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Green Lake Section 319 Small Watersheds Focus Program Nine Element Plan

MINNESOTA POLLUTION CONTROL AGENCY

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Photo credit: Perleberg 2006

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Executive summary

Green Lake is the largest lake in Isanti County and it is a priority area to the local residents because of its high recreational value. The Green Lake Watershed is a 12-digit Hydrologic Unit Code (HUC12) watershed (070102070503) in the Rum River HUC8 watershed (07010207). Its drainage area is approximately 25 square miles (15,988 acres) and includes the North Brook and Wyanett Creek subwatersheds along with the "local watershed" consisting of the direct lakeshed and the drainage areas to Bratlin Creek and Old Judge's Ditch.

The Green Lake Watershed was chosen by our partners because of the many plans and reports that help with targeting, specifically Green Lake has completed subwatershed assessments (SWA), called *The Green Lake Subwatershed Retrofit Analysis for Areas Draining Directly to the Lake* and *The Green Lake Rural Stormwater Retrofit Analysis of North Brook and Wayanett Creek*. The SWAs provide detailed information needed to target and prioritize projects and BMPs. Targeting of the critical loading sites identified by the SWAs will be the most effective and cost-efficient way to achieve the water quality standards for Green Lake. The goal of the Green Lake watershed partners is to delist Green Lake from the Minnesota 303(d) impaired waters list. Green Lake is listed for mercury and polychlorinated biphenyls (PCB) in fish tissue, fish index of biotic integrity (FIBI), and nutrients/eutrophication. The BMPs and projects chosen and described in this plan will outline the process to achieve their goals. It is expected that practices in this plan will yield reductions in P loading and increase habitat quality to achieve water quality standards for P and FIBI in ten years.

This plan will be updated every two years to add additional milestones and activities by utilizing the evaluation of BMPs and effectiveness monitoring to determine water quality impacts. Watershed partners will systematically identify which practices are working the best and which ones are not, and then using this information make course corrections as needed.

The Minnesota statewide mercury TMDL addresses mercury reductions in fish tissue. Atmospheric deposition of mercury goes beyond the borders of both Minnesota and the U.S., making it extremely difficult to manage. Both the mercury and PCB in fish tissue are old listings, dating back to the 1990s. It is possible that these two impairments may have improved without further action. Testing fish tissue in the future may show that some or both of these impairments have resolved.

Introduction

The Green Lake Section 319 Small Watershed Focus Program Nine Element (NKE) Plan was developed by compiling and synthesizing information from previous studies and planning documents conducted in the watershed. Much of the text and concepts in this NKE are derived from the various existing studies and plans in the watershed. Additional information is provided when necessary to address all of the U.S. Environmental Protection Agency's (EPA) nine key elements of a watershed-based plan. Key documents include:

- Green Lake Improvement District Lake Management Plan, 2013-2018, 2012
- Green Lake Monitoring Report, 2018
- Green Lake Tributary Monitoring Report, 2018
- Green Lake Phosphorus Diagnostic Study Technical Memo, 2019
- Final Rum River Watershed Total Maximum Daily Load, 2017
- Rum River Watershed Fish Based Lake IBI Stressor Identification Report, 2016
- Rum River Watershed Monitoring and Assessment Report, 2016
- Rum River Watershed Restoration and Protection Strategy Report, 2017
- Groundwater Report: Rum River Watershed, 2016

1.1 EPA nine elements

The intent of the Green Lake NKE is to concisely address the nine elements identified in EPA's Handbook for Developing Watershed Plans to Restore and Protect our Waters (EPA 2008 are critical to preparing effective watershed plans to address nonpoint source pollution. EPA emphasizes the use of watershed-based plans containing the nine elements in Section 319 watershed projects in its guidelines for the Clean Water Act Section 319 program and grants (EPA 2013). The nine elements are listed in Table 1 along with the section of this report in which each element can be found.

Table 1. Nine elements and associated report section(s)

Section 319 Nine Elements	Applicable Report Section
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.	Section 4.0
An estimate of the load reductions expected from management measures.	Section 7.0
A description of the nonpoint source management measures that will need to be implemented to achieve load reductions in element b, and a description of the critical areas in which those measures will be needed to implement this plan.	Section 7.0
An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.	Section 7.0 and 10
An information and education component used to enhance public understanding of the project and encourage the public's early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.	Section 8.0
Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.	Section 7.0

Section 319 Nine Elements	Applicable Report Section
A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.	Section 7.0
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.	Section 7.0
A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item h immediately above.	Section 9.0

1.2 Nonpoint source (NPS) pollution management

Numerous nonpoint pollution management activities and planning efforts have been and are being conducted in the Green Lake NKE project area. The Green Lake Improvement District Lake Management Plan (Green Lake Improvement District 2012) identified priority issues for the lake and specific objectives and actions to address those priority issues Table 2. Following recommendations from the lake management plan, a subwatershed retrofit analysis was conducted for a portion of the Green Lake watershed. The Green Lake Subwatershed Retrofit Analysis (Isanti SWCD 2014) identified potential stormwater retrofitting opportunities to reduce the amount of nutrients from stormwater runoff entering Green Lake. A variety of project types were identified in the analysis. These efforts resulted in extensive education and outreach, monitoring, and project implementation activities in the Green Lake Watershed.

Table 2. Priority issues from the Green Lake Improvement District Lake Management Plan

Priority Issue	Objectives
Water Quality	Maintain intact shoreline buffers and re-vegetate areas of erosion into Green Lake Show a positive trend in trophic status of Green Lake Manage subsurface sewage treatment systems
Aquatic Invasive Species	Users of public access points to Green Lake understand the urgency of aquatic invasive species prevention and have tools to ensure they do not introduce any Management of current aquatic invasive species in Green Lake
Land Management/Zoning	Property owners and users of Green Lake understand potential impacts of their land use and boating activities on lake
Fisheries	Work with DNR to preserve the habitat and support the fishery of lake

A TMDL for Green Lake was completed in 2017 as part of the Final Rum River Watershed Total Maximum Daily Load (MPCA 2017). General restoration strategies for the lake were included in the Rum River Watershed Restoration and Protection Strategy Report (MPCA 2017). The *Green Lake Phosphorus Diagnostic Study* (Wenck 2019) was recently completed by incorporating more recent data in the development of an updated phosphorus budget for the lake and watershed. The diagnostic study included management recommendations to achieve the phosphorus reductions needed to meet the water quality goal for the lake.

1.3 Watershed partners

Several agencies and organizations have been active in one or more watershed management-related activities in the Green Lake Watershed. These entities form the basis of the watershed management team for the Green Lake NKE. A list of these with a brief description of their involvement is given in Table 3.

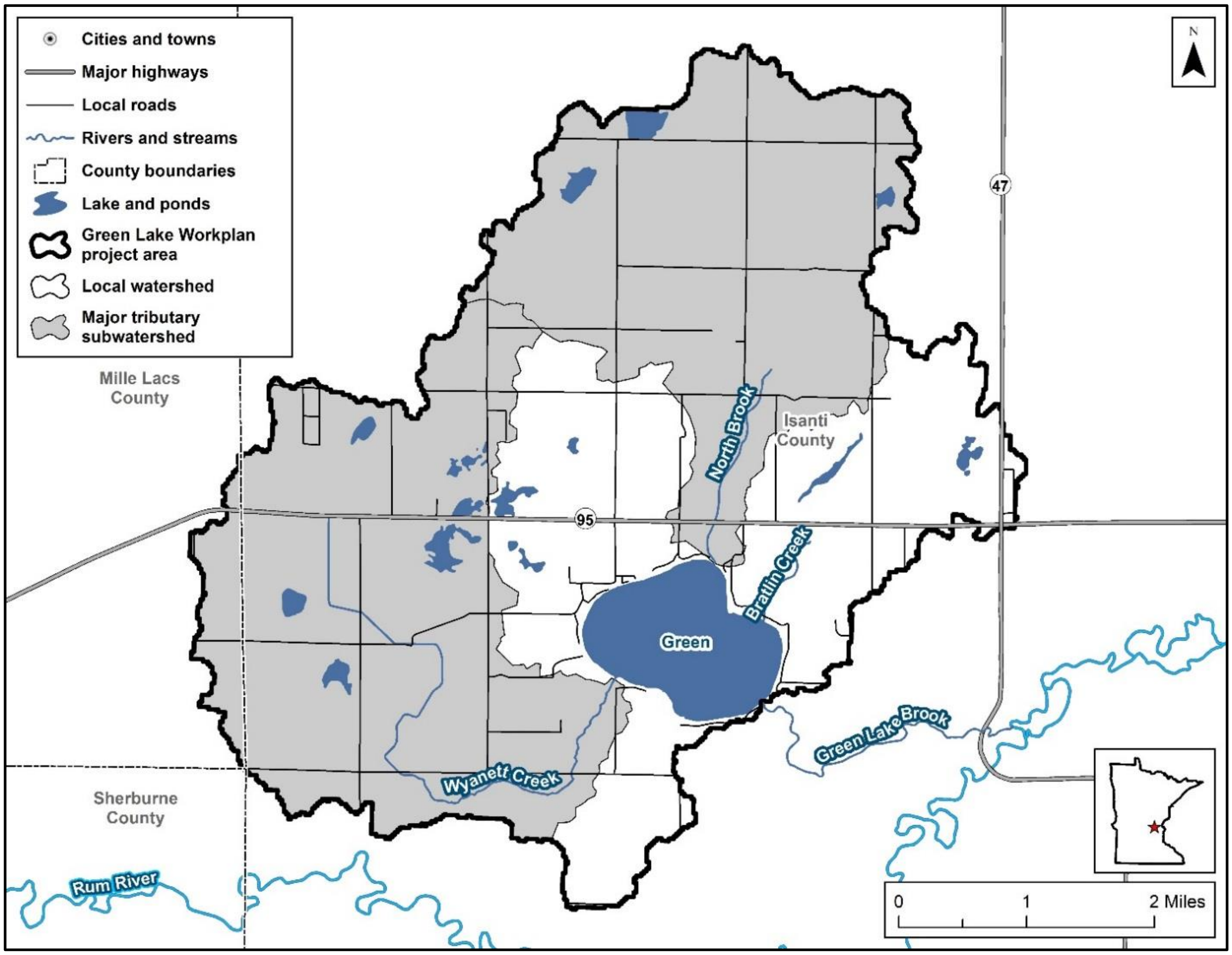
Table 3. Agencies and organizations participating in watershed activities in the Green Lake Watershed

Entity	Description of Activities
Isanti Soil and Water Conservation District	Provide financial and technical assistance to landowners in order to implement conservation projects. Coordinate with partners to improve water quality.
Isanti County Zoning	Enforce wetland, shoreline, and SSTS ordinances. Coordinate AIS program.
Isanti County Ditch Authority	Manage 103E Ditches, coordinate with SWCD and Zoning to include conservation drainage management practices are included in management of ditches.
Green Lake Improvement District	Work with lakeshore owners to implement shoreline restoration program, coordinate with local and state agencies to manage lake health, collect water quality data.
The Nature Conservancy	Provide assistance for water quality protection.
Rum River Watershed 1W1P Partners	Coordinate watershed management priorities and funding.
Wyanett Township	Manage Township roads, manage the Feldspar public lake access and work with other government units to assist with water management.
Spencerbrook Township	Manage Township roads, work with other government units to assist with water management.
USDA – NRCS	Provide financial and technical assistance to implement agricultural conservation practices.
Minnesota Department of Natural Resources	Issue public waters permits and aquatic plant management permits. Manage fish resources, the state public lake access, and North Brook Aquatic Management Area.
Minnesota Pollution Control Agency (MPCA)	Provide funding assistance to implement conservation practices.
Minnesota Department of Agriculture	Implement the Minnesota Agricultural Water Quality Certification Program which helps producers implement practices to improve water quality.
Volunteer Water Monitors	Collect water quality data.
Private Landowners	Implement conservation practices to improve water quality. Influence other landowners to do similar work.

2. Watershed description

The Green Lake Watershed is located in west-central Isanti County, approximately 6.8 miles east of Princeton (Figure 1). The watershed area is approximately 15,988 acres (about 25 square miles). For the purposes of this NKE, the subwatersheds to North Brook and Wyanett Creek are considered “major tributary subwatersheds” and the remaining project area is considered the “local watershed” and includes the drainage areas of Bratlin Creek and Old Judge’s Ditch.

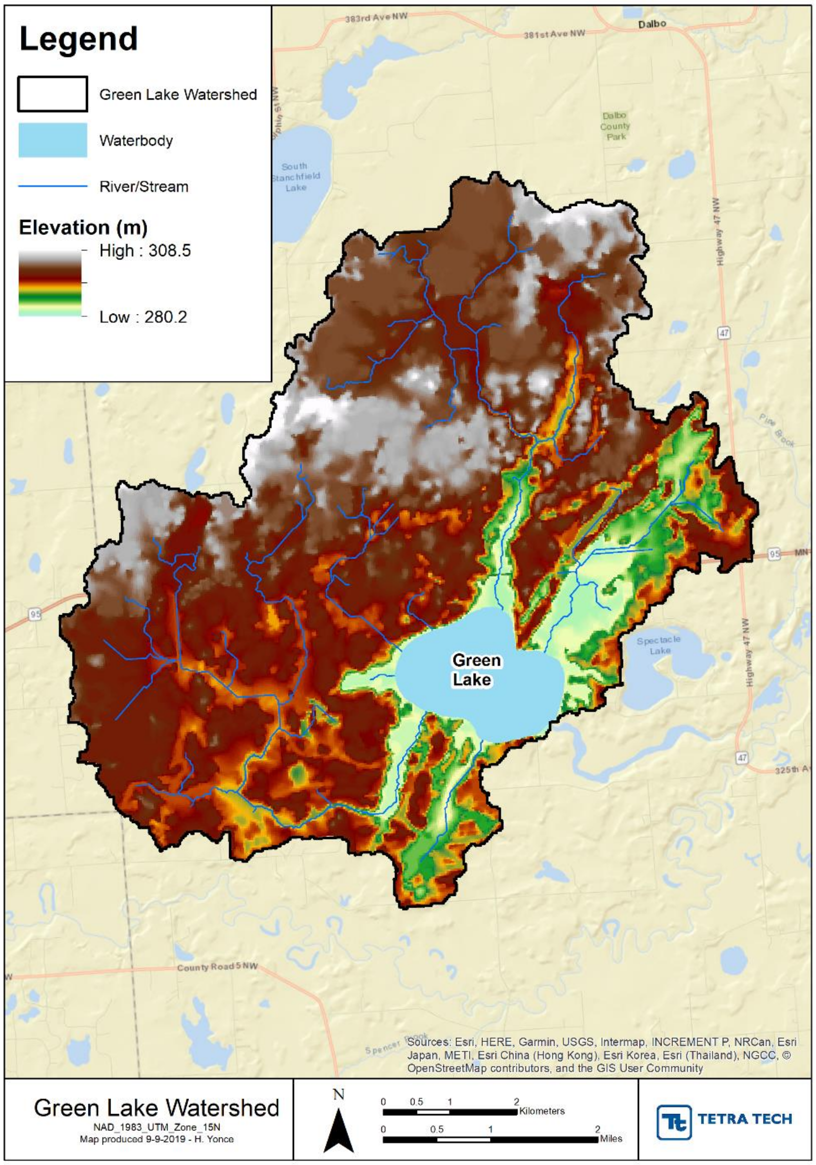
Figure 1. Green Lake Watershed



2.1 Topography and drainage

The Green Lake Watershed (HUC12 070102070503) is located in the south-central portion of the Rum River Watershed (Middle Rum River HUC10 0701020705), which flows from Mille Lacs Lake to the Mississippi River in Anoka, Minnesota. Green Lake receives water via precipitation, overland flow, and several tributaries. The main inlets to Green Lake are Wyanett Creek, North Brook, and Bratlin Creek (Figure 1). Old Judge’s Ditch located on the western side of Green Lake near 335th Avenue also discharges to the lake. Green Lake Brook is the outlet to Green Lake and sends water to the Rum River (Green Lake Improvement District 2012). During extreme spring water levels, Green Brook flow can reverse into Green Lake from downstream (DNR Lake Files; via Perleberg 2006). The elevation of the watershed ranges from 918.6 – 1,121 feet (280.2 – 308.5 meters) above sea level (Figure 2).

Figure 2. Topography of the Green Lake Watershed

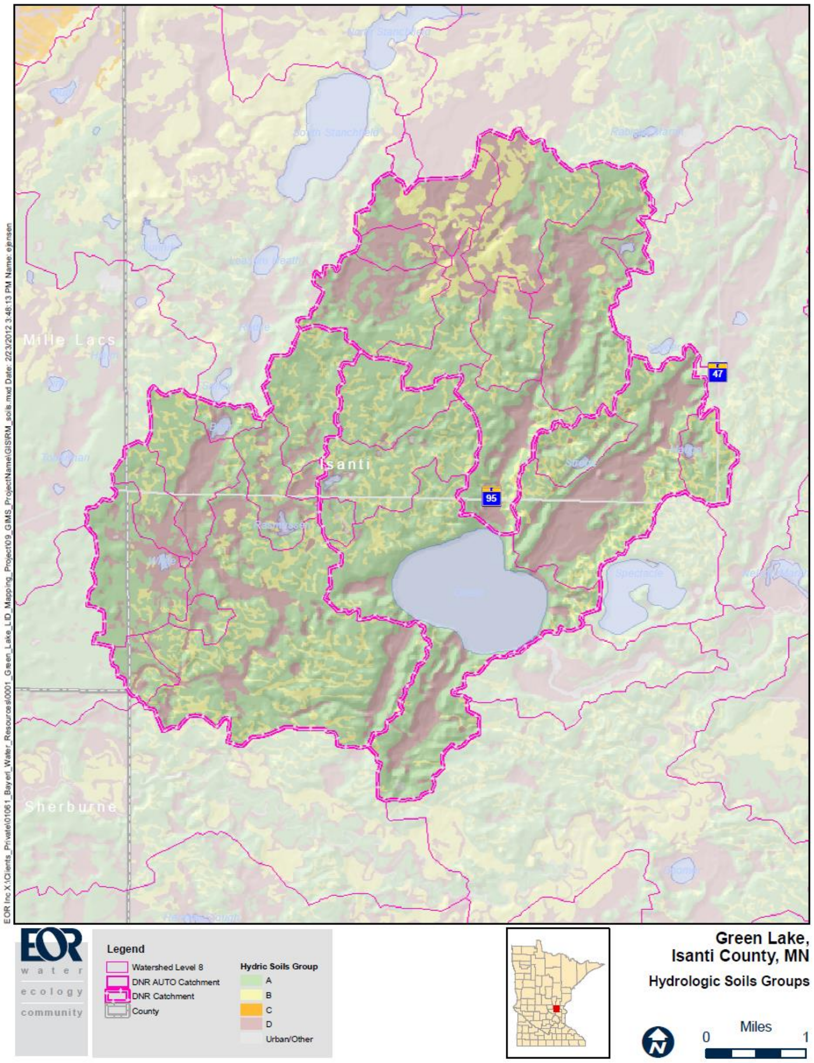


2.2 Geology and soils

Green Lake is situated in the North Central Hardwood Forests ecoregion in the Anoka Sand Plain, an outwash plain characterized by thin layers of sand and silt with numerous bogs and depressions (Borgstrom 2016). The geology of the watershed is dominated by sand and gravel glacial sediments overlying Precambrian sandstone, siltstone and conglomerate and Paleozoic sandstone, siltstone and shale.

Soils can be classified according to the hydrologic soil group that describes in part the runoff potential and infiltration properties of the soil. Hydrologic soil group classifications across the watershed are largely classified as A (low runoff potential, high infiltration rates), with a smaller amount of D soils (high runoff potential, low infiltration rates), and in the furthest north part of the watershed some B soils (moderate infiltration) (Figure 3).

Figure 3. Hydrologic soil groups in the Green Lake Watershed (EOR 2012)



2.3 Waterbodies

Green Lake (30-0136-00) is the largest lake in Isanti County, Minnesota. The waterbody covers approximately 833 acres with a littoral area of 357 acres and a shore length of 4.61 miles. The maximum lake depth is 28 feet, the mean depth is about 16 feet, and the lake is classified as a “deep lake” for management and regulatory purposes. The lake is a general elliptical shape from the northwest to southeast, which provides a long wind fetch. The drainage area to the lake is large with a watershed to lake-surface area ratio of about 19:1.

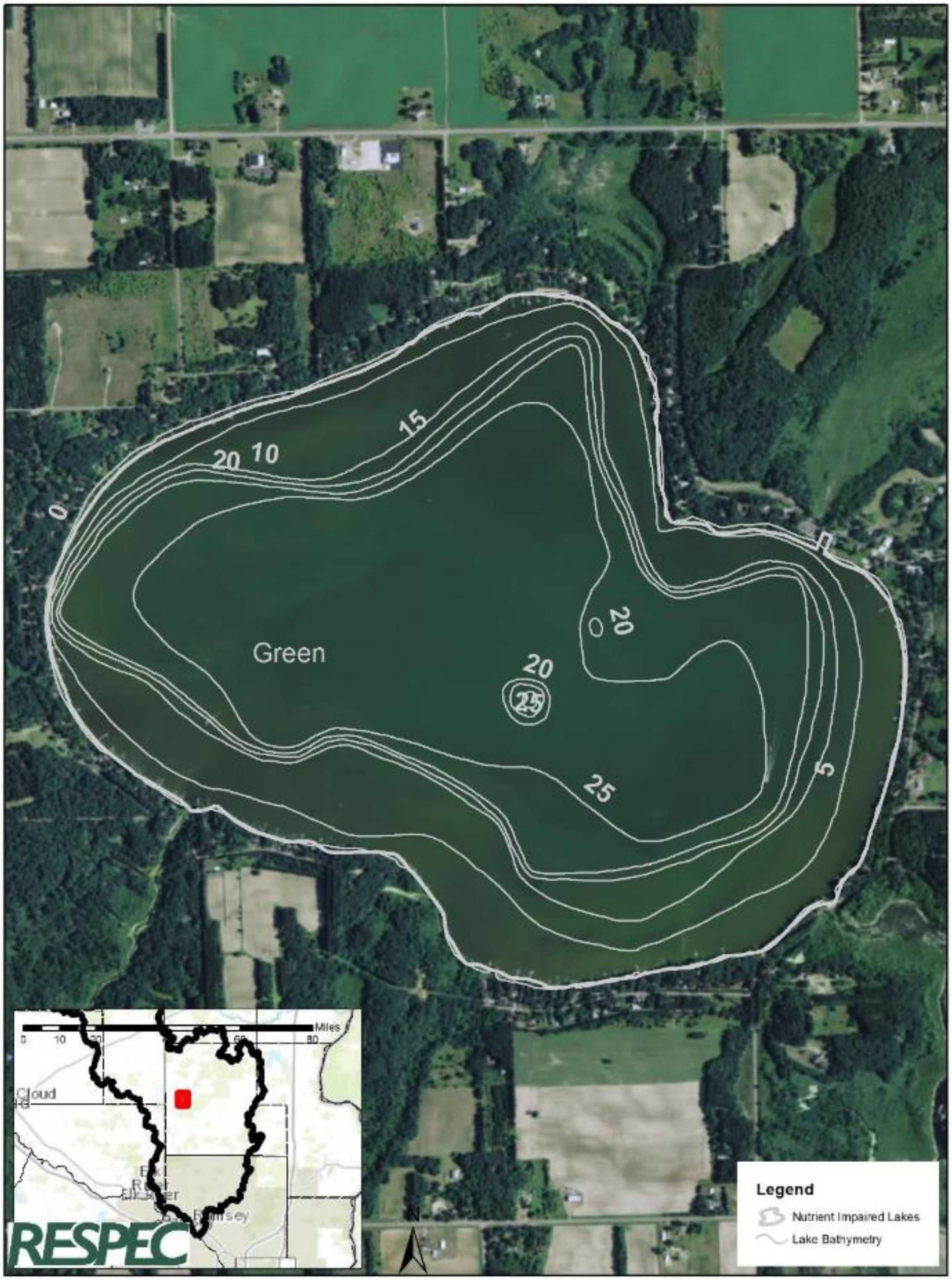
Green Lake has one public access maintained by the DNR on the northern side of the waterbody. Green Lake has an Osgood Index Value of 2.7, suggesting that periodic mixing occurs due to its surface area, fetch, and depth structure (MPCA 2017). Additional physical characteristics of Green Lake are provided in Table 4. A map of Lake Bathymetry is provided in Figure 4. The outlet of Green Lake is Green Lake Brook.

There are four named tributaries that drain into Green Lake: North Brook, Wyanett Creek, Bratlin Creek, and Old Judge’s Ditch. North Brook and Wyanett Creek are the largest tributaries. Two smaller tributaries are Old Judge's Ditch that flows into the western side of the lake, and Bratlin Creek that flows north to south into the eastern side of the lake, east of North Brook.

Table 4. Green Lake Select Morphometric and Watershed Characteristics (MPCA 2017)

Characteristics	Green Lake	Source
Lake-Surface Area (acres)	833	DNR LakeFinder
Number of Islands	0	
Percent Lake Littoral Surface Area	43%	DNR LakeFinder
Drainage Area, Including Lake acres(ac)/square kilometers(km2)	15,887ac/64.3 km2	Model Subwatersheds
Watershed Area to Lake Area Ratio	19.1:1	Calculated
Wetland Area (% of watershed)	21.7	University of Minnesota (2016]
Number of Upland Lakes	Numerous small	U.S. Geological Survey topographic maps
Number of Perennial Inlet Streams	2	U.S. Geological Survey topographic maps
Lake Volume (acre-feet (ac-ft)/cubic hectometers(hm3))	13,499ac-fl/ 16.7 hm^3	DNR LakeFinder
Mean Depth (ft/ m)	16.2 ft/4.9 m	DNR LakeFinder
Annual Lake-Level Fluctuations (ft): typical, maximum	1-4+ ft	DNR Lake Levels
Maximum Depth (ft/m)	28 ft/ 8.5 m	DNR LakeFinder
Maximum Fetch Length (miles(mi)/ Kilometers (km))	1.57mi/2.53km	Measured in Google Earth
Lake Geometry Ratio	5.0	Calculated
Osgood Index	2.7	Calculated
Estimated Water Residence Time (years)	1.4 years	Calculated
Public Access	1	DNR
Shore Land Properties	164	Isanti County
DNR Fisheries Class	27	DNR

Figure 4. Green Lake Bathymetry (MPCA 2017)



2.4 Aquatic habitat and wetlands

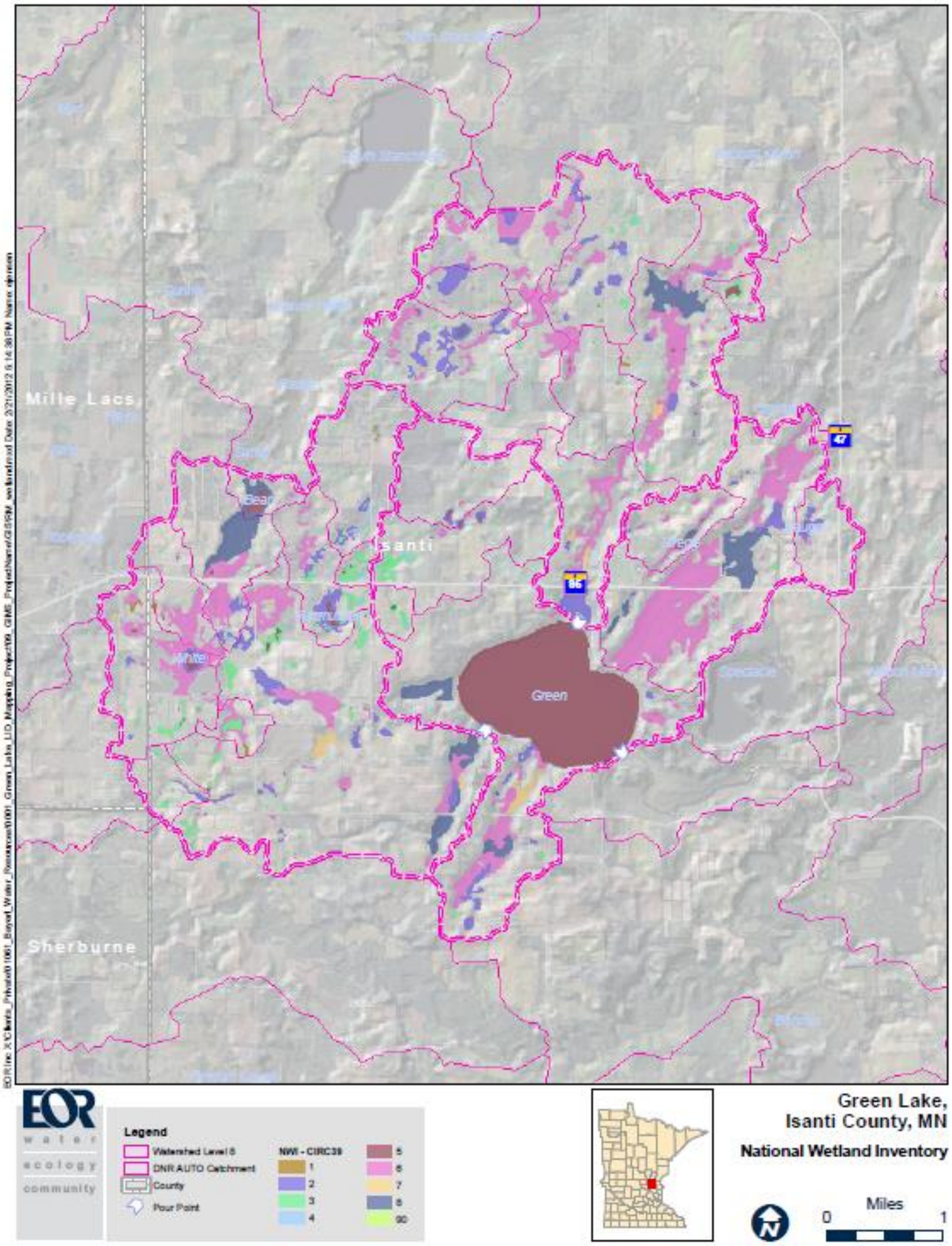
Green Lake is a designated infested water for aquatic invasive species. Curlyleaf pondweed was first noted in a 1971 survey of the lake. Eurasian watermilfoil was found in the lake in 2000. Both species were found during the lake stressor identification process (Borgstrom 2016).

There are numerous wetland complexes within the contributing watershed ranging in size from 10 – 45 acres with many smaller wetlands and those associated with flowing waters (Borgstrom 2016, Figure 5). Approximately 21.7% of the contributing area is classified as wetlands based on the land use raster NLCD 2011. Descriptions of the National Wetland Inventory (NWI) wetland types located in the project area are provided in Table 5.

Table 5. Descriptions of the NWI wetland types in the Green Lake NKE project area

NWI wetland type	Description
1	Seasonally flooded basin or flat. Soil is covered with water or is waterlogged during variable seasonal periods but usually is well-drained during much of the growing season. Vegetation varies greatly according to season and duration of flooding: from bottomland hardwoods to herbaceous plants.
2	Wet meadow. Soil is usually without standing water during most of the growing season but is waterlogged within at least a few inches of the surface. Meadows may fill shallow basins, sloughs, or farmland sags, or these meadows may border shallow marshes on the landward side. Vegetation includes grasses, sedges, rushes and various broad-leaved plants. Other wetland plant community types include low prairies, sedge meadows and calcareous fens.
3	Shallow marsh. Soil is usually waterlogged early during the growing season and may often be covered with as much as 6 inches or more of water. These marshes may nearly fill shallow lake basins or sloughs, or may border deep marshes on the landward side. These are common as seep areas on irrigated lands. Vegetation includes grass, bulrush, spikerush and various other marsh plants such as cattail, arrowhead, pickerelweed and smartweed.
4	Deep marsh. Soil is usually covered with 6 inches to 3 feet or more of water during the growing season. They completely fill shallow lake basins, potholes, limestone sinks and sloughs, or they may border open water in such depressions. Vegetation includes cattail, reed, bulrush, spikerush and wild rice. In open areas, pondweed, naiad, coontail, water-milfoil, waterweed, duckweed, waterlily or spatterdock may occur.
5	Shallow open water. Shallow ponds and reservoirs are included in this type. Water is usually less than 10 feet deep and fringed by a border of emergent vegetation.
6	Shrub swamp. Soil is usually waterlogged during the growing season and is often covered with as much as 6 inches of water. These occur mostly along sluggish streams and occasionally on flood plains. Vegetation includes alder, willow, buttonbush, dogwood and swamp-privet.
7	Wooded swamps. Soil is waterlogged at least to within a few inches of the surface during the growing season and is often covered with as much as 1' of water. These occur mostly along sluggish streams, on old riverine oxbows, on flat uplands and in ancient lake basins. Forest vegetation includes tamarack, arborvitae, black spruce, balsam fir, red maple and black ash. Deciduous swamps frequently support beds of duckweed and smartweed. Other wetland plant community types include lowland hardwood swamps and coniferous swamps.
8	Bogs. Soil is usually waterlogged. These occur mostly in ancient lake basins, on flat uplands and along sluggish streams. Vegetation is woody or herbaceous or both, usually on a spongy covering of mosses. Typical plants are heath shrub, sphagnum moss and sedge. In the North, leatherleaf, Labrador tea, cranberry and cottongrass are often present. Scattered, often stunted, black spruce and tamarack may occur.
90	Riverine systems

Figure 5. Wetlands in the Green Lake Watershed (EOR 2012)



North Brook Aquatic Management Area

According to [Minn. Stat. 86A.05, subd. 14](), "aquatic management areas may be established to protect, develop, and manage lakes, rivers, streams, and adjacent wetlands and lands that are critical for fish and other aquatic life, for water quality, and for their intrinsic biological value, public fishing, or other compatible outdoor recreational uses."

The North Brook Aquatic Management Area is approximately 19 acres and is located along North Brook (Figure 6). It provides angler and management access, protection of critical shore land habitat, and an area for education and research. General usage activities include angling, non-motorized travel, wildlife observation, hunting, and trapping.

Figure 6. North Brook Aquatic Management Area (Image from Minnesota DNR AMA webpage)

Shoreline assessment

An assessment of Green Lake's shoreline development and disturbance was conducted in June 2013 (Borgstrom 2016). Following the lakeshore assessment, Score the Shore survey protocols were used and resulted in a mean score of 55.7 (range is 0 to 100). The survey score is comprised of scores for three zones: shoreland, shoreline, and aquatic (Table 6). About 89% of the Score the Shore survey sites are classified as developed, which contributed to the low score for Green Lake as a whole (Table 7). During the survey, 32% of sites had woody habitat but there was not any emergent vegetation. Most of the undeveloped shoreline is associated with a single large parcel of land held by one owner.

Table 6. Breakdown of how each of the three zones (shoreland, shoreline, aquatic) on Green Lake scored utilizing the Score the Shore survey and a categorical interpretation (excellent, good, fair, poor) of that score (Borgstrom 2016).

Zone	Sample size	Mean zone habitat score (0-33.3)	Rating
Shoreland	37	16.2	Poor
Shoreline	37	14.4	Poor
Aquatic	37	25.1	Good

Table 7. Score the Shore survey scores overall as well as for developed and undeveloped sites on Green Lake and categorical interpretation (excellent, good, fair, poor) of that score (Borgstrom, 2016)

Broad land use classification	Sample size	Mean lakeshore habitat score (0-100)	Rating
All sites	37	55.7	Poor
Developed	33	50.6	Poor
Underdeveloped	4	98.3	Excellent

The *Green Lake Subwatershed Retrofit Analysis for Areas Draining Directly to the Lake* (Isanti SWCD 2015) describes the lakeshore of Green Lake as mostly intensely managed by homeowners. Lawn mowing to the water's edge, sand beaches, beach raking, and aquatic vegetation removal are commonplace. Rock riprap and retaining walls are present in some areas. The analysis still found that much of the lakeshore is a candidate for lakeshore restorations (44% of the lakeshore and 95 potential sites). In addition, the Lake Improvement District has identified lakeshore restorations as a priority in its lake management plan.

2.5 Groundwater

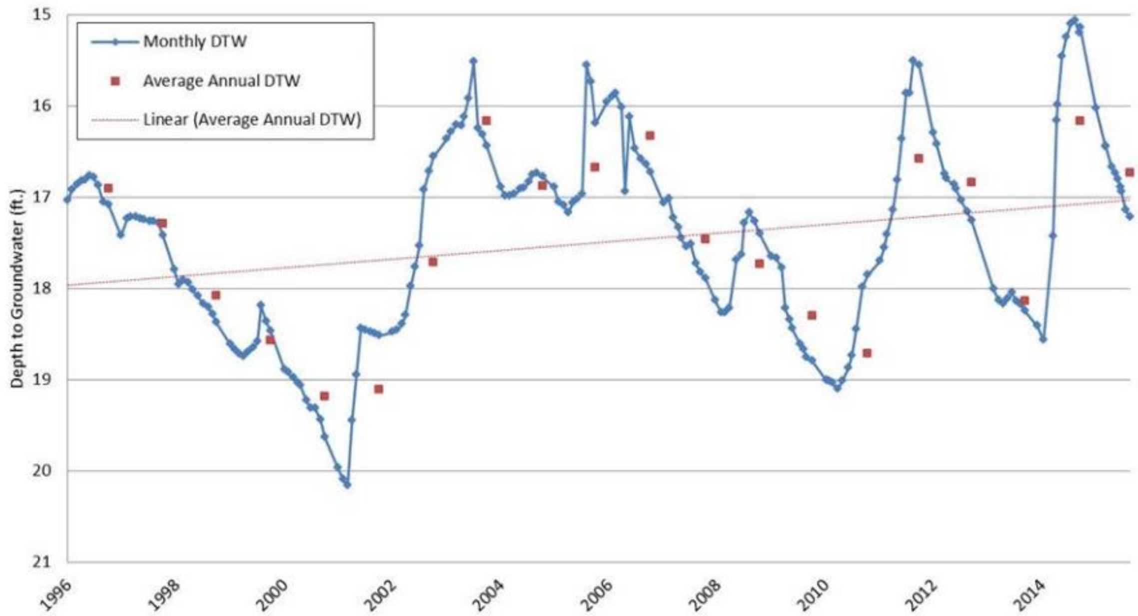
The Green Lake region is underlain by the Metro Province Groundwater District. This groundwater district is characterized by "sand aquifers in generally thick (greater than 100 feet) sandy and clayey glacial drift overlying Precambrian sandstone and Paleozoic sandstone, limestone, and dolostone aquifers".

The Metro Province contains surficial and buried aquifers: the St. Peter aquifer, Prairie du Chien-Jordan, Franconia Ironton-Galesville and Mt. Simon-Hinckley aquifers. Glacial sand and gravel aquifers are shallow and occur as result of glacial influences, and they are found in outwash plains, along river and in old lakebeds throughout the state.

The buried sand and gravel aquifers include the Quaternary Buried Artesian Aquifer (QBAA), the Quaternary Buried Unconfined Aquifer, and the Quaternary Buried Undifferentiated Aquifer. It is from these aquifers that the majority of wells in this region of Minnesota yield the greatest amount of groundwater (MPCA 1998). Other important sources of groundwater are the surficial sand and gravel aquifers, which consist of well-sorted outwash deposits. Two main aquifers included in this category are the Quaternary Water Table Aquifer (QWTA) and the Quaternary Undifferentiated Unconfined Aquifer. In the Rum River watershed, the QWTA and QBAA aquifers are the primary Quaternary sources for groundwater withdrawal. The Rum River Groundwater Report details depth to groundwater at well 30005 near Green Lake (Figure 7).

DTW = Depth to water

Figure 7. Depth to groundwater for observation well 30005 near Princeton and Green Lake 1996-2005 (MPCA 2016a).



2.6 Land use

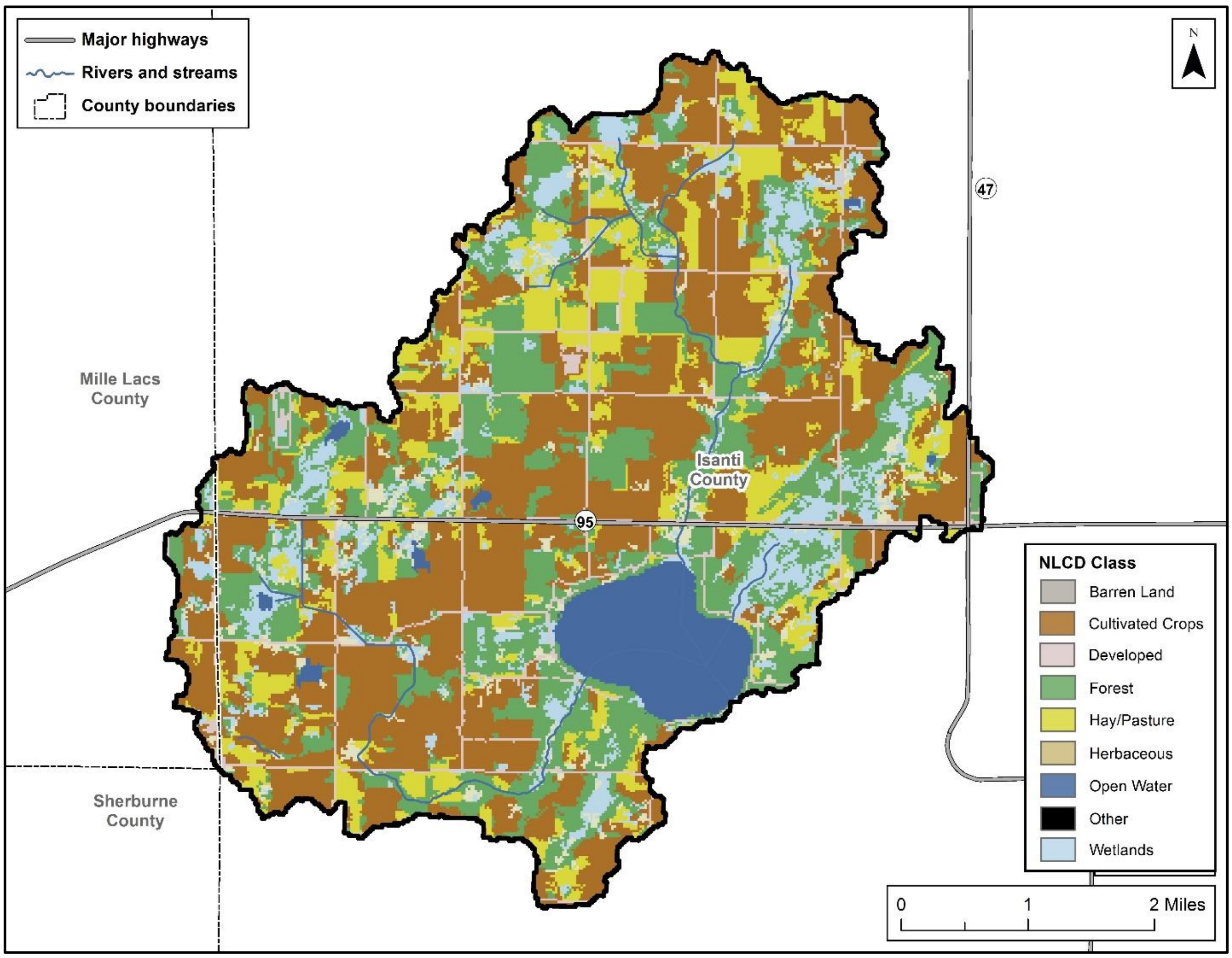
Land cover for the Green Lake Watershed is provided in Figure 10. Natural areas make up 41% of the watershed including forest, wetlands, herbaceous cover and open water. Hay and pasture account for 14% of the watershed. The remaining watershed is in cultivated crops (40%) or is developed (5%). Note that about 3% of the watershed changed from cultivated land to developed land between 2006 and 2011 based on NLCD results; however, generally there has been very little change in land cover over the past two decades.

The shoreline on Green Lake is developed with residential homes and a public boat access on the north end of the lake (Perleberg 2006). Many of the developed lots along Green Lake have tree cover canopy that is not recognized in the 2011 NLCD dataset (Figure 8). The greatest concentration of residential development in the contributing watershed is on the shores of Green Lake. The shoreline is developed on all but one 0.22 mile stretch along the point on the southern shore. Currently, there are 198 residential lots adjacent to Green Lake that are not public land, and there are an additional 54 lots within 1,000 feet of the shore and within the contributing watershed that have houses or cabins on them (Borgstrom 2016). There are about 32 docks per mile of shoreline (Beck et al. 2013).

Table 8. Land cover and use (excluding the area of Green Lake)

	Developed	Forest	Grassland	Pasture	Cropland	Wetland	Feedlot	Total
Wyanett Creek	430	1,324	668	9	1,764	1,308	3	5,506
North Brook	268	883	934	22	1,375	1,282	14	4,779
Green Lake	372	1,494	687	10	1,213	1,002	0	4,778
Total	1,070	3,702	2,289	41	4,352	3,592	17	15,063

Figure 8. Green Lake Watershed land cover (NLCD 2011)



2.7 Feedlots and animal operations

There are five registered feedlots, with one being a Confined Animal Feeding Operation (CAFO) in the Green Lake Watershed (Table 9).

Table 9. Animals in the Green Lake Watershed

Animals	Number animals
Beef cattle	90
Dairy cattle	2,900

Animals	Number animals
Horses	35
Turkeys	73,000

2.8 Wastewater

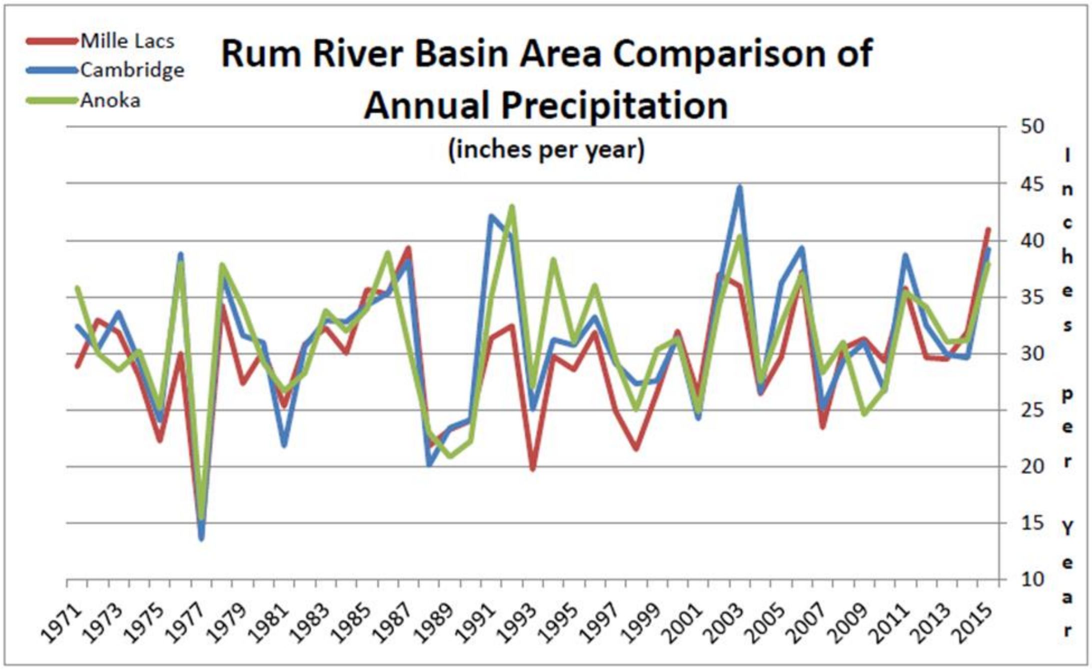
Wastewater treatment and handling within the watershed is important as it may impact nutrient loading to waterways and waterbodies. There are no wastewater treatment plants present within the Green Lake Watershed, however all residents are served by subsurface wastewater treatment systems (SSTS). Isanti County estimates that there are approximately 175 SSTSs located immediately surrounding Green Lake. Based on recent county-wide estimates, approximately 6% of those systems are considered failing. Nutrient loading from SSTSs to Green Lake was estimated to be 68 pounds per year (lbs/yr) based on this information (Wenck 2019).

2.9 Climate and precipitation

The Rum River TMDL report (MPCA 2017) noted subtle north-south gradients across the entire Rum River Watershed, as defined by storm precipitation intensities and durations, annual precipitation, evaporation, and frost-free periods with higher levels tracking south in the basin. Growing-season runoff is expected to be affected by wide variations of month-to-month rainfall amounts, increasing average temperatures, and storm intensities. Storm-precipitation intensities for the typical 24-hour storm and multiday wet periods can be substantial with potential wide-ranging impacts that affect communities, agricultural producers, streams, lakes, wetlands, and associated aquatic habitats. Collectively, these basic climate and hydrologic cycle components vary considerably between years and seasonally, which potentially results in wide ranges of watershed runoff and the associated runoff-pollutant dynamics that should be factored into future restoration/protection and monitoring program design considerations.

Climate variability for the Rum River Watershed was assessed by using available long-term data for sites from the Midwest Regional Climate Center, DNR gridded precipitation data, and National Oceanic and Atmospheric Administration’s databases summarized for east-central Minnesota (Climate Division 6). Few monitoring stations with long-term climate data exist in the Rum River Watershed; hence, interpolated data from the DNR’s gridded precipitation network and the Climate Division data were evaluated. Annual precipitation at three gages in the Rum River Watershed show an overall range in precipitation from approximately 14 inches per year in 1977 to 45 inches per year in 2004 (Figure 9).

Figure 9. Comparison of Annual Precipitation for Representative Sites of the North (Mille Lacs), Central (Cambridge), and Lower (Anoka) Rum River Basin (MPCA 2017)



3. Water quality and quantity

3.1 Water quality standards

The federal Clean Water Act requires states to designate beneficial uses for all waters and develop water quality criteria to protect each use. Water quality standards consist of several parts:

- Beneficial uses — Identify how people, aquatic communities, and wildlife use our waters
- Numeric criteria — Amounts of specific pollutants allowed in a body of water and still protects it for the beneficial uses
- Narrative criteria — Statements of unacceptable conditions in and on the water to protect the beneficial uses
- Antidegradation protections — Extra protection for high-quality or unique waters and existing uses

Together, the beneficial uses, numeric and narrative criteria, and antidegradation protections provide the framework for achieving Clean Water Act goals. Minnesota's water quality standards are provided in Minnesota Rules chapter 7050. All current state water rules administered by the MPCA are available on the Minnesota water rules page (https://www.pca.state.mn.us/water/water-quality-rules).

Beneficial uses

The beneficial uses for public waters in Minnesota are grouped into one or more classes as defined in Minn. R. ch. 7050.0140. The classes and beneficial uses are:

- Class 1 – domestic consumption
- Class 2 – aquatic life and recreation

- Class 3 – industrial consumption
- Class 4 – agriculture and wildlife
- Class 5 – aesthetic enjoyment and navigation
- Class 6 – other uses and protection of border waters
- Class 7 – limited resource value waters

The aquatic life use class now includes a tiered aquatic life uses framework for rivers and streams. The framework contains three tiers—exceptional, general, and modified uses. All surface waters are protected for multiple beneficial uses.

Numeric criteria and state standards

Narrative and numeric water quality criteria for all uses are listed for four common categories of surface waters in Minn. R. ch. 7050.0220. The four categories are:

- Cold water aquatic life and habitat, also protected for drinking water: classes 1B; 2A, 2Ae, or 2Ag; 3A or 3B; 4A and 4B; and 5
- Cool and warm water aquatic life and habitat, also protected for drinking water: classes 1B or 1C; 2Bd, 2Bde, 2Bdg, or 2Bdm; 3A or 3B; 4A and 4B; and 5
- Cool and warm water aquatic life and habitat and wetlands: classes 2B, 2Be, 2Bg, 2Bm, or 2D; 3A, 3B, 3C, or 3D; 4A and 4B or 4C; and 5
- Limited resource value waters: classes 3C; 4A and 4B; 5; and 7

The narrative and numeric water quality criteria for the individual use classes are listed in Minn. R. ch. 7050.0221 through 7050.0227. The procedures for evaluating the narrative criteria are presented in Minn. R. ch. 7050.0150.

The MPCA assesses individual water bodies for impairment for class 2 uses—aquatic life and recreation. Class 2A waters are protected for the propagation and maintenance of a healthy community of cold water sport or commercial fish and associated aquatic life and their habitats. Class 2B waters are protected for the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish, and associated aquatic life and their habitats. Both class 2A and 2B waters are also protected for aquatic recreation activities including bathing and swimming.

Protection for aquatic recreation entails the maintenance of conditions safe and suitable for swimming and other forms of water recreation. In streams, aquatic recreation is assessed by measuring the concentration of E. coli in the water, which is used as an indicator species of potential waterborne pathogens. To determine if a lake supports aquatic recreational activities, its trophic status is evaluated using total phosphorus, Secchi depth, and chlorophyll-a as indicators. Lakes that are enriched with nutrients and have abundant algal growth are eutrophic and do not support aquatic recreation.

Protection of aquatic life entails the maintenance of a healthy aquatic community as measured by fish and macroinvertebrate IBIs. Fish and invertebrate IBI scores are evaluated against criteria established for individual monitoring sites by water body type and use subclass (exceptional, general, and modified).

