukesha
Weather Station: WI Milwaukee WSO Airport
Land Use Area (Acres)
AUTHOR

Existing Conditions: Year 2010

1. Input watershed land use area (ac) and precipitation (in)

Watershed	Urban	Cropland	Pastureland	Forest	User Defined	Feedlots	Feedlot Percent Paved	Total
MC-1	1	144	0	0	0	0	0-24%	145
MC-2	378	775	544	144	0	2	0-24%	1843
MC-3	273	707	185	34	0	14	0-24%	1213
MC-4	135	292	122	39	0	0	0-24%	588
MC-2a	2	0	0	6	0	0	0-24%	8
MC-2b	103	56	154	47	0	0	0-24%	360

8. Input or modify urban land use distribution

Watershed	Urban Area (ac.)	Commercial %	Industrial %	Institutional %	Transportation %	Multi-Family %	Single-Family %	Urban-Cultivated	Vacant (developed)	Open Space %	Total % Area
MC-1	1	0	0	0	100	0	0	0	0	0	100
MC-2	378	0.7	0	0	19.5	0	79.8	0	0	0	100
MC-3	273	0.4	0	0	19	0	64.4	0	0	16.2	100
MC-4	135	0	0	0	36	0	64	0	0	0	100
MC-2a	2	0	0	0	0	0	100	0	0	0	100
MC-2b	103	1	0	0	30.6	0	68.4	0	0	0	100

Planned Conditions: Year 2035

1. Input watershed land use area (ac) and precipitation (in)

Watershed	Urban	Cropland	Pastureland	Forest	User Defined	Feedlots	Feedlot Percent Paved	Total
MC-1	11	126	0	7	0	0	0-24%	144
MC-2	435	740	516	151	0	2	0-24%	1844
MC-3	211	767	185	34	0	14	0-24%	1211
MC-4	147	287	120	39	0	0	0-24%	593
MC-2a	1	0	0	6	0	0	0-24%	7
MC-2b	103	56	154	47	0	0	0-24%	359

8. Input or modify urban land use distribution

Watershed	Urban Area (ac.)	Commercial %	Industrial %	Institutional %	Transportation %	Multi-Family %	Single-Family %	Urban-Cultivated	Vacant (developed)	Open Space %	Total % Area
MC-1	11	0	0	0	37	0	63	0	0	0	100
MC-2	435	0.8	0	0	18.3	0	79.7	0	0	1.2	100
MC-3	211	0.4	0	0	24.6	0	75	0	0	0	100
MC-4	147	0	0	0	36.5	0	63.5	0	0	0	100
MC-2a	1	0	0	0	0	0	100	0	0	0	100
MC-2b	103	1.1	0	0	29.8	0	68.5	0	0	0.6	100

Agricultural Animals

Data Source: Agricultural animal distribution is based on USDA Census of Agriculture 2012 and consultation with local NRCS and Waukesha and Washington County staff. It is important to note that these numbers were not changed when modelling for the planned 2035 land use load conditions.

2. Input agricultural animals

Watershed	Beef Cattle	Dairy Cattle	Swine (Hog)	Sheep	Horse	Chicken	Turkey	Duck	# of months manure applied
MC-1	1	3	1	0	1	1	0	0	8
MC-2	13	50	10	5	20	20	1	1	8
MC-3	6	24	5	3	10	10	0	1	8
MC-4	3	12	2	1	5	5	0	0	8
MC-2a	0	0	0	0	0	0	0	0	8
MC-2b	1	6	1	1	3	3	0	0	8
Total	24	95	19	10	39	39	1	2	

Septic Systems

Data Source: The total number of septic systems were provided by the model default, but were distributed amongst the subwatershed based on area of rural lands. These numbers were not changed for the planned 2035 estimated pollutant loads.

3. Input septic system and illegal direct wastewater discharge data

Watershed	No. of Septic Systems	Population per Septic System	Septic Failure Rate, %	Wastewater Direct Discharge, # of People	Direct Discharge Reduction, %
MC-1	8	3	0.96	0	0
MC-2	142	3	0.96	0	0
MC-3	68	3	0.96	0	0
MC-4	34	3	0.96	0	0
MC-2a	1	3	0.96	0	0
MC-2b	20	3	0.96	0	0

Hydrologic Soil Group

Data Source: Hydrological soil group is based on STATSGO database and the most dominant soil type was chosen for each subwatershed.

5. Select average soil hydrologic group (SHG), SHG A = highest infiltration and SHG D = lowest infiltration

Watershed	SHG A	SHG B	SHG C	SHG D	SHG Selected	Soil N conc.%	Soil P conc.%	Soil BOD conc.%
MC-1	○	◉	○	○	B	0.080	0.031	0.160
MC-2	○	◉	○	○	B	0.080	0.031	0.160
MC-3	○	◉	○	○	B	0.080	0.031	0.160
MC-4	○	◉	○	○	B	0.080	0.031	0.160
MC-2a	○	◉	○	○	B	0.080	0.031	0.160
MC-2b	○	◉	○	○	B	0.080	0.031	0.160

STEPL EXISTING 2010 VERSUS PLANNED 2035 LAND USE LOAD COMPARISONS BY SUBWATERSHED FOR NITROGEN (N), PHOSPHORUS (P), BIOLOGICAL OXYGEN DEMAND (BOD), AND SEDIMENT

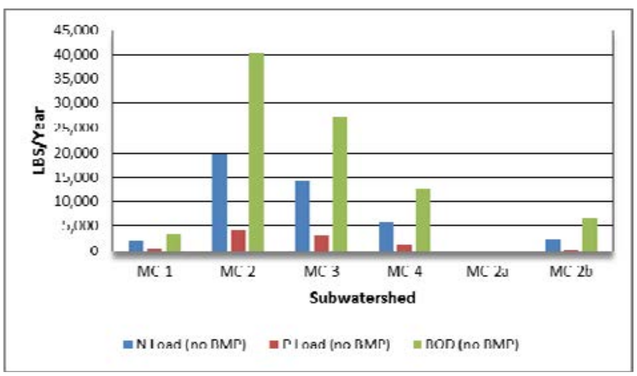
Existing Land Use: 2010

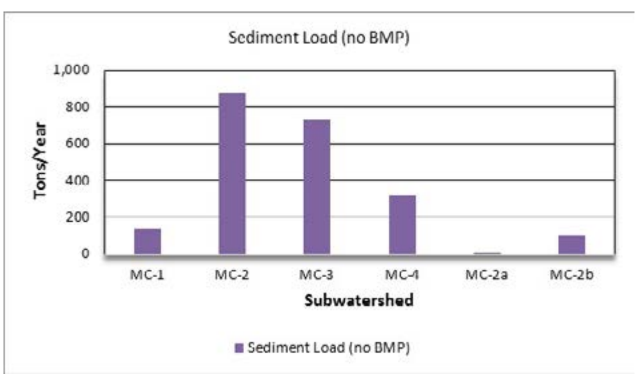
1. Total load by subwatershed(s)

Watershed	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)
	lb/year	lb/year	lb/year	t/year
MC-1	2012.0	540.2	3391.2	133.8
MC-2	19872.3	4053.1	40260.0	873.0
MC-3	14199.9	3214.9	27234.4	725.7
MC-4	5829.7	1354.8	12701.7	320.0
MC-2a	7.9	1.9	33.0	0.2
MC-2b	2413.0	438.2	6715.9	99.4
Total	44334.7	9603.1	90336.2	2152.2

2. Total load by land uses (no BMP)

Sources	N Load (lb/yr)	P Load (lb/yr)	BOD Load (lb/yr)	Sediment Load (t/yr)
Urban	5832.07	1000.46	21172.91	140.76
Cropland	27341.32	7358.86	45661.33	1830.11
Pastureland	5481.53	590.22	17092.79	180.55
Forest	63.87	30.48	153.37	3.94
Feedlots	5654.04	627.19	6445.69	0.00
User Defined	0.00	0.00	0.00	0.00
Septic	100.59	39.40	410.73	0.00
Gully	0.00	0.00	0.00	0.00
Streambank	0.00	0.00	0.00	0.00
Groundwater	0.00	0.00	0.00	0.00
Total	44473.43	9646.62	90936.82	2155.36





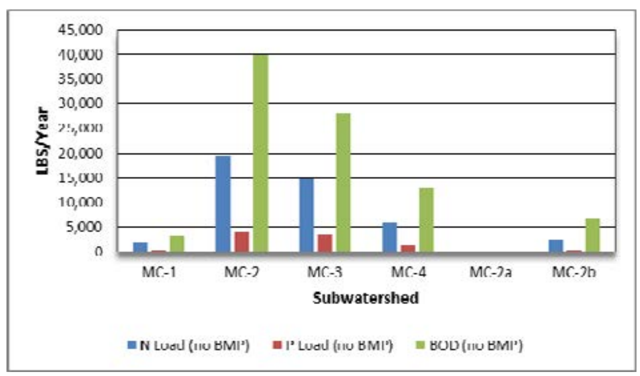
Planned Land Use: 2035

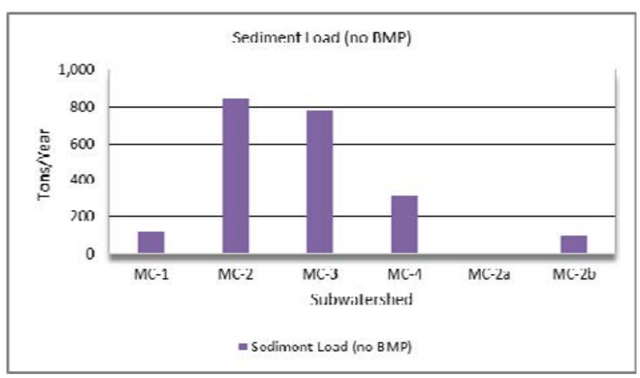
1. Total load by subwatershed(s)

Watershed	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)
	lb/year	lb/year	lb/year	t/year
MC-1	1838.9	486.8	3238.7	119.1
MC-2	19486.5	3950.2	39954.3	841.6
MC-3	14887.1	3418.9	28138.8	777.8
MC-4	5859.9	1354.1	12919.1	317.9
MC-2a	5.5	1.5	21.7	0.2
MC-2b	2395.6	435.2	6664.1	98.8
Total	44473.4	9646.6	90936.8	2155.4

2. Total load by land uses (no BMP)

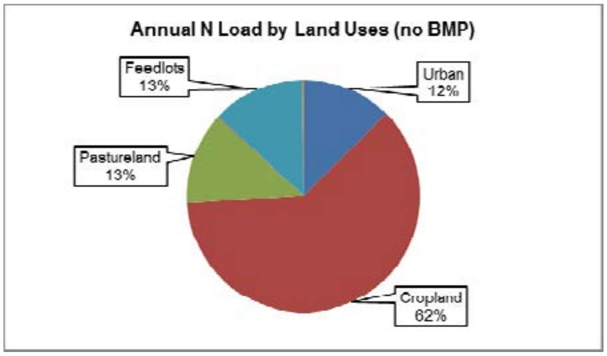
Sources	N Load (lb/yr)	P Load (lb/yr)	BOD Load (lb/yr)	Sediment Load (t/yr)
Urban	5556.67	948.18	20100.16	134.07
Cropland	27311.26	7350.81	45611.25	1828.19
Pastureland	5651.39	608.52	17622.42	186.15
Forest	60.77	29.00	145.91	3.75
Feedlots	5654.04	627.19	6445.69	0.00
User Defined	0.00	0.00	0.00	0.00
Septic	100.59	39.40	410.73	0.00
Gully	0.00	0.00	0.00	0.00
Streambank	0.00	0.00	0.00	0.00
Groundwater	0.00	0.00	0.00	0.00
Total	44334.72	9603.10	90336.16	2152.16

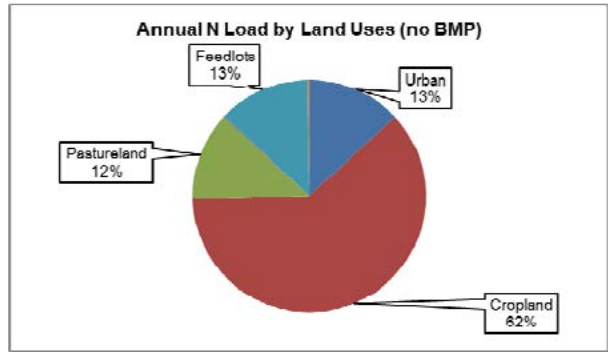


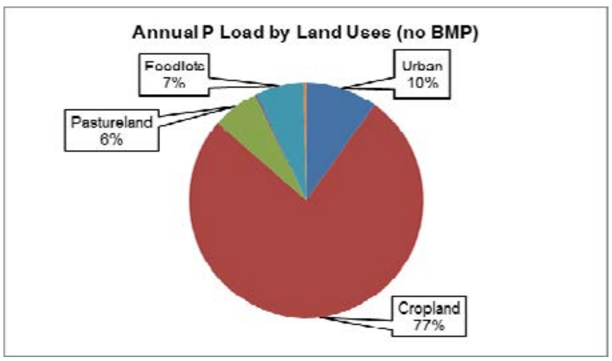


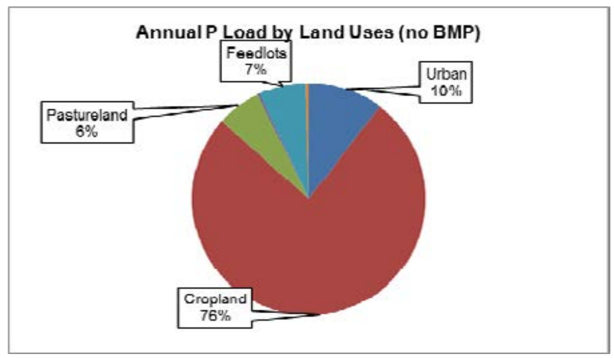
STEPL EXISTING 2010 VERSUS PLANNED 2035 LAND USE LOAD COMPARISONS BY SUBWATERSHED FOR NITROGEN (N), PHOSPHORUS (P), BIOLOGICAL OXYGEN DEMAND (BOD), AND SEDIMENT (cont.)

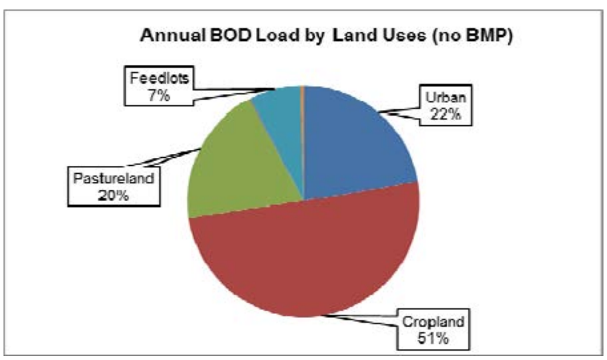
Existing Land Use: 2010 | **Planned Land Use: 2035**

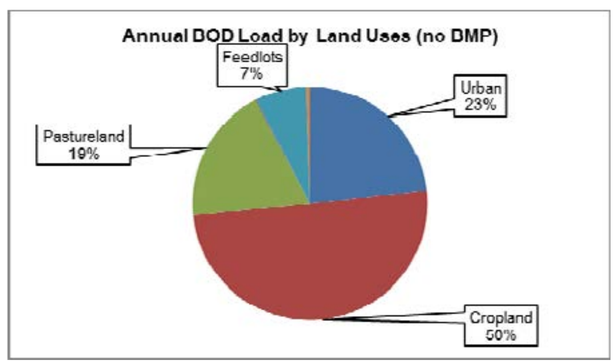


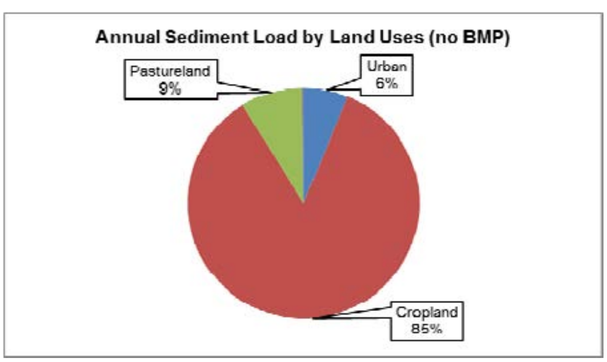


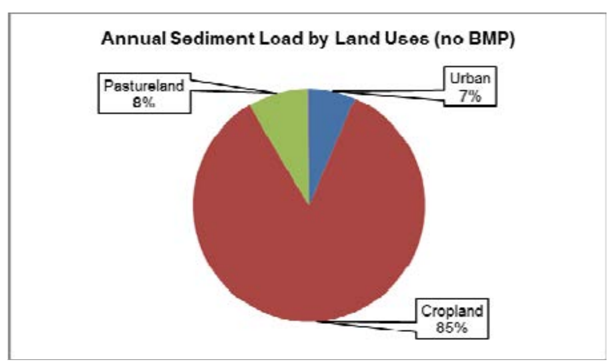












STEPL LOAD REDUCTION RESULTS FOR AGRICULTURAL BEST MANAGEMENT PRACTICES (BMPs) FOR CROPLAND

Upland Practices applied to Cropland:

Individual BMP efficiency values for nitrogen, phosphorus, biological oxygen demand, and sediment were based on values used by the Chesapeake Bay Model (CBM) and data from the Minnesota Department of Agriculture (MDA) as well as input from Waukesha and Washington County and NRCS staff.[1] Although it is well established that combined BMP efficiencies can greatly increase the overall percent reduction for pollutants such as detailed in the Plum-Kankaput Creek Watershed Plan,[2] it was beyond the scope of this project to determine the proportions of each of these practices being applied to each field in the Mason Creek watershed. However, estimates of the overall proportions of existing and proposed BMPs for fields throughout the Mason Creek watershed were provided by Perry Lindquist, Waukesha County Land Resources Manager, and Paul Sebo, Washington County Conservationist. Therefore, each practice was modelled separately to show existing load reductions and feasible planned load reductions as summarized below.

Table B.1
STEPL BMP Practices and Efficiencies Used in the Mason Creek Watershed Modeling

Conservation Practices	Existing Practices Implemented (percent of agricultural lands)	Proposed Practices Implemented (percent of agricultural lands)	Efficiency				Data Source
			N	P	BOD	Sediment	
Reduced Tillage	5%	75% No Till	0.55	0.45	ND	0.55	MDA
No Till	50%	75%	0.59	0.69	ND	0.78	MDA
Nutrient Management	50%	100%	0.08	0.15	ND	0.25	CBM
Cover Crop	0%	50%	0.30	0.25	ND	0.35	MDA

Source: SEWRPC

STEPL LOAD REDUCTION RESULTS FOR REDUCED TILLAGE PRACTICES

Existing Conditions: 5 percent Reduced Tillage

1. Total load by subwatershed(s)

Watershed	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)	N Reduction	P Reduction	BOD Reduction	Sediment Reduction	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year
MC-1	2012.0	540.2	3391.2	133.8	54.8	12.9	23.5	3.7	1957.2	527.3	3367.8	130.1
MC-2	19872.3	4053.1	40260.0	873.0	294.9	69.4	126.3	19.7	19577.4	3983.7	40133.6	853.3
MC-3	14199.9	3214.9	27234.4	725.7	269.0	63.3	115.2	18.0	13930.9	3151.6	27119.2	707.7
MC-4	5829.7	1354.8	12701.7	320.0	111.1	26.1	47.6	7.4	5718.6	1328.7	12654.1	312.6
MC-2a	7.9	1.9	33.0	0.2	0.0	0.0	0.0	0.0	7.9	1.9	33.0	0.2
MC-2b	2413.0	438.2	6715.9	99.4	21.3	5.0	9.1	1.4	2391.7	433.2	6706.7	97.9
Total	44334.7	9603.1	90336.2	2152.2	751.1	176.7	321.8	50.3	43583.7	9426.4	90014.4	2101.9

Proposed Conditions: 75 Percent No Till (see below)

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[1] *Simpson, Thomas, and Sarah Weammert, Developing Best Management Practice Definitions and Effectiveness Estimates for Nitrogen, Phosphorus and Sediment in the Chesapeake Bay Watershed. University of Maryland Mid-Atlantic Water Program, 2009; Minnesota Department of Agriculture, Miller, T. P., J. R. Peterson, C. F. Lenhart, and Y. Nomura,* The Agricultural BMP Handbook for Minnesota*, , September 2012, www.leg.state.mn.us/lrl/lrl.asp*

[2] *Outagamie County Land Conservation Department,* Nonpoint Source Implementation Plan for the Plum and Kankapot Creek Watersheds*, Appendix D, STEPL load reduction results for combined BMP's for cropland & pastureland practices, streambank restoration, riparian buffer, and wetland restoration, 2014.*

STEPL LOAD REDUCTION RESULTS FOR NO TILL PRACTICES

Existing Conditions: 50 percent No Till

1. Total load by subwatershed(s)

Watershed	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)	N Reduction	P Reduction	BOD Reduction	Sediment Reduction	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year
MC-1	2012.0	540.2	3391.2	133.8	628.3	192.4	332.9	52.0	1383.7	347.8	3058.3	81.8
MC-2	19872.3	4053.1	40260.0	873.0	3381.3	1035.4	1791.5	279.9	16490.9	3017.6	38468.4	593.1
MC-3	14199.9	3214.9	27234.4	725.7	3084.7	944.6	1634.3	255.4	11115.2	2270.3	25600.1	470.4
MC-4	5829.7	1354.8	12701.7	320.0	1274.0	390.1	675.0	105.5	4555.7	964.7	12026.7	214.6
MC-2a	7.9	1.9	33.0	0.2	0.0	0.0	0.0	0.0	7.9	1.9	33.0	0.2
MC-2b	2413.0	438.2	6715.9	99.4	244.3	74.8	129.5	20.2	2168.6	363.4	6586.4	79.1
Total	44334.7	9603.1	90336.2	2152.2	8612.6	2637.4	4563.2	713.0	35722.1	6965.7	85773.0	1439.2

Proposed Conditions: 75 percent No Till

1. Total load by subwatershed(s)

Watershed	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)	N Reduction	P Reduction	BOD Reduction	Sediment Reduction	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year
MC-1	2012.0	540.2	3391.2	133.8	942.4	288.6	499.3	78.0	1069.6	251.6	2891.9	55.8
MC-2	19872.3	4053.1	40260.0	873.0	5072.0	1553.2	2687.3	419.9	14800.3	2499.9	37572.7	453.2
MC-3	14199.9	3214.9	27234.4	725.7	4627.0	1416.9	2451.5	383.0	9572.9	1798.0	24782.9	342.7
MC-4	5829.7	1354.8	12701.7	320.0	1911.0	585.2	1012.5	158.2	3918.7	769.6	11689.3	161.8
MC-2a	7.9	1.9	33.0	0.2	0.0	0.0	0.0	0.0	7.9	1.9	33.0	0.2
MC-2b	2413.0	438.2	6715.9	99.4	366.5	112.2	194.2	30.3	2046.5	326.0	6521.7	69.0
Total	44334.7	9603.1	90336.2	2152.2	12918.9	3956.1	6844.7	1069.5	31415.8	5647.0	83491.4	1082.7

STEPL LOAD REDUCTION RESULTS FOR NUTRIENT MANAGEMENT PLAN PRACTICES

Existing Conditions: 50 percent Nutrient Management Plan

1. Total load by subwatershed(s)

Watershed	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)	N Reduction	P Reduction	BOD Reduction	Sediment Reduction	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year
MC-1	2012.0	540.2	3391.2	133.8	116.0	48.4	106.7	16.7	1896.0	491.7	3284.5	117.1
MC-2	19872.3	4053.1	40260.0	873.0	624.1	260.7	574.2	89.7	19248.1	3792.4	39685.8	783.3
MC-3	14199.9	3214.9	27234.4	725.7	569.4	237.8	523.8	81.8	13630.5	2977.1	26710.6	643.9
MC-4	5829.7	1354.8	12701.7	320.0	235.2	98.2	216.3	33.8	5594.5	1256.6	12485.4	286.2
MC-2a	7.9	1.9	33.0	0.2	0.0	0.0	0.0	0.0	7.9	1.9	33.0	0.2
MC-2b	2413.0	438.2	6715.9	99.4	45.1	18.8	41.5	6.5	2367.9	419.4	6674.4	92.9
Total	44334.7	9603.1	90336.2	2152.2	1589.7	663.9	1462.6	228.5	42745.0	8939.2	88873.6	1923.6

Proposed Conditions: 100 percent Nutrient Management Plan

1. Total load by subwatershed(s)

Watershed	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)	N Reduction	P Reduction	BOD Reduction	Sediment Reduction	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year
MC-1	2012.0	540.2	3391.2	133.8	231.9	96.9	213.4	33.3	1780.1	443.3	3177.8	100.4
MC-2	19872.3	4053.1	40260.0	873.0	1248.3	521.3	1148.4	179.4	18624.0	3531.8	39111.5	693.6
MC-3	14199.9	3214.9	27234.4	725.7	1138.7	475.6	1047.6	163.7	13061.1	2739.3	26186.8	562.0
MC-4	5829.7	1354.8	12701.7	320.0	470.3	196.4	432.7	67.6	5359.4	1158.4	12269.1	252.4
MC-2a	7.9	1.9	33.0	0.2	0.0	0.0	0.0	0.0	7.9	1.9	33.0	0.2
MC-2b	2413.0	438.2	6715.9	99.4	90.2	37.7	83.0	13.0	2322.8	400.6	6632.9	86.4
Total	44334.7	9603.1	90336.2	2152.2	3179.4	1327.9	2925.1	457.0	41155.3	8275.2	87411.1	1695.1

STEPL LOAD REDUCTION RESULTS FOR COVER CROP PRACTICES

Existing Conditions: 0 percent Cover Crop (see STEPL Loads for Existing Land Use: 2010 on page 4 of this Appendix)

Proposed Conditions: 50 percent Cover Crop

1. Total load by subwatershed(s)

Watershed	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)	N Reduction	P Reduction	BOD Reduction	Sediment Reduction	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year
MC-1	2012.0	540.2	3391.2	133.8	309.5	75.2	149.4	23.3	1702.5	464.9	3241.9	110.4
MC-2	19872.3	4053.1	40260.0	873.0	1665.8	405.0	803.9	125.6	18206.5	3648.1	39456.1	747.4
MC-3	14199.9	3214.9	27234.4	725.7	1519.6	369.4	733.3	114.6	12680.2	2845.5	26501.1	611.2
MC-4	5829.7	1354.8	12701.7	320.0	627.6	152.6	302.9	47.3	5202.1	1202.2	12398.9	272.7
MC-2a	7.9	1.9	33.0	0.2	0.0	0.0	0.0	0.0	7.9	1.9	33.0	0.2
MC-2b	2413.0	438.2	6715.9	99.4	120.4	29.3	58.1	9.1	2292.6	409.0	6657.8	90.3
Total	44334.7	9603.1	90336.2	2152.2	4242.9	1031.5	2047.6	319.9	40091.8	8571.6	88288.6	1832.2

STEPL LOAD REDUCTION RESULTS FOR EXISTING RIPARIAN BUFFERS, 75 FOOT RIPARIAN BUFFER EXPANSION AREAS, CONVERSION OF FARMED POTENTIAL RESTORABLE WETLANDS, AND CONVERSION OF FARMED STEEP SLOPES

Based upon discussions with Santina Wortman, U.S. Ecological Protection Agency (EPA), Tetra Tech staff, and, Peter Vincent and Ralph Reznick from the Michigan Department of Environmental Quality (DEQ), it was determined that we utilize the wetland BMP efficiency applied only to the converted cropland area approach. This approach uses the acres of cropland to be converted to wetland and applies a wetland detention BMP efficiency to calculate reductions.

To determine the load reductions from the existing riparian buffer areas, it was assumed that areas of buffer would be converted to either cropland, pasture, or urban land uses (Determination of land use was based on 2010 land use designations. Wetland and woodland land uses were assumed to be lost to cropland).

Table B.2
STEPL BMP Practices and Efficiencies Used in the Mason Creek Watershed Modeling

Conservation Practice	Acres (percent of total land area in watershed)	Acres (percent of total land area in watershed)	Efficiency				Data Source
			N	P	BOD	Sediment	
Existing Riparian Buffers	1,418 (26.9%)	1,418 (26.9%)	0.675	0.66	ND	0.625	MDA
75 foot buffer expansion areas	- -	25 (0.5%)	0.675	0.66	ND	0.625	MDA
Convert Currently Farmed Potentially Restorable Wetlands	- -	205 (3.9%)	0.675	0.66	ND	0.625	MDA
Convert Farmed Steep Slopes to Filter Strips	- -	125 (2.4%)	0.7	0.75	ND	0.650	STEPL
	Subtotal	1,773 (33.6%)					

Source: SEWRPC

Existing Conditions: Load Reductions from Existing Riparian Buffers (see Map B.1)

1. Total load by subwatershed(s)

Watershed	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)	N Reduction	P Reduction	BOD Reduction	Sediment Reduction	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year
MC-1	193.0	53.3	395.7	31.4	125.3	33.8	125.7	19.6	67.8	19.5	270.0	11.8
MC-2	7638.4	2003.6	16387.7	1161.4	4968.3	1272.3	4643.8	725.9	2670.1	731.3	11743.9	435.5
MC-3	998.5	250.1	2224.8	142.6	650.7	158.9	569.9	89.1	347.8	91.2	1654.9	53.5
MC-4	665.4	177.1	1448.6	101.8	431.1	112.5	405.1	63.6	234.3	64.6	1043.5	38.2
MC-2a	50.0	13.8	102.6	8.1	32.5	8.8	32.6	5.1	17.6	5.1	70.0	3.1
MC-2b	307.2	80.0	684.8	45.4	199.1	50.8	180.6	28.4	108.1	29.1	504.2	17.0
Total	9852.5	2577.9	21244.3	1490.8	6406.8	1637.2	5957.7	931.8	3445.6	940.7	15286.5	559.1

Proposed Conditions: Additional Load Reductions for Installation of 75 Foot Width Riparian Buffers (see Map B.1)

1. Total load by subwatershed(s)

Watershed	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)	N Reduction	P Reduction	BOD Reduction	Sediment Reduction	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year
MC-1	49.0	15.9	99.5	11.3	31.3	10.0	45.0	7.0	17.7	5.9	54.4	4.2
MC-2	118.5	36.0	253.7	25.0	76.0	22.7	100.0	15.6	42.5	13.3	153.7	9.4
MC-3	77.5	23.5	166.3	16.3	49.7	14.8	65.2	10.2	27.8	8.7	101.1	6.1
MC-4	9.7	1.9	39.9	0.5	6.5	1.3	1.4	0.3	3.2	0.7	38.5	0.2
MC-2a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MC-2b	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	254.8	77.3	559.4	53.1	163.5	48.7	211.7	33.2	91.3	28.6	347.7	19.9

Proposed Conditions: Additional Load Reductions for Conversion of Currently Farmed Potentially Restorable Wetlands (see Map B.2)

1. Total load by subwatershed(s)

Watershed	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)	N Reduction	P Reduction	BOD Reduction	Sediment Reduction	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year
MC-1	190.3	62.4	385.7	44.5	121.3	39.3	178.0	27.8	69.0	23.1	207.7	16.7
MC-2	1236.7	357.0	2695.5	239.8	796.4	225.3	959.2	149.9	440.3	131.7	1736.3	89.9
MC-3	671.1	212.5	1374.6	147.7	429.4	133.9	590.9	92.3	241.7	78.6	783.7	55.4
MC-4	88.4	29.4	178.9	21.2	56.3	18.5	84.8	13.2	32.1	10.9	94.1	7.9
MC-2a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MC-2b	75.0	25.0	151.7	18.1	47.7	15.7	72.3	11.3	27.3	9.3	79.4	6.8
Total	2261.4	686.2	4786.4	471.3	1451.0	432.6	1885.1	294.6	810.4	253.6	2901.2	176.7

Proposed Conditions: Additional Load Reductions for Conversion of Currently Farmed Steep Slopes to Filter Strips (see Map B.2)

1. Total load by subwatershed(s)

Watershed	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)	N Reduction	P Reduction	BOD Reduction	Sediment Reduction	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year
MC-1	257.0	83.8	521.1	59.5	170.4	55.5	247.3	38.6	86.6	28.3	273.7	20.8
MC-2	490.3	157.9	995.0	110.8	325.5	104.8	460.8	72.0	164.8	53.1	534.3	38.8
MC-3	332.6	107.9	674.5	76.2	220.6	71.5	317.1	49.5	112.0	36.4	357.4	26.7
MC-4	491.5	158.3	997.3	111.0	326.3	105.0	461.8	72.2	165.2	53.2	535.5	38.9
MC-2a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MC-2b	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1571.4	507.9	3187.9	357.4	1042.8	336.9	1487.0	232.3	528.6	171.0	1700.9	125.1

STEPL LOAD REDUCTION RESULTS FOR CONCENTRATED FLOW DITCHES/GULLIES CONVERTED TO GRASSED WATERWAYS

Load Reductions from seven concentrated flow ditches/gullies that are proposed to be converted to grassed waterways were calculated with the STEPL Model Spreadsheet, which is the same as the Region 5 Model Spreadsheet. A BMP efficiency of 70 percent was used for the 7 concentrated flow ditches/gullies, as shown in the tables below. Both of these models estimate the annual tons of gross erosion as sediment delivered at the edge of field. Since this plan is looking at load reductions to the stream system, a delivery ratio needs to be applied.[3] Ephemeral gully delivery rates for an integrated (connected) system are typically 50 to 90 percent.[4] A delivery ratio of 70 percent was assumed for concentrated flow ditch load delivery to calculate actual loads delivered to Mason Creek, which was the same used for gully erosion in the Plum-Kankaput Plan.[5] Widths and depths of each concentrated flow ditch/gully along Mason Creek were determined from direct assessment by SEWRPC staff in the summer and fall of 2014. Total lineal feet of drainages was determined by GIS methods. Measurements were used for inputs into the STEPL model. The 'years to form' input was estimated to be one year. Locations of the concentrated flow ditches/gullies are located on Map B.3.

Proposed Conditions: Total load reductions for proposed priority grassed waterways

1. Gully dimensions											
Gully	Top Width (ft)	Bottom Width (ft)	Depth (ft)	Length (ft)	Years to Form	BMP Efficiency (0-1)	Soil Textural Class	Soil Dry Weight (ton/ft3)	Nutrient Correction Factor	Annual Load (ton)	Load Reduction (ton)
Gully1	14	8	0.8	525	1	0.7	Silt Loam	0.0425	1	196.3500	137.4450
Gully2	10	8	0.6	434	1	0.7	Silt Loam	0.0425	1	99.6030	69.7221
Gully3	9.5	7	0.6	595	1	0.7	Organic	0.011	1.5	32.3978	22.6784
Gully4	13	7	1	1396	1	0.7	Organic	0.011	1.5	153.5600	107.4920
Gully5	8	6	1	610	1	0.7	Organic	0.011	1.5	46.9700	32.8790
Gully6	8	6	0.9	472	1	0.7	Organic	0.011	1.5	32.7096	22.8967
Gully7	8	6	0.8	360	1	0.7	Organic	0.011	1.5	22.1760	15.5232

Existing Load From Gullies					Existing Load Delivered to Stream (Accounting for 70% Delivery Ratio)				Load Reduction From BMP Installation (70% BMP Efficiency Applied)				Total Load Delivered to Stream After BMP Installation (70% BMP Efficiency Applied)			
Gully ID	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)	N Load Delivered (no BMP)	P Load Delivered (no BMP)	BOD Load Delivered (no BMP)	Sediment Load Delivered (no BMP)	N Reduction	P Reduction	BOD Reduction	Sediment Reduction	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year
Gully1	314.2	121.0	628.3	196.4	219.9	84.7	439.8	137.4	153.9	59.3	307.9	96.2	66.0	25.4	131.9	41.2
Gully2	159.4	61.4	318.7	99.6	111.6	42.9	223.1	69.7	78.1	30.1	156.2	48.8	33.5	12.9	66.9	20.9
Gully3	77.8	29.9	155.5	32.4	54.4	21.0	108.9	22.7	38.1	14.7	76.2	15.9	16.3	6.3	32.7	6.8
Gully4	368.5	141.9	737.1	153.6	258.0	99.3	516.0	107.5	180.6	69.5	361.2	75.2	77.4	29.8	154.8	32.2
Gully5	112.7	43.4	225.5	47.0	78.9	30.4	157.8	32.9	55.2	21.3	110.5	23.0	23.7	9.1	47.3	9.9
Gully6	78.5	30.2	157.0	32.7	55.0	21.2	109.9	22.9	38.5	14.8	76.9	16.0	16.5	6.3	33.0	6.9
Gully7	53.2	20.5	106.4	22.2	37.3	14.3	74.5	15.5	26.1	10.0	52.2	10.9	11.2	4.3	22.4	4.7
Total	1164.3	448.2	2328.6	583.8	815.0	313.8	1630.0	408.6	570.5	219.6	1141.0	286.0	244.5	94.1	489.0	122.6

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[3]*Outagamie County Land Conservation Department,* Nonpoint Source Implementation Plan for the Plum and Kankapot Creek Watersheds, *Appendix D. Region 5 Model Inputs for gully stabilization, 2014.*

[4]*Natural Resources Conservation Services (NRCS),* Erosion and Sediment Delivery. Field Office Technical Guide, *March 1998, efotg.sc.egov.usda.gov/references/public/IA/Erosion_and_sediment_delivery.pdf*

[5]*Outagamie County Land Conservation Department, 2014, Op. cit.*

STEPL LOAD REDUCTION RESULTS FOR STREAMBANK RESTORATION PRACTICES

Total length, height, and severity of each eroding streambank site along Mason Creek were determined from direct assessment by SEWRPC staff in the summer and fall of 2014. Measurements were used for inputs into the STEPL model. The tables below indicate impaired streambank inputs as well as pollutant loads and load reductions. All of the streambank erosion sites are located on Map B-3. A BMP efficiency of 75 percent was used to calculate load reductions for these eroding sites.