The ecoregion standard for aquatic recreation protects lake users from nuisance algal bloom conditions fueled by elevated phosphorus concentrations that degrade recreational use potential.

Antidegradation policies and procedures

The purpose of the antidegradation provisions in Minn. R. ch. 7050.0250 through 7050.0335 is to achieve and maintain the highest possible quality in surface waters of the state. To accomplish this purpose:

1. Existing uses and the level of water quality necessary to protect existing uses shall be maintained and protected.
2. Degradation of high water quality shall be minimized and allowed only to the extent necessary to accommodate important economic or social development.
3. Water quality necessary to preserve the exceptional characteristics of outstanding resource value waters shall be maintained and protected.
4. Proposed activities with the potential for water quality impairments associated with thermal discharges shall be consistent with section 316 of the Clean Water Act, United States Code, title 33, section 1326.

Standards and criteria in Green Lake Watershed

The waterbodies in the Green Lake Watershed are designated as class 2B waters. Green Lake is defined as a deep lake. The water quality standards and criteria used in assessing the streams and lakes include the following parameters:

- ***Escherichia (E.) coli*** – not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies between April 1 and October 31.
- Dissolved oxygen (DO) – daily minimum of 5.0 mg/L.
- pH – to be between 6.5 and 9.0 standard units.
- Total suspended solids (TSS) – 30 mg/L not to be exceeded more than 10% of the time between April 1 and October 31.
- Stream eutrophication – based on summer average concentrations for the Central Nutrient Region
- Total phosphorus concentration less than or equal to 100 µg/L and
- Chlorophyll-a (seston) concentration less than or equal to 18 µg/L or
- Diel dissolved oxygen flux less than or equal to 3.5 mg/L or
- Five-day biochemical oxygen demand concentration less than or equal to 2.0 mg/L.

If the TP criterion is exceeded and no other variable is exceeded, the eutrophication standard is met.

- Lake eutrophication – based on summer average values for deep lakes in the North Central Hardwood Forest (NCHF) Ecoregion
  - Total phosphorus concentration less than or equal to 40 µg/L and
  - Chlorophyll-a concentration less than or equal to 14 µg/L or
  - Secchi disk transparency not less than 1.4 meters (4.59 feet).
- Biological indicators – The basis for assessing the biological community are the narrative water quality criteria and assessment factors in Minn. R. 7050.0150. Attainment of these standards is measured through sampling of the aquatic biota and is based on impairment thresholds for

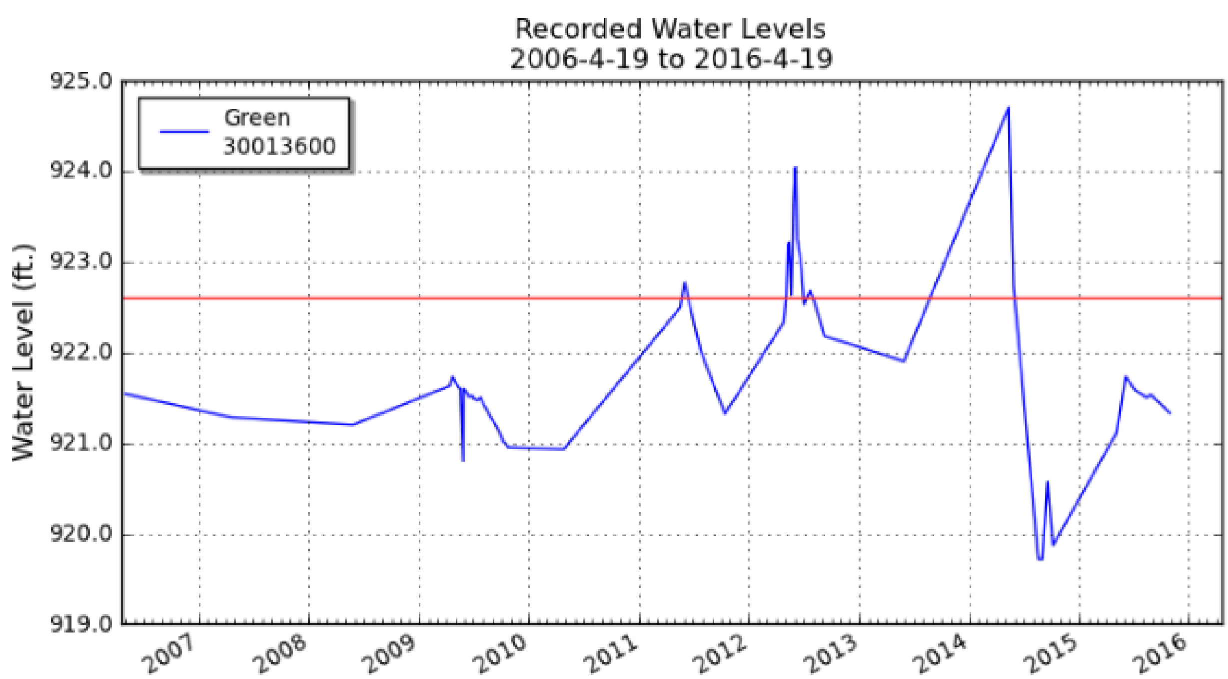
indices of biological integrity (IBI) that vary by use class. Appendix 4.2 and 4.3 in the Rum River Watershed Monitoring and Assessment Report (MPCA 2016b) provides the IBI numeric thresholds.

- Mercury – The standard for class 2 waters is based on the mercury concentration in edible fish tissue: 0.2 mg/kg fish mercury concentration.
- PCBs – A concentration of 0.22 mg/kg in fish tissue is used to determine if the fish meet the protection level goals for fish consumers. Concentrations above this amount result in a water body being listed as impaired.

3.2 Lake water levels

Lake water level elevation is measured for Green Lake, for which the average water elevation from 2007 to 2016 is approximately 922.7 feet (Figure 10). Lake-level fluctuations can be large and range from about one foot to four feet. Note that there are no monitored stream gages along any tributaries to Green Lake.

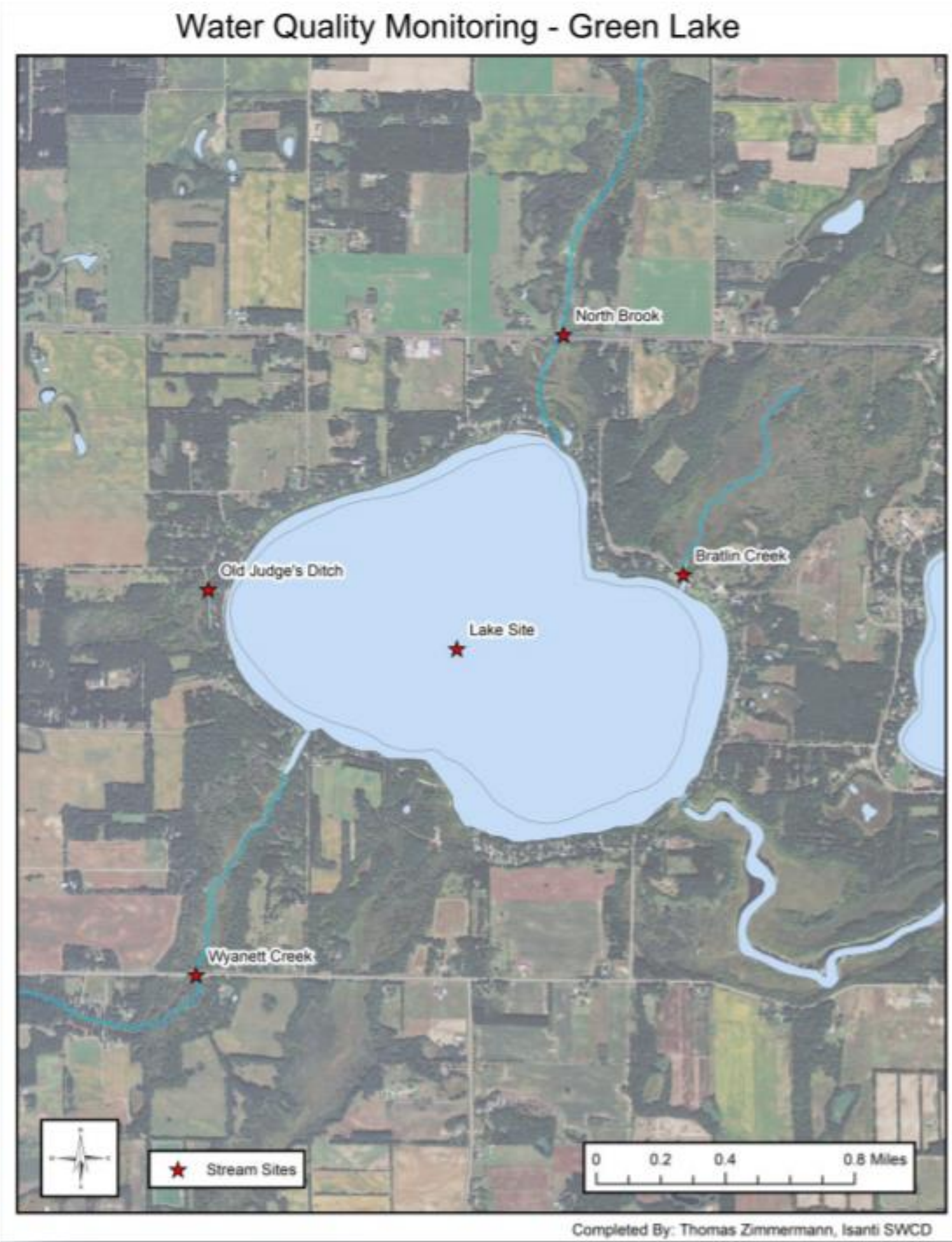
Figure 10. Green Lake Lake-Level Fluctuations (MPCA 2017; MN LakeFinder)



3.3 Water quality data summaries

Water quality monitoring has occurred at stations located at the downstream end of the four major tributaries to Green Lake (North Brook, Bratlin Creek, Old Judge's Ditch, Wyanett Creek), as well as in the lake itself (Figure 13). Water quality results at these sites are summarized in the following sections.

Figure 11. Water quality monitoring locations along stream sites and Green Lake (Isanti SWCD 2018b)



Lake water quality

Total phosphorus, Chl-a, and Secchi data summary

Generally, the information in this section was excerpted from the Rum River TMDL report (MPCA 2017). Green Lake's monitoring data for the TMDL period included 17 paired samples of TP, chlorophyll-a (chl-a), and Secchi transparency data and 96 individual Secchi measurements collected between 2006 and 2015. Corresponding growing-season averages for TP, chl-a, and Secchi transparency with corresponding lake standards are summarized in Table 10, which illustrates that lake averages exceed the TP and chl-a standards. Average Secchi values do not exceed the standard threshold. Lake TP and chl-a averages remained above standards in recent years, which suggests persistent watershed sources. Secchi transparency, however, does not show a downward trend in clarity. This may reflect aquatic vegetation shifts. Annual average growing-season data are shown in Figure 12, Figure 13, and Figure 14. Monthly trends of data are shown in Figure 15, Figure 16, and Figure 17. P monthly means showed a progressive increase over the growing season from about 35 micrograms per liter (µg/L) to about 75 µg/L. The corresponding chl-a monthly mean values increase sequentially during the summer months to a peak of about 43 µg/L. Correspondingly, June to September average monthly Secchi transparencies vary from approximately 1.75 meters to about 1.5 meters.

Table 10. 2006-2015 total phosphorus, chl-a, and Secchi transparency growing-season means for Green Lake (MPCA 2017)

Parameter	Minimum	Mean	Maximum	Standard deviation	Sample number	Lake standards
TP (ug/l)	26	50.6	90.0	20.6	17	=<40
Chl-a (ug/l	7	27.5	69	21	17	=<14
Secchi disk depth (m)	.5	1.6	4.6	.8	96	=> 1.4

Figure 12. Annual growing-Season mean of TP concentrations for Green Lake (MPCA 2017)

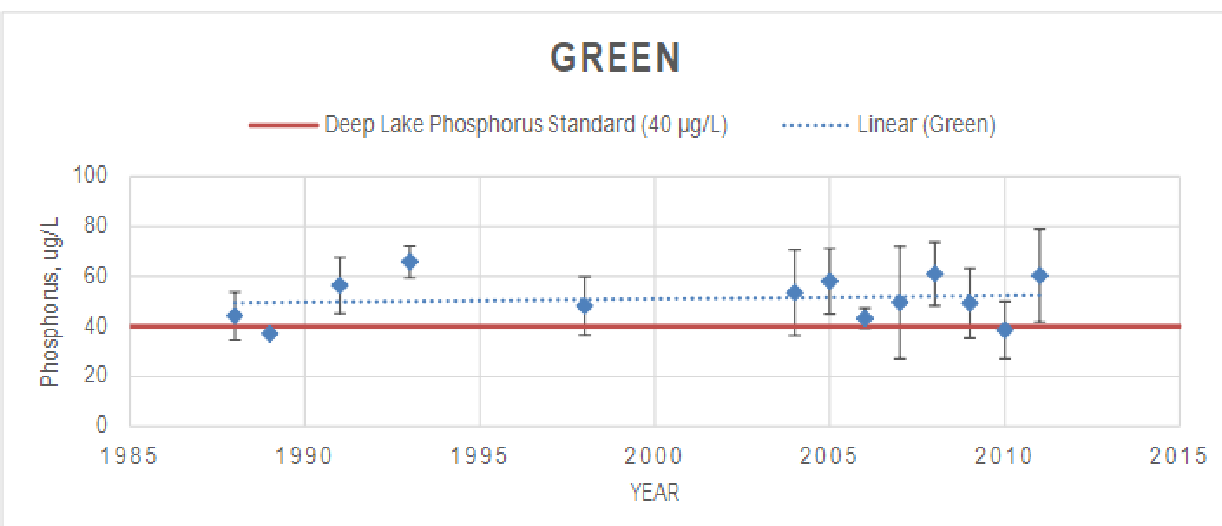


Figure 13. Annual growing-season mean of chlorophyll-a concentrations for Green Lake (MPCA 2017)

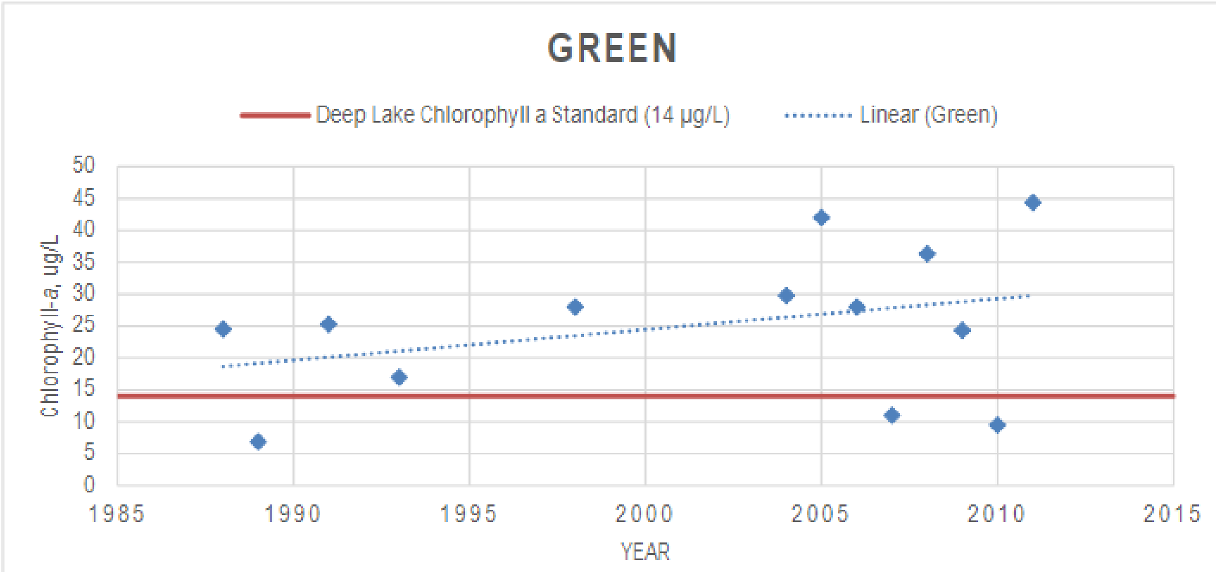


Figure 14. Annual growing-season mean of Secchi transparency for Green Lake (MPCA 2017)

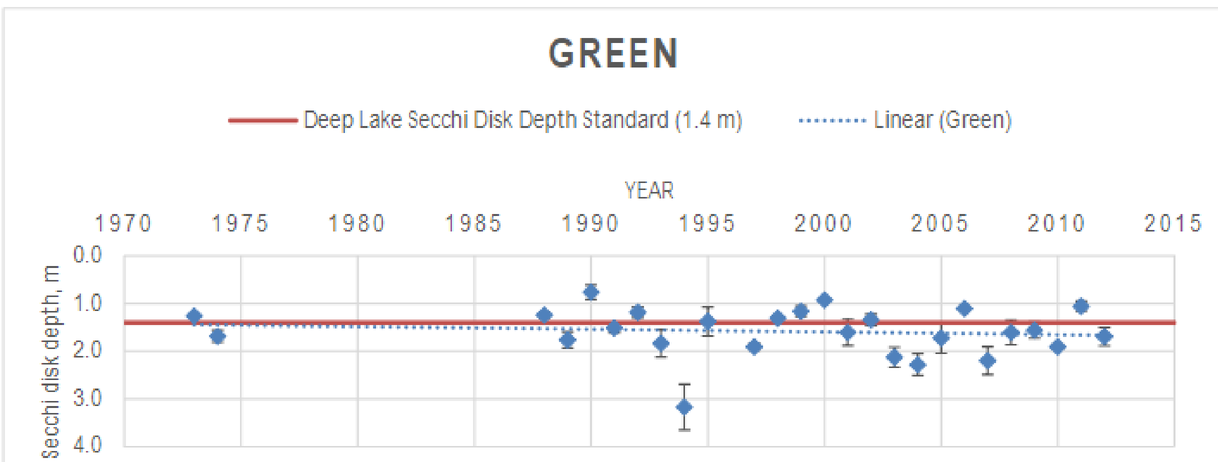


Figure 15. Growing-season monthly mean of TP for Green Lake (all available data between 2006-2015) (MPCA 2017)

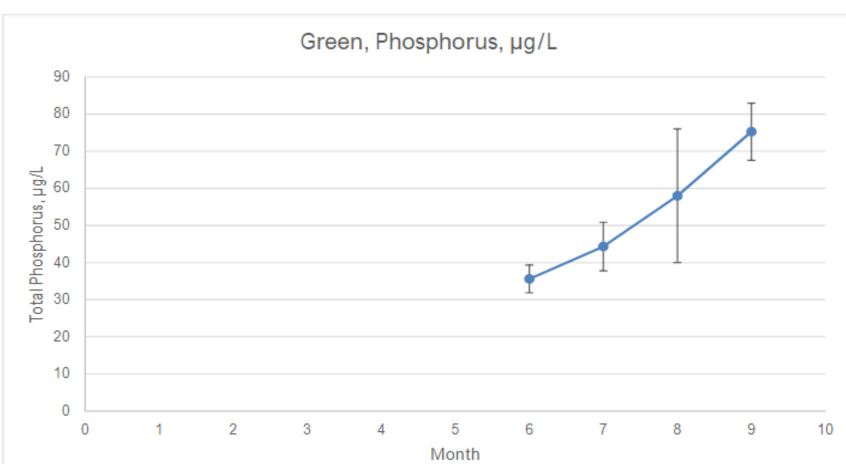


Figure 16. Growing-season monthly mean of chlorophyll-*a* for Green Lake (all available data between 2006-2015) (MPCA 2017).

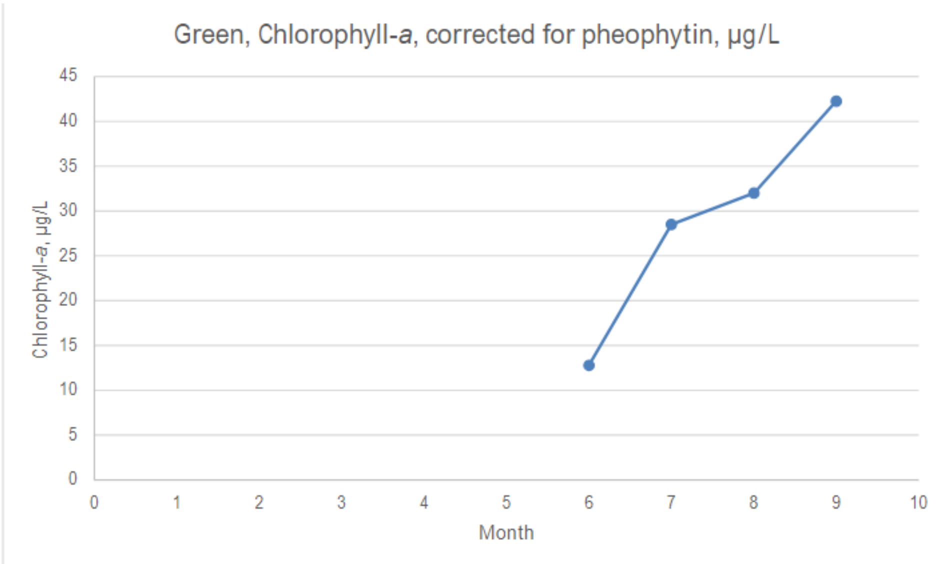
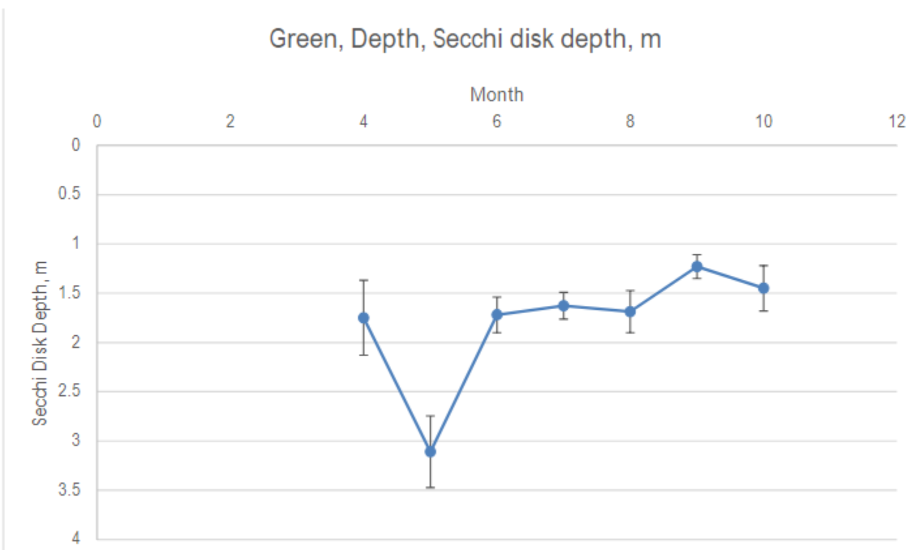


Figure 17. Growing-season monthly mean of Secchi transparency for Green Lake (all available data between 2006-2015) (MPCA 2017).



Dissolved Oxygen and Temperature Data Summary

DO and temperature data monitored in depth profiles were examined to better define lake-mixing patterns that affect biological responses and lake TP dynamics (MPCA 2017). Available data from 1988 to 1991 are plotted in Figure 18 and Figure 19 for temperature and DO, respectively. As shown in Figure 20 and Figure 21, Green Lake is a deep lake in the Rum River Watershed, which is noted to develop a thermocline and experience typical declining summer oxygen values in the hypolimnion to concentrations less than 2.0 mg/l.

Figure 18. Lake temperature profiles for Green Lake (MPCA 2017).

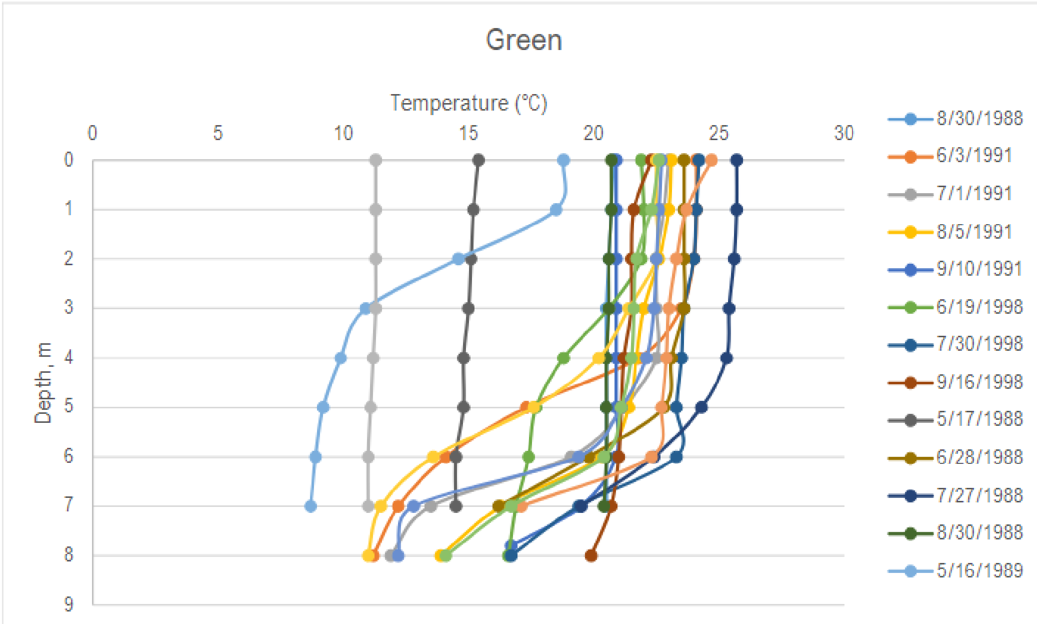
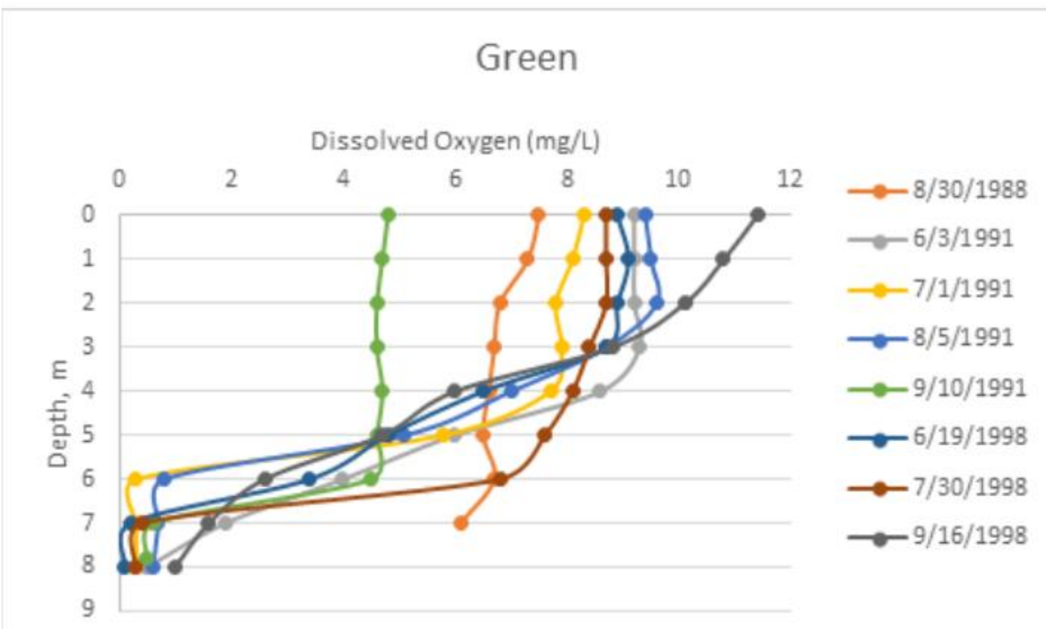


Figure 19. Dissolved oxygen profiles for Green Lake (MPCA 2017)



Fisheries data summary

Green Lake is primarily managed for walleye and northern pike, and the DNR's 2012 assessment found walleye size and abundance at historic highs. The walleye population is maintained through annual fingerling stocking. Common carp and black bullheads were found at the low end of the normal range for this type of lake.

The DNR has conducted surveys of fish relative abundance with standardized methods on a 5-year cycle in Green Lake since 1979. These survey methods allow inference of relative abundance by comparing catch rates over time and to normal ranges for lakes with similar characteristics. Lake survey catch per unit effort data from Green Lake suggest that overall fish abundance has varied significantly over time, has stayed mostly within normal ranges for similar lakes, and based on most recent survey in 2016 abundance is currently reaching the upper normal range in abundance. Benthivore (substrate feeding) fish populations exhibit similar trends over time in Green Lake, but account for small proportion of overall catch per unit effort (sampling bias may account for these differences) (Wenck 2019).

Inference about the effects of fish abundance on water quality in Green Lake is limited by the lack of data on planktivorous fish abundance and Common Carp biomass density. Available data suggests that currently the state of its piscivorous game fishery is favorable for high water clarity and a macrophyte dominated stable state. The predictable occurrence of Common Carp in DNR catch data over time is indicative of a reproducing population existing within the lake and/or subwatershed, warranting specific sampling to quantify biomass density of this benthivorous species. If Common Carp biomass density is higher than 100 kg/ha (Bajer et al 2009), suppressive management of this invasive/nuisance species would be a method to increase water quality in Green Lake that is commonly employed by water managers in the region (Wenck 2019).

Aquatic Vegetation Data Summary

Curlyleaf pondweed (CLP) and Eurasian water milfoil (EWM) are aquatic invasive species present in Green Lake. Limnopro Aquatic Science (2018) indicated that the range of CLP in the littoral zone of the lake has expanded from approximately 4% in 2005 to 35% in 2012 to 44% in 2018. EWM coverage of the lake in mid-June of 2005 and 2012 was 34% and 28%, respectively. The 2018 survey by Limnopro occurred in mid-May prior to the dominant growth of EWM, so coverage was underrepresented (Limnopro 2018). EWM generally is a problem for much of the summer; whereas, CLP naturally dies off at the beginning of July.

Stream water quality

Tributary monitoring is conducted at the outlets of the main tributaries to Green Lake, and the locations and frequency of sampling has increased over the past decade. In 2018, eight sampling events were targeted at the four major tributary outlets. Sampling events included four rain events and four baseflow periods that were sampled for TP, TSS, and transparency. Measurements in the field included DO, temperature, conductivity, pH, and flow. Water levels were also tracked continually in both North Brook and Wyanett Creek, measuring every four hours from early May through early November.

The Green Lake Tributary Monitoring Report (Isanti SWCD 2018b) details the following water quality data summaries about each main tributary to Green Lake:

- North Brook: TP concentrations observed in 2018 were lower than previous years (due in part to high volume of precipitation) but there is still plenty of opportunity for improvement in water quality.
- Wyanett Creek: TP levels were lower in 2018 than previous years (due to high precipitation) but plenty of opportunity for improvement.
- Bratlin Creek: This location typically has good water health (with the exception of the early season).
- Old Judge's Ditch: In 2018 flow was lowest therefore TP contribution was lowest to lake.

3.4 Water quality impairment assessments

The MPCA assesses the use support of individual water bodies in Minnesota. A water body is defined as an individual stream reach, lake, or wetland and is identified as an assessment unit. Each assessment unit is assigned an assessment unit identification (AUID). Stream AUIDs are delineated using the 1:24,000 scale National Hydrography Dataset. Streams and rivers often contain more than one stream reach based on the presence of tributaries, lakes and wetlands, and other landscape changes. There are no MPCA assessed stream AUIDs in the Green Lake Watershed. Lake and wetland AUIDs are based on the DNR's Protected Waters Inventory.

The assessment of aquatic recreation in lakes is based on total phosphorus, chl-a, and Secchi depth, and the assessment of aquatic life in lakes is based on chloride and fish data, where available. Where applicable and where sufficient data exist, other designated uses (e.g., limited resource value water, drinking water, and aquatic consumption) are assessed.

The Rum River Monitoring and Assessment Report (MPCA 2016b) concluded that Green Lake (30-0136-00) is eutrophic and not meeting the aquatic recreation standard due to excess nutrients. The poor water quality of Green Lake is reflected in the fish surveys and lack of complex nearshore habitat. Green Lake is also not meeting its aquatic life standard due to low fish bioassessment scores.

Mercury was analyzed in fish tissue samples collected from the Rum River and 11 lakes, including Green as part of the Fish Contaminant Monitoring Program. In addition, polychlorinated biphenyls (PCBs) were measured in fish in the Rum River and 7 lakes. Fish tissue from Green Lake was tested in both efforts and was found to be impaired for both pollutants (MPCA 2016b). No other waterbodies or applicable beneficial uses in the Green Lake Watershed were assessed as part of that effort.

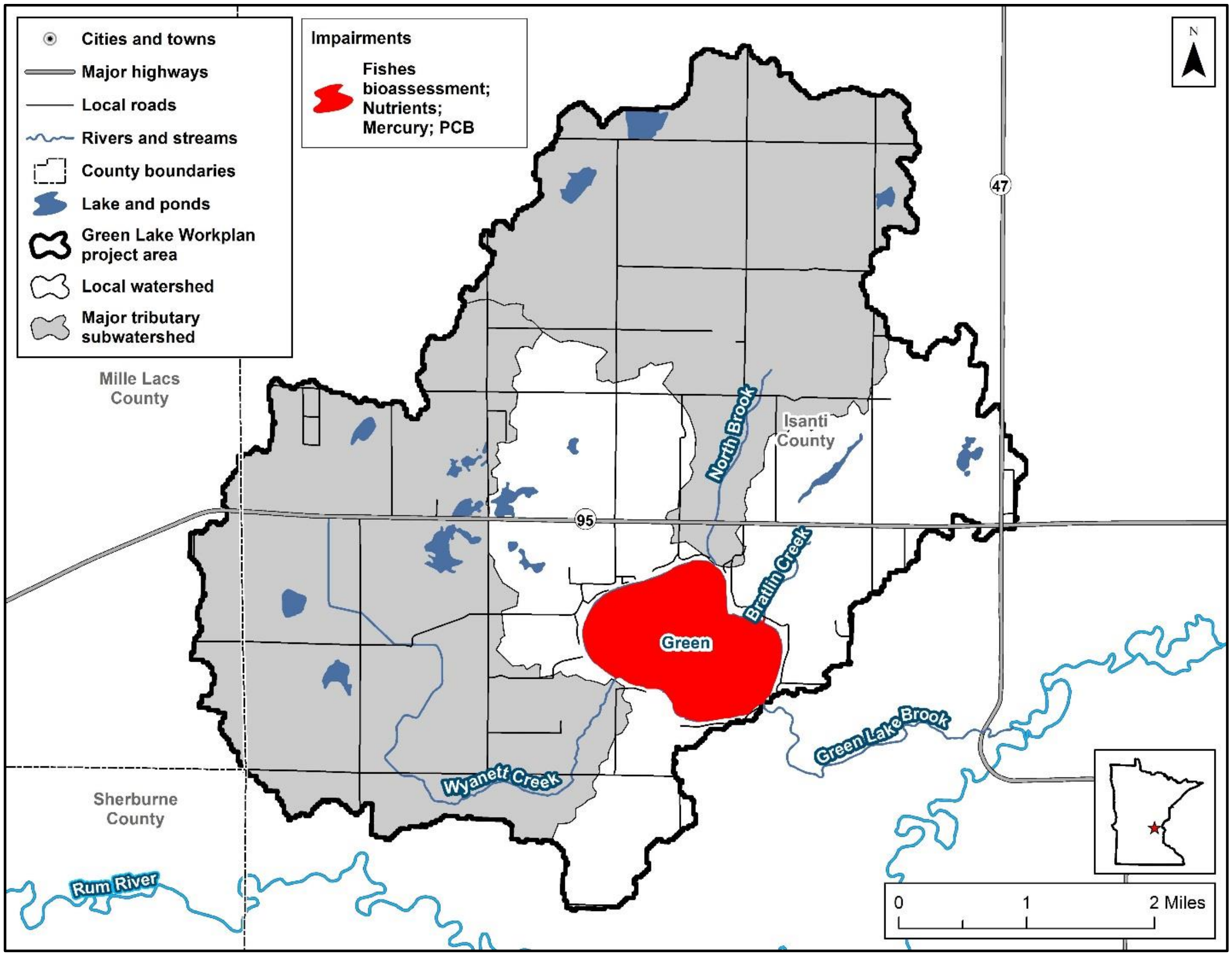
3.5 Impairments 303(d) listings

Water quality impairments are identified on Minnesota's 303(d) list. The most recent approved updates of the 303(d) list occurred in 2018; however, Green Lake Watershed has listed impairments dating back to 1998. Figure 20 shows the impairments and Table 11 describes the criteria, date of listing and the status of total maximum daily load (TMDL) development.

Table 11. Impaired lakes in the Green Lake Watershed

Lake name	Reach description	Classification	Year listed	Affected designated use	Pollutant or stressor	Status of TMDL
Green	8 MI E of Princeton	2B, 3C	1998	Aquatic Consumption	Mercury in fish tissue	Approved 2008
			1998	Aquatic Consumption	PCB in fish tissue	2020 Target completion
			2016	Aquatic Life	Fishes bioassessments	2027 Target completion
			2008	Aquatic Recreation	Nutrient/ eutrophication biological indicators	Approved 2017

Figure 20. Impairments in the Green Lake Watershed



3.6 Stressor identification for biological impairments

Biological stressor identification is the process of identifying the major factors causing harm to fish, macroinvertebrates and other aquatic organisms. The MPCA conducts a stressor identification process to identify the likely stressors causing either fish or macroinvertebrate biota impairments. This process encompasses both evaluation of pollutants and non-pollutant-related (e.g., altered hydrology, fish passage, habitat) factors as potential stressors. The Rum River Watershed Fish based Lake IBI Stressor Identification Report (Borgstrom 2016) evaluated the potential stressors of the fish bioassessment impairment in Green Lake. Borgstrom (2016) summarizes that "[t]he poor water quality and high disturbance (greater than 40%) within the watershed…would indicate that there is not one key cause of the reduced fish community, but rather a synergistic effect due to poor water quality, and lack of quality in-lake and nearshore habitat."

3.7 Watershed TMDLs

The Clean Water Act, Section 303(d) requires TMDLs to be completed for surface waters that do not meet applicable water quality standards necessary to support their designated uses. A TMDL determines the maximum amount of a pollutant a receiving waterbody can assimilate while still achieving water quality standards and allocates allowable pollutant loads to various sources needed to meet water quality standards.

Green Lake was added to the Minnesota impaired waters list in 2008 for having high nutrients (too much phosphorus). The listing triggered the completion of a TMDL study in 2017 by the MPCA (Table 12). The TMDL study identified the need for a 39% overall phosphorus reduction or approximately 1,840 lbs/yr P.

Table 12. TMDL for Green Lake (MPCA 2017)

Green Lake Load Allocation		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Margin of Safety 10%				**319.17**	**0.87**		
Wasteload	Construction Stormwater	0.90	< 0.01	0.90	< 0.01	0.00	—
	Industrial Stormwater	5.04	0.01	5.04	0.01	0.00	—
	Total WLA	5.94	0.01	5.94	0.01	0.00	—
Load	Tributary 281	1,820.84	4.99	1,085.74	2.97	735.10	40
	Tributary 283	1,290.18	3.53	809.92	2.22	480.26	37
	Local Watershed	1,286.36	3.53	771.81	2.12	514.55	40
	SSTS	110.25	0.30	0.00	0.00	110.25	100
	Atmospheric Deposition	199.15	0.55	199.15	0.55	0.00	—
	Total LA	4,706.78	12.90	2,866.62	7.86	1,840.16	39
Total Load (WLA + LA)		4,712.72	12.91	2,872.56	7.87	1,840.16	39
Loading Capacity (WLA + LA + MOS)				**3,191.73**	**8.74**		

In addition, Green Lake has an aquatic consumption impairment due to high levels of mercury measured in fish tissue. Minnesota developed a statewide mercury TMDL that was approved by EPA in 2007. The MPCA updates information in the approved statewide mercury TMDL every two years. For more information on mercury impairments, see the statewide mercury TMDL at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/special-projects/statewide-mercury-tmdl-pollutant-reduction-plan.html.

Following the completion of the TMDL, Isanti SWCD and the Green Lake Improvement District (LID) collected additional flow and water quality measurements from various ditches and streams that discharge to the lake. Wenck (2019) provided an updated diagnostic study using this data and an internal load component. The NKE plan is based on this diagnostic study. The study determined that a 54% reduction in P was needed, or an approximately 2,142 lbs/yr. The breakdown of reductions needed by watershed segment is described in Table 13.

Table 13. Load reductions by watershed segment for Green Lake (Wenck 2019)

Source Load	Existing TP Load	Allowable TP Load	Estimated Load Reduction	
	[lbs/yr]	**[lbs/yr]**	**[lbs/yr]**	**[Percent]**
Wyanett Creek	753	388	365	49%
North Brook	438	256	182	42%
Bratlin Creek	120	120	0	0%
Old Judge's Ditch	193	136	57	29%
Remaining Local Watershed	70	61	9	12%
SSTS	68	64	4	6%
Internal Load	2,064	539	1,525	74%
Curly-leaf pondweed	49	49	0	0%
Atmosphere	199	199	0	0%
TOTAL LOAD	**3,954**	**1,812**	**2,142**	**54%**

4. Pollutant source assessments

Pollutant source assessments are completed by MPCA for typical pollutant impairment listings and where a biological stressor ID process identifies a pollutant as a stressor. The pollutants of concern in the Green Lake Watershed include phosphorus. Mercury and PCBs are also an issue from early monitoring and impairment assessment.

4.1 Phosphorus

The *Green Lake Diagnostic Study Technical Memo* (Wenck 2019) described phosphorus sources to Green Lake by subwatershed and other sources (Table 14). The HSPF model estimated P contributions by land use in the overall watershed, but did not include the internal loading components and did include atmospheric deposition. With these differences, the HSPF land use contribution estimates are assumed to be representative of the upland watershed contributions. Figure 21, Figure 22, figure 23, and Table 14 describe the HSPF estimate of pollutant source by land use in three segments.

The HSPF model broke out the watersheds by Wyanett Creek, North Brook Creek, and the remaining Green Lake Watershed. The Diagnostic Study broke out the watersheds by Wyanett Creek, North Brook Creek, Bratlin Creek, Old Judge's Ditch, and remaining watershed. The HSPF Green Lake Watershed includes the Diagnostic Study Bratlin, Old Judge's Ditch, and remaining watershed.

Phosphorus contributions from functioning SSTS are considered insignificant. Atmospheric deposition of phosphorus is a source of P that is largely not controllable. Internal loading is a significant source of P to the lake through P release from anoxic bottom sediment and aquatic vegetation uptake of P and release of P upon senescence.

Table 14. Existing non-point phosphorus loads by source to Green Lake (adapted from Wenck 2019)

Source Load		Existing load (lbs/yr)
Major tributaries	Wyanett Creek	753
	North Brook Creek	438
Local watershed	Bratlin Creek	120
	Old Judge's Ditch	193
	Remaining watershed	70
SSTS		68
Atmospheric deposition		199
Internal loading		2,064
Curly leaf pondweed		49
Total existing load		**3,954**

Figure 21. Upland watershed sources of P by land use to Green Lake Watershed as estimated by HSPF

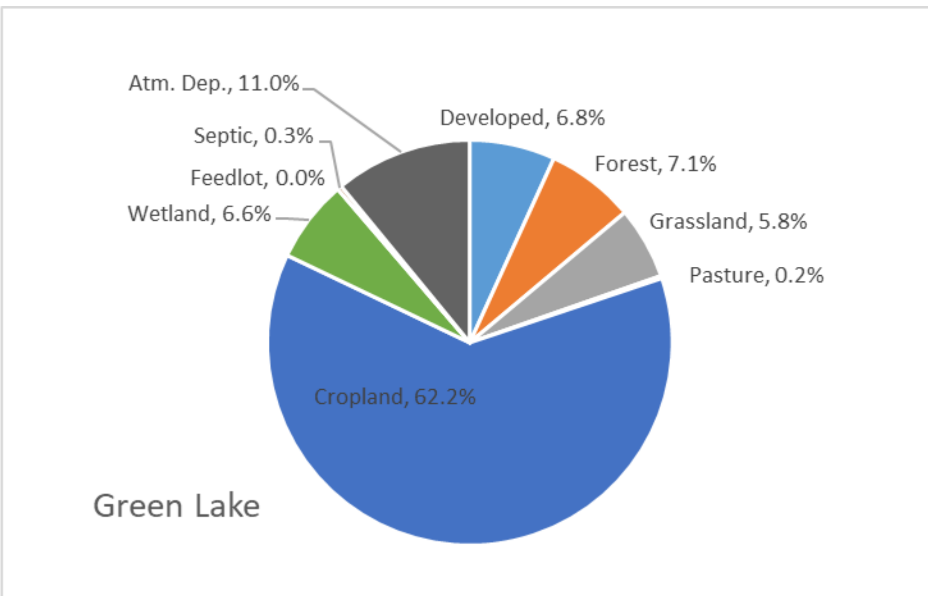


Figure 22. Upland watershed sources of P by land use to Wyanett Creek as estimated by HSPF

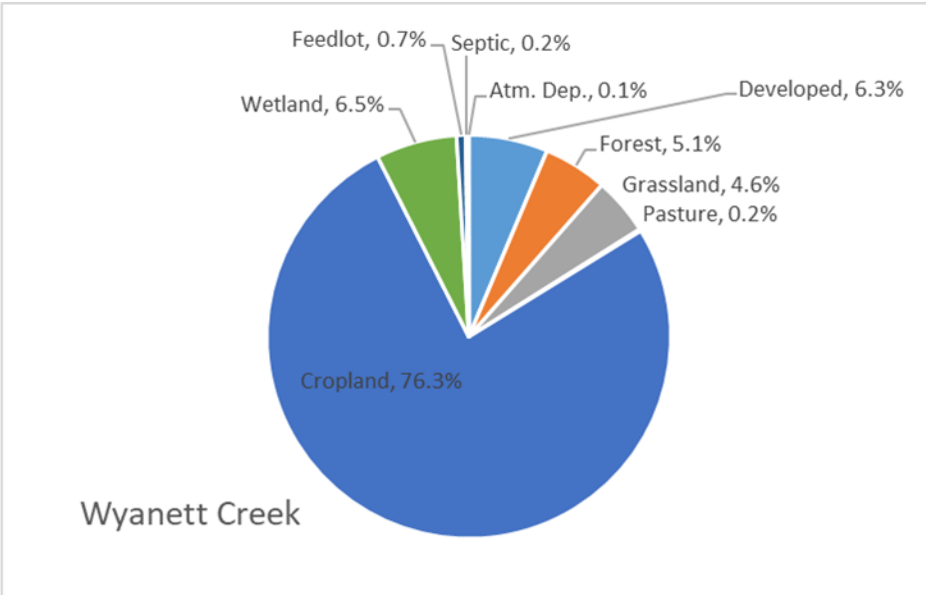


Figure 23. Upland watershed sources of P by land use to North Brook as estimated by HSPF

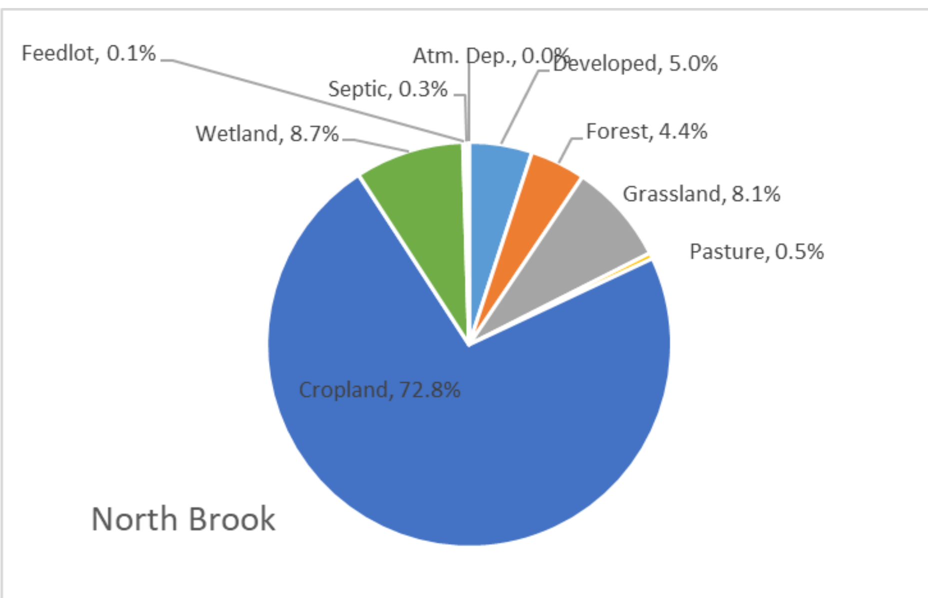


Table 15. Percent P loading by land use, SSTS, and atmospheric deposition for the three watershed segments in the HSPF model

Watershed	Developed	Forest	Grassland	Pasture	Cropland	Wetland	Feedlot	SSTS	Atm. Dep.
Wyanett Creek	6.3%	5.1%	4.6%	0.2%	76.3%	6.5%	0.7%	0.2%	0.1%
North Brook	5.0%	4.4%	8.1%	0.5%	72.8%	8.7%	0.1%	0.3%	0.0%
Green Lake	6.8%	7.1%	5.8%	0.2%	62.2%	6.6%	0.0%	0.3%	11.0%
Total	6.1%	5.5%	5.8%	0.3%	71.6%	7.1%	0.4%	0.3%	3.0%
Average	6.1%	5.5%	6.2%	0.3%	70.5%	7.3%	0.3%	0.3%	3.7%

4.2 Mercury

Almost all the mercury in Minnesota's lakes and rivers is delivered by the atmosphere. Mercury can be carried great distances on wind currents before it is brought down to earth in rain and snow. About 90% of the mercury deposited on Minnesota comes from other states and countries. Similarly, the vast majority of Minnesota's mercury emissions are carried by wind to other states and countries. It's impossible for Minnesota to solve this problem alone; the United States and other countries must greatly reduce mercury releases from all sources.

Atmospheric deposition of mercury is uniform across the state and supplies more than 99.5% of the mercury getting into fish. Agency research has demonstrated that 70% of current mercury deposition in Minnesota comes from human sources and 30% from natural sources, such as volcanoes. There are no known natural sources in the state that emit mercury directly to the atmosphere.

4.3 Polychlorinated biphenyls (PCBs)

An impairment for PCBs in fish tissue was added to the 303(d) list in 1998. There has been no TMDL completed for this impairment. The status of this pollutant is not known. The watershed partners will study fish tissue to determine whether this is still a concern.

5. Watershed prioritization

Priority watershed and critical areas are identified for the Green Lake NKE. These critical areas were identified using information in existing planning documents and represent the areas with the most potential to address the stressors and sources of impairment within the project area:

- **Priority Area #1:** Major tributary subwatersheds. In 2018, monitoring efforts conducted in the four inlets to Green Lake evaluated TP, TSS, and transparency during wet and dry events. Water quality results indicated that the subwatersheds to North Brook and Wyanett Creek contribute the highest levels of external pollutant loading to Green Lake and should be priority locations for restoration projects. Critical subwatersheds and catchments within the subwatersheds are identified in **Error! Reference source not found.**.
- **Priority Area #2:** Nearshore areas (**Error! Reference source not found.**). The Rum River Watershed Fish based Lake IBI Stressor Identification Report (Borgstrom 2016) identified poor riparian land use as a stressor to the fish bioassessment impairment and found that there was a

high level of disturbed land use within 1,000 feet of the shoreline. As such, a nearshore critical area of a 2,000 foot buffer around Green Lake was created. This buffer accounts for the 1,000 feet identified by Borgstrom (2016) and any nearby areas of disturbance.

- **Priority Area #3:** Other tributaries to Green Lake. Runoff from agricultural land use was identified as a source of phosphorus in the Green Lake TMDL (MPCA 2017).
- **Priority Area #4:** Internal loading. The Diagnostic Study identified internal loading as a significant contributor to the P on the lake. To start addressing the internal loads, the Green Lake partners will act by removing curlyleaf pondweed annually. Once 50% of the upland loading has been addressed, the partners are planning a feasibility study for an alum treatment (Table 18).

Figure 24. Critical (labeled as priority) zones in the North Brook and Wyanett Creek Watersheds

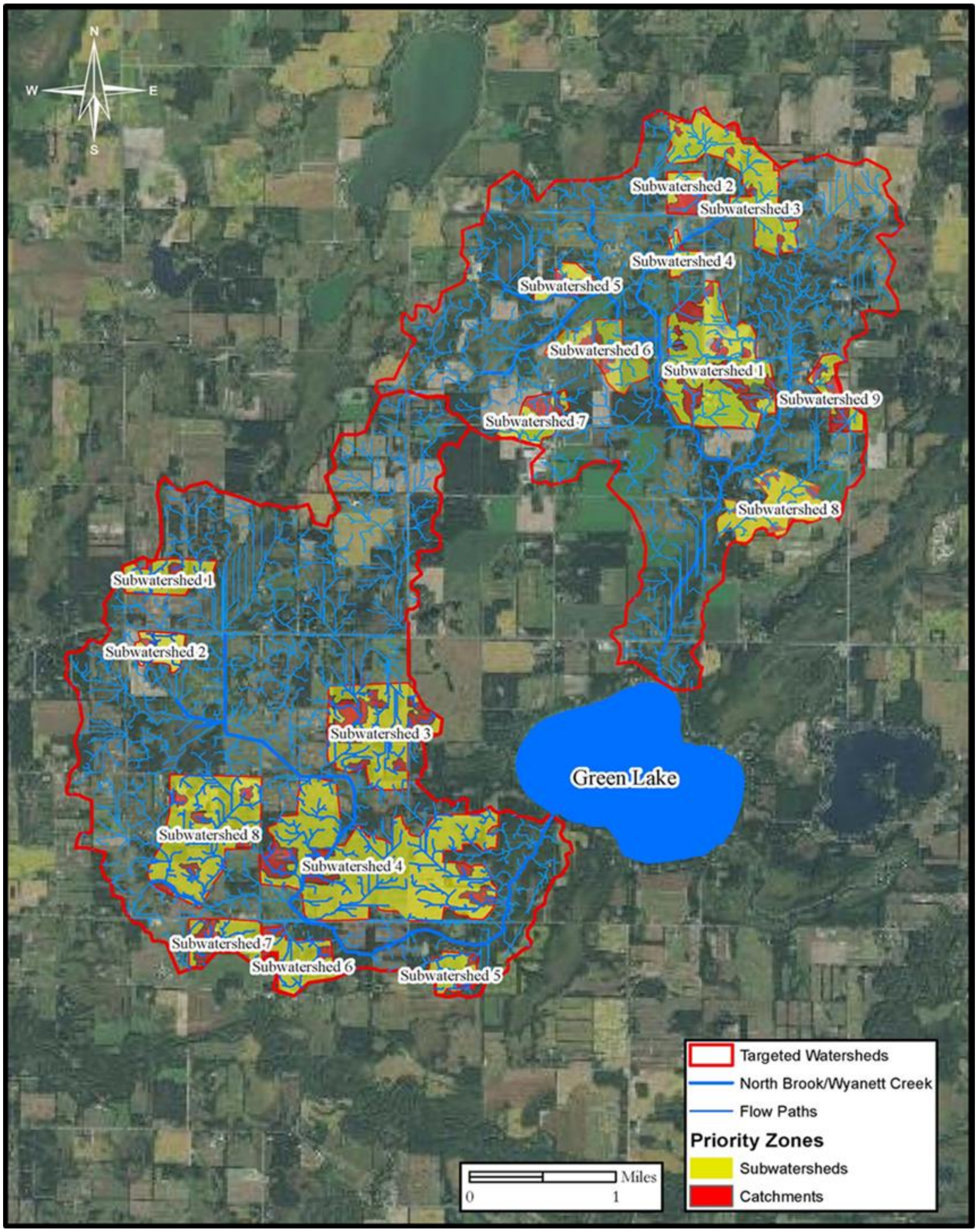
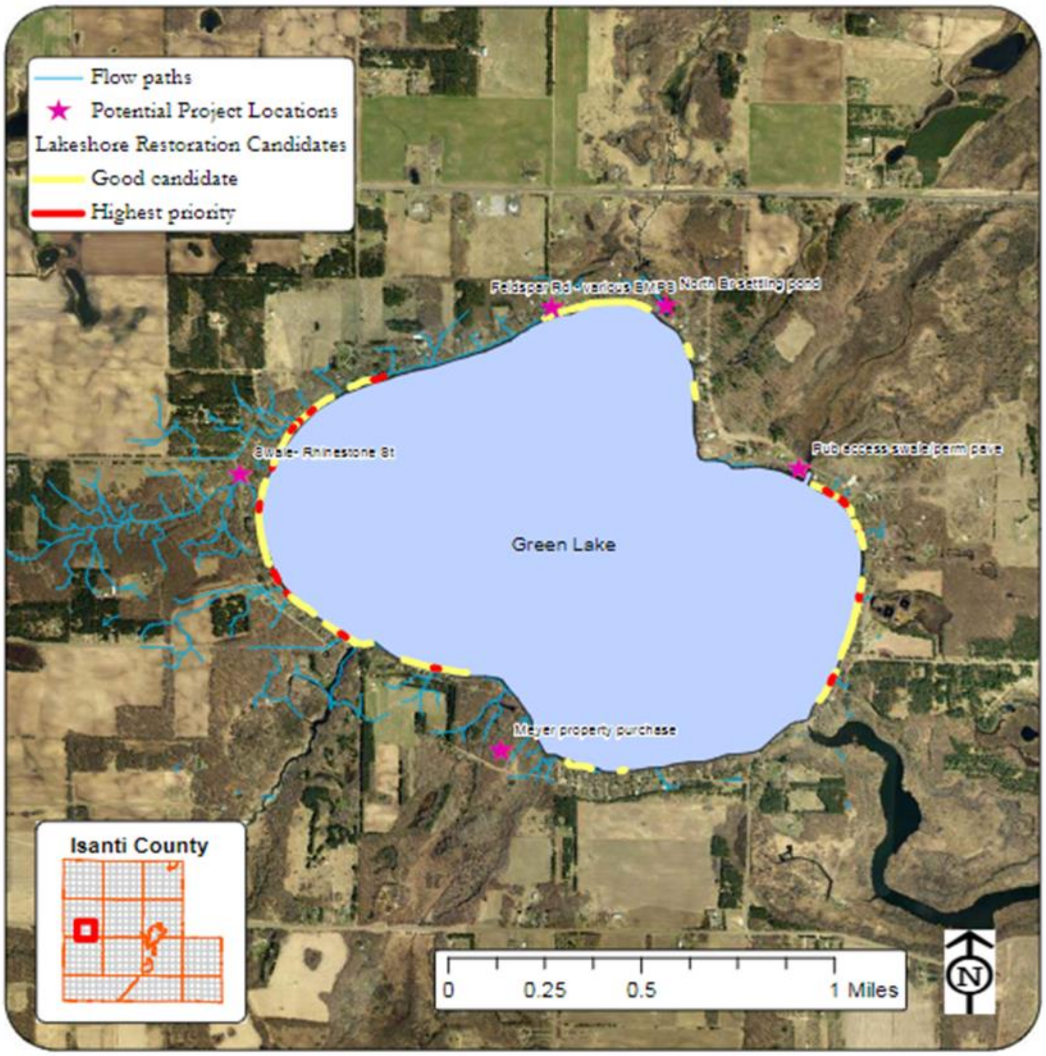


Figure 25. Critical locations for shoreline restoration projects on Green Lake



6. Watershed goals

Restoration goals are developed for impairments within the Green Lake Watershed and are derived from existing TMDLs and planning documents. Protection goals are established for other pollutants or parameters of concern.

6.1 Restoration goals

- Phosphorus: Meet water quality standards for nutrients/eutrophication in Green Lake. The Green Lake TMDL requires an overall reduction of 39% or 1,840 lbs/yr of phosphorus loading to meet water quality standards. The Green Lake Diagnostic Study identified an overall needed reduction of 54% or 2,142 lbs/yr. This NKE plan exceeds the reductions identified in the Green Lake Diagnostic Study.
- Fish Community: Meet biological criteria for fish in Green Lake. The threshold for fish IBI in Green Lake is 45.
- Reduce phosphorus loading to Green Lake

- Improve nearshore/riparian habitat
- Improve in-lake habitat
- Mercury: Meet goals of the Statewide Mercury TMDL. The long-term goal of the mercury TMDL is for the fish to meet water quality standards; the approach for Minnesota's share is mass reductions from state mercury sources. This mercury TMDL establishes that there needs to be a 93% reduction in state emissions from 1990 for the state to meet its share. Water point sources will be required to stay below 1% of the total load to the state and all but the smallest dischargers will be required to develop mercury minimization plans. Air sources of mercury will have a 93% emission reduction goal.
- PCBs: Determine current PCB concentrations in fish tissue below the water quality standard. No TMDL has been completed to address this impairment.

6.2 Protection goals

- Maintain water quality in Bratlin Creek. No further phosphorus reduction is needed in Bratlin Creek to achieve water quality standards for nutrients/eutrophication in Green Lake (Wenck 2019).
- Groundwater Protection: Protect groundwater quality in the Green Lake Watershed. Addressing nutrient loading will benefit the groundwater in the sandy soils of Green Lake Watershed.
- Aquatic Invasive Species. The Green Lake Improvement District (2016) identified preventing the spread of aquatic invasive species as a priority for Green Lake.

7. Implementation plan

Management strategies and activities to meet watershed goals have been described in many existing documents. This section summarizes those strategies and activities and expands upon them based on local input and priorities.

The following management practices and activities have been identified for the Green Lake Watershed. Implementation of all of these plans will achieve the water quality standards for Green Lake for nutrients. There are multiple benefits to each of the BMPs and they are expected to improve habitat conditions, ultimately increasing and diversifying the FIBI for Green Lake. Each of the sections include a ten-year timeline of activities and goals for this watershed, which should net the expected reductions for nutrients and improve habitat to meet state water quality standards. The Diagnostic Study identifies the current P loading as 3,954 lbs/yr. If this plan is implemented, it is estimated to reduce P loading by 2,510 lb/yr (63%).

7.1 Community partners

The SWCD is partnering with the Green Lake Improvement District to build a locally-led and funded shoreline restoration program that builds the capacity of the lake group such that they are able to fund, plan and install near-shore stormwater reduction projects on their own. The SWCD provides technical assistance but the lake group is responsible for getting the landowners on board, projects designed, contracts signed and projects installed. This program is based off a similar successful program on another local lake and it results in more efficiency of limited SWCD time and resources. Activities for community ordinances and other activities are described in Table 16.

Table 16. Protection actions via regulatory activities, goals, milestones, and assessment

	Milestones/schedule					Goals	Cost		Assessment criteria
Practice	**2-year**	**4-year**	**6-year**	**8-year**	**10-year**			**per unit**	
Update local ordinances to adopt Minimal Impact Design Standards (MIDS)			Two presentations to LGU staff and policy makers on MIDS options and strategies	Begin working on policy updates.	Update County ordinance and regulations	MIDS used as standard	$1,500	yr	County Ordinance updated
County shoreline ordinance update	Shoreline ordinances reviewed.	Shoreline ordinances updated				Stricter and/or more clearly defined shoreland regulations required by state to be enforced at the local level continue to be supported.	$1,500	yr	Rules and regulations enforced
Host workshop to help landowners and builders understand rules and stormwater mitigation methods		Host workshop- a minimum of 10 participants	Host workshop- a minimum of 10 participants	Host workshop- a minimum of 10 participants	Host workshop- a minimum of 10 participants	Landowners and contractors aware of County ordinances/rules and stormwater practices.	$1,000	yr	#participants at workshops

7.2 Agricultural BMPs

Runoff from cropland was identified as a source of phosphorus to Green Lake in the Rum River TMDL (MPCA 2017). Water and sediment control basins (WASCOBS), cover crops, and filter strips were selected to address phosphorus loading using an agricultural best management practices (BMP) scenario based on a review of existing planning documents. The implementation modeling scenario assumed 50% of agricultural land treated with an equal distribution of the three BMPs (1/3 of the acres treated with WASCOBs, 1/3 with cover crops, and 1/3 filter strips) in the North Brook and Wyanett Creek Watersheds. A 44% implementation level was used for the local watershed as it achieved the required reductions for that area. These BMPs can be used in combination as a treatment train, which would yield additional benefits. Water retention practices also address habitat concerns.

Wetland restoration acts to slow surface water runoff and provide P treatment. Wetlands in the watershed have been affected by efforts to drain the land for crop production. Opportunities to restore wetlands will be pursued in conjunction with implementation of the ditch maintenance plan. Priority areas for wetland restorations include the North Brook and Wyanett Creek subwatersheds.

Agricultural BMP activities are described in Table 17 include practices specified in the Green Lake Subwatershed Retrofit Analysis for Areas Draining Directly to the Lake and Green Lake Rural Stormwater Retrofit Analysis of North Brook and Wyanett Creek (See Appendices B and C). A summary of the practices specific to these retrofit analyses by watershed can be found in Appendix F. For the purposes of this NKE plan, Table 16 includes those practices and the additional practices required to meet the estimated reductions to meet water quality standards, along with milestones and assessment criteria needed to evaluate the progress of the NKE plan implementation. Each of the analyses include maps to illustrate the targeting of the BMPs.

The estimated P reductions in Table 17 total 1,090 lbs/yr, which is greater than the 613 lbs/yr reduction in P needed for upland watershed P loading as identified in the *Green Lake Diagnostic Study (Wenck 2019)*.

Table 17. Agricultural practices, milestones, reductions, goals, and assessment criteria

Practice	Milestones/schedule					Goals	Estimated phosphorus reductions (lbs/yr)	Cost		Assessment criteria
	2-year	**4-year**	**6-year**	**8-year**	**10-year**				**per unit**	
Water Retention: Increasing water quantity on the land and reducing water quantity and rate into surface water (i.e. wetland restorations, in-line or off-line settling ponds, basins, and/or filters; alterations to improve or restore hydrology; alterations to increase storage; alterations to improve habitat and other wetland functions; stream/ditch channel restoration and/or maintenance		Install 2 BMPs	Install 2 BMPs	Install 2 BMPs	Install 2 BMPs	Continue project identification and install 8 projects	250	$10,000	project	Volume of water held on the land.

Practice	Milestones/schedule					Goals	Estimated phosphorus reductions (lbs/yr)	Cost		Assessment criteria
	2-year	4-year	6-year	8-year	10-year				per unit	
Identify areas w/in stream/ditch corridor for potential projects	North Brook: Establish and implement process a process to evaluate sites and identify potential improvements where necessary. Process could include: desktop analysis, upstream/downstream paired water quality monitoring, walking survey of channel to assess sedimentation, channel conditions, hydrology; wetland vegetation assessment such as rapid floristic quality assessment.	Continue with North Brook evaluations	Wyanette: Establish and implement process a process to evaluate sites and identify potential improvements where necessary. Process could include: desktop analysis, upstream/downstream paired water quality monitoring, walking survey of channel to assess sedimentation, channel conditions, hydrology; wetland vegetation assessment such as rapid floristic quality assessment.	Continue with North Brook evaluations	Continue evaluation process	Database of wetland restoration locations identified.	NA	$11,000	year	#locations for wetland restorations identified

Practice	Milestones/schedule					Goals	Estimated phosphorus reductions (lbs/yr)	Cost		Assessment criteria
	2-year	**4-year**	**6-year**	**8-year**	**10-year**				**per unit**	
Direct Contact Outreach		Landowner contacts (phone, knock, flyer, newsletter, etc.) to landowners w/identified potential locations- 5 contacts made.	Landowner contacts (phone, knock, flyer, newsletter, etc.) to landowners w/identified potential locations- 5 contacts made.	Landowner contacts (phone, knock, flyer, newsletter, etc.) to landowners w/identified potential locations- 5 contacts made.	Landowner contacts (phone, knock, flyer, newsletter, etc.) to landowners w/identified potential locations- 5 contacts made.	Develop partnership with Isanti community and gain buy in. Market SWCD as a resource for landowners wanting to implement conservation.	NA	$1,000	year	# of landowners contacted # of interested landowners
Education	Attend 1 Township and County Board Meeting to propose protection opportunities	Attend 1 Township and County Board Meeting to propose protection opportunities	Attend 1 Township and County Board Meeting to propose protection opportunities		Attend 1 Township and County Board Meeting and propose protection opportunities		NA	$2,000	year	Volume of water held on the land.
Social Media		Social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Develop partnership with Isanti community and gain buy in. Market SWCD as a resource for landowners wanting to implement conservation.	NA	$5,000	year	# of social media posts # of followers. # of landowners that contact the SWCD because of this platform.
WASCOBs		Design/ implement 3 WASCOBs	Design/ implementation of 3 WASCOBs	Design/ implementation of 5 WASCOBs	Assess effectiveness of WASCOBs	Total of 11 WASCOBs installed	66	$20,000	project	# of acres

Practice	Milestones/schedule					Goals	Estimated phosphorus reductions (lbs/yr)	Cost		Assessment criteria
	2-year	4-year	6-year	8-year	10-year				per unit	
Agricultural Technician to conduct outreach and implement programs	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	ISWCD is a credible source of implementation and information to landowners		$15,000	.25 staff person	.25 staff position funded
Direct Contact Outreach	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Evaluate the effectiveness of outreach design	Increase interest in installing WASCOBs and develop a list of producers willing to partner.	NA	$1,000	year	# of landowners contacted # of sites identified # of interested landowners
Education	host 1 educational workshop with minimum 8 attendees	host 1 educational workshop with minimum 10 attendees	host 1 educational/demonstration workshop with minimum 12 attendees	host 1 Demonstration workshop with minimum 114 attendees	Assess effectiveness of workshop	Develop partnership with our agriculture community and gain buy in. Host by annual educational workshops	NA	$4,000	year	# of attendees, # of WASCOBs installed as a result of the workshops/demonstration

Practice	Milestones/schedule					Goals	Estimated phosphorus reductions (lbs/yr)	Cost		Assessment criteria
	2-year	4-year	6-year	8-year	10-year				per unit	
Social Media	Create social media outreach program: 24 social media posts	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Develop partnership with our agriculture community and gain landowner buy in. Increase landowner office contact.	NA	$5,000	year	# of social media posts # of followers. Number of landowners that contact the SWCD because of this platform
Landowner Discussion Group	Organize landowner discussion group (quarterly meetings)	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Create an opportunity for landowners to discuss current ag practices, conservation obstacles, conservation implementation.	NA	$4,000	Year	# of participating landowners
Cover Crops	Implement cover crops into 5% (173 acres) of Wyanett/North Brook row crow land	Implement cover crops into 5% (173 acres) of Wyanett/North Brook row crow land	Implement cover crops into 10% (343 acres) of Wyanett/North Brook row crow land	Implement cover crops into 10% (343 acres) of Wyanett/North Brook row crow land	Implement cover crops into 10% (343 acres) of Wyanett/North Brook row crow land	Total of 75% of row crop acres in cover crops	321	$50	acre	# of acres with where cover crops have been used or are currently being used.
Agricultural Technician to conduct outreach and implement programs	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	ISWCD is a credible source of implementation and information to landowners		$15,000	.25 staff person	.25 staff position funded

Practice	Milestones/schedule					Goals	Estimated phosphorus reductions (lbs/yr)	Cost		Assessment criteria
	2-year	4-year	6-year	8-year	10-year				per unit	
Direct Contact Outreach	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Evaluate the effectiveness of outreach design	Develop partnership with our agriculture community and gain landowner buy in. Increase landowner office contact.	NA	$1,000	year	# of landowners contacted # of interested landowners
Education	host 1 educational workshop with minimum 8 attendees	host 1 educational workshop with minimum 10 attendees	host 1 educational/demonstration workshop with minimum 12 attendees	host 1 Demonstration workshop with minimum 114 attendees	Assess effectiveness of workshop	Develop partnership with our agriculture community and gain buy in. Host by annual educational workshops	NA	$4,000	year	# of attendees, acres of cover crops installed as a result of the workshops/demonstration
Cover Crop Field Day	Annual Field day with 10 participants (others held outside watershed)			Annual Field day with 10 participants (others held outside watershed)		Facilitate 10 new cover crop implementations	NA	$500	year	# of field day participants

Practice	Milestones/schedule					Goals	Estimated phosphorus reductions (lbs/yr)	Cost		Assessment criteria
	2-year	4-year	6-year	8-year	10-year				per unit	
Social Media	Create social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Develop partnership with our agriculture community and gain landowner buy in. Increase landowner office contact.	NA	$5,000	year	# of social media posts # of followers. Number of landowners that contact the SWCD because of this platform.
Landowner Discussion Group	Organize landowner discussion group (quarterly meetings)	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Create an opportunity for landowners to discuss current ag practices, conservation obstacles, conservation implementation.	NA	$4,000	Year	# of participating landowners
Conservation tillage/no till		Develop Conservation Tillage Program. Invest into minimal tillage equipment and develop rental program	Implement conservation tillage program. Convert 10% conventional tillage operations to minimal tillage operations. (346 acres of want/North Brook row crop land)	Implement conservation tillage program. Convert 15% conventional tillage operations to minimal tillage operations. (346 acres of Wyanett/North Brook row crop land)	Implement conservation tillage program. Convert 20% conventional tillage operations to minimal tillage operations. (346 acres of Wyanett/North Brook row crop land)	Total of 75% of row crop acres using conservation tillage	213	$150	acre	# of acres converted to minimal till

Practice	Milestones/schedule					Goals	Estimated phosphorus reductions (lbs/yr)	Cost		Assessment criteria
	2-year	4-year	6-year	8-year	10-year				per unit	
Agricultural Technician to conduct outreach and implement programs	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	ISWCD is a credible source of implementation and information to landowners		$15,000	.25 staff person	.25 staff position funded
Direct Contact Outreach	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Evaluate the effectiveness of outreach tool.	Develop partnership with our agriculture community and gain buy in. Market SWCD as a resource for landowners wanting to implement conservation.	NA	$1,000	year	# of landowners contacted # of interested landowners
Education		host 1 educational workshop with minimum 10 attendees	host 1 educational/demonstration workshop with minimum 12 attendees	host 1 Demonstration workshop with minimum 114 attendees	Assess effectiveness of workshop	Develop partnership with our agriculture community and gain buy in. Host by annual educational workshops	NA	$5,000	year	# of attendees, acres of converted tillage practices as a result of the workshops/demonstration

Practice	Milestones/schedule					Goals	Estimated phosphorus reductions (lbs/yr)	Cost		Assessment criteria
	2-year	**4-year**	**6-year**	**8-year**	**10-year**				**per unit**	
Social Media	Create social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Develop partnership with our agriculture community and gain landowner buy in. Increase landowner office contact.	NA	$5,000	year	# of social media posts # of followers. Number of landowners that contact the SWCD because of this platform.
Landowner Discussion Group	Organize landowner discussion group (quarterly meetings)	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Create an opportunity for landowners to discuss current ag practices, conservation obstacles, conservation implementation.	NA	$4,000	Year	# of participating landowners
Grassed waterways			5 grassed waterways (Identified in rural assessment)	10 grassed waterways (Identified in rural assessment)	15 grassed waterways (Identified in rural assessment)	59 grassed waterways installed	232	$60	ln ft	# of linear feet of grassed waterways
Agricultural Technician to conduct outreach and implement programs	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	ISWCD is a credible source of implementation and information to landowners		$15,000	.25 staff person	.25 staff position funded

Practice	Milestones/schedule					Goals	Estimated phosphorus reductions (lbs/yr)	Cost		Assessment criteria
	2-year	4-year	6-year	8-year	10-year				per unit	
Direct Contact Outreach		Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of contacted annually)	Evaluate the effectiveness of outreach tool.	Develop partnership with our agriculture community and gain buy in. Market SWCD as a resource for landowners wanting to implement conservation.	NA	$1,000	year	# of landowners contacted # of interested landowners
Education		host 1 educational workshop with minimum 10 attendees	host 1 educational/demonstration workshop with minimum 12 attendees	host 1 Demonstration workshop with minimum 114 attendees	Assess effectiveness of workshop	Develop partnership with our agriculture community and gain buy in. Host by annual educational workshops	NA	$5,000	year	# of attendees, # of waterways installed as a result of the workshops/demonstration
Social Media		Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Develop partnership with our agriculture community and gain landowner buy in. Increase landowner office contact.	NA	$5,000	year	# of social media posts # of followers. #of landowners that contact the SWCD because of this platform.

Practice	Milestones/schedule					Goals	Estimated phosphorus reductions (lbs/yr)	Cost		Assessment criteria
	2-year	4-year	6-year	8-year	10-year				per unit	
Landowner Discussion Group	Organize landowner discussion group (quarterly meetings)	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Create an opportunity for landowners to discuss current ag practices, conservation obstacles, conservation implementation.	NA	$4,000	Year	# of participating landowners
Filter Strips			3 grassed waterways (Identified in rural assessment)	3 grassed waterways (Identified in rural assessment)	5 grassed waterways (Identified in rural assessment)	Identify 25 more areas where filter strips would be beneficial	8.88	$100	acre	# acres treated
Agricultural Technician to conduct outreach and implement programs	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	5 site visits, outreach as identified below	ISWCD is a credible source of implementation and information to landowners		$15,000	.25 staff person	.25 staff position funded
Direct Contact Outreach		Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10 landowner of	Kitchen table discussions and landowner contacts (phone, knock, flyer, newsletter, etc.) in ag producers in the area (Minimum 10	Evaluate the effectiveness of outreach tool.	Develop partnership with our agriculture community and gain buy in. Market SWCD as a resource for landowners wanting to implement conservation.	NA	$1,000	year	# of landowners contacted # of interested landowners

Practice	Milestones/schedule					Goals	Estimated phosphorus reductions (lbs/yr)	Cost		Assessment criteria
	2-year	4-year	6-year	8-year	10-year				per unit	
		contacted annually)	contacted annually)	landowner of contacted annually)						
Education		host 1 educational workshop with minimum 10 attendees	host 1 educational/demonstration workshop with minimum 12 attendees	host 1 Demonstration workshop with minimum 14 attendees	Assess effectiveness of workshop	Develop partnership with our agriculture community and gain buy in. Host by annual educational workshops	NA	$5,000	year	# of attendees, # of filter strips installed as a result of the workshops/demonstration
Social Media		Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Develop partnership with our agriculture community and gain landowner buy in. Increase landowner office contact.	NA	$5,000	year	# of social media posts # of followers. #of landowners that contact the SWCD because of this platform.
Landowner Discussion Group/Farmer Led Council	Organize landowner discussion group (quarterly meetings)	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Continue landowner discussion group (quarterly meetings). Assess effectiveness.	Create an opportunity for landowners to discuss current ag practices, conservation obstacles, conservation implementation.	NA	$4,000	Year	# of participating landowners

7.3 Internal load management

Internal P load controls include an alum treatment, carp management, and curly-leaf pondweed controls to seal P in bottom sediments, reduce bottom sediment suspension by carp, and reduce P release early in the summer from curly-leaf pondweed growth and senescence, respectively.

Chemical treatment of a lake with alum is a common practice in Minnesota to address internal loading. Costs of alum treatment can range from $750,000 to $2 million. A sediment internal load feasibility study is needed to determine feasibility, P reduction effectiveness, and cost prior to an alum treatment. Estimated cost for the feasibility study, including core sampling, laboratory analysis, and a final memo, is approximately $17,000. Part of the analysis of the feasibility study for a chemical treatment such as alum, will include assess the external loading reductions to ensure the best use of the application.

A carp abundance and density study was recommended to determine the extent carp population control would reduce sediment P release. However, locals do not feel that excessive carp populations are an issue. As such, this item was moved to a “last resort” item in the implementation plan. A general cost estimate for three carp density surveys is $15,000. Research suggests that P reductions with decreased carp densities are variable. Research does suggest that carp management aids the control of aquatic invasive plant species by encouraging the growth of native aquatic plant species. A 20 percent reduction in P release in shallow areas of the lake is estimated.

Controlling aquatic invasive plant species, especially curly leaf pondweed, has been demonstrated to improve Secchi disk clarity significantly. Control has been identified as a means of reducing the internal load by preventing the associated loading with the mid-June dieback (James et al. 2007). Control is estimated to reduce P loading by 10 lbs/yr.

The Isanti SWCD has worked with the Lake Improvement District to generate interest and engagement. The LID will be continuing the aquatic invasive species control. This work will continue to contribute toward pollutant reductions and is described here; however, it should be noted that the LID will be taking the lead on this work.

Internal loading BMP activities are described in **Table 18**. The estimated reductions for internal P loading are 1,582 lbs/yr. The *Green Lake Diagnostic Study (Wenck 2019)* estimates that a 1,525 lb/yr reduction is needed. In year five, partners will assess the effectiveness of internal and external reduction efforts and adapt the plan accordingly.

Table 18. Internal load activities, milestones, goals, reductions, and assessment criteria for Green Lake

Practice	Milestones/schedule					Goals	Estimated phosphorus reductions	Cost		Assessment criteria
	2-year	4-year	6-year	8-year	10-year		(lb/yr)		per unit	
Alum treatment			Sediment internal load feasibility study to identify potential for alum		Alum treatment	90% reduction in P	1572.5	$.75-2M		pounds of P reduced
Sediment internal load feasibility study to identify potential for alum				Outreach and education surrounding alum treatment		Assess effectiveness in reducing internal loading	NA	$17,000	survey	Study complete
Carp management					Common Carp density assessment, develop common carp mitigation plan.			$15,000	survey	Study complete
Curlyleaf pondweed treatment	Herbicide treatments to reduce amount of curly-leaf pondweed	Evaluate effectiveness of herbicide treatments	Herbicide treatments to reduce amount of curly-leaf pondweed	Evaluate effectiveness of herbicide treatments	Herbicide treatments to reduce amount of curly-leaf pondweed	Determine most effective curly-leaf pond weed treatment	10	$4,000	yr	# of acres of CLPW treated

Practice	Milestones/schedule					Goals	Estimated phosphorus reductions	Cost		Assessment criteria
	2-year	4-year	6-year	8-year	10-year		(lb/yr)		per unit	
Evaluate the effectiveness of upland and internal load management and analyze data		Analyze the effectiveness of internal and external load management and make appropriate changes				Determine the effectiveness of the internal and external load management activities		$500	ea	Analysis applied

7.4 SSTS compliance

SSTS were identified as a source of phosphorus to Green Lake in the Rum River TMDL. Regular pumping of SSTS and the upgrade of failing systems is important for both nutrient and human health reasons. Annual inspections, in addition to regular maintenance, ensure that systems are functioning properly. It is estimated there are 175 SSTS including 11 failing systems in the watershed.

SSTS activities are described in Table 19. Planned SSTS replacement/upgrading will yield an estimated 4 lbs/yr P reduction, which is the recommended reduction identified by the *Green Lake Diagnostic Study (2019)*.

Table 19. SSTS practices, milestones, reductions, and assessment criteria for Green Lake

	Milestones/schedule					Goals	Estimated phosphorus reductions	Cost		Assessment criteria
Practice	**2-year**	**4-year**	**6-year**	**8-year**	**10-year**		**(lb/yr)**		**per unit**	
SSTS compliance			Conduct review of SSTS information: Compile database of existing information to verify SSTS non-compliance. Should include: year home built, lot size, most recent point of sale, age of SSTS, SSTS inspection records, review of pump maintenance records. See diagnostic study for details.	Determine compliance of SSTS-voluntary inspections	Update non-compliant SSTS	Upgrade 10 SSTS	4	10000 to 20000	SSTS	# of SSTS upgraded/replaced
Education/ Outreach		Provide educational materials regarding proper function and maintenance of SSTS		Provide educational materials regarding proper function and maintenance of SSTS		Provide educational materials regarding proper function and maintenance of SSTS	NA	$1,000	yr	# of landowners reached

7.5 Near-shore restoration

Runoff from impervious, urban areas was identified as a source of phosphorus to Green Lake in the Rum River TMDL (MPCA 2017). Urban retrofit opportunities were identified in the Green Lake Subwatershed Retrofit Analysis (Isanti SWCD 2014). Reduction estimates and modeling scenarios were completed using WinSLAMM. Area described as urban is primarily lakeshore development, with some residential development outside that area. There is no MS4 permit in this area.

Poor lakeshore habitat was identified as a stressor to the fish community in Green Lake (Borgstrom 2016). Locations along the Green Lake lakeshore were identified as candidates for restoration projects. **Error! Reference source not found.** identifies the good and highest priority locations for restoration based on a survey of shoreline conditions. The following activities were included in the Green Lake management plan (Green Lake Improvement District 2012):

- Fund and restore native vegetation to eroded and mowed sites around Green Lake
- Pursue surface water zoning in areas that are sensitive to shoreline erosion and/or habitat destruction.

It is expected that lakeshore restoration activities will reduce the P loading to the lake and improve the aquatic habitat of the lake and improve the fish's bioassessments impairment.

Restoration of native vegetation will occur along the lakeshore and in the near-shore waters. Terrestrial native vegetation reduces runoff and P loading from lakeshore homes and lawns. It also improves bird and wildlife habitat. Aquatic native vegetation can provide some P uptake, but provides improved aquatic life habitat. The presence of native vegetation is a significant change in public perceptions prioritizing manicured green lawns to the shore and beaches without weeds. Restoration to native vegetation will require aquatic invasive species control. The partners will assess the improvement of the habitat at least twice over the next ten years (Table 22).

Near shore, restoration activities are described in Table 20. Near shore, estimated P reductions are 34 lbs/yr. The *Green Lake Diagnostic Study* does not provide a specific reduction for near shore lake activities.

Table 20. Nearshore projects with activities, milestones, goals, reductions, and assessment criteria

	Milestones/schedule					Long term goals greater than ten years	Estimated phosphorus reductions	Cost		Assessment criteria
Practice	**2-year**	**4-year**	**6-year**	**8-year**	**10-year**		**(lb/yr)**		**per unit**	
Nearshore Stormwater Retrofits: Bioretention, filtration, infiltration, erosion control, diversion, etc.	Identify appropriate BMPs and develop Design	Install Projects	Identify appropriate BMPs and develop Design	Install Projects	Identify appropriate BMPs and develop Design	Address all project options within the lakeshed.	23.4	$800,000	All Projects	# acres treated
Direct Contact Outreach	Landowner contacts (phone, knock, flyer, newsletter, etc.) to landowners within areas directly connected to Green Lake or tributaries	Landowner contacts (phone, knock, flyer, newsletter, etc.) to landowners within areas directly connected to Green Lake or tributaries	Landowner contacts (phone, knock, flyer, newsletter, etc.) to landowners within areas directly connected to Green Lake or tributaries	Landowner contacts (phone, knock, flyer, newsletter, etc.) to landowners within areas directly connected to Green Lake or tributaries	Landowner contacts (phone, knock, flyer, newsletter, etc.) to all landowners within the lakeshed	Develop partnership with our lake community and gain buy in. Market SWCD as a resource for landowners wanting to implement conservation.	NA	$1,000	year	# of landowners contacted # of interested landowners

	Milestones/schedule					Long term goals greater than ten years	Estimated phosphorus reductions	Cost		Assessment criteria
Practice	**2-year**	**4-year**	**6-year**	**8-year**	**10-year**		**(lb/yr)**		**per unit**	
Education	host 1 educational workshop with minimum 10 attendees	host 1 educational/Demonstration workshop with minimum 10 attendees	host 1 educational/Demonstration workshop with minimum 10 attendees	host 1 educational/Demonstration workshop with minimum 10 attendees	Assess effectiveness of workshop	Develop partnership with our lake community and gain buy in. Market SWCD as a resource for landowners wanting to implement conservation.	NA	$5,000	year	# of attendees, # of projects installed as a result of the workshops/demonstration
Social Media		Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Develop partnership with our lake community and gain buy in. Market SWCD as a resource for landowners wanting to implement conservation.	NA	$5,000	year	# of social media posts # of followers. # of landowners that contact the SWCD because of this platform.

	Milestones/schedule					Long term goals greater than ten years	Estimated phosphorus reductions	Cost		Assessment criteria
Practice	**2-year**	**4-year**	**6-year**	**8-year**	**10-year**		**(lb/yr)**		**per unit**	
Land Protection: Easements/ Purchases		Identify sensitive/high priority lands using: Metro Wildlife Corridor Focus areas, DNR Wildlife Action Network, Rum River Landscape Stewardship Plan RAQ Scores		Easements/Purchase Land (32 acres)	Easements/Purchase Land (32 acres)	Protect 250 acres.	8.9	$10,000	acre	# acres protected
Direct Contact Outreach		Landowner contacts (phone, knock, flyer, newsletter, etc.) to parcels using prioritization tools such as: Metro Wildlife Corridor Focus areas, DNR Wildlife Action Network Landscape Stewardship Plan RAQ scores,	Landowner contacts (phone, knock, flyer, newsletter, etc.) to parcels using prioritization tools such as: Metro Wildlife Corridor Focus areas, DNR Wildlife Action Network Landscape Stewardship Plan RAQ scores,	Landowner contacts (phone, knock, flyer, newsletter, etc.) to parcels using prioritization tools such as: Metro Wildlife Corridor Focus areas, DNR Wildlife Action Network Landscape Stewardship Plan RAQ scores,	Landowner contacts (phone, knock, flyer, newsletter, etc.) to parcels using prioritization tools such as: Metro Wildlife Corridor Focus areas, DNR Wildlife Action Network Landscape Stewardship Plan RAQ scores,	Develop partnership with Isanti community and gain buy in. Market SWCD as a resource for landowners wanting to implement conservation.	NA	$1,000	year	# of landowners contacted # of interested landowners
Education		Attend 1 Township and County Board Meeting to propose protection opportunities	Attend 1 Township and County Board Meeting to propose protection opportunities		Attend 1 Township and County Board Meeting and propose protection opportunities		NA	$2,000	year	# of acres put into easements or purchased

	Milestones/schedule					Long term goals greater than ten years	Estimated phosphorus reductions	Cost		Assessment criteria
Practice	**2-year**	**4-year**	**6-year**	**8-year**	**10-year**		**(lb/yr)**		**per unit**	
Social Media		Social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Continue social media outreach program: 24 social media posts.	Develop partnership with Isanti community and gain buy in. Market SWCD as a resource for landowners wanting to implement conservation.	NA	$5,000	year	# of social media posts # of followers. # of landowners that contact the SWCD because of this platform.

7.6 Statewide Mercury TMDL Implementation

Atmospheric deposition of mercury is uniform across the state and supplies more than 99.5% of the mercury getting into fish. Agency research has demonstrated that 70% of current mercury deposition in Minnesota comes from human sources and 30% from natural sources, such as volcanoes. There are no known natural sources in the state that emit mercury directly to the atmosphere.

The long-term goal of the mercury TMDL is for the fish to meet water quality standards; the approach for Minnesota's share is mass reductions from state mercury sources. This mercury TMDL establishes that there needs to be a 93% reduction in state emissions from 1990 for the state to meet its share. Water point sources will be required to stay below 1 percent of the total load to the state and all but the smallest dischargers will be required to develop mercury minimization plans. Air sources of mercury will have a 93% emission reduction goal.

Almost all the mercury in Minnesota's lakes and rivers is delivered by the atmosphere. Mercury can be carried great distances on wind currents before it is brought down to earth in rain and snow. About 90% of the mercury deposited on Minnesota comes from other states and countries. Similarly, the vast majority of Minnesota's mercury emissions are carried by wind to other states and countries. It is impossible for Minnesota to solve this problem alone; the United States and other countries must greatly reduce mercury releases from all sources.

Because mercury in runoff is derived from atmospheric deposition, mercury in stormwater is accounted for in the calculation of the atmospheric load. Separate strategies for reducing nonpoint sources are not included in this plan because implementation of the strategies in section 4 to reduce air deposition will ultimately reduce stormwater loading.

Any efforts to reduce soil erosion will tend to reduce mercury entering a lake or river from nonpoint water sources. Many of these practices are already employed for control of sediment and nutrient loading and will result in reducing mercury loading to surface waters.

7.7 PCB Remediation

In Minnesota, PCBs are subject to the Federal Toxic Substance Control Act Regulations administered by the EPA and the Minnesota Hazardous Waste Rules administered by the MPCA (MPCA 2013). This pollutant understanding is limited. The strategy for this pollutant will be to confirm the continued presence of PCBs in fish tissue, conduct source assessment, and develop a mitigation plan, if necessary.

Table 21 describes the expected costs, milestones, goals and assessment criteria for PCB remediation practices and activities.

Table 21. PCB activities

Management strategy or activity		Milestones/schedule					Goals	Estimated phosphorus reductions	Cost		Assessment criteria
	Practice	**2-year**	**4-year**	**6-year**	**8-year**	**10-year**		**(lb/yr)**		**per unit**	
PCBs	Tissue analysis				Redo tissue analysis and confirm PCB levels in fish		Fish tissue remains below maximum threshold		$5,000		# samples
	Remediation of source(s) of PCBs	Feasibility study on PCB removal/ containment	Plan developed for PCB removal/ containment	Implement plan (update milestones)	Implement plan (update milestones)	Plan completed and implementation milestones set for years 4, 6, and 8	< 0.22 mg/kg PCBs in fish tissue		$10,000		# samples

7.8 Reduction estimates

The combined P reductions for the practices described in Section 7 is 2,520 lb/yr. This exceeds the reduction required by the Green Lake TMDL and the recommended reductions of the Green Lake Diagnostic study. It is expected that if implemented fully, this plan will achieve the necessary reductions to achieve the P water quality standards for Green Lake in 10 years. The IBI impairment will improve based on the decreased nutrient loading and improved habitat via AIS control and shoreline restoration. The removal and management of aquatic invasive species will provide native plants a chance to thrive, thus increasing habitat. The stabilization of the shoreline with native vegetation and bioengineering stabilization practices.

8. Education and outreach

Information and education activities recommended for Green Lake in existing reports include:

- Develop an intensive education program for all property owners in the Green Lake watershed to learn about the potential impacts of their land use activities on the lake. Develop a mailing list and send a newsletter and other promotional materials.
- Provide information to property owners on the benefits of native vegetation to water quality of the lake and habitat.
- Educate Green Lake property owners on the impacts of altered shoreline and boat motors to aquatic vegetation in Green Lake.
- Provide information on workshops for design and management of rain gardens and benefits of no-mow lawns. Encourage attendance of lakeshore property owners.
- Provide information to property owners on proper care and maintenance of SSTS.
- State and other agencies should work with townships and others to coordinate educational and outreach activities.
- DNR review of the Low Impact Development management plan and coordinate DNR activities where applicable.
- Implemented the SWCDs Agricultural Outreach Plan.

9. Monitoring

Green Lake water quality monitoring by Isanti SWCD and the Green Lake Improvement District began in 2016 to monitor the health of Green Lake. The monitoring data collected through this effort helps get a better understanding of the factors driving high phosphorus levels in Green Lake and tracks trends and effectiveness of practices installed to reduce phosphorus loading to the lake. The lake and stream monitoring is described below.

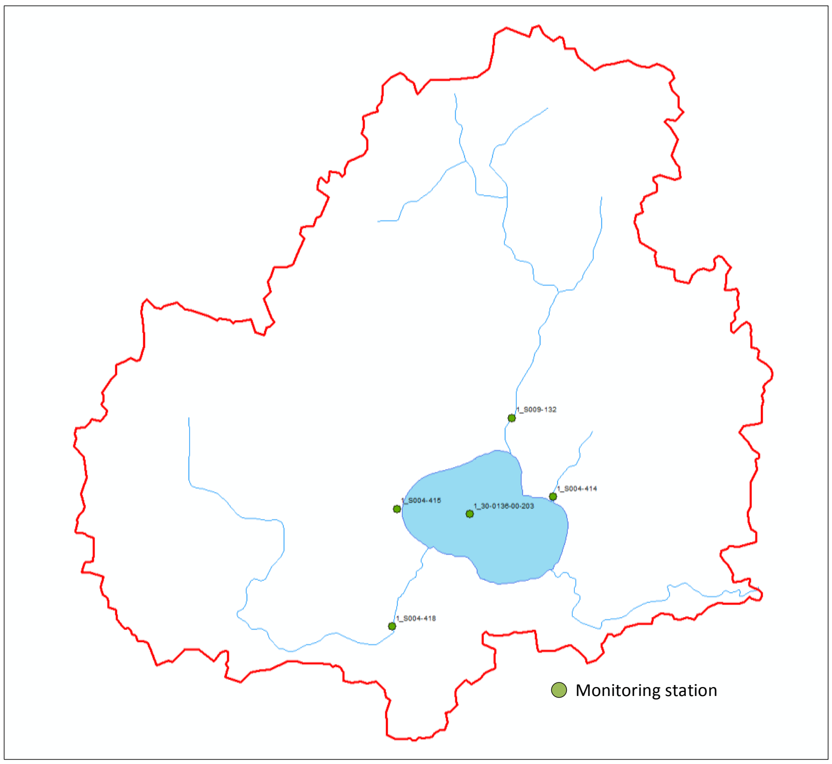
Lake

Volunteers from the Green Lake Improvement District collect TP, chl-a, and transparency (Secchi disk) data every two weeks during the months of May through September. SWCD staff conduct profiles for dissolved oxygen, pH, conductivity and temperature data once a month in Green Lake from June through September. SWCD staff provide training, equipment, and coordinated lab testing for this effort.

The monitoring data collected through this effort helps get a better understanding of the factors driving high phosphorus levels in Green Lake and tracks trends and effectiveness of practices installed to reduce phosphorus loading to the lake.

- In lake, monitoring site (Figure 26) based on current schedule: three years monitoring and three years break or as deemed necessary. Sampling should occur once every two weeks May through October. Measurements should include Secchi transparency, TP and chl-*a*.
- Investigate internal load to the lake thought sediment core sampling
- Continue bi-weekly Citizen's Lake Monitoring Program Secchi transparency readings on Green Lake.

Figure 26. Monitoring sites in Green Lake Watershed



Streams

SWCD staff collected data from North Brook, Wyanett Creek, Bratlin Creek, and Old Judge's Ditch into Green Lake from 2015-2017 (Figure 26). Sampling was targeted to rain events and base flow. The samples were tested for TP, TSS, and transparency. Dissolved oxygen, temperature, conductivity, pH and water flow were also measured in the field. The data helped determine which tributary should be a higher priority for water quality projects.

Future monitoring plans include:

- Expand existing monitoring efforts along tributaries to include ortho-P and dissolved phosphorus parameters.
- Conduct longitudinal surveys (4-5 events) along North Brook and Wyanett Creek to evaluate changes in water quality from upstream to downstream and pinpoint potential problem areas. Surveys should target different times of year and flow conditions and include the following parameters: TSS, TP, ortho-P, DO, temperature, pH, and flow.

- Conduct outlet monitoring for North Brook and Wyanett Creek to measure pollutant loads entering Green Lake. Establish an upstream monitoring site on each stream to provide upstream/downstream paired water quality monitoring to evaluate the change in water quality due to BMP implementation. Parameters to be measured include TSS, TP, ortho-P, DO, temperature, pH, and flow.
- Conduct a walking survey of channel to assess sedimentation, channel conditions, hydrology, etc.
- Conduct a wetland vegetation assessment such as the rapid floristic quality assessment.

BMP implementation is tracked by the Board of Water and Soil Resources (BWSR) in its eLINK database for state-funded implementation and the United States Department of Agriculture for federally-funded implementation. Both agencies track the locations of BMP installations; however, reporting is generally limited to individual watersheds due to data privacy limits.

The estimated cost of the lake and stream monitoring is shown in Table 22.

Table 22. Estimated monitoring costs

Monitoring type	Description	Unit cost (annual)	Total (10-years)
Stream flow and water quality sampling and analysis	0.05 FTE for 4 sites 0.05 FTE for data analysis Lab costs/4 site Equipment/2 outlet sites	$5,000 $5,000 $8,000 $5,000/site	$280,000
Lake monitoring	0.01 FTE for 1 site Lab costs/1 site	$1,000 $2,000	$30,000
Stream and lake habitat and vegetation surveys	0.05 FTE (2 times per 10-year period)	$5,000	$10,000
Total			**$320,000**

10 Financial and technical resources

Implementation of the Green Lake NKE will require additional financial and technical resources.

A list of existing funding sources available to support implementation is provided in Table 23.

Table 23. Partial list of funding sources for restoration and protection strategies

Sponsor or Information Source	Program Description
MPCA	**Section 319 Grants:** Federal grant funding from the EPA as part of the Clean Water Act, Section 319. Grants awarded by MPCA to local governmental units and other groups are to address NPS pollution through implementation projects. **Clean Water Partnership Loan**: The state funded Clean Water Partnership Program awards no-interest loans to local governmental units for work on projects that address nonpoint source pollution. **Clean Water State Revolving Fund:** The state revolving fund provides loans to for both point source (wastewater and stormwater) and nonpoint source water pollution control projects.
BWSR	**Clean Water Fund Competitive Grants:** These grants are to restore, protect, and enhance water quality. Eligible activities must be consistent with a comprehensive watershed management plan, county comprehensive local water management plan, soil and water conservation district comprehensive plan, metropolitan local water plan or metropolitan groundwater plan that has been State approved and locally adopted or an approved TMDL, WRAPS document, surface water intake plan, or well head protection plan. **The Erosion Control and Water Management Program**: commonly known as the State Cost-Share Program: This program provides funds to Soil and Water Conservation Districts to share the cost of systems or practices for erosion control, sedimentation control, or water quality improvements that are designed to protect and improve soil and water resources. Through this program, land occupiers can request financial and technical assistance from their local District for the implementation of conservation practices. **Watershed-based funding (1W1P):** Watershed-based funding is provided to watershed partnerships that have completed comprehensive watershed management plans under the 1W1P program or the Metropolitan Surface Water or Groundwater Management framework. The funding is an alternative to the traditional competitive grant processes often used to fund water quality improvement projects.
Minnesota Department of Agriculture (MDA)	**AgBMP Loan Program:** This program encourages implementation of BMPs that prevent or reduce pollution problems, such as runoff from feedlots, erosion from farm fields and shoreline, and noncompliant septic systems and wells. MDA provides a wide array of other information from their agency as well as other state and federal agencies on conservation programs addressing agriculture and other land uses. In addition, Clean Water Research Projects are available for funding.
Minnesota DNR	**DNR grants** are available for a variety of programs relating to land preservation, wildlife and habitat, native prairie, forestry and wetlands.
USDA NRCS	**Environmental Quality Incentives Program (EQIP):** EQIP is a voluntary program to implement conservation practices, or activities, such as conservation planning, that address natural resource concerns for agricultural producers. **Conservation Reserve Program – Continuous Signup:** This program is a USDA Farm Service Agency-funded voluntary program designed to help farmers restore and protect environmentally sensitive land—particularly wetlands, wildlife habitat and water quality buffers. **Conservation Stewardship Program:** Conservation Stewardship Program is a voluntary program to improve resource conditions such as soil quality, water quality, water quantity, air quality, habitat quality, and energy.

Literature cited

Bajer, P.G., and Sorensen, P. W. 2012. Using boat electrofishing to estimate the abundance of invasive Common Carp in small Midwestern lakes. North American Journal of Fisheries Management.

Beck MW, Vondracek B, Hatch LK, Vinje J. 2013. Semi-automated analysis of high-resolution aerial images to quantify docks in glacial lakes. Journal of Photogrammetry and Remote Sensing. 81: 60-69. DOI: 10.1016/j.isprsjprs.2013.04.006

Borgstrom, L. 2016. Rum River Watershed Fish based Lake IBI Stressor Identification Report. Minnesota Pollution Control Agency and Minnesota Dept. of Natural Resources. MPCA document number: wq-ws-07010207a.

EOR (Emmons & Olivier Resources, Inc.) 2012. Green Lake, Isanti County, MN: Hydrologic Soil Groups Map. https://www.greenlakemnid.com/uploads/8/0/0/1/80013388/soils.pdf

EPA (U.S. Environmental Protection Agency). 2002. Onsite Wastewater Treatment Systems Manual. EPA/625/R-00/008. U.S. EPA, Office of Water and Office of Research and Development. February 2002.

EPA (United States Environmental Protection Agency). 2011. PCB TMDL Handbook. US Environmental Protection Agency Office of Wetlands, Oceans and Watersheds. Watershed Branch (4503T) 1200 Pennsylvania Avenue, NW Washington, DC 20460. December 2011. EPA 841-R-11-006

Green Lake Improvement District. 2012. Green Lake Improvement District Lake Management Plan, 2013-2018.

Isanti SWCD (Soil and Water Conservation District). 2014. Green Lake Subwatershed Retrofit Analysis (for areas draining directly to the lake). Prepared in partnership with the Metro Conservation Districts.

Isanti SWCD (Soil and Water Conservation District). 2018a. Green Lake Monitoring Report.

Isanti SWCD (Soil and Water Conservation District). 2018b. Green Lake Tributary Monitoring Report.

Lenhart, C., B. Gordon, J. Peterson, W. Eshenaur, L. Gifford, B. Wilson, J. Stamper, L. Krider, and N. Utt. 2017. Agricultural BMP Handbook for Minnesota, 2nd Edition. St. Paul, MN: Minnesota Department of Agriculture.

Limnopro Aquatic Science. 2018. Green Lake (DOW 30013600) Isanti County, Minnesota: Lake Status Report.

MNDNR-Fisheries. 2015. Historic Management plans and surveys of Green Lake from MNDNR Fisheries Hinckley Office. 306 Power Avenue North, Hinckley, Minnesota, 55037, United States of America: Minnesota Department of Natural Resources, Section of Fisheries.

MPCA (Minnesota Pollution Control Agency). 2013. Manifest and Dispose of PCBs. MPCA document number: w-hw4-48d. June 2013.

MPCA (Minnesota Pollution Control Agency). 2016a. Groundwater Report: Rum River Watershed. MPCA document number: wq-ws1-11.