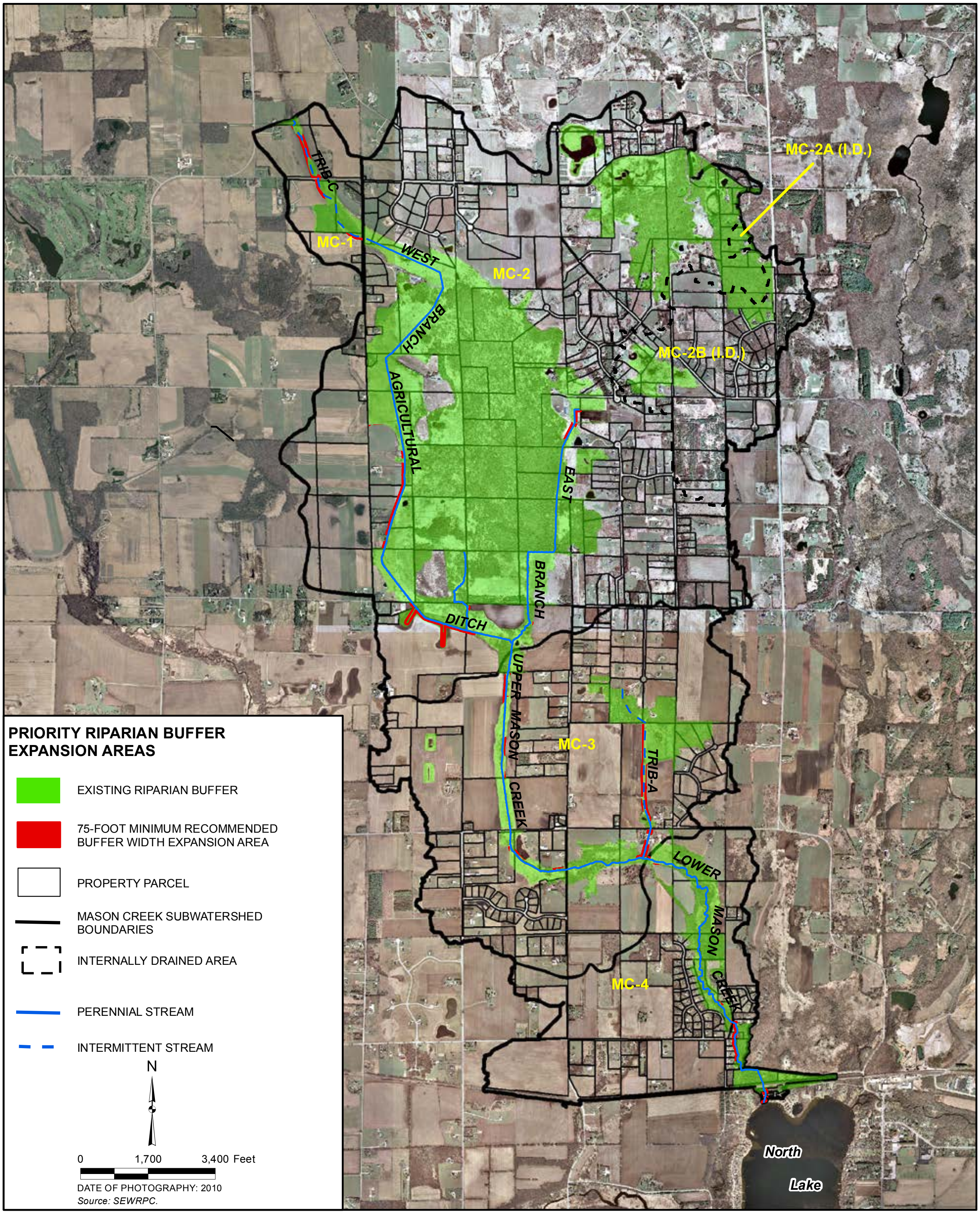
2. Impaired streambank dimensions in the different watersheds

Subbasin	Strm Bank	Length (ft)	Height (ft)	Lateral Recession	Rate Range (ft/yr)	Rate (ft/yr)	BMP Efficiency (0-1)	Soil Textural Class	Soil Dry Weight (ton/ft3)	Nutrient Correction Factor	Annual Load (ton)	Load Reduction (ton)
MC-4	1	51.9	3	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	0.8602	0.6452
	2	58.8	2	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	0.6497	0.4873
	3	113.8	4	3. Severe	0.3 - 0.5	0.4	0.75	Silt Loam	0.0425	1	7.7384	5.8038
	4	58	2	1. Slight	0.01 - 0.05	0.03	0.75	Silt Loam	0.0425	1	0.1479	0.1109
	5	163	2	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	1.8012	1.3509
	6	52.1	2	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	0.5757	0.4318
	7	240.3	2	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	2.6553	1.9915
	8	37	1	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	0.2044	0.1533
	9	116.5	2	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	1.2873	0.9655
	10	60.6	2	1. Slight	0.01 - 0.05	0.03	0.75	Silt Loam	0.0425	1	0.1545	0.1159
	11	87.1	1	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	0.4812	0.3609
	12	91.2	1.5	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	0.7558	0.5669
MC-3	13	49.6	1.5	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	0.4111	0.3083
	14	65.6	1.5	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	0.5437	0.4077
	15	88	3	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	1.4586	1.0940
	16	46.4	1.5	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	0.3845	0.2884
	17	57	2	1. Slight	0.01 - 0.05	0.03	0.75	Silt Loam	0.0425	1	0.1454	0.1090
	18	38.4	3	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	0.6365	0.4774
MC-2	19	70.6	1	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	0.3901	0.2925
	20	113.8	2	1. Slight	0.01 - 0.05	0.03	0.75	Silt Loam	0.0425	1	0.2902	0.2176
	21	55.9	1	1. Slight	0.01 - 0.05	0.03	0.75	Silt Loam	0.0425	1	0.0713	0.0535
	22	53.8	2	1. Slight	0.01 - 0.05	0.03	0.75	Organic	0.011	1.5	0.0355	0.0266
	23	160.6	1	3. Severe	0.3 - 0.5	0.4	0.75	Organic	0.011	1.5	0.7066	0.5300
	24	73.4	3	2. Moderate	0.06 - 0.2	0.13	0.75	Organic	0.011	1.5	0.3149	0.2362
	25	31.6	2	2. Moderate	0.06 - 0.2	0.13	0.75	Organic	0.011	1.5	0.0904	0.0678
	26	51.3	2	2. Moderate	0.06 - 0.2	0.13	0.75	Organic	0.011	1.5	0.1467	0.1100
	27	58.4	2.5	1. Slight	0.01 - 0.05	0.03	0.75	Silt Loam	0.0425	1	0.1862	0.1396
	28	24.7	2	2. Moderate	0.06 - 0.2	0.13	0.75	Silt Loam	0.0425	1	0.2729	0.2047

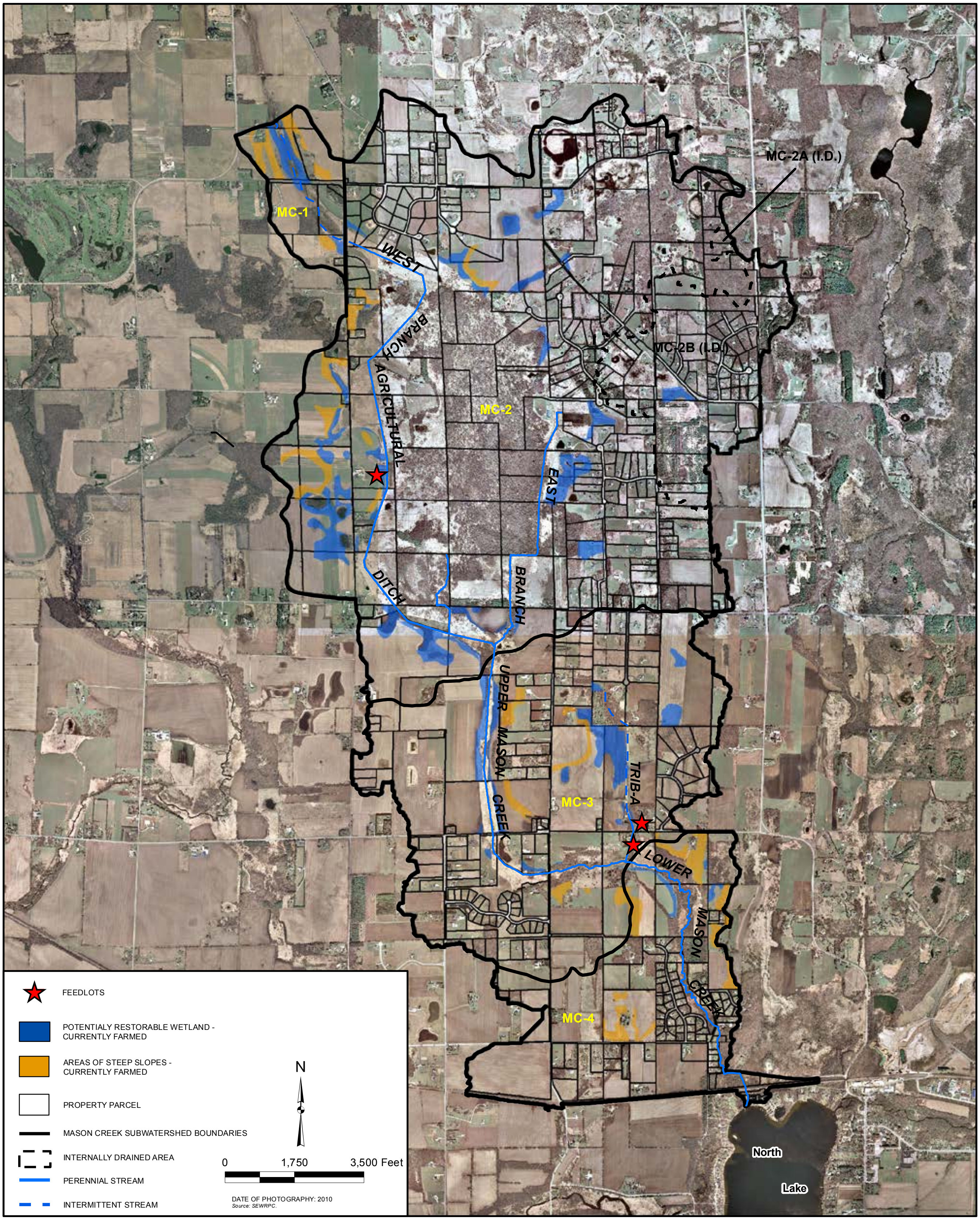
1. Total load by subwatershed(s)

Subbasin	Erosion ID	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)	N Reduction	P Reduction	BOD Reduction	Sediment Reduction	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
		lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year
MC-4	1	1.4	0.5	2.8	0.9	1.0	0.4	2.1	0.6	0.3	0.1	0.7	0.2
	2	1.0	0.4	2.1	0.6	0.8	0.3	1.6	0.5	0.3	0.1	0.5	0.2
	3	12.4	4.8	24.8	7.7	9.3	3.6	18.6	5.8	3.1	1.2	6.2	1.9
	4	0.2	0.1	0.5	0.1	0.2	0.1	0.4	0.1	0.1	0.0	0.1	0.0
	5	2.9	1.1	5.8	1.8	2.2	0.8	4.3	1.4	0.7	0.3	1.4	0.5
	6	0.9	0.4	1.8	0.6	0.7	0.3	1.4	0.4	0.2	0.1	0.5	0.1
	7	4.2	1.6	8.5	2.7	3.2	1.2	6.4	2.0	1.1	0.4	2.1	0.7
	8	0.3	0.1	0.7	0.2	0.2	0.1	0.5	0.2	0.1	0.0	0.2	0.1
	9	2.1	0.8	4.1	1.3	1.5	0.6	3.1	1.0	0.5	0.2	1.0	0.3
	10	0.2	0.1	0.5	0.2	0.2	0.1	0.4	0.1	0.1	0.0	0.1	0.0
	11	0.8	0.3	1.5	0.5	0.6	0.2	1.2	0.4	0.2	0.1	0.4	0.1
	12	1.2	0.5	2.4	0.8	0.9	0.3	1.8	0.6	0.3	0.1	0.6	0.2
MC-3	13	0.7	0.3	1.3	0.4	0.5	0.2	1.0	0.3	0.2	0.1	0.3	0.1
	14	0.9	0.3	1.7	0.5	0.7	0.3	1.3	0.4	0.2	0.1	0.4	0.1
	15	2.3	0.9	4.7	1.5	1.8	0.7	3.5	1.1	0.6	0.2	1.2	0.4
	16	0.6	0.2	1.2	0.4	0.5	0.2	0.9	0.3	0.2	0.1	0.3	0.1
	17	0.2	0.1	0.5	0.1	0.2	0.1	0.3	0.1	0.1	0.0	0.1	0.0
	18	1.0	0.4	2.0	0.6	0.8	0.3	1.5	0.5	0.3	0.1	0.5	0.2
MC-2	19	0.6	0.2	1.2	0.4	0.5	0.2	0.9	0.3	0.2	0.1	0.3	0.1
	20	0.5	0.2	0.9	0.3	0.3	0.1	0.7	0.2	0.1	0.0	0.2	0.1
	21	0.1	0.0	0.2	0.1	0.1	0.0	0.2	0.1	0.0	0.0	0.1	0.0
	22	0.1	0.0	0.2	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
	23	1.7	0.7	3.4	0.7	1.3	0.5	2.5	0.5	0.4	0.2	0.8	0.2
	24	0.8	0.3	1.5	0.3	0.6	0.2	1.1	0.2	0.2	0.1	0.4	0.1
	25	0.2	0.1	0.4	0.1	0.2	0.1	0.3	0.1	0.1	0.0	0.1	0.0
	26	0.4	0.1	0.7	0.1	0.3	0.1	0.5	0.1	0.1	0.0	0.2	0.0
	27	0.3	0.1	0.6	0.2	0.2	0.1	0.4	0.1	0.1	0.0	0.1	0.0
	28	0.4	0.2	0.9	0.3	0.3	0.1	0.7	0.2	0.1	0.0	0.2	0.1
Total		38.5	14.8	76.9	23.4	28.9	11.1	57.7	17.5	9.6	3.7	19.2	5.8

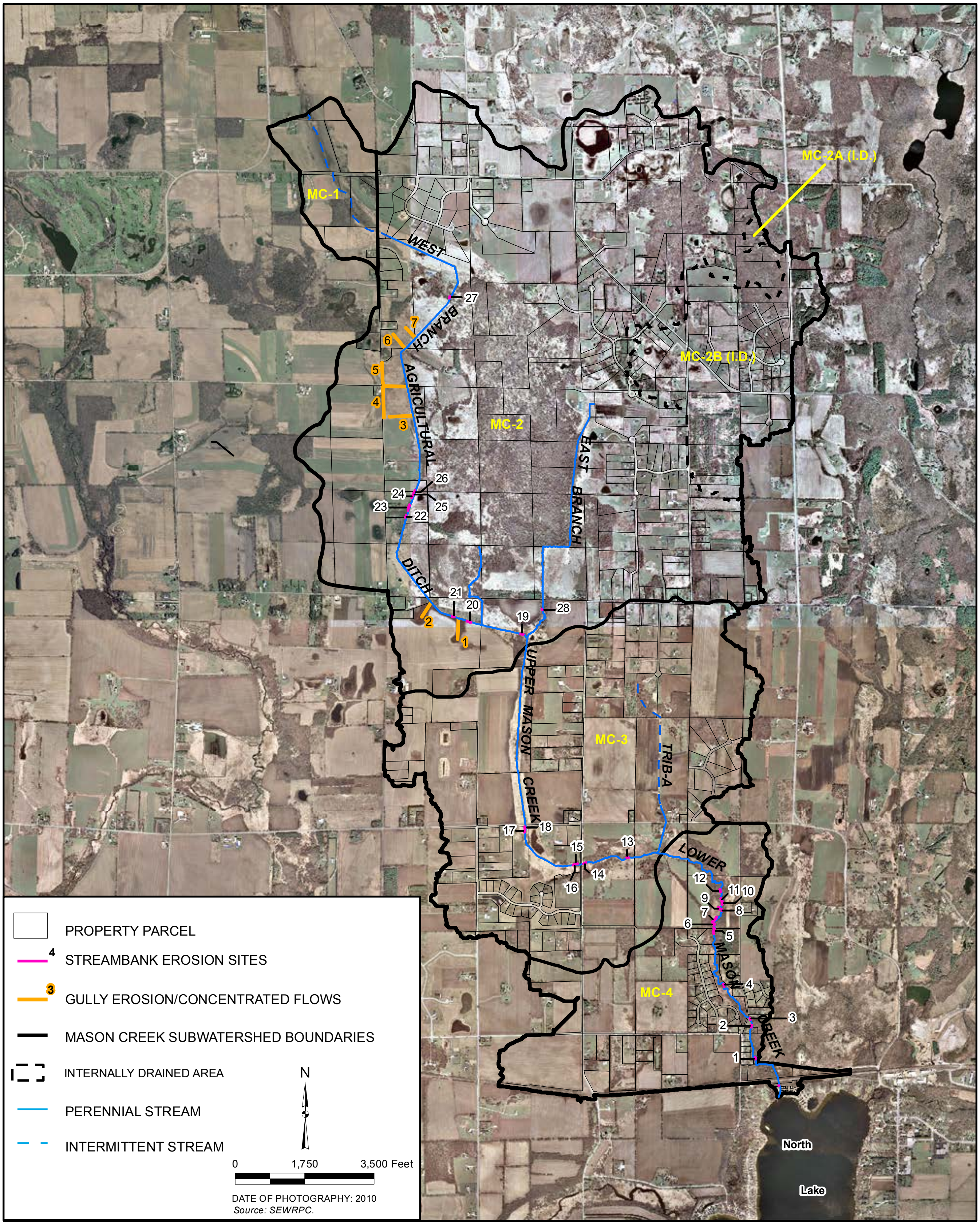
Map B.1
Existing Riparian Buffers and 75-Foot Buffer Expansion Areas Within the Mason Creek Watershed: 2014



Map B.2
Potentially Restorable Wetlands and Steep Slopes that are Currently Farmed Within the Mason Creek Watershed: 2014



Map B.3
Bank Erosion Sites and Concentrated Flow Ditches Along Mason Creek: 2014



SEWRPC RIPARIAN BUFFER GUIDE NO. 1
"MANAGING THE WATER'S EDGE"
APPENDIX C

Managing the Water's Edge

Making Natural Connections

Problem Statement:

Despite significant research related to buffers, there remains no consensus as to what constitutes optimal riparian buffer design or proper buffer width for effective pollutant removal, water quality protection, prevention of channel erosion, provision of fish and wildlife habitat, enhancement of environmental corridors, augmentation of stream baseflow, and water temperature moderation.

Southeastern Wisconsin Regional Planning Commission

Our purpose in this document is to help protect and restore water quality, wildlife, recreational opportunities, and scenic beauty.

This material was prepared in part with funding from the U.S. Environmental Protection Agency Great Lakes National Program Office provided through CMAP, the Chicago Metropolitan Agency for Planning.

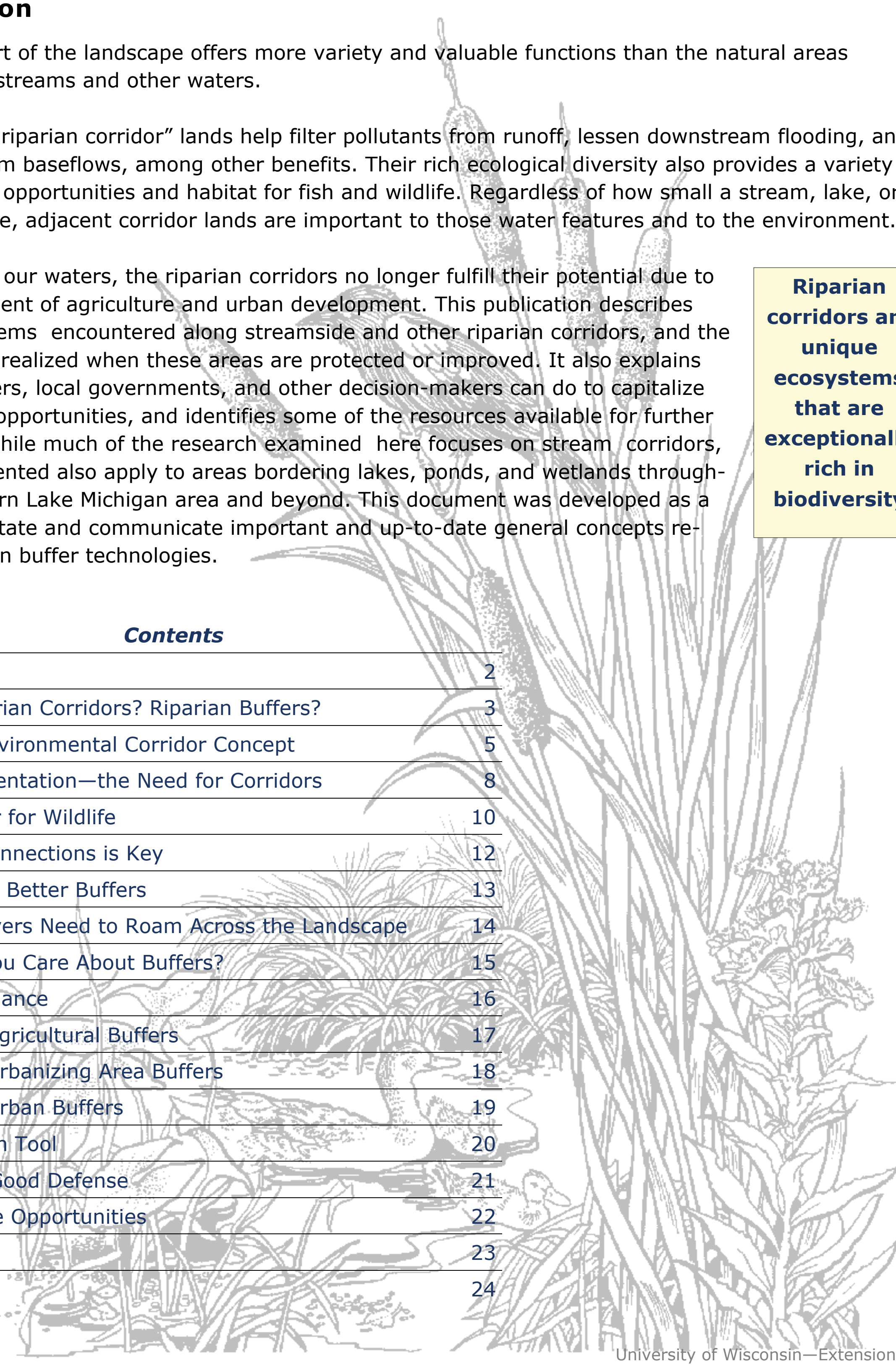
Introduction

Perhaps no part of the landscape offers more variety and valuable functions than the natural areas bordering our streams and other waters.

These unique "riparian corridor" lands help filter pollutants from runoff, lessen downstream flooding, and maintain stream baseflows, among other benefits. Their rich ecological diversity also provides a variety of recreational opportunities and habitat for fish and wildlife. Regardless of how small a stream, lake, or wetland may be, adjacent corridor lands are important to those water features and to the environment.

Along many of our waters, the riparian corridors no longer fulfill their potential due to the encroachment of agriculture and urban development. This publication describes common problems encountered along streamside and other riparian corridors, and the many benefits realized when these areas are protected or improved. It also explains what landowners, local governments, and other decision-makers can do to capitalize on waterfront opportunities, and identifies some of the resources available for further information. While much of the research examined here focuses on stream corridors, the ideas presented also apply to areas bordering lakes, ponds, and wetlands throughout the southern Lake Michigan area and beyond. This document was developed as a means to facilitate and communicate important and up-to-date general concepts related to riparian buffer technologies.

Riparian corridors are unique ecosystems that are exceptionally rich in biodiversity

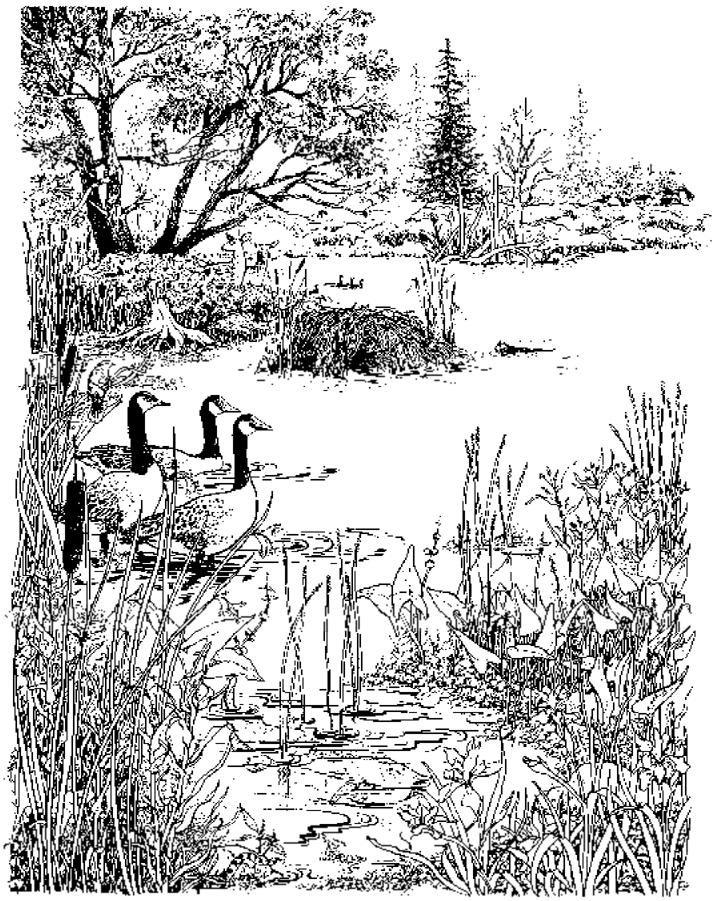


Contents

University of Wisconsin—Extension

What Are Riparian Corridors? Riparian Buffer Zones?

The word riparian comes from the Latin word *ripa*, which means bank. However, in this document we use riparian in a much broader sense and refer to land adjoining any water body including ponds, lakes, streams, and wetlands. This term has two additional distinct meanings that refer to 1) the "natural or relatively undisturbed" corridor lands adjacent to a water body inclusive of both wetland and upland flora and fauna and 2) a buffer zone or corridor lands in need of protection to "buffer" the effects of human impacts such as agriculture and residential development.



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The word buffer literally means something that cushions against the shock of something else (noun), or to lessen or cushion that shock (verb). Other useful definitions reveal that a buffer can be something that serves to separate features, or that is capable of neutralizing something, like filtering pollutants from stormwater runoff. Essentially, buffers and buffering help protect against adverse effects.

Riparian buffer zones function as core habitat as well as travel corridors for many wildlife species.

Riparian buffers are zones adjacent to waterbodies such as lakes, rivers, and wetlands that simultaneously protect water quality and wildlife, including both aquatic and terrestrial habitat. These zones minimize the impacts of human activities on the landscape and contribute to recreation, aesthetics, and quality of life. **This document summarizes how to maximize both water quality protection and conservation of aquatic and terrestrial wildlife populations using buffers.**

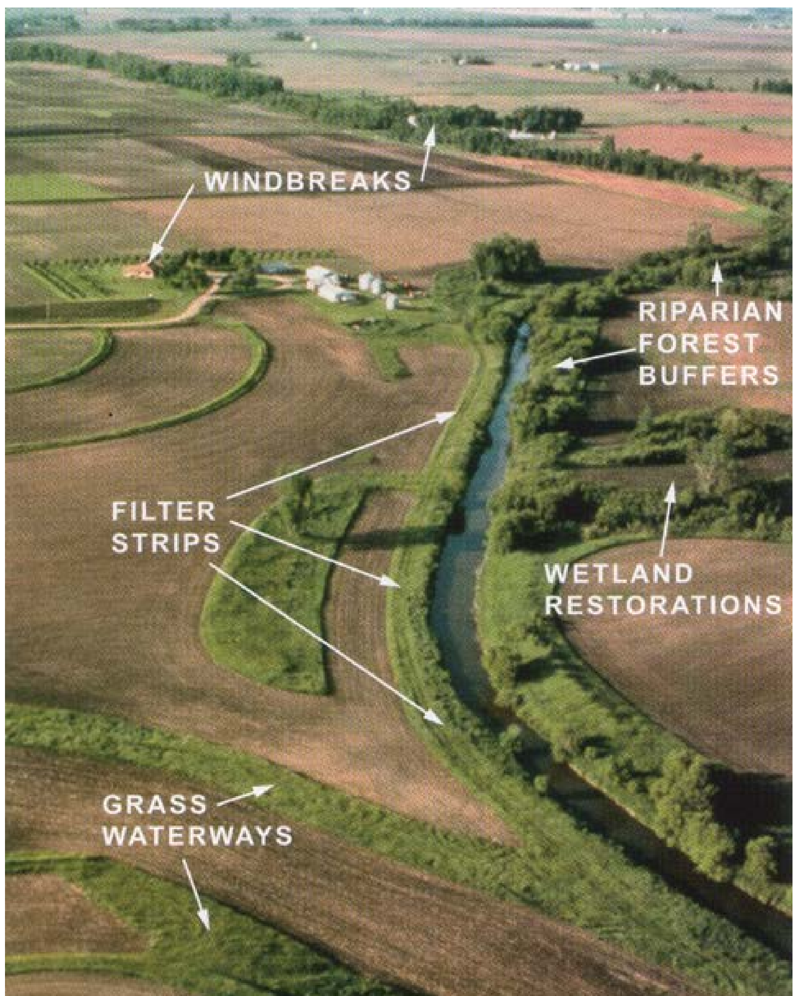
Managing the Water's Edge

What Are Riparian Corridors? Riparian Buffer Zones?

Buffers **can** include a range of complex vegetation structure, soils, food sources, cover, and water features that offer a variety of habitats contributing to diversity and abundance of wildlife such as mammals, frogs, amphibians, insects, and birds. Buffers can consist of a variety of canopy layers and cover types including ephemeral (temporary-wet for only part of year) wetlands/seasonal ponds/spring pools, shallow marshes, deep marshes, wetland meadows, wetland mixed forests, grasslands, shrubs, forests, and/or prairies. Riparian zones are areas of transition between aquatic and terrestrial ecosystems, and they can potentially offer numerous benefits to wildlife and people such as pollution reduction and recreation.

In the water resources literature, riparian buffers are referred to in a number of different ways. Depending on the focus and the intended function of a buffer, or a buffer-related feature, buffers may be referred to as stream corridors, critical transition zones, riparian management areas, riparian management zones, floodplains, or green infrastructure.

It is important to note that within an agricultural context, the term buffer is used more generally to describe filtering best management practices most often at the water's edge. Other practices which can be interrelated may also sometimes be called buffers. These include grassed waterways, contour buffer strips, wind breaks, field border, shelterbelts, windbreaks, living snow fence, or filter strips. These practices may or may not be adjacent to a waterway as illustrated in the photo to the right. For example, a grassed waterway is designed to filter sediment and reduce erosion and may connect to a riparian buffer. These more limited-purpose practices may link to multipurpose buffers, but by themselves, they are not adequate to provide the multiple functions of a riparian buffer as defined here.



U.S. Department of Agriculture, Natural Resource Conservation Service, Ohio Office.

Beyond the Environmental Corridor Concept

The term "environmental corridors" (also known as "green infrastructure") refers to an interconnected green space network of natural areas and features, public lands, and other open spaces that provide natural resource value. Environmental corridor planning is a process that promotes a systematic and strategic approach to land conservation and encourages land use planning and practices that are good for both nature and people. It provides a framework to guide future growth, land development, and land conservation decisions in appropriate areas to protect both community and natural resource assets.

Environmental corridors are an essential planning tool for protecting the most important remaining natural resource features in Southeastern Wisconsin and elsewhere. Since development of the environmental corridor concept, there have been significant advancements in landscape ecology that have furthered understanding of the spatial and habitat needs of multiple groups of organisms. In addition, advancements in pollutant removal practices, stormwater control, and agriculture have increased our understanding of the effectiveness and limitations of environmental corridors. In protecting water quality and providing aquatic and terrestrial habitat, there is a need to better integrate new technologies through their application within riparian buffers.

SEWRPC has embraced and applied the environmental corridor concept developed by Philip Lewis (Professor Emeritus of Landscape Architecture at the University of Wisconsin-Madison) since 1966 with the publication of its first regional land use plan. Since then, SEWRPC has refined and detailed the mapping of environmental corridors, enabling the corridors to be incorporated directly into regional, county, and community plans and to be reflected in regulatory measures. The preservation of environmental corridors remains one of the most important recommendations of the regional plan. Corridor preservation has now been embraced by numerous county and local units of government as well as by State and Federal agencies. The environmental corridor concept conceived by Lewis has become an important part of the planning and development culture in Southeastern Wisconsin.

Beyond the Environmental Corridor Concept

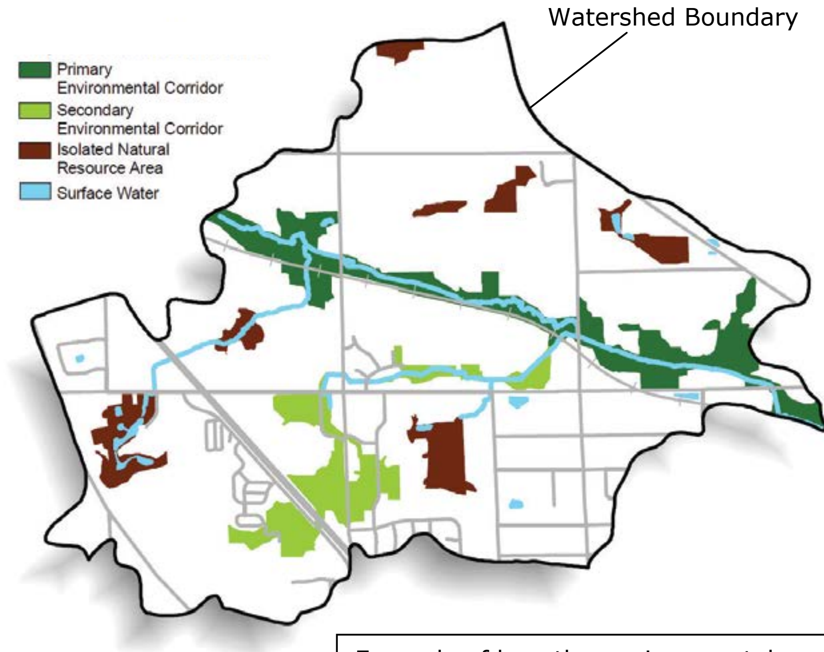
Environmental corridors are divided into the following three categories.

- **Primary environmental corridors** contain concentrations of our most significant natural resources. They are at least 400 acres in size, at least two miles long, and at least 200 feet wide.
- **Secondary environmental corridors** contain significant but smaller concentrations of natural resources. They are at least 100 acres in size and at least one mile long, unless serving to link primary corridors.
- **Isolated natural resource areas** contain significant remaining resources that are not connected to environmental corridors. They are at least five acres in size and at least 200 feet wide.