MPCA (Minnesota Pollution Control Agency). 2016b. Rum River Watershed Monitoring and Assessment Report. MPCA document number: wq-ws3-07010207b

MPCA (Minnesota Pollution Control Agency). 2017. Final Rum River Watershed Total Maximum Daily Load (Bacteria, DO, Nutrients). MPCA document number: wq-iw8-56e.

Nürnberg, G. K., 1988. Prediction of Phosphorus Release Rates from Total and Reductant Soluble Phosphorus in Anoxic Lake Sediments. Canadian Journal of Fishers and Aquatic Sciences, Vol. 45, pp. 453-462.

Perleberg, D. 2006. Aquatic Vegetation of Green Lake (DOW 30-0136-00-00), Isanti County, Minnesota, June 14-15, 2005. Minnesota Dept. of Natural Resources, Ecological Services Division, 1601 Minnesota Dr., Brainerd, MN 56401. 15 pp.

Porcher, E. 1989. Ground Water Contamination Susceptibility in Minnesota. Minnesota Pollution Control Agency. 29 pp.

RESPEC. 2017a. Rum River Watershed Restoration and Protection Strategy Report. Prepared for MPCA. MPCA document number: wq-ws4-34a.

RESPEC. 2017b. Documentation of the Best Management Practice Database Available in the Scenario Application Manager. Draft Topical Report RSI-2742. Prepared for the Minnesota Pollution Control Agency, Saint Paul, MN. October 2017.

University of Minnesota. 2016. Metadata, Minnesota Land Cover Classification and Impervious Surface Area by Landsat and LiDAR: 2013 Update - Version 1. Retrieved June 1, 2016, from http://portal.gis.umn.edu/map_data_metadata/LandCover_MN2013.html.

USGS (U.S. Geologic Survey). 2016. Wyanett Quadrangle, Minnesota-Isanti Co. 7.5 Minute Series. U.S. Department of the Interior.

Wenck (Wenck Associates, Inc.) 2019. Green Lake Phosphorus Diagnostic Study Technical Memo. October 3, 2019.

Appendix A
WINSLAMM model assumptions

Treatment analysis

For each potential project (except lakeshore restorations, see next section) pollutant removal estimates were obtained using the stormwater model WinSLAMM. WinSLAMM uses an abundance of stormwater data from the upper Midwest and elsewhere to quantify runoff volumes and pollutant loads from urban areas. It is useful for determining the effectiveness of proposed stormwater control practices. It has detailed accounting of pollutant loading from various land uses, and allows the user to build a model "landscape" that reflects the actual landscape being considered. The user is allowed to place a variety of stormwater treatment practices that treat water from various parts of this landscape. It uses rainfall and temperature data from a typical year, routing stormwater through the user's model for each storm.

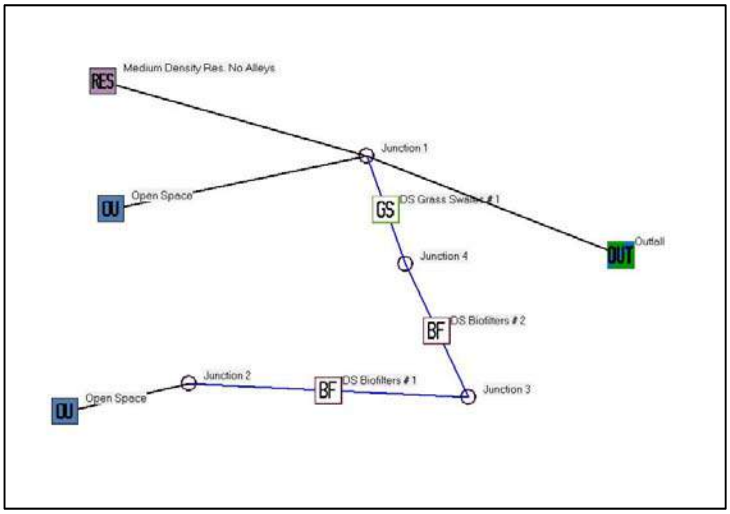
A "base" model was created which estimated pollutant loading from each catchment in its present-day state. To accurately model the land uses in each catchment, we delineated each land use in each catchment using ArcGIS, and assigned each a WinSLAMM standard land use file. A site specific land use file was created by adjusting total acreage and converting to "sand" soils to account for the sandy soils in the study area. This process resulted in a model that included estimates of the acreage of each type of source area (roof, road, lawn, etc.) in each catchment. For certain source areas critical to our models we verified that model estimates were accurate by measuring actual acreages in ArcGIS and adjusting the model acreages if needed.

Once the "base" model was created, each proposed stormwater treatment practice was added to the model and pollutant reductions were generated. Because neither a detailed design of each practice nor in-depth site investigation was completed, a generalized design for each practice was used. Whenever possible, site-specific parameters were included. Design parameters were modified to obtain various levels of treatment. It is worth noting that we modeled each practice individually, and the benefits of projects may not be additive, especially if serving the same area. Reported treatment levels are dependent upon optimal site selection and sizing.

WinSLAMM stormwater computer model inputs

General WinSLAMM Model Inputs	
Parameter	**File/Method**
Land use acreage	**ArcGIS**
Precipitation/Temperature Data	**Minneapolis 1959 – the rainfall year that best approximates a typical year.**
Winter season	**Included in model. Winter dates are 11-4 to 3-13.**
Pollutant probability distribution	**WI_GEO01.ppd**
Runoff coefficient file	**WI_SL06 Dec06.rsv**
Particulate solids concentration file	**WI_AVG01.psc**
Particle residue delivery file	**WI_DLV01.prr**
Street delivery files	**WI files for each land use.**

Example WinSLAMM stormwater model schematic



Lakeshore Erosion and Runoff Pollutant Estimation

WinSLAMM modeling alone could not accurately estimate pollutants generated from eroding lakeshore, nor the pollutant reduction that may occur by installing a project. To estimate lakeshore pollutants, we used a two-step process that accounted for (1) overland flow from lakeshore backyards plus (2) the eroding lakeshore face.

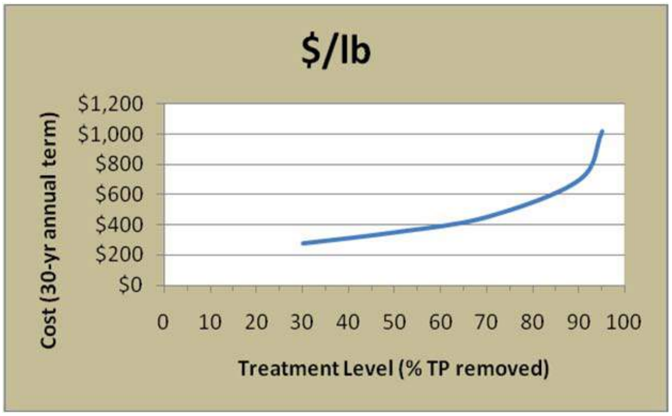
1. Overland Flow - We used WinSLAMM to estimate pollutant generation from the backyards of lakeshore homes. We created a custom WinSLAMM standard land use that replicated typical Green Lakeshore properties, including half of the home's roof, backyard and landscaping. In our base model the runoff from these surfaces flowed over sandy backyard soils to the lake. In our proposed project models the runoff was directed through a vegetated swale at the water's edge.
2. Eroding Lakeshore Face - We used a modified version of the Wisconsin NRCS streambank erosion method to calculate sediment loss from the lakeshore face, and then calculated phosphorus in that sediment using the MN Board of Water and Soil Resources (BWSR) water erosion pollutant calculator for streams and ditches. Assumptions for the NRCS bank erosion method included a 1.2 ft tall eroding face with an lateral recession rate of 0.12 feet/year (moderate erosion). The bulk density of the eroded material was assumed to be 100 lbs per cubic foot, the NRCS published value for sandy loam. This yielded an estimation of pounds of eroded material lost per year. The phosphorus content of that material was calculated based on a conversion factor of one pound of phosphorus per 1,481 pounds of soil, as derived from the BWSR erosion calculator.

We categorized candidate lakeshore restoration sites as either "good candidates" or "high priorities." Good candidates were sites that lacked a vegetated buffer at least 5 feet deep from the lakeshore and had active instability/erosion. High priority sites additionally had overland flow concentrations

converging at the site and would be especially well suited to a vegetated buffer to filter that water. Paths of concentrated flow were determined using the NRCS Terrain Analysis tools for GIS, with LiDAR data.

Cost Estimates

Cost estimates were annualized costs that incorporated design, installation, installation oversight, and maintenance over a 30-year period. In cases where promotion to landowners is important, such as rain gardens and lakeshore restorations, those costs were included as well. In cases where multiple, similar projects are proposed in the same locality, promotion and administration costs were estimated using a non-linear relationship that accounted for savings with scale. Design assistance from an engineer is assumed for practices in-line with the stormwater conveyance system, involving complex stormwater treatment interactions, or posing a risk for upstream flooding. It should be understood that no site-specific construction investigations were done as part of this stormwater assessment, and therefore cost estimates account for only general site considerations.

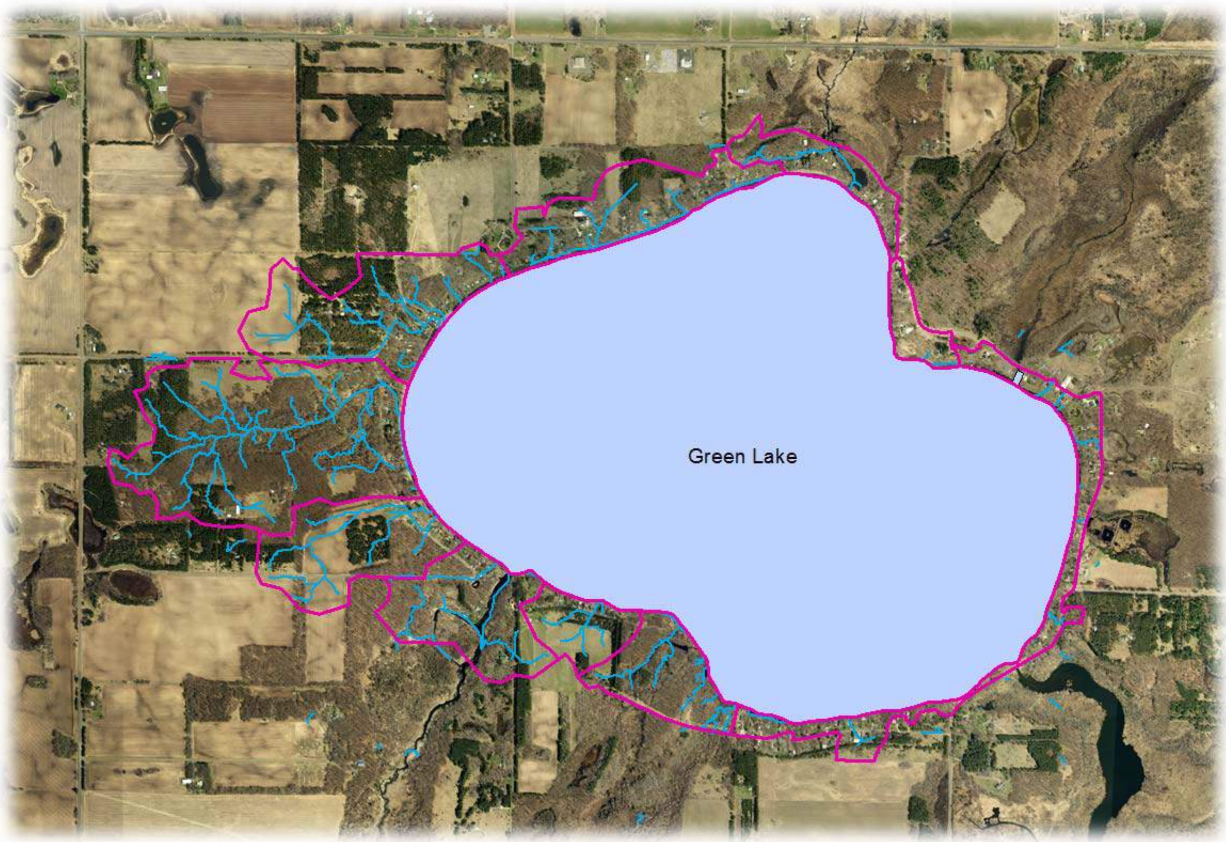


The costs associated with several different pollution reduction levels were calculated in certain cases. Generally, more or larger practices result in greater pollution removal. However the costs of obtaining the highest levels of treatment are often prohibitively expensive (see figure). By comparing costs of different treatment levels, the project partners can best choose the project sizing that meets their goals.

Step 5: Evaluation and Ranking

The cost per pound of phosphorus treated was calculated for each potential retrofit project, and projects were ranked by this cost effectiveness measure. Only projects that seem realistic and feasible were considered. The recommended level was the level of treatment that would yield the greatest benefit per dollar spent while being considered feasible and not falling below a minimal amount needed to justify crew mobilization and outreach efforts. Local officials may wish to revise the recommended level based on water quality goals, finances or public opinion.

Appendix B.
Green Lake Subwatershed Retrofit Analysis for Areas Draining Directly to the Lake



Green Lake
Subwatershed Retrofit Analysis
For Areas Draining Directly to the Lake

Prepared by:

Isanti Soil and Water Conservation District
in partnership with the Metro Conservation Districts

Funding provided by the Clean Water Fund
(from the Clean Water, Land and Legacy Amendment)

August 14, 2014

Contents

Executive Summary

Green Lake is located within Wyanett Township of Isanti County, Minnesota. This study provides recommendations for cost effectively improving treatment of stormwater in areas draining directly to the lake (i.e. the near lake area), with the purpose of lake water quality improvement. It does not cover areas that drain to Green Lake through a stream. This report provides sufficient detail to identify projects, rank projects by cost effectiveness at removing phosphorus and begin project planning. It includes project concepts and relative cost estimates for project selection. Site specific planning, designs and refined cost estimates should be done after committed partnerships for project installation are in place. This study should be considered one part of an overall watershed restoration strategy which includes the entire lake's watershed.

The 866 acre Green Lake has been designated as "impaired" for not meeting state water quality standards for nutrient eutrophication – excess phosphorus. The lakeshore is heavily developed, but the larger watershed is a mixture of rural residential, agricultural and open space. The lakeshore homeowners have formed a lake improvement district to organize and fund aquatic invasive species treatment and water quality improvement efforts.

This stormwater analysis focuses on "stormwater retrofitting." Stormwater retrofitting refers to adding stormwater treatment to an already built-up area. This process is investigative and creative. While stormwater conveyances (curbs, gutters, pipes) are largely absent around Green Lake, overland channel flow and practices at the water's edge do deliver pollutants to the lake. Stormwater treatment is largely absent around Green Lake because much of it developed before modern day stormwater treatment requirements, or on a parcel-by-parcel basis without comprehensive stormwater treatment planning.

Stormwater retrofitting success is sometimes improperly judged by the number of projects installed or by comparing costs alone. Those approaches neglect to consider how much pollution is removed per dollar spent. In this stormwater analysis we estimated both costs and pollutant reductions and used them to calculate cost effectiveness of each possible project.

Areas that drain to Green Lake were delineated using available GIS subwatershed information. Those areas were then divided into 11 smaller stormwater drainage areas, or catchments. For each catchment, modeling of stormwater volume and pollutants was completed using the software WinSLAMM. Base and existing conditions were modeled, including accounting for existing stormwater treatment practices. In the case of eroding lakeshore, we modeled runoff to that lakeshore in WinSLAMM, calculated bank erosion using the Wisconsin NRCS Field Office Technical Guide method, and added the two.

The total subwatershed analyzed for this project consisted of 489 acres. These areas contribute an estimated 40.5 acre feet of runoff, 60 pounds of phosphorus, and 15,051 pounds of total suspended solids to Green Lake each year. Lakeshore erosion contributes an estimated additional 24.4 pounds of phosphorus and 137,057 pounds of total suspended solids.

In comparison, a 1995 diagnostic study of Green Lake by Water Research and Management, Inc. estimated that total phosphorus loading to the lake is 3584 lbs per year. In other words, the direct drainage area represents approximately 2.3% of the phosphorus loading to the lake. It is noteworthy, however, that the near-lake residents are often most motivated to voluntarily install water quality improvement projects. Aside from pollutant reduction, water's edge projects can improve habitat, which is beneficial to the lake fishery.

Potential stormwater retrofits were identified using GIS tools and field investigation. Green Lake Improvement District members identified some of the projects and gave agency staff a tour of these potential projects. Staff did additional desktop and field investation, identifying additional projects. Concept designs for projects were developed and modeled to estimate reductions in volume, total phosphorus, and total suspended solids. Cost estimates were developed for each project, including 30 years of operations and maintenance. Projects were ranked by cost effectiveness with respect to their reduction of total phosphorus. At some sites, multiple project concepts were considered.

A variety of stormwater retrofit project types were identified. They included:

- Residential curb-cut rain gardens,
- Diverting water to swales,
- Land purchase for protection from further development,
- Permeable pavement,
- Trench grate sediment traps,
- Hydrodynamic separators, and
- Lakeshore restorations.

If the most cost effective practice were installed at each project site, 20.7 pounds of phosphorus would be prevented from reaching the lake. This would be a 23% reduction of the phosphorus from the study area. Note that this is not a simple addition of all possible projects because in some cases there is more than one project option at a site.

Funding limitations and landowner interest may make installing all projects difficult. Instead, it is recommended that projects be installed in order of cost effectiveness (pounds of pollution reduced per dollar spent). Other factors, including a project's educational value/visibility, construction timing, total cost or non-target pollutant reduction also affect project installation decisions and will need to be weighed by resource managers when selecting projects to pursue.

This report provides conceptual sketches or photos of recommended stormwater retrofitting projects. The intent is to provide an understanding of the approach. If a project is selected, site-specific designs must be prepared. Some require engineered feasibility studies and plan sets. This typically occurs after committed partnerships are formed to install the project. Committed partnerships must include willing landowners when installed on private property.

The tables on the next pages summarize potential projects. Potential projects are organized from most cost effective to least. Reported treatment levels are dependent upon optimal site selection and sizing. More detail about each project can be found in the remainder of this report.

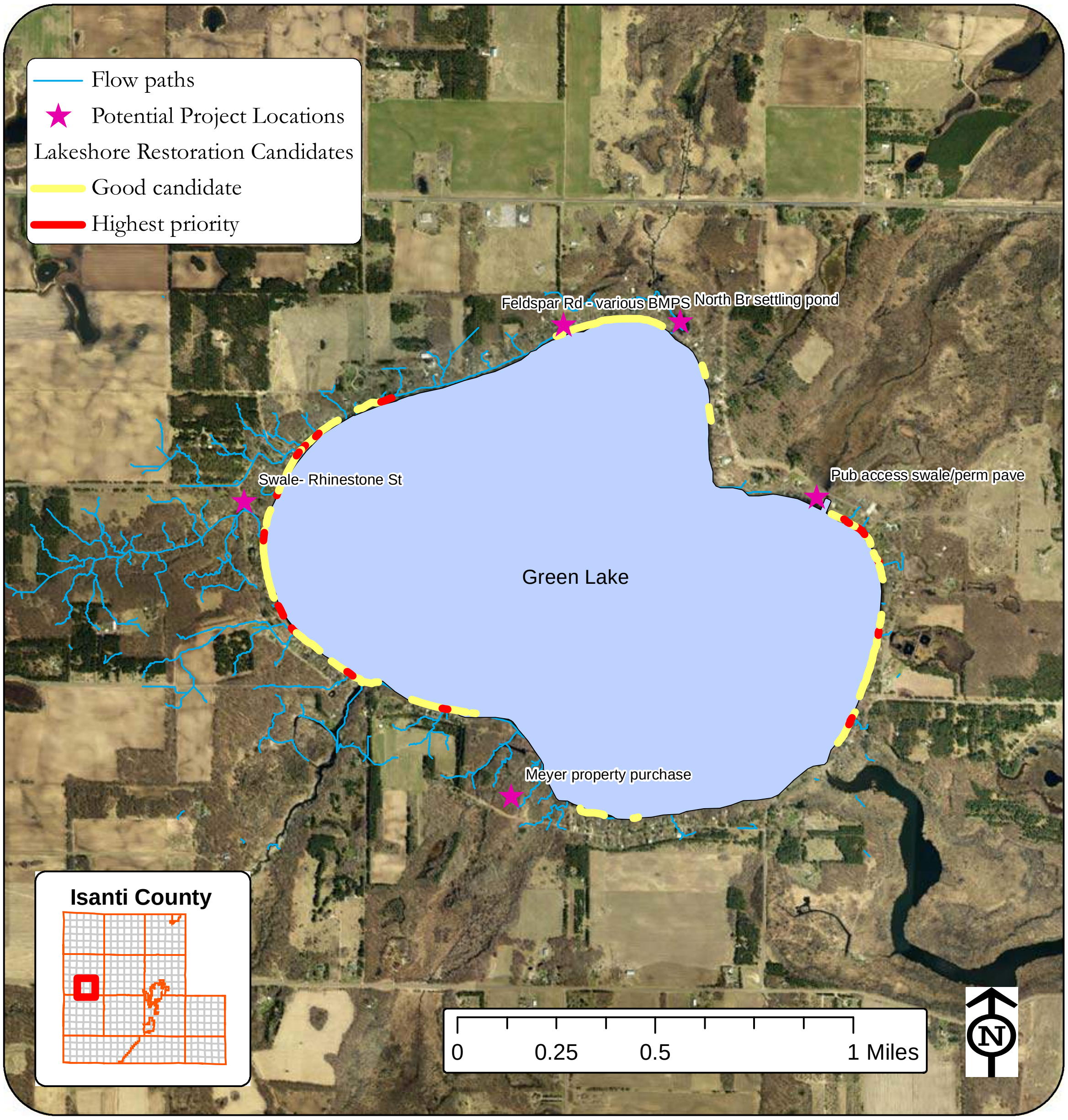
The approaches in this report are consistent with the Green Lake Improvement District Management Plan for 2013-2018. Portions of that plan that are at least partially accomplished by this study include producing a survey of shoreline conditions to prioritize need for restoration, providing information about rain gardens and prioritizing placement, and moving closer to 'shovel ready' projects for water quality improvement.

This study covered only areas draining directly to the lake due to funding limitations. A similar study of the remainder of the watershed should be done so that all projects for the lake can be judged relative to each other's cost effectiveness. Such a study appears likely for 2015-16. Projects in the lake's direct drainage area are an important part of improving water quality, but will be insufficient alone.

Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness with respect to total phosphorus (TP) reduction.
Volume and total suspended solids (TSS) reductions are also shown. For more information on each project refer to the catchment profile pages in this report.

Project Rank	Catchment ID	Retrofit Type (refer to catchment profile pages for additional detail)	Projects Identified	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Total Project Cost	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ 1,000lb-TSS (30-year)	Estimated cost/ lb-TP (30-year)	Notes/Description
1	GL-9	Rain gardens - Feldspar St	2	0.7	186	0.4	$29,550	$450	$7,715	$2,050	Pave gravel road that washes out into the lake, install 2 rain gardens.
2	GL-1	Swale - public boat parking	1	0.3	134	0.3	$15,541	$100	$4,612	$2,060	Redirect boat landing runoff into the lakeshore swale.
3	GL-9	Grass swale at bottom of Feldspar St (road not paved)	1	0.6	175	0.4	$22,472	$840	$8,149	$2,648	A grass swale at the water's edge of Feldspar St, which currently runs into the lake.
4	GL-3	Land protection - 62 acres	1	8.9	2736	7.7	$611,910	$6,000	$9,648	$2,966	Purchase fee title or an easement for property on SW side of the lake, currently for sale.
5	Lakeshore	Lakeshore restoration - All 95 Candidate Sites	95	10.7	137,028	0.4	$437,770	$21,375	$262	$3,352	Restore all candidate lakeshore restoration sites, or some lesser amount. Offers habitat benefits in addition to water quality.
6	Lakeshore	Lakeshore restoration - 15 High Priority Sites	15	1.6	20,871	0.1	$70,129	$3,375	$274	$3,505	Restore the 15 candidate lakeshores where active erosion and concentrated flow occur.
7	GL-9	Permeable asphalt - 20% of Fedlspar St	1	0.7	222	0.5	$59,334	$1,000	$13,414	$4,254	Pave gravel road that washes out into the lake, including 20% permeable pavement.
8	GL-7	Diversion to swale - Rhinestone St	1	0.1	26	0.3	$11,509	$100	$18,601	$4,836	Divert street runoff to roadside swale. Some diversion already occurs due to road crowning.
9	GL-1	Permeable asphalt - 20% public boat parking	1	0.6	317	0.9	$61,884	$1,200	$10,293	$5,438	Install permeable asphalt on 20% of public boat landing parking.
10	GL-9	Trench grate sediment traps - Feldspar St	1	0.4	74	0.0	$35,415	$1,000	$34,591	$5,535	Pave gravel road that washes out into the lake, including trench grate sediment traps.
11	GL-9	Hydrodynamic device - Feldspar St	1	0.4	39	0.0	$41,014	$1,500	$75,451	$7,168	Pave gravel road that washes out into the lake, including commercial hydrodynamic separator.
Further examination needed											
12	GL-10	Settling pond - North Branch Creek	1	undetermined							Would treat runoff from a greater area than the scope of this study.
Considered but excluded											
13	GL-4	Swale - 330th Avenue	1	0.0	0	0.0	$8,278	$450	no benefit	no benefit	Swale on undeveloped lot at saddle in road. Modeling found no benefit.

Potential Water Quality Improvement Projects



About this Document

Lake Management Planning

This Stormwater Retrofit Analysis is a watershed management tool to help prioritize water quality improvement projects by performance and cost effectiveness. This process helps maximize the value of each dollar spent.

It is part of larger efforts including the Green Lake Improvement District's (GLID) Lake Management Plan for 2013-2018, Isanti County Water Plan and others. Some of the objectives of the GLID plan that significantly advanced by this work are listed in the table below.

Green Lake Improvement District's (GLID) 2013-2018 Lake Management Plan objectives which are advanced by this study.

Green Lake Management Plan Strategies	Advancement by this study
Strategy 1: Produce visual data of the shoreline of Green Lake by videotaping or producing low flying photos to determine extent of vegetation degradation and prioritize need for restoration	Completed
Strategy 2: Work with the Isanti County Local Water Management Plan to fund and restore native vegetation to eroded/mowed sites.	Funding need quantified. Project sites identified and prioritized.
Strategy 3: Provide information on workshops for design and management of rain gardens to prevent overland runoff into the lake and benefits of "no-mow" on shorelines.	High priority sites identified.
Strategy 8: Work with landowners, Isanti County Zoning and PICKM to provide "shovel ready" projects such as rain gardens and/or shoreline re-vegetation projects for prevention of stormwater runoff within the drainage area of Green Lake.	Project concepts and cost estimates prepared.
Strategy 12: Work with Anoka County SWCD to determine a stormwater assessment for the catchments of Green Lake.	Completed for directly draining areas.
Strategy 32: Provide information to property owners on the benefits of native vegetation to the water quality of the lake and for wildlife habitat.	Highest priority properties identified. Information sufficient to write compelling grant applications.
Strategy 30: Work with the DNR and Soil and Water Conservation District to identify and preserve the sensitive areas of Green Lake.	Highest priority properties identified.
Strategy 34: Provide info to property owners on the benefits of native vegetation to the water quality] and for wildlife habitat. Strategy 35: Educate the Green Lake property owners on the impacts of alterations of the natural shoreline areas…	Identified properties with lakeshore erosion or runoff problems. Quantified shoreline impacts and benefits of restorations.

It is expected that this study contains a framework for on-the-ground projects to improve Green Lake. Installing these projects will require the efforts of the GLID, Isanti Soil and Water Conservation District, and County Water Planning team. There is a need for a broader study that examines the remainder of the watershed not covered in this study.

Document Organization

This document is organized into three major sections, plus references and appendices. Each section is briefly described below.

Methods

The methods section outlines general procedures used when analyzing the subwatershed. It overviews the processes of retrofit scoping, desktop analysis, retrofit reconnaissance investigation, cost/treatment analysis, and project ranking.

Catchment Profiles

The subwatershed directly draining to Green Lake was divided into stormwater catchments for the purpose of this analysis. Each catchment was given a unique ID number. For each catchment, the following information is detailed:

Catchment Description

Within each catchment profile is a table that summarizes basic catchment information including acres, land cover, parcels, and estimated annual pollutant and volume loads. A brief description of the land cover, stormwater infrastructure, and any other important general information is also described. Existing stormwater practices are noted, and their estimated effectiveness presented.

Retrofit Recommendations

The recommendation section describes the conceptual retrofit(s) that were scrutinized. It includes tables outlining the estimated pollutant removals by each, as well as costs. A map provides promising locations for each retrofit approach.

Retrofit Ranking

This section ranks stormwater retrofit projects across all catchments to create a prioritized project list. The list is sorted by cost per pound of total phosphorus removed for each project over 30 years. The final cost per pound treatment value includes installation and maintenance costs.

There are many possible ways to prioritize projects, and the list provided in this report is merely a starting point. Other considerations for prioritizing installation may include:

- Non-target pollutant reductions
- Timing projects to occur with other road or utility work
- Project visibility
- Availability of funding
- Total project costs
- Educational value

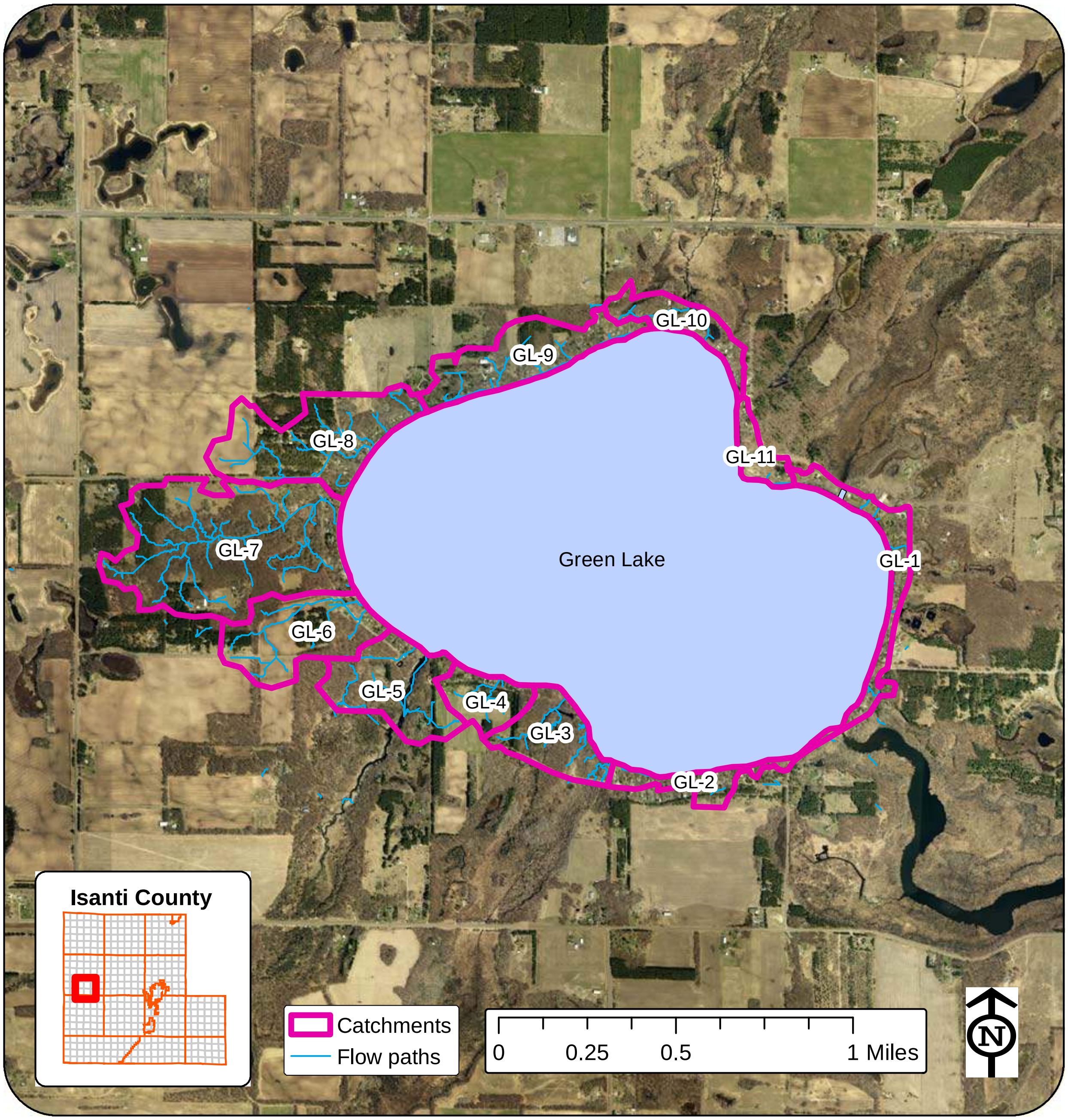
Descriptions of the pollutants of interest in this study.

Pollutant	Description
Total Phosphorus (TP)	A nutrient essential to the growth of organisms, and is commonly the limiting factor in the primary productivity of surface water bodies, including algal blooms in lakes. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particle form. (adapted from MPCA website)
Total Suspended Solids (TSS)	Very small particle remaining dispersed in a liquid due to turbulent mixing that can create turbid or cloudy conditions (MPCA website). TSS is important because of the brown or cloudy appearance it imparts on the water, smothering of fish habitat that can occur and other pollutants that can be attached to the particles.

References

This section identifies various sources of information synthesized to produce the protocol utilized in this analysis.

Map of catchments referred to in this report. Catchment profiles on the following pages provide additional detail.



Methods

Selection of Subwatershed

Many factors are considered when choosing which subwatershed to assess for stormwater retrofits, but always focus on the drainage to an important lake, river, or stream. Water quality monitoring data, non-degradation report modeling, and TMDL studies are just a few of the resources available to help determine which water bodies are a priority. Assessments supported by a Local Government Unit with sufficient capacity (staff, funding, available GIS data, etc.) to greater facilitate the assessment also rank highly. For some communities a stormwater assessment complements their MS4 stormwater permit. The focus is always on a high priority waterbody.

For this assessment, portions of the Green Lake subwatershed were chosen for study. Green Lake is a major recreational lake that is impaired due to excess phosphorus. The lake's watershed is over 12,000 acres. Due to limited funding, this study was able to examine only the 489 acres directly draining to the lake (i.e. not through streams). This area was chosen because its proximity to the lake translates into direct water quality impacts, it is the area of densest development in the watershed, has little or no stormwater treatment and because near-lake landowners are often most vested in the lake's water quality and a Lake Improvement District (LID) covers this area and is a valuable partner for installing projects.

Targeted pollutants for this study were total phosphorus and total suspended solids. Total phosphorus is a nutrient commonly associated with stormwater that causes excessive algae production and low oxygen levels in lakes and rivers. Green Lake is listed as "impaired" by the MN Pollution Control Agency for excessive phosphorus. Total suspended solids was also chosen as a target pollutant because it is also commonly associated with stormwater and causes turbidity in lakes and rivers. Suspended solids are also important because many other pollutants, such as phosphorus heavy metals, are attached to the particles. Volume of stormwater was tracked throughout this study because it is necessary for pollutant loading calculations and retrofit project considerations.

Stormwater pollutants – Pollutants studied by this stormwater assessment were phosphorus and total suspended solids. Example sources include street grime (top left and center), runoff from parking (top right), and lakeshore erosion and backyard runoff (bottom).

1.2

Subwatershed Assessment Methods

The process used for this assessment is outlined below and was modified from the Center for Watershed Protection's *Urban Stormwater Retrofit Practices,* Manuals 2 and 3 (Schueler, 2005, 2007). Locally relevant design considerations were also incorporated into the process (*Minnesota Stormwater Manual*).

Step 1: Retrofit Scoping

Retrofit scoping includes determining the objectives of the retrofits (volume reduction, target pollutant, etc.) and the level of treatment desired. It involves meeting with local land use managers and lake improvement district members to determine the issues in the subwatershed. This step also helps to define preferred retrofit treatment options and retrofit performance criteria. In order to create a manageable area to assess in large subwatersheds, a focus area may be determined.

Step 2: Desktop Retrofit Analysis

The desktop analysis involves computer-based scanning of the subwatershed for potential retrofit catchments and/or specific sites. This step also identifies areas that don't need to be assessed because of existing stormwater infrastructure. Accurate GIS data are extremely valuable in conducting the desktop retrofit analysis. Some of the most important GIS layers include: 2-foot or finer topography, hydrology, soils, watershed/subwatershed boundaries, parcel boundaries, high-resolution aerial photography and the storm drainage infrastructure (with invert elevations).

For this assessment, digital records of stormwater infrastructure were unimportant because few or no stormwater conveyances exist. High-resolution aerial photography and parcel boundaries were available from Isanti County. LiDAR fine topography data was available from the State.

Desktop retrofit analysis features to look for and associated potential stormwater retrofit projects.

Feature	Potential Retrofit Project
Flow concentration	Swales, infiltration practices, grade stabilization.
Existing Ponds	Add storage and/or improve water quality by excavating pond bottom, modifying riser, raising embankment, and/or modifying flow routing.
Open Space	New regional treatment (pond, bioretention).
Roadway Culverts	Add wetland or extended detention water quality treatment upstream.
Outfalls	Split flows or add storage below outfalls if open space is available.
Conveyance system	Add or improve performance of existing swales, ditches and non-perennial streams.
Large Impervious Areas (campuses, commercial, parking)	Stormwater treatment on site or in nearby open spaces.
Neighborhoods	Utilize right of way, roadside ditches, curb-cut rain gardens, or filtering systems to treat stormwater before it enters storm drain network.

Step 3: Retrofit Reconnaissance Field Investigation

After identifying potential retrofit sites through the desktop search, a field investigation was conducted to evaluate each site and identify additional opportunities. During the investigation, the drainage area and stormwater infrastructure mapping data were verified. Site constraints were assessed to determine the most feasible retrofit options as well as eliminate sites from consideration. The field investigation may have revealed additional retrofit opportunities that went unnoticed during the desktop search.

In addition to car and foot based field investigation, a survey of the lakeshore was completed for Green Lake by boat. This allowed staff to document stormwater outfalls, inventory the shoreline condition and see potential project locations from a different perspective. One boat tour was done with lake improvement district members to benefit from their knowledge and a second tour was done with staff alone to gather detailed data.

General list of stormwater BMPs considered for each catchment/site.

Stormwater Treatment Options for Retrofitting		
Area Treated	**Best Management Practice**	**Potential Retrofit Project**
5-500 acres	Extended Detention	**12-24 hr detention of stormwater with portions drying out between events (preferred over wet ponds). May include multiple cell design, infiltration benches, sand/peat/iron filter outlets and modified choker outlet features.**
	Wet Ponds	**Permanent pool of standing water with new water displacing pooled water from previous event.**
	Wetlands	**Depression less than 1-meter deep and designed to emulate wetland ecological functions. Residence times of several days to weeks. Best constructed off-line with low-flow bypass.**
0.1-5 acres	Bioretention	**Use of native soil, soil microbe and plant processes to treat, evapotranspirate, and/or infiltrate stormwater runoff. Facilities can either be fully infiltrating, fully filtering or a combination thereof.**
	Filtering	**Filter runoff through engineered media and passing it through an under-drain. May consist of a combination of sand, soil, compost, peat, and iron.**
	Infiltration	**A trench or sump that is rock-filled with no outlet that receives runoff. Stormwater is passed through a conveyance and pretreatment system before entering infiltration area.**
	Swales	**A series of vegetated, open channel practices that can be designed to filter and/or infiltrate runoff.**
	Other	**On-site, source-disconnect practices such as rain-leader disconnect rain gardens, rain barrels, green roofs, cisterns, stormwater planters, dry wells, or permeable pavements.**

Step 4: Treatment Analysis/Cost Estimates

Sites most likely to be conducive to addressing the pollutant reduction goals and appearing to have feasible design, installation, and maintenance were chosen for a cost/benefit analysis. Estimated costs included design, installation, and maintenance annualized across the anticipated project lifespan (10-30 yrs). Estimated benefits included are pounds of phosphorus and total suspended solids removed, though projects were ranked only by cost per pound of phosphorus removed annually.

Treatment analysis

For each potential project (except lakeshore restorations, see next section) pollutant removal estimates were obtained using the stormwater model WinSLAMM. WinSLAMM uses an abundance of stormwater data from the upper Midwest and elsewhere to quantify runoff volumes and pollutant loads from urban areas. It is useful for determining the effectiveness of proposed stormwater control practices. It has detailed accounting of pollutant loading from various land uses, and allows the user to build a model “landscape” that reflects the actual landscape being considered. The user is allowed to place a variety of stormwater treatment practices that treat water from various parts of this landscape. It uses rainfall and temperature data from a typical year, routing stormwater through the user’s model for each storm.

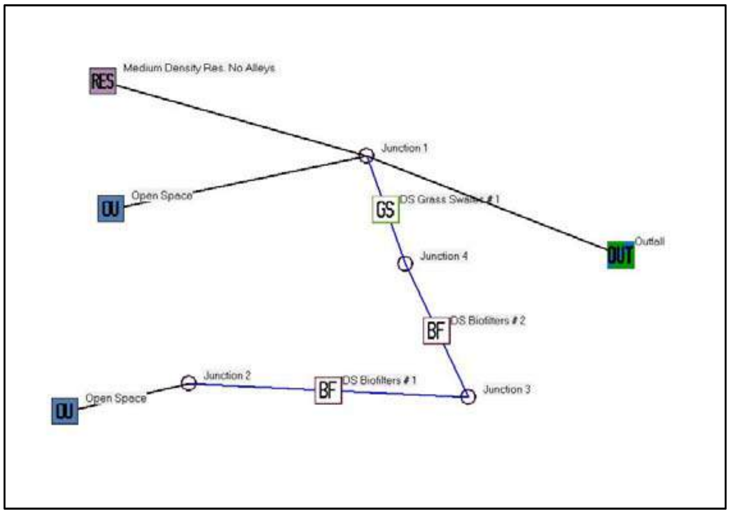
A “base” model was created which estimated pollutant loading from each catchment in its present-day state. To accurately model the land uses in each catchment, we delineated each land use in each catchment using ArcGIS, and assigned each a WinSLAMM standard land use file. A site specific land use file was created by adjusting total acreage and converting to “sand” soils to account for the sandy soils in the study area. This process resulted in a model that included estimates of the acreage of each type of source area (roof, road, lawn, etc.) in each catchment. For certain source areas critical to our models we verified that model estimates were accurate by measuring actual acreages in ArcGIS and adjusting the model acreages if needed.

Once the “base” model was created, each proposed stormwater treatment practice was added to the model and pollutant reductions were generated. Because neither a detailed design of each practice nor in-depth site investigation was completed, a generalized design for each practice was used. Whenever possible, site-specific parameters were included. Design parameters were modified to obtain various levels of treatment. It is worth noting that we modeled each practice individually, and the benefits of projects may not be additive, especially if serving the same area. Reported treatment levels are dependent upon optimal site selection and sizing.

WinSLAMM stormwater computer model inputs

General WinSLAMM Model Inputs	
Parameter	**File/Method**
Land use acreage	**ArcGIS**
Precipitation/Temperature Data	**Minneapolis 1959 – the rainfall year that best approximates a typical year.**
Winter season	**Included in model. Winter dates are 11-4 to 3-13.**
Pollutant probability distribution	**WI_GEO01.ppd**
Runoff coefficient file	**WI_SL06 Dec06.rsv**
Particulate solids concentration file	**WI_AVG01.psc**
Particle residue delivery file	**WI_DLV01.prr**
Street delivery files	**WI files for each land use.**

Example WinSLAMM stormwater model schematic



Lakeshore Erosion and Runoff Pollutant Estimation

WinSLAMM modeling alone could not accurately estimate pollutants generated from eroding lakeshore, nor the pollutant reduction that may occur by installing a project. To estimate lakeshore pollutants, we used a two-step process that accounted for (1) overland flow from lakeshore backyards plus (2) the eroding lakeshore face.

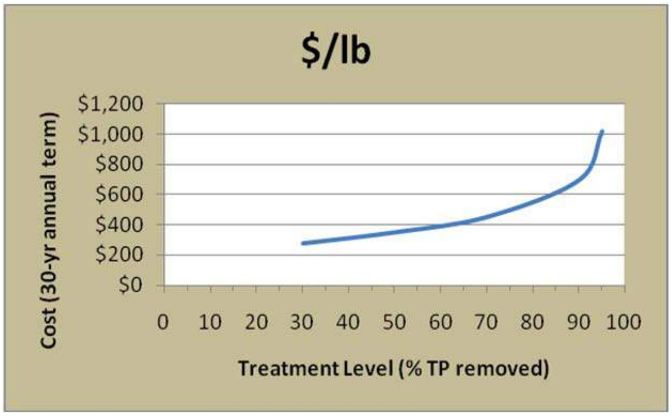
1. <u>Overland Flow -</u> We used WinSLAMM to estimate pollutant generation from the backyards of lakeshore homes. We created a custom WinSLAMM standard land use that replicated typical Green Lakeshore properties, including half of the home's roof, backyard and landscaping. In our base model the runoff from these surfaces flowed over sandy backyard soils to the lake. In our proposed project models the runoff was directed through a vegetated swale at the water's edge.
2. <u>Eroding Lakeshore Face -</u> We used a modified version of the Wisconsin NRCS streambank erosion method to calculate sediment loss from the lakeshore face, and then calculated phosphorus in that sediment using the MN Board of Water and Soil Resources (BWSR) water erosion pollutant calculator for streams and ditches. Assumptions for the NRCS bank erosion method included a 1.2 ft tall eroding face with an lateral recession rate of 0.12 feet/year (moderate erosion). The bulk density of the eroded material was assumed to be 100 lbs per cubic foot, the NRCS published value for sandy loam. This yielded an estimation of pounds of eroded material lost per year. The phosphorus content of that material was calculated based on a conversion factor of one pound of phosphorus per 1,481 pounds of soil, as derived from the BWSR erosion calculator.

We categorized candidate lakeshore restoration sites as either "good candidates" or "high priorities." Good candidates were sites that lacked a vegetated buffer at least 5 feet deep from the lakeshore and had active instability/erosion. High priority sites additionally had overland flow concentrations

converging at the site and would be especially well suited to a vegetated buffer to filter that water. Paths of concentrated flow were determined using the NRCS Terrain Analysis tools for GIS, with LiDAR data.

Cost Estimates

Cost estimates were annualized costs that incorporated design, installation, installation oversight, and maintenance over a 30-year period. In cases where promotion to landowners is important, such as rain gardens and lakeshore restorations, those costs were included as well. In cases where multiple, similar projects are proposed in the same locality, promotion and administration costs were estimated using a non-linear relationship that accounted for savings with scale. Design assistance from an engineer is assumed for practices in-line with the stormwater conveyance system, involving complex stormwater treatment interactions, or posing a risk for upstream flooding. It should be understood that no site-specific construction investigations were done as part of this stormwater assessment, and therefore cost estimates account for only general site considerations.



The costs associated with several different pollution reduction levels were calculated in certain cases. Generally, more or larger practices result in greater pollution removal. However the costs of obtaining the highest levels of treatment are often prohibitively expensive (see figure). By comparing costs of different treatment levels, the project partners can best choose the project sizing that meets their goals.

Step 5: Evaluation and Ranking

The cost per pound of phosphorus treated was calculated for each potential retrofit project, and projects were ranked by this cost effectiveness measure. Only projects that seem realistic and feasible were considered. The recommended level was the level of treatment that would yield the greatest benefit per dollar spent while being considered feasible and not falling below a minimal amount needed to justify crew mobilization and outreach efforts. Local officials may wish to revise the recommended level based on water quality goals, finances or public opinion.

How to Read Catchment Profiles

Much of the remainder of this report is pages referred to as "Catchment Profiles." These profiles provide the important details for each of this study's 11 catchments, including:

- Summary of existing conditions, including existing stormwater infrastructure, and estimated pollutant export to Coon Lake
- Map of the catchment
- Recommended stormwater retrofits, pollutant reductions, and costs.

Following all of the catchment profiles (and also in the executive summary) is a summary table that ranks all projects in all catchments by cost effectiveness.

To save space and avoid being repetitive, explanations of the catchment profiles are provided below. We strongly recommend reviewing this section before moving forward in the report.

The analyses of each catchment are broken into "base, existing, and proposed" conditions. They are defined as follows:

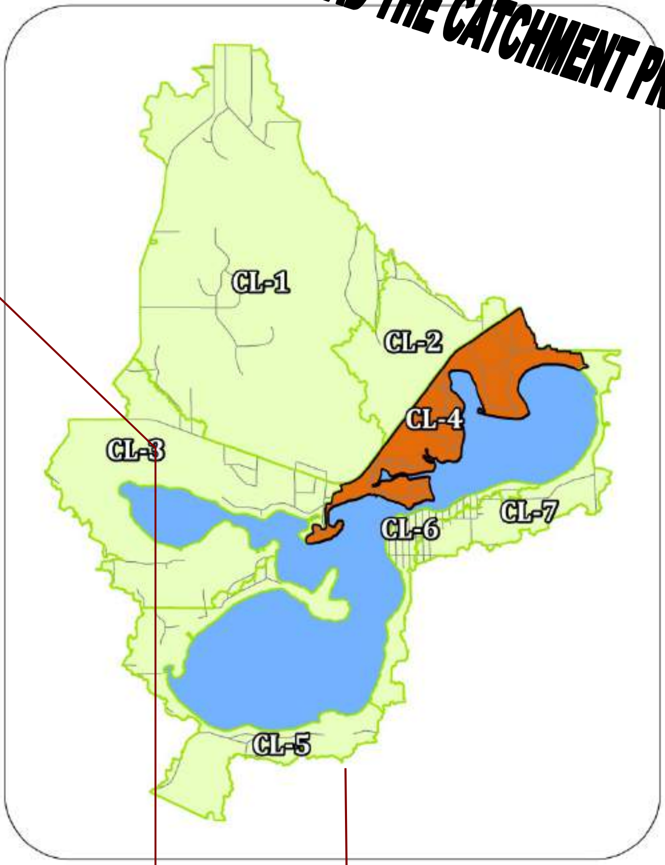
Base conditions -	Volume and pollutant loadings from the catchment landscape without any stormwater practices.
Existing conditions -	Volume and pollutant loadings after already-existing stormwater practices, if any, are taken into account.
Proposed conditions -	Volume and pollutant loadings after proposed stormwater retrofits.

The example catchment profile on the following pages explains important features of each profile.

EXAMPLE Catchment A

HOW TO READ THE CATCHMENT PROFILES

Existing Catchment Summary	
Acres	58.90
Dominant Land Cover	Residential
Parcels	237
TP (lb/yr)	131.2
TSS (lb/yr)	36,410
Volume (acre-feet/yr)	95.2



CATCHMENT DESCRIPTION
Example Catchment is primarily comprised of medium-density, single-family residential development…

EXISTING STORMWATER TREATMENT
Existing stormwater treatment practices within Example Catchment consist of street cleaning with a mechanical sweeper in the spring and fall and a network of stormwater treatment ponds…

Catchment ID banner.

Volume and pollutants generated from this catchment under existing conditions, and excludes existing network-wide treatment practices

Catchment locator map.

HOW TO READ THE CATCHMENT PROFILES

Catchment-level analysis of existing conditions.

EXAMPLE Catchment Specific Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Grass swale, street sweeping			
	TP (lb/yr)	140.5	11.4	8%	**129.1**
	TSS (lb/yr)	39,928	4,769.0	12%	**35,159**
	Volume (acre-feet/yr)	90.5	0.9	1%	**89.6**

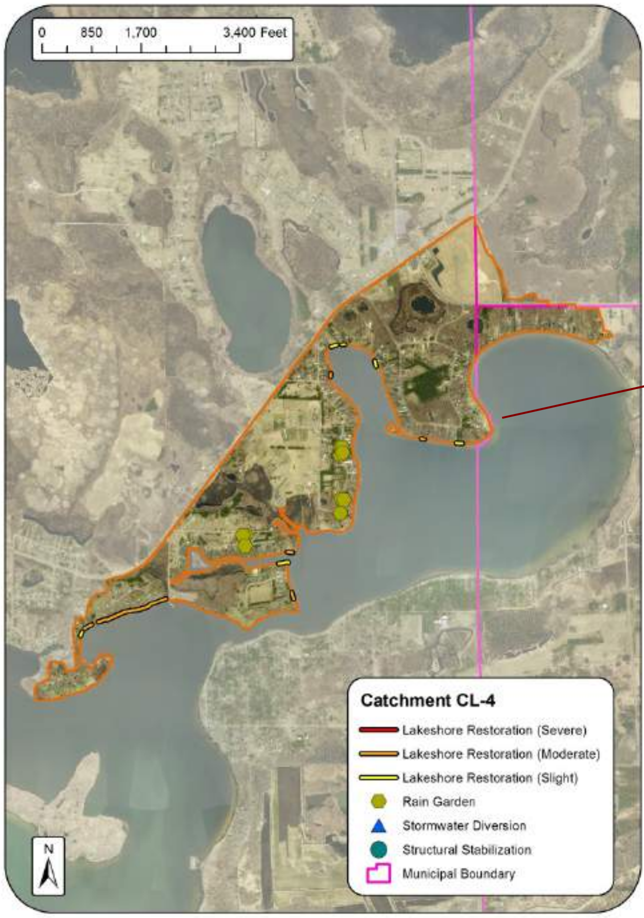
Volume of water and pounds of pollutants generated from the catchment without any stormwater management practices (base conditions).

Pollutants and volume <u>removed</u> by existing stormwater management practices (existing conditions).

Percent reductions by existing practices.

Pollutants and volume exiting the catchment after existing practices.

HOW TO READ THE CATCHMENT PROFILES



Map shows catchment boundaries, stormwater infrastructure (where available), and the locations of proposed stormwater retrofits.

Proposed stormwater retrofits. The project ID corresponds to this project's catchment and project type.

RETROFIT RECOMMENDATIONS

Project ID: CL-4 Residential Rain Gardens

Drainage Area – 18.8 acres
Location – Central portion of catchment CL-4 along Front Blvd., Hupp St., and Channel Lane
Property Ownership – Private
Description – Most stormwater pollutants generated in this catchment derive from the residential properties along the lake. Little space is available for large retrofits which can treat multiple properties along the lakeshore. However, there are some opportunities to install curb-cut rain gardens (see Appendix C for design options). Up to ten ideal rain garden locations were identified (see map on the previous page). Generally, ideal rain garden locations are immediately up-gradient of a catch basin serving a large drainage area. Considering typical landowner participation rates, scenarios with 1, 2 and 4 rain gardens were analyzed to treat the residential land use. Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table.

HOW TO READ THE CATCHMENT PROFILES

EXAMPLE Catchment Specific Cost/Benefit Analysis

Volume or pollutant removal this project will achieve.

Three "levels" of this project are compared: 1, 2, or 4 rain gardens, for example.

Cumulative pollutant removal achieved by this project and already-existing practices.

Curb-Cut Rain Gardens

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1		2		4	
	Total Size of BMPs	250	sq-ft	500	sq-ft	1,000	sq-ft
	TP (lb/yr)	0.6	0.5%	1.1	0.9%	1.9	1.5%
	TSS (lb/yr)	190	0.6%	335	1.0%	592	1.7%
	Volume (acre-feet/yr)	0.4	0.4%	0.8	0.9%	1.4	1.6%
Cost	Administration & Promotion Costs*	$4,234		$8,468		$11,096	
	Design & Construction Costs**	5,876		11,752		23,504	
	Total Estimated Project Cost (2014)	**$10,110**		**$20,220**		**$34,600**	
	Annual O&M***	$225		$450		$900	
Efficiency	30-yr Average Cost/lb-TP	**$937**		**$1,022**		**$1,081**	
	30-yr Average Cost/1,000lb-TSS	**$2,958**		**$3,355**		**$3,468**	
	30-yr Average Cost/ac-ft Vol.	**$1,405**		**$1,405**		**$1,467**	

*For 1-2 gardens: 58 hours/BMP at $73/hour

*For 4 gardens: (104 hours at $73/hour base cost) + (12 hours/BMP at $73/hour)

**($20/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150 for 10-year rehabilitation) + ($75 for routine maintenance)

Notes on how costs were determined.

Project installation cost estimation.

Cost effectiveness at phosphorus removal. The project cost is divided by phosphorus removal in pounds (30 yrs). Includes operations and maintenance (O&M) over the project life (30 years unless otherwise noted).

Cost effectiveness at suspended solids removal. The project cost is divided by suspended solids removal in pounds (30 yrs). Includes operations and maintenance (O&M) over the project life (30 years unless otherwise noted).

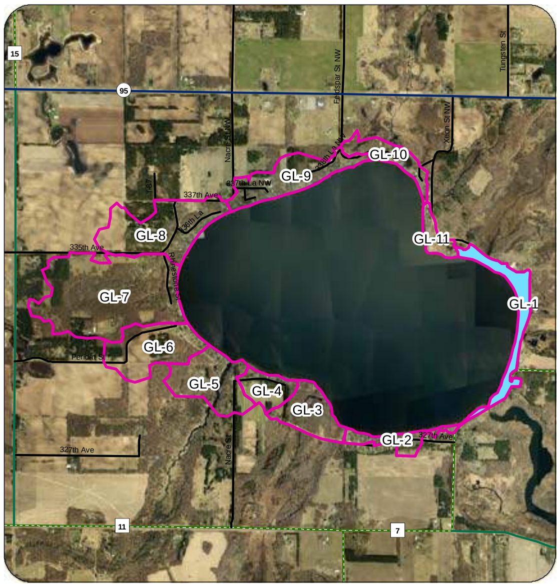
Compare cost effectiveness of various project "levels" in these rows for phosphorus or suspended solids removal. Compare cost effectiveness numbers between projects to determine the best value.

Green Lake Catchment Profiles

See the following pages for profiles of each catchment and an analysis of proposed projects in each.

Catchment GL-1

Existing Catchment Summary	
Acres	30
Dominant Land Cover	Residential
Parcels	46
TP (lbs/yr)	9.1
TSS (lbs/yr)	3,022
Volume (acre-feet/yr)	5.8



CATCHMENT DESCRIPTION

Catchment GL-1 is on the eastern shore of Green Lake along Xenon Street. It includes residential areas and the DNR-owned public boat landing.

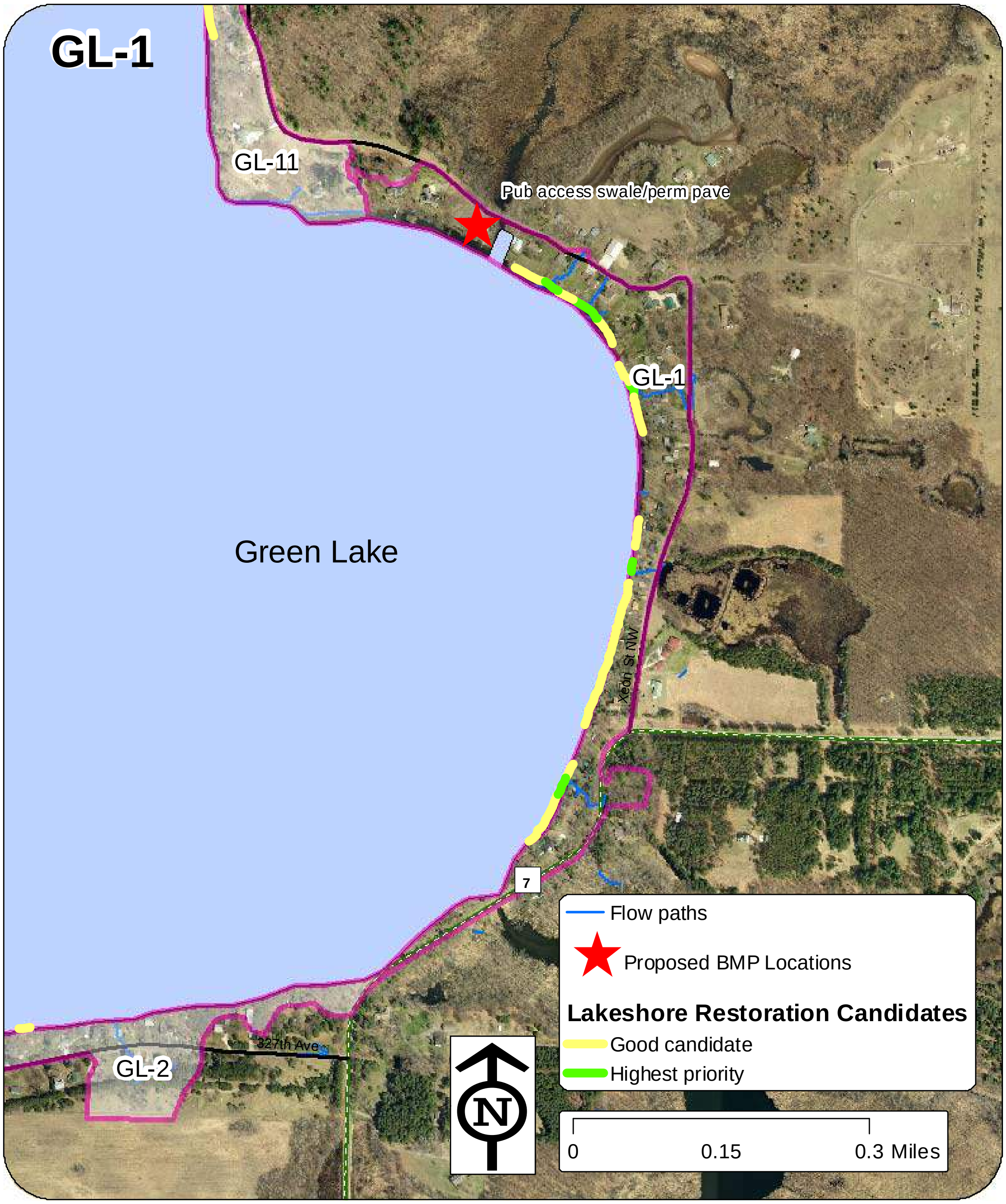
EXISTING STORMWATER TREATMENT

There is currently no treatment of stormwater generated in this catchment. The table below shows the pollutant loading to the lake from this catchment.

EXISTING CONDITIONS

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	0			
	Total Size of BMPs	None			
	TP (lb/yr)	9.1	0.0	0%	**9.1**
	TSS (lb/yr)	3,022	0.0	0%	**3,022**
	Volume (acre-feet/yr)	5.8	0.0	0%	**5.8**

RETROFIT RECOMMENDATIONS



Project ID: GL-1 Swale at Public Boat Parking

Drainage Area – 1.24 acres
Location – East side of Green Lake along Xenon Street.
Property Ownership – Public – MN DNR
Description – Presently, the public boat landing's parking lot primarily drains to the boat dock. This is evidenced by the placement of rock to prevent washouts and topography (see map below). Treatment of this water could be accomplished by diverting it into an existing swale between the pavement and lakeshore. Diversion could be accomplished by installing diagonal speed bumps or trench grates. Trench grates were considered in this analysis.
The swale is approximately 25 feet wide by 175 feet long. However water would be diverted to only the lower portion of the swale, so only about 60 feet of it was considered to be providing treatment. The swale is filled with lake water during flood conditions, and would provide no treatment at those times.

Conceptual images –

Cost effectiveness analysis – Swale at public boat landing

	Public Boat Access		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	Number of BMPs		
	Total Size of BMPs	30	ln ft
	TP (lb/yr)	0.3	3.3%
	TSS (lb/yr)	134	4.4%
	Volume (acre-feet/yr)	0.3	5.0%
Cost	Administration & Promotion Costs*	$1,460	
	Design & Construction Costs**	14,081	
	Total Estimated Project Cost (2014)	**$15,541**	
	Annual O&M***	$100	
Efficiency	**30-yr Average Cost/lb-TP**	**$2,060**	
	30-yr Average Cost/1,000lb-TSS	**$4,612**	
	30-yr Average Cost/ac-ft Vol.	**$2,131**	

Project ID: ML-1 Permeable Pavement at Public Boat Parking

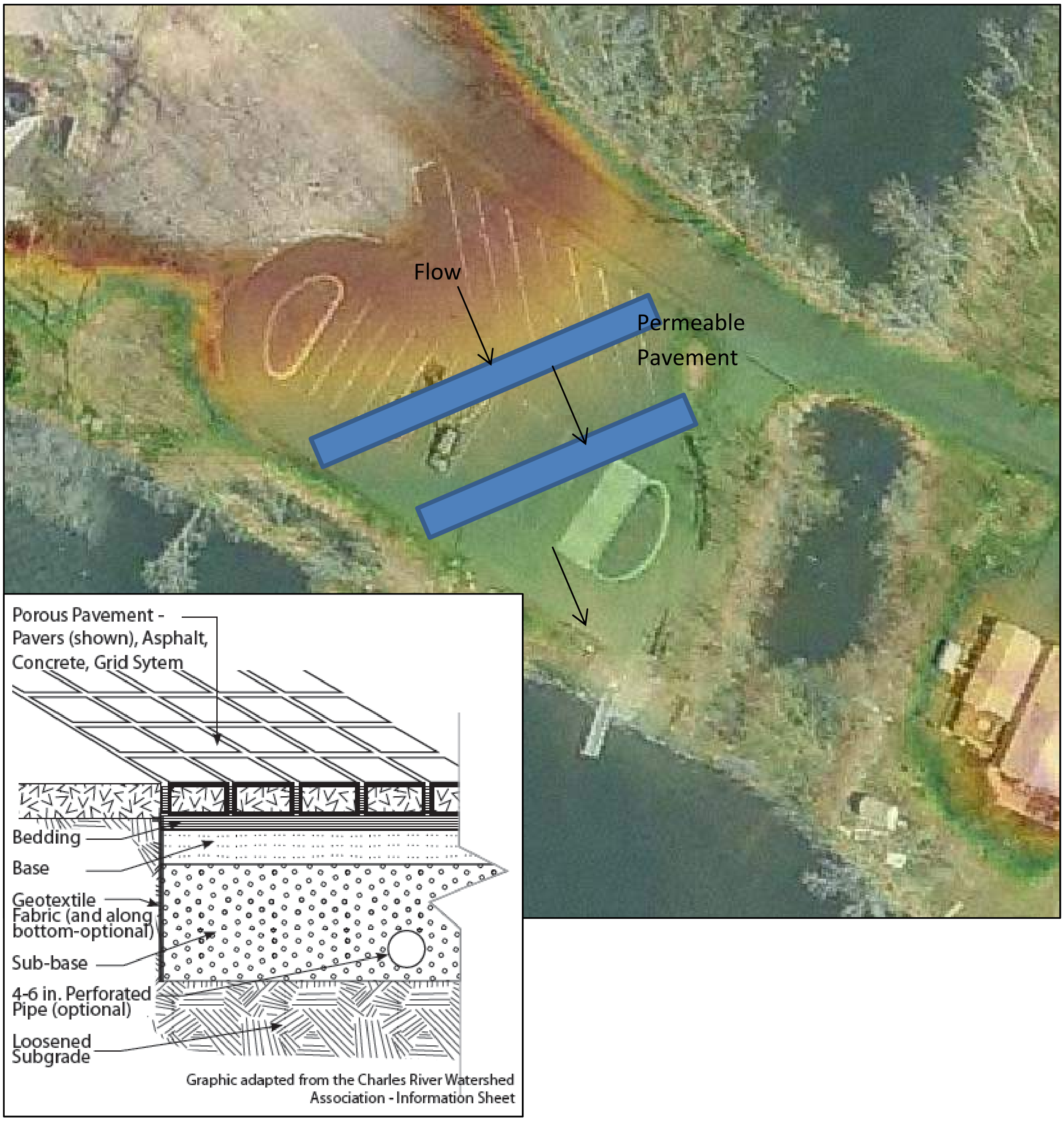
Drainage Area – 1.24 acres

Location – East side of Green Lake along Xenon Street.

Property Ownership – Public – MN DNR

Description – Presently, the public boat landing's parking lot primarily drains to the boat dock. This is evidenced by the placement of rock to prevent washouts and topography (see map below). Treatment of this water could be accomplished by infiltration through permeable pavement. Most of the parking lot could be treated by strategically placed strips of permeable pavement.

Conceptual images –



Source: Metro Conservation Districts

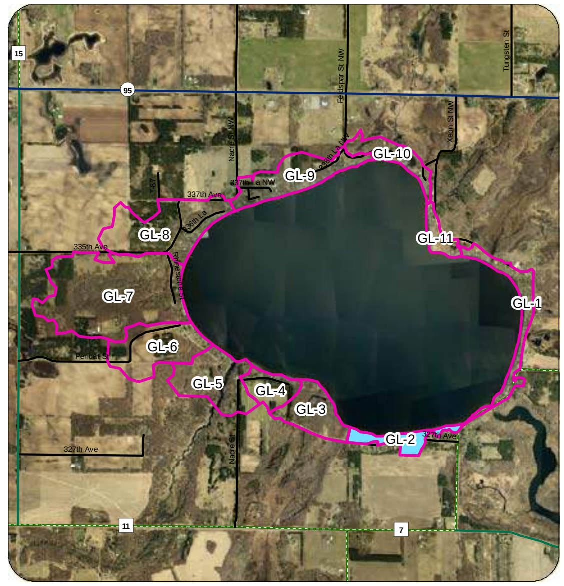
Cost effectiveness analysis – Permeable pavement at public boat parking

We considered three scenarios of permeable asphalt at the public boat landing: Replacing 10%, 20% and 30% of the existing pavement with permeable asphalt. The lowest cost per pound of phosphorus removed is achieved with just 10% permeable asphalt, however 20% should be considered because the incremental cost increase is small and the performance of permeable asphalt will decrease over time if not vacuumed. Vacuum cleaning would probably be very infrequent because street sweeping does not regularly occur in the area.

	Permeable Asphalt						
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	10% Perm Asphalt		20% Perm Asphalt		30% Perm Asphalt	
	Total Size of BMPs	2,831	sq-ft	5,663	sq-ft	9,147	sq-ft
	TP (lb/yr)	0.5	5.5%	0.6	6.6%	0.6	6.6%
	TSS (lb/yr)	290	9.6%	317	10.5%	327	10.8%
	Volume (acre-feet/yr)	0.8	14.0%	0.9	15.3%	0.9	15.8%
Cost	Administration & Promotion Costs*	$4,380		$4,380		$4,380	
	Design & Construction Costs**	$29,190		$57,504		$92,346	
	Total Estimated Project Cost (2014)	**$33,570**		**$61,884**		**$96,726**	
	Annual O&M***	$1,000		$1,200		$1,400	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,238**		**$5,438**		**$7,707**	
	30-yr Average Cost/1,000lb-TSS	**$7,307**		**$10,293**		**$14,141**	
	30-yr Average Cost/ac-ft Vol.	**$2,584**		**$3,642**		**$4,994**	

Catchment GL-2

Existing Catchment Summary	
Acres	16
Dominant Land Cover	Residential
Parcels	29
TP (lbs/yr)	7.9
TSS (lbs/yr)	2,296
Volume (acre-feet/yr)	6.6



CATCHMENT DESCRIPTION

Catchment GL-5 consists of medium density residential. The catchment is narrow band of land along the lakeshore with little room for stormwater treatment.

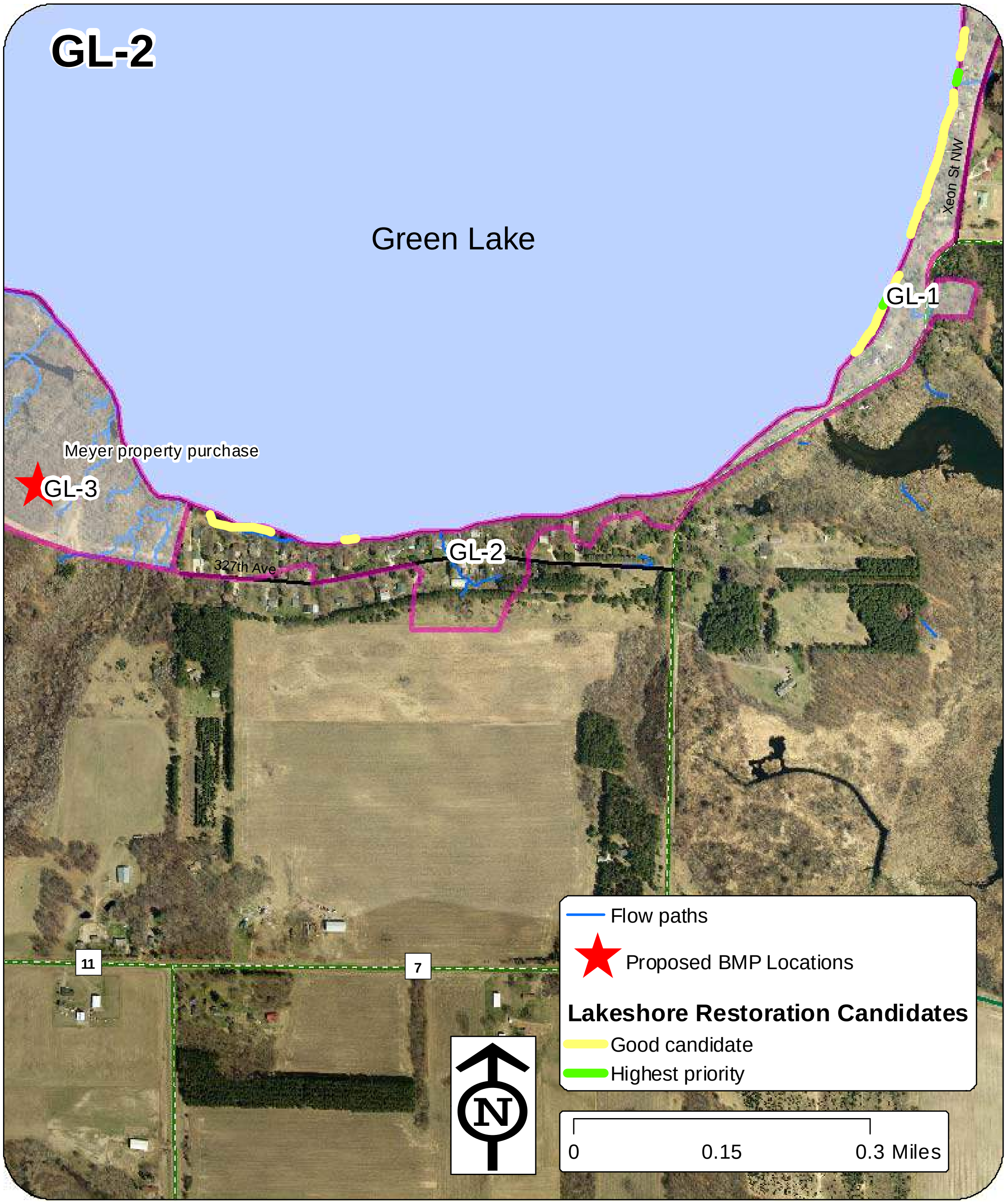
EXISTING STORMWATER TREATMENT

There is currently no treatment of stormwater in this catchment. The table below shows the pollutant loading to the lake from this catchment.

EXISTING CONDITIONS

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	0			
	Total Size of BMPs	None			
	TP (lb/yr)	7.9	0.0	0%	**7.9**
	TSS (lb/yr)	2,296	0.0	0%	**2,296**
	Volume (acre-feet/yr)	6.6	0.0	0%	**6.6**

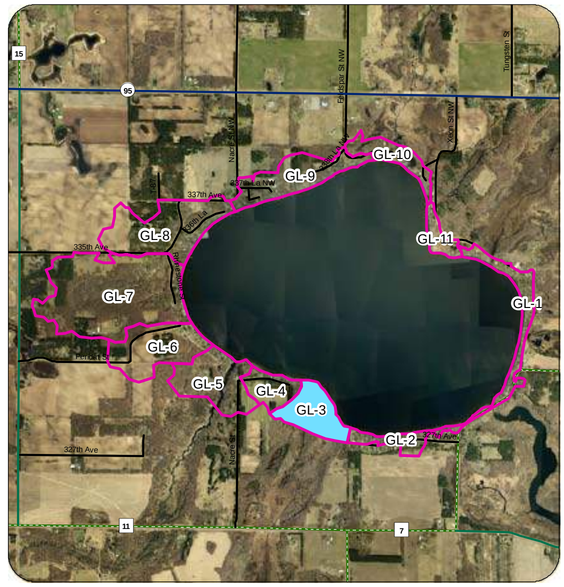
RETROFIT RECOMMENDATIONS



No proposed projects identified - The only stormwater projects recommended for this catchment are lakeshore restorations, which are covered separately in a later section.

Catchment GL-3

Existing Catchment Summary	
Acres	33
Dominant Land Cover	Forest
Parcels	1
TP (lbs/yr)	2.0
TSS (lbs/yr)	56
Volume (acre-feet/yr)	1.2



CATCHMENT DESCRIPTION

Catchment GL-3 consists almost entirely of one vacant property. That property has been singled out as a potential site for land protection that will benefit the lake.

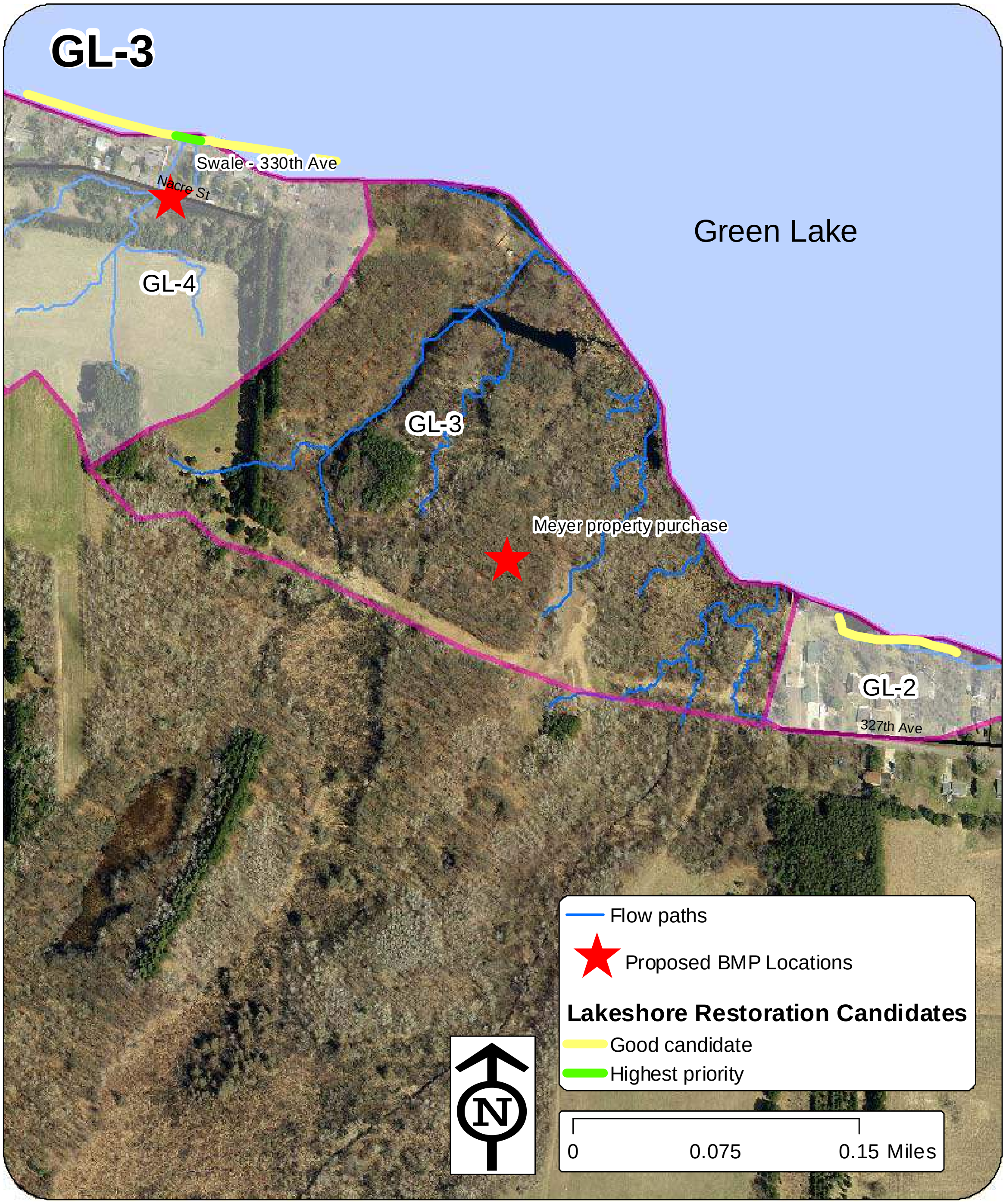
EXISTING STORMWATER TREATMENT

There is currently no treatment of stormwater in this catchment, however because it is vacant land in a relatively natural state no constructed treatment would be expected. The table below shows the pollutant loading to the lake from this catchment in its current condition.

EXISTING CONDITIONS

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	0			
	Total Size of BMPs	None			
	TP (lb/yr)	2.0	0.0	0%	**2.0**
	TSS (lb/yr)	56	0.0	0%	**56**
	Volume (acre-feet/yr)	1.2	0.0	0%	**1.2**

RETROFIT RECOMMENDATIONS



Project ID: GL-3 Land Protection

Location – This property is the majority of catchment GL-3.
Property Ownership – Private
Description – The 62 acre property that makes up the majority of catchment GL-3 was for sale at the time of this report writing. The purchase price is approximately $545,000. Much of the property is lowland and not suitable for development, but approximately 17 acres is upland that may be suitable for development. If developed, it is anticipated that various wetland crossings, fill or excavation could occur, in addition to impervious surfaces that would generate new stormwater discharges to the lake.

We modeled this property in its current state, and with 17 acres developed. Without new stormwater controls, new medium density residential development would export 8.9 lbs of phosphorus and 2,736 lbs of suspended solids per year to the lake above the present day condition. Additionally, there would likely be habitat loss through land clearing, lakeshore clearing and wetland filling/excavation.

This property should be considered for protection. This could occur through fee title purchase, purchase as part of the DNR's Aquatic Management Area Program, purchase of development rights or easements. Isanti County Parks was asked to look at this property, but it did not fit into their long range planning and budget.

At the time this report is being prepared, purchase of this property by a new private landowner is rumored to be underway. If that is the case and development is being considered, local units of government should address land protection options with the new owner. If development becomes imminent, requiring robust stormwater treatment and minimizing wetland filling or excavation should be a high priority.

Conceptual images – The land considered for protection is highlighted in blue below.

Cost effectiveness analysis – Land protection by purchase of 62 acres

	Land Protection		
	Cost/Removal Analysis	**New Pollutants Prevented**	**% Reduction**
Treatment	Number of BMPs	1	
	Total Size of BMPs	62	acres
	TP (lb/yr)	8.9	NA
	TSS (lb/yr)	2,736	NA
	Volume (acre-feet/yr)	7.7	NA
Cost	Administration & Promotion Costs*	$66,910	
	Property Purchase**	$545,000	
	Total Estimated Project Cost (2014)	**$611,910**	
	Annual O&M***	$6,000	
Efficiency	**30-yr Average Cost/lb-TP**	**$2,966**	
	30-yr Average Cost/1,000lb-TSS	**$9,648**	
	30-yr Average Cost/ac-ft Vol.	**$3,447**	

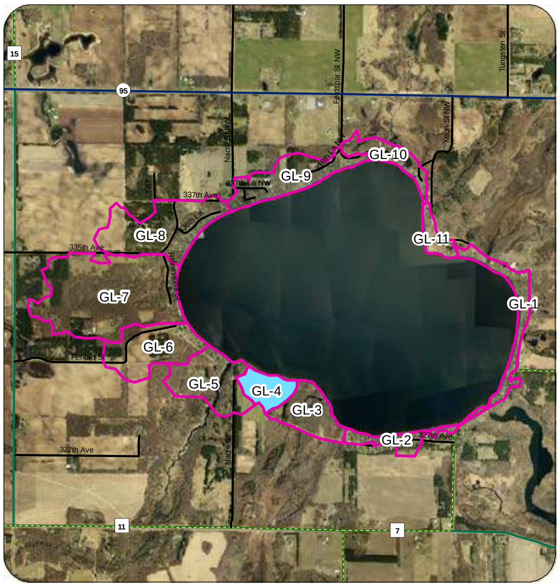
*Indirect Cost: Realator (7% of purchase price)+ $5,000 closing costs + 120 hours at $73/hr staff time + $15,000 demolish existing structures and site rehab.

**Excludes any costs to develop the parcel for public recreation, such as a park.

***$2,000/yr for property taxes + $2,000/yr for maintenance.

Catchment GL-4

Existing Catchment Summary	
Acres	21
Dominant Land Cover	Residential
Parcels	17
TP (lbs/yr)	1.3
TSS (lbs/yr)	366
Volume (acre-feet/yr)	0.9



CATCHMENT DESCRIPTION

Catchment GL-4 consists of a line of approximately 7 lakeshore homes, plus fields and woods to the south. Drainage is to the center of this catchment, where there is a flow path across the road, down a vacant lakeshore lot and into the lake. In reality, little surface runoff occurs because of the lack of impervious surfaces and soils with high infiltration capacity.

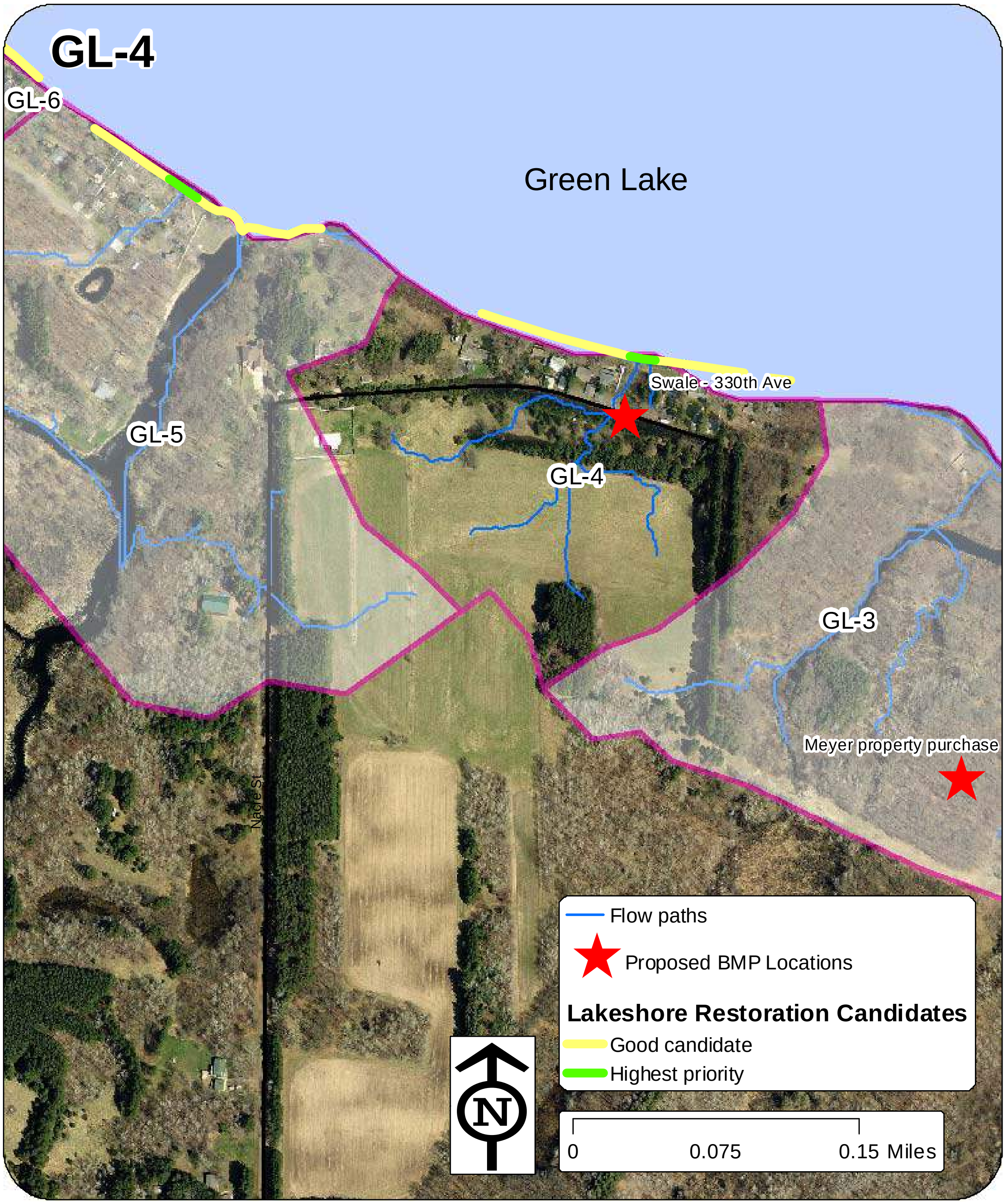
EXISTING STORMWATER TREATMENT

There is currently no intentional, man-made treatment of stormwater, however runoff is generally treated by a swale. Most runoff in the catchment concentrates in one location on 330th Avenue. From that spot it travels over a vacant lakeshore lot which serves like a vegetated swale, filtering runoff and allowing infiltration. The table below lists treatment that occurs through this process.

EXISTING CONDITIONS

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	Total Size of BMPs	100' lakeshore swale			
	TP (lb/yr)	1.8	0.5	28%	**1.3**
	TSS (lb/yr)	379	13.0	3%	**366**
	Volume (acre-feet/yr)	1.2	0.3	22%	**0.9**

RETROFIT RECOMMENDATIONS



Project ID: GL-4 Swale at 330th Avenue

Drainage Area – 14.61 acres
Location – The property east of 7057 330th Avenue.
Property Ownership – Private
Description – This vacant property currently serves like a swale for stormwater draining from much of the catchment. It is at a low spot in the landscape, funneling runoff to Green Lake. While already providing stormwater treatment, we investigated whether improvements could be made that would provide even more stormwater treatment.

We considered the addition of two check dams and unmowed vegetation along the existing swale. This would provide additional infiltration of stormwater. We found that no additional stormwater treatment would be achieved. The project was dropped from consideration.

Maintaining this private, vacant lot in its current condition should be a high priority. Mowing the grass short in this area is discouraged because it would reduce filtering and infiltration. It is notable that this property is a "high priority" location for a lakeshore restoration due to the concentration of overland flow and shoreline condition (see later in this report).

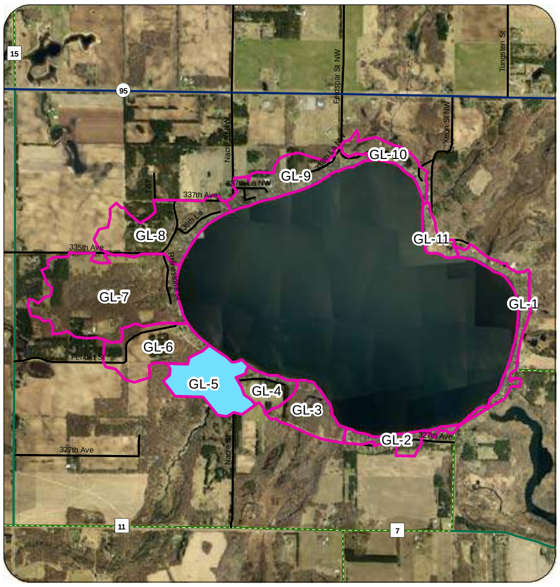
If this segment of 330th Avenue were ever paved (i.e. generating more stormwater) this project should be reconsidered. The vacant parcel would become critical for treatment. In that case, purchase of an easement or fee title on the parcel should be considered in order to allow more robust stormwater BMPs.

Cost effectiveness analysis – Swale at 330th Avenue

Check Dams Along Swale			
	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	2	
	Total Size of BMPs	500	sq-ft
	TP (lb/yr)	0.0	0.0%
	TSS (lb/yr)	0	0.0%
	Volume (acre-feet/yr)	0.01	1.1%
Cost	Administration & Promotion Costs*	$876	
	Design & Construction Costs**	7,402	
	Total Estimated Project Cost (2014)	**$8,278**	
	Annual O&M***	$450	
Efficiency	30-yr Average Cost/lb-TP	**No benefit**	
	30-yr Average Cost/1,000lb-TSS	**No benefit**	
	30-yr Average Cost/ac-ft Vol.	**$72,593**	

Catchment GL-5

Existing Catchment Summary	
Acres	49
Dominant Land Cover	Forest
Parcels	12
TP (lbs/yr)	4.9
TSS (lbs/yr)	1,213
Volume (acre-feet/yr)	3.6



CATCHMENT DESCRIPTION

Catchment GL-5 consists of a line of approximately 11 lakeshore homes, plus fields and woods to the southwest. Wyanett Creek, one of the two largest tributaries to Green Lake, flows through the middle of this catchment. Little surface runoff occurs because of the lack of impervious surfaces and soils with high infiltration capacity.

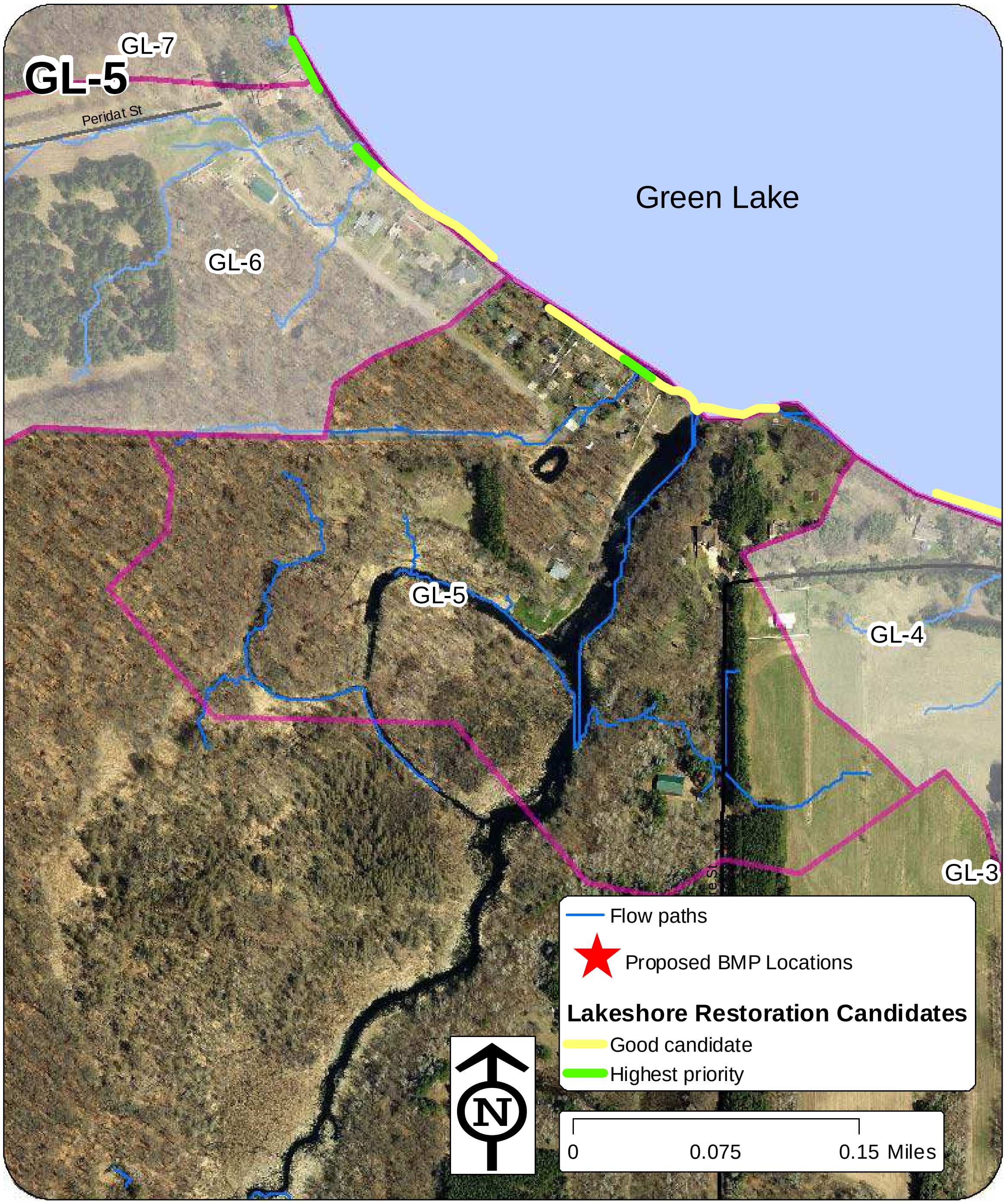
EXISTING STORMWATER TREATMENT

There is currently no intentional, man-made treatment of stormwater. The catchment generates little stormwater due to the amount of open space and lack of stormwater conveyances. The table below shows the pollutant loading to the lake from this catchment in its current condition.

EXISTING CONDITIONS

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	0			
	Total Size of BMPs	None			
	TP (lb/yr)	4.9	0.0	0%	**4.9**
	TSS (lb/yr)	1,213	0.0	0%	**1,213**
	Volume (acre-feet/yr)	3.6	0.0	0%	**3.6**

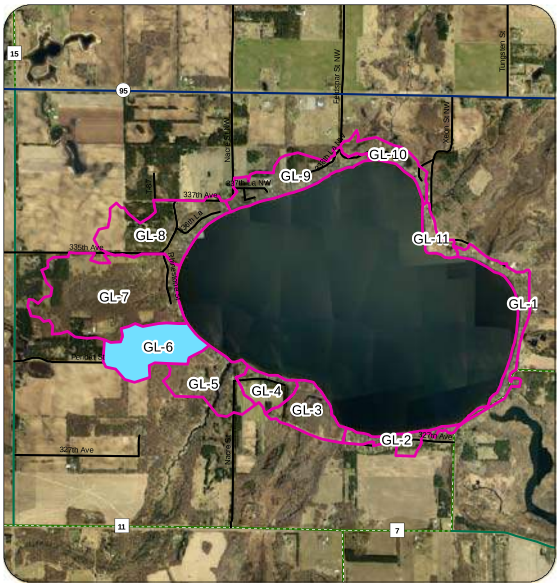
RETROFIT RECOMMENDATIONS



No proposed projects identified - The only stormwater projects recommended for this catchment are lakeshore restorations, which are covered separately in a later section.

Catchment GL-6

Existing Catchment Summary	
Acres	52
Dominant Land Cover	Forest
Parcels	7
TP (lbs/yr)	3.5
TSS (lbs/yr)	619
Volume (acre-feet/yr)	2.3



CATCHMENT DESCRIPTION

Catchment GL-6 consists of a line of approximately 6 lakeshore homes, 20 acres of woodland and 12 acres of agricultural fields. Little surface runoff occurs because of the lack of impervious surfaces and soils with high infiltration capacity.

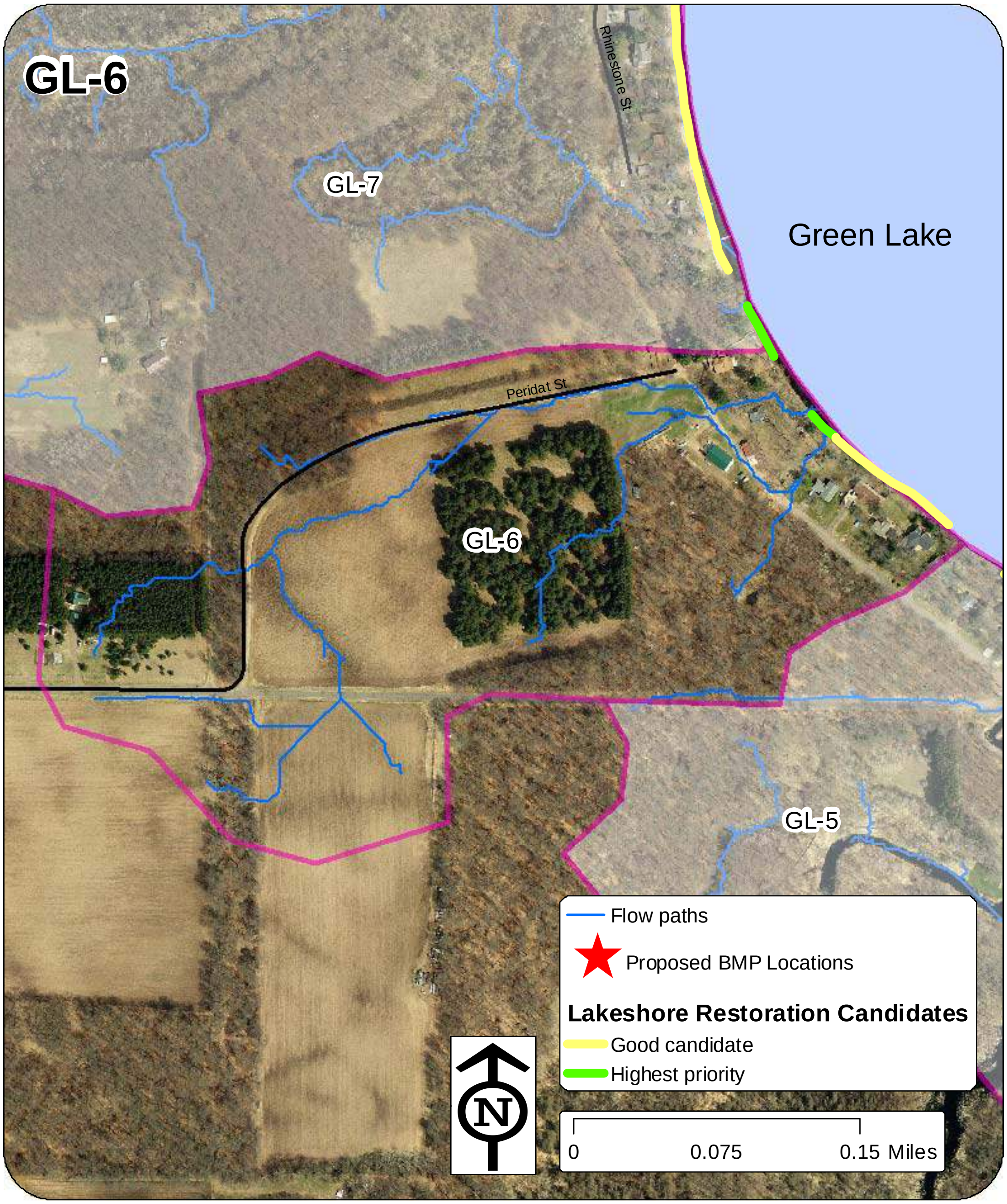
EXISTING STORMWATER TREATMENT

There is currently no intentional, man-made treatment of stormwater. The catchment generates little stormwater due to the large amount of open space and lack of stormwater conveyances. The table below shows the pollutant loading to the lake from this catchment in its current condition.

EXISTING CONDITIONS

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	0			
	Total Size of BMPs	None			
	TP (lb/yr)	3.5	0.0	0%	**3.5**
	TSS (lb/yr)	619	0.0	0%	**619**
	Volume (acre-feet/yr)	2.3	0.0	0%	**2.3**

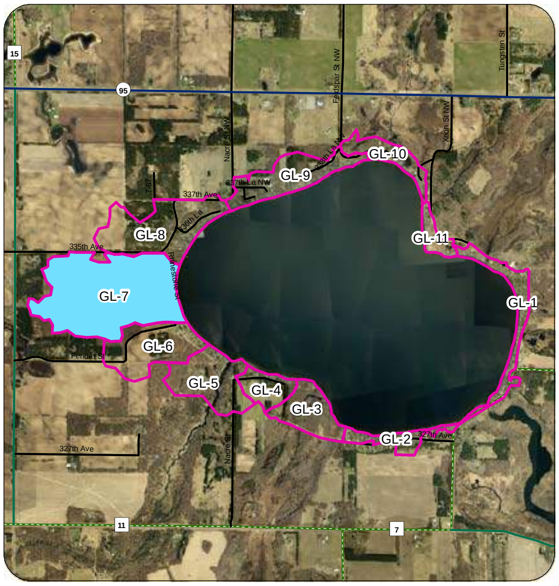
RETROFIT RECOMMENDATIONS



No proposed projects identified - The only stormwater projects recommended for this catchment are lakeshore restorations, which are covered separately in a later section.

Catchment GL-7

Existing Catchment Summary	
Acres	137
Dominant Land Cover	Forest
Parcels	29
TP (lbs/yr)	7.6
TSS (lbs/yr)	1,151
Volume (acre-feet/yr)	5.2



CATCHMENT DESCRIPTION

Catchment GL-7 consists of a line of approximately 12 lakeshore homes, but the majority is undeveloped woodland, wetland and grassland. A perennial stream flow through the middle of the catchment, crosses Rhinetone Street, and empties into the lake. Much of this catchment is lowland.