Key Features of Environmental Corridors

- Lakes, rivers, and streams
- Undeveloped shorelands and floodlands
- Wetlands
- Woodlands
- Prairie remnants
- Wildlife habitat
- Rugged terrain and steep slopes
- Unique landforms or geological formations
- Unfarmed poorly drained and organic soils
- Existing outdoor recreation sites
- Potential outdoor recreation sites
- Significant open spaces
- Historical sites and structures
- Outstanding scenic areas and vistas

Beyond the Environmental Corridor Concept

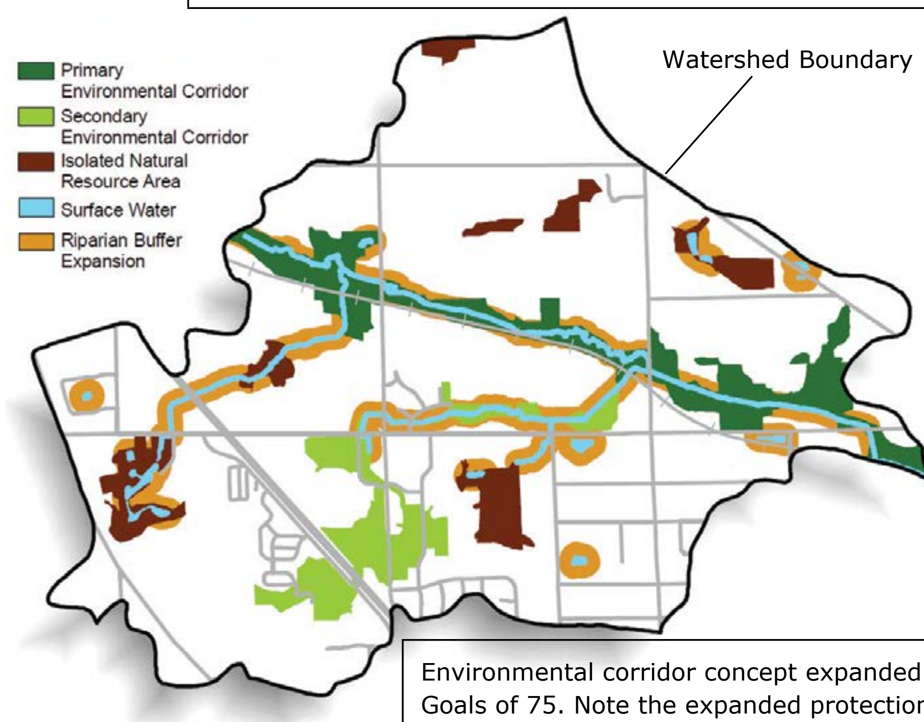


The Minimum Goals of **75** within a Watershed

75% minimum of total stream length should be naturally vegetated to protect the functional integrity of the water resources. (Environment Canada, How Much Habitat is Enough? A Framework for Guiding Habitat Rehabilitation in Great lakes Areas of Concern, Second Edition, 2004)

75 foot wide minimum riparian buffers from the top edge of each stream bank should be naturally vegetated to protect water quality and wildlife. (SEWRPC Planning Report No 50, A Regional Water Quality Management Plan for the Greater Milwaukee Watersheds, December 2007)

Example of how the environmental corridor concept is applied on the landscape. For more information see "Plan on It!" series **Environmental Corridors: Lifelines of the Natural Resource Base** at http://www.sewrpc.org/SEWRPC/LandUse/EnvironmentalCorridors.htm



Environmental corridor concept expanded to achieve the Goals of 75. Note the expanded protection in addition to the connection of other previously isolated areas.

Habitat Fragmentation—The Need for Corridors

Southeastern Wisconsin is a complex mosaic of agricultural and urban development. Agricultural lands originally dominated the landscape and remain a major land use. However, such lands continue to be converted to urban uses. Both of these dominant land uses fragment the landscape by creating islands or isolated pockets of wetland, woodland, and other natural lands available for wildlife preservation and recreation. By recognizing this fragmentation of the landscape, we can begin to mitigate these impacts.

New developments should incorporate water quality and wildlife enhancement or improvement objectives as design criteria by looking at the potential for creating linkages with adjoining lands and water features.

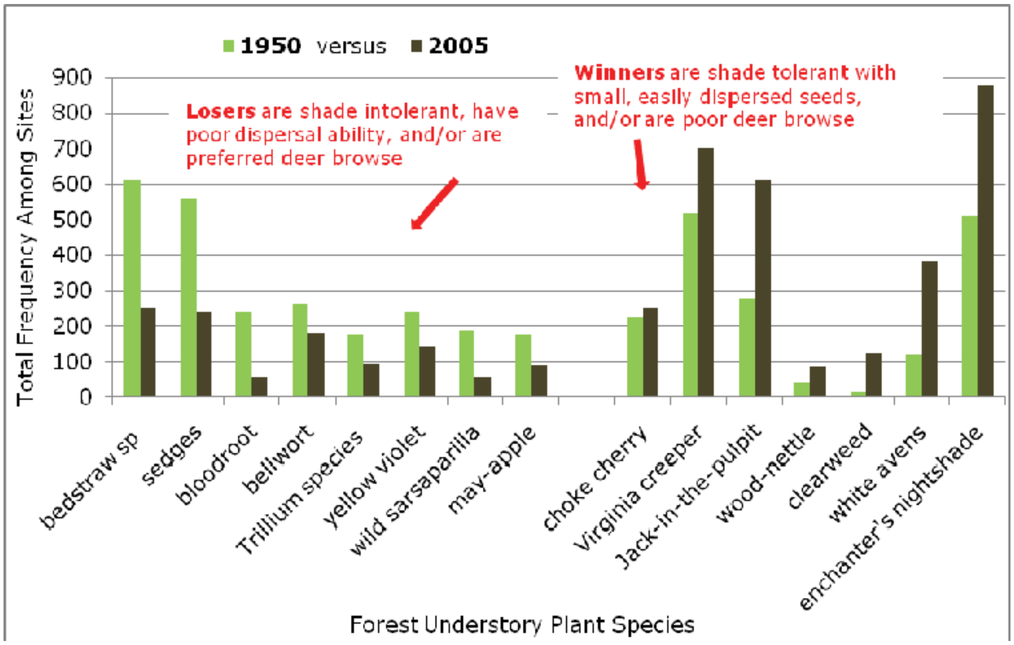
At the time of conversion of agricultural lands to urban uses, there are opportunities to re-create and expand riparian buffers and environmental corridors reconnecting uplands and waterways and restoring ecological integrity and scenic beauty locally and regionally. For example, placement of roads and other infrastructure across stream systems could be limited so as to maximize continuity of the riparian buffers. This can translate into significant cost savings in terms of reduced road maintenance, reduced salt application, and limited bridge or culvert maintenance and replacements. This simple practice not only saves the community significant amounts of money, but also improves and protects quality of life. Where necessary road crossings do occur, they can be designed to provide for safe fish and wildlife passage.

Overland travel routes for wildlife are often unavailable, discontinuous, or life endangering within the highly fragmented landscapes of Southeastern Wisconsin and elsewhere.

State Threatened Species: Blanding's turtle

Habitat Fragmentation—The Need for Corridors

Forest understory plant species abundance among stands throughout Southern Wisconsin



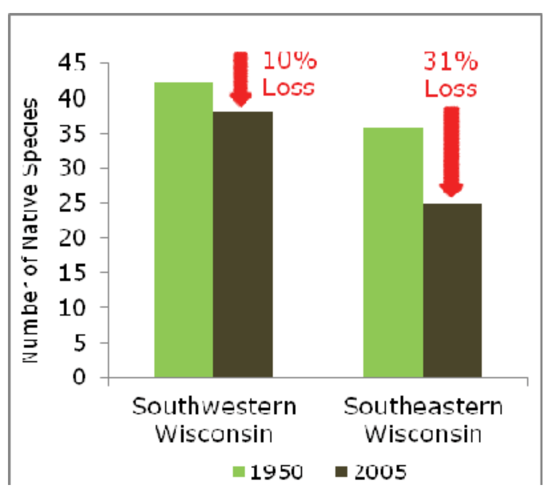
Forest fragmentation has led to significant plant species loss within Southern Wisconsin

(Adapted from David Rogers and others, 2008, Shifts in Southern Wisconsin Forest Canopy and Understory Richness, Composition, and Heterogeneity, Ecology, 89 (9): 2482-2492)

"…these results confirm the idea that large intact habitat patches and landscapes better sustain native species diversity. It also shows that people are a really important part of the system and their actions play an increasingly important role in shaping patterns of native species diversity and community composition. Put together, it is clear that one of the best and most cost effective actions we can take toward safeguarding native diversity of all types is to protect, enhance and create corridors that link patches of natural habitat."
Dr. David Rogers, Professor of Biology at the University of Wisconsin-Parkside

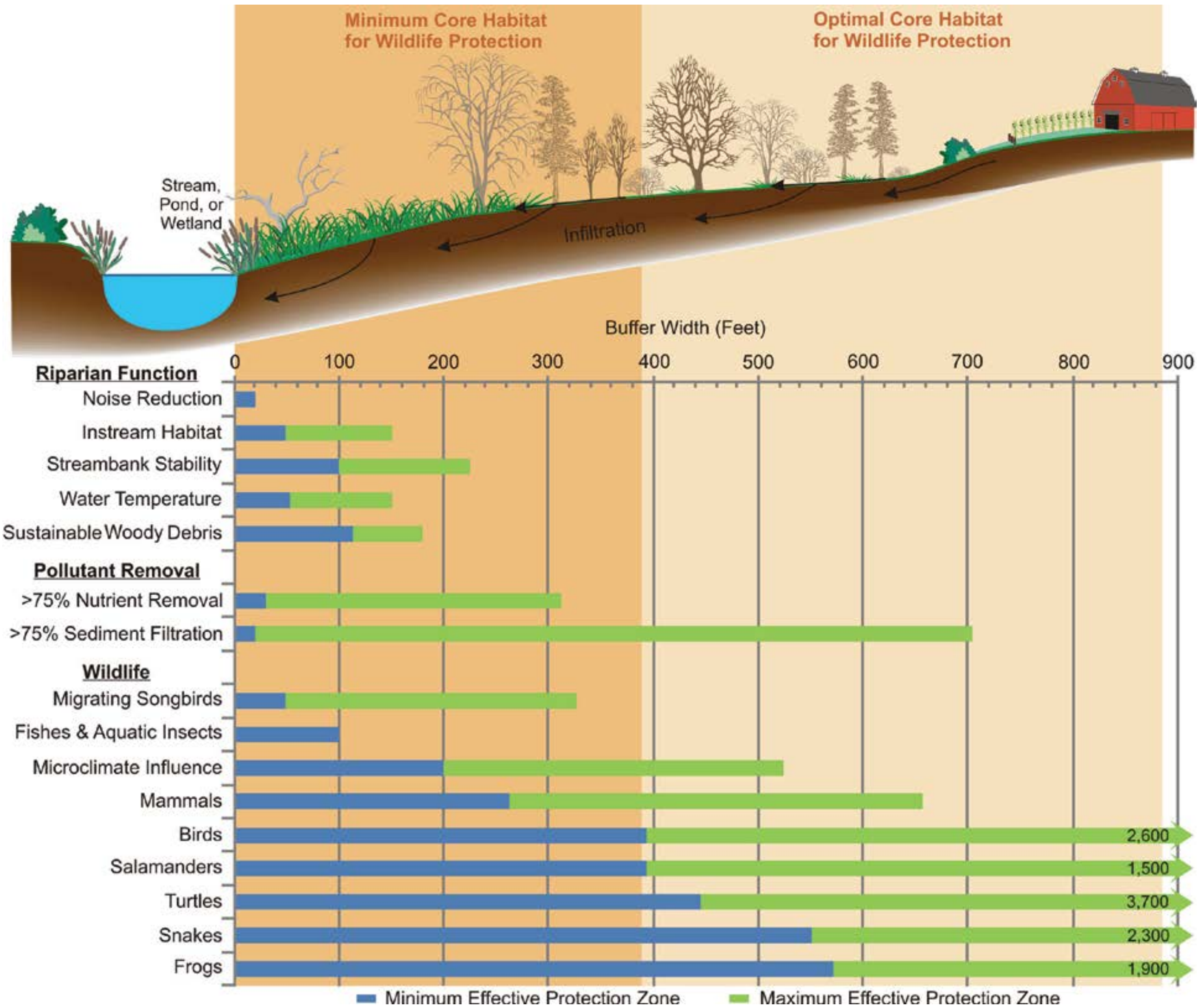
Since the 1950s, forests have increasingly become more fragmented by land development, both agricultural and urban, and associated roads and infrastructure, which have caused these forests to become isolated "islands of green" on the landscape. In particular, there has been significant loss of forest understory plant species over time (shrubs, grasses, and herbs covering the forest floor.) It is important to note that **these forests lost species diversity even when they were protected as parks or natural areas**.

One major factor responsible for this decline in forest plant diversity is that routes for native plants to re-colonize isolated forest islands are largely cut-off within fragmented landscapes. For example, the less fragmented landscapes in Southwestern Wisconsin lost fewer species than the more fragmented stands in Southeastern Wisconsin. In addition, the larger-sized forests and forests with greater connections to surrounding forest lands lost fewer species than smaller forests in fragmented landscapes.



Wider is Better for Wildlife

Why? Because buffer size is the engine that drives important natural functions like food availability and quality, access to water, habitat variety, protection from predators, reproductive or resting areas, corridors to safely move when necessary, and help in maintaining the health of species' gene pools to prevent isolation and perhaps extinction.



One riparian buffer size does not fit all conditions or needs. There are many riparian buffer functions and the ability to effectively fulfill those functions is largely dependent on width. Determining what buffer widths are needed should be based on what functions are desired as well as site conditions. For example, as shown above, water temperature protection generally does not require as wide a buffer as provision of habitat for wildlife. Based on the needs of wildlife species found in Wisconsin, the minimum core habitat buffer width is about 400 feet and the optimal width for sustaining the majority of wildlife species is about 900 feet. Hence, the value of large undisturbed parcels along waterways which are part of, and linked to, an environmental corridor system. The minimum effective buffer width distances are based on data reported in the scientific literature and the quality of available habitats within the context of those studies.

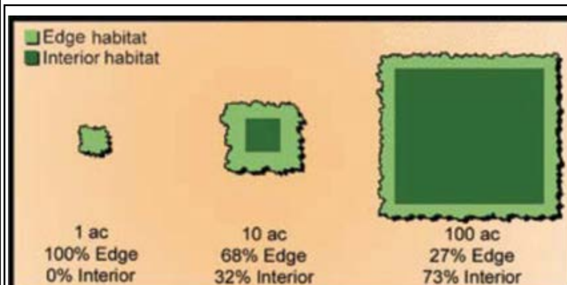
Wider is Better for Wildlife

Wildlife habitat needs change within and among species. **Minimum Core Habitat and Optimum Core Habitat distances were developed from numerous studies to help provide guidance for biologically meaningful buffers to conserve wildlife biodiversity.** These studies documented distances needed for a variety of biological (life history) needs to sustain healthy populations such as breeding, nesting, rearing young, foraging/feeding, perching (for birds), basking (for turtles), and overwintering/dormancy/hibernating. These life history needs require different types of habitat and distances from water, for example, one study found that Blanding's turtles needed approximately 60-foot-wide buffers for basking, 375 feet for overwintering, and up to 1,200 feet for nesting to bury their clutches of eggs. Some species of birds like the Blacked-capped chickadee or white breasted nuthatch only need about 50 feet of buffer, while others like the wood duck or great blue heron require 700-800 feet for nesting. Therefore, **understanding habitat needs for wildlife species is an important consideration in designing riparian buffers.**

Although *Ambystoma* salamanders require standing water for egg laying and juvenile development, most other times of the year they can be found more than 400 feet from water foraging for food.

Wisconsin Species	Mimimum Core Habitat (feet)	Optimum Core Habitat (feet)	Number of Studies
Frogs	571	1,043	9
Salamanders	394	705	14
Snakes	551	997	5
Turtles	446	889	27
Birds	394	787	45
Mammals	263	No data	11
Fishes and Aquatic Insects	100	No data	11
Mean	388	885	

This approach was adapted from *R.D. Semlitsch and J.R. Bodie, 2003, Biological Criteria for Buffer Zones around Wetlands and Riparian Habitats for Amphibian and Reptiles, Conservation Biology, 17(5):1219-1228*. These values are based upon studies examining species found in Wisconsin and represent mean linear distances extending outward from the edge of an aquatic habitat. The Minimum Core Habitat and Optimum Core Habitat reported values are based upon the mean minimum and mean maximum distances recorded, respectively. Due to a low number of studies for snake species, the recommended distances for snakes are based upon values reported by *Semlitsch and Bodie.*



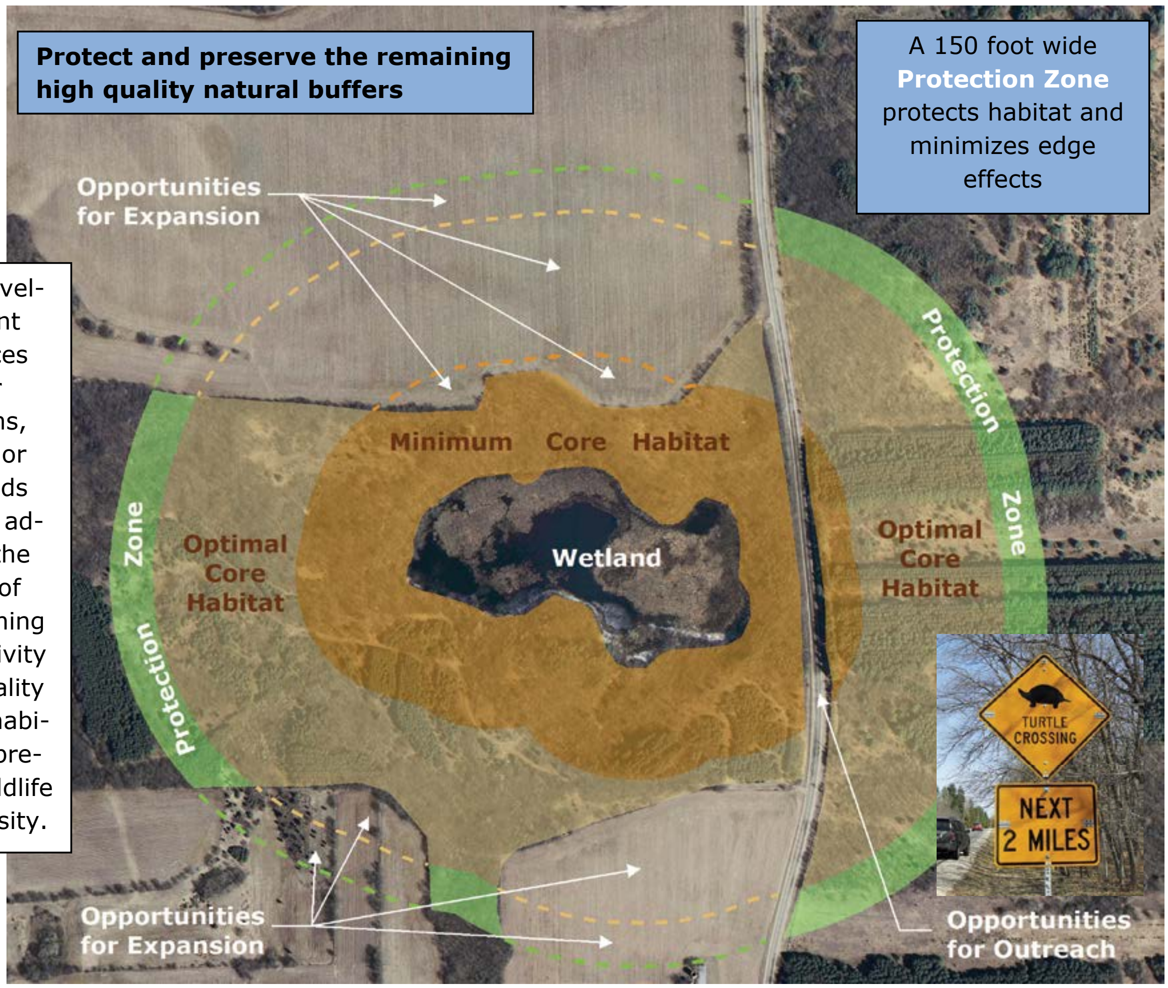
*"**Large patches typically conserve a greater variety and quality of habitats, resulting in higher species diversity and abundance."** Larger patches contain greater amounts of interior habitat and less edge effects, which benefits interior species, by providing safety from parasitism, disease, and invasive species.*

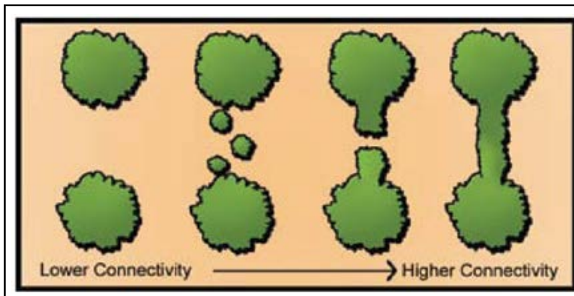
(Bentrup, G. 2008. Conservation buffers: design guidelines for buffers, corridors, and greenways. Gen. Tech. Rep. SRS-109. Asheville, NC: Department of Agriculture, Forest Service, Southern Research Station)

Maintaining Connections is Key

Like humans, all forms of wildlife require access to clean water. Emerging research has increasingly shown that, in addition to water, more and more species such as amphibians and reptiles cannot persist without landscape connectivity between quality wetland and upland habitats. Good connectivity to upland terrestrial habitats is essential for the persistence of healthy sustainable populations, because these areas provide vital feeding, overwintering, and nesting habitats found nowhere else. Therefore, both aquatic and terrestrial habitats are essential for the preservation of biodiversity and they should ideally be managed together as a unit.

Land development practices near streams, lakes, or wetlands need to address the issue of maintaining connectivity with quality upland habitats to preserve wildlife biodiversity.





Increasing connectivity among quality natural landscapes (wetlands, woodlands, prairies) can benefit biodiversity by providing access to other areas of habitat, increasing gene flow and population viability, enabling recolonization of patches, and providing habitat (Bentrup 2008).

Basic Rules to Better Buffers

There are opportunities to improve buffer functions to improve water quality and wildlife habitat, even in urban situations

- Channelized ditch
- Historic flooplain fill
- Invasive species dominate

- Meandered stream
- Reconnected floodplain
- Wetland diversity added
- Native species restored

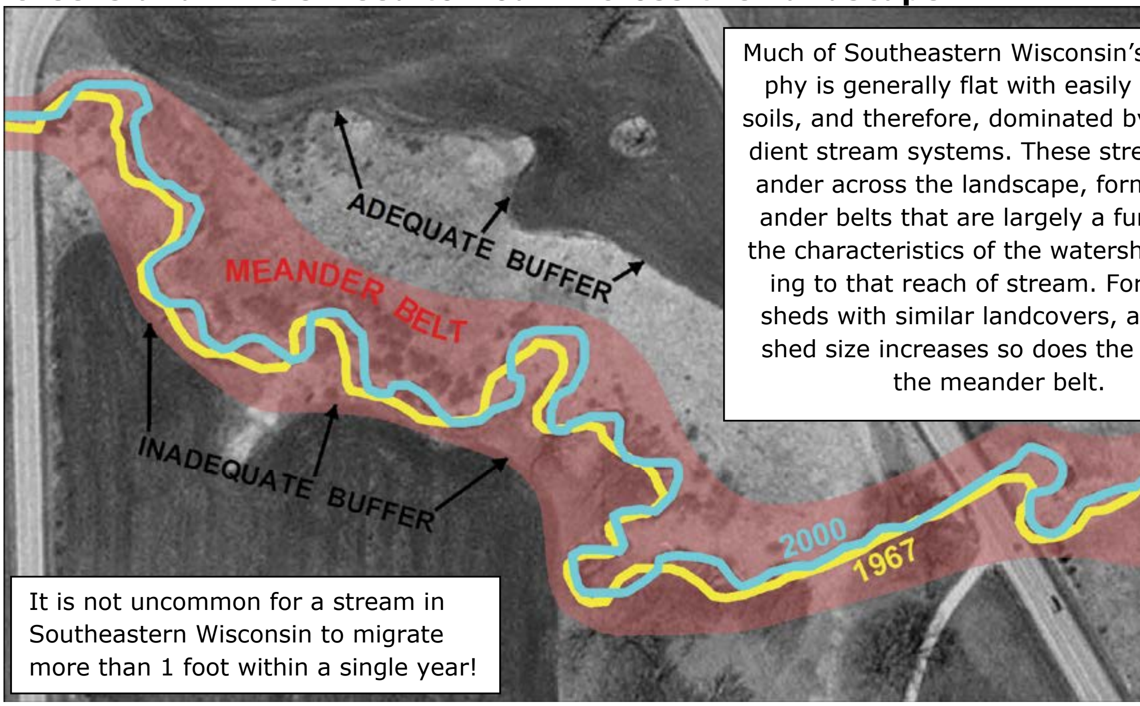
Protecting the integrity of native species in the region is an objective shared by many communities. The natural environment is an essential component of our existence and contributes to defining our communities and neighborhoods. Conservation design and open space development patterns in urbanizing areas and farm conservation programs in rural areas have begun to address the importance of maintaining and restoring riparian buffers and connectivity among corridors.

How wide should the buffer be? Unfortunately, there is no one-size-fits all buffer width adequate to protect water quality, wildlife habitat, and human needs. Therefore, the answer to this question depends upon the predetermined needs of the landowner and community objectives or goals. As riparian corridors become very wide, their pollutant removal (buffering) effectiveness may reach a point of diminishing returns compared to the investment involved. However, the prospects for species diversity in the corridor keep increasing with buffer width. For a number of reasons, 400- to 800-foot-wide buffers are not practical along all lakes, streams, and wetlands within Southeastern Wisconsin. Therefore, communities should develop guidelines that remain flexible to site-specific needs to achieve the most benefits for water resources and wildlife as is practical.

Key considerations to better buffers/corridors:

- Wider buffers are better than narrow buffers for water quality and wildlife functions
- Continuous corridors are better than fragmented corridors for wildlife
- Natural linkages should be maintained or restored
- Linkages should not stop at political boundaries
- Two or more corridor linkages are better than one
- Structurally diverse corridors (e.g., diverse plant structure or community types, upland and wetland complexes, soil types, topography, and surficial geology) are better than corridors with simple structures
- Both local and regional spatial and temporal scales should be considered in establishing buffers
- Corridors should be located along dispersal and migration routes
- Corridors should be located and expanded around rare, threatened, or endangered species
- Quality habitat should be provided in a buffer whenever possible
- Disturbance (e.g. excavation or clear cutting vegetation) of corridors should be minimized during adjacent land use development
- Native species diversity should be promoted through plantings and active management
- Non-native species invasions should be actively managed by applying practices to preserve native species
- Fragmentation of corridors should be reduced by limiting the number of crossings of a creek or river where appropriate
- Restoration or rehabilitation of hydrological function, streambank stability, instream habitat, and/or floodplain connectivity should be considered within corridors.
- Restoration or retrofitting of road and railway crossings promotes passage of aquatic organisms

Creeks and Rivers Need to Roam Across the Landscape



Much of Southeastern Wisconsin's topography is generally flat with easily erodible soils, and therefore, dominated by low gradient stream systems. These streams meander across the landscape, forming meander belts that are largely a function of the characteristics of the watershed draining to that reach of stream. For watersheds with similar landcovers, as watershed size increases so does the width of the meander belt.

It is not uncommon for a stream in Southeastern Wisconsin to migrate more than 1 foot within a single year!

Healthy streams naturally meander or migrate across a landscape over time. Streams are transport systems for water and sediment and are continually eroding and depositing sediments, which causes the stream to migrate. When the amount of sediment load coming into a stream is equal to what is being transported downstream—and stream widths, depths, and length remain consistent over time—it is common to refer to that stream as being in a state of **"dynamic equilibrium."** In other words the stream retains its physical dimensions (equilibrium), but those physical features are shifted, or migrate, over time (dynamic).

Room to Roam

Riparian buffer widths should take into account the amount of area that a stream needs to be able to self-adjust and maintain itself in a state of dynamic equilibrium. … These are generally greater than any minimum width needed to protect for pollutant removal alone.

Streams are highly sensitive, and they respond to changes in the amounts of water and sediment draining to them, which are affected by changing land use conditions. For example, streams can respond to increased discharges of water by increased scour (erosion) of bed and banks that leads to an increase in stream width and depth—or "degradation." Conversely, streams can respond to increased sedimentation (deposition) that leads to a decrease in channel width and depth—or "aggradation."

Managing the Water's Edge

Why Should You Care About Buffers?

Economic Benefits:

- Increased value of riparian property
- Reduced lawn mowing time and expense
- Increased shade to reduce building cooling costs
- Natural flood mitigation protection for structures or crops
- Pollution mitigation (reduced nutrient and contaminant loading)
- Increased infiltration and groundwater recharge
- Prevented loss of property (land or structures) through erosion
- Greater human and ecological health through biodiversity

Recreational Benefits:

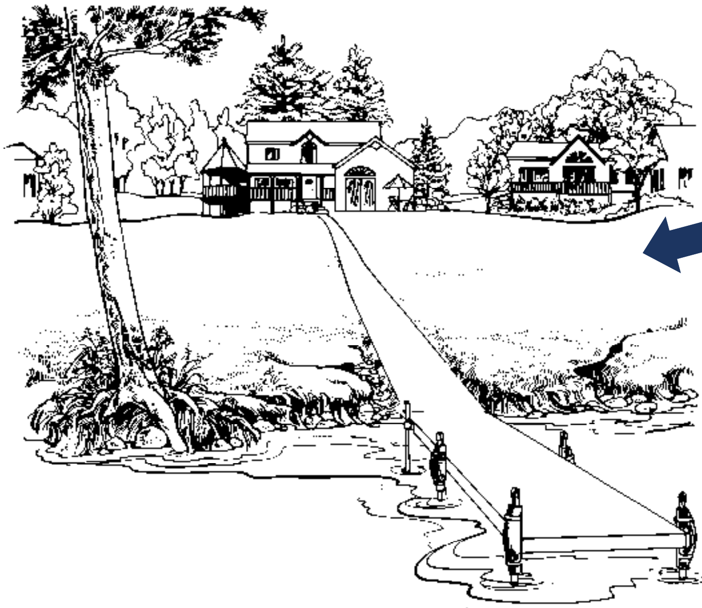
- Increased quality of the canoeing/kayaking experience
- Improved fishing and hunting quality by improving habitat
- Improved bird watching/wildlife viewing quality and opportunities
- Increased potential for expansion of trails for hiking and bicycling
- Opportunities made available for youth and others to locally reconnect with nature

Riparian buffers make sense and are profitable monetarily, recreationally, and aesthetically!

Social Benefits:

- Increased privacy
- Educational opportunities for outdoor awareness
- Improved quality of life at home and work
- Preserved open space/balanced character of a community
- Focal point for community pride and group activities
- Visual diversity
- Noise reduction

A Matter of Balance



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Although neatly trimmed grass lawns are popular, these offer limited benefits for water quality or wildlife habitat. A single house near a waterbody may not seem like a "big deal," but the cumulative effects of many houses can negatively impact streams, lakes, and wetlands.

All the lands within Southeastern Wisconsin ultimately flow into either the Mississippi River or the Great Lakes systems. The cumulative effects of agriculture and urban development in the absence of mitigative measures, ultimately affects water quality in those systems. Much of this development causes increases in water runoff from the land into wetlands, ponds, and streams. This runoff transports water, sediments, nutrients, and other pollutants into our waterways that can lead to a number of problems, including flooding that can cause crop loss or building damage; unsightly and/or toxic algae blooms; increased turbidity; damage to aquatic organisms from reduced dissolved oxygen, lethal temperatures, and/or concentrations of pollutants; and loss of habitat.

Riparian buffers are one of the most effective tools available for defending our waterways. Riparian buffers can be best thought of as forming a living, self-sustainable protective shield. This shield protects investments in the land and all things on it as well as our quality of life locally, regionally, and, ultimately, nationally. Combined with stormwater management, environmentally friendly yard care, effective wastewater treatment, conservation farming methods, and appropriate use of fertilizers and other agrichemicals, **riparian buffers complete the set of actions that we can take to minimize impacts to our shared water resources.**

Lakeshore buffers can take many forms, which require a balancing act between lake viewing, access, and scenic beauty. Lakeshore buffers can be integrated into a landscaping design that complements both the structural development and a lakeside lifestyle. Judicious placement of access ways and shoreline protection structures, and preservation or reestablishment of native vegetation, can enhance and sustain our use of the environment.

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Case Study—Agricultural Buffers

Agricultural nonpoint source pollution runoff continues to pose a threat to water quality and aquatic ecosystems within Wisconsin and elsewhere. In an effort to address this problem, the Wisconsin Buffer Initiative was formed with the goal of designing a buffer implementation program to achieve science-based, cost-effective, water quality improvements (report available online at http://www.soils.wisc.edu/extension/nonpoint/wbi.php).

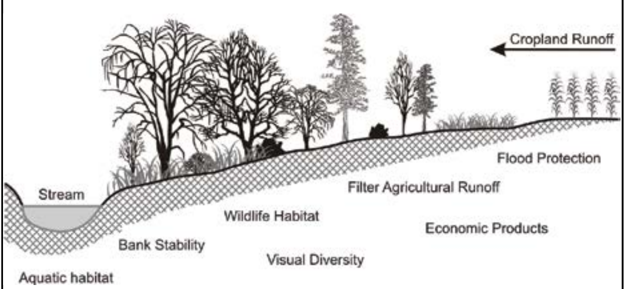
While it is true that riparian buffers alone may not always be able to reduce nutrient and sediment loading from agricultural lands, WBI researchers found that "...***riparian buffers are capable of reducing large percentages of the phosphorus and sediment that are currently being carried by Wisconsin streams. Even in watersheds with extremely high loads (top 10%), an average of about 70% of the sediment and phosphorus can be reduced through buffer implementation***." (*Diebel, M.J. and others, 2009, Landscape planning for agricultural nonpoint source pollution reduction III: Assessing Phosphorus and sediment reduction potential, Environmental Management, 43:69-83.*).

Challenge:
Buffers may take land out of cultivated crop production and require additional cost to install and maintain. Cost sharing, paid easements, and purchase of easements or development rights may sometimes be available to offset costs.

Benefits:
Buffers may offset costs by producing perennial crops such as hay, lumber, fiber, nuts, fruits, and berries. In addition, they provide visual diversity on the landscape, help maintain long-term crop productivity, and help support healthier fish populations for local enjoyment.

Federal and state natural resource agencies have long recognized the need to apply a wide range of Best Management Practices on agricultural lands to improve stream water quality. Although there are many tools available in the toolbox to reduce pollutant runoff from agricultural lands, such as crop rotations, nutrient and manure management, conservation tillage, and contour plowing, riparian buffers are one of the most effective tools to accomplish this task. Their multiple benefits and inter-connectedness from upstream to downstream make riparian buffers a choice with watershed-wide benefits.

Determine what benefits are needed.



The USDA in *Agroforestry Notes* (AF Note-4, January 1997) outlines a four step process for designing riparian buffers for Agricultural lands:

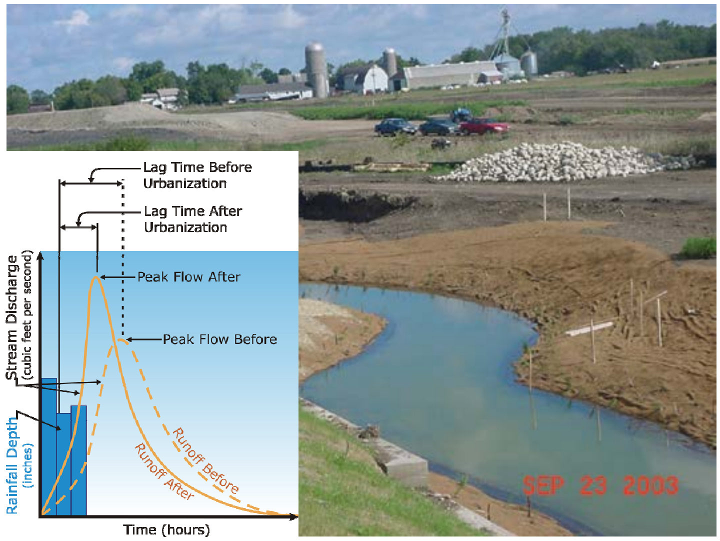
1-Determine what buffers functions are needed
2-Identify the best types of vegetation to provide the needed benefits
3-Determine the minimum acceptable buffer width to achieve desired benefits
4-Develop an installation and maintenance plan

Drain tiles can bypass infiltration and filtration of pollutants by providing a direct pathway to the water and "around" a buffer. This is important to consider in design of a buffer system which integrates with other agricultural practices.

Case Study—Urbanizing Area Buffers

When development occurs near a waterbody, the area in driveways, rooftops, sidewalks, and lawns increases, while native plants and undisturbed soils decrease. As a result, the ability of the shoreland area to perform its natural functions (flood control, pollutant removal, wildlife habitat, and aesthetic beauty) is decreased. In the absence of mitigating measures, one the consequences of urban development is an increase in the amount of stormwater, which runs off the land instead of infiltrating into the ground. Therefore, **urbanization impacts the watershed, not only by reducing groundwater recharge, but also by changing stream hydrology** through increased stormwater runoff volumes and peak flows. This means less water is available to sustain the baseflow regime. The urban environment also contains increased numbers of pollutants and generates greater pollutant concentrations and loads than any other land use. This reflects the higher density of the human population and associated activities, which demand measures to protect the urban water system.

Mitigation of urban impacts may be as simple as not mowing along a stream corridor or changing land management and yard care practices, or as complex as changing zoning ordinances or widening riparian corridors through buyouts.

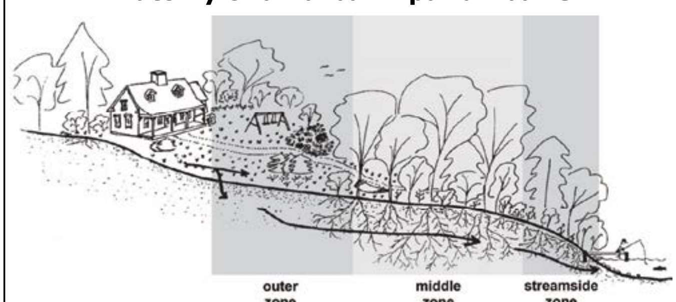


Comparison of hydrographs before and after urbanization. Note the rapid runoff and greater peak streamflow tied to watershed development. (Adapted from Federal Interagency Stream Restoration Working Group (FISRWG), Stream Corridor Restoration: Principles, Processes, and Practices, October 1998)

Challenge:
Urban development requires balancing flood protection, water quality protection, and the economic viability of the development.

Opportunities:
Buffers may offset costs by providing adequate space for providing long-term water quantity and water quality protection. In addition, they provide visual diversity on the landscape, wildlife habitat and connectedness, and help maintain property values.