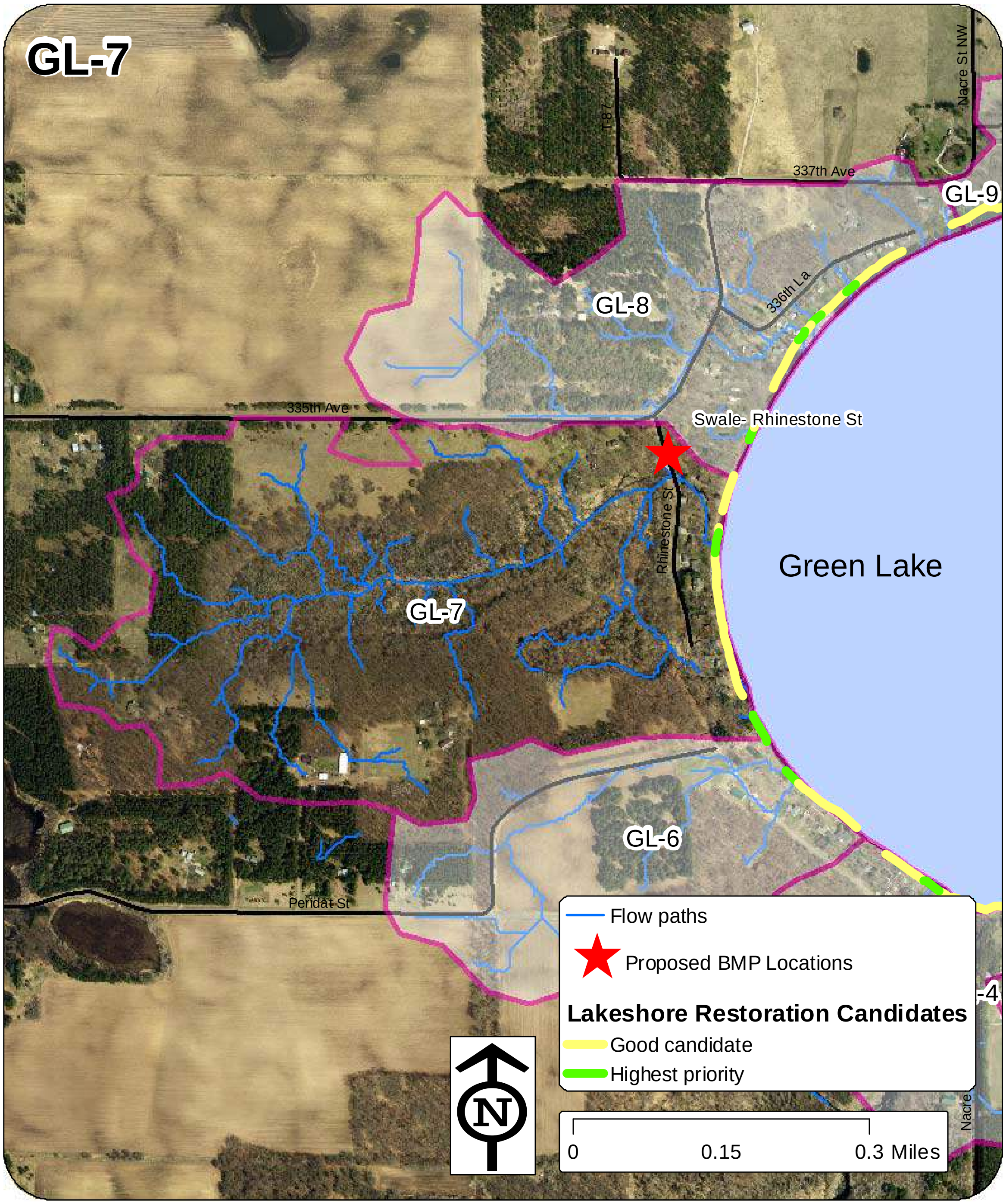
EXISTING STORMWATER TREATMENT

Some unintentional stormwater treatment occurs. Because of topography, approximately 30% of stormwater from Rhinestone Street ends up in roadside swales which lead to the stream. This swale affords modest treatment of the water. The table below lists treatment that occurs through this process.

EXISTING CONDITIONS

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	0			
	Total Size of BMPs	None			
	TP (lb/yr)	7.7	0.1	1%	**7.6**
	TSS (lb/yr)	1,165	14.0	1%	**1,151**
	Volume (acre-feet/yr)	5.3	0.2	3%	**5.2**

RETROFIT RECOMMENDATIONS



Project ID: GL-7 Rhinestone Street Diversion to Swale

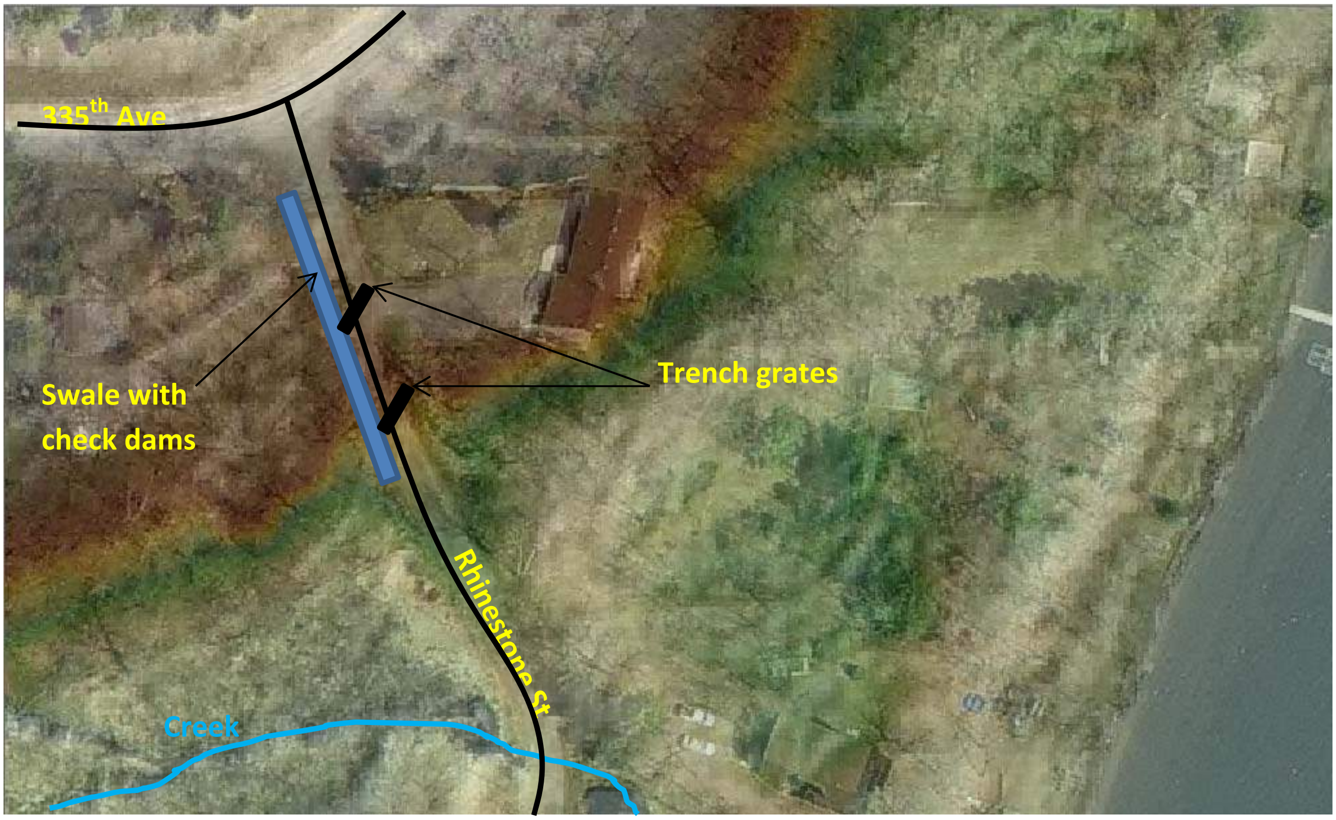
Drainage Area – Rhinestone Street surface – 0.58 ac

Location – Rhinestone Street, from 335th Avenue to about 3430 Rhinestone Street (350 feet south, downhill).

Property Ownership – Private/private. This project would occur within the road right of way. Adjacent landowner cooperation may assist. Bruce Bomier, who is an enthusiastic supporter of this project owns land on the lake side of the street. According to Mr. Bomier, a 33 ft strip of land on the opposite side of the road is publicly owned (a result of historic misplacement of the roadway), though this is not shown on property records.

Description – This project would increase the amount of road surface runoff that is directed to roadside swales, and increase the effectiveness of those swales. Presently, about 30% of road runoff reaches the roadside swales. The remainder reaches the creek/lake directly. Through trench grates in the road surface, up to 80% of the runoff could be directed to the swales. Treatment in the swales could be improved by the installation of check dams.

Conceptual images –

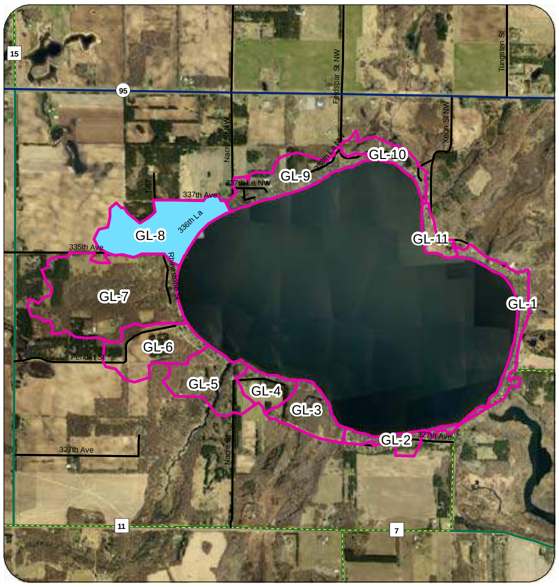


Cost effectiveness analysis – Rhinestone Street Diversion to Swale

	Diversion to Swale		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	Number of BMPs	1	
	Total Size of BMPs	100	linear ft
	TP (lb/yr)	0.1	1.3%
	TSS (lb/yr)	26	2.3%
	Volume (acre-feet/yr)	0.3	6.4%
Cost	Administration & Promotion Costs*	$2,920	
	Design & Construction Costs**	$8,589	
	Total Estimated Project Cost (2014)	**$11,509**	
	Annual O&M***	$100	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,836**	
	30-yr Average Cost/1,000lb-TSS	**$18,601**	
	30-yr Average Cost/ac-ft Vol.	**$1,466**	

Catchment GL-8

Existing Catchment Summary	
Acres	69
Dominant Land Cover	Forest
Parcels	29
TP (lbs/yr)	6.3
TSS (lbs/yr)	1,379
Volume (acre-feet/yr)	4.2



CATCHMENT DESCRIPTION

Catchment GL-7 consists of a line of approximately 19 lakeshore homes. The remaining 2/3rds are woods and fields. Stormwater follows one main flow path through this catchment to the lake, and residents have noted erosion near where it crosses 336th Lane. Other, smaller flow paths to the lake also exist.

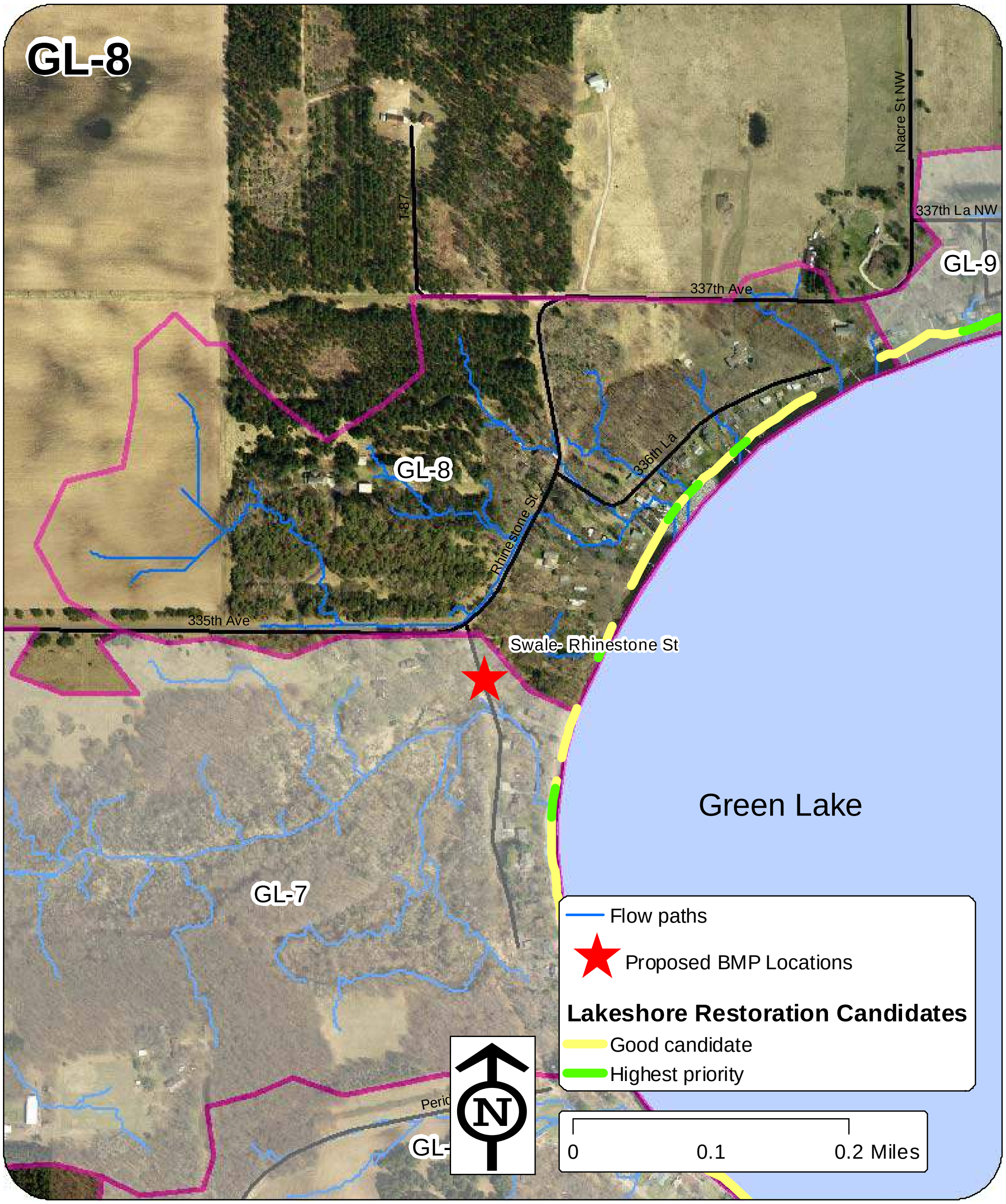
EXISTING STORMWATER TREATMENT

There is currently no intentional, man-made treatment of stormwater. The table below shows the pollutant loading to the lake from this catchment in its current condition.

EXISTING CONDITIONS

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	0			
	Total Size of BMPs	None			
	TP (lb/yr)	6.3	0.0	0%	**6.3**
	TSS (lb/yr)	1,379	0.0	0%	**1,379**
	Volume (acre-feet/yr)	4.2	0.0	0%	**4.2**

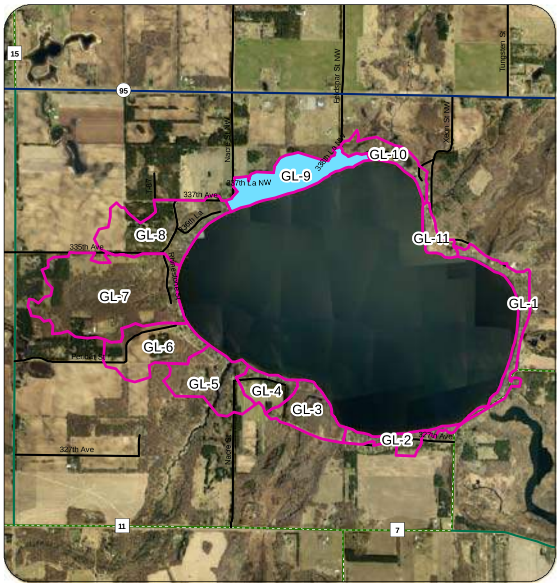
RETROFIT RECOMMENDATIONS



No proposed projects identified - The only stormwater projects recommended for this catchment are lakeshore restorations, which are covered separately in a later section.

Catchment GL-9

Existing Catchment Summary	
Acres	47
Dominant Land Cover	Residential
Parcels	34
TP (lbs/yr)	9.8
TSS (lbs/yr)	2,718
Volume (acre-feet/yr)	6.6



CATCHMENT DESCRIPTION

Catchment GL-9 consists of a line of approximately 16 lakeshore homes. There are steep slopes near the lakeshore. This is a narrow catchment following the lakeshore.

A notable problem area in this catchment is Feldspar Street, which is gravel and ends in the lake. This street serves as a lake access for nearby residents and a path to drive onto the lake ice in winter. It chronically washes out due to its long flow path straight into the lake, moderate slope and gravel surface. Whatever washes off the road ends up in the lake.

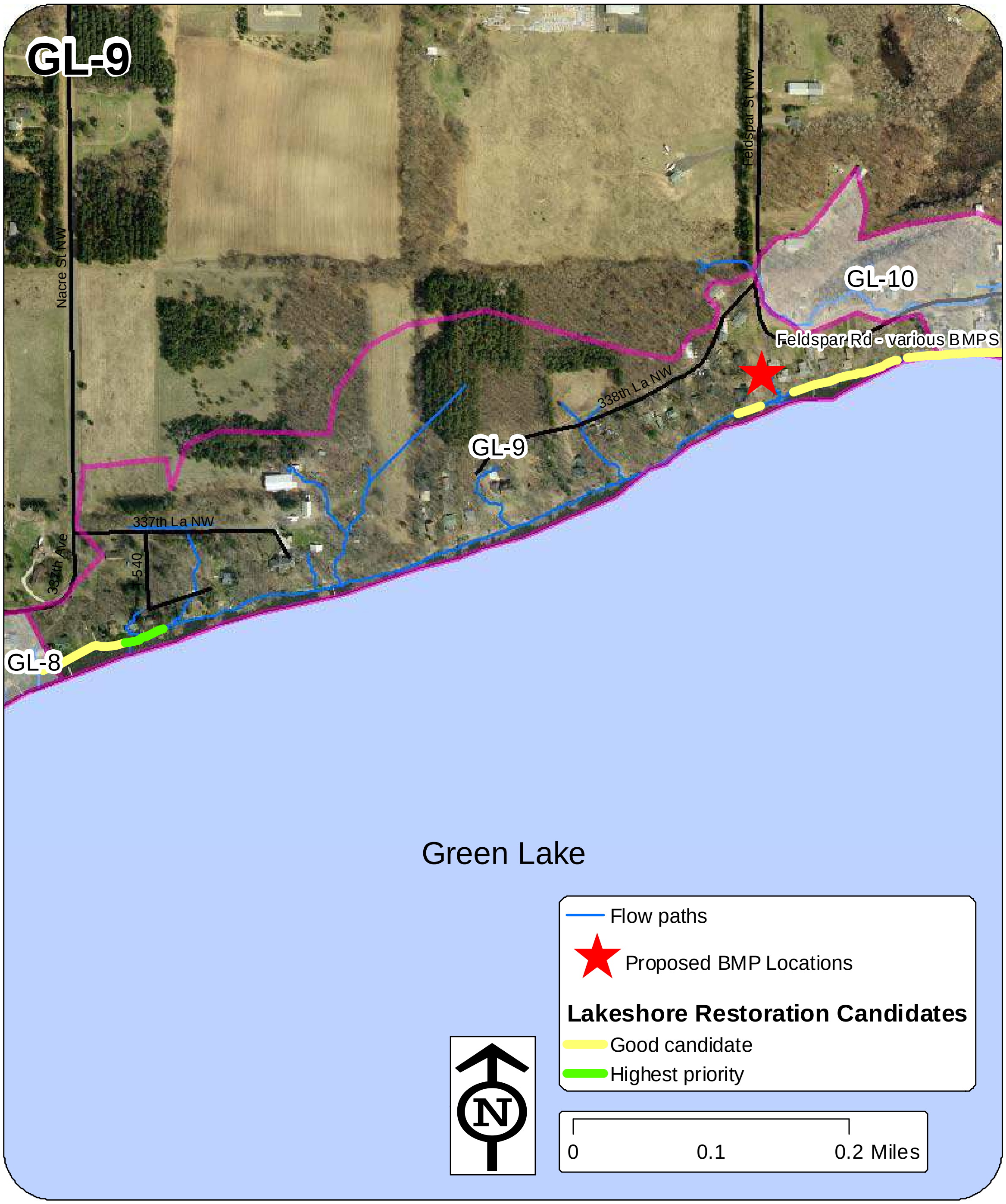
EXISTING STORMWATER TREATMENT

There is currently no intentional, man-made treatment of stormwater. The table below shows the pollutant loading to the lake from this catchment in its current condition.

EXISTING CONDITIONS

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	0			
	Total Size of BMPs	None			
	TP (lb/yr)	9.8	0.0	0%	**9.8**
	TSS (lb/yr)	2,718	0.0	0%	**2,718**
	Volume (acre-feet/yr)	6.6	0.0	0%	**6.6**

RETROFIT RECOMMENDATIONS



Project ID: GL-9 Feldspar Street Rain Gardens

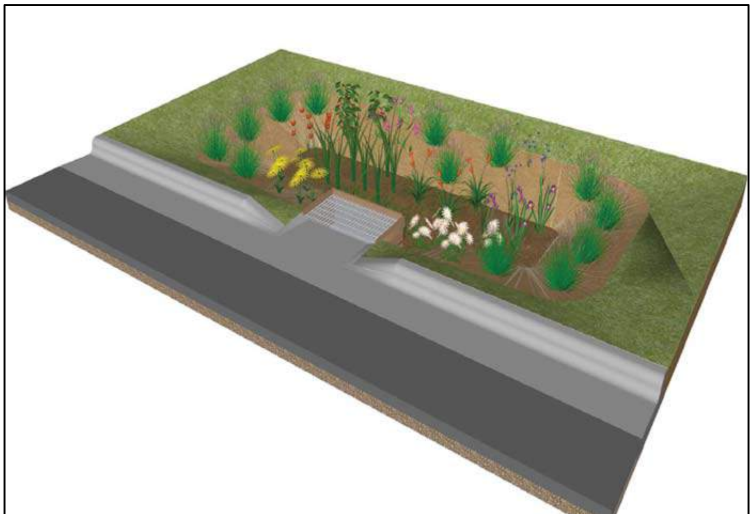
Drainage Area – 1.57 acres

Location – Feldspar Street, from 338th Lane to the lakeshore

Property Ownership – Wyanett Township road right of way, private adjacent lands

Description – To correct washout of Feldspar Street and pollutant delivery into Green Lake we considered paving this gravel road and adding 2-3 rain gardens. Paving is necessary to prevent future washouts of the gravel surface, delivery of that sediment into the rain gardens or lake and to crown the road for water delivery into the rain gardens. Each rain garden was assumed to be approximately 250 square feet, and completed in partnership with willing adjacent landowners. Rain Guardian™ pre-treatment chambers are recommended at the inlet to each rain garden.

Conceptual images –



Source: Anoka Conservation District

Feldspar Street at Green Lake

Before/24-48 hours after rain
Source: Anoka Conservation District

During rain

Cost effectiveness analysis – Feldspar Street Rain Gardens

	Curb-Cut Rain Gardens				
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	2		3	
	Total Size of BMPs	500	sq-ft	750	sq-ft
	TP (lb/yr)	0.7	7.1%	0.7	7.1%
	TSS (lb/yr)	186	6.8%	211	7.8%
	Volume (acre-feet/yr)	0.4	6.3%	0.5	7.3%
Cost	Administration & Promotion Costs*	$2,920		$4,380	
	Design & Construction Costs**	26,630		32,506	
	Total Estimated Project Cost (2014)	**$29,550**		**$36,886**	
	Annual O&M***	$450		$675	
Efficiency	**30-yr Average Cost/lb-TP**	**$2,050**		**$2,721**	
	30-yr Average Cost/1,000lb-TSS	**$7,715**		**$9,026**	
	30-yr Average Cost/ac-ft Vol.	**$3,450**		**$3,927**	

Project ID: GL-9 Feldspar Street Grass Swale, Close Road

Drainage Area – 1.57 acres

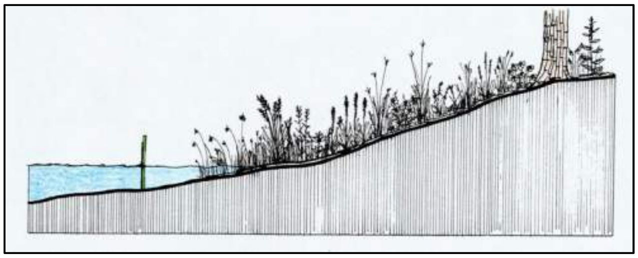
Location – Feldspar Street, from 338th Lane to the lakeshore

Property Ownership – Wyanett Township road right of way

Description – To correct washout of Feldspar Street and pollutant delivery into Green Lake we considered converting the bottom 70 feet of the road at the lakeshore into a vegetated swale. This option would require closing the bottom of the road, so it would no longer serve as a lake access point for boats or vehicles. This option would not address washouts of the upper, sloped portions of the road but would capture much of the sediment before it is delivered into the lake. A road washout/maintenance issue would remain.

The road would not need to be paved for this option. The cost-effectiveness analysis below shows scenarios with pave and unpaved road. Paving appears to offer little additional pollutant removal, however our models do not address unpaved roads well.

Conceptual images –



Cost effectiveness analysis – Feldspar Street Grass Swale, Close Road

	Grass swale at bottom of road				
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1- Rd Not Paved		1- Road Paved	
	Total Size of BMPs	4,200	sq-ft	4,200	sq-ft
	TP (lb/yr)	0.6	6.1%	0.7	7.1%
	TSS (lb/yr)	195	7.2%	197	7.2%
	Volume (acre-feet/yr)	0.4	6.3%	0.4	6.1%
Cost	Administration & Promotion Costs*	$2,920		$2,920	
	Design & Construction Costs**	19,552		34,430	
	Total Estimated Project Cost (2014)	**$22,472**		**$37,350**	
	Annual O&M***	$840		$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$2,648**		**$2,979**	
	30-yr Average Cost/1,000lb-TSS	**$8,149**		**$10,584**	
	30-yr Average Cost/ac-ft Vol.	**$3,820**		**$5,213**	

Project ID: GL-9 Feldspar Street Trench Grate Sediment Traps

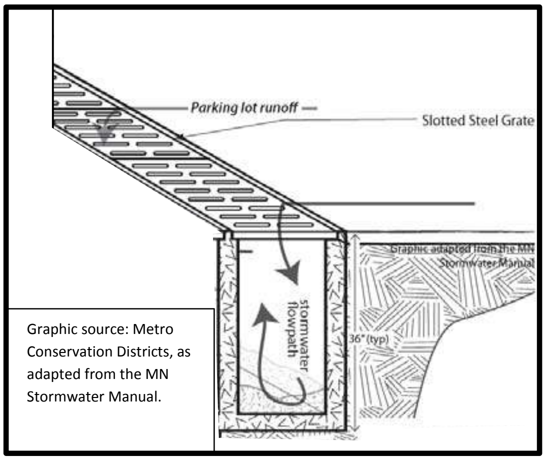
Drainage Area – 1.57 acres

Location – Feldspar Street, from 338th Lane to the lakeshore

Property Ownership – Public road right of way

Description – To correct washout of Feldspar Street and pollutant delivery into Green Lake we considered paving the road and installing a series of baffled trench grate sediment traps. These in-pavement trenches would serve to capture sediment and would require periodic cleaning. We examined scenarios with 2, 3 or 4 sediment traps.

Conceptual images –



Graphic source: Metro Conservation Districts, as adapted from the MN Stormwater Manual.

Cost effectiveness analysis – Feldspar Street Trench Grate Sediment Traps

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	2		3		4	
	Total Size of BMPs	40	sq-ft	60	sq-ft	80	sq-ft
	TP (lb/yr)	0.4	4.1%	0.4	4.1%	0.5	5.1%
	TSS (lb/yr)	64	2.4%	74	2.7%	82	3.0%
	Volume (acre-feet/yr)	0.0	0.0%	0.0	0.0%	0.0	0.0%
Cost	Administration & Promotion Costs*	$4,380		$4,380		$4,380	
	Design & Construction Costs**	32,035		38,424		44,812	
	Total Estimated Project Cost (2014)	**$36,415**		**$42,804**		**$49,192**	
	Annual O&M***	$1,000		$1,200		$1,400	
Efficiency	**30-yr Average Cost/lb-TP**	**$5,535**		**$6,567**		**$6,079**	
	30-yr Average Cost/1,000lb-TSS	**$34,591**		**$35,497**		**$37,070**	
	30-yr Average Cost/ac-ft Vol.	**no volume reduction**		**no volume reduction**		**no volume reduction**	

Project ID: GL-9 Feldspar Street Hydrodynamic Device

Drainage Area – 1.57 acres

Location – Feldspar Street, from 338th Lane to the lakeshore

Property Ownership – Wyanett Township road right of way

Description – To correct washout of Feldspar Street and pollutant delivery into Green Lake we paving the road and adding hydrodynamic devices. Hydrodynamic devices connect to stormwater pipes, using gravity, baffles or vortex to trap sediment. Advantages include a small footprint and underground installation. Disadvantages include cost and need for regular cleaning.

Because hydrodynamic devices are proprietary and differ significantly, we based our model upon one – the Downstream Defender from Hydro International. The four foot diameter model is appropriately sized for this location. This choice is not an endorsement of the product.

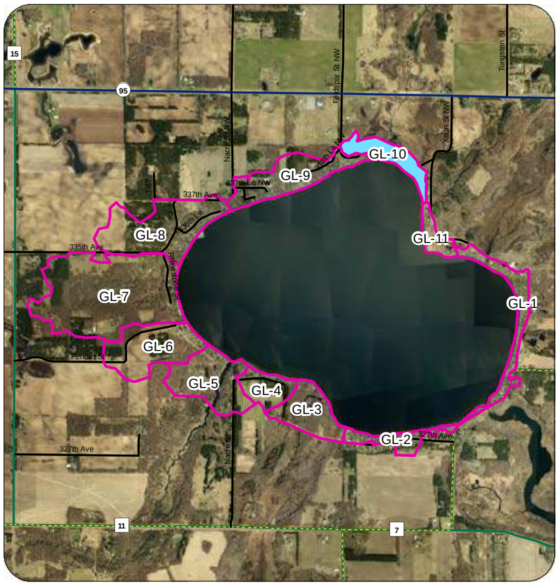
Hydrodynamic devices require periodic cleaning. Research at the University of Minnesota St. Anthony Falls Laboratory has found that cleaning after 1-2 storm events is sometimes needed to maintain performance. Because other vacuum trucks are not in the vicinity of Green Lake for other street sweeping or maintenance, regular maintenance would be unlikely.

Cost effectiveness analysis – Feldspar Street Hydrodynamic Device

	Hydrodynamic Device		
	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	4	ft
	TP (lb/yr)	0.4	4.1%
	TSS (lb/yr)	38	1.4%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$5,256	
	Design & Construction Costs**	35,758	
	Total Estimated Project Cost (2014)	**$41,014**	
	Annual O&M***	$1,500	
Efficiency	**30-yr Average Cost/lb-TP**	**$7,168**	
	30-yr Average Cost/1,000lb-TSS	**$75,451**	
	30-yr Average Cost/ac-ft Vol.	**no volume reduction**	

Catchment GL-10

Existing Catchment Summary	
Acres	23
Dominant Land Cover	Residential
Parcels	45
TP (lbs/yr)	4.3
TSS (lbs/yr)	1,236
Volume (acre-feet/yr)	2.5



CATCHMENT DESCRIPTION

Catchment GL-10 consists of a line of lakeshore homes.

There are steep slopes near the lakehore. This is a narrow catchment following the lakehore. Most of this catchment is lowland. North Brook enters Green Lake in this catchment.

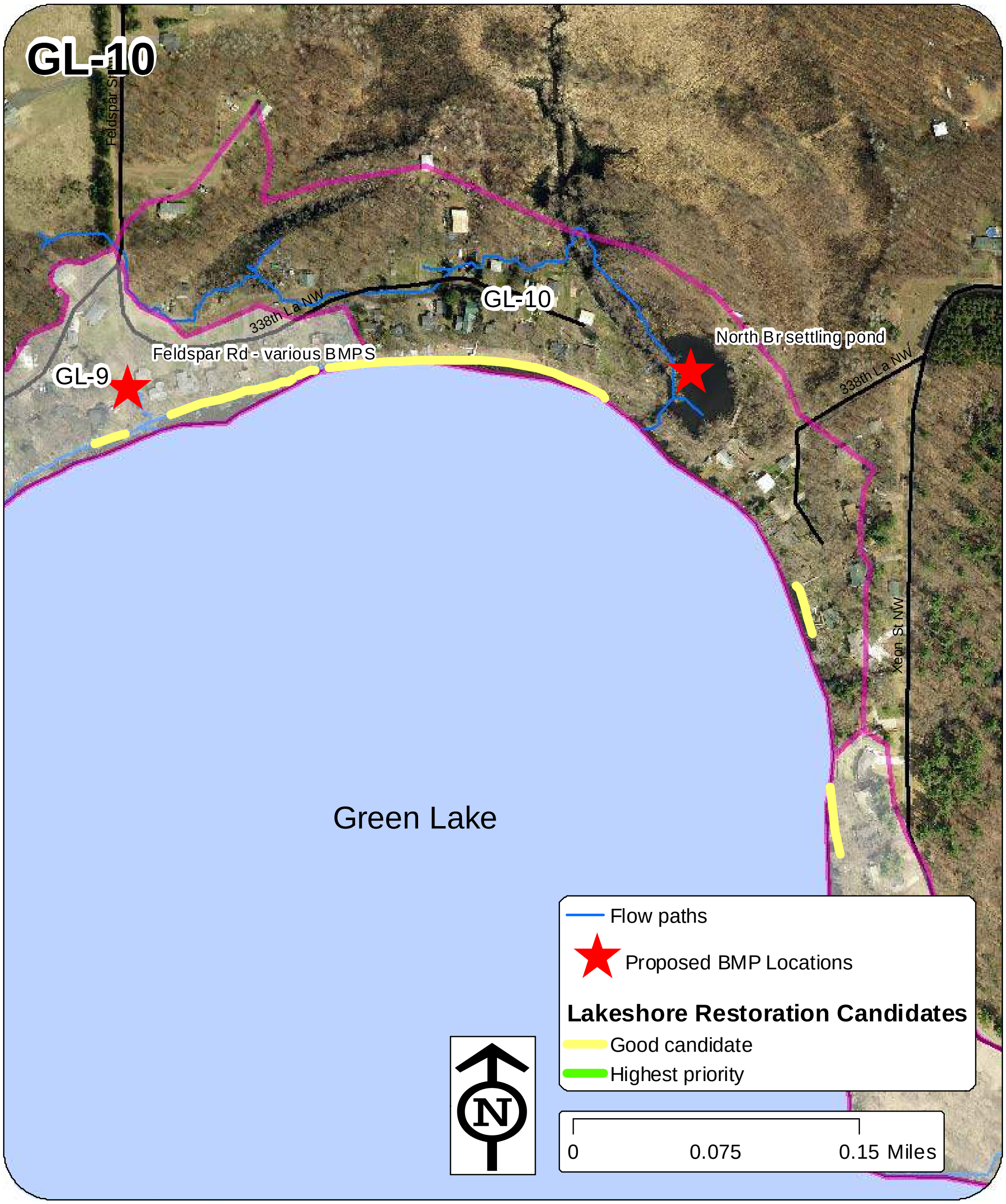
EXISTING STORMWATER TREATMENT

There is currently no stormwater treatment in this catchment. The table below shows the pollutant loading to the lake from this catchment in its current condition.

EXISTING CONDITIONS

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	0			
	Total Size of BMPs	None			
	TP (lb/yr)	4.3	0.0	0%	**4.3**
	TSS (lb/yr)	1,236	0.0	0%	**1,236**
	Volume (acre-feet/yr)	2.5	0.0	0%	**2.5**

RETROFIT RECOMMENDATIONS



Project ID: GL-10 North Brook Settling Pond

Drainage Area – Entire North Brook subwatershed
Location – Mouth of North Brook into Green Lake
Property Ownership – Private
Description – Presently there is an basin alongside North Brook, near the shoreline of Green Lake. It is unclear how creek water is routed through this basin. However, with some modification (excavation, water re-routing, etc) the basin might serve as settling pond for the entire North Brook subwatershed. North Brook is the second largest source of phosphorus loading to Green Lake, after Wyanett Creek, according to a 1995 lake diagnostic study by Water Research and Management, Inc, accounting for 22% of phosphorus loading.

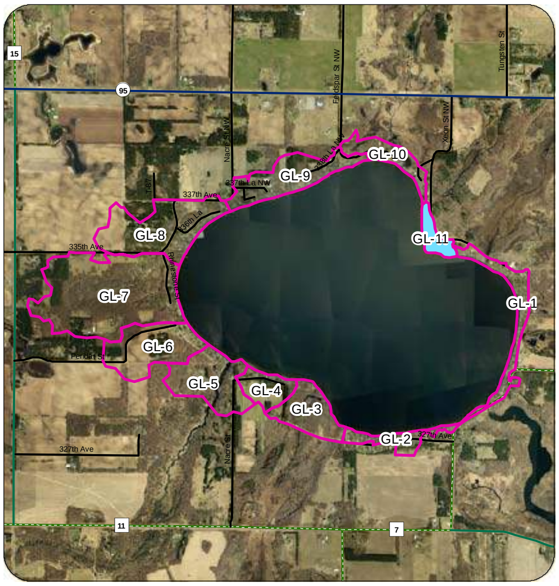
Additional study is needed to determine the feasibility of this project, recommended work and likely benefits. At this time, it is unclear if the pond is online or offline of the stream. Diverting stream flows through the pond may be desirable. Pond excavation may be needed to achieve settling. Such a pond would be most effective during low flows. During high flows, the pond might become one with Green Lake. Because the project might treat an entire subwatershed, further study is warranted.

Conceptual images –

Cost effectiveness analysis – North Brook Settling Pond
Because this project would serve the entire North Brook subwatershed, a detailed examination was beyond the scope of this study. It should be considered for future study, when modeling of that subwatershed is done and project benefits can be estimated.

Catchment GL-11

Existing Catchment Summary	
Acres	12
Dominant Land Cover	Residential
Parcels	11
TP (lbs/yr)	3.3
TSS (lbs/yr)	995
Volume (acre-feet/yr)	1.6



CATCHMENT DESCRIPTION

Catchment GL-11 consists entirely of lakeshore homes. It includes only the lands between Xenon Street and the lake. This land is high above the land, with steep slopes near the lakeshore.

EXISTING STORMWATER TREATMENT

There is currently no intentional, man-made treatment of stormwater. The table below shows the pollutant loading to the lake from this catchment in its current condition.

EXISTING CONDITIONS

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	0			
	Total Size of BMPs	None			
	TP (lb/yr)	3.3	0.0	0%	**3.3**
	TSS (lb/yr)	995	0.0	0%	**995**
	Volume (acre-feet/yr)	1.6	0.0	0%	**1.6**

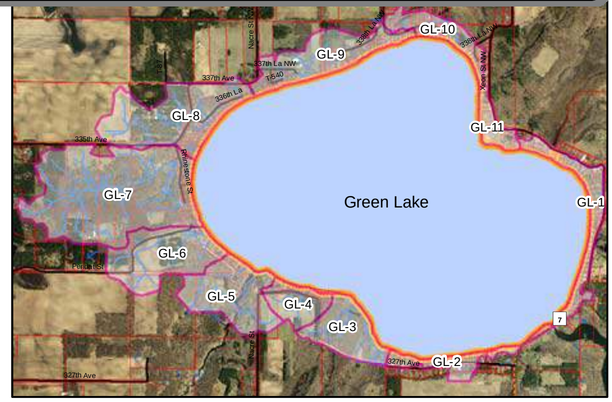
RETROFIT RECOMMENDATIONS

No proposed projects identified - The only stormwater projects recommended for this catchment are lakeshore restorations, which are covered separately in a later section.

Lakeshore

Existing Catchment Summary*	
Dominant Land Cover	Residential
Parcels	177
TP (lbs/yr)	24.4
TSS (lbs/yr)	137,057
Volume (acre-feet/yr)	0.4

**Pollutant loading from lakeshore is in addition to catchment loading shown in other catchment profiles.*



DESCRIPTION

The lakefront, at the water's edge, was examined separately from upland treatment in the catchments. This was done because erosion and runoff from the lakeshore is delivered directly into the lake. It is a problematic area, where residents attempt to balance recreational access, aesthetics, wave erosion, ice jacking and water quality.

On the whole, Green Lakeshore is intensely managed by homeowners. Mowing to the water's edge, sand beaches, beach raking and aquatic vegetation removal are commonplace. Some landowners have used rock rip rap or retaining walls. Still, much of the lakeshore (43.8%; 95 sites) is a candidate for a lakeshore restoration, including correcting erosion and installing vegetated buffers. The Lake Improvement District identified lakeshore restorations as a priority in its lake management plan.

Existing shoreline conditions were exacerbated in spring 2014. During the wettest June on record, and an overall wet spring, the lake flooded over its banks. A no-wake boating rule was instituted for the entire lake, but nonetheless high water caused extensive shoreline damage and erosion. Damage included soil losses behind some riprap, retaining walls and other hard structures. The maps on the following pages were made before those events, in fall 2013.

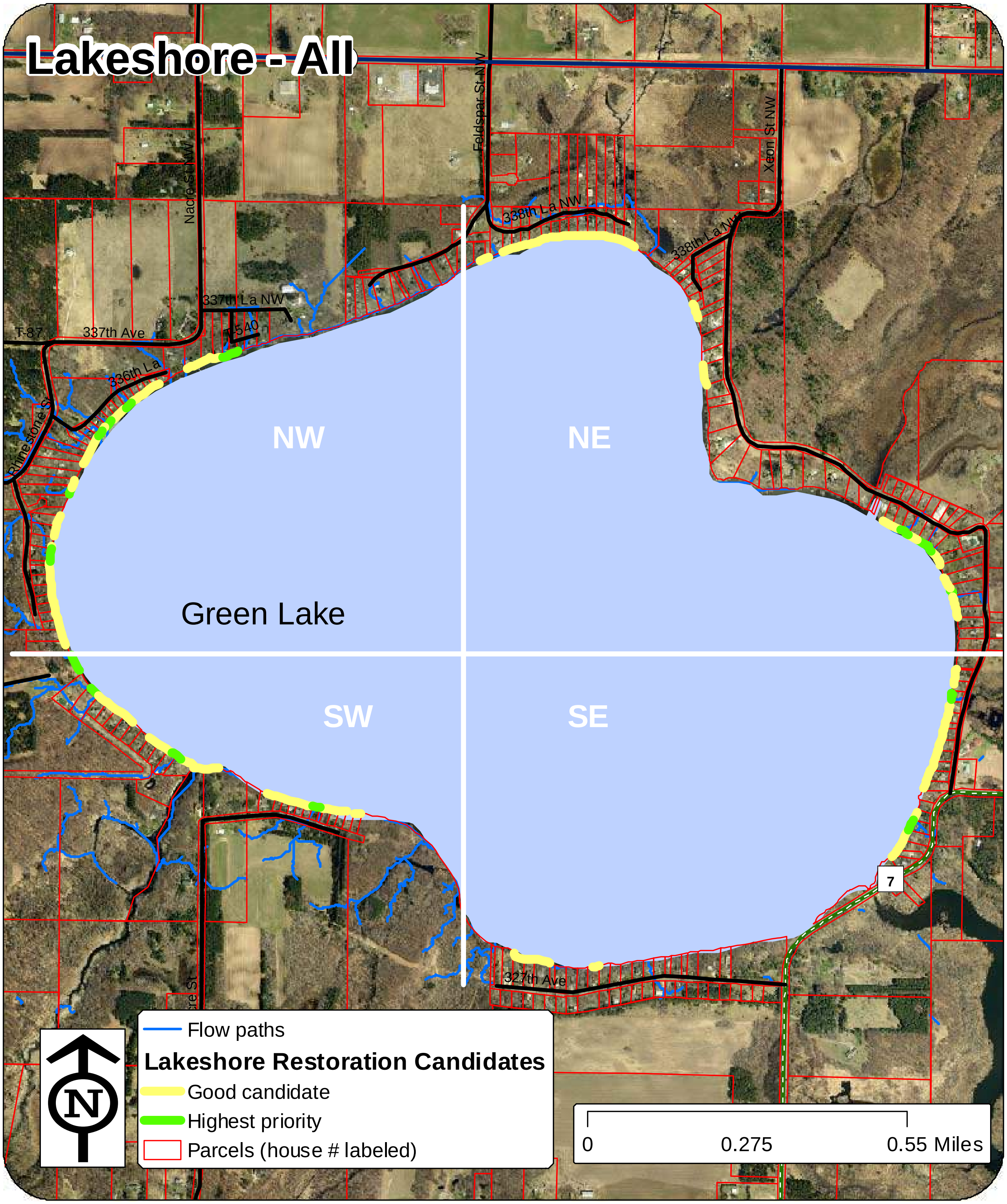
EXISTING STORMWATER TREATMENT

Many properties have vegetated buffers, rip-rap or other measures to prevent erosion and filter overland flow before it reaches the lake. We did not quantify the benefits from these practices. We did quantify the pollutant loading from lakeshores that are lakeshore restoration candidates. Candidates were defined as having less than 5 feet wide unmowed vegetation and/or active bank erosion. These candidates are presently contributing the pollutant loads to the lake that are listed in the table below.

Network-Wide Existing Conditions

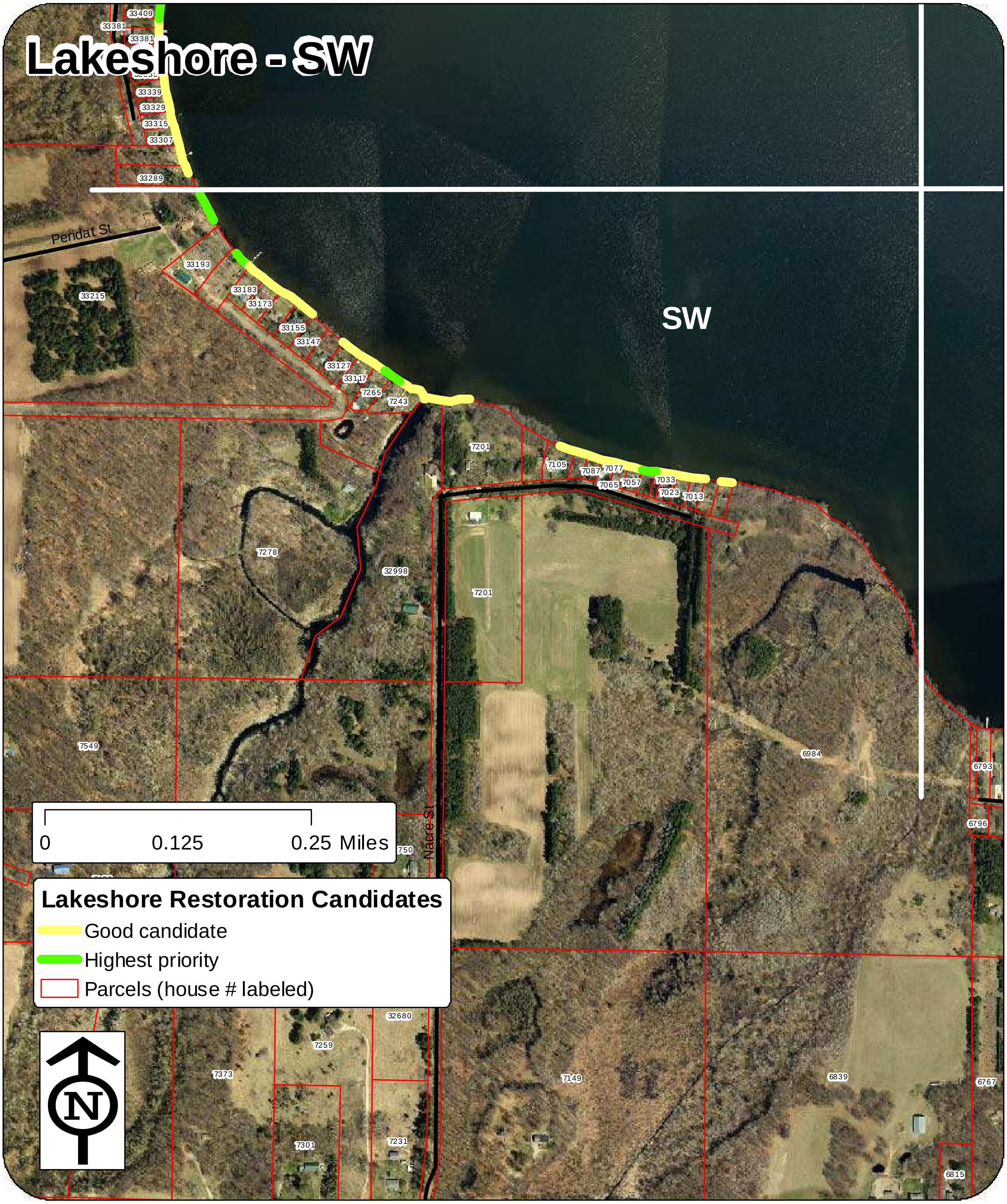
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	0			
	Total Size of BMPs*	None			
	TP (lb/yr)	24.4	0.0	0%	**24.4**
	TSS (lb/yr)	137,057	0.0	0%	**137,057**
	Volume (acre-feet/yr)	0.4	0.0	0%	**0.4**

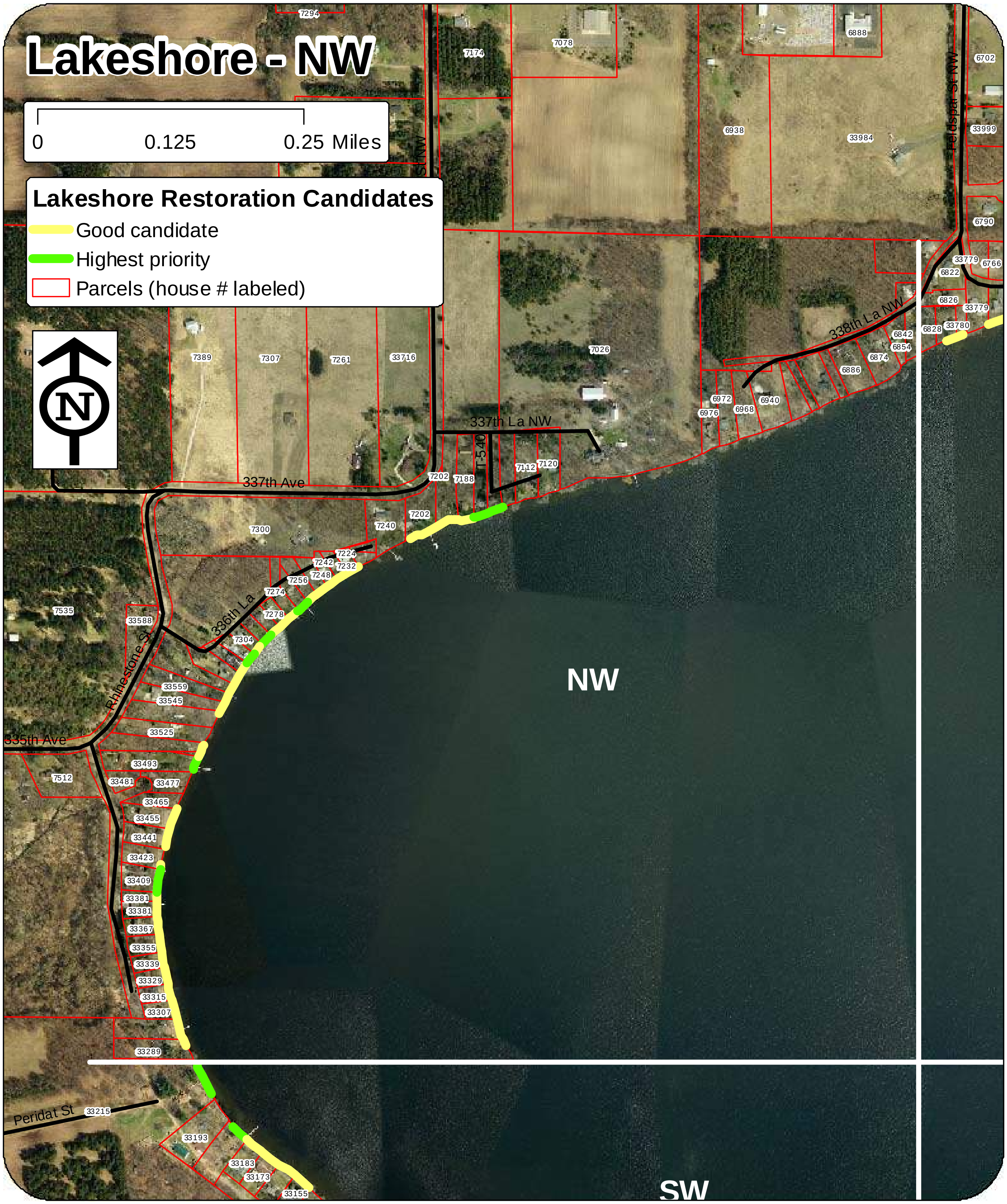
RETROFIT RECOMMENDATIONS (maps on the following pages break the lake into quarters)



Lakeshore - NE
0
0.125
0.25 Miles
Lakeshore Restoration Candidates
Good candidate
Highest priority
Parcels (house # labeled)
N
NE
SE
Feldspar St
Xeon St NW
338th La NW


Lakeshore - SE
SE
Xeon St NW
327th Ave
7
Lakeshore Restoration Candidates
Good candidate
Highest priority
Parcels (house # labeled)
0
0.125
0.25 Miles


Lakeshore - SW
SW
Peridat St
Nacre St
33409
33381
33381
33339
33329
33315
33307
33289
33193
33215
33183
33173
33155
33147
33127
33117
7265
7243
7201
7105
7087
7077
7065
7057
7033
7023
7013
7278
32998
7201
7549
6984
6793
6796
750
32680
7259
7373
7149
6839
6767
7301
7231
6815
0
0.125
0.25 Miles
Lakeshore Restoration Candidates
Good candidate
Highest priority
Parcels (house # labeled)
N


Lakeshore - NW
0
0.125
0.25 Miles
Lakeshore Restoration Candidates
Good candidate
Highest priority
Parcels (house # labeled)
N
337th Ave
337th La NW
338th La NW
336th La
Rhinestone St
335th Ave
Peridat St
T-540
NW
SW
7294
7174
7078
6888
6702
6938
33984
33999
6790
33779
6766
6822
6826
6842
6828
33780
6854
6874
6886
6972
6940
6968
6976
7026
7389
7307
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7300
7224
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7256
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7304
7535
33588
33559
33545
33525
33493
7512
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33465
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33409
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33355
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33315
33307
33289
33215
33193
33183
33173
33155

Project ID: All 95 candidate lakeshore restorations

Location – Dispersed around the lakeshore, see maps

Property Ownership – Private

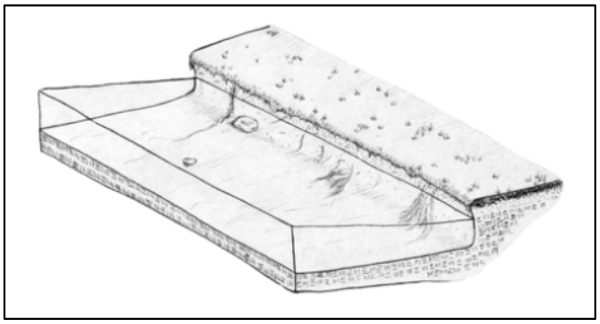
Description – 95 candidate lakeshore restorations were identified in fall 2013. Each is an average of 100 feet of lakefront that has less than a five foot wide vegetated buffer and/or active erosion.

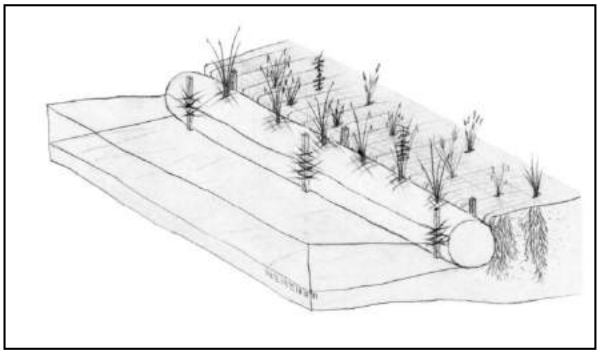
In spring 2014 major flooding occurred around Green Lake. This damage adds an undetermined number of properties to the list of candidates for lakeshore restorations. Given the large number of candidates, and these potential additions, a new survey of lakeshore conditions and ranking of properties with willing landowners is necessary.

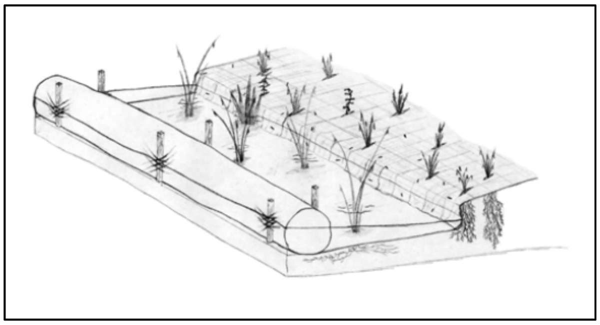
At each candidate lakeshore site we envision that 65% of the lakeshore (i.e. 65 ft of an average 100 ft frontage) will be stabilized to prevent future erosion and a unmowed vegetated buffer that is 20 feet wide (i.e. spanning 20 ft from the water's edge to manicured lawn). Bioengineering techniques which utilize deep rooted native plants and biodegradable materials, such as coconut fiber logs and erosion blankets, are favored. Some site conditions may justify use of other techniques not including Envirolok™ bags, or rock riprap with bioengineering techniques or a vegetated buffer. Hard structures, including rock alone or retaining walls, are not favored because they lack habitat attributes.

Conceptual images –

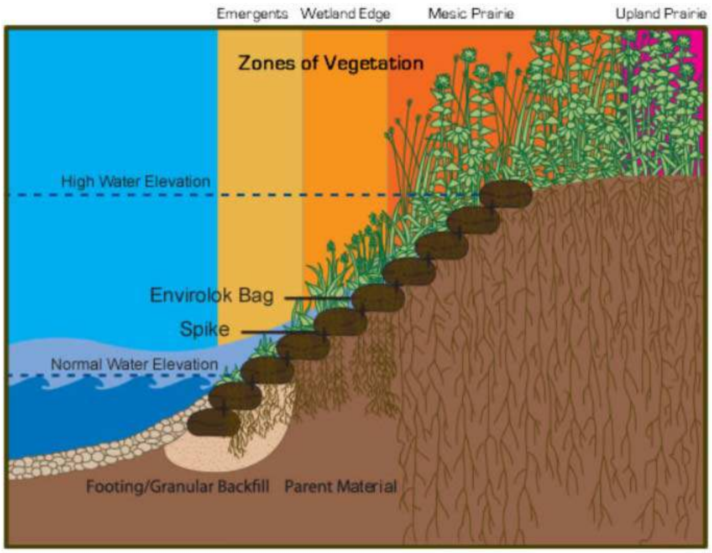
Lakeshore restorations with bioengineering and native plants (source: Metro Conservation Districts)







Envirolok bags used in lakeshore restoration (source: Envirolok LLC)



Cost effectiveness analysis – All 95 candidate lakeshore restorations

Because it is highly unlikely that landowners at all 95 candidate lakeshore restoration sites would be interested in this work, we considered a variety of scenarios. The table below presents the costs and benefits for doing 1, 10, 20, 30, 40 and 95 lakeshore restorations.

Because there are so many candidate sites, a site-specific analysis of each was not done. However, site-by-site review of properties where homeowners are interested is recommended when selecting sites for installation.

While some benefits of lakeshore restorations can be quantified, others cannot. The habitat provided by these projects is not included in our numeric analysis. Native, unmowed vegetation near and in the lake is valuable for nutrient uptake, refuges for herbivores that eat algae and fish habitat. These benefits should be considered when ranking projects for installation.

Lakeshore Restorations

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1		10		20		30		40		95	
	Total Size of BMPs*	65	ft	650	ft	1,300	ft	1,950	ft	2,600	ft	6,176	ft
	TP (lb/yr)	0.110	0.5%	1.130	4.6%	2.260	9.3%	3.390	13.9%	4.520	18.5%	10.730	44.0%
	TSS (lb/yr)	1,442	1.1%	14,424	10.5%	28,848	21.0%	43,272	31.6%	57,696	42.1%	137,028	100.0%
	Volume (acre-feet/yr)	0.005	1.0%	0.045	10.1%	0.091	20.3%	0.136	30.4%	0.181	40.6%	0.431	96.4%
Cost	Administration & Promotion Costs	$2,920		$2,920		$4,380		$7,300		$10,220		$17,520	
	Design & Construction Costs**	$5,125		$47,663		$89,688		$133,250		$179,375		$420,250	
	Total Estimated Project Cost (2014)	**$8,045**		**$50,583**		**$94,068**		**$140,550**		**$189,595**		**$437,770**	
	Annual O&M***	$225		$2,250		$4,500		$6,750		$9,000		$21,375	
Efficiency	30-yr Average Cost/lb-TP	**$4,483**		**$3,483**		**$3,379**		**$3,373**		**$3,389**		**$3,352**	
	30-yr Average Cost/1,000lb-TSS	**$342**		**$273**		**$265**		**$264**		**$266**		**$262**	
	30-yr Average Cost/ac-ft Vol.	**$109,593**		**$86,889**		**$84,185**		**$84,081**		**$84,453**		**$83,490**	

*Each BMP is a 65 ft lakeshore restoration that treats 100 ft of candidate lakeshore.

**Assumes all labor is by a contractor. Many installation tasks can be completed by the landowner for lower cost.

Project ID: 15 high priority lakeshore restorations

Location – Dispersed around the lakeshore, see maps

Property Ownership – Private

Description – Of the 95 candidate sites for lakeshore restoration we identified, 15 were noted as the highest priority. Stormwater runoff flow paths from uplands converge at these sites, meaning unmowed vegetated buffers would be especially beneficial.

Conceptual images –

See images above for all 95 lakeshore restorations.

Cost effectiveness analysis – All 95 candidate lakeshore restorations

If all 15 of the highest priority lakeshore restorations were installed, the estimated costs and pollutant removal would be achieved.

	Lakeshore Restorations		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	15	
	Total Size of BMPs*	940	ft
	TP (lb/yr)	1.630	6.7%
	TSS (lb/yr)	20,872	15.2%
	Volume (acre-feet/yr)	0.066	14.7%
Cost	**Administration & Promotion Costs**	$3,504	
	Design & Construction Costs**	$66,625	
	Total Estimated Project Cost (2014)	**$70,129**	
	Annual O&M***	$3,375	
Efficiency	**30-yr Average Cost/lb-TP**	**$3,505**	
	30-yr Average Cost/1,000lb-TSS	**$274**	
	30-yr Average Cost/ac-ft Vol.	**$87,083**	

*Each BMP is a 65 ft lakeshore restoration that treats 100 ft of candidate lakeshore.

**Assumes all labor is by a contractor. Many installation tasks can be completed by the landowner for lower cost.

Retrofit Ranking

The table on the following page summarizes potential projects. Potential projects are organized from most cost effective to least, based on cost per pound of total phosphorus (TP) removed. Reported treatment levels are dependent upon optimal siting and sizing. Installation of projects in series will result in lower total treatment than the simple sum of treatment across the individual projects due to treatment train effects. In some cases, multiple potential projects are identified for one site, so simple addition of pollutant reductions from all projects would overestimate achievable benefits. More detail about each project can be found in the catchment profile pages of this report. Projects that were deemed unfeasible due to prohibitive size, number, or were too expensive to justify installation are not included in the tables on the next pages.

Lakeshore restorations are a unique project type included in this report. While some benefits of lakeshore restorations can be quantified, others cannot. The habitat provided by these projects is not included in our numeric analysis. Native, unmowed vegetation near and in the lake is valuable for nutrient uptake, refuges for herbivores that eat algae, and fish habitat. These benefits should be considered when ranking projects for installation.

In addition to the projects proposed in this report, it is recommended that lake-friendly cultural practices be continued and, where appropriate, increased. Examples that are especially applicable to Green Lake include:

1) **Yard care practices**. A wide variety of yard care practices can affect the lake. Some include fertilizer use, yard waste disposal, and leaving unmowed buffers in strategic locations.
2) **Curly-leaf Pondweed (CLP) treatment**. Early spring treatment of CLP reduces the amount of vegetation to senesce (or die-off) in mid-summer. Senescing CLP can be a source of biologically-available phosphorus within waterbodies and can increase the likelihood of algal blooms. A future strategy may also be harvesting CLP, instead of herbicide application, as removal of the plant will remove any phosphorus the plant had used for growth. This action, performed lake-wide, could in theory reduce internal loading of phosphorus within the lake.
3) **Septic systems**. Regular pumping of septic systems and upgrade of failing systems is important for both nutrient and human health reasons. The water table is high near Green Lake, and Green Lake is connected to it. Many septic systems are near the water table. Additionally, the lake sometimes floods, putting lake water in, around or over septic systems.

   The University of Minnesota Extension service provides tools to estimate pumping frequency needed. Three year pumping intervals are common. Holding tanks require much more frequent pumping.

   Locating and replacing leaky septic systems near the lake is important. Leaky septic systems can be a significant source of phosphorus and coliform to the lake, depending upon the severity of the leak, proximity to the lake, and soil characteristics between the leaky septic system and the lake.

Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness with respect to total phosphorus (TP) reduction. Volume and total suspended solids (TSS) reductions are also shown. For more information on each project refer to the catchment profile pages in this report.

Project Rank	Catchment ID	Retrofit Type (refer to catchment profile pages for additional detail)	Projects Identified	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Total Project Cost	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ 1,000lb-TSS (30-year)	Estimated cost/ lb-TP (30-year)	Notes/Description
1	GL-9	Rain gardens - Feldspar St	2	0.7	186	0.4	$29,550	$450	$7,715	$2,050	Pave gravel road that washes out into the lake, install 2 rain gardens.
2	GL-1	Swale - public boat parking	1	0.3	134	0.3	$15,541	$100	$4,612	$2,060	Redirect boat landing runoff into the lakeshore swale.
3	GL-9	Grass swale at bottom of Feldspar St (road not paved)	1	0.6	175	0.4	$22,472	$840	$8,149	$2,648	A grass swale at the water's edge of Feldspar St, which currently runs into the lake.
4	GL-3	Land protection - 62 acres	1	8.9	2736	7.7	$611,910	$6,000	$9,648	$2,966	Purchase fee title or an easement for property on SW side of the lake, currently for sale.
5	Lakeshore	Lakeshore restoration - All 95 Candidate Sites	95	10.7	137,028	0.4	$437,770	$21,375	$262	$3,352	Restore all candidate lakeshore restoration sites, or some lesser amount. Offers habitat benefits in addition to water quality.
6	Lakeshore	Lakeshore restoration - 15 High Priority Sites	15	1.6	20,871	0.1	$70,129	$3,375	$274	$3,505	Restore the 15 candidate lakeshores where active erosion and concentrated flow occur.
7	GL-9	Permeable asphalt - 20% of Fedlspar St	1	0.7	222	0.5	$59,334	$1,000	$13,414	$4,254	Pave gravel road that washes out into the lake, including 20% permeable pavement.
8	GL-7	Diversion to swale - Rhinestone St	1	0.1	26	0.3	$11,509	$100	$18,601	$4,836	Divert street runoff to roadside swale. Some diversion already occurs due to road crowning.
9	GL-1	Permeable asphalt - 20% public boat parking	1	0.6	317	0.9	$61,884	$1,200	$10,293	$5,438	Install permeable asphalt on 20% of public boat landing parking.
10	GL-9	Trench grate sediment traps - Feldspar St	1	0.4	74	0.0	$35,415	$1,000	$34,591	$5,535	Pave gravel road that washes out into the lake, including trench grate sediment traps.
11	GL-9	Hydrodynamic device - Feldspar St	1	0.4	39	0.0	$41,014	$1,500	$75,451	$7,168	Pave gravel road that washes out into the lake, including commercial hydrodynamic separator.
Further examination needed											
12	GL-10	Settling pond - North Branch Creek	1	undetermined							Would treat runoff from a greater area than the scope of this study.
Considered but excluded											
13	GL-4	Swale - 330th Avenue	1	0.0	0	0.0	$8,278	$450	no benefit	no benefit	Swale on undeveloped lot at saddle in road. Modeling found no benefit.

References

Minnesota Stormwater Steering Committee. 2005. *Minnesota Stormwater Manual.* Minnesota Pollution Control Agency. St. Paul, MN.

Schueler et. al. 2005. *Methods to Develop Restoration Plans for Small Urban Watersheds. Manual 2, Urban Subwatershed Restoration Manual Series*. Center for Watershed Protection. Ellicott City, MD.

Schueler et. al. 2007. *Urban Stormwater Retrofit Practices. Manual 3, Urban Subwatershed Restoration Manual Series. Center for Watershed Protection*. Ellicott City, MD.

Treatment analysis

For each potential project (except lakeshore restorations, see next section) pollutant removal estimates were obtained using the stormwater model WinSLAMM. WinSLAMM uses an abundance of stormwater data from the upper Midwest and elsewhere to quantify runoff volumes and pollutant loads from urban areas. It is useful for determining the effectiveness of proposed stormwater control practices. It has detailed accounting of pollutant loading from various land uses, and allows the user to build a model "landscape" that reflects the actual landscape being considered. The user is allowed to place a variety of stormwater treatment practices that treat water from various parts of this landscape. It uses rainfall and temperature data from a typical year, routing stormwater through the user's model for each storm.

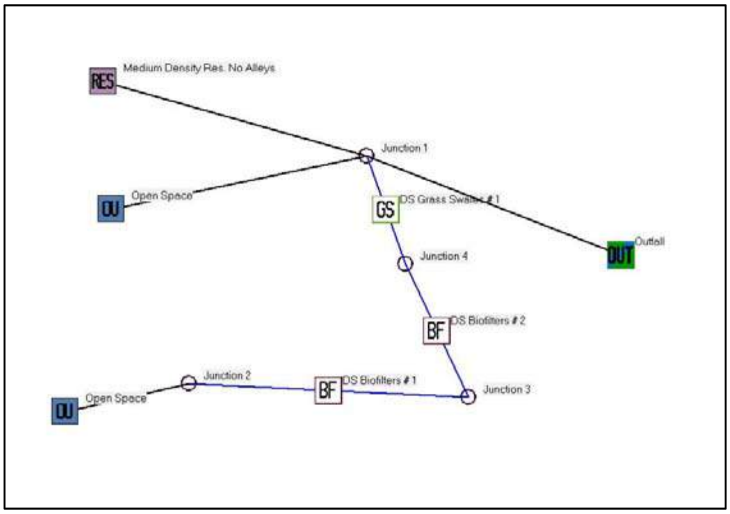
A "base" model was created which estimated pollutant loading from each catchment in its present-day state. To accurately model the land uses in each catchment, we delineated each land use in each catchment using ArcGIS, and assigned each a WinSLAMM standard land use file. A site specific land use file was created by adjusting total acreage and converting to "sand" soils to account for the sandy soils in the study area. This process resulted in a model that included estimates of the acreage of each type of source area (roof, road, lawn, etc.) in each catchment. For certain source areas critical to our models we verified that model estimates were accurate by measuring actual acreages in ArcGIS and adjusting the model acreages if needed.

Once the "base" model was created, each proposed stormwater treatment practice was added to the model and pollutant reductions were generated. Because neither a detailed design of each practice nor in-depth site investigation was completed, a generalized design for each practice was used. Whenever possible, site-specific parameters were included. Design parameters were modified to obtain various levels of treatment. It is worth noting that we modeled each practice individually, and the benefits of projects may not be additive, especially if serving the same area. Reported treatment levels are dependent upon optimal site selection and sizing.

WinSLAMM stormwater computer model inputs

General WinSLAMM Model Inputs	
Parameter	**File/Method**
Land use acreage	**ArcGIS**
Precipitation/Temperature Data	**Minneapolis 1959 – the rainfall year that best approximates a typical year.**
Winter season	**Included in model. Winter dates are 11-4 to 3-13.**
Pollutant probability distribution	**WI_GEO01.ppd**
Runoff coefficient file	**WI_SL06 Dec06.rsv**
Particulate solids concentration file	**WI_AVG01.psc**
Particle residue delivery file	**WI_DLV01.prr**
Street delivery files	**WI files for each land use.**

Example WinSLAMM stormwater model schematic



Lakeshore Erosion and Runoff Pollutant Estimation

WinSLAMM modeling alone could not accurately estimate pollutants generated from eroding lakeshore, nor the pollutant reduction that may occur by installing a project. To estimate lakeshore pollutants, we used a two-step process that accounted for (1) overland flow from lakeshore backyards plus (2) the eroding lakeshore face.

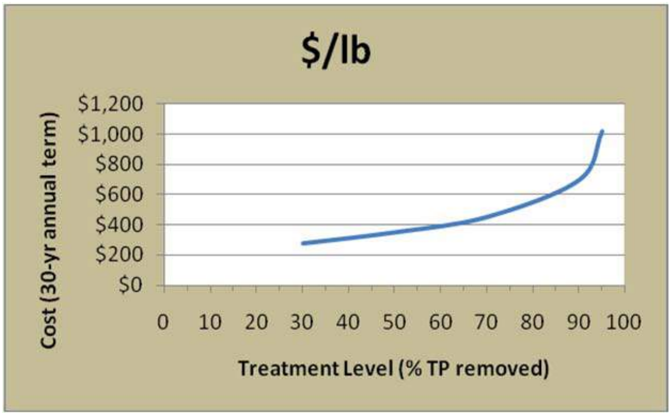
1. <u>Overland Flow -</u> We used WinSLAMM to estimate pollutant generation from the backyards of lakeshore homes. We created a custom WinSLAMM standard land use that replicated typical Green Lakeshore properties, including half of the home's roof, backyard and landscaping. In our base model the runoff from these surfaces flowed over sandy backyard soils to the lake. In our proposed project models the runoff was directed through a vegetated swale at the water's edge.
2. <u>Eroding Lakeshore Face -</u> We used a modified version of the Wisconsin NRCS streambank erosion method to calculate sediment loss from the lakeshore face, and then calculated phosphorus in that sediment using the MN Board of Water and Soil Resources (BWSR) water erosion pollutant calculator for streams and ditches. Assumptions for the NRCS bank erosion method included a 1.2 ft tall eroding face with an lateral recession rate of 0.12 feet/year (moderate erosion). The bulk density of the eroded material was assumed to be 100 lbs per cubic foot, the NRCS published value for sandy loam. This yielded an estimation of pounds of eroded material lost per year. The phosphorus content of that material was calculated based on a conversion factor of one pound of phosphorus per 1,481 pounds of soil, as derived from the BWSR erosion calculator.

We categorized candidate lakeshore restoration sites as either "good candidates" or "high priorities." Good candidates were sites that lacked a vegetated buffer at least 5 feet deep from the lakeshore and had active instability/erosion. High priority sites additionally had overland flow concentrations

converging at the site and would be especially well suited to a vegetated buffer to filter that water. Paths of concentrated flow were determined using the NRCS Terrain Analysis tools for GIS, with LiDAR data.

Cost Estimates

Cost estimates were annualized costs that incorporated design, installation, installation oversight, and maintenance over a 30-year period. In cases where promotion to landowners is important, such as rain gardens and lakeshore restorations, those costs were included as well. In cases where multiple, similar projects are proposed in the same locality, promotion and administration costs were estimated using a non-linear relationship that accounted for savings with scale. Design assistance from an engineer is assumed for practices in-line with the stormwater conveyance system, involving complex stormwater treatment interactions, or posing a risk for upstream flooding. It should be understood that no site-specific construction investigations were done as part of this stormwater assessment, and therefore cost estimates account for only general site considerations.

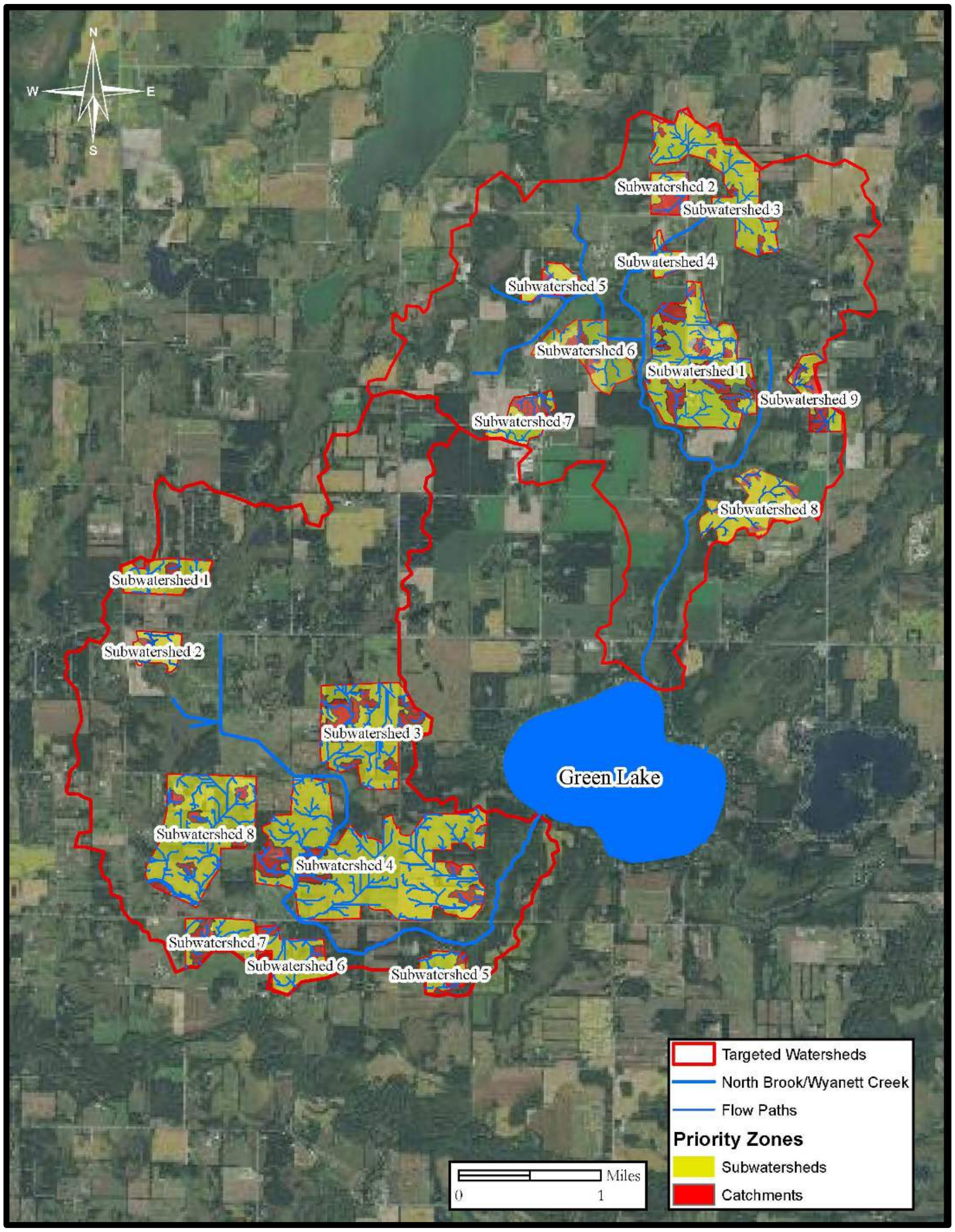


The costs associated with several different pollution reduction levels were calculated in certain cases. Generally, more or larger practices result in greater pollution removal. However the costs of obtaining the highest levels of treatment are often prohibitively expensive (see figure). By comparing costs of different treatment levels, the project partners can best choose the project sizing that meets their goals.

Step 5: Evaluation and Ranking

The cost per pound of phosphorus treated was calculated for each potential retrofit project, and projects were ranked by this cost effectiveness measure. Only projects that seem realistic and feasible were considered. The recommended level was the level of treatment that would yield the greatest benefit per dollar spent while being considered feasible and not falling below a minimal amount needed to justify crew mobilization and outreach efforts. Local officials may wish to revise the recommended level based on water quality goals, finances or public opinion.

Appendix C
Green Lake Rural Stormwater Retrofit Analysis of North Brook and Wyanett Creek



Green Lake Rural Stormwater Retrofit Analysis of North Brook and Wyanett Creek

Prepared by:

Isanti Soil and Water Conservation District

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Contents

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Executive Summary

This study provides recommendations for cost effectively improving treatment of stormwater from areas outside of the direct drainage area (considered rural) of Green Lake; more specifically, the two major inlets: Wyanett Creek and North Brook. This report provides sufficient detail to identify projects, rank projects by cost effectiveness at removing phosphorus and begin project planning. It includes project concepts and relative cost estimates for project selection. Site specific planning, designs and refined cost estimates should be done after committed partnerships for project installation are in place. A study focusing on the direct drainage area—areas not first draining into a tributary—was completed in 2017 (Green Lake Direct Drainage SWA, 2015).

This stormwater analysis focuses on "stormwater retrofitting" and ranking projects on cost effectiveness. Stormwater retrofitting refers to adding stormwater treatment to an already developed area or areas being used for production. This process is investigative and creative. Stormwater retrofitting success is sometimes improperly judged by the number of projects installed or by comparing costs alone. Those approaches neglect to consider how much pollution is removed per dollar spent. In this stormwater analysis we estimated both costs and pollutant reductions and used them to calculate cost effectiveness of each possible project.

Green Lake has been designated as "impaired" for not meeting state water quality standards for nutrient eutrophication – excess phosphorus. The lakeshore is heavily developed and the watershed (the land area draining into the lake) is a mixture of rural residential, agricultural, wetlands and forested cover. The lakeshore homeowners formed a lake improvement district to organize and fund aquatic invasive species treatment and water quality improvement efforts to help understand lake trends. These efforts include surface water monitoring for total phosphorus and total suspended solids in the lake and four tributaries, including Wyanett Creek and North Brook. Other variables being monitored include PH, temperature, dissolved oxygen, conductivity, flow and water level. Tributary monitoring results will be used to select the drainage area to be targeted first (i.e. Wyanett Creek vs. North Brook).

Wyanett Creek, approximately 6.5 miles long, begins northwest of Green Lake, and flows into the lake on the southwest side. The majority of the 5,502 acre drainage area is located in Wyanett Township. A small portion of the drainage area also extends into Spencer Brook Township and Mille Lacs County. The majority of the land cover is row crop, hay and pasture (3,187 acres). 54 acres of the watershed is classified as low density residential. The remaining land cover consists of forests and wetlands which for the most part, border Wyanett Creek. Stream water quality monitoring efforts showed consistently high concentrations of total phosphorous (TP) during the 2016 sampling season. The average concentrations of TP for this location was 247 µg/L, significantly higher than the range of expected concentrations for this ecoregion and the TMDL Study TP goal of 100 µg/L. Furthermore, based on one season of data, Wyanett Creek is contributing more pounds of phosphorus to the lake than North Brook. These preliminary results suggest the Wyanett Creek watershed be high priority and efforts to minimize nutrient and sediment loading be taken as soon as possible.

North Brook, just over eight miles long, flows into the lake on the north side. The entire 4,774 acres of drainage area is located in Wyanett Township. The drainage area is dominated by hay and row crops (3,018 acres). Similar to the Wyanett Creek drainage area, the land cover adjacent to North Brook is predominantly wetland and forest. Like Wyanett Creek, water quality monitoring results showed consistently high concentrations of total phosphorous (TP) during the 2016 sampling season. The average concentration of TP for this location was 181 µg/L, exceeding the range of expected concentrations for this ecoregion as well as the TMDL Study TP goal of 100 µg/L. Based on one season of data, it was determined North Brook may be contributing slightly less phosphorus to the lake than Wyanett Creek. These preliminary results suggest that conservation efforts should first focus on Wyanett Creek watershed; however, more data is needed to be certain.

The combine 10,276 acre rural watersheds were delineated through the use of NRCS Engineering Tools. Priority subwatersheds were determined using Chisago SWCD protocol (Rural Subwatershed Analysis Protocol Part 1 – Targeting). Once priority subwatersheds were established, they were focused on for Best Management Practice (BMP) implementation through a desktop search using various GIS tools and areal imagery. Field verifications were made when possible; however, limited access to private property lots hindered verification in most cases. The Chisago SWCD "Rural Subwatershed Analysis Protocol Part 2 - Prioritizing" was utilized to direct BMP site selection and modeling.

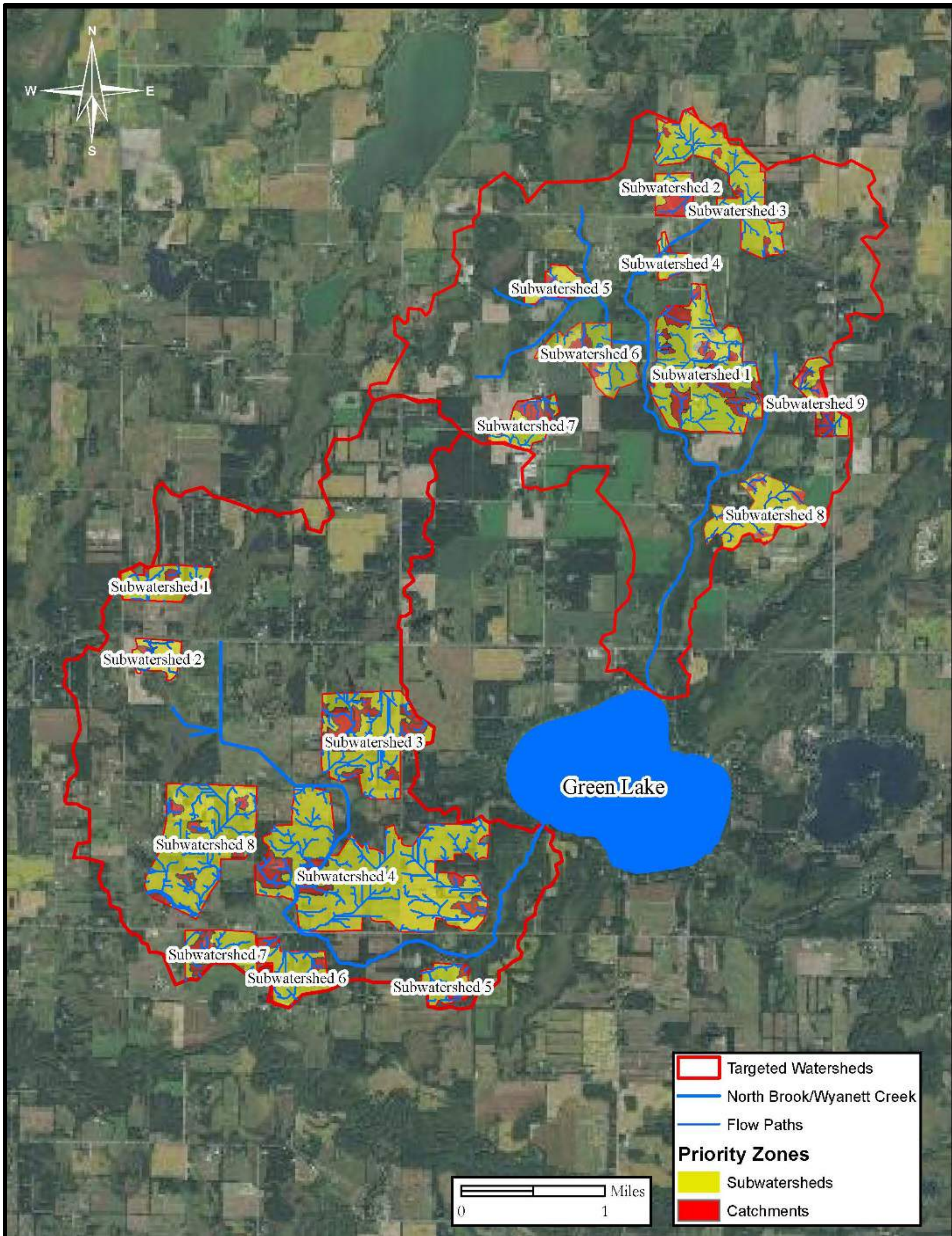
Potential stormwater retrofits identified during this analysis were then modeled to estimate reductions in total phosphorus and total suspended solids. Finally, cost estimates were developed for each retrofit project, including 10-30 years of operations and maintenance. Projects were ranked by cost effectiveness with respect to their reduction of total phosphorus.

A variety of stormwater retrofit approaches were identified. They included:

- Water and sediment control basins (WASCOB),
- Grassed waterways,
- Filter strips,
- Permanent vegetation,
- Wetland restorations.

If a project is selected, site-specific designs must be prepared. In addition, many of the proposed retrofits (e.g. water and sediment control basins) will require engineered plan sets if selected. This typically occurs after committed partnerships are formed to install the project. Committed partnerships must include willing landowners when installed on private property. Other factors, including a project's educational value/visibility, construction timing, total cost, or non-target pollutant reduction also affect project installation decisions and will need to be weighed by resource managers when selecting projects to pursue.

This document will be modified to include updates as needed.



North Brook and Wyanett Creek priority subwatersheds and catchments.

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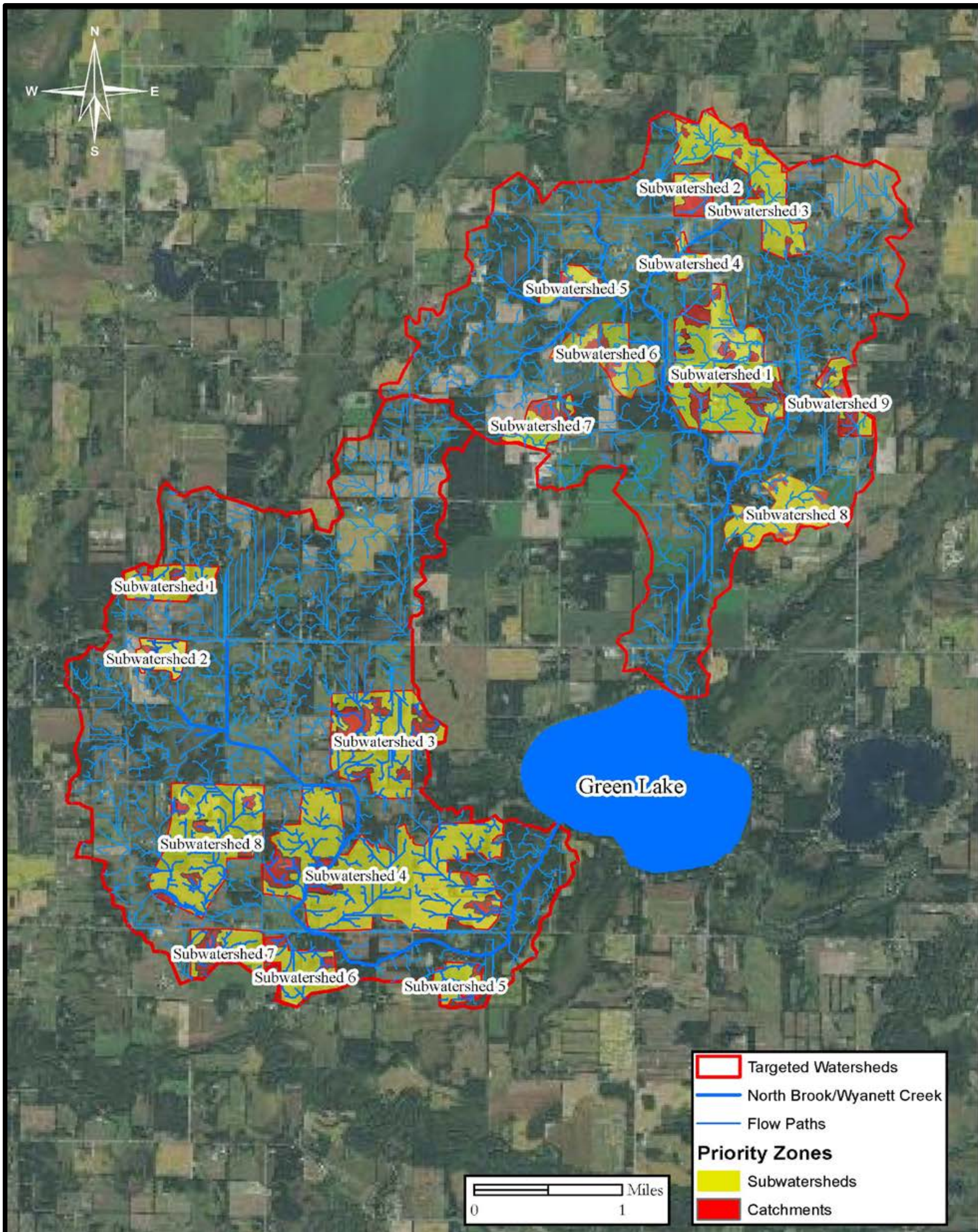

North Brook and Wyanett Creek watershed with concentrated flow paths.

Retrofit Ranking

The tables on the next pages summarize potential projects organized from most cost effective to least, based on cost per pound of total phosphorus removed. Reported treatment levels are dependent upon optimal siting and sizing. More detail about each project can be found in the catchment profile pages of this report. Projects that were deemed unfeasible due to prohibitive size, number, or were too expensive to justify installation are not included in the tables on the next pages.

Installing all of these projects is unlikely due to funding limitation and landowner interest. Instead, it is recommended that projects be installed I order of cost-effectiveness (points of pollution reduced per dollar spent). Other factors, including a projects educational value, visibility, construction timing, total cost, focusing on upstream projects that benefit all lakes, or non-target pollutant reduction also affect project installation decisions and will need to be weighted by resource managers when selecting projects.

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North Brook Watershed BMP ranking based on $ per lb of TP removed						
BMP Characteristics				Cost-Benefit		
Project Ranking	**Priority Zone**	**Sub-Basin**	**Applicable Practice**	**Practice Cost**	**P reduction (lb/yr)**	**$ per lb TP Removed**
1	4	2	Filter Strip	173.55	2.71	$64.04
2	4	1	Filter Strip	224.91	1.99	$113.02
3	1	2	Grassed Waterway	3,148.83	24.84	$126.76
4	1	1	Grassed Waterway	1,666.33	13.14	$126.81
5	6	2	Grassed Waterway	895.43	3.51	$255.11
6	1	14	Grassed Waterway	539.63	1.54	$350.41
7	3	2	Grassed Waterway	978.45	2.74	$357.10
8	7	3	Grassed Waterway	1,476.57	3.98	$371.00
9	3	3	Grassed Waterway	806.48	2.02	$399.25
10	1	5	Grassed Waterway	824.27	1.86	$443.16
11	1	4	Grassed Waterway	1,197.86	2.69	$445.30
12	1	8	Grassed Waterway	1,891.67	4.12	$459.14
13	2	2	Grassed Waterway	2,223.75	4.79	$464.25
14	8	1	Grassed Waterway	1,043.68	2.23	$468.02
15	9	1	Grassed Waterway	1,043.68	2.23	$468.02
16	8	5	Grassed Waterway	1,191.93	2.51	$474.87
17	1	9	Grassed Waterway	1,553.66	3.19	$487.04
18	7	4	Grassed Waterway	1,571.45	2.58	$609.09
19	1	12	Grassed Waterway	1,476.57	2.42	$610.15
20	7	1	Grassed Waterway	646.37	1.05	$615.59
21	7	5	Grassed Waterway	2,496.53	4.02	$621.03

Table 1: North Brook Watershed Project Ranking

Table 1 Continued: North Brook Watershed Project Ranking

North Brook Watershed BMP ranking based on $ per lb of TP removed						
BMP Characteristics				Cost-Benefit		
22	9	3	Grassed Waterway	1,856.09	2.97	$624.95
23	9	2	Grassed Waterway	2,069.57	3.31	$625.25
24	8	6	Grassed Waterway	604.86	0.96	$630.06
25	7	2	Grassed Waterway	978.45	1.53	$639.51
26	9	4	Grassed Waterway	2,336.42	3.62	$645.42
27	3	1	Grassed Waterway	907.29	1.29	$703.33
28	3	6	Grassed Waterway	1,387.62	1.97	$704.38
29	3	5	Grassed Waterway	670.09	0.95	$705.36
30	3	4	Grassed Waterway	2,621.06	3.48	$753.18
31	8	4	WASCOB	17,548.62	7.69	$2,282.01
32	8	2	WASCOB	26,469.99	9.18	$2,883.44
33	4	3	Grassed Waterway	1,601.10	0.52	$3,079.04
34	1	13	WASCOB	17,058.44	4.92	$3,467.16
35	8	3	WASCOB	31,567.91	6.53	$4,834.29
36	6	3	WASCOB	35,097.25	3.86	$9,092.55
37	1	3	WASCOB	46,763.65	5	$9,352.73
38	9	5	WASCOB	50,391.02	3.8	$13,260.79
NA	1	6	Wetland Restoration	TBD	TBD	TBD
NA	1	7	Wetland Restoration	TBD	TBD	TBD
NA	1	10	Wetland Restoration	TBD	TBD	TBD
NA	1	11	Wetland Restoration	TBD	TBD	TBD
NA	2	1	Wetland Restoration	TBD	TBD	TBD
NA	4	4	Wetland Restoration	TBD	TBD	TBD
NA	6	1	Wetland Restoration	TBD	TBD	TBD
NA	5	1	Wetland Restoration	TBD	TBD	TBD

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Table 2: Wyanett Creek Watershed Project Ranking

Wyanett Creek Watershed BMP ranking based on $ per lb of TP removed						
BMP Characteristics				Cost-Benefit		
Project Ranking	**Priority Zone**	**Sub-Basin**	**Applicable Practice**	**Practice Cost**	**P reduction (lb/yr)**	**$ per lb TP Removed**
24	4	6	Grassed Waterway	$2,217.82	10.86	$204.22
30	5	2	Grassed Waterway	$2,140.73	8.09	$264.61
37	7	3	Grassed Waterway	$1,310.53	4.46	$293.84
42	8	4	Grassed Waterway	$1,719.70	5.81	$295.99
20	4	3	Grassed Waterway	$990.31	3.16	$313.39
44	8	6	Grassed Waterway	$1,701.91	5.32	$319.91
41	8	3	Grassed Waterway	$2,057.71	6.08	$338.44
39	8	1	Grassed Waterway	$1,856.09	5.39	$344.36
11	3	6	Grassed Waterway	$1,061.47	2.81	$377.75
29	5	1	Grassed Waterway	$776.83	2.03	$382.67
45	8	7	Grassed Waterway	$2,158.52	5.45	$396.06
8	3	3	Grassed Waterway	$889.50	2.23	$398.88
40	8	2	Grassed Waterway	$2,235.61	5.45	$410.20
17	3	12	Grassed Waterway	$2,793.03	6.57	$425.12
18	4	1	Grassed Waterway	$2,567.69	5.95	$431.54
14	3	9	Filter Strip	$135.60	0.31	$437.42
13	3	8	Filter Strip	$447.48	1.02	$438.71
12	3	7	Filter Strip	$440.70	1	$440.70
36	7	2	Grassed Waterway	$2,235.61	4.96	$450.73
28	4	10	Grassed Waterway	$1,743.42	3.8	$458.79
26	4	8	Grassed Waterway	$1,950.97	4.25	$459.05

Table 2 Continued: Wyanett Creek Watershed Project Ranking

Wyanett Creek Watershed BMP ranking based on $ per lb of TP removed						
BMP Characteristics				Cost-Benefit		
27	4	9	Grassed Waterway	$1,915.39	4.17	$459.33
31	6	1	Grassed Waterway	$1,197.86	2.51	$477.24
35	7	1	Grassed Waterway	$1,197.86	2.51	$477.24
15	3	10	Grassed Waterway	$1,802.72	3.48	$518.02
33	6	3	Grassed Waterway	$1,310.53	2.49	$526.32
10	3	5	Grassed Waterway	$1,014.03	1.76	$576.15
2	1	2	Grassed Waterway	$1,535.87	2.56	$599.95
1	1	1	Grassed Waterway	$1,862.02	3.1	$600.65
25	4	7	Grassed Waterway	$1,209.72	2	$604.86
4	2	1	Grassed Waterway	$2,318.63	3.66	$633.51
32	6	2	Grassed Waterway	$2,235.61	3.51	$636.93
3	1	3	Grassed Waterway	$1,470.64	2.28	$645.02
43	8	5	Filter Strip	$716.76	0.67	$1,069.79
9	3	4	Filter Strip	$484.06	0.45	$1,075.70
46	8	8	Filter Strip	$350.98	0.28	$1,253.52
21	4	3	Filter Strip	$207.79	0.16	$1,298.68
23	4	5	Filter Strip	$211.68	0.16	$1,323.00
22	4	4	Filter Strip	$174.33	0.13	$1,340.96
7	3	2	WASCOB	$12,646.77	8.99	$1,406.76
6	3	1	WASCOB	$37,254.06	7.93	$4,697.86
16	3	11	WASCOB	$57,743.79	4.75	$12,156.59
19	4	2	WASCOB	$68,625.90	4.69	$14,632.39
38	7	4	Wetland Restoration	TBD	TBD	TBD
5	2	2	Wetland Restoration	TBD	TBD	TBD
34	6	4	Wetland Restoration	TBD	TBD	TBD

About this Document

This Stormwater Retrofit Analysis is a watershed management tool to help prioritize stormwater retrofit projects by performance and cost effectiveness. This process helps maximize the value of each dollar spent.

This document presents the findings of both Wyanett Creek and Northbrook watershed study. Both waterbodies outlet to Green Lake. The watersheds were analyzed separately and the projects identified were compared to each other only if they were in the same watershed

Rural Subwatersheds:
This covers the areas (priority subwatersheds) within the major watershed draining to Wyanett Creek and Northbrook. The Chisago SWCD protocol "Rural Subwatershed Analysis Protocol Part 1-Targeting" was used to highlight the areas with the highest potential for contributing sediment and nutrients to Wyanett Creek and North Brook. Using computer analytic tools, catchments were identified within the subwatersheds that would likely benefit from a water quality project.

Document Organization

This document is organized into three major sections plus references. Each section is briefly described below.

Methods

The methods section outlines general procedures used when analyzing the watersheds. It overviews the processes of retrofit scoping, desktop analysis, retrofit reconnaissance investigation, cost/treatment analysis, and project ranking.

Catchment Profiles

Each catchment and priority subwatershed was given a unique ID number. For each catchment, the following information is detailed:

Catchment Description

Within each catchment profile is a table that summarizes basic catchment information including acres, and land cover. A brief description of the land cover, stormwater infrastructure, and any other important general information is also described.

Retrofit Recommendations

The recommendation section describes the conceptual retrofit(s) that were scrutinized. It includes tables outlining the estimated pollutant removals by each, as well as costs. A map provides promising locations for each retrofit approach.

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Retrofit Ranking

This section ranks stormwater retrofit projects across all selected catchments to create a prioritized project list. The list is sorted by cost per pound of total phosphorus removed for each project. The final cost per pound treatment value includes installation and maintenance costs. Projects identified were ranked against each other if they shared the same watershed. There were wetland restorations identified that were not ranked. Further analysis is needed to determine the cost benefit for the wetland projects identified.

There are many possible ways to prioritize projects, and the list provided in this report is merely a starting point. Other considerations for prioritizing installation may include:

- Non-target pollutant reductions
- Timing projects to occur with other road or utility work
- Project visibility
- Availability of funding
- Total project costs
- Educational value
- Landowner willingness

References

This section identifies various sources of information synthesized to produce the protocol utilized in this analysis.

Appendices

This section provides supplemental information and/or data used at various point along the assessment protocol

Methods:

Selection of Subwatershed

Many factors are considered when choosing which subwatershed to assess for stormwater retrofits, but always focus on the drainage to an important lake, river, or stream. Water quality monitoring data, non-degradation report modeling, and TMDL studies are just a few of the resources available to help determine which waterbodies are a priority. Assessments supported by a Local Government Unit with sufficient capacity (staff, funding, available GIS data, etc.) to greater facilitate the assessment also rank highly. The focus is always on a high priority waterbody.

Rural Subwatershed Selection

This assessment includes the area of land draining to Wyanett Creek and Northbrook that eventually drain into Green Lake. NRCS tools were used to identify subwatersheds and Chisago SWCD targeting protocol was utilized to identify subwatersheds that had the highest potential for pollutant loading.

Targeted pollutants for this study were total phosphorus and total suspended solids. Total phosphorus is a nutrient commonly associated with stormwater that causes excessive algae production and low oxygen levels in lakes and rivers. Total suspended solids was also chosen as a target pollutant because it is also commonly associated with stormwater and causes turbidity in lakes and rivers. Suspended solids are also important because many other pollutants, such as phosphorus or heavy metals, are attached to the particles.

Subwatershed Assessment Methods

Step 1: Retrofit Scoping

Retrofit scoping includes determining the objectives of the retrofits (volume reduction, target pollutant, etc.) and the level of treatment desired. It involves meeting with local land use managers and lake improvement district members to determine the issues in the subwatershed. This step also helps to define preferred retrofit treatment options and retrofit performance criteria. In order to create a manageable area to assess in large subwatersheds, a focus area may be determined.

Step 2: Desktop Retrofit Analysis

The desktop analysis involves computer-based scanning of the subwatershed for potential retrofit catchments and/or specific sites. This step also identifies areas that don't need to be assessed because of existing stormwater infrastructure or current land uses. Accurate GIS data is extremely valuable in conducting the desktop retrofit analysis. Some of the most important GIS layers include: 2-foot or finer topography, hydrology, soils, watershed/subwatershed boundaries, parcel boundaries and high-resolution aerial photography.

Step 3: Retrofit Reconnaissance Field Investigation

After identifying potential retrofit sites through the desktop search, a field investigation was conducted to evaluate each site and identify additional opportunities. Rural retrofit projects can be difficult to verify due to the location of the project. Many of the projects are located on private property and cannot be viewed from the street. Future landowner contact will be important but for now project installation success is assumed heavily on desktop analysis.

Step 4: Treatment Analysis/Cost Estimates

Sites most likely to be conducive to addressing the pollutant reduction goals and appearing to have feasible design, installation, and maintenance were chosen for a cost/benefit analysis. Estimated costs included design, installation, and maintenance annualized across the anticipated project lifespan (10-30 yrs). Estimated benefits included are pounds of phosphorus and total suspended solids removed, though projects were ranked only by cost per pound of phosphorus removed annually.

Treatment analysis

Rural Catchments:

Following watershed delineation, the Chisago Soil and Water Conservation Service Rural Targeting Protocol was utilized to determine high priority locations within the watershed (Chisago SWCD – Rural Subwatershed Analysis Protocol Part 1 – Targeting). This process uses numerous factors included in the Revised Universal Soil Loss Equation (rainfall erosivity, soil types, land use, topography) to determine which areas are more susceptible to soil loss. Catchments were delineated through the Natural Resource Conservation Service Engineering Tool. Spatial information was examined through ESRI's ArcGIS package, using the Targeting protocol as guidance. 17 priority zones were identified through this process, eight in Wyanett Creek and 9 in North Brook.