Anatomy of an urban riparian buffer



The most effective urban buffers have three zones:

Outer Zone-Transition area between the intact buffer and nearest permanent structure to capture sediment and absorb runoff.

Middle Zone-Area from top of bank to edge of lawn that is composed of natural vegetation that provides wildlife habitat as well as improved filtration and infiltration of pollutants.

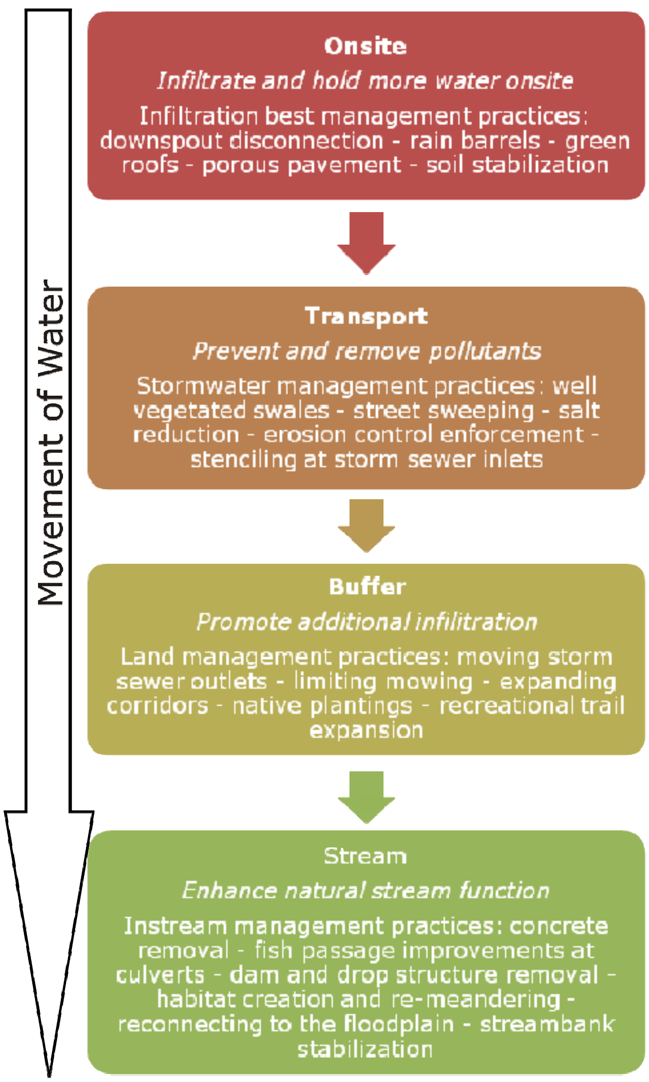
Streamside Zone-Area from the water's edge to the top of the bank or uplands that provides critical connection between water, wetland, and upland habitats for wildlife as well as protect streams from bank erosion

(Fact sheet No. 6 Urban Buffer in the series Riparian Buffers for Northern New Jersey)

Case Study—Urban Buffers

Placement of riparian buffers in established urban areas is a challenge that requires new and innovative approaches. In these areas, historical development along water courses limits options and requires balancing flood management protection versus water quality and environmental protection needs. Consequently, some municipalities have begun to recognize the connections between these objectives and are introducing programs to remove flood-prone structures and culverts from the stream corridors and allow recreation of the stream, restoring floodplains, and improving both the quality of life and the environment.

In urban settings it may be necessary to limit pollution and water runoff before it reaches the buffer.



Challenge:
There are many potential constraints to establishing, expanding, and/or managing riparian buffers within an urban landscape. Two major constraints to establishment of urban buffers include:

1) **Limited or confined space to establish buffers** due to encroachment by structures such as buildings, roadways, and/or sewer infrastructure;

2) **Fragmentation of the landscape** by road and railway crossings of creeks and rivers that disrupt the linear connectedness of buffers, limiting their ability to provide quality wildlife habitat.

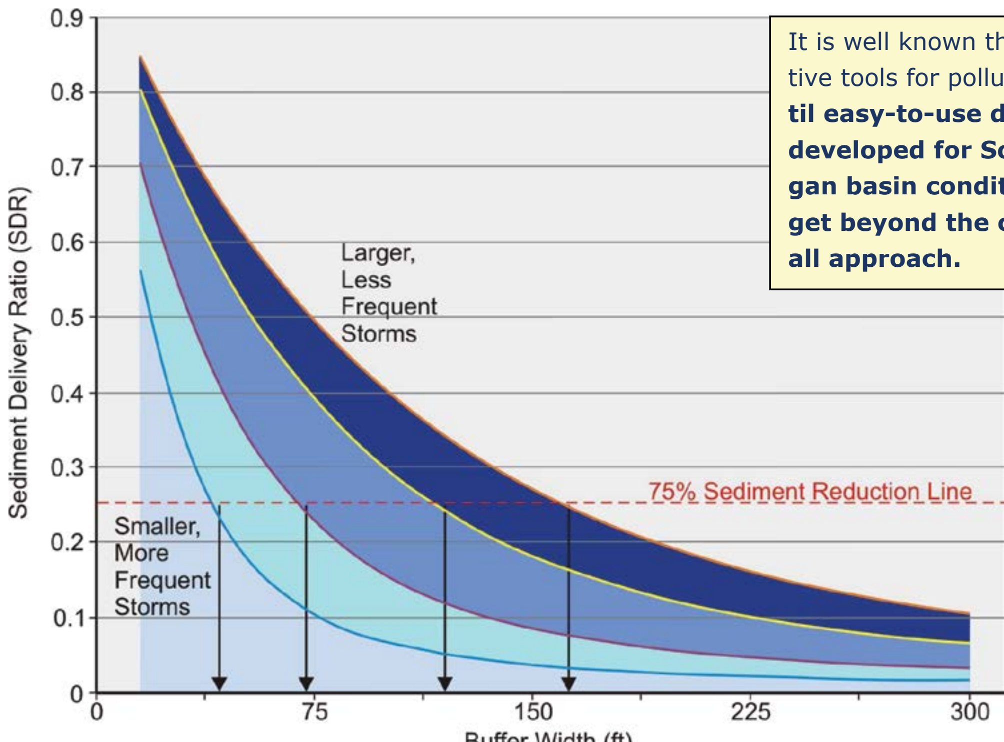
Much traditional stormwater infrastructure intercepts runoff and diverts it directly into creeks and rivers, bypassing any benefits of buffers to infiltrate or filter pollutants. This is important to consider in design of a buffer system for urban waterways, which begin in yards, curbsides, and construction sites, that are figuratively as close to streams as the nearest storm sewer inlet.

A Buffer Design Tool

Design aids are needed to help municipalities, property owners, and others take the "guesswork" out of determining adequate buffer widths for the purpose of water resource quality protection. While there are various complex mathematical models that can be used to estimate sediment and nutrient removal efficiencies, they are not easily applied by the people who need them including homeowners, farmers, businesses and developers.

To fill this gap, design aid tools are being developed using factors such as slope, soils, field length, incoming pollutant concentrations, and vegetation to allow the user to identify and test realistic buffer widths with respect to the desired percent pollutant load reduction and storm characteristics. By developing a set of relationships among factors that determine buffer effectiveness, the width of buffer needed to meet specific goals can be identified.

In the example below, 50-foot-wide buffers are necessary to achieve 75 % sediment removal during small, low intensity storms, while buffers more than 150 feet wide are necessary to achieve the same sediment reduction during more severe storms. Based on this information, decision-makers have the option of fitting a desired level of sediment removal into the context of their specific conditions. Under most conditions, a 75-foot width will provide a minimum level of protection for a variety of needs (SEWRPC PR No. 50, Appendix O.)



It is well known that buffers are effective tools for pollutant removal, but **until easy-to-use design aid tools are developed for Southern Lake Michigan basin conditions, we can never get beyond the current one size fits all approach.**

This generalized graph depicts an example of model output for an optimal buffer width to achieve a 75% sediment reduction for a range of soil and slope, vegetation, and storm conditions characteristic of North Carolina. *(Adapted from Muñoz-Carpena R., Parsons J.E.. 2005. VFSMOD-W: Vegetative Filter Strips Hydrology and Sediment Transport Modeling System v.2.x. Homestead, FL: University of Florida. http://carpena.ifas.ufl.edu/vfsmod/citations.shtml)*

Managing the Water's Edge

Buffers Are A Good Defense

Today's natural resources are under threat. These threats are immediate as in the case of chemical accidents or manure spills, and chronic as in the case of stormwater pollution carrying everything from eroded soil, to fertilizer nutrients, to millions of drips from automobiles and other sources across the landscape. Non-native species have invaded, and continue to invade, key ecosystems and have caused the loss of native species and degradation of their habitats to the detriment of our use of important resources.

> ***"Riparian ecosystems are naturally resilient,*** *provide linear habitat connectivity, link aquatic and terrestrial ecosystems, and create thermal refugia for wildlife: all characteristics that can contribute to ecological adaptation to climate change."*
>
> *(N. E. Seavy and others, Why Climate Change Makes Riparian Restoration More Important Than Ever: Recommendations for Practice and Research, 2009, Ecological Restoration 27(3):330-338)*

A more subtle, but growing, concern is the case of stresses on the environment resulting from climate change. Buffers present an opportunity for natural systems to adapt to such changes by providing the space to implement protective measures while also serving human needs. **Because riparian buffers maintain an important part of the landscape in a natural condition, they offer opportunities for communities to adjust to our changing world.**

Well-managed riparian buffers are a good defense against these threats. In combination with environmental corridors, buffers maintain a sustainable reserve and diversity of habitats, plant and animal populations, and genetic diversity of organisms, all of which contribute to the long-term preservation of the landscape. Where they are of sufficient size and connectivity, riparian buffers act as reservoirs of resources that resist the changes that could lead to loss of species.

Refuge or protection from increased water temperatures as provided by natural buffers is important for the preservation of native cold-water, cool-water, and warm-water fishes and their associated communities.

Buffers Provide Opportunities

River, lake, and wetland systems and their associated riparian lands form an important element of the natural resource base, create opportunities for recreation, and contribute to attractive and well-balanced communities. These resources can provide an essential avenue for relief of stress among the population and improve quality of life in both urban and rural areas. Such uses also sustain industries associated with outfitting and supporting recreational and other uses of the natural environment, providing economic opportunities. Increasing access and assuring safe use of these areas enhances public awareness and commitment to natural resources. Research has shown that property values are higher adjoining riparian corridors, and that such natural features are among the most appreciated and well-supported parts of the landscape for protection.

We demand a lot from our riparian buffers!

Sustaining this range of uses requires our commitment to protect and maintain them.

Managing the Water's Edge

Summary

The following guidance suggestions highlight key points to improve riparian corridor management and create a more sustainable environment.

Riparian corridors or buffers along our waters may contain varied features, but all are best preserved or designed to perform multiple important functions.

Care about buffers because of their many benefits. Riparian buffers make sense and are profitable monetarily, recreationally, aesthetically, as well as environmentally.

Enhance the environmental corridor concept. Environmental corridors are special resources which deserve protection. They serve many key riparian corridor functions, but in some cases, could also benefit from additional buffering.

Avoid habitat fragmentation of riparian corridors. It is important to preserve and link key resource areas, making natural connections and avoiding habitat gaps.

Employ the adage "wider is better" for buffer protection. While relatively narrow riparian buffers may be effective as filters for certain pollutants, that water quality function along with infiltration of precipitation and runoff and the provision of habitat for a host of species will be improved by expanding buffer width where feasible.

Allow creeks and rivers room to roam across the landscape. Streams are dynamic and should be buffered adequately to allow for natural movement over time while avoiding problems associated with such movement.

Consider and evaluate buffers as a matter of balance. Riparian buffers are a living, self-sustainable shield that can help balance active use of water and adjoining resources with environmental protection.

Agricultural buffers can provide many benefits. Riparian buffers in agricultural settings generally work well, are cost-effective, and can provide multiple benefits, including possibly serving as areas to raise certain crops.

Urban buffers should be preserved and properly managed. Though often space-constrained and fragmented, urban buffers are important remnants of the natural system. Opportunities to establish or expand buffers should be considered, where feasible, complemented by good stormwater management, landscaping, and local ordinances, including erosion controls.

A buffer design tool is needed and should be developed. Southeastern Wisconsin and the Southern Lake Michigan Basin would benefit from development of a specific design tool to address the water quality function of buffers. Such a tool would improve on the currently available general guidance on dimensions and species composition.

Buffers are a good defense. Combined with environmental corridors, riparian buffers offer a good line of defense against changes which can negatively impact natural resources and the landscape.

Managing the Water's Edge

MORE TO COME

Future editions in a riparian buffer planning series are being explored with the intent of focusing on key elements of this critical land and water interface. Topics may include:

- Information sharing and development of ordinances to integrate riparian buffers into existing land management plans and programs
- Integration of stormwater management practices and riparian buffer best management practices
- Application of buffers within highly constrained urban corridors with and without brownfield development
- Installation of buffers within rural or agricultural lands being converted to urban uses
- Utilization of buffers in agricultural areas and associated drainage systems
- Integration of riparian buffers into environmental corridors to support resources preservation, recreation and aesthetic uses
- Preservation of stream courses and drainageways to minimize maintenance and promote protection of infrastructure
- Guidance for retrofitting, replacement, or removal of infrastructure such as dams and road crossings, to balance transportation, recreation, aesthetic, property value, and environmental considerations.
- Protection of groundwater recharge and discharge areas
- Protection of high quality, sensitive coastal areas, including preservation of recreational potential

MORE INFORMATION

This booklet can be found at http://www.sewrpc.org/RBMG-no1 . Please visit the website for more information, periodic updates, and a list of complementary publications.

* * *

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APPENDIX D

MASON CREEK POTENTIALLY RESTORABLE WETLAND EVALUATION

MASON CREEK POTENTIALLY RESTORABLE WETLAND EVALUATION

Step 1. Information to Help Determine Appropriate Restoration Targets

A. **Pre-Settlement Vegetation (see Map 1.3 in Chapter 1 of this report)** – Pre-settlement vegetation in the Mason Creek sub-watershed consisted primarily of forested plant community types. These included maple-basswood-red oak forest, oak forest, conifer swamp/bog, and lowland hardwoods. There was a small area of relatively open oak savanna in the northern part of the sub-watershed. Significant areas of non-forested wetland were also present in the northern and western parts of the sub-watershed.

B. **Historical Aerial Imagery** – Agricultural land use was already extensive in 1940 (Figure D.1). Trees occurred primarily in the northeastern portion of the watershed in areas where pre-settlement vegetation was mapped as oak forest and maple-basswood-red oak forest and in the central portion of the sub-watershed where pre-settlement vegetation was mapped as conifer swamp/bog. Other wetland areas were predominantly open, particularly in the western and northwestern portion of the sub-watershed. Figure D.2 shows how portions of the western and northwestern part of the Mason Creek sub-watershed appeared in 1940, with patches of trees and shrubs (dark gray) visible to the far right with more open wetlands immediately to their west (lighter gray). Portions of some of the open wetlands were farmed.

C. **Natural Areas and Rare Species Records** – The 425-acre Mason Creek Swamp (SEWRPC NA-3, Figure D.2) is the only SEWRPC- or State-designated natural area in the sub-watershed. Much of this swamp is mapped as conifer swamp/bog in the pre-settlement vegetation, but it appears to be dominated by lowland hardwoods presently. There is no vegetation inventory for this natural area, and its designation is based on its size and relative lack of disturbance inferred from historical aerial photographs. The Chenequa Wetland Complex (SEWRPC NA-3, Figure D.2) is located immediately adjacent to the far southeastern portion of the Mason Creek sub-watershed. This wetland consists of tussock sedge wet meadow, Midwest cattail deep marsh, dogwood-mixed willow shrub meadow, and

Figure D.1
1940 Aerial Photograph that Includes a Portion of the Mason Creek Subbasin Area

Source: University of Wisconsin-Madison

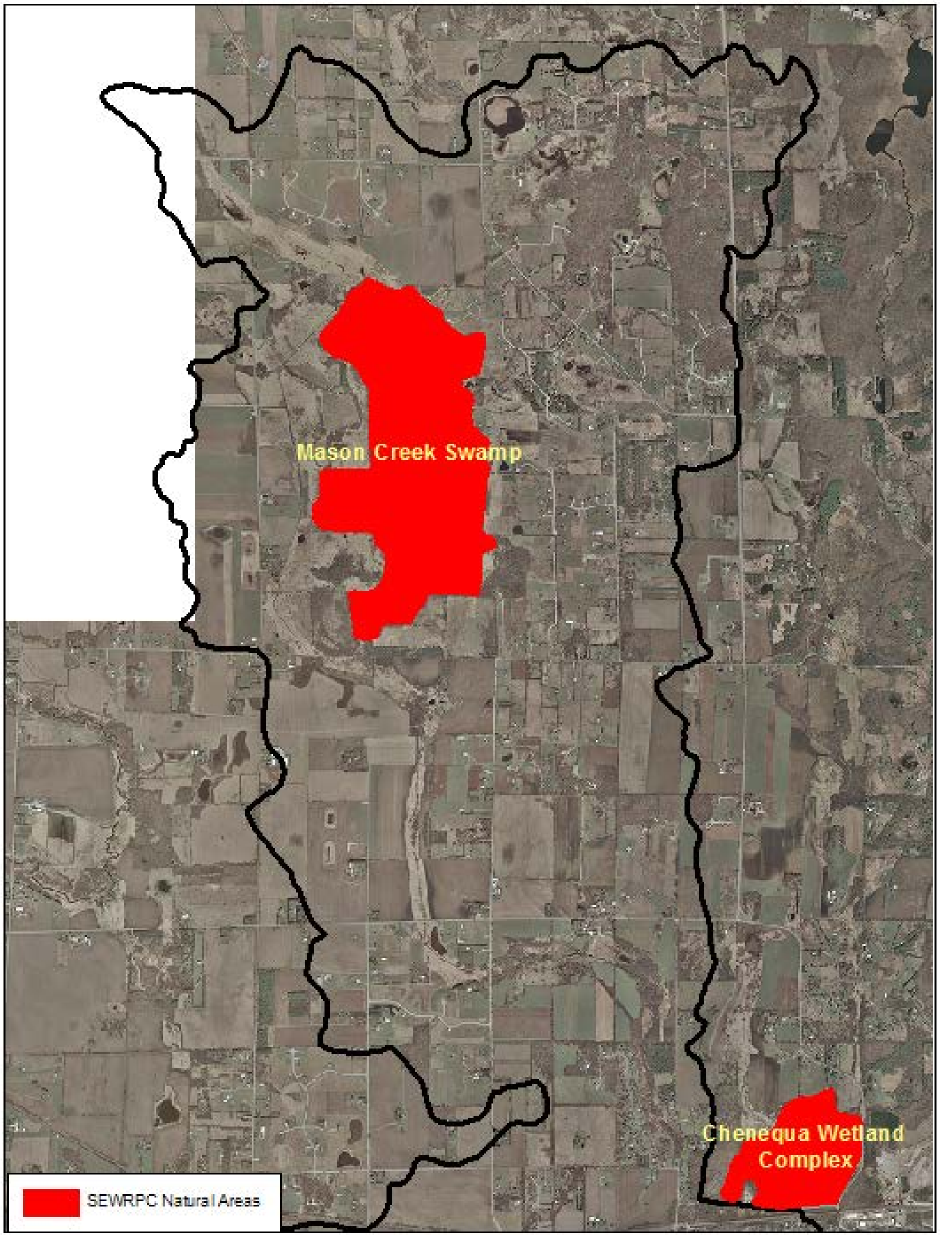
central tamarack-red maple rich swamp. Tubercled orchid, a State threatened species, was collected there in 1855, but it has not been observed since. Inventories by SEWRPC staff occurred in 1992 and 1999. Including the orchid, 90 native plant species have been recorded from this natural area.

Step 2. Appropriate Restoration Targets

The pre-settlement vegetation mapping is coarse, but a large portion of the potentially restorable wetlands in the western and northern portion of the sub-watershed are mapped as open wetland in the pre-settlement vegetation inventory and should be restored to open, herbaceous plant communities. Other potentially restorable wetlands to south are mapped as forested plant community types in the pre-settlement vegetation, and some are mapped as upland community types. Those potentially restorable wetlands mapped as upland plant community types were likely too small to constitute dominant community types in the initial land surveys. However, given both present and historical (1940) forested cover in nearby or adjacent areas, these potentially restorable wetlands were likely dominated by hardwood swamp.

Potential restorable wetlands that have soils that are saturated to the surface or that are inundated with water up to six inches deep for most of the growing season should be restored to shallow marsh (Table D.1). Historically open wetlands that are typically only saturated or inundated in the spring or following heavy rain events should be restored to sedge meadow (Table D.2); most potentially restorable wetlands likely fall into this category. Wetlands that were forested prior to settlement could be restored using lowland hardwoods (Table D.3). The ongoing death of green and black ash trees as the emerald ash borer spreads across the Region and the historical decimation of American elms by Dutch elm disease have caused/are causing

Figure D.2
Natural Areas in, and Adjacent to, the Mason Creek Watershed



Source: SEWRPC

lowland hardwood swamps dominated by these species to be replaced by other wetland community types. Restoration of lowland hardwood swamps using ash and elm is not advised. The restoration of hardwood swamps involves the initial planting of only woody vegetation, because most appropriate herbaceous species require the shading from the canopy. In all cases the appropriate restoration target community in a given location depends upon the hydrologic regime in place upon the cessation of agricultural practices, removal of tile, and any earth moving activities that may occur. Small elevation gradients (less than one foot) can separate different wetland plant communities. Establishing communities dominated by native lowland hardwood swamp species (e.g. silver maple), sedge meadow species (e.g., tussock sedge) or shallow marsh species (e.g., broad-leaved cattail) are reasonable goals for the restoration of the respective plant community types.

Table D.1
A Partial List of Species that are Often Either Co-Dominant or Abundant in Shallow Marshes Within Southeastern Wisconsin

Latin Name	Common Name	Vegetation Type
Carex atherodes	Slough sedge	Sedge
Carex lacustris	Lake sedge	Sedge
Eleocharis palustris and E. erythropoda	Spike rush	Sedge
Glyceria grandis	Giant manna grass	Grass
Juncus torreyi	Torrey's rush	Rush
Leersia oryzoides	Rice cut-grass	Grass
Sagittaria latifolia	Arrowhead	Forb
Schoenoplectus fluviatilis	River bulrush	Sedge
Schoenoplectus tabernaemontani	Soft-stem bulrush	Sedge
Sparganium eurycarpum	Bur-reed	Forb
Stachys tenuifolia	Smooth hedge-nettle	Forb
Typha latifolia	Broad-leaved cattail	Forb

Source: SEWRPC

Areas outside of the wetlands should generally be restored to maple-basswood-red oak forest or oak forest, with the latter on areas with better drainage from steeper slopes or well-drained soils. Restoration of oak savanna where it historically occurred (Figure D.2) or prairie would enhance wildlife value. In general, upland restoration adjacent to existing or restored wetlands would minimize disturbances near the wetland edge that would otherwise promote the establishment and spread of invasive species and reduce the amount of sediment and surface-runoff entering wetlands from surrounding uplands after heavy rain events (sediment and nutrients carried by runoff also promote invasive species).

Step 3. Prioritizing sites

Consider, at least qualitatively, the below factors in order to maximize potential for successfully establishing native-dominated communities and conserving existing native plant communities.

A. Parcel size – Large and/or adjacent parcels should be priorities, because restored areas that maximize interior versus perimeter will be the easiest to manage and experience less pressure from invasive species.

B. Within-parcel ecological considerations – Parcels that can offer greater habitat complexity (i.e. marsh, sedge meadow, hardwood or conifer swamps, and/or upland community types) rather than just one community type have the potential to support more species and more ecological functions. Candidate parcels should be surveyed for invasive species, so that likely future actions and costs for invasive species management can be determined, at least on a relative basis among candidate parcels. Those parcels where the boundary between planned restoration activities and invasive species (e.g. reed canary grass) are minimized should be given priority.

C. High-quality existing natural communities – Besides Mason Creek, the most valuable natural feature in the Mason Creek sub-watershed is Mason Creek Swamp (SEWRPC NA-3). The integrity of Mason Creek Swamp would be improved by the restoration of potentially restorable wetlands and uplands between Mason Creek to the West and the drainage ditch to the east and potentially restorable wetlands and adjacent uplands to the north. While there has been no inventory, aerial photography shows that Mason Creek Swamp has been extensively ditched and drained and has large areas where the color of dormant season vegetation is consistent with buckthorn and reed canary grass. A site visit would be necessary to determine the locations of relatively high-quality remnant natural communities, the impacts and extent of invasive species, and any restoration or management needs.

Step 4. Implementation of Restoration and Management Process

A. Seeding or Planting Herbaceous Plants – What follows is a brief summary of the applicable restoration process. The Minnesota Board of Soil and Water Resources and the Minnesota Department

Table D.2
A Partial List of Species that are Often Either Co-Dominant or Abundant in Sedge Meadows Within Southeastern Wisconsin

Latin Name	Common Name	Vegetation Type
Asclepias incarnate	Marsh milkweed	Forb
Calamagrostis canadensis	Canada blue-joint	Grass
Carex lacustris	Lake sedge	Sedge
Carex pellita	Broad-leaved woolly sedge	Sedge
Carex stipata	Awlfruit sedge	Sedge
Carex stricta	Tussock sedge	Sedge
Carex trichocarpa	Hairy-fruited sedge	Sedge
Cicuta maculate	Water hemlock	Forb
Eutrochium maculatum	Spotted Joe-Pye weed	Forb
Helianthus grosseserratus	Saw-tooth sunflower	Forb
Impatiens capensis	Jewelweed	Forb
Iris virginica	Blue flag iris	Forb
Juncus dudleyi	Common rush	Rush
Lycopus americanus	Common bugleweed	Forb
Salix bebbiana	Bebb's willow	Shrub
Salix discolor	Pussy willow	Shrub
Scirpus cyperinus	Woolgrass sedge	Sedge
Solidago gigantean	Giant goldenrod	Forb
Stachys tenuifolia	Smooth hedge-nettle	Forb
Symphyotrichum puniceum (syn. S. lucidulum and S. firmum)	Marsh aster	Forb
Verbena hastate	Blue vervain	Forb

Source: SEWRPC

Table D.3
A Partial List of Trees and Shrubs Appropriate for Hardwood Swamp Restoration Within Southeastern Wisconsin

Latin Name	Common Name	Vegetation Type
Acer rubrum	Red maple	Tree
Acer saccharinum	Silver maple	Tree
Betula allegheniensis	Yellow birch	Tree
Cornus alba	Red-osier dogwood	Shrub
Cornus obliqua	Silky dogwood	Shrub
Populus deltoides	Cottonwood	Tree
Quercus bicolor	Swamp white oak	Tree
Quercus palustris[a]	Pin oak	Tree
Salix amygdaloides	Peach leaf willow	Tree
Sambucus nigra subsp, canadensis	Elderberry	Shrub
Viburnum lentago	Nannyberry	Shrub

[a] *Native but rare and generally of more southerly distribution.*

Source: SEWRPC

of Transportation have produced an excellent, detailed restoration guide for wetlands.[1] Ensure that no herbicide with residual activity (e.g. atrazine) has been used for at least one year on agricultural lands. Ideally, cultivated land is farmed through the growing season that precedes restoration planting in order to prevent the proliferation of weeds. Restoration may then be attempted with seed broadcast on to bare, agricultural land. Seeding of herbaceous species should occur from mid-November through December, or otherwise over shallow snow or bare ground before February 15. This is because many species require a cool, moist period prior to germination, and many wetland species will even

[1] *Robert L. Jacobson,* Restoring & Managing Native Wetland & Upland Vegetation, *Minnesota Board of Soil & Water Resources, Minnesota Department of Transportation, www.shootingstarnativeseed.com/documents/BWSR-wetland-guide.pdf*

germinate in the cool weather of early spring, which gives them a good head start. Seeding at the appropriate time may be risky in areas that are likely to be inundated early in the spring, because this may lift seed and carry it away. In such locations, plugs and/or pre-vegetated mats may be planted instead. Many of herbaceous species spread extensively by rhizomes, so planting plugs spaced a foot or two apart can achieve native plant coverage rather quickly. Plugs can be planted when the soil is moist and expected to remain so, and pre-vegetated mats can be staked into standing water, but planting in autumn should occur early enough that adequate root development can occur to prevent frost heave. The annual weeds that grow in fallow farm fields have the potential to kill native seedlings by robbing them of light. If soils are firm enough to allow it, areas that develop closed canopies of annual weeds should be mowed to a height of eight inches as needed to prevent native seedling mortality. This is time sensitive, and an implementation plan should be in place before it is needed. Mowing is best performed by a sickle mower, which lays down cut material in an even layer that quickly dries and deteriorates. Rotary mowers tend to leave clumps that can smother seedlings, but mowing with a rotary mower is still preferred to not mowing vigorous annual weeds.

B. **Planting Trees and Shrubs** – Plant trees in early spring following guidelines from the Natural Resource Conservation Service.[2] Fall planting in wet soils can lead to frost heave.

C. **Invasive Species** – Wetland plant communities are extremely vulnerable to invasive species, because water can disperse the seeds or vegetative parts of invasive plants, and because nutrients and sediments that are funneled from surrounding agricultural and developed lands diminish the relative competitive abilities of both existing and establishing native wetland vegetation. Even if native species are sown or transplanted into former agricultural lands, the end result is likely to be large areas dominated by reed canary grass (*Phalaris arundinacea*) or other invasive species unless plans are in place to detect and control invasive species from the beginning. Once an area becomes dominated by reed canary grass, reversal of the situation is costly and time-consuming. Invasion is also promoted by disturbance, so control efforts that create disturbance and negatively impact desired vegetation can be counter-productive. Especially troublesome wetland invasive plants aside from reed canary grass in SE Wisconsin include giant reed (*Phalaris australis* subsp. australis), narrow-leaved and hybrid cattails (*Typha angustifolia* and *Typha x glauca*), giant manna grass (*Glyceria maxima*), hairy willow-Herb (*Epilobium hirsutum*), common and glossy buckthorns (*Rhamnus cathartica* and *Rhamnus frangula*) and purple loosestrife (L*ythrum salicaria*).

D. **Other Long** – Term Management—Prescribed fire or mechanical and chemical removal of common and glossy buckthorns and/or thinning of other woody species may be necessary to maintain the open nature of sedge meadows. Without monitoring and timely response most natural community types in southeast Wisconsin are vulnerable to invasion and subsequent dominance by exotic species.

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[2] *Natural Resources Conservation Service,* Hand-Planting Guidelines for Bareroot Trees and Shrub, *www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1167617.pdf*

APPENDIX E

SOIL QUALITY INDICATORS

Source: U.S. Department of Agriculture, National Resources Conservation Service, see website for more information, www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/assessment/?cid=stelprdb1237387

USDA Natural Resources Conservation Service

Indicator	Test	Function
?	?	?

Soil Quality Indicators

Physical, Chemical, and Biological Indicators for Soil Quality Assessment and Management

A series of information sheets for physical, chemical, and biological indicators is available to help conservationists and soil scientists with soil quality assessment. Use this guide to learn more about selecting appropriate soil quality indicators to assess specific soil functions. Visit http://go.usa.gov/zUAH for more information and to download copies of the information sheets.

What is soil quality?

Concise definitions for soil quality include "fitness for use" and "the capacity of a soil to function." Combining these, soil quality is the ability of a soil to perform the functions necessary for its intended use.

Soil functions include:

- sustaining biological **D**iversity, activity, and productivity
- regulating **W**ater and solute flow
- **F**iltering, buffering, degrading organic and inorganic materials
- storing and cycling **N**utrients and carbon
- providing physical **S**tability and support

TIP: *The* ***Function*** *icon at the top right corner of each information sheet uses* ***D, W, F, N, or S*** *to show the function(s) that is most affected by the subject indicator.*

How is soil quality measured?

The quality of a soil, or its capacity to function, is evaluated using ***inherent*** and ***dynamic*** soil properties. These properties serve as ***indicators*** of soil function because it is difficult to measure function directly and observations may be subjective.

Inherent, or use-invariant, soil properties change very little or not at all with management. Inherent soil properties form over thousands of years and result primarily from the soil forming factors: climate, topography, parent material, biota, and time. Examples of inherent properties are soil texture, type of clay, depth to bedrock, and drainage class.

Dynamic, or management dependent, soil properties are affected by human management and natural disturbances over the human time scale, i.e., decades to centuries. Significant changes in dynamic soil properties can occur in a single year or growing season. There are many dynamic soil properties, several of which are the subjects of this information sheet series.

Soil indicators are often divided into **P**hysical, **C**hemical and **B**iological categories depending on how they affect soil function. However, these categories are not always clearly defined since a soil property or indicator can affect multiple soil functions or categories.

TIP: *The* ***Indicator*** *icon at the top right corner of each information sheet uses* ***P, C, or B*** *to show the category in which the indicator best fits.*

Depending on the indicator and the method used to evaluate it, properties are assessed in the **F**ield, **L**aboratory, or even an **O**ffice when no special equipment is required.

TIP: *The* ***Test*** *icon at the top right corner of each information sheet uses* ***F, L, or O*** *to show where indicator assessment takes place for the method highlighted on the information sheet.*

Helping People Help the Land

Selecting soil quality indicators

A soil function – indicator matrix (fig. 1) can be used to select appropriate indicators for assessing a particular soil function. Additionally, if an indicator is already being measured, the matrix reveals the indicator's relationship to other soil functions, thus maximizing the usefulness of the collected data.

Each indicator listed in the matrix below is linked to its accompanying information sheet. The information sheets:

- define and describe the indicator
- relate the indicator to soil function
- discuss inherent and dynamic factors influencing it
- suggest management practices to improve soil function
- provide a reference for an assessment method

Figure 1. Soil function – indicator matrix: when a direct relationship exists between the function and indicator, increasing reliability and ease of use of the associated assessment method is shown with increasing stars.

	Soil Function				
Soil Quality Indicator	**Sustain biological diversity, activity, and productivity "D"**	**Regulate and partition water and solute flow "W"**	**Filter, buffer, degrade, detoxify organic and inorganic materials "F"**	**Store and cycle nutrients and carbon "N"**	**Physical stability and support for plants and structures associated with human habitation "S"**
Aggregate Stability [a,c,f]	★★	★★	—	★★	★★½
Available Water Capacity [a,g]	★★★	★★½	—	★★	—
Bulk Density [a,h]	★★½	★★★	—	★	★★★
Earthworms [b,d]	★★★	—	★★★	★★★	★★★
Infiltration [b,e,i]	—	★★	★	—	—
Particulate Organic Matter [a,c]	★★★	★★★	★★★	★★★	★★★
Potentially Mineralizable Nitrogen [a,c]	★★★	—	—	★★★	—
Reactive Carbon [a]	★★	★	★★★	★★	★★
Slaking [b,e,i,j]	★	★★½	—	—	—
Soil Crusts [b,d]	—	★★½	—	—	—
Soil Electrical Conductivity [b]	—	★★★	—	—	—
Soil Enzymes [a]	★★★	—	—	★★★	—
Soil Nitrate [b]	★	★	—	—	—
Soil pH [b,d]	★★	★★★	★★★	★★★	—
Soil Respiration [a,b,c]	★★★	—	★	★★★	★★
Soil Structure and Macropores [b,d]	★½	★½	★	★	★★
Total Organic Carbon [a]	★★★	★★★	★★★	★★★	★★★

[a] laboratory/office method
[b] field method
[c] time consuming
[d] simple visual observation
[e] variability requires large sample number
[f] perhaps the most informative physical indicator
[g] important for drought prone areas
[h] important for weight to volume conversions, small sampling errors result in significant interpretation problems
[i] effective educational method
[j] qualitative

 January 2015

APPENDIX F

DESCRIPTION OF FIELD MEASUREMENTS AND LOCATIONS FOR MASON CREEK CROSS-SECTION AND POINT FEATURE DATA: SUMMER 2014

CROSS-SECTION DATA

Stream Bank Characteristics

Bankfull Width: The stream channel that is formed by the dominant discharge, also referred to as the active channel, which meanders across the floodplain as it forms pools and riffles. Defined by the discharge that occurs when water just begins to leave the channel and spread onto the floodplain.

Bank Height: Height of the bank from the streambed to the top edge of the lateral scour line as shown in Figure F.1.

Undercut Depth: A bank that has had its toe of slope, or base, cut away by the water action creating overhangs in the stream as shown in Figure F.1.

Slope: Ratio of horizontal distance divided by the vertical height of the streambank as shown in Figure F.2.

Instream Habitat Characteristics

Width: The width of the existing water surface measured at a right angle to the direction of flow from shore to shore.

Maximum Depth: The vertical height of the water column from the existing water surface level to the lowest point of the streambed.

Habitat Type: An aquatic unit, consisting of an aggregation of habitats having equivalent structure, function, and responses to disturbance. Pool, riffle, and run habitat types were observed in the Jackson Creek watershed.

- A pool is that area of the water column that has slow water velocity and is usually deeper than a riffle or run (Figure F.3). Pools usually form around bends or around large-scale obstructions that laterally constrict the channel or cause a sharp drop in the water surface profile.
- Riffles are portions of the water column where water velocity is fast, stream depths are relatively shallow, and the water surface gradient is relatively steep (Figure F.4).
- A run is that area of the water column that does not form distinguishable pools or riffles, but has a rapid nonturbulent flow. A run is usually too deep to be a riffle and has flow velocities too fast to be a pool.

Figure F.1
Example of Bank Height and Undercut Depth Measured at an Actively Eroding Site

NOTE: These photos were not taken within the Mason Creek watershed and are for illustrative purposes only.

Source: SEWRPC

Figure F.2
Example of Length of Erosion and Bank Slope Measured at an Actively Eroding Site

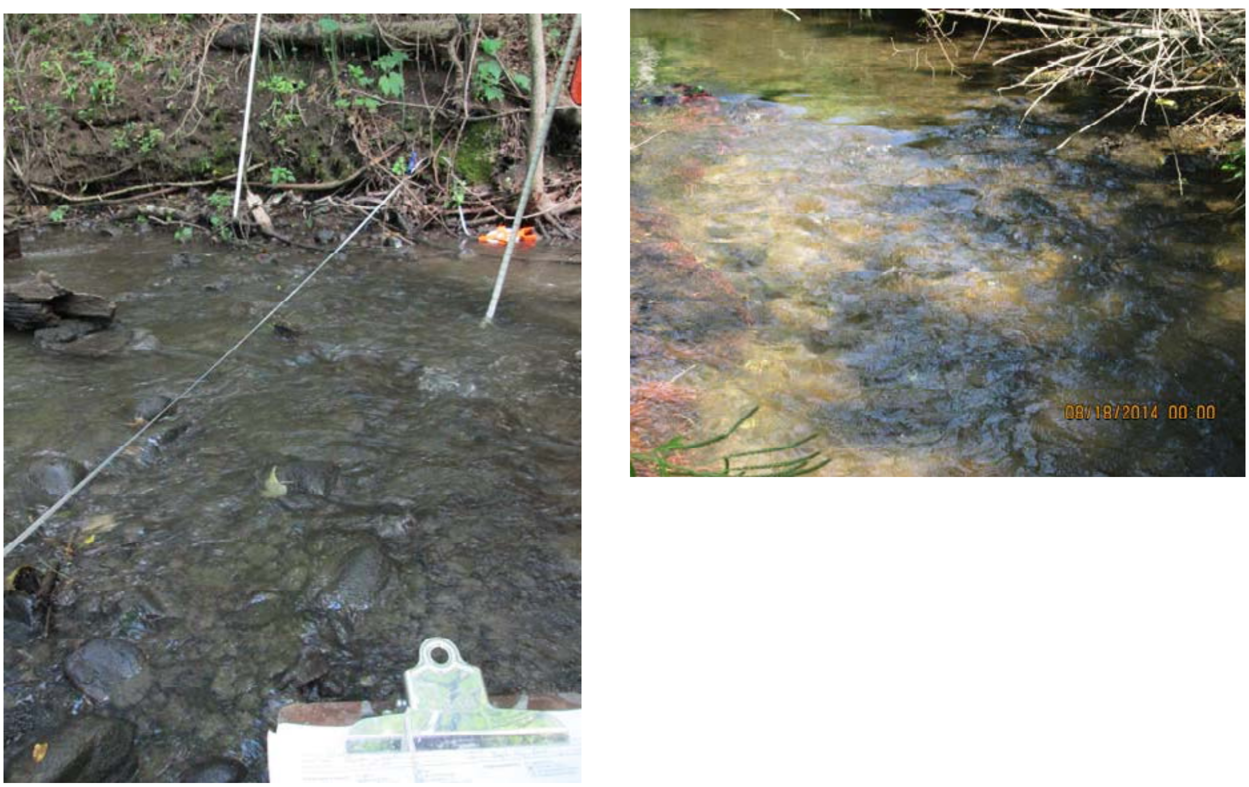
NOTE: This photo was not taken within the Mason Creek watershed and is for illustrative purposes only.

Source: SEWRPC

Figure F.3
Typical Deep Water/Low Velocity Pool Habitats in the Mason Creek Watershed: 2014

Source: SEWRPC

Figure F.4
Typical Shallow Water/High Velocity Riffle Habitats in the Mason Creek Watershed: 2014



Source: SEWRPC

Substrates: Refers to the materials that make up the streambed. Substrate composition in the streams of the Mason Creek watershed was determined visually by recording the dominant substrate types within the transect. The following categories of substrate type were used.

- Bedrock: Solid rock forming a continuous surface.
- Boulder: Rocks with a diameter of 10 to 20 inches.
- Cobble: Rocks with a diameter of 2.5 to 10 inches.
- Gravel: Rocks with a diameter of 0.07 to 2.5 inches.
- Sand: Inorganic particles smaller than gravel, but coarser than silt with a diameter of 0.002 to 0.07 inch.
- Silt: Fine inorganic particles, typically dark brown in color. Feels greasy and muddy in hands. The material is loose and does not retain shape when compacted into a ball and will not support a person's weight when it makes up the stream bottom. Silt particles have a diameter of less than 0.0001 inch.
- Peat: A fibrous mass of organic matter in various stages of decomposition, generally dark brown to black in color and of spongy consistency.
- Clay: Very fine, inorganic, dark brown or gray particles. Individual particles are barely visible or not visible to the unaided eye. The particles feel gummy and sticky and slippery underfoot. Clay particles retain shape when compacted and partially or completely support a person's weight when they comprise the stream bottom. Clay particles have a diameter of less than 0.0001 inch.

Sediment Depth: The depth of fine sediments (usually silt) that overlay or comprise the streambed. Sediment depth is an indicator of sediment deposition and was measured to the nearest 0.5 inch.

Woody Debris: Large pieces or aggregations of smaller pieces of wood (e.g., logs, large tree branches, root tangles) located in, or in contact with, the water surface.

Cover: This can be one, or any combination, of characteristics that include undercut banks, overhanging vegetation, water velocities, logs or woody debris, deep pools, boulders and other substrates, aquatic macrophytes, and algae that provide 1) protection from predators, 2) feeding areas, 3) spawning habitat, or 4) some other benefit such as shading.

POINT FEATURE DATA

Crossing: A structure (e.g., bridge or culvert) that crosses over is lying within the stream channel.

Drain Tile: A subsurface drainage system (plastic or metal corrugated pipe) that allows excess water from agricultural and urban lands to discharge into a drainage ditch, stream or wetland.

Pool: A single maximum depth is recorded within a pool habitat (See Habitat Type and Figure F.3).

Riffle: A single maximum depth is recorded within a riffle habitat (See Habitat Type and Figure F.4).

Stormwater Outlet: Any culvert or drainage system that allows for excess storm water to discharge into a certain location. It should be noted that in 2014 the SEWRPC field staff did not identify any stormwater outlets along Mason Creek.

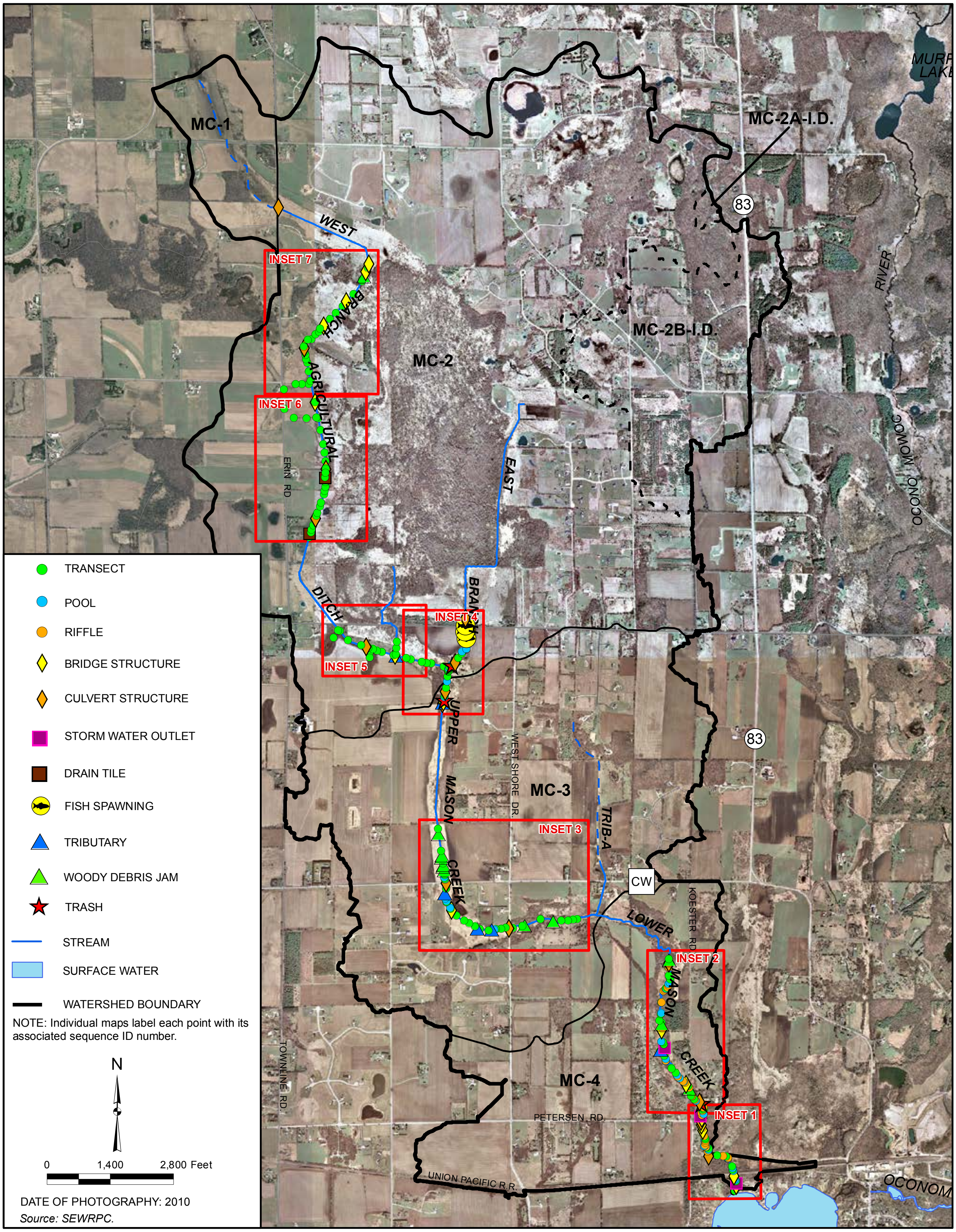
Trash: Identify and describe trash or any debris that is within or adjacent to the stream channel.

Woody Debris Jam: Identify and describe the extent of the obstruction in the channel

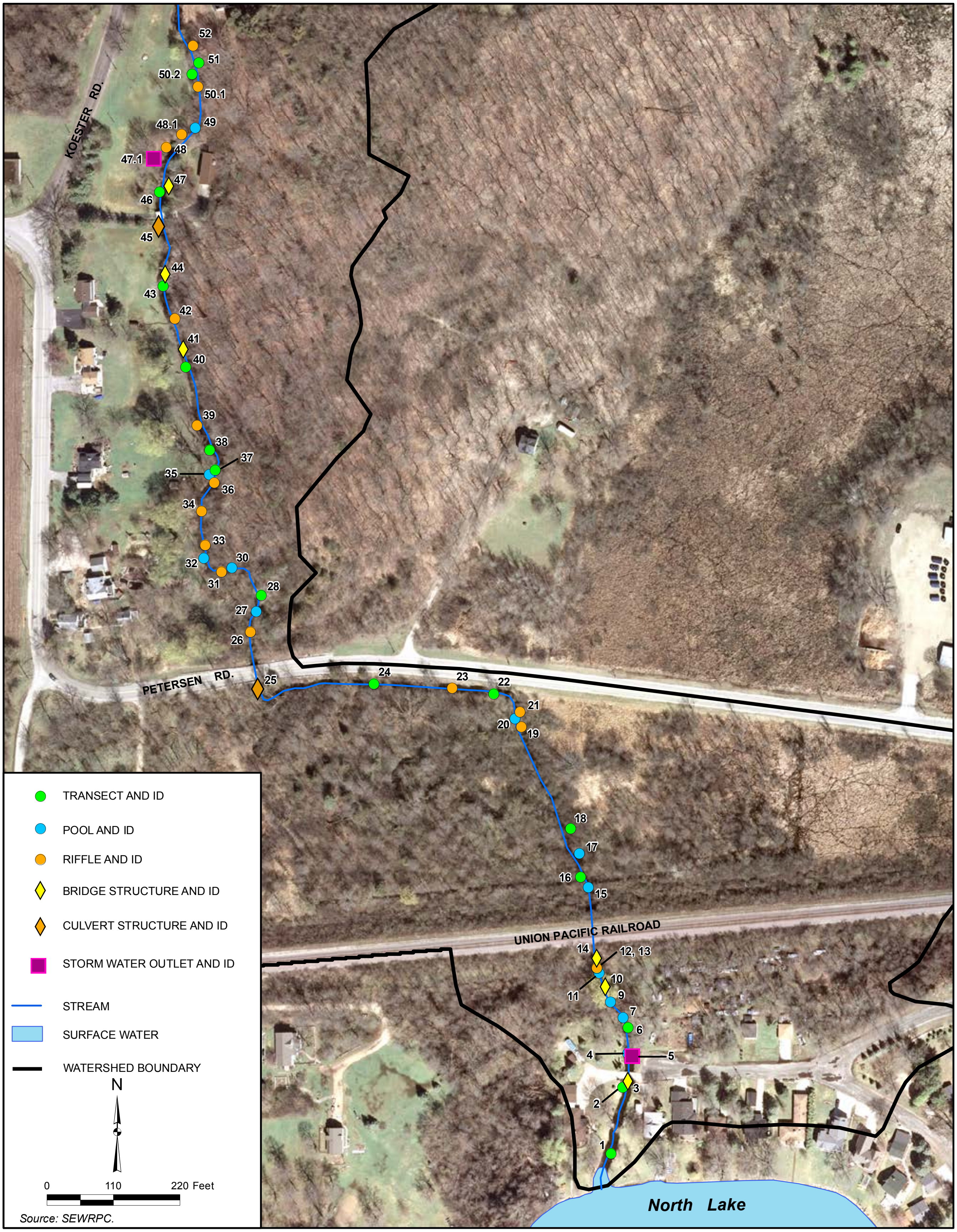
The transect and point feature data within the Mason Creek watershed are shown on Maps F.1 through F.8. Table F.1 lists the data and measurements collected at each transect along with a description detailing how each measurement is taken as well as description of the point features mapped.

Note that all of this data, site locations, and associated shape files are available on a CD in the inside back cover of this report or available to download from the SEWRPC website at www.sewrpc.org/SEWRPC/DataResources.htm

Map F.1
Mason Creek Watershed Stream Inventory Location Map: 2014



Map F.1 (continued) Inset 1



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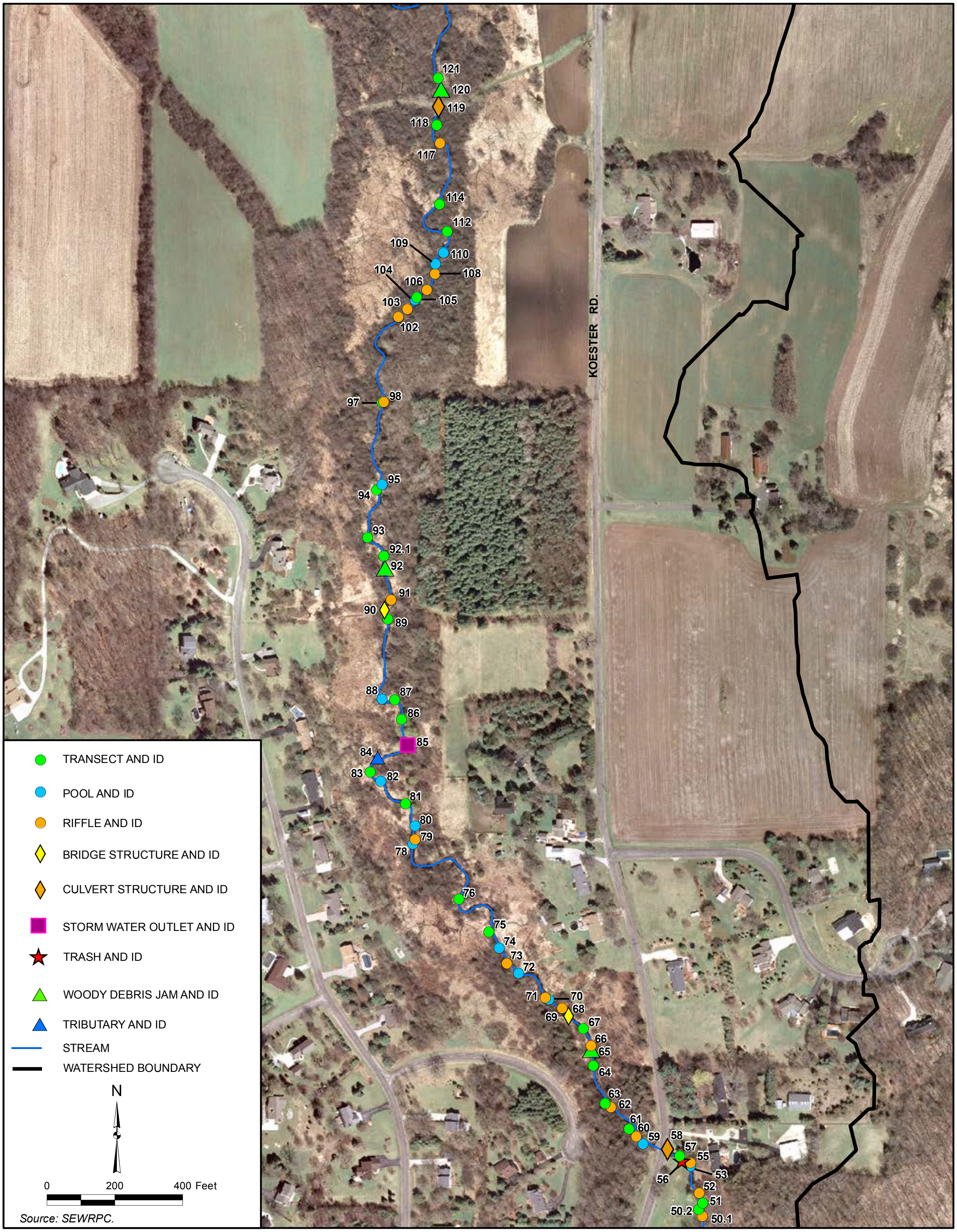
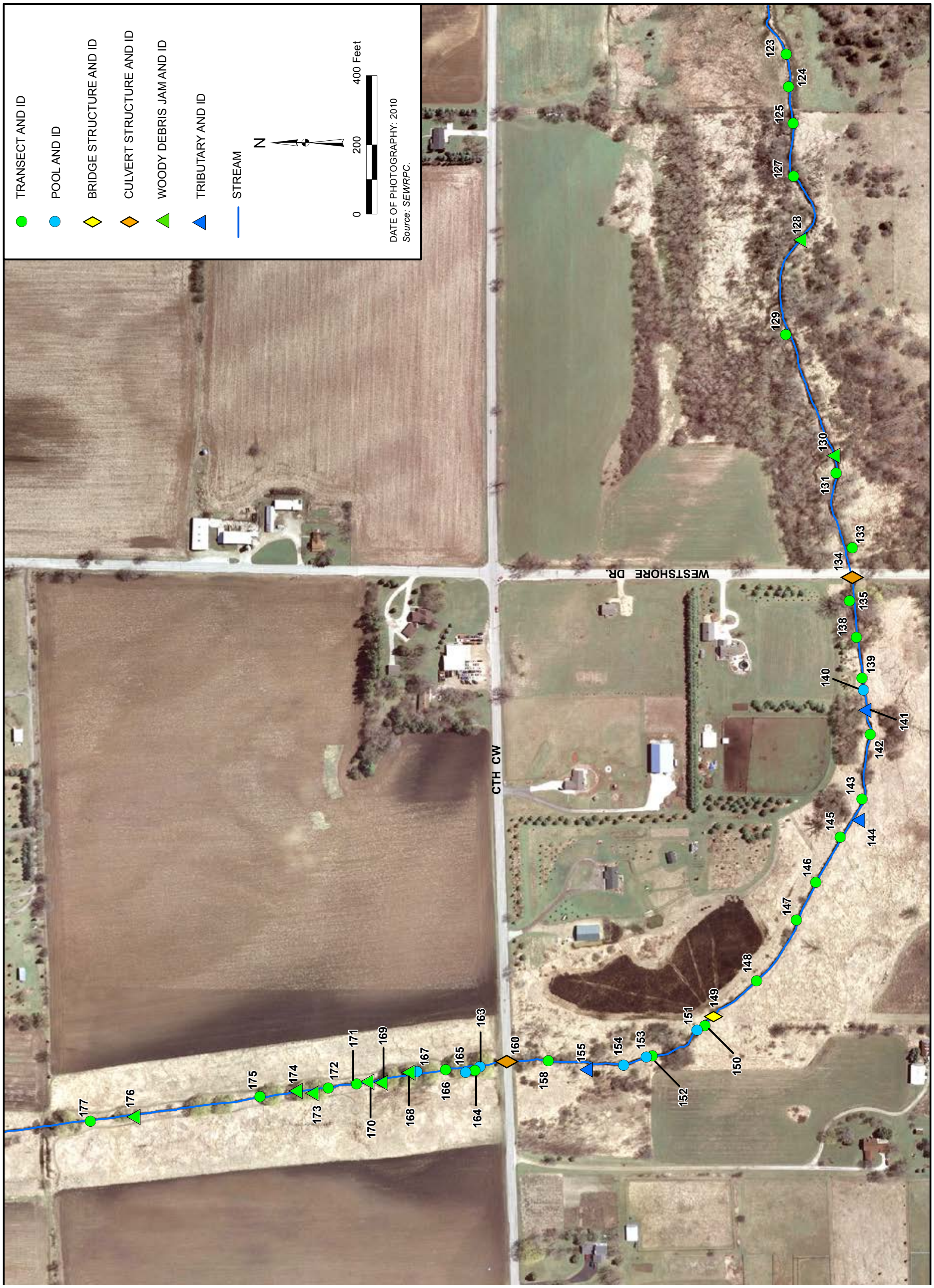
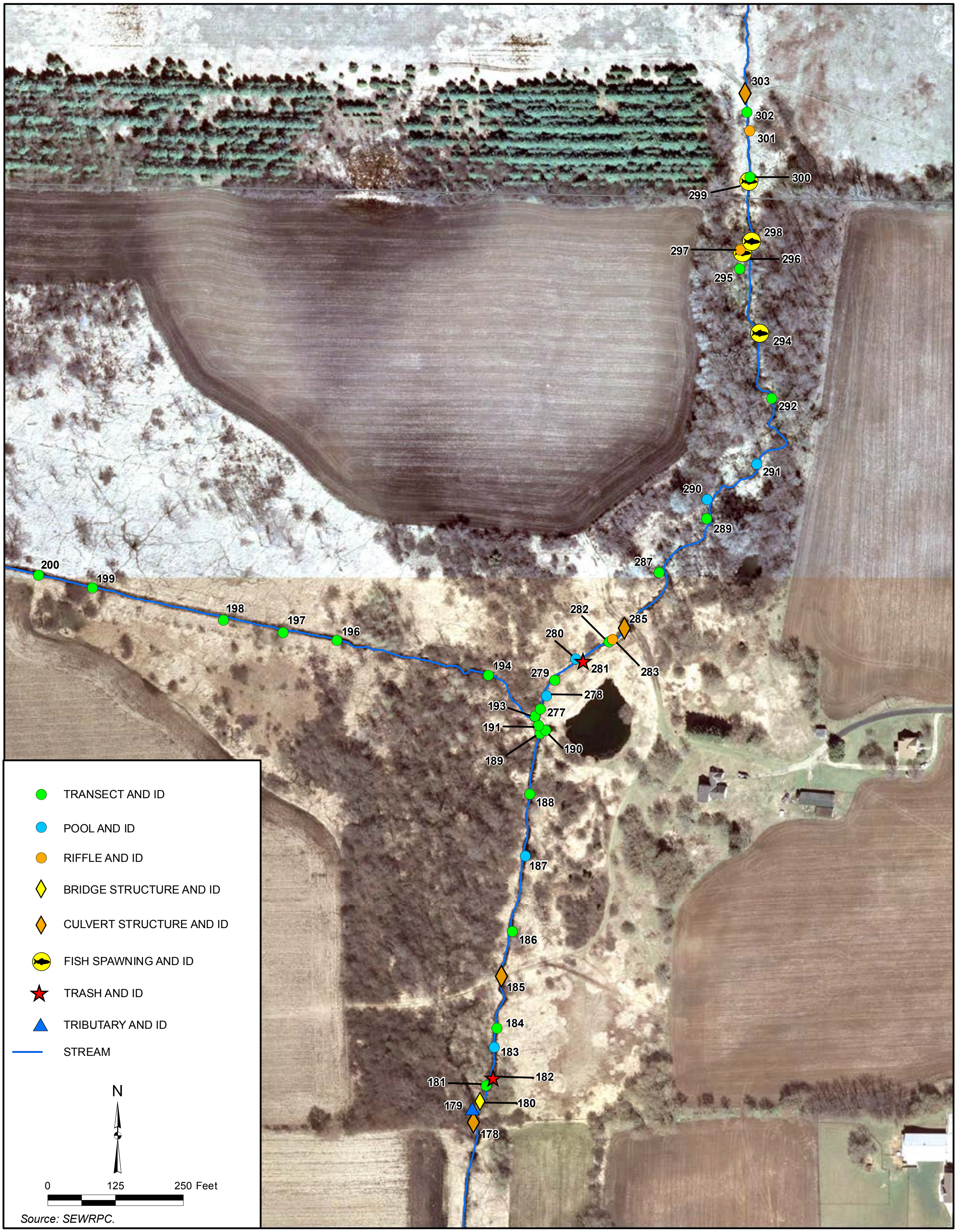


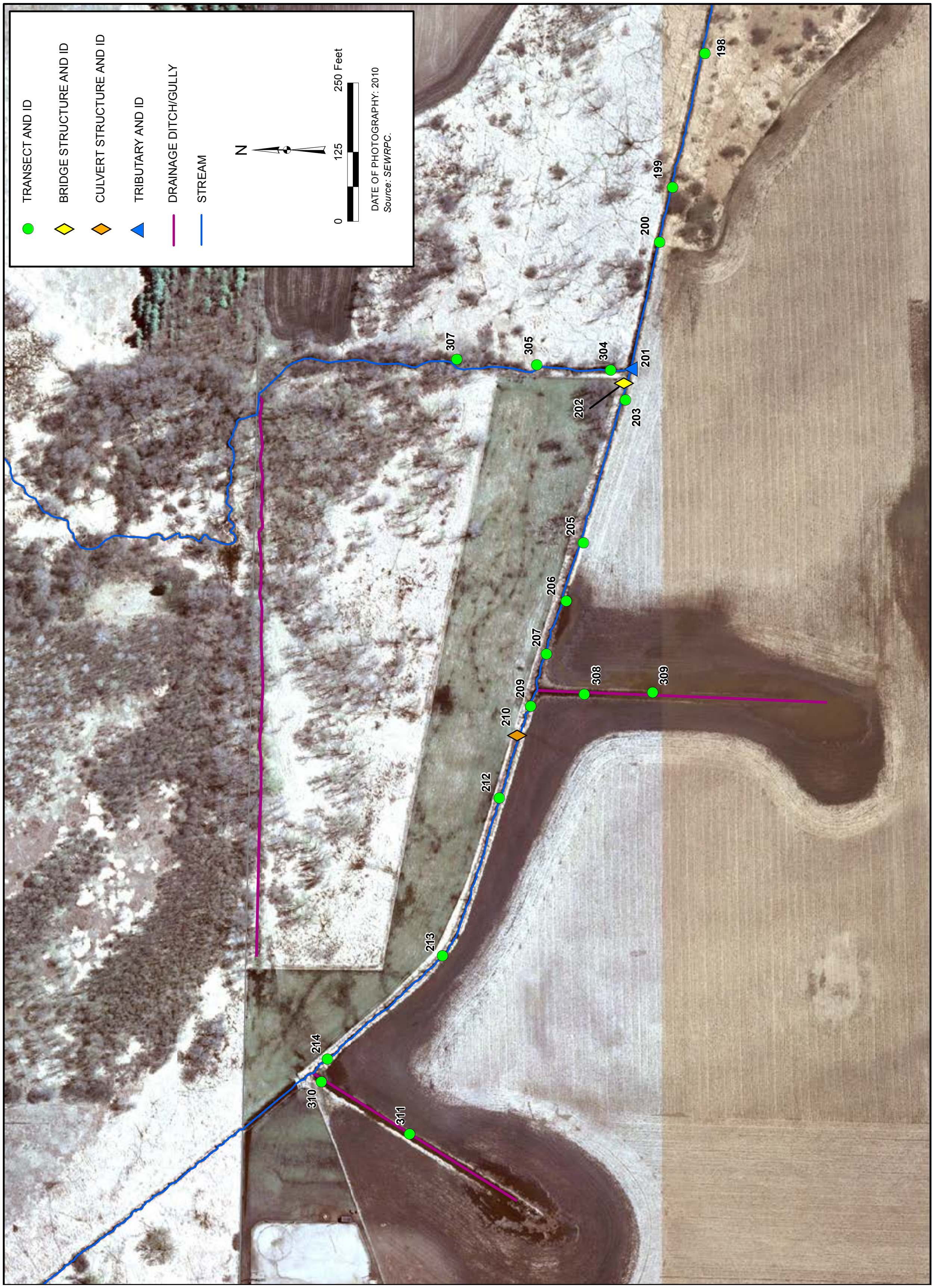
Map F.1 (continued) Inset 3



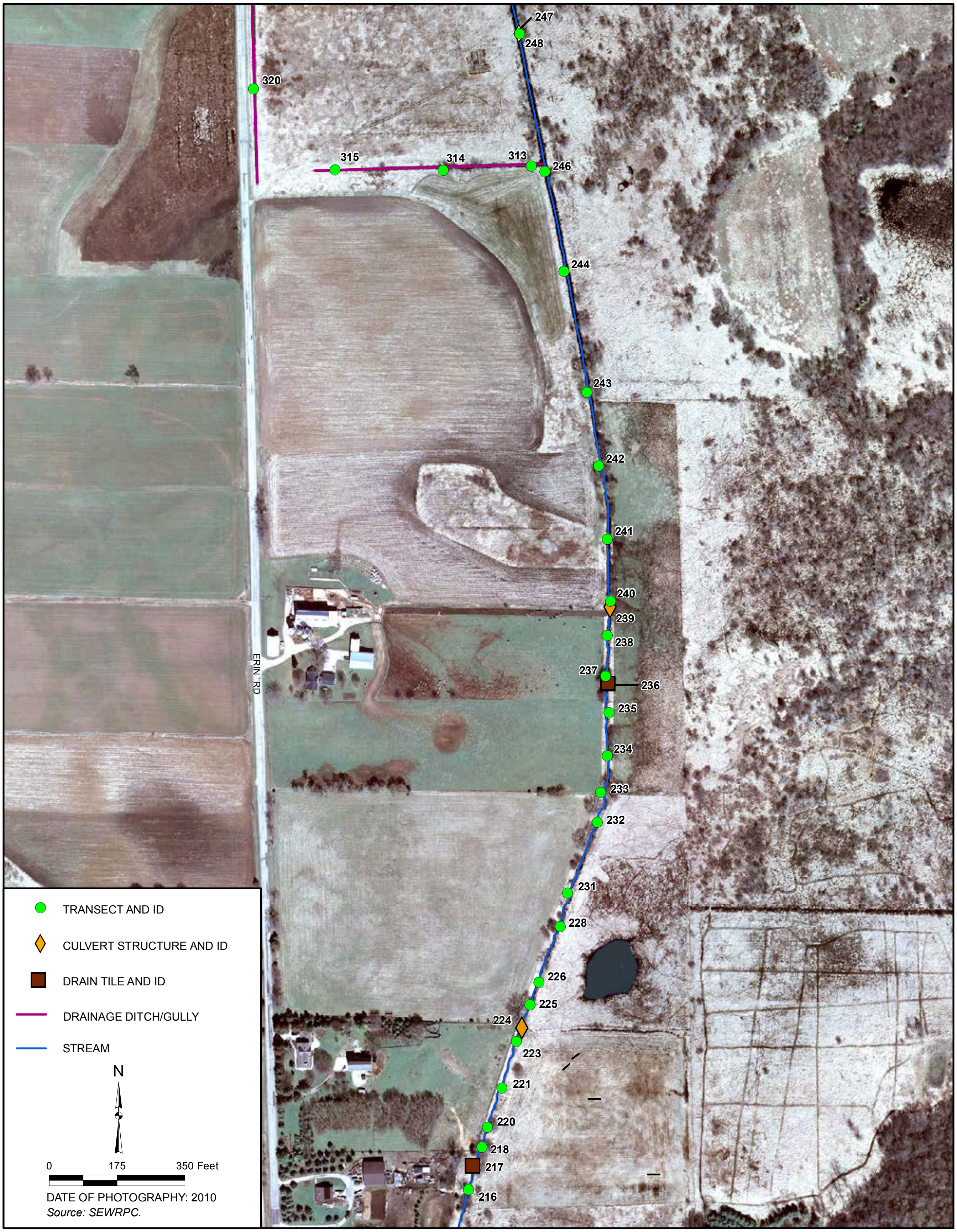
Map F.1 (continued) Inset 4



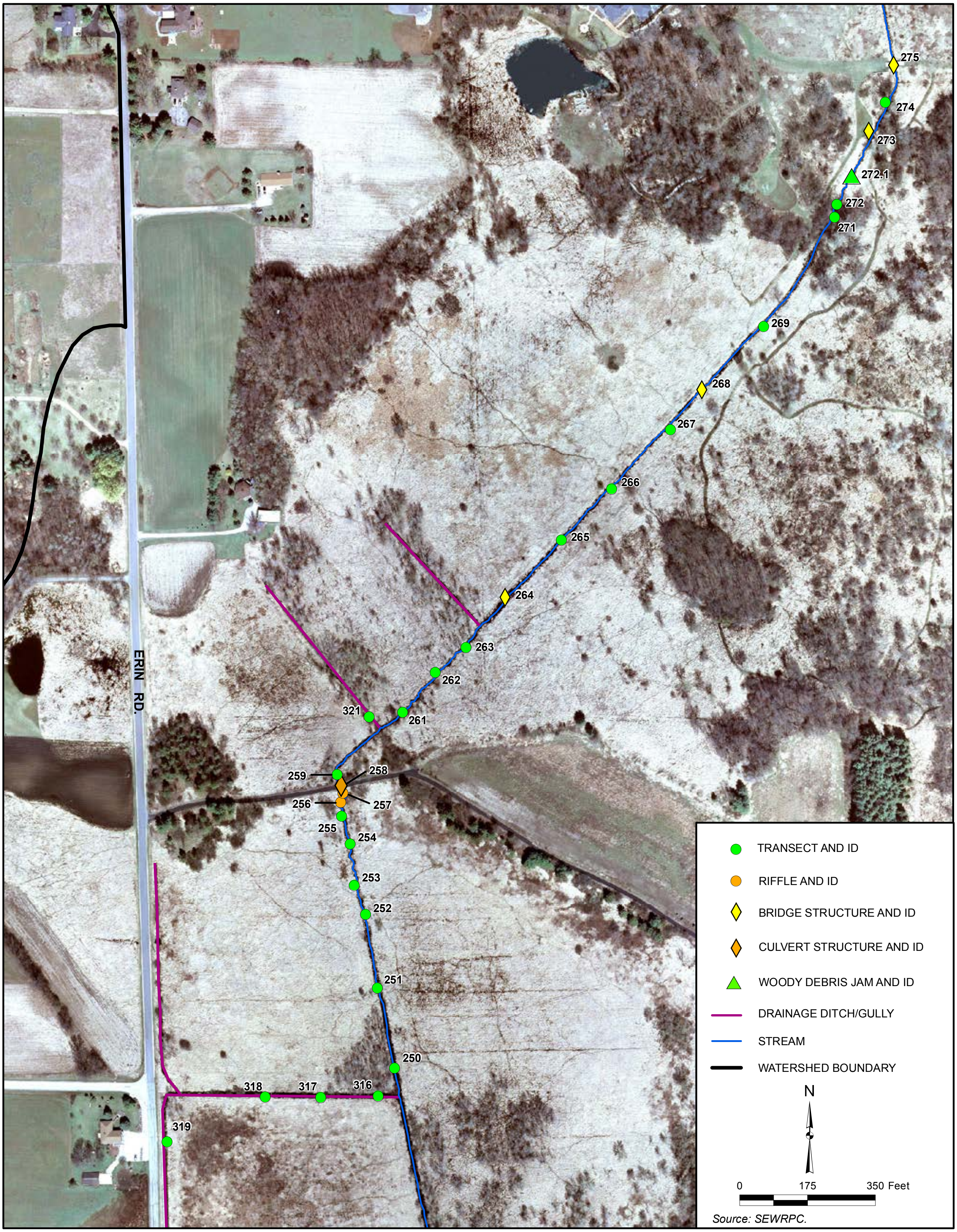
Map F.1 (continued) Inset 5



Map F.1 (continued) Inset 6



Map F.1 (continued) Inset 7



Source: SEWRPC.

Table F.1
Transect and Point Feature Data Descriptions Collected as Part of the Mason Creek Stream Inventory Conducted by SEWRPC Staff: 2014 (See Maps F.1-F.8)

Parameters	Description
Sequence	Each point surveyed, from upstream to downstream, was given a sequence ID number in the final Master Data Table. Sequence numbers are shown in the Appendix F Stream Inventory Maps F.2 through F.8.
Class	Each point surveyed was assorted into a *class*, such as Cross-Section, Drainage Ditch, Drain Tile, Erosion, Geomorphology, Infrastructure, Pond Outlet, Pool, Riffle, Spawning Site, Trash, Tributary, and Woody Debris Jam,
Class_Order	Each class listed above was grouped separately and each point within that specific group was given a Class_Order number.
Feature	Classes such as, geomorphology and infrastructure were associated with different *features* (e.g., "stream crossing" or "stormwater outlet" within the infrastructure class).
Feature2	The feature "stream crossing" was further categorized as either a "bridge" or "culvert."
GIS_ID	Each point surveyed was given a GIS_ID during the infield survey using a GPS device (e.g., "MST22" stands for: Mason Creek structure number 22).

Parameters	Transect/Cross-Section Features
WaterWidth	*Wetted (water) stream width* or low flow channel width at the time of the survey at stream cross-sections.
Incised_Ht	*Incised Height* ***was*** collected at stream cross-sections where the stream channel is substantially disconnected from its floodplain. This is a vertical measurement from middle of streambed to the height of the lowest bank.
Incised_Wt	*Incised Width* ***was*** collected at cross-sections where the stream is substantially disconnected from its floodplain. This is a horizontal measurement from top of lowest bank height to the opposite bank.
BF_Width	*Bankfull Width*. The measurement of the channel width that occurs when water just begins to leave the channel and spread onto the floodplain.
LB_Length	*Left Bank Length*. **Horizontal** measurement collected from top of bankfull (left bank) directly out to where it would meet the toe of bank. This was collected at each surveyed cross-section.
LB_Height	*Left Bank Height*. **Vertical** measurement from toe of bank directly straight up to top of bankfull. This was collected at each surveyed cross-section.
LB_SLOPE	*Left Bank Slope*. The left bank ratio of horizontal distance divided by the vertical height of the streambank. This measurement was taken at stream cross-sections.
RB_Length	*Right Bank Length*. **Horizontal** measurement collected from top of bankfull (left bank) directly out to where it would meet the toe of bank. This was collected at each surveyed cross-section.
RBfromBF	*Right Bank Length From Bankfull*. A calculation (bankfull width minus right bank length) that gives the right bank length for each surveyed cross-section.
RB_Height	*Right Bank Height*. Vertical measurement from toe of bank directly straight up to top of bankfull.
RB_SLOPE	*Right Bank Slope*. The right bank ratio of horizontal distance divided by the vertical height of the streambank. This measurement was taken at stream cross-sections.
BF_AVG	*Average Bankfull Depth (ft.)*. The average depth measured at the bankfull discharge, or where water would flow out from the banks. Bankfull depths were measured at three to five points evenly spaced across a surveyed cross-section.
BF_MAX	*Maximum Bankfull Depth (ft.)*. The maximum depth measured at the bankfull discharge, or where water would flow out from the banks. Bankfull depths were measured at three to five points evenly spaced across a surveyed cross-section.
BF_AREA	*Bankfull Area*. A calculation (bankfull width multiplied by average bankfull depth) that measures the amount of space, or area, that water would have to take up in order to spill out into the floodplain, at each surveyed cross-section.
Water_1	*Water Depth (ft.)* The **first** water depth measured at a stream cross-section. Each cross-section measured three to five water depths that were evenly spaced across the stream (e.g., Water_1, Water_2, Water_3, Water_4, and Water_5).
Water_AVG	*Average Water Depth (ft.)*. The average water depth across the stream channel measured at each stream cross-section. Water depths were measured at three to five points evenly spaced across a surveyed cross-section.

Table F.1 (continued)

Parameters	Transect/Cross-Section Features
Water_MAX	*Maximum Water Depth (ft.)*. The maximum water depth across the stream channel measured at stream cross-section. Water depths were measured at three to five points evenly spaced across a surveyed cross-section
Water_AREA	*Water Area.* A calculation (water width multiplied by average water depth) that measures the amount of space, or area, water takes up at each surveyed cross-section.
W_D_ratio	*Water to Depth Ratio.* A calculation of bankfull width divided by average water depth to give the average water to depth ratio.
Sed_Water_1	*Sediment plus Water Depth (ft.)* Sediment depth plus the water depth measured at stream cross-sections. Sediment and water depths were measured at three to five points evenly spaced across a surveyed cross-section
Sed_1	*Sediment Depth (ft.)* The **first** sediment depth measured at a stream cross-section. Each cross-section contained three to five sediment depth measurements evenly spaced across that particular cross-section (e.g., Sed_1, Sed_2, Sed_3, Sed_4, and Sed_5).
Avg_Sed	*Average Sediment Depth (ft.)* The average depth of sediment measured across the stream at surveyed cross-sections.
Max_sed	*Maximum Sediment Depth (ft.)* The maximum depth of sediment measured across the stream at surveyed cross-sections.
LB_Under_Max	*Maximum Left Bank Undercut (ft.)* Undercut banks occur when the toe of the bank is eroded away, leaving just the top of the bank overhanging the stream. This measures the deepest undercut point on the left bank of a surveyed cross section.
LB_Under_Avg	*Average Left Bank Undercut (ft.)* Undercut banks occur when the toe of the bank is eroded away, leaving just the top of the bank overhanging the stream. This measurement is the average depth of the undercutting on the left bank.
RB_Under_Max	*Maximum Right Bank Undercut (ft.)* Undercut banks occur when the toe of the bank is eroded away, leaving just the top of the bank overhanging the stream. This measures the deepest undercut point on the right bank of a surveyed cross section.
RB_Undcer_Avg	*Average Right Bank Undercut (ft.)* Undercut banks occur when the toe of the bank is eroded away, leaving just the top of the bank overhanging the stream. This measurement is the average depth of the undercutting on the right bank.
Silt_ct	*Percent Silt.* The percentage of streambed substrates at a surveyed cross-section that are made up of silt.
Sand_ct	*Percent Sand.* The percentage of streambed substrates at a surveyed cross-section that are made up of sand.
Gravel_ct	*Percent Gravel.* The percentage of streambed substrates at a surveyed cross-section that are made up of gravel.
Cobble_ct	*Percent Cobble.* The percentage of streambed substrates at a surveyed cross-section that are made up of cobbles.
Boulder_ct	*Percent Boulder.* The percentage of streambed substrates at a surveyed cross-section that are made up of boulders.
Bedrock_ct	*Percent Bedrock.* The percentage of streambed substrates at a surveyed cross-section that are made up of bedrock.
Clay_ct	*Percent Clay.* The percentage of streambed substrates at a surveyed cross-section that are made up of clay.
Detritus_ct	*Percent Detritus.* The percentage of streambed substrates at a surveyed cross-section that are made up of organic matter, such as leaf-litter.
HABITAT	Type of stream habitat at surveyed stream cross-sections (pool, riffle, or run).
VELOCITY	An observation taken at stream cross-sections of how fast (slow, moderate, fast) the water is flowing in the stream.
SHADING	Portion of the stream at a surveyed stream cross-section that is shaded by overhanging trees, shrubs, or grasses. **0-** unshaded; **1-** partially shaded; **2-** halfway shaded; **3-** mostly shaded.
COVER	*Amount of instream fish cover.* The percent of stream containing some form of fish cover at a surveyed cross-section. **0** indicating none or 0 percent instream cover; **1-** less than 25 percent instream cover; **2-** 25 to 75 percent instream cover; **3-** greater than 75 percent instream cover.
WOOD_DEB	*Woody Debris.* The percent of stream that contains woody debris at a surveyed cross-section. **0** indicating none or 0 percent of stream containing woody debris; **1-** less than 25 percent; **2-** 25 to75 percent; **3-** greater than 75 percent of woody debris.

Table F.1 (continued)

Parameters	Transect/Cross-Section Features
AQ_PLANTS	*Aquatic Plants*. The percent stream that contains aquatic plants at a surveyed cross-section. . **0** indicating none or 0 percent of aquatic vegetation; **1-** less than 25 percent; **2-** 25 to75 percent; **3-** greater than 75 percent of aquatic plants.
ALGAE	Percent of stream that contains algae at a surveyed stream cross-section. **0** indicating none or 0 percent of stream contains algae; **1-** less than 25 percent; **2-** 25 to75 percent; **3-** greater than 75 percent of algae.
OH_VEG	*Vegetative Cover*. Indicates that overhanging vegetation fish cover was present at the surveyed cross-section.
MACRO	*Aquatic Plant Cover*. Indicates that aquatic plant fish cover was present at the surveyed cross-section.
ALGAE1	*Algae Cover*. Indicates that algae fish cover was present at the surveyed cross-section.
LOGS_WOODY_DEB	*Woody Debris Cover*. Indicates that woody debris fish cover was present at the surveyed cross-section.
ROOTS	*Root Cover*. Indicates that root cover was present at the surveyed cross-section.
BOULD_COBB	*Boulder/Cobble Cover*. Indicates that boulder and/or cobble cover was present at the surveyed cross-section.
WILDLIFE	*Wildlife*. Observed wildlife was noted at each cross-section.
BANK	*Right Bank Angle of Less than 90 Degrees*. Indicates that the right bank was less than 90 degrees at the surveyed cross-section.
BANK_1	*Right Bank Angle of 90 Degrees*. Indicates that the right bank was 90 degrees at the surveyed cross-section.
UNDERCUT	*Undercut Right Bank*. Average measurement of the cut bank depth at which the bank is overhanging the stream.
BANK1	*Left Bank Angle of Less than 90 Degrees*.
BANK1_1	*Left Bank Angle of 90 Degrees*.
UNDERCUT1	*Undercut Left Bank*. Average measurement of the cut bank depth at which the bank is overhanging the stream.

Parameters	Point Features
Stream Crossing	*A structure*, either a bridge or culvert crossing, identified along with its measurements during the instream field survey.
Drain Tile	A drain tile identified within the stream system. Measurements taken include diameter and material of drain tile (metal or plastic), left or right bank and whether or not it was actively draining.
Pool	A *substantial pool* or deep point within the water column identified. Water depth and width are measured.
Riffle	Portions of the water column where water velocity is fast, stream depths are relatively shallow, and the water surface gradient is relatively steep. Measurements include riffle width, depth and length.
Stormwater Outlet	Stormwater drainage systems identified. Includes stormwater pond outlets or drainage ditch culverts. Culvert diameter, location, and culvert material are noted.
Trash	Any tire(s), large pieces of metal, or plastic material identified within the streambed that would need to be removed. Description and location of the trash is noted during the field survey.
Woody Debris Jam	Large pieces or aggregations of smaller pieces of wood (e.g., logs, large tree branches, root tangles) located in, or in contact with, the water surface often resulting in water backup or interfering with stream flow. General description of the woody debris jam is noted, such as size, impoundment of water and any impacts it is creating within the stream system.

Source: SEWRPC

APPENDIX G

DITCH CHECK/CHECK DAM AND DITCH TURNOUT MANAGEMENT PRACTICES

Source: State of California, Department of Transportation, Check Dams, Section 4, Storm Water Quality Handbooks, Project Planning and Design Guide, Construction Site Best Management Practices (BMPs) Manual, Storm Water Pollution Prevention Plan (SWPPP) and Water Pollution Control Program (WPCP) Preparation Manual, March 2003, www.dot.ca.gov/hq/construc/stormwater/SC-04.pdf

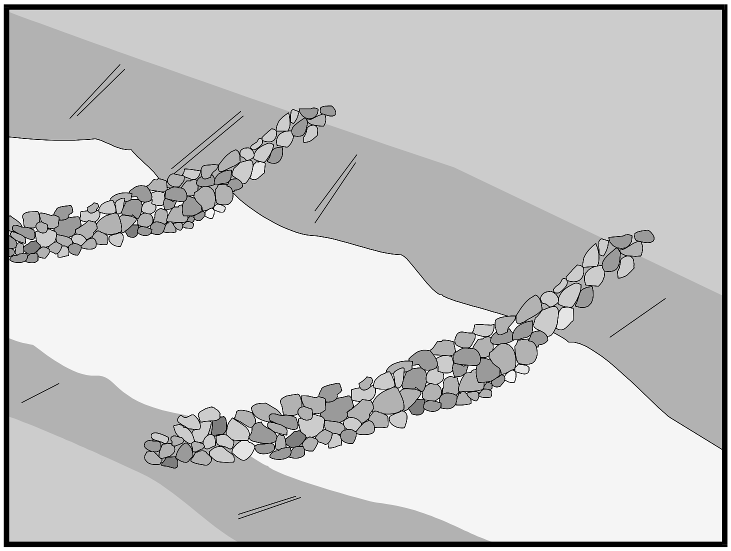
Part of the Conservation Practices for Homeowners Factsheet Series, available at:

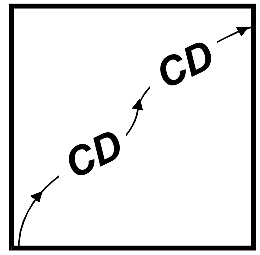
Maine DEP (800.452.1942)
www.maine.gov/dep/blwq/docwatershed/materials.htm

Portland Water District (207.774.5961)
www.pwd.org/news/publications.php
www.pwd.org/sites/default/files/turnouts.pdf

Check Dams

SC-4





Standard Symbol

BMP Objectives

● Soil Stabilization
● Sediment Control
○ Tracking Control
○ Wind Erosion Control
○ Non-Storm Water Management
○ Materials and Waste Management

Definition and Purpose

Check dams reduce scour and channel erosion by reducing flow velocity and encouraging sediment settlement. A check dam is a small device constructed of rock, gravel bags, sandbags, fiber rolls, or other proprietary product placed across a natural or man-made channel or drainage ditch.

Appropriate Applications

- Check dams may be installed:
  - In small open channels that drain 4 ha (10 ac) or less.
  - In steep channels where storm water runoff velocities exceed 1.5 m/s (4.9 ft/sec).
  - During the establishment of grass linings in drainage ditches or channels.
  - In temporary ditches where the short length of service does not warrant establishment of erosion-resistant linings.
- This BMP may be implemented on a project-by-project basis with other BMPs when determined necessary and feasible by the Resident Engineer (RE).

Limitations

- Not to be used in live streams.
- Not appropriate in channels that drain areas greater than 4 ha (10 ac).
- Not to be placed in channels that are already grass lined unless erosion is expected, as installation may damage vegetation.
- Require extensive maintenance following high velocity flows.
- Promotes sediment trapping, which can be re-suspended during subsequent storms or removal of the check dam.

Standards and Specifications

- Not to be constructed from straw bales or silt fence.
- Check dams shall be placed at a distance and height to allow small pools to form behind them. Install the first check dam approximately 5 meters (16 ft) from the outfall device and at regular intervals based on slope gradient and soil type.
- For multiple check dam installation, backwater from downstream check dam shall reach the toe of the upstream dam.
- High flows (typically a 2-year storm or larger) shall safely flow over the check dam without an increase in upstream flooding or damage to the check dam.
- Where grass is used to line ditches, check dams shall be removed when grass has matured sufficiently to protect the ditch or swale.
- Rock shall be placed individually by hand or by mechanical methods (no dumping of rock) to achieve complete ditch or swale coverage.
- Fiber rolls may be used as check dams if approved by the RE or the Construction NPDES Coordinator. Refer to SC-5 "Fiber Rolls."
- Gravel bags may be used as check dams with the following specifications:

Materials

- ***Bag Material:*** Bags shall be either polypropylene, polyethylene or polyamide woven fabric, minimum unit weight 135 g/m2 (four ounces per square yard), mullen burst strength exceeding 2,070 kPa (300 psi) in conformance with the requirements in ASTM designation D3786, and ultraviolet stability exceeding 70% in conformance with the requirements in ASTM designation D4355.
- ***Bag Size:*** Each gravel-filled bag shall have a length of 450 mm (18 in), width of 300 mm (12 in), thickness of 75 mm (3 in), and mass of approximately 15 kg (33 lb). Bag dimensions are nominal, and may vary based on locally available materials. Alternative bag sizes shall be submitted to the RE for approval prior to deployment.
- ***Fill Material:*** Fill material shall be between 10 mm and 20 mm (0.4 and 0.8 inch) in diameter, and shall be clean and free from clay balls, organic matter, and other deleterious materials. The opening of gravel-filled bags shall be secured such that gravel does not escape. Gravel-filled bags shall be between 13 kg and 22 kg (28 and 48 lb) in mass. Fill material is subject to approval by the RE.

Installation

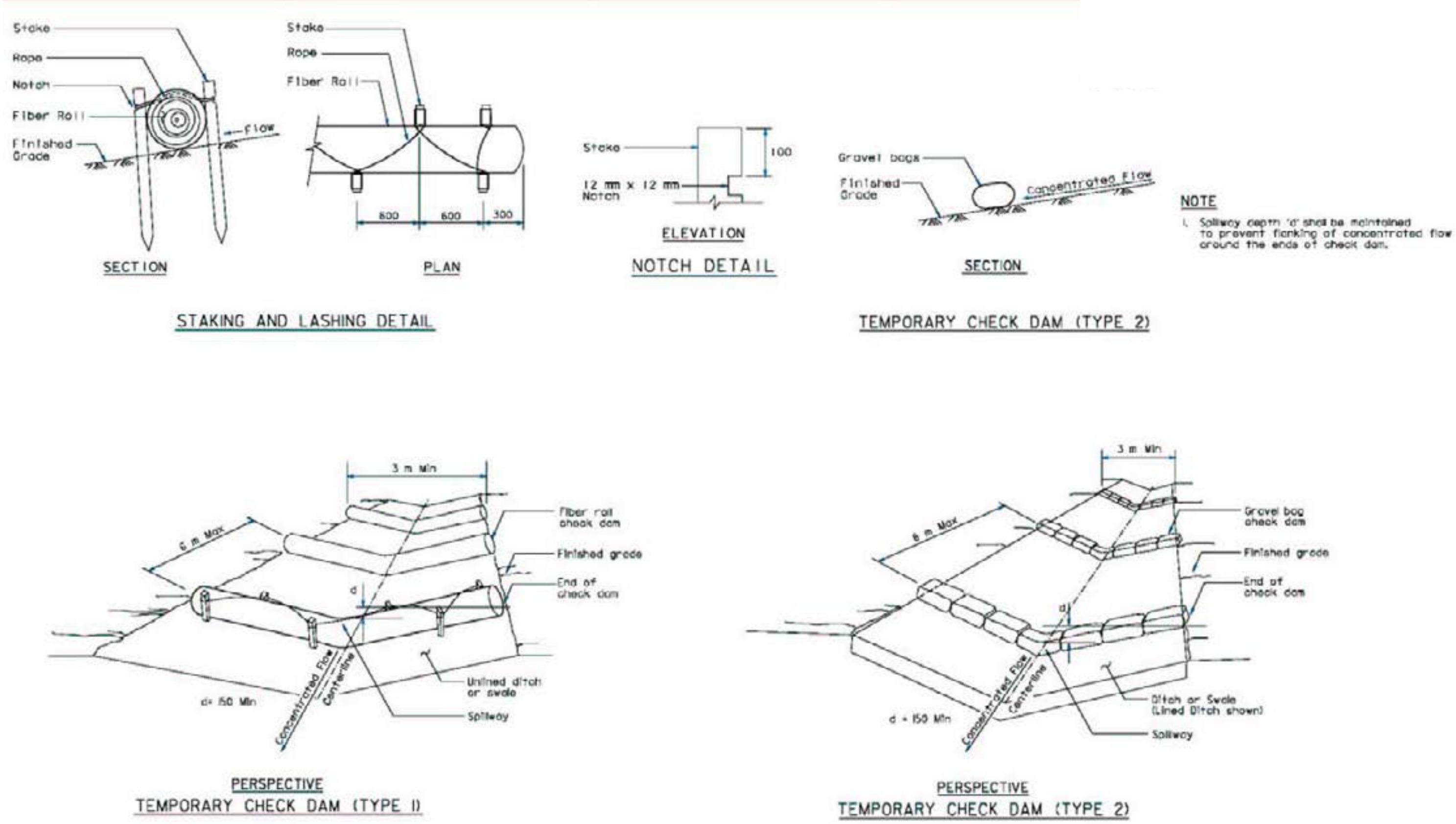
- Install along a level contour.
- Tightly abut bags and stack gravel bags using a pyramid approach.

Gravel bags shall not be stacked any higher than 1 meter (3.2 ft).

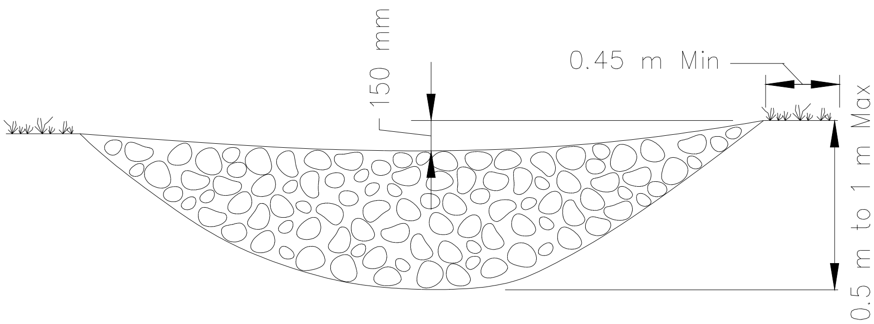
– Upper rows of gravel bags shall overlap joints in lower rows.

Maintenance and Inspection

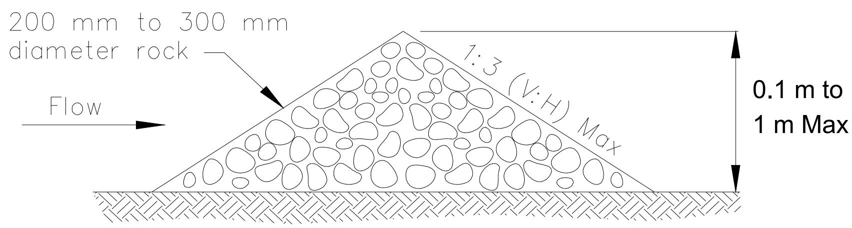
- Inspect check dams after each significant rainfall event. Repair damage as needed or as required by the RE.
- Remove sediment when depth reaches one-third of the check dam height.
- Remove accumulated sediment prior to permanent seeding or soil stabilization.
- Remove check dam and accumulated sediment when check dams are no longer needed or when required by the RE.
- Removed sediment shall be incorporated in the project at locations designated by the RE or disposed of outside the highway right-of-way in conformance with the Standard Specifications.



Stake
Rope
Notch
Fiber Roll
Finished Grade
Flow
SECTION
Stake
Rope
Fiber Roll
600
600
300
PLAN
STAKING AND LASHING DETAIL
Stake
12 mm x 12 mm Notch
100
ELEVATION
NOTCH DETAIL
Gravel bags
Finished Grade
Concentrated Flow
SECTION
TEMPORARY CHECK DAM (TYPE 2)
NOTE
1. Spillway depth 'd' shall be maintained to prevent flanking of concentrated flow around the ends of check dam.
3 m Min
6 m Max
d
Fiber roll check dam
Finished grade
End of check dam
Unlined ditch or swale
Spillway
Concentrated Flow
Centerline
d= 150 Min
PERSPECTIVE
TEMPORARY CHECK DAM (TYPE 1)
3 m Min
6 m Max
d
Gravel bag check dam
Finished grade
End of check dam
Ditch or Swale (Lined Ditch shown)
Spillway
Concentrated Flow
Centerline
d = 150 Min
PERSPECTIVE
TEMPORARY CHECK DAM (TYPE 2)



ELEVATION



TYPICAL ROCK CHECK DAM SECTION

ROCK CHECK DAM

NOT TO SCALE

TURNOUTS

~diverting water off roads and driveways~

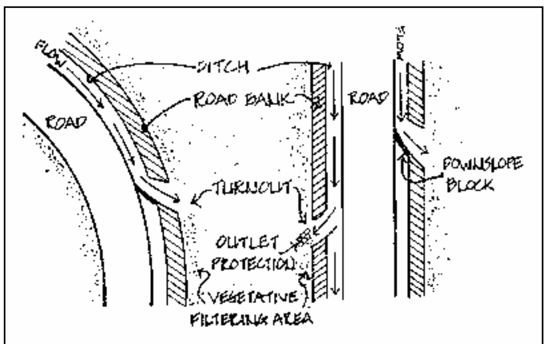
Portland Water District

Purpose: Any camp road, even properly constructed ones, alter natural drainage patterns. On camp roads, the biggest concern is to get water off the road surface as quickly as possible. When surface water is not drained off the road, it can lead to washouts, muddy conditions, and potholes.

Turnouts return stormwater runoff as sheet flow to natural drainage areas. Often turnouts are simply extensions of ditches that redirect water into the woods and disperse runoff before it can cause erosion. Turnouts reduce the speed of runoff, allowing soil particles to settle out instead of being transported to a stream, river, or lake. Water and nutrients can then be filtered and absorbed by the surrounding vegetation.

Installation: Turnouts are used to direct water away from the road into a vegetated buffer area, and can be constructed on paved or gravel roads with or without ditches. Turnouts can be the width of a backhoe bucket, a bulldozer blade, or a handheld shovel. Turnouts should intersect the ditch at the same depth, and gently slope down and away from the road.

As it is easier to disperse smaller volumes of water at a time, turnouts should be constructed as often as possible. Ideally, turnouts should be placed every 50 feet. Utilize the natural contours of the land and install turnouts frequently enough to prevent large volumes of runoff from accumulating along the side of the road. Turnouts should be placed closer on steeper slopes. However, check with abutting property owners to ensure this water will not adversely impact their property.



DETAIL - TURNOUTS

Turnouts should be stabilized so as not to create additional soil erosion. The turnout can be seeded and stabilized with hay mulch or erosion control blankets. Alternately, on steeper slopes or areas receiving greater flow, 3"-6" angular stone rip-rap placed over non-woven getotextile fabric can be used to line the structure.

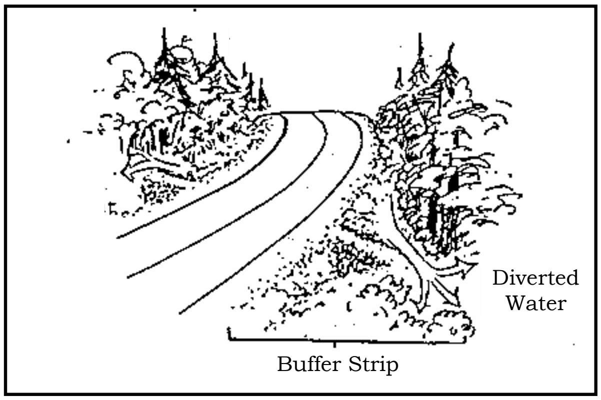
The turnout should have a flared end section that is level and lined with rock to spread out the flow. This level-lip spreader or rock dam converts the concentrated, channeled flow into slower, sheet flow just before it discharges into the vegetated area.

Most importantly, do NOT outlet turnouts into existing stream channels or drainage ways!

Materials: No special tools or equipment are required to construct turnouts. A backhoe, FrontRunner, or even a shovel can be used to build a turnout.

As with ditches, turnouts must be stabilized to keep from causing further erosion problems as they discharge stormwater away from the road. Turnouts with less than a 5% slope can be seeded with a conservation mix and mulched with hay or an erosion control blanket until the seed germinates. On steeper slopes, secure non-woven geotextile fabric on the soil and cover with 3”-6” stone rip-rap.

Care needs to be taken on the outlet of the structure. It is vital that the channeled water be spread out and slowed so it does not erode the neighboring land. Turnouts should have a flared end section that is level and lined with rock to spread out the flow. Use 4”-6” crushed, angular stone for the outlet.



Maintenance: Because the turnout may have a secondary function as a small sediment trap, maintenance is critical to ensure excessive sedimentation from storm events does not fill the structure and render it nonfunctional.

Check turnouts during and after large storm events for erosion or accumulation of debris. Any turnout will fill with sediment over time, and it is critical to remove this material for the structure to function properly. Confirm that water flows evenly into the vegetation, and does not form an erosive channel. Shift stone, as needed, to stop any channelized flow.

Have a post-storm plan in place for checking for damage and determining maintenance needs.

Part of the ***Conservation Practices for Homeowners*** Factsheet Series, available at:
Maine DEP (800.452.1942); http://www.maine.gov/dep/blwq/docwatershed/materials.htm
Portland Water District (207.774.5961); http://www.pwd.org/news/publications.php

May 2006 DEPLW0786

Source: Minnesota Wetland Restoration Guide, Blocking and Filling Surface Drainage Ditches, Technical Guidance Document WRG 4A-1, October 2015, bwsr.state.mn.us/restoration/resources/documents/appendix-4a-1.pdf

APPENDIX H

DITCH PLUG MANAGEMENT PRACTICE

BLOCKING AND FILLING SURFACE DRAINAGE DITCHES

TECHNICAL GUIDANCE DOCUMENT

Document No.: WRG 4A-1
Publication Date: 10/14/2015

Table of Contents

INTRODUCTION

Surface ditches are common in Minnesota and have drained and altered countless wetlands. When attempting to restore wetlands drained by surface ditches, it is usually necessary to place earth fills at strategic locations within the drainage ditch to block the flow of water. This wetland restoration strategy is commonly referred to as constructing a "ditch plug". While these earthen fills are often thought of as being only small, simple structures, ditch plugs are essentially small dams and must be designed and constructed accordingly.

Figure 1. Construction of an Earthen Plug Across Drainage Ditch

In addition to constructing appropriately located and designed ditch plugs, there is often a need or desire to also completely fill the entire reach of ditch within the planned restoration area. In certain landscape settings, this additional action will be necessary for the successful restoration of wetland hydrology.

APPLICATION

Drainage ditches remove excess water that collects on the land surface as well as in the soil profile. They provide a means to manage or lower water tables and can rapidly convey runoff from wetlands to areas downstream. Ditches can be just a few inches to many feet in depth, depending on topography and landscape setting.

Drainage ditches can be located in depressional wetlands, sloped wetlands, and wetland flats. As discussed in Section 3-4 and in Appendix 3-A of the Guide, each of these wetland types interact with surface and ground water to varying degrees depending on hydrogeologic factors such as soil characteristics, geologic setting, and water table position. It is important that the dynamic nature of a drained wetland's hydrogeology be understood to accurately determine effective design strategies for restoration. More specifically, it will be important to determine if a ditch plug alone will be effective in restoring hydrology to the wetland or if the entire open reach of ditch through the wetland also needs to be filled in.

Ditch plugs should be located and designed to effectively restore hydrology to the drained wetland. The constructed plug should prevent the downstream functioning ditch system from affecting the wetland. This requires that a long-enough section of ditch be plugged and filled with compacted soil to block or cutoff any drainage effect from the downstream ditch.

When constructing ditch plugs, additional benefits can be achieved by also filling in portions of the ditch system immediately upstream and downstream of the plug. This will increase the overall length of fill and provide for a more effective plug without substantially increasing construction costs. In many cases, complete filling of a drainage ditch through a restored wetland should also be considered. This provides a more effective and permanent restoration of site hydrology and allows for recontouring and restoration of topography as part of construction.

Figure 2. Shallow Ditch Being Filled

DESIGN CONSIDERATIONS

Ditch plugs are small dams and must be designed and constructed accordingly. Their design should consider site topography, subgrade soils and required foundation treatments, stripping requirements, location and suitability of backfill materials, compaction requirements, embankment fill heights and slopes, settlement allowances, stabilization requirements, etc. Detailed discussions of these and other important items relating to embankment design and construction can be found in Section 4.5 Earthen Embankments of the Guide.

To effectively block and restore wetland hydrology, ditch plugs should generally be about **75 to 100** feet in total length. Considerations for increasing this length are necessary when more extensive lateral drainage effects from the downstream drainage system exist. This includes situations when the plug is located in sandy or organic soils. A plug's length may be decreased when restoring wetlands drained by shallow ditches that are generally less than 2 feet in depth. In these situations, the overall length of the plug within the ditch should not be less than **50** feet. To achieve these effective lengths, ditch plugs will need to have fairly broad tops widths (> 10 feet) and relatively flat side slopes (> 8 to 1).

The requirements for site preparation and stripping will be an important design component. The design should ensure that all vegetation, roots, sediment, organic matter, and other unsuitable soils are removed from the area under the plug prior to its construction. Because of the potential for excess accumulated sediments and organic matter within the ditch bottom, the design should consider deeper stripping depths at the bottom of the ditch as compared to ditch side slopes and bank tops (**Figure 3**).

At each planned plug location, an evaluation of requirements for stripping or foundation excavation and treatments should be made.

The source of fill material for the plug will also be an important design consideration. If not available from the immediate area, provisions for transporting suitable borrow from other areas of the project will be needed. To minimize

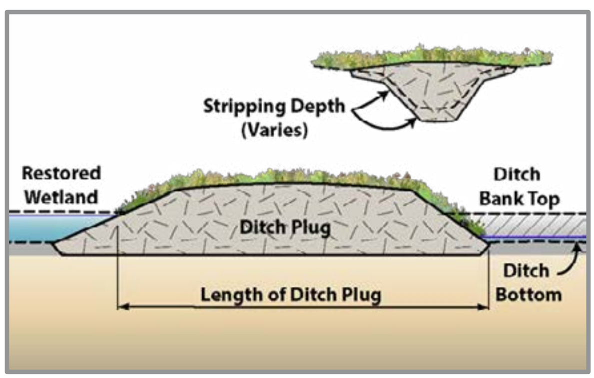


Figure 3. Ditch Plug Design Details

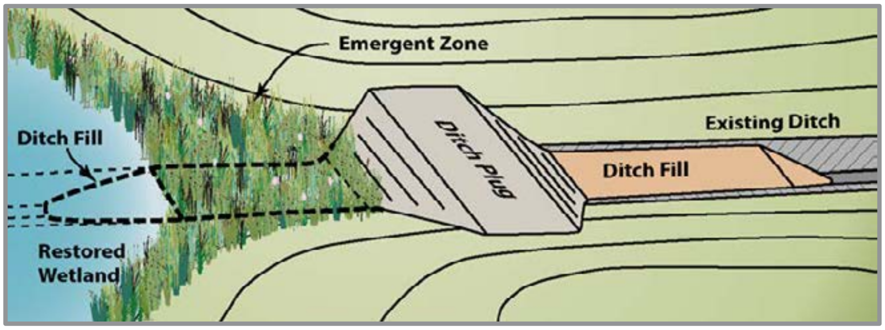


Figure 4. Ditch Plug Complimented with Adjacent Ditch Fills

construction costs, the effective length of a plug can be accomplished by finishing the grading with additional, random fills placed both upstream and downstream of the constructed plug (**Figure 4**). This design strategy allows for fairly broad embankments with flat slopes and provides for a natural looking aesthetic plug that not only successfully restores wetland hydrology but is also effective at addressing problems with rodent burrowing and potential wave action.

Generally, plugs should be designed as embankments and be constructed to prevent overtopping. In limited situations, ditch plugs can be designed to overtop and serve as a spillway for managing wetland discharges. This condition requires extra design precautions to ensure the plug will be stable and experience only infrequent flows across them. For that reason, flow-over ditch plugs are limited to smaller wetlands with limited watershed areas where discharge rates, volumes, and velocities are expected to be minimal. Additional discussion regarding the design of flow-over ditch plugs occurs in Section 4.4 Outlet Structures.

Ditch fills are often constructed in conjunction with ditch plugs. When used, ditch fills provide a more complete restoration and in some settings, may be necessary to provide for effective restoration of the wetland. They are typically more straightforward to design and construct than ditch plugs. When feasible, it is recommended to fill and recontouring the entire length of ditch through the wetland being restored.

Specific requirements for location, length, and methods to construct ditch plugs and fills will vary depending on type of wetland that is being restored and specific characteristics of a site including; topography, soils, and ditch configuration. Additional discussion on this follows.

DEPRESSIONAL WETLANDS

Surface ditches are commonly used to drain depressional shallow to deep marsh or "pothole" wetlands. Typically, a single ditch will exit the wetland basin and a well-placed ditch plug may be all that is needed to effectively restore wetland hydrology. The design should ensure that the location and length of the ditch plug will prevent the functioning downstream drainage system from having continued drainage influences on the restored wetland basin. This requires careful consideration to the location and length of the plug with respect to the planned wetland edge, site soils, and topography. Ideally, the ditch plug should be located at or just downstream of the restored wetland's edge.

The placement of additional fills in the ditch just upstream and downstream of the plug will aide in its overall restoration effectiveness including helping to reduce or eliminate adverse drainage effects by the downstream ditch (**Figure 5**).

Certain depressional wetlands are surface water dependent and not affected by groundwater. Drainage ditches constructed through these wetlands may have penetrated through an impervious bottom substrate into an underlying pervious soil layer. This can further aide in removing hydrology from the wetland. In these settings, a ditch plug alone will often be ineffective at restoring functional hydrology. An effective restoration requires that the ditch through the wetland also be completely filled in attempt to recreate the seal between the wetland and underlying pervious soils. This usually occurs in surface water dependent wetlands where the surface hydric soils or substrates are underlain with sand or sand lenses.

Wetland outlet structures, vegetated spillways in particular, can influence the location and layout of earthfills used to restore wetlands. Additional discussion on this occurs in Section 4.5 Earthen Embankments.

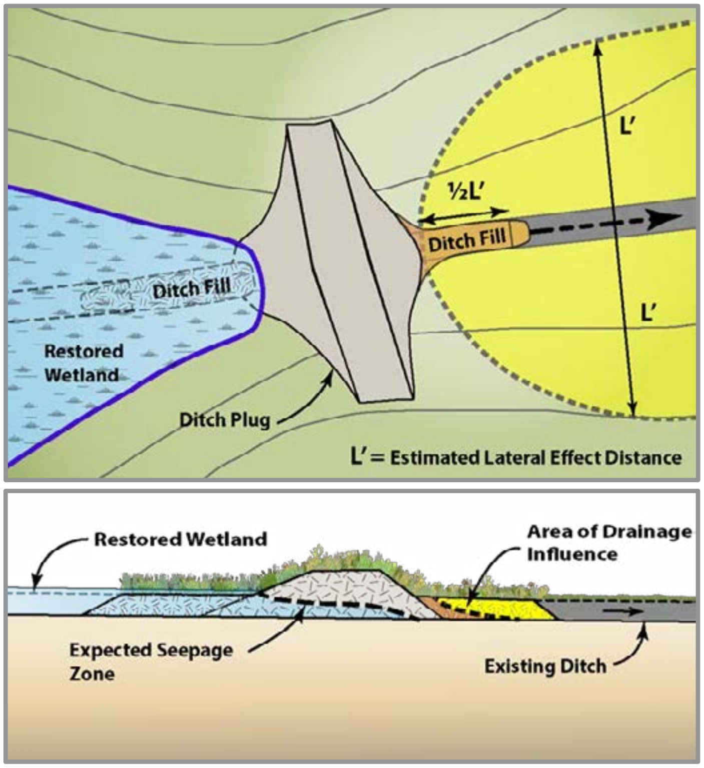


Figure 5. Ideal Location and Design Layout for a Ditch Plug in a Depressional Wetland Settings

Sloped Wetlands

Because of the moderate to steeply sloping topography associated with sloped wetlands, a single ditch plug is likely to be ineffective at restoring hydrology to the wetland. The restoration of sloped wetlands requires at least one ditch plug at the bottom or lowest elevation of the ditch with additional plugs, spaced periodically apart, on the remaining portions of the ditch.

> The restoration of ditch drained sloped wetlands can provide a number of design and construction challenges

Information on site soils, grade or slope of the land, and specific locations and depths of existing ditches is needed for a functional design. For each reach of open ditch that exists, the design objective should be, at minimum, to construct multiple ditch plugs spaced so they exist every **one** to **three** feet of vertical slope relief of the land surface. This stepped or segmented approach to performing ditch plugs helps to reduce excessive hydraulic "head" differences from one plug to the next and more evenly distributes restored hydrology throughout the sloped wetland area.

The entire reach of open ditch between the constructed plugs should also be filled in to ensure full restoration of the site and to help prevent excessive ponding against any of the constructed plugs (**Figure 6**).

Non-Depressional Wetland Flats

Non-depressional wetland flats typically consist of vast areas of peat or organic soils. Extensive ditch systems are often used to drain wetlands in this type of landscape setting. When restoration of these wetland types is possible, the construction of multiple ditch plugs and fills is usually needed.

The soils that are often associated with these types of wetlands generally have relatively high permeability rates therefore; it is recommended for effective restoration of wetland hydrology that at least **150** feet of open ditch be plugged and filled at each desired location. If less permeable soils exist, the length of the plug/fill block can be reduced but should not be less than **100** feet.

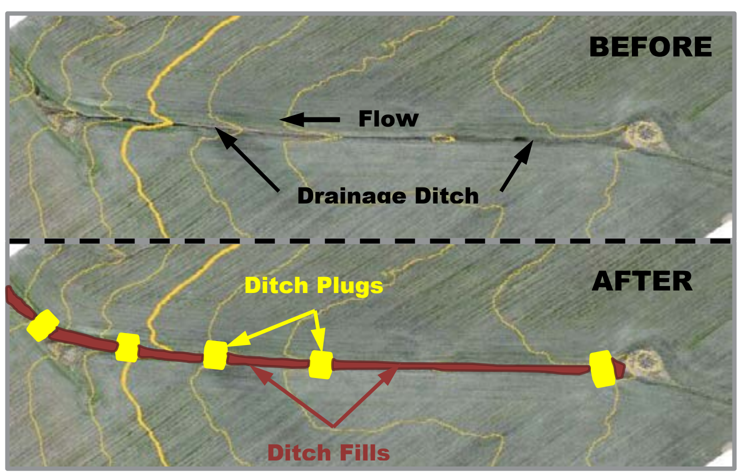


Figure 6. Ditch Plug/Fill Design for Sloped Wetland Setting – 2 Foot Contours

In addition, when attempting to restore non-depressional wetland flats that are large in size, some grade or elevation drop may exist across the landscape. While this elevation change may seem subtle, the effective restoration of wetland hydrology to these landscapes may require that multiple plugs and fills be considered to address this elevation change. For this situation, refer to the discussion on sloped wetlands above for applicable design guidance, however, it may be necessary to alter the design criteria with plugs instead spaced every **one** foot of vertical slope relief.

Strong consideration should be given to completely backfill open ditches between constructed ditch plugs to ensure full restoration of these wetlands.

Figure 7. Importing Material to Fill Ditch thru Non-Depressional Wetland

Project Boundaries/Property Lines

Special consideration is needed when planned ditch plugs and fills are in close proximity to project or property boundaries. Depending on site soils and the downstream land use, it may be necessary or beneficial to incorporate specific design measures to address and prevent potential adverse impacts to the adjoining, downstream lands. This can often be accomplished in one of two ways.

The first method is for any planned ditch plugs to be offset from the project/property line by at least **25** feet to allow for a short reach of the ditch to remain functioning within the project boundary. Leaving a short reach of the existing drainage ditch

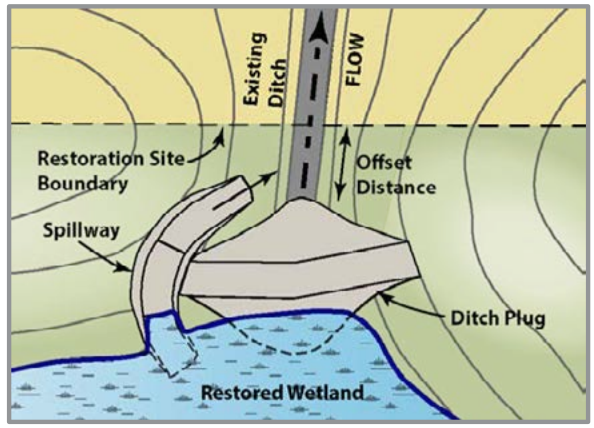


Figure 8. Ditch Plug Offset from Property Line

intact between the plug and property line may help prevent negative off-site hydrologic impacts as a result of the restoration while at the same time allowing wetland outlets including spillways to be constructed where they can safely discharge and outlet into the ditch before exiting the property (**Figure 8**).

An alternative is to work with the adjoining property owner and install additional drainage provisions just within the adjoining property to ensure protection against hydrologic effects of the adjoining restoration project. A single tile line or ditch, offset and parallel to the project boundary, will usually suffice. The length, size and offset distance from the project boundary are design parameters that, in addition to regulatory compliance, need consideration.

CONSTRUCTION REQUIREMENTS

Requirements for site preparation, topsoil stripping, foundation treatments, location and suitability of borrow materials, compaction, settlement allowances, finished grades, and for methods to stabilize the constructed fills and other disturbed areas are all important aspects of the construction process.

If constructing both ditch plugs and ditch fills, separate construction requirements unique to each restoration design strategy are needed. These requirements should be clearly stated as part of prepared construction plans and specifications and then adhered to as part of construction.

Ditch Plugs

Site preparation and stripping requirements for ditch plugs is a critical first step in their construction and must be carefully completed. All vegetation, roots, sediment, and organic matter should be removed from the area under the plug prior to its construction. Existing vegetation should be carefully evaluated prior to stripping. If it contains weeds or other undesired vegetative species consideration should be given to burying it as part of any associated ditch filling (see ditch fill discussion below).

Figure 9. Ditch Area being Stripped Prior to Plug Construction

Additional excavations to remove unsuitable soils within the ditch bottom will need consideration as part of the stripping operations. Depending on conditions, it may be necessary to dewater the ditch within the construction area to facilitate proper construction conditions and to achieve specified compaction requirements for ditch fills.

Figure 10. Ditch Plug under Construction

Figure 11. Compaction of Constructed Ditch Plug

The selection, placement, and compaction of fills will be an important part of a ditch plug's construction. Fills should be placed in lifts and compacted per requirements of the plan and specifications. The initial first few feet of fill material will typically be the most difficult to compact due to location and conditions at bottom of the ditch. Additional discussion of compaction requirements for embankments occurs in Section 4.5 Earthen Embankments.

Some settlement of the compacted fills as part of the ditch plug's construction will occur. Under ideal conditions with good backfill material and compaction methods, settlement amounts of 5 to 10 percent of the total fill height should be expected. Under less than ideal conditions, settlement amounts of 10 to 15 percent are possible. More settlement will occur in the center of the ditch where fill heights are greater. The finished grading of the plug should be overbuilt and crowned to account for the expected settlement (**Figure 12**).

Figure 12. Finished Ditch Plug with Crown in Middle

DITCH FILLING AND RECONTOURING

Stripping of the existing ditch bottom or side slopes will usually not be necessary when constructing general ditch fills. Existing ditch spoil material, if present, can simply be pushed into the ditch to accomplish the filling. If the spoil bank contains invasive or other undesired vegetation, it is recommended to have the contractor first remove and push into the ditch the surface layer of ditch spoils to ensure the undesired vegetation gets placed towards the bottom portion of the ditch fill and adequately buried (**Figure 13**).

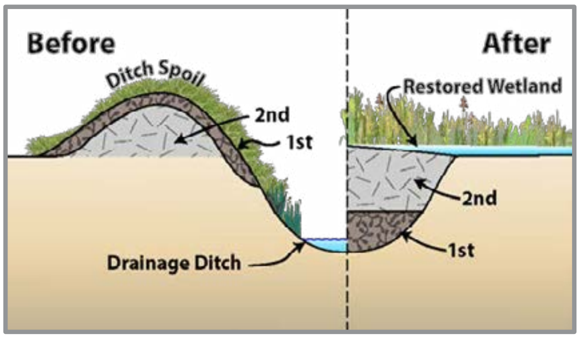


Figure 13. Construction Sequence to Address Invasive or Undesired Vegetation on Ditch Bank

Because ditch spoils decompose, settle, erode, and are often spread into adjoining fields, the quantity of available ditch spoil material is often less than what is needed to completely fill a ditch. When complete filling of a ditch is desired, careful selection of alternative sources of fill or borrow material often becomes an important design and construction consideration. Travel routes and further compaction of wetland soils is an issue that may need consideration if borrow materials are hauled from areas away from the ditch.

It is recommended that some amount of compaction be conducted of general ditch fills to prevent excessive settling. The initial first few feet will typically be the most difficult to compact due to location and potential presence of water in the ditch. Depending on conditions, it may be necessary to allow the contractor to build a base within the ditch bottom of one to three feet of material before requiring any compaction. Beyond that, general compaction of soils placed in the ditch using lifts of about 12 inches will yield the best results. With consideration to construction conditions and methods for placement and compaction, settlement rates of up to 20 percent or higher can be expected for ditch fills, especially in areas where organic soils are used.

When filling ditches within sloped wetlands, it will be important to overbuild the ditch fills so that upon their settling, they still remain slightly higher than the surrounding wetland. This helps to evenly spread or distribute restored hydrology to the surrounding sloped wetland soils and to prevent surface runoff from overtopping and eroding the constructed fills.

OTHER CONSIDERATIONS

- When necessary, provisions for obtaining borrow materials to construct ditch plugs and fills will be needed. Discussion and consideration for obtaining supplemental borrow material from within areas of the planned wetland occurs in Section 4.6 Sediment Removal, Scrapes, and Other Excavations.

- Design consideration is needed to address potential issues with wave or rodent damage to constructed ditch plugs. Additional discussion on this topic occurs in Section 4.5 Earthen Embankments.

- As wetlands and their respective watersheds get larger, the need to manage runoff from the restored wetland often require that ditch plugs be constructed in conjunction with spillways and/or other outlet structures to safely transfer runoff from the wetland to the downstream ditch system. The type of outlet used will likely influence the location and design of ditch plugs and associated ditch fills.

- Other considerations for filling open ditches as part of restoration construction include concerns for hunter safety and removing deep water habitat from a project, which can create a condition for potentially undesirable aquatic species, such as fathead minnows, to survive over the winter.

- Consideration is needed to address stabilizing areas of the restoration site that are disturbed during construction. All disturbed areas should be seeded with consideration for additional stabilization on slopes and in other areas where concentrated flow may occur. This can include the use of straw mulch, erosion control blankets, hydro mulching, etc.

COST

The cost to construct ditch plugs and fills varies and is primarily dependent on the amount of site preparation work and earthfills needed to accomplish restoration goals.

Costs to construct ditch plugs will generally include stripping the area under the plug, transporting, placing, compacting and finish grading of fill materials, and methods to stabilize the completed fills (seeding and mulching). The size (height and length) of the plug will directly affect fill volumes and cost. Required subgrade improvements (core trench) and more direct means of stabilizing the completed fills (erosion control blankets, hydro seeding-mulching, etc.) will add additional costs.

Costs to fill a ditch will vary depending on length and size of the ditch and whether fills need to be hauled from alternative borrow areas to supplement existing spoil quantities. The costs associated with grading, hauling, placing, and compacting fill materials needs consideration when determining the extent of ditch fill needed. Due to the difficulty of measuring fill volumes, ditch fill work is recommended to be completed at an hourly rate or per lineal foot of ditch filled. When possible, consider filling ditches with excavated materials from other construction actions such as excavation of core trenches, spillways, sediment removal areas, etc.

Seeding of the disturbed areas is optional and likely dependent on type of wetland restored. For example, seeding and stabilizing the disturbed ditch fill area within a sloped wetland setting is critical to success, whereas it becomes less important in a depressional wetland setting

MAINTENANCE

Locations where ditch plugs and fills are constructed will need periodic inspection to identify and correct problems. Various problems can include excessive erosion, scouring, or sloughing of the constructed fills, excessive settling of backfill materials, seepage thru constructed ditch plugs, wave or rodent damage, and poor establishment of vegetative cover.

ADDITIONAL REFERENCES

Other Related Technical Guidance Documents can be found in Appendix 4-A of the Minnesota Wetland Restoration Guide.

Standard Engineering Drawings to aide in the design of ditch plugs and fills along with other drainage manipulation strategies are provided in Appendix 4-B.

APPENDIX I

CHANNEL FORMING DISCHARGES

Source: Andy Ward, Jessica L. D'Ambrosio, and Jonathan Witter, "Channel-Forming Discharges", The Ohio State University Department of Food, Agricultural, and Biological Engineering and the Ohio NEMO Program, The Ohio State University-Extension, Fact Sheet Agriculture and Natural Resources, Report No. AEX-445-03, 2008.

THE OHIO STATE UNIVERSITY EXTENSION

FACT SHEET

Agriculture and Natural Resources

AEX-445-03

Channel-Forming Discharges

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What Is Channel-Forming Discharge?

Have you ever wondered why a stream is located where it is, is bigger or smaller than another stream, why it is crooked, or why some streams are wide and shallow while others are narrow and deep? The answers to these questions enable us to understand the origin and evolution of a stream system, which will help us to develop ways to protect, enhance, or sustain these complex and fragile ecosystems. Streams are constantly changing and, like any physical system, trying to create balance between all of the factors acting on them. The balance of constantly changing factors is called *dynamic equilibrium*. Two primary influences on the equilibrium of a stream system are the quantity and movement of both water and sediment. We call the movement of water or sediment *discharge*. The quantity and movement of both water and sediment tend to balance each other within the confines of the stream channel and this is what, ultimately, gives the stream bed and banks their shape or form. We also can call this movement *channel-forming discharge*. The purpose of this fact sheet is to provide an explanation of channel-forming discharges, their importance to stream systems, and how they can be determined.

Factors That Give Stream Channels Shape

A natural stream running through the middle of a valley will have a main channel and a connected *active floodplain*—land closest to the channel that is flooded often (Figure 1). The channel carries water and sediment discharges through the system that is related to a specific, predictable amount of flow called the *bankfull discharge* or *effective discharge.* When the discharge is higher than the channel can hold within its banks, the extra water and sediment spills out over the banks and onto the floodplain. The active floodplain, if connected to the channel, helps to decrease the speed at which water is flowing and helps to maintain dynamic equilibrium so that the bed and banks are not washed away during a big storm event.

Figure 1. A small urban stream with a connected active floodplain containing less than the bankfull discharge; note the distinct shape and size of both stream banks. B: The same stream with a bankfull, or channel-forming discharge, after a rainstorm.

If we understand the balance between water and sediment discharges—or *fluvial processes*—we can begin to predict what happens to the stream when these factors are out of balance (Figure 2). For example, if higher water flow is not able to spill out onto the floodplain, it may be picking up sediment from the bed and banks. This is called *degradation* and can cause erosion and *scour* (Figure 2A, C). On the other hand, if water containing a lot of sediment is flowing very slowly because of a dam installed downstream, the heavier sediment particles will drop out of the water flow and deposit on the bed and banks. This is called *aggradation,* which is a build up of material (Figure 2B, D).

The *bankfull discharge* is often related to the amount of water flowing in a stream that fills the main channel and begins to spill onto the active floodplain[1, 2]. Bankfull discharge is a range of flows (volume per unit time) that is most important in forming a channel, floodplains (benches), and banks. When we talk about *bankfull discharge,* we also talk about the collection and/or analysis of data relating to the channel shape and size, or *dimension*[3, 4].

The term *effective discharge* is the amount of water (again, volume per unit time) that transports the most sediment over the long term[2]. When we talk about effective discharge we also talk about the collection and/or analysis of data related to the type and amount of sediment in that flow of water. This moving sediment is called the *suspended* and/or *bedload sediment*[5]. Often, the terms *bankfull* and *effective discharge* are considered to be synonymous. For example, Leopold[6] stated that bankfull discharge is "considered to be the channel-forming or effective discharge". Powell and others[7] found that, for large rivers in Ohio, the bankfull and effective discharge were often similar.

The term *bankfull* causes some confusion in some artificial, or constructed, channels such as agricultural ditches because the size of the ditch is unrelated to *fluvial processes*, or the size that nature would form naturally. In streams that are *entrenched* or *incised*, or too deep (this is common in urban and many rural settings), the bankfull stage is lower than the top of the bank and is identified as a bench, change in bank material and vegetation, the top of point bars, or a scour line. By taking measurements of the stream, we can predict the size and shape of the stream, or its *bankfull geometry*, when it is in equilibrium.

The force that flowing water exerts on the bed and banks of a stream channel is called *shear stress*. Shear stress is typically used to describe scouring or degrading of the bed and banks. Except on bends, it is related to the depth of flow of the water and the slope of the channel bed. The deeper the water, or the steeper the slope of the bed, the greater the force. For every place in a stream there will be some combination of water depth and bed slope that will cause the bed or banks to scour. A simple but approximate way of estimating when scour will occur is to use Andy's

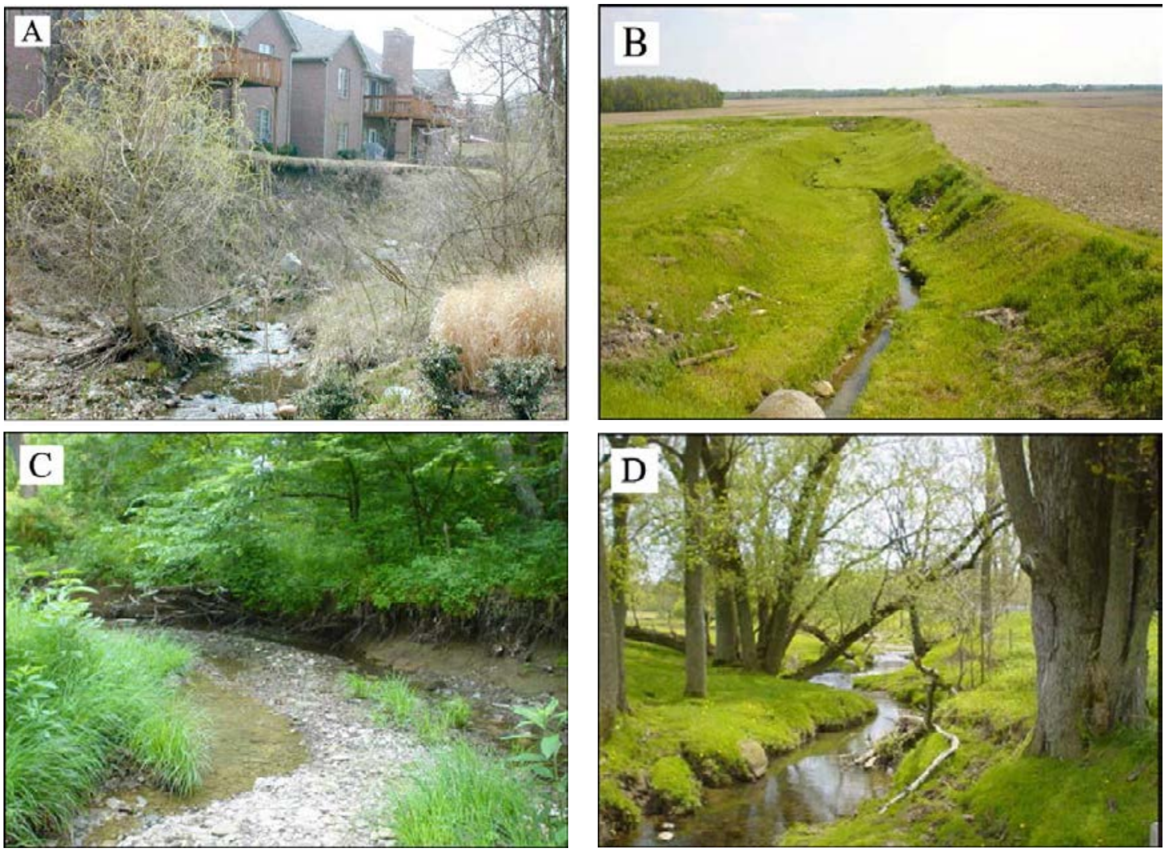

Figure 2. A: A deeply incised stream that is out of equilibrium due to urbanization. B: An agricultural ditch was built too wide and has naturally started forming a new floodplain and is changing its form to regain equilibrium. C: Aggradation of sediment, called a flat point bar, on the left is occurring to regain equilibrium; the point bar will continue to build up until it is at the same level as the connected active floodplain on the left side of the picture. D: An incised rural stream that has become unattached from its active floodplain, the pasture on either side of the trees.

Rule, which states, "if the depth of flow is 1 foot and the bed slope is 1% then the average size bed material that will start to move will be 1 inch." If you use those particular units, multiplying depth and slope will give you the approximate sediment diameter. For example, if the depth of flow in the channel is 4 feet and the bed slope is 0.5% then the average size bed material (called the d_{50}) that will move with the flow of water will be 2 inches (4 *multiplied by* 0.5).

For many streams that are in equilibrium we will find, by using Andy's Rule, that the average bed material size is related to the average bankfull depth and the bed slope. The method is not exact and in some cases the shear stress is better related to other factors. If there is no relationship between bankfull depth, bed slope, and bed material size, it might be an indication that the stream is not in equilibrium. In a straight section of a stream (called a *reach*) average shear stresses on the banks are about 80% of those on the bed. On the outside of a bend, the shear stresses on the banks might be several times larger than those on the bed. This is the main reason why banks erode and streams shift their position.

What Data Do I Need To Determine Channel-Forming Discharges?

Obtaining highly detailed stream data, also called *surveying,* can be a time consuming and difficult activity, particularly in large rivers. Fortunately, useful guidelines for smaller, shallower streams—also called *wadeable*—are available[8]. For each *reach*, data are collected over a stream length equal to at least 20 times the channel width so that the survey includes at least two bends in the channel. Channel width and depth measurements depend on an ability to correctly measure the location of the *bankfull elevation*. Signs of *bankfull elevation* in a stream can be found at the back of point bars, significant breaks in slope, benches, changes in vegetation, or at the top of the bank. Determining the bankfull elevation is not an easy thing to do and requires a lot of practice and good observation skills (Figure 3).

One channel width and depth measurements are taken at the *bankfull elevation,* data can be plotted on a graph (using a basic spreadsheet program like Microsoft Excel) and related to watershed size—or *drainage area*—for the channel. The relationship is indicated with a trend line, and an equation for predicting each component is generated. When many of these measurements from different locations are plotted on the same graph for the same watershed over a range of drainage areas, these relationships are called *regional curves* (Figure 4). To illustrate this idea we will use data for the Scioto River near Higby, Ohio, which has a drainage area at this location of 5,131 square miles. The measured bankfull width is 567 feet, the measured mean bankfull depth is 12.1 feet, and the bankfull cross-sectional area (width multiplied by depth) is 6,880 square feet. Using the regional curve for the Scioto River shown in Figure 4, the predicted (calculated using the equations on the graph) bankfull width is 475 feet, the predicted mean bankfull depth is 14.1 feet, and the bankfull cross-sectional area is 6,710 square feet. It is not uncommon for estimates obtained from a regional curve and measured values to vary by 50% or more, so regional curves should be used with caution.

Determining the Bankfull Discharge

Discharge in a channel can be calculated by knowing just a few pieces of information. This is illustrated in the following sequence of equations. Discharge is calculated by knowing the cross-sectional area of the stream and the average velocity of the flowing water:

$$q = va$$

This is also called the *equation of continuity*, where *q* is the discharge (ft^3/sec), *a* is the cross-sectional area of the stream (ft^2) and *v* is the average velocity of flowing water (ft/sec). Bankfull velocities for low gradient channels (<2% bed slope) will usually be between 2 and 5 ft/s. At the Higby gage the bankfull velocity is about 4 ft/s. To determine the average velocity, *v,* you must know the slope, *S,* of the bed (ft/ft), the hydraulic radius, *R,* of the channel (ft) and something called a Manning's roughness coefficient, *n*. This velocity calculation is called *Manning's equation*:

$$v = \frac{1.5}{n} R^{2/3} S^{1/2}$$

Figure 3. A: Measuring bankfull features in an urban stream. B: Bankfull flow in the same stream with water depths and currents that make taking measurements unsafe.

Manning's *n* is an indicator of how much resistance to flow a channel bed has and can be found in a hydrology textbook estimated from other equations[9,10]. Most channels in Ohio will have a Manning's *n* value of 0.025 to 0.05. To calculate the hydraulic radius of the channel, *R*, you need to know *P*, the wetted perimeter (ft) of the channel cross-section (see Figure 5):

$$R = \frac{a}{P}$$

Determining the Effective Discharge

Effective discharge is related to the sediment transport rate (Figure 6). Low discharges—or smaller flow rates—associated with small storm events transport a small amount of sediment, and high discharges—or larger flow rates—associated with large storm events transport a very high amount of sediment (Figure 6A). However, the largest storm events producing the largest discharge flow rates do not happen very often so the total sediment load carried over many years is very small (Figure 6B). Small storm events producing smaller discharge flow rates happen very often so the total amount of sediment carried is large (Figure 6B). When the frequency of a discharge event is multiplied by the rate at which sediment is transported for that frequency, we obtain Figure 6C, which is a measure of the total sediment load carried for that particular discharge. Therefore, in Figure 6C, the *effective discharge* rate, which carries the most sediment over time, is around 17,000 cubic feet per second (cfs) and is carrying 100,000 tons of sediment per year.

This approach for determining the amount of sediment moving through a system—also called *geomorphic work*—is known as the Wolman-Miller model[11]. The reason the data do not all fall on the trend line in Figure 6A is because there are seasonal and annual changes in land use that affect a stream system. For example, a large storm producing a lot of

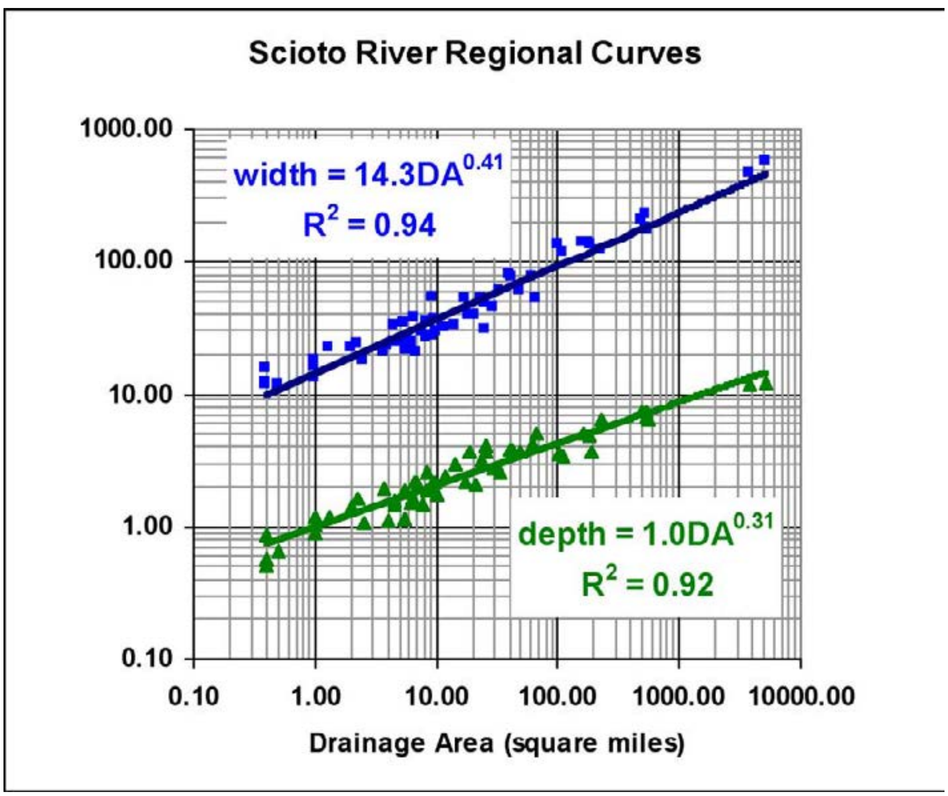

Figure 4. Regional curve for the Scioto River watershed near Higby, Ohio.

runoff during frozen conditions might contain little sediment while a much smaller storm producing runoff might contain high sediment loads from a recently plowed field or land disturbed by a development project.

How Often Do We Get Channel-Forming Discharges?

It is difficult to determine exactly how many times each year a channel-forming discharge will occur on a particular stream reach because we usually do not have detailed enough data to make those predictions. Based on an analysis of annual discharge data for humid and semi-humid regions, the channel-forming discharge generally may occur or be exceeded several times a year. The return period is the likelihood a storm event will occur or be exceeded. For example, the 10-year recurrence interval storm event has a 10% chance of occurring in any given year. In Ohio's streams, *bankfull discharge* may be associated with a return period that is less than the 1-year recurrence interval event[7]. However there are many streams where it is in the 1 to 2 year range, and some streams where the recurrence interval approaches 5 years. Information on the recurrence interval of channel-forming discharges should only be used as one piece of evidence in determining the bankfull characteristics of a channel.

Figure 7 shows recurrence interval information for discharges on the Scioto River near Higby, Ohio. Using the data in Figure 7, for an *effective discharge* of 17,000 cfs the regression lines predict RIs of 0.45 and 0.92 years. For an *effective discharge* of 26,000 cfs the two lines provide RIs of 1.1 and 1.3 years. Because of the limitations of data available or methods developed to analyze them, we advise caution in interpreting discharge and recurrence interval data. To illustrate this using the data for the Scioto River near Higby, Ohio, there are on average more than 24 days a year with discharges exceeding 17,000 cfs. Yet, in 1954 there were no daily discharges larger than 17,000 cfs while in 1996 there were 10 events, lasting a total of 73 days, which exceeded 17,000 cfs. As a general guideline, it should be expected that, for most streams and rivers in Ohio, flows exceeding the channel forming discharge would occur at least a few times annually.

What About Discharges That Are Not Channel-Forming?

A question that we might ask is, why do smaller or larger discharges than the *effective discharge* not form channels, banks, benches, and bars that are different than those associated with the stream channel? The answer to this question is not simple. There probably

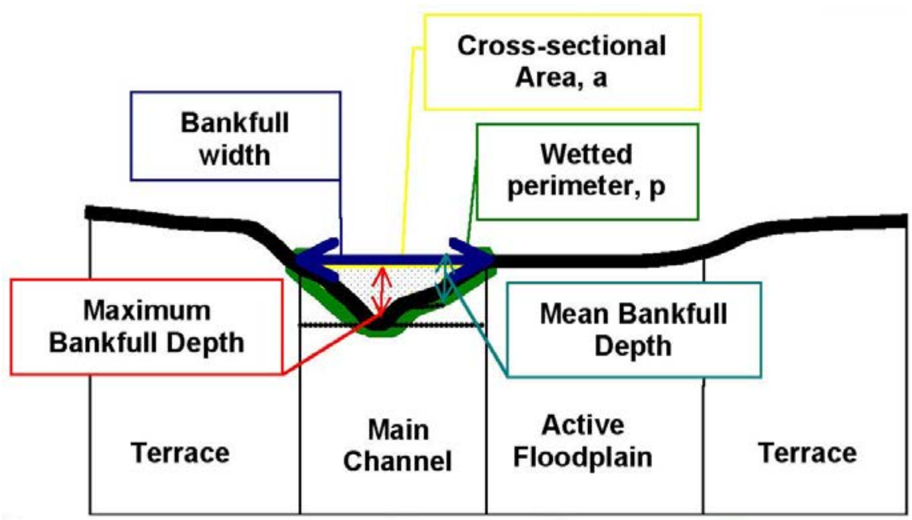

Figure 5. Cross-section of a channel with an active floodplain and terraces.

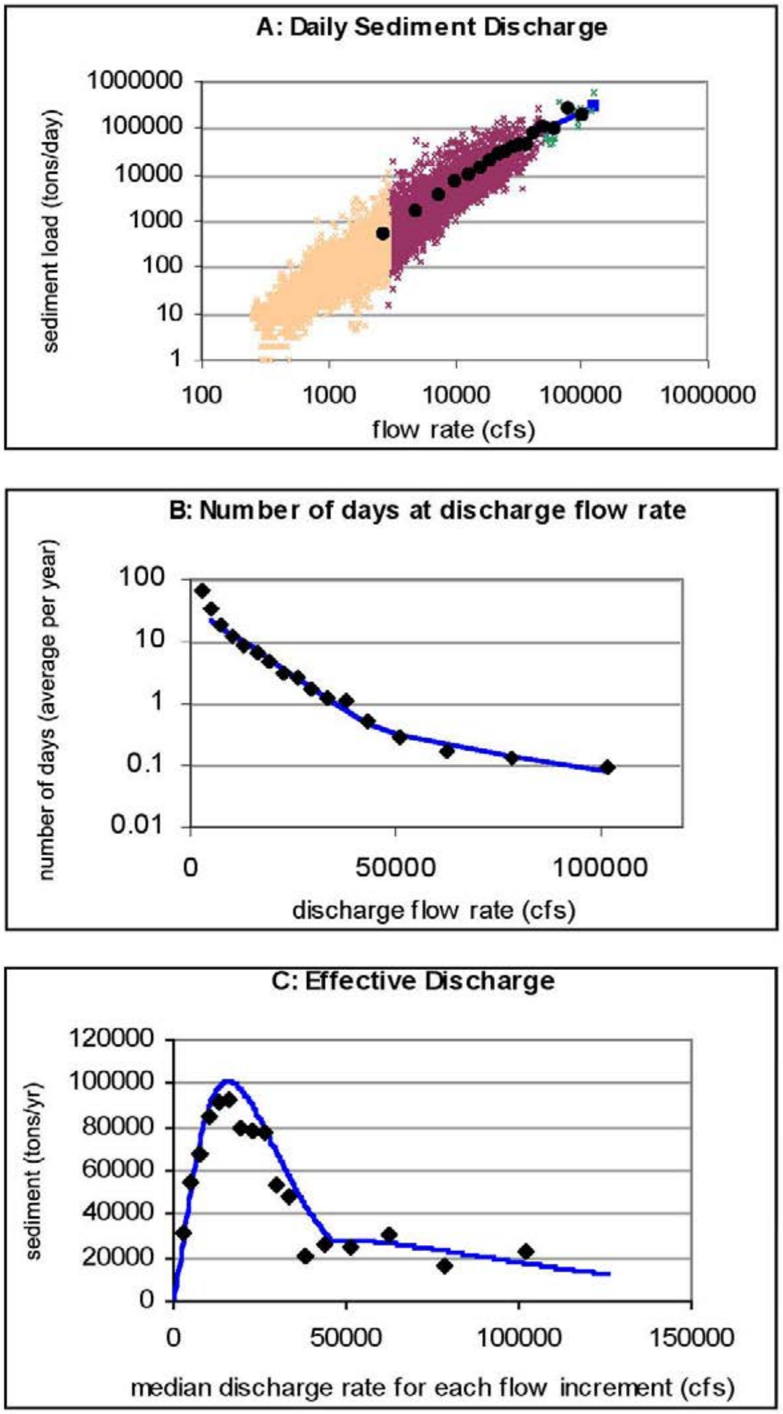

Figure 6. Illustration for Scioto River, Ohio, explaining that effective discharge carries the largest total seidment load. A: Plot of measured discharge and sediment data. B: Frequency of different median discharge rates. C: Plot of sediment load versus median discharge—the peak sediment load occurs at the effective discharge value.

is a wide range of discharges that have the potential to shape a river channel. For example, we have found in Northwest Ohio discharges associated with high subsurface drainage flows form a low bench in most agricultural drainage ditches. Why are similar features not formed in natural rivers or other ditches? First, very low discharges are ineffective in moving sediment and can only transport very fine material such as clay. If fine clays are not available, there will be little or no sediment transport. Second, the ability of these low discharges to scour the bed and banks of a channel also is very low. Third, if beds, banks, and benches are to be formed as primary features of the system, then there must be a way to effectively stabilize the deposited sediments so they do not eventually wash downstream. In the case of many agricultural ditches, vegetation provides stabilization and it grows very quickly on these features.

In a natural channel we might think of discharges lower than the effective discharge either: (1) being too small to scour and/or transporting sufficient sediment to create permanent features; or (2) occurring too frequently to allow the deposited materials to stabilize. Perhaps harder to understand and visualize is why discharges larger than the *effective discharge* do not scour and wash away the banks, benches, and bars. In places along a river system, extreme storm events might cause bank instability problems, but on average, most channel and floodplain features that are in dynamic equilibrium have relatively stable banks and beds. Once balanced, they do not *aggrade* (build up due to sediment deposits) or *degrade* (downcut due to scour) because discharges larger than the effective discharge spread out across the floodplain, have low velocities when they flow across these features, and in the main channel have similar forces on the bed and banks to those produced by the *effective discharge*.

Why Is My Channel the Shape It Is?

We have seen that the size of a channel is related to the forces on the bed and banks, the size of the bed and bank material, the discharge that carries the most sediment over a long period of time, the bed slope, and the depth of flow associated with the channel-forming discharge. So, why are channels not the same shape?

In a pasture, where there are clay soils that are stabilized by dense grass roots, we might find a narrow but deep channel. In a woodland, where there are clay/loam soils and large sparse tree roots that anchor the soil, we might find a wide and shallow channel. The constant degrading and aggrading of stream beds and banks leads to bends forming in the channel and the channel, if not constrained by valley walls, to moving

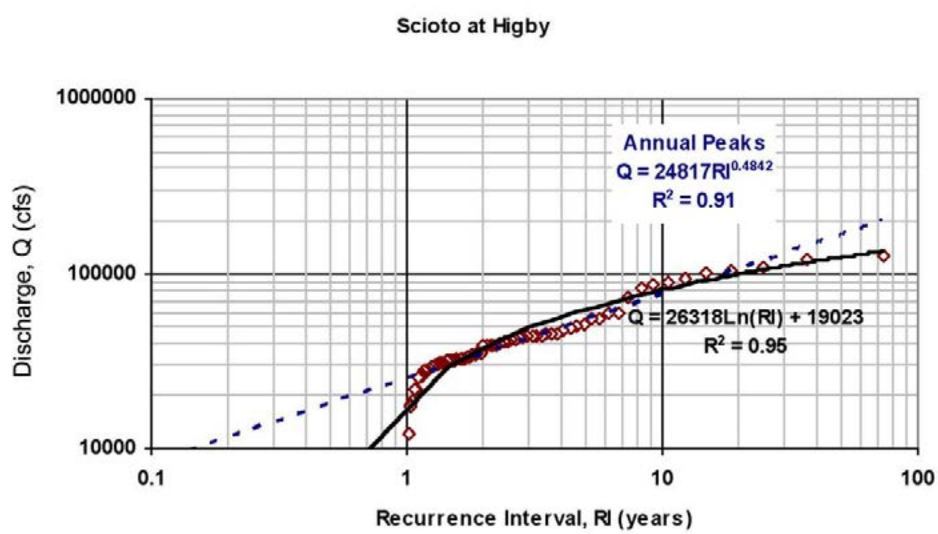

Figure 7. Discharge versus recurrence interval relationships at the Higby, Ohio USGS stream gage.

through a valley over time. This is mainly related to the resistance of the beds and banks to scour and the stability of the banks. Some materials will scour more easily than others. For example, if a channel bed has degraded to bedrock (this can be thought of as its foundation) it will have trouble getting deeper. To maintain dynamic equilibrium, the banks will scour and the channel will widen. In other cases, vegetation on the banks will help to stabilize the bank materials and it might be easier for the bed to scour than the banks. If we understand the balance between water and sediment discharges—or *fluvial processes*—we can begin to predict what happens to the stream when these factors are out of balance.

Acknowledgments

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References

[1]Wolman, M. G., & Leopold, L. B. (1957). *River flood plains: Some observations on their formation* (United States Geological Survey Professional Paper 282-C). Washington, DC: US Government Printing Office.

[2]Wolman, M. G., & Miller, J. P. (1960). Magnitude and frequency of forces in geomorphic processes. *Journal of Geology, 68,* 54–74.

[3]Rosgen, D. L. (1994). A classification of natural rivers. *Catena, 22,* 169–199.

[4]Johnson, P. A., & Heil, T. M. (1996). Uncertainty in estimating bankfull conditions. *Journal of the American Water Resources Association, 32*(6), 1283–1291.

[5]Emmett, W. W., & Wolman, M. G. (2001). Effective discharge and gravel-bed rivers. *Earth Surface Processes and Landforms, 26,* 1369–1380.

[6]Leopold, L. B. (1994). *A view of the river*. Cambridge: Harvard University Press.

[7]Powell, G. E., Mecklenburg, D., & Ward, A. D. (2006). Evaluating channel-forming discharges: A study of large rivers in Ohio. *Transactions of the American Society of Agricultural and Biological Engineering, 49*(1), 35–46.

[8]Harrelson, C. C., Rawlins, C. L., & Potyondy, J. P. (1994). Stream channel reference sites: An illustrated guide to field technique. General technical report RM 245, US Dept. of Agriculture Forest Service Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

[9]Newbury, R., & Gaboury, M. (1993). Exploration and rehabilitation of hydraulic habitats in streams using principles of fluvial behaviour. *Freshwater Biology, 29*(2), 195–210.

[10]Ward, A. D., & Trimble, S. T. (2004). *Environmental hydrology* (2nd ed.). Boca Raton: CRC Press, Inc.

[11]Andrews, E. D., & Nankervis, J. M. (1995). Effective discharge and the design of channel maintenance flows for gravel-bed rivers. In Costa, J. E., Miller, A. J., Potter, K. W., & Wilcock, P. R. (Eds.), *Natural and anthropogenic influences in fluvial geomorphology: AGU monograph series no. 89* (pp. 151–164). Washington, DC: American Geophysical Union.

STREAM CROSSING DESCRIPTION, LOCATION, CONDITION, FISH PASSAGE, AND NAVIGATION RATING ASSESSMENT WITHIN THE MASON CREEK WATERSHED: 2014

APPENDIX J

Table J.1
Structure Description, Location, Condition, and Fish Passage Rating Assessment Within the Mainstem and Headwaters of Mason Creek: 2014

Stream Reach	Structure Number	Crossing Name	Description	River Mile	Culvert/Bridge Length (feet)	Ditch Erosion	General Condition	Limiting Water Depth (feet)	Embedded Depth (feet)	Fish Passage Rating	Recommended Actions
Lower Mason Creek	1	Private Driveway	Metal and concrete span bridge	0.04	14.0	Minor	Good	1.6	--	Passable	None
	2	Private Walking Bridge	Wood span bridge	0.07	--	--	--	--	--	Passable	None
	3	Union Pacific Railway	Concrete open bottom arch bridge	0.08	66.0	Stable	Fair	0.4	--	Passable	None
	4	Peterson Drive	Two cell concrete box culvert, each cell is 6-feet-wide and 5-feet-high	0.25	41.0	Stable	Good	1.0	0.6	Passable	None
	5	Private Walking Bridge	Wood span bridge	0.37	--	--	--	--	--	Passable	None
	6	Private Walking Bridge	Wood span bridge	0.40	--	--	--	--	--	Passable	None
	7	Private Driveway	One smoot metal ellipse culvert, 4.8-feet-wide and 3.3-feet high; Culvert outlet is perched 0.6 feet above water surface; Sections of culvert coming apart under driveway	0.41	16.0	Stable	Poor; outlet perched above water surface; Scour pond with water depth of 2.7 feet; Culvert sections splitting under driveway	0.4	None	Barrier to Fish Passage	Replace with appropriately sized culvert at stream grade
	8	Private Walking Bridge	Wood span bridge	0.43	--	--	--	--	- -	Passable	None
	9	Koester Road	Three corrugated metal pipe arch culverts, each approximately 5.5-feet wide and 3.8-feet-high; Excessive amounts of cobble and boulders at upstream side of culverts causing obstruction for many species of fish during baseflow conditions	0.50	51.0	Minor	Poor; rusting through at points	0.3-0.5	None	Barrier to Fish Passage	Remove excess cobble and boulder and place evenly along adjacent banks, leave any stone more than 70% submerged (at baseflow conditions) in place
	10	Private Walking Bridge	Wood span bridge	0.60	--	--	--	--	--	Passable	None
	11	Private Walking Bridge	Wood span bridge	0.94	--	--	--	--	--	Passable	None
	12	Private Road Crossing	One 4.0-foot-diameter round concrete culvert; Culvert is undersized creating water velocities that prohibit the ability of many species of fish to pass through at baseflow conditions	1.26	19.0	Minor	Fair	0.6	None	Potential Barrier to Fish Passage	Remove or replace with appropriately sized culvert or backwater culvert with instream weir(s) to reduce water velocity and increase depth
Upper Mason Creek	13	Westshore Drive	Two corrugated metal pipe arch culverts approximately 6.6-feet-wide and 4.0-feet-high; Culverts are 30% and 50% plugged with silt	2.12	48.0	Stable	Fair	0.5-0.7	0.4-1.9	Passable	Monitor siltation within culverts
	14	Private Walking Bridge	Wood and metal beam span bridge	2.39	--	--	--	--	--	Passable	None

Table J.1 (continued)

Stream Reach	Structure Number	Crossing Name	Description	River Mile	Culvert/Bridge Length (feet)	Ditch Erosion	General Condition	Limiting Water Depth (feet)	Embedded Depth (feet)	Fish Passage Rating	Recommended Actions
Upper Mason Creek (continued)	15	CTH CW	One corrugated metal pipe arch culvert, 15-feet-wide and 3.5-feet-high; Roadside fencing has fallen into stream on downstream side of culvert and is accumulating debris and may impede fish passage if not removed	2.51	50.0	Minor	Fair	0.4	1.0	Potential Barrier to Fish Passage	Remove roadway fencing and debris accumulated from channel at downstream side of culvert
	16	Abandoned Private Culverts	One metal ellipse pipe culvert 4.2-feet-wide and 3.0-feet-high; One 1.5-foot-diameter metal round culvert; Culverts are abandoned and unnecessary and are collecting debris	3.28	10.0	Moderate	Poor, rusted through	--	--	Potential Barrier to Fish Passage	Remove both culverts and accumulated debris from channel
	17	Private Walking Bridge	Wood span bridge	3.30	--	--	--	--	--	Passable	None
	18	Private Farm Road Crossing	One concrete box culvert 6.2-feet-wide and 2.5-feet-high	3.32	18.0	Minor	Fair	0.6	None	Passable	None
East Branch of Mason Creek	19	Private ford Crossing	Water is flowing over the crossing and there are also three concrete round pipe culverts embedded underneath the road crossing, each approximately 0.7-feet-diamater serving to reduce water depths over the ford.	0.05	--	--	--	0.3	--	Potential Barrier to Fish Passage	Remove embedded pipes from this crossing and consider regrading and/or installing weirs to increase water depths and decrease water widths
	20	Abandoned Private Culvert	One concrete round culvert 3.0-feet-diameter	0.30	--	--	--	0.4	--	Passable	None

Notes: The red indicated high priority and yellow color indicates moderate priority ratings to address fish passage issues in the watershed.
This table is not a complete inventory of stream crossings. Only structures that field crews were able to access are included.

Source: SEWRPC

Figure J.1
Stream Crossing Locations Within the Mason Creek Watershed: 2014

1- PRIVATE DRIVEWAY (RM 0.04)

2- PRIVATE WALKING BRIDGE (RM 0.07)

3- UNION PACIFIC RAILWAY (RM 0.08)

4- PETERSEN DRIVE (RM 0.25)

5- PRIVATE WALKING BRIDGE (RM 0.37)

6- PRIVATE WALKING BRIDGE (RM 0.40)

7- PRIVATE DRIVEWAY (RM 0.41)

8- PRIVATE WALKING BRIDGE (RM 0.43)

9- KOESTER ROAD (RM 0.50)

10- PRIVATE WALKING BRIDGE (RM 0.60)

11- PRIVATE WALKING BRIDGE (RM 0.94)

12- PRIVATE CROSSING (RM 1.26)

Figure J.1 (continued)

13- WESTSHORE DRIVE (RM 2.12)

14- PRIVATE WALKING BRIDGE (RM 2.39)

15- CTH CW (RM 2.51)

16- ABANDONED CULVERTS (RM 3.28)

17- PRIVATE WALKING BRIDGE (RM 3.30)

18- PRIVATE CROSSING (RM 3.32)

EAST BRANCH
19- FORD CROSSING (RM 0.05)

EAST BRANCH
20- PRIVATE CROSSING (RM 0.30)

Source: SEWRPC

Map J.1
Stream Crossings Within the Mason Creek Watershed: 2014

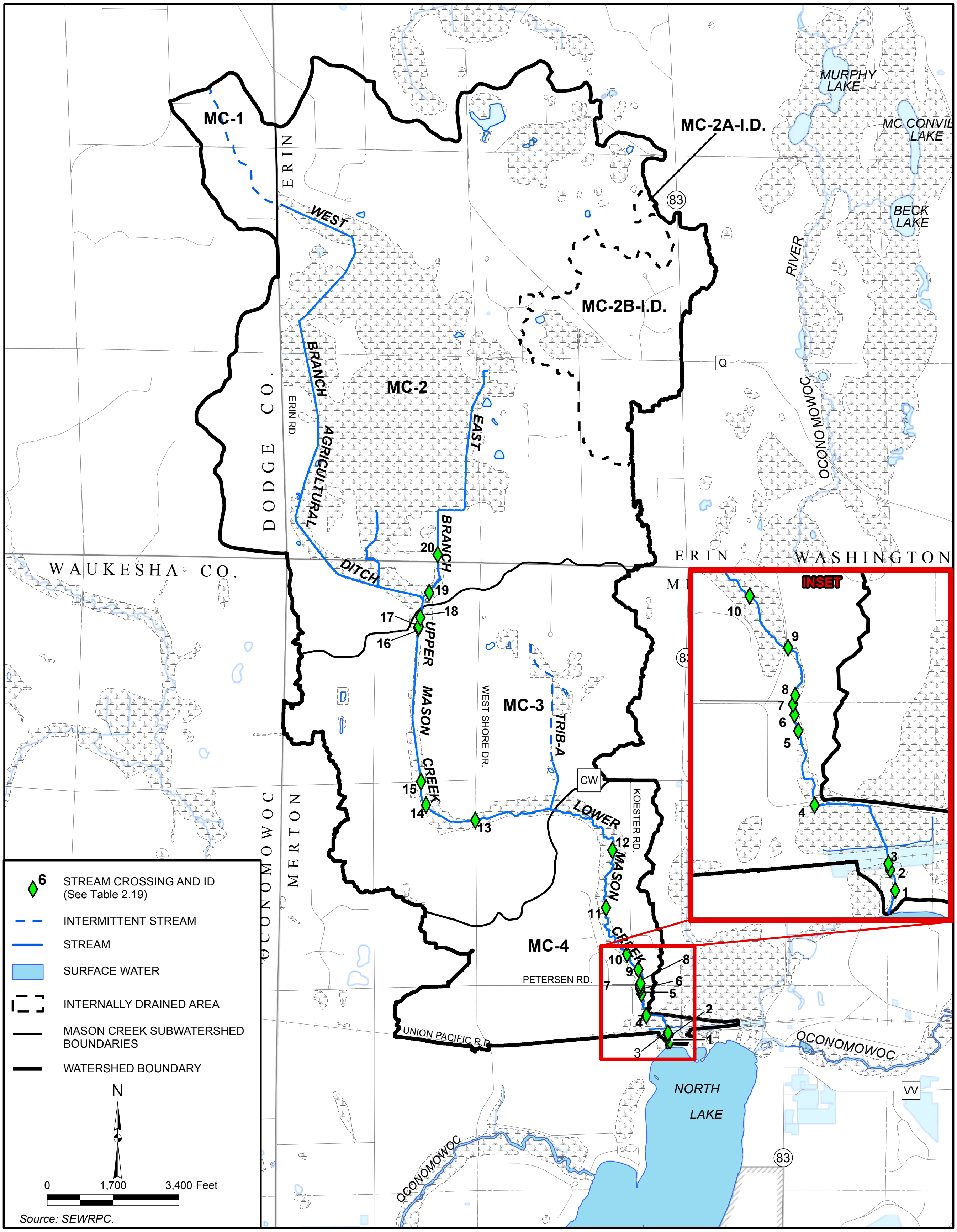

Figure J.2
Comparison of Undersized and Adequately Sized and Placed Culverts

Undersized culvert. Properly sized and placed culverts.

Source: Minnesota Department of Natural Resources

TYPES OF CROSSINGS[1]

- The number of stream crossings should be minimized.
- If a crossing is necessary, structures that maintain to the extent possible the existing streambed and bank conditions are preferable; therefore, bridges spanning streams are preferable to other structures.
- If a culvert is necessary, open bottom structures are preferable to closed bottom structures.
- If a closed bottom culvert is necessary, box culverts, elliptical, or pipe arch culverts are preferable to round pipe culverts, because round pipes generally reduce stream width to a much larger degree than the aforementioned structures, causing long term upstream and downstream passage limitations (see physical considerations below).
- Offsetting Multiple Culverts—If multiple culverts are necessary, it is recommended that the culvert inverts be offset vertically and only one culvert be designed to provide passage during low flow conditions and the additional culverts be used to pass the higher flow events (see Figure J.2 below). Therefore, the low flow culvert will be the only culvert, in a series of two or more culverts, designed to provide fish passage during low flows and shall meet the physical requirements of passage above.

BIOLOGICAL CONSIDERATIONS[2]

- Contact the area WDNR fisheries manager prior to design and construction to minimize impacts.[3]
- Species of fish present (coldwater, warmwater, threatened, endangered, species of special concern).
- Life stages to potentially be impacted (e.g., egg development within substrates should be avoided).
- Migration timing of affected species/ life stages (e.g., adult spawning times should be avoided).

[1] *Department of Fish and Game, Division of Ecological Restoration,* Massachusetts Stream Crossings Handbook*, Editors: Amy Singler, Brian Graber, and Carrie Banks, Writing and design: biodrawversity (www.biodrawversity.com), 2nd Edition, June 2012, www.mass.gov/eea/docs/dfg/der/pdf/stream-crossings-handbook.pdf*

[2] *British Colombia Ministry of Forests,* Fish-stream crossing guidebook*, For. Prac. Br., Min. For., www.for.gov.bc.ca/tasb/legsregs/fpc/FPCGUIDE/Guidetoc.htm, Victoria, B.C. Forest Practices Code of British Columbia guidebook, 2002.*

[3] *UW-Extension and WDNR,* Fish Friendly Culverts*, 2002.*

PHYSICAL CONSIDERATIONS[4]

It is important to note that in order to achieve the minimum physical criteria outlined below, the culvert(s) will need to be oversized as part of the design to ensure adequate long-term fish passage as well as the ability to pass the design period rainfall event.

It is understood that it may not be possible to achieve some of the minimum passage criteria below based upon specific on-site conditions or constraints, however, the closer the designed and completed culvert can meet these criteria the better the long-term passage and overall sustainability of the fishery will be achieved in this region.

Provide Adequate Depth

- Slope—Culvert should be installed with a slope that matches the riffle slope as measured in the thalweg[5] (see Minnesota DNR guidelines)[6]

- Water Depth and Velocity—Water depths and velocities should be comparable to those found in the natural channel at a variety of flows. Depths should maintain the determined thalweg depth at any point within the culvert during low flow periods (see Minnesota DNR guidelines).

- Installation Below Grade—The culvert should be installed so that the bottom of the structure is buried to a depth equal to 1/6th the bankfull width of the stream (up to two feet) below the natural grade line elevation of the stream bottom (see Minnesota DNR guidelines). The culvert should then be filled to stream grade with natural substrates. The substrates should consist of a variety of gravel ranging from one to four inches in diameter and either mixed with nonuniformly laid riprap or uniformly placed alternate riprap baffles, large enough to be stable during the culvert design discharge, which will ensure stability of substrates during high flow events.

Provide Adequate Width and Openness

- Crossing Span (see Massachusetts Stream Crossings Handbook):[7]

    - General—Spans channel width (a minimum of 1.2 times the bankfull with of the stream).

    - Optimum—Spans the streambed and banks (at least 1.3 times the bankfull width) with sufficient capacity to provide dry passage for wildlife (see Figure J.3). Culvert width shall match the bankfull width (minimum) of the existing channel (see Figure J.4).

- Openness (see Massachusetts Stream Crossings Handbook):[8]

    - General—Openness ratio (cross sectional area/crossing length) of at least 0.82 feet. The crossing should be wide and high relative to its length.

    - Optimum—Openness ratio of at least 1.64 feet and minimum height of six feet. If conditions significantly reduce wildlife passage near a crossing (e.g. steep embankments, high traffic volumes, or other physical barriers), maintain a minimum height of eight feet and openness ratio of 2.46 feet.

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[4] *Washington Department of Fish and Wildlife, Habitat and Lands Program, Environmental Engineering Division,* Fish Passage Design at Road Culverts: A Design Manual for Fish Passage at Road Crossings, *Washington, March 3, 1999.*

[5] *The thalweg is the lowest point of the streambed.*

[6] *Minnesota DNR, Best Practices for Meeting DNR General Public Waters Work Permit GP 2004-0001, March 2006.*

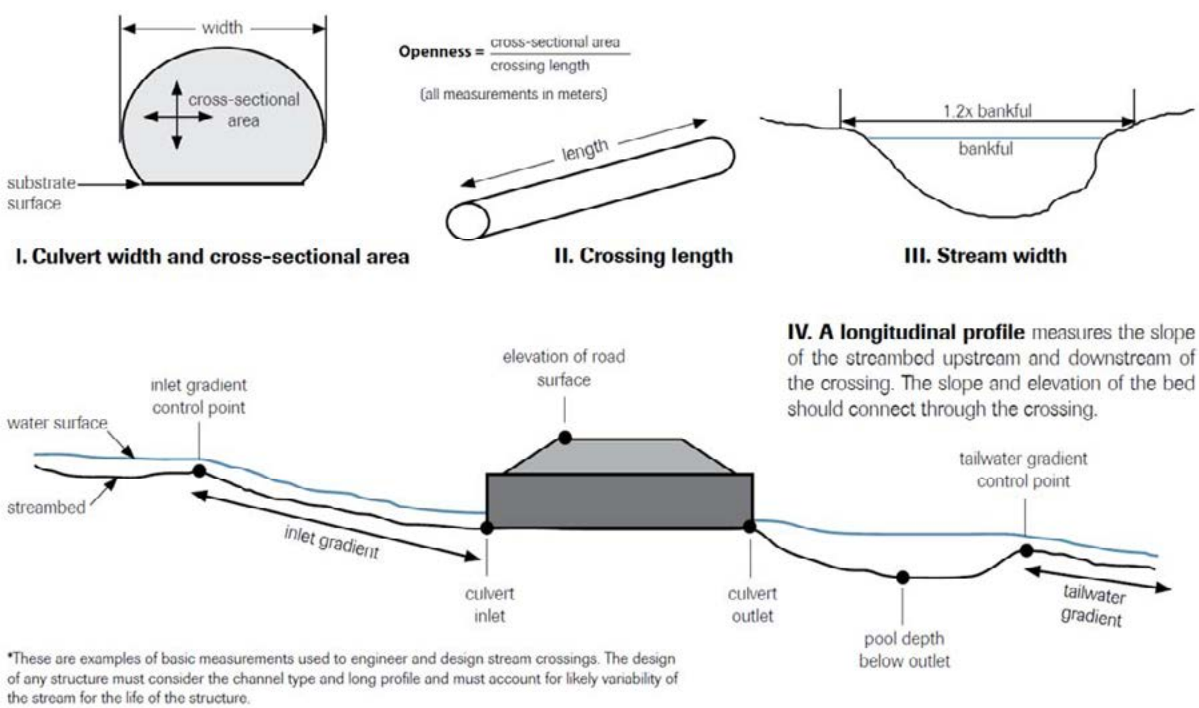
[7] *Department of Fish and Game, Massachusetts Stream Crossings Handbook, June 2012.*

[8] *Ibid.*

Figure J.3
Key Features that Promote Both Fish and Wildlife Passage

Source: Department of Fish and Game, Massachusetts Stream Crossings Handbook, June 2012

Figure J.4
Common Stream Crossing Measurements



Source: Department of Fish and Game, Massachusetts Stream Crossings Handbook, June 2012.

Provide Adequate Resting Areas

- Length—Culverts that exceed more than 75 feet in length need to provide additional resting areas (e.g., installation of baffles or weirs) within the culvert to facilitate passage.[9]

Inlet and Outlet Protection

- Align the culvert with the existing stream alignment (e.g., 90 degree bends at the inlet or outlet should be avoided, even though this will increase culvert length, see Minnesota DNR guidelines).[10]
- The low flow culvert should be centered on the thalweg of the channel to ensure adequate depths inside the culvert.
- Provide grade control where there is potential for head-cuts that could degrade the channel.
- It may be necessary to install riprap protection on the outside bank below the outlet to reduce bank erosion during high flow events.

[9] *Thomas Slawski and Timothy Ehlinger, "Habitat Improvement in Box Culverts: Management in the Dark?," North American Journal of Fisheries Management, Volume 18:676-685, 1998.*

[10] *Minnesota DNR, March 2006 op.cit.*

APPENDIX K

THE ST. CROIXS/RED CEDAR RIVER BASIN: FARMER-LED WATERSHED COUNCIL PROJECT

Source: Julia Olmstead, UW-Extension Watershed Project Coordinator, The St. Croix/Red Cedar River Basin: Farmer-Led Watershed Council Project, UW-River Falls, 123i RDI Building, River Falls, WI 54022, see website for more information at https://datcp.wi.gov/Documents/FLWCP.pdf

The St. Croix/Red Cedar River Basin Farmer-Led Watershed Council Project:

Utilizing Performance-Based Farmer-Led Watershed Councils to Reduce Phosphorus Runoff, Improve Water Quality and Enhance Agricultural Productivity

Project objectives: To improve water quality in the Red Cedar and St. Croix River basins through reduced phosphorus and sediment loading; to increase farmer knowledge about, and engagement with, water quality issues, including the adoption of conservation practices; to develop leadership around water quality among farmers in the selected sub-watersheds; and to develop a unique collaborative model of water quality improvement through farmer engagement that can be replicated in watersheds throughout the Upper Mississippi River Basin and nationwide.

Project approach: Phosphorus (P) pollution reductions and the expansion of farm conservation activities will occur by way of an innovative, farmer-directed conservation incentives program. Four Farmer-Led Watershed Councils are up and running in Pierce, Polk, St. Croix and Dunn Counties. Each council receives an annual pool of funding ($17,000 in 2014, provided by the Minneapolis-based McKnight Foundation), with which they can design a conservation incentives program that achieves water-quality goals. The farmers themselves determine the best paths to conservation success within their watershed, and recruit and encourage other farmers to participate. County Land Conservation Department staff and University of Wisconsin-Extension staff work closely with the farmer councils to provide technical assistance, facilitation, resource information and education, as well as monitor the project's outcomes.

Project partners:

Dunn County Land Conservation Division

Pierce County Land and Water Conservation Department

Polk County Land and Water Resources Department

St. Croix County Land and Water Conservation Department

UW-Extension

Wisconsin DNR

Wisconsin Farmers Union

BACKGROUND

The St. Croix and Red Cedar River Basins, situated in west central Wisconsin, each contain several impaired waterways. The two basins include fourteen total maximum daily load (TMDL) projects The land base in these basins is predominantly agricultural. Farming systems that create excess nutrient and sediment run-off are a primary source of pollution. According to the U.S. Geological Survey, agriculture sources contribute more than seventy percent of the nitrogen (N) and phosphorus (P) pollution to the Gulf of Mexico via the Mississippi Basin.[1] Because these basins drain into the Mississippi River, strategies to decrease agriculture's contribution to nutrient and sediment pollution would have a significant impact on improving water quality in the Upper Mississippi River Basin (UMRB) and further downstream.

"... agriculture sources contribute more than seventy percent of the nitrogen (N) and phosphorus (P) pollution to the Gulf of Mexico via the Mississippi Basin."

There have been many attempts to reduce P and other nonpoint source (NPS) pollutants within these basins, with mixed results. Strategies to-date have largely focused on the development of technical tools for assessment and improvements. However, those strategies have missed the

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human social factors – farmers internalizing the need for better water quality, and making long-term coordinated management decisions based on that internalization – necessary for the widespread diffusion of those tools and sustainable water quality improvements.[2]

The U.S. Environmental Protection Agency recognizes the importance of citizen participation in successful long-term NPS strategies.[3] The lack of progress in meeting NPS reduction goals in the affected basins reinforces the need for innovations to better engage farmers in environmental management. In Iowa, a Farmer-Led Watershed Council model that combines performance-based environmental management with farmer leadership and civic engagement has resulted in significant improvements in the Soil Conditioning Index (SCI) and Phosphorus Index (P index), and has reduced nitrogen use and sediment delivery, all due to participants' management changes.[4] This successful innovation, which has been replicated in several sub-watersheds in northeast Iowa with similar success, serves as the model for our project.

"The lack of progress in meeting NPS reduction goals in the affected basins reinforces the need for innovations to better engage farmers in environmental management."

These Iowa successes have occurred in relatively small watersheds of USGS Hydrological Unit Code (HUC) 12 or similar scale. Farmer councils were developed in each watershed. Iowa State Extension provided technical and financial resources to allow the farmers to determine the best conservation mechanisms for improved water quality. In each watershed, farmers developed a set of performance-based incentives that they encouraged all farmers within the watershed to adopt. The co-development of farmer leadership alongside strong technical support and facilitation has led to wide participation within the watersheds, increased adoption of conservation practices, and long-term commitment to these management strategies by farmers. The projects are all ongoing.

Our project, made up of four pilot sub-watersheds ranging from about 7,000 to 33,000 acres in the St. Croix and Red Cedar River basins, shares the approach with Iowa. Because of existing conservation partnerships developed over years, we have a significant opportunity to observe the effectiveness of this innovation across watersheds, as we are leveraging the technical and financial resources of county, state and non-governmental partners. This is a unique opportunity to improve UMRB water quality and to further develop and promote a model for farmer engagement that can be spread to other watersheds nationwide.

INNOVATIONS

We consider this project innovative for the following reasons:

1. Farmers decide the best paths to water quality and conservation goals, and then conservation partners provide them with the technical resources to get there.

2. The partnership is combining technical conservation practices with civic engagement and farmer-leadership development strategies at a watershed level.

3. The project involves leveraging multi-level and multi-location collaboration, including county conservation departments, university Extension, the WI Department of Natural Resources and non-governmental organizations.

METHODS

The project is based on a model of civic engagement that develops knowledge and creates leadership and action on water quality by farmers. Farmer-Led Watershed Councils now exist in four target sub-watersheds in Pierce, Polk, St. Croix and Dunn Counties. These sub-watersheds were selected because they have both high P-loads as well as a critical number of farmers receptive to leading projects which educate and involve their local farm community in soil conservation and phosphorus runoff reductions.

One of the key innovations of this project is the leading role farmers will play, a strategy based on the successful participatory models of resident-led watershed projects developed by Iowa State Extension and others. The project coordinator (employed by University of Wisconsin-Extension) and the county conservationists will provide technical support, education and facilitation to the farmer councils, as well as a small pool of money, but will not dictate to farmers the best course of action to achieve water quality goals. The councils will decide how best to approach the task of water quality improvement in their watershed. They will have the freedom to select which conservation practices to incentivize, to create monitoring and evaluation plans, and to devise outreach strategies that are tailored to the particulars of their watersheds. In this way, farmers in the councils will become not only conservation leaders within their watersheds, but also strong advocates for the adoption of conservation practices and resources in their farm communities. This type of participatory approach has achieved sustained reductions in P and other water pollutants.

This project combines the considerable strengths of the partners with current watershed management TMDL goals in a groundbreaking collaborative. Conceptually, it draws from research and resources on civic engagement from the University of Minnesota, Iowa State University's sociological work on farmer-led, performance-based watershed projects, and the concept of landscape disproportionality analysis from the University of Wisconsin.[5] Project partners have created a local- and county-led watershed management implementation project partnership within the Red Cedar and St. Croix River (WI portion) Basins. Because of the reach of the many partners involved in this collaboration, it anticipates an increasing adoption of both the participatory model as well as the conservation practices themselves beyond the pilot watersheds and throughout the river basins.

Specifically, our methods are as follows:

Objective 1: Developing farmer-led councils in four pilot watersheds. The project coordinator from UW-Extension and staff from the Land Conservation Department offices in each of the four counties that contain the watersheds are working closely to facilitate and develop the farmer-led councils. Farmer councils have been meeting regularly since February 2013.

Project Personnel

DUNN COUNTY:

Dan Prestebak, Conservationist; Amanda Hanson, Conservation Planner

PIERCE COUNTY:

Rod Webb, Conservationist

POLK COUNTY:

Tim Ritten, Conservationist; Eric Wojchik, Conservation Planner

ST. CROIX COUNTY:

Bob Heise, Conservationist; Kyle Kulow, Conservation Planner

UW-EXTENSION:

Julia Olmstead, Outreach Specialist/ Project Coordinator; Paul Kivlin, Nutrient Management Specialist

Objective 2: Phosphorus-loading inventories in each watershed. To measure our progress, as well as for the farmer council to target the biggest P contributors, county conservation staff and UW-Extension nutrient management specialists will work with farmers to do P indexing on as many fields as possible within the watershed. The P Index assigns a number – 0, 1, 2, 4, 8 or 16 – to each of the conditions which can affect phosphorus losses, where 0 is the lowest P loss potential and 16 is the highest P loss potential. This is completed according to the probability of P loss from the site. Council members will take the lead to encourage non-participating or hesitant farmers to get involved.

Objective 3: Measurable reductions in phosphorus runoff. Several of the incentives we suggest to the farmer councils will result in P pollution reductions, including improved manure management, grass waterways, cover crops and grid sampling for precision agriculture methods. We will be able to track these reductions via annual P index assessments as well as by leveraging already existing edge-of-field water monitoring sites that are located in each watershed. We will also encourage farmers to target conservation activities to the heaviest contributors to P loading within the watersheds.

Objective 4: Increased adoption of conservation practices by farmers within the watershed. The farmer councils will determine which conservation practices are most useful and attractive to farmers within the watershed. They will create an incentives program before the start of the growing season, which will offer small amounts of compensation for farmers to adopt conservation practices. Farmers will be able to choose from a suite of incentive options the council has put together, which can include, but is not limited to: cover crop trials, corn stalk nitrate testing, nutrient management planning, manure spreader calibration, grass waterways, phosphorus indexing, grid sampling and bioreactors. A key component of the project model is the leadership taken by farmers in influencing each other. The council farmers will play a lead role in encouraging other farmers to become involved, using field days, mailings to other farmers, and one-on-one conversations.

Funding:

Staffing time: WI DNR provides funding for the project coordinator's position via UW-Extension, and supports ¼ staff time in each county LCD via a Lakes Grant (this is matched by the county for ½ FTE toward project).

Conservation incentives: The McKnight Foundation (a private, Minneapolis-based foundation) has provided a two-year grant of $100,000 total for the councils.

[1]Alexander, Richard B., Richard A. Smith, Gregory E. Schwarz, Elizabeth W. Boyer, Jacqueline V. Nolan and John W. Brakebill. 2008. "Differences in Phosphorus and Nitrogen Delivery to the Gulf of Mexico from the Mississippi River Basin." *Environmental Science & Technology* 42(3):822-830

[2]Morton, Lois Wright and Chich Yuan Weng. 2009. "Getting to Better Water Quality Outcomes: The Promise and Challenge of the Citizen Effect." *Agriculture and Human Values* 26(1):83-94

[3]U.S. EPA. 2008. *Handbook for Developing Watershed Plans to Restore and Protect Our Waters.* USEPA. Office of Water Nonpoint Source Control Branch. EPA 841-B-050005

[4]Morton, Lois Wright and Jean McGuire. 2011. "Getting to Performance-Based Outcomes at the Watershed Level" in *Pathways for Getting to Better Water Quality: The Citizen Effect* edited by L.L.W. Morton and S.S. Brown. New York: Springer.

[5]Nowak, Pete, Sarah Bowen, and Perry E. Cabot. 2006. "Disproportionality as a Framework for Linking Social and Biophysical Systems." *Society and Natural Resources* 19:153-173

Farmer-Led WATERSHED COUNCIL

For More Information:

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