The Natural Resource Conservation Service (NRCS) Engineering Tool was utilized to determine catchments within each of the 17 priority subwatersheds. Additional information such as average slopes and concentrated flow paths were determined through the Tool as well. Following catchment determination, Chisago SWCD's Rural Priority Protocol (Part 2 – Prioritizing) was followed to determine potential rural BMP projects and to model potential pollutant reductions. Again, these projects would be located within the 17 Priority Subwatershed determined through the Targeting exercise as these areas hold the greatest potential for soil and nutrient export. A desktop analysis was completed using a variety of tools including aerial photography, topography, soils, etc. to determine potential BMP or management practice options within the 17 zones. These potential BMPs were spatially located on maps and field verified where possible.

Current conditions were determined using RUSLE2 software. All fields were assumed to utilize a corn / soybean rotation (RUSLE setting Corn FC Disk Fld Cult-Soybeans FC Disk Fld Cult) and contouring was assumed at a middle value for the absolute row grade. Board of Water and Soil Resources' (BWSR) Pollution Reduction Estimator spreadsheet was used to determine the level of phosphorus and sediment reduction achieved based on the BMP practice being utilized. Table 3 displays the most common BMPs selected for Priority Zone catchments and the modeling procedures that were utilized for each one.

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Table 3. Rural catchment BMPS and modeling programs for Wyanett Creek and North Brook Subwatershed Assessment.

Parameter / BMP	***Model***
WASCOB / Grassed waterway	BWSR Spreadsheet - Gully
Filter Strip	BWSR Spreadsheet - Filter Strip; RUSLE2
Gully Stabilization	BWSR Spreadsheet - Gully
Wetland Restoration	TBD

Cost Estimates

Rural Catchments:

Cost estimates were annualized costs that incorporated installation costs, contracted annual maintenance, yearly operation and maintenance over a 10 year period, design costs and installation oversight. The cost of the project is largely dependent on the size and complexity, so these estimates were determined to be mid-range expectations for the associated project types. It should be understood that detailed site specific construction investigations were not done as part of this assessment and therefore cost estimates account for only general site consideration.

Table 4. Rural BMP practices and estimated costs.

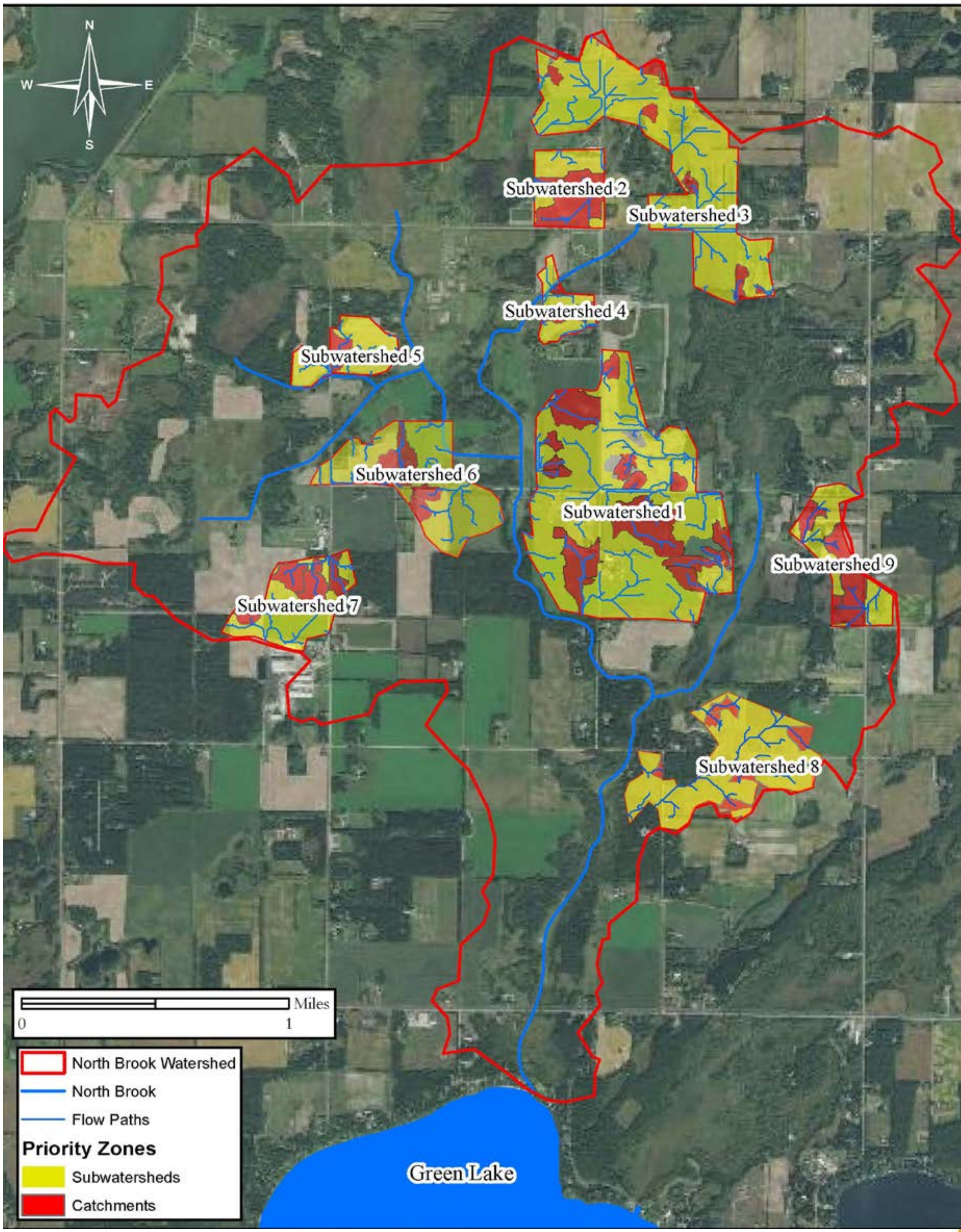
BMP	Initial Installation Cost ($/Unit)	Contracted annual maintenance cost ($/unit)	O & M Term (Years)	Design Cost ($70/hr)	Installation Oversight Cost ($70/hr)	Total Installation Cost (Including 1 year maintenance)
Grassed waterway (1,000 ft)	$4.00	$0.25	10	$1,120.00	$560.00	$5,930.00
WASCOB (0-10 acres drainage area)	$8,438.00	$100.00	10	$843.80	$421.90	$9,803.70
WASCOB (10-20 acres drainage area)	$11,250.00	$150.00	10	$1,125.00	$562.50	$13,087.50
WASCOB (20-40 acres drainage area)	$16,875.00	$200.00	10	$1,687.50	$843.75	$19,606.25
Filter strip (10 acres)	$500.00	$10.00	10	$1,120.00	$560.00	$6,780.00
Nutrient Mgmt (10 acres)	$11.00	$0.00	10	$560.00	$280.00	$950.00
Wetland Creation (10 acres)	$7,000.00	$45.00	10	$2,800.00	$1,400.00	$74,650.00
Wetland Restoration (10 acres)	$3,000.00	$45.00	10	$2,800.00	$1,400.00	$34,650.00
Permanent Vegetation (10 acre)	$400.00	$80.00	10	$1,120.00	$500.00	$6,110.00

**Cost estimates taken from Chisago SWCD report (Chisago Lakes Chain of Lakes Watershed SWA, North Center Lake Subwatershed report, 2014) except for Permanent Vegetation (Sherburne SWCD estimate).*

Evaluation and Ranking

The cost per pound of phosphorus treated was calculated for potential retrofit projects, and projects were ranked by this cost effectiveness measure. Only projects that seem realistic and feasible were considered. The recommended level was the level of treatment that would yield the greatest benefit per dollar spent while being considered feasible and not falling below a minimal amount needed to justify crew mobilization and outreach efforts. Local officials may wish to revise the recommended level based on water quality goals, finances or public opinion.

Catchment Profiles – North Brook Rural Catchments

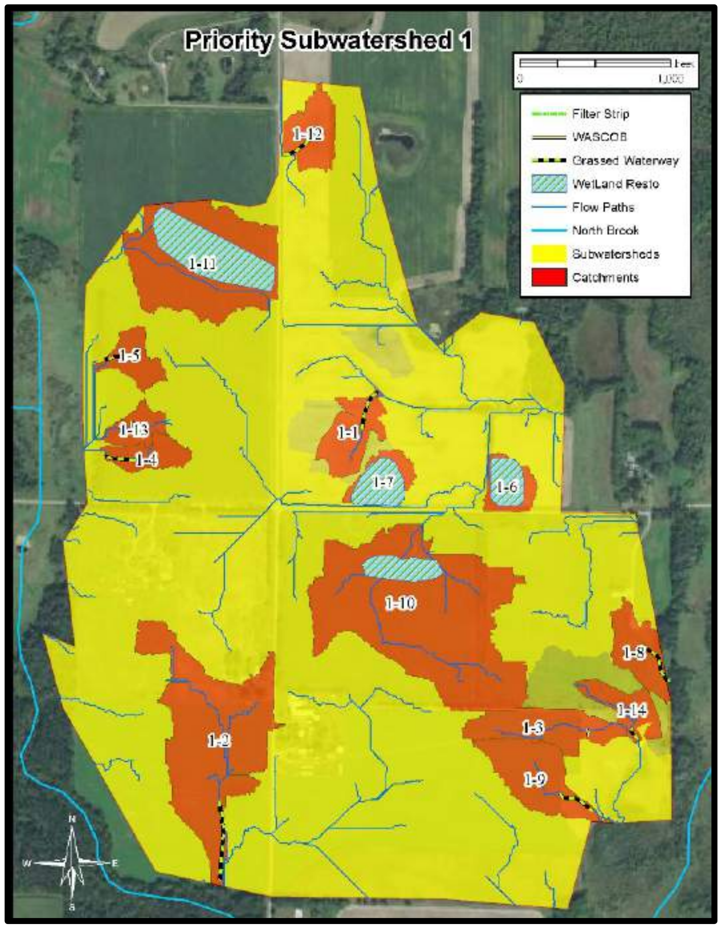


North Brook Subwatershed and Catchments

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Priority Subwatershed 1

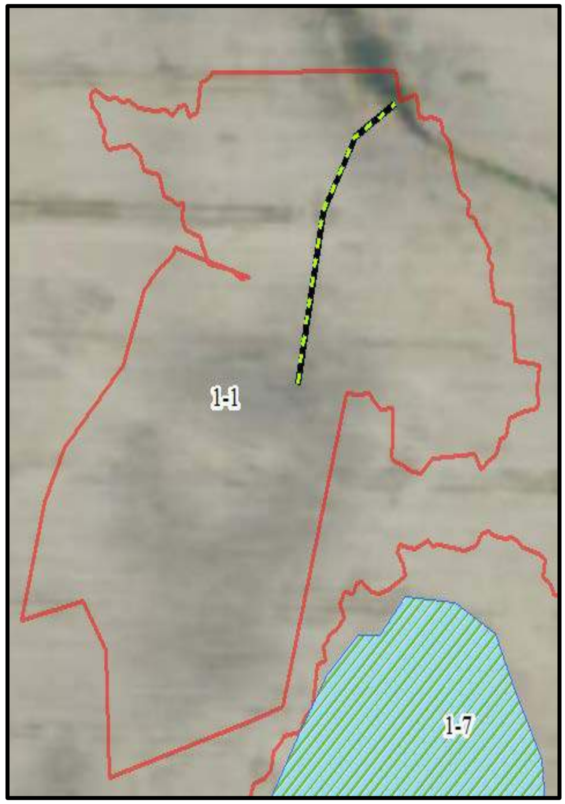
Priority subwatershed 1 is the largest identified subwatershed (351 acres). Due to the fact that North Brook flows along the east and west boarder of drainage area, it was selected area as a high priority. The majority of land use is agricultural with wetlands and forests bordering North Brook. A total of 14 catchments were identified within the area as being high priority for implementing successful water quality projects. Among the 14 identified projects, four are wetland restorations. These projects were not modeled and will need further analysis to calculate pollution reductions. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to North Brook and Green Lake.



Priority Subwatershed 1 Summary	
Acres addressed	65.1
Dominant Land Cover	Agricultural
Total Catchments	14
Potential BMPs	14
Potential TP reduction (lb/yr)	63.72
Potential TSS reduction (tons/yr)	74.95

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 1
Catchment 1



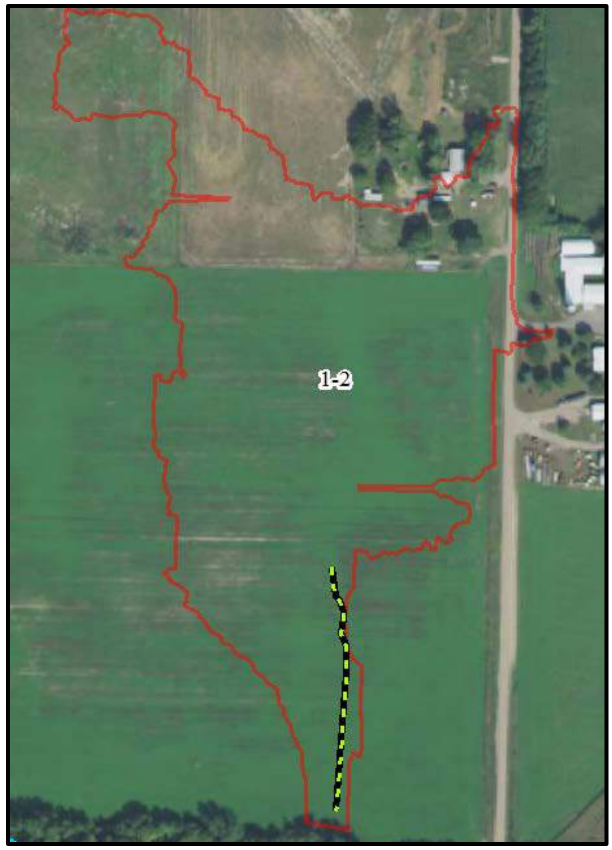
Drainage Area – 2.11 acres
Property Ownership – Private
Site Specific Information – A grassed waterway is recommended as a water quality project for this catchment. Among other criteria, topography indicated a potential for gully formation. Implementing this practice would vegetate the concentrated flow path, reduce overland flow and prevent soil loss. It was assumed based on aerial photography, the concentrated flow path outlets directly to an open water ditch, in turn increasing the amount of nutrient loading to North Brook and eventually Green Lake.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,666.33	**13.14**	**$126.81**

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Grassed Waterway	Sediment reduction (t/yr)	15.46
Acres	2.11			Soil Loss reduction (t/yr)	15.46
Soil	Blomford loamy fine sand	Vol Voided (ft^3)	281	Phosphorus reduction (lb/yr)	13.14
Average slope	2	Length (ft)	281		
		Years	1		
		Distance to SW (ft)	0		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 1
Catchment 2



Drainage Area – 16.5 acres
Property Ownership – Private
Site Specific Information – A grassed waterway, located on the southern portion of the catchment, is recommended as a water quality project for this catchment. Among other criteria, topography indicated a potential for gully formation, especially at rivers edge. Implementing this practice would vegetate the concentrated flow path, reduce overland flow and prevent soil loss. It was assumed based on aerial photography, the concentrated flow path outlets directly to an open water ditch, in turn increasing the amount of nutrient loading to North Brook and eventually Green Lake.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$3,148.83	**24.84**	**$126.76**

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	Grassed Waterway	Sediment reduction (t/yr)	29.21
Acres	16.65			Soil Loss reduction (t/yr)	29.21
Soil	Zimmerman fine sand and fine sand 7to 12 percent slopes	Vol Voided (ft^3)	531	Phosphorus reduction (lb/yr)	24.84
Slope length (ft)		Length (ft)	531		
Average slope	4.7	Years	1		
		Distance to SW (ft)	0		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – WASCOB
Subwatershed 1
Catchment 3

Drainage Area – 4.77 acres
Property Ownership – Private
Site Specific Information – Catchment 3 is 100% agricultural land use. The east section of the catchment shows steep slopes with an obvious linear depression corresponding with the elevation data. Implementing a WASCOB in this area would greatly reduce overland flow through the gullied area. Topography also indicates the practice would allow farming alteration to be kept to a minimum.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$46,763.65	**5.00**	**$9,352.73**

Current Conditions		Added Practice		Reduction	
Sub-Basin	3	Type	WASCOB	Sediment reduction (t/yr)	5.88
Acres	4.77			Soil Loss reduction (t/yr)	22
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	4.77	Phosphorus reduction (lb/yr)	5
		Length (ft)	400		
Average slope	3.41	Years	1		
		Distance to SW (ft)	586		

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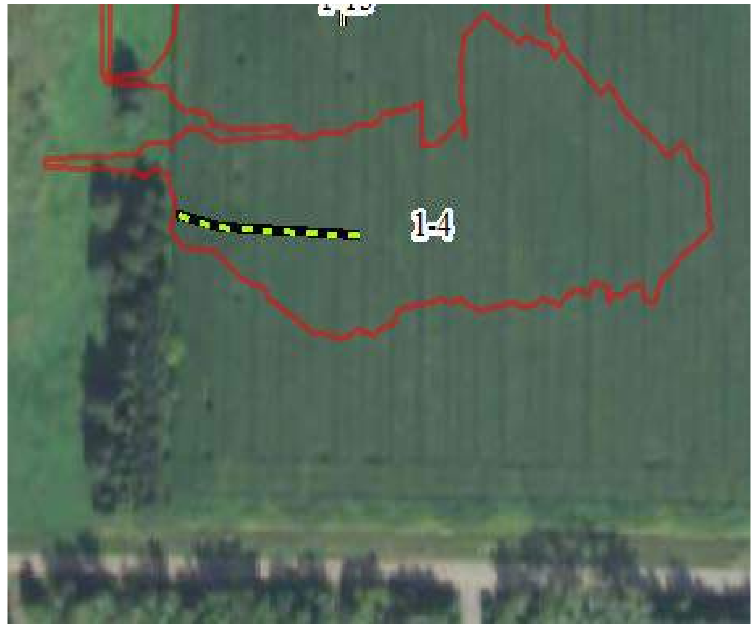
Project ID – Grassed Waterway
Subwatershed 1
Catchment 4



Drainage Area – 2.18 acres
Property Ownership – Private
Site Specific Information – A grassed waterway, located on the western portion of the catchment, is recommended as a water quality project for this catchment. Among other criteria, topography indicated a potential for gully formation. Implementing this practice would vegetate the concentrated flow path, reduce overland flow and prevent soil loss. Slopes in this area are moderately steep and could benefit from establishing permanent vegetation to help stabilize soils and reduce runoff into the adjacent wetland

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,197.86	**2.69**	**$445.30**

Current Conditions		Added Practice		Reduction	
Sub-Basin	4	Type	Grassed Waterway	Sediment reduction (t/yr)	3.16
Acres	2.18			Soil Loss reduction (t/yr)	11.11
Soil	Braham Loamy fine sand, 2 to 7 percent slopes	Vol Voided (ft^3)	202	Phosphorus reduction (lb/yr)	2.69
		Length (ft)	202		
Average slope	3.07	Years	1		
		Distance to SW (ft)	434		

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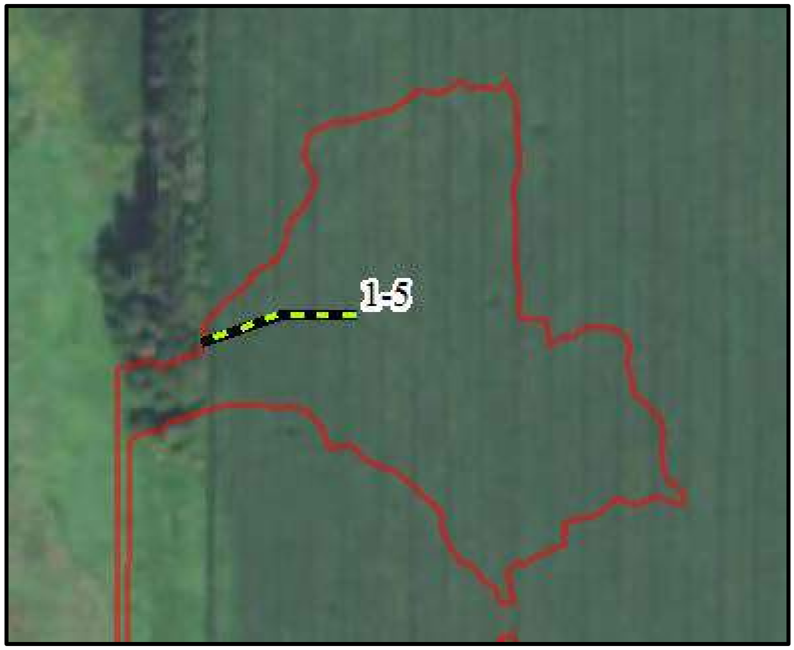
Project ID – Grassed Waterway
Subwatershed 1
Catchment 5



Drainage Area – 2.3 acres
Property Ownership – Private
Site Specific Information – A Grassed Waterway, located on the western portion of the catchment, is recommended as a water quality project for this catchment. Among other criteria, topography indicated a potential for gully formation. Implementing this practice would vegetate the concentrated flow path, reduce overland flow and prevent soil loss. Slopes in this area are moderately steep and could benefit from establishing permanent vegetation to help stabilize soils and reduce runoff into the adjacent wetland.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$824.27	**1.86**	**$443.16**

Current Conditions		Added Practice		Reduction	
Sub-Basin	5	Type	Grassed Waterway	Sediment reduction (t/yr)	2.19
Acres	2.33			Soil Loss reduction (t/yr)	7.65
Soil	Braham Loamy fine sand, 2 to 7 percent slopes	Vol Voided (ft^3)	139	Phosphorus reduction (lb/yr)	1.86
		Length (ft)	139		
Average slope	4.18	Years	1		
		Distance to SW (ft)	425		

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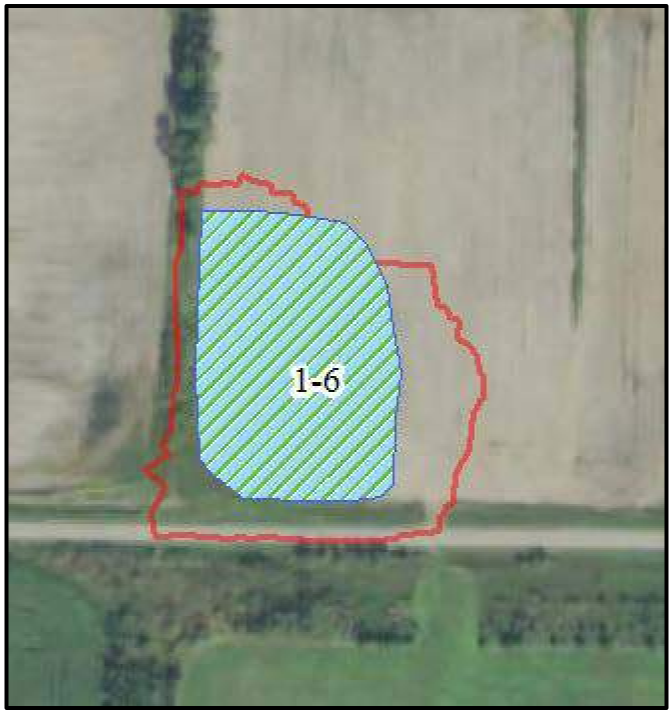
Project ID – Wetland Resto
Subwatershed 1
Catchment 6



Drainage Area – 2.44 acres
Property Ownership – Private
Site Specific Information – Located at the southwestern section of the agricultural field is a low depression in the landscape that would has the potential to be restored to wetland. Using historical aerial photos it was determined this location is marginal land, showing hydrologic indicators in the majority of the photos. Wetland Restorations were not modeled during this assessment however the opportunity is there to restore an area to a more diverse environment that would improve water quality and improve wildlife habitat.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
Unknown	**Unknown**	**Unknown**

Current Conditions		Added Practice		Reduction	
Sub-Basin	6	Type	Wetland Resto	Sediment reduction (t/yr)	0
Acres	2.44			Soil Loss reduction (t/yr)	0
Soil	Isanti mucky loamy fine sand	Vol Voided (ft^3)	0	Phosphorus reduction (lb/yr)	0
		Length (ft)	0		
Average slope	3.79	Years	1		
		Distance to SW (ft)	0		

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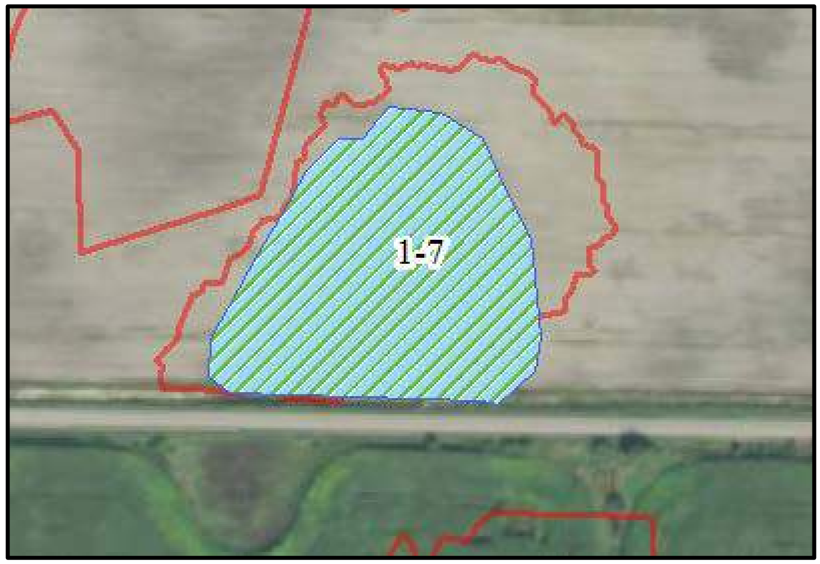
Project ID – Wetland Restoration
Subwatershed 1
Catchment 7



Drainage Area – 2.7 acres.

Property Ownership – Private

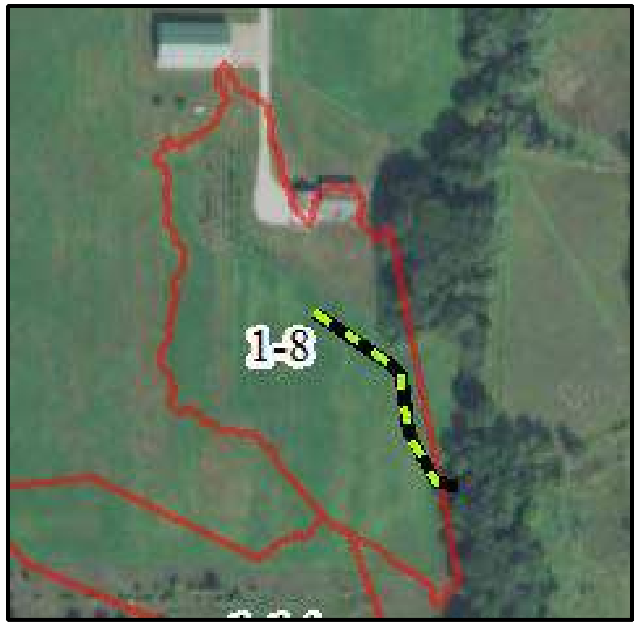
Site Specific Information – Located at the southern section of the agricultural field is a low depression in the landscape that would has the potential to be restored to wetland. Using historical aerial photos it was determined this location is marginal land, showing hydrologic indicators in the majority of the photos. Wetland Restorations were not modeled during this assessment however the opportunity is there to restore an area to a more diverse environment that would improve water quality and improve wildlife habitat.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
Unknown	**Unknown**	**Unknown**

Current Conditions		Added Practice		Reduction	
Sub-Basin	7	Type	Wetland Resto	Sediment reduction (t/yr)	0
Acres	2.7			Soil Loss reduction (t/yr)	0
Soil	Isanti mucky loamy fine sand	Vol Voided (ft^3)	0	Phosphorus reduction (lb/yr)	0
		Length (ft)	0		
Average slope	2.86	Years	1		
		Distance to SW (ft)	0		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID –Grassed Waterway
Subwatershed 1
Catchment 8



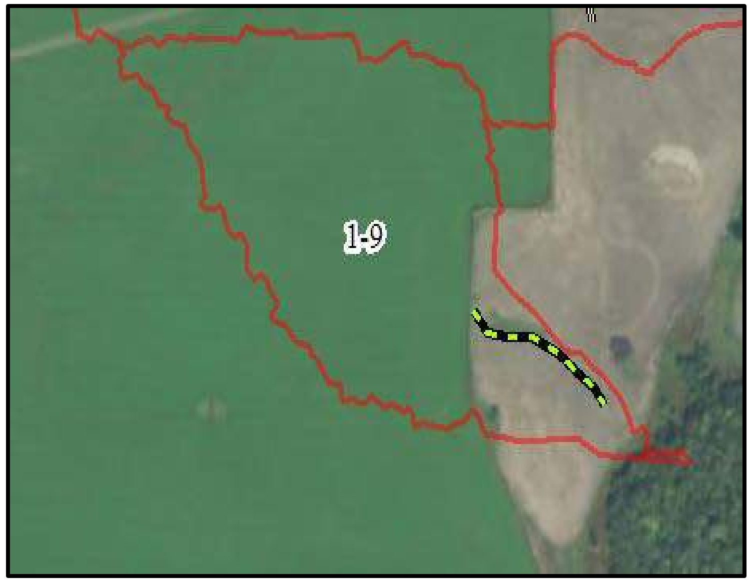
Drainage Area – 3.28 acres
Property Ownership – Private
Site Specific Information – A Grassed Waterway, located on the eastern portion of the catchment, is recommended as a water quality project for this catchment. Among other criteria, topography indicated potential for gully formation. Implementing this practice would vegetate the concentrated flow path, reduce overland flow and prevent soil loss. Slopes in this area are moderately steep and could benefit from establishing permanent vegetation to help stabilize soils and reduce runoff into the adjacent wetland.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,891.67	**4.12**	**$459.14**

Current Conditions		Added Practice		Reduction	
Sub-Basin	8	Type	Grassed Waterway	Sediment reduction (t/yr)	4.85
Acres	3.28			Soil Loss reduction (t/yr)	17.55
Soil	Zimmerman fine sand and fine sand 7to 12 percent slopes	Vol Voided (ft^3)	319	Phosphorus reduction (lb/yr)	4.12
		Length (ft)	319		
Average slope	8.1	Years	1		
		Distance to SW (ft)	500		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 1
Catchment 9



Drainage Area – 5.3 acres
Property Ownership – Private
Site Specific Information – A filter strip, located on the eastern portion of the catchment, is recommended as a water quality project for this catchment. Among other criteria, topography indicated potential for gully formation. Implementing this practice would vegetate the concentrated flow path, reduce overland flow and prevent soil loss. Slopes in this area are moderately steep and could benefit from establishing permanent vegetation to help stabilize soils and reduce runoff into the adjacent wetland.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,553.66	**3.19**	**$487.04**

Current Conditions		Added Practice		Reduction	
Sub-Basin	9	Type	Grassed Waterway	Sediment reduction (t/yr)	3.76
Acres	5.38			Soil Loss reduction (t/yr)	14.41
Soil	Zimmerman fine sand, 1 to 6 percent slopes	Vol Voided (ft^3)	262	Phosphorus reduction (lb/yr)	3.19
		Length (ft)	730		
Average slope	5.06	Years	1		
		Distance to SW (ft)	665		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

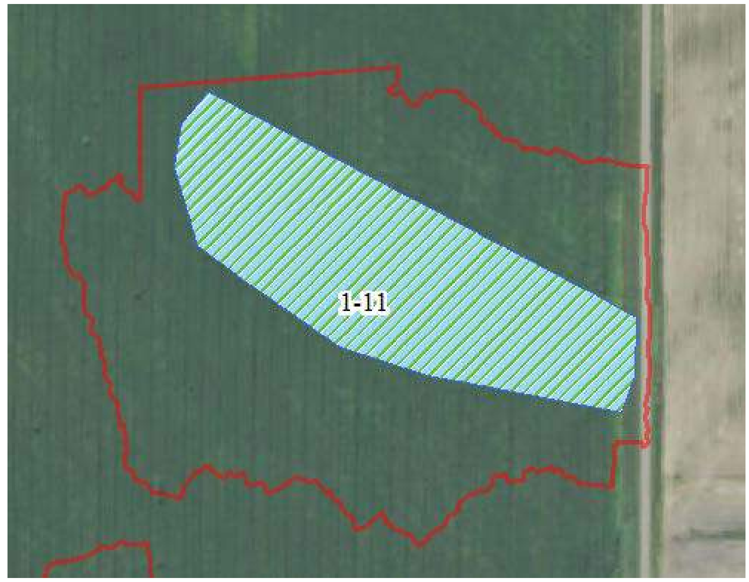
Project ID – Wetland Restoration
Subwatershed 1
Catchment 10

Drainage Area – 25.6 acres
Property Ownership – Private
Site Specific Information – Located at the northern section of the agricultural field is a low depression in the landscape that has the potential to be restored to wetland. Using historical aerial photos it was determined this location is marginal land, showing hydrologic indicators in the majority of the photos. Wetland Restorations were not modeled during this assessment however the opportunity is there to restore an area to a more diverse environment that would improve water quality and improve wildlife habitat.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
Unknown	Unknown	Unknown

Current Conditions		Added Practice		Reduction	
Sub-Basin	10	Type	Wetland Resto	Sediment reduction (t/yr)	0
Acres	25.6			Soil Loss reduction (t/yr)	0
Soil	Isanti mucky loamy fine sand	Vol Voided (ft^3)	0	Phosphorus reduction (lb/yr)	0
		Length (ft)	0		
Average slope	2.46	Years	1		
		Distance to SW (ft)	0		

Project ID – Wetland Resto
Subwatershed 1
Catchment 11



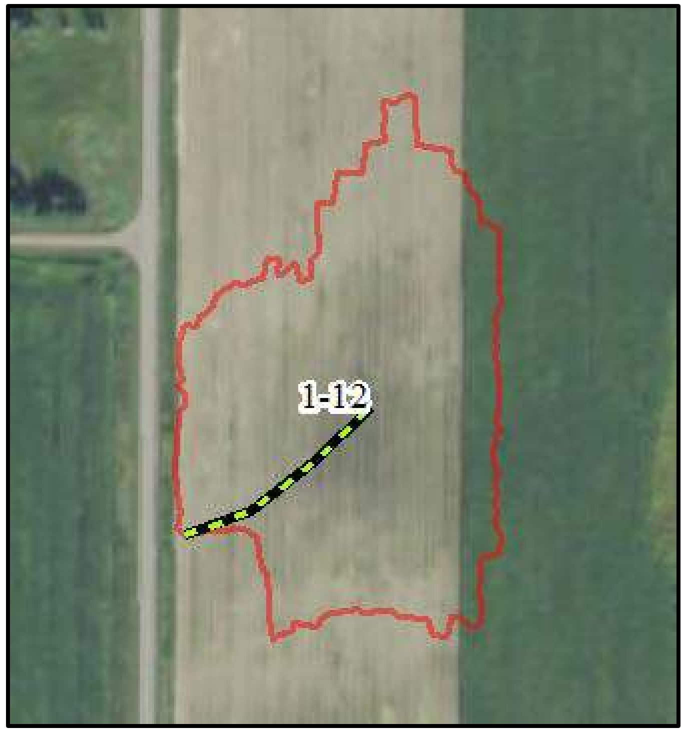
Drainage Area – 14.77 acres
Property Ownership – Private
Site Specific Information – Located in the middle of the agricultural field is a low depression in the landscape that has the potential to be restored to wetland. Using historical aerial photos, it was determined this location is marginal land, showing hydrologic indicators in the majority of the photos. Wetland Restorations were not modeled during this assessment however the opportunity is there to restore an area to a more diverse environment that would improve water quality and improve wildlife habitat.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
Unknown	Unknown	Unknown

Current Conditions		Added Practice		Reduction	
Sub-Basin	11	Type	Wetland Resto	Sediment reduction (t/yr)	0
Acres	14.77			Soil Loss reduction (t/yr)	0
Soil	Isanti mucky loamy fine sand	Vol Voided (ft^3)	0	Phosphorus reduction (lb/yr)	0
		Length (ft)	0		
Average slope	3.38	Years	1		
		Distance to SW (ft)	0		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 1
Catchment 12



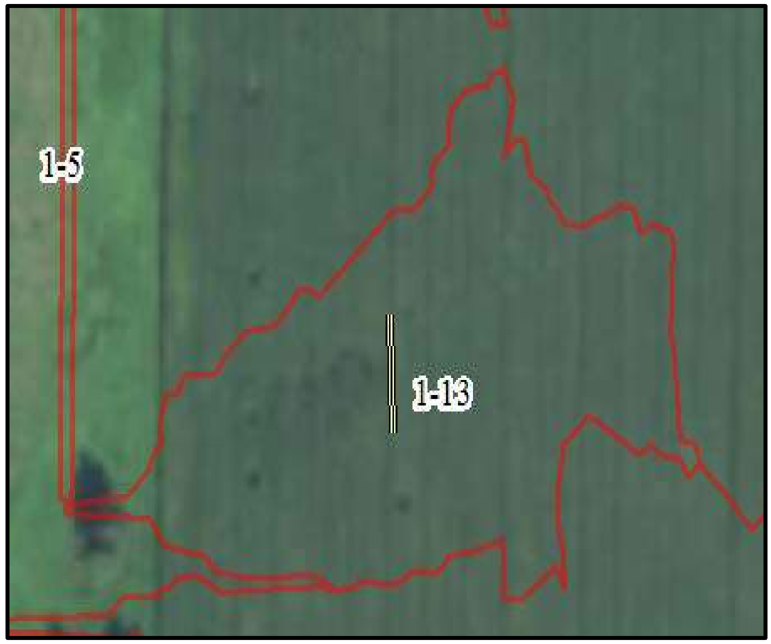
Drainage Area – 3.2 acres
Property Ownership – Private
Site Specific Information – A grassed waterway located on the western portion of the catchment is recommended as a water quality project for this catchment. Among other criteria, aerial photography indicated potential for gully formation. Implementing this practice would vegetate the concentrated flow path, reduce overland flow and prevent soil loss. The flow path could be assumed to outlet into an open water roadside ditch which would increase the potential of nutrient loading to North Brook and eventually Green Lake.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,476.57	**2.42**	**$610.15**

Current Conditions		Added Practice		Reduction	
Sub-Basin	12	Type	Grassed Waterway	Sediment reduction (t/yr)	2.84
Acres	3.2			Soil Loss reduction (t/yr)	13.7
Soil	Blomford loamy fine sand	Vol Voided (ft^3)	249	Phosphorus reduction (lb/yr)	2.42
		Length (ft)	249		
Average slope	2.05	Years	1		
		Distance to SW (ft)	2000		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – WASCOB
Subwatershed 1
Catchment 13



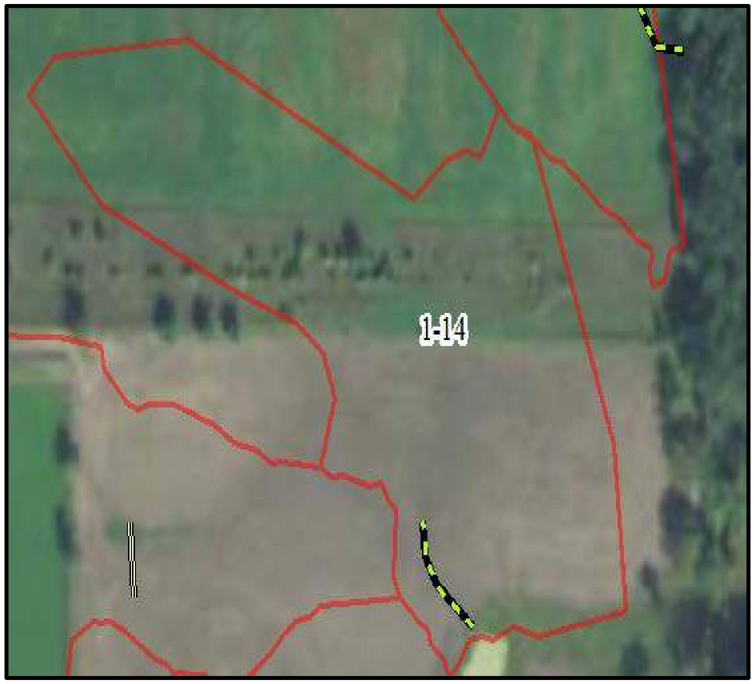
Drainage Area – 1.74 acres
Property Ownership – Private
Site Specific Information –
Catchment 13 is 100% agricultural land use. Starting in the middle of the catchment running west shows steep slopes with an obvious linear depression corresponding with the elevation data. Implementing a WASCOB in this area would greatly reduce overland flow through the gullied area. Topography also indicates the practice would allow farming alteration to be kept to a minimum.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$17,058.44	**4.92**	**$3,467.16**

Current Conditions		Added Practice		Reduction	
Sub-Basin	13	Type	Grassed Waterway	Sediment reduction (t/yr)	5.79
Acres	1.74			Soil Loss reduction (t/yr)	19.75
Soil	Braham Loamy fine sand, 2 to 7 percent slopes	Vol Voided (ft^3)	1.74	Phosphorus reduction (lb/yr)	4.92
		Length (ft)	359		
Average slope	4.46	Years	1		
		Distance to SW (ft)	377		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 1
Catchment 14



Drainage Area – 2.57 acres
Property Ownership – Private
Site Specific Information – A grassed waterway, located on the south west portion of the catchment is recommended as a water quality project for this catchment. Among other criteria, topography indicated potential for gully formation. Implementing this practice would vegetate the concentrated flow path, reduce overland flow and prevent soil loss. Slopes in this area are moderately steep and could benefit from establishing permanent vegetation to help stabilize soils and reduce runoff into the adjacent wetland.

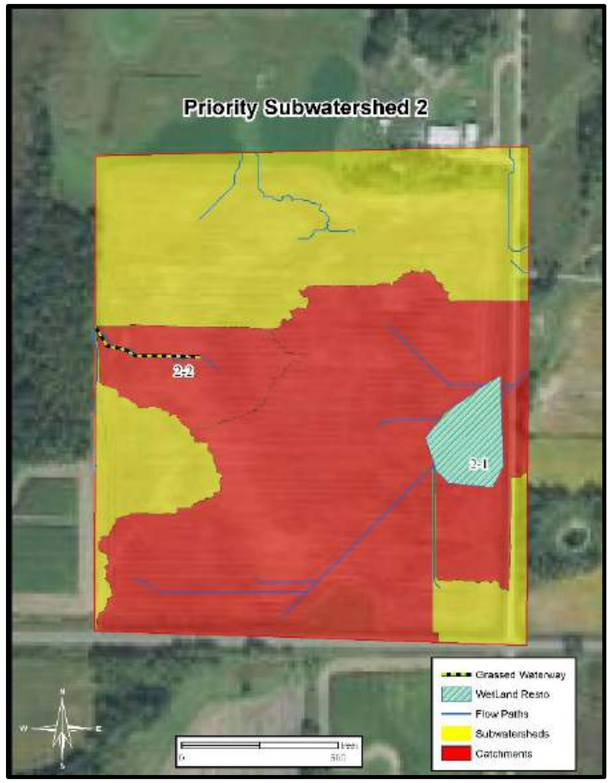
Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$539.63	**1.54**	**$350.41**

Current Conditions		Added Practice		Reduction	
Sub-Basin	14	Type	Grassed Waterway	Sediment reduction (t/yr)	1.81
Acres	2.57			Soil Loss reduction (t/yr)	5.01
Soil	Zimmerman fine sand and fine sand 7to 12 percent slopes	Vol Voided (ft^3)	91	Phosphorus reduction (lb/yr)	1.54
		Length (ft)	144		
Average slope	9.19	Years	1		
		Distance to SW (ft)	135		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Priority Subwatershed 2

Priority subwatershed 2 is 49 acres of 100% agricultural land. It is located 650 feet of North Brook at the northern most tip. While the slopes in this area are moderate, they do show indications of erosion. The area is surrounded, for the most part, by agricultural land use but there are small sections of forest and wetlands on the west side. This priority subwatershed has two proposed projects; however, like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to North Brook and Green Lake.



Priority Subwatershed 2 Summary	
Acres addressed	49
Dominant Land Cover	Agricultural
Total Catchments	2
Potential BMPs	2
Potential TP reduction (lb/yr)	4.79
Potential TSS reduction (tons/yr)	5.63

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Wetland Restoration Subwatershed 2 Catchment 1

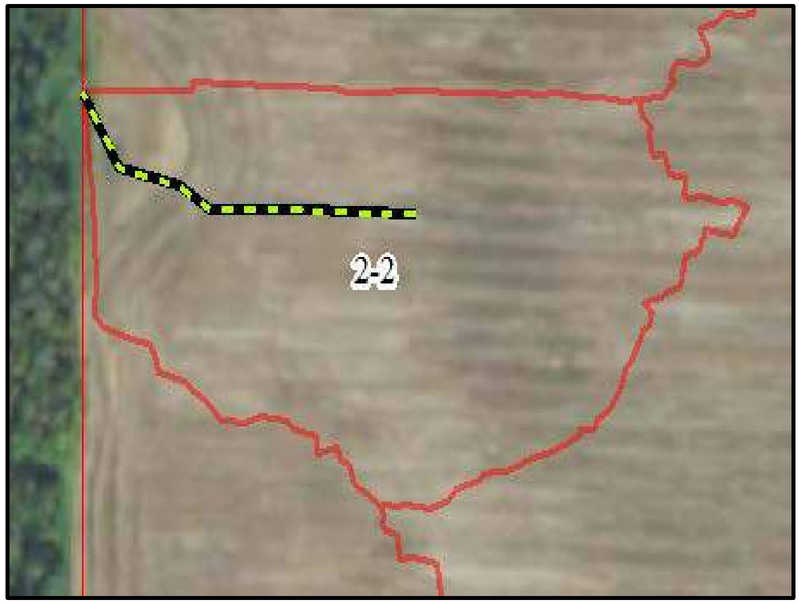
Drainage Area – 4.03 acres
Property Ownership – Private
Site Specific Information – Located in the middle of the agricultural field is a low depression in the landscape that has the potential to be restored to wetland. Using historical aerial photos it was determined this location is marginal land, showing hydrologic indicators in the majority of the photos. Wetland Restorations were not modeled during this assessment however the opportunity is there to restore an area to a more diverse environment that would improve water quality and improve wildlife habitat.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
Unknown	Unknown	Unknown

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Wetland Resto	Sediment reduction (t/yr)	NA
Acres	4.03	Area (acres)	1.38	Soil Loss reduction (t/yr)	NA
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	0	Phosphorus reduction (lb/yr)	NA
		Length (ft)	0		
Average slope	5	Years	1		
		Distance to SW (ft)			

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway Subwatershed 2 Catchment 2



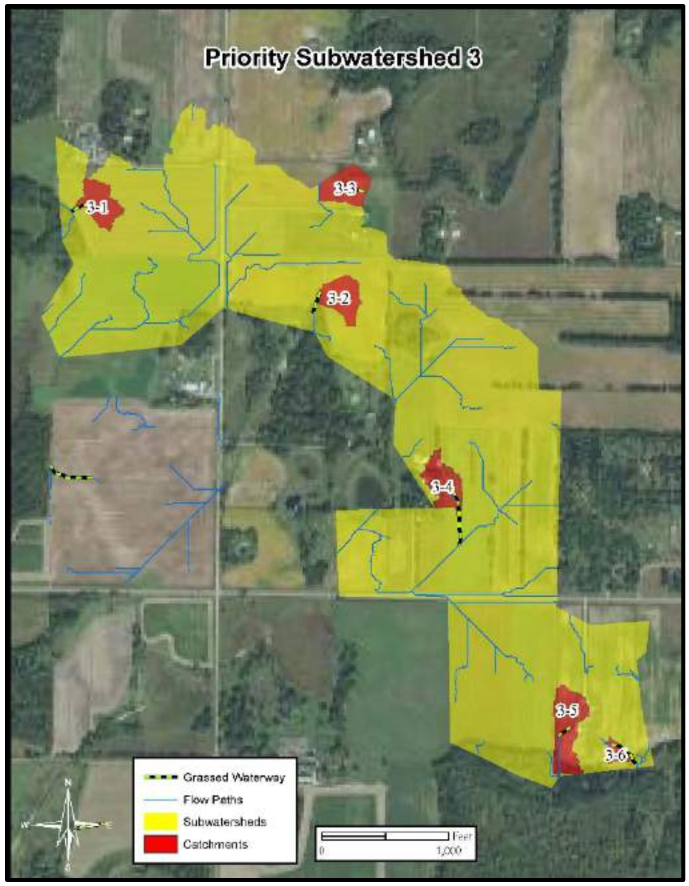
Drainage Area – 3.56 acres
Property Ownership – Private
Site Specific Information – A grassed waterway is being proposed at the north west section of the catchment. The entire catchment is agricultural land with moderate slope. Among other desk top analysis, aerial photography indicated potential for gully formation. Implementing this practice would vegetate the concentrated flow path, reduce overland flow and prevent soil loss.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$2,223.75	4.79	464.25

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	Grassed Waterway	Sediment reduction (t/yr)	5.63
Acres	3.56	Area (acres)		Soil Loss reduction (t/yr)	20.63
Soil	y fine sand, 2 to 7 pe	Vol Voided (ft^3)	375	Phosphorus reduction (lb/yr)	4.79
		Length (ft)	375		
Average slope	2.43	Years	1		
		Distance to SW (ft)	531		

Priority Subwatershed 3

Priority subwatershed 3 is 209 acres. The majority of land use is agriculture and there and are three small farmsteads located in the drainage area. A minimal amount of the area is forested. Subwatershed three is the farthest north priority area and comes within 200 feet of North Brook near the southern section. The slopes in this area are moderate to severe with sandy soils. Six priority catchments were identified during desktop analysis where water quality projects are recommended. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation.

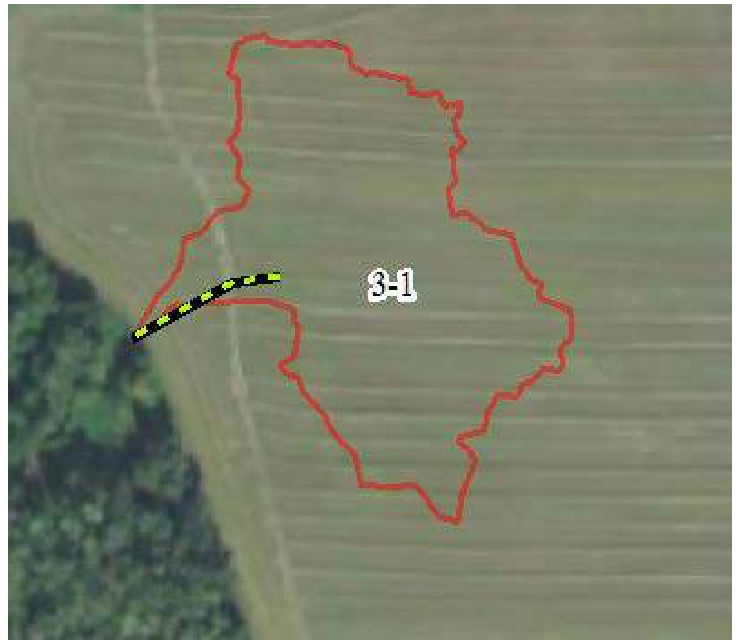


Priority Subwatershed 3 Summary	
Acres addressed	209
Dominant Land Cover	Agricultural
Total Catchments	6
Potential BMPs	6
Potential TP reduction (lb/yr)	12.45
Potential TSS reduction (tons/yr)	14.63

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

CLEAN WATER LAND & LEGACY AMENDMENT

Project ID – Grassed Waterway
Subwatershed 3
Catchment 1



Drainage Area – 1.9 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located on the west side of the catchment and outlets into adjacent forest land.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$907.29	1.29	$703.33

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Grassed Waterway	Sediment reduction (t/yr)	1.51
Acres	1.9	Area (acres)		Soil Loss reduction (t/yr)	8.42
Soil	Hayden fine sandy loam, 2 to 7 percent slopes	Vol Voided (ft^3)	153	Phosphorus reduction (lb/yr)	1.29
		Length (ft)	153		
Average slope	2.5	Years	1		
		Distance to SW (ft)	4000		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 3
Catchment 2

Drainage Area – 2 acres
Property Ownership – Private
Site Specific Information - The Catchment is estimated 98% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located on the west side of the catchment and outlets into adjacent forest wetland area.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$978.45	2.74	$357.10

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	Grassed Waterway	Sediment reduction (t/yr)	3.22
Acres	2	Area (acres)		Soil Loss reduction (t/yr)	9.08
Soil	anoka loamy fine sand, 2 to 7 percent slopes	Vol Voided (ft^3)	165	Phosphorus reduction (lb/yr)	2.74
		Length (ft)	165		
Average slope	165	Years	1		
		Distance to SW (ft)	150		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway Subwatershed 3 Catchment 3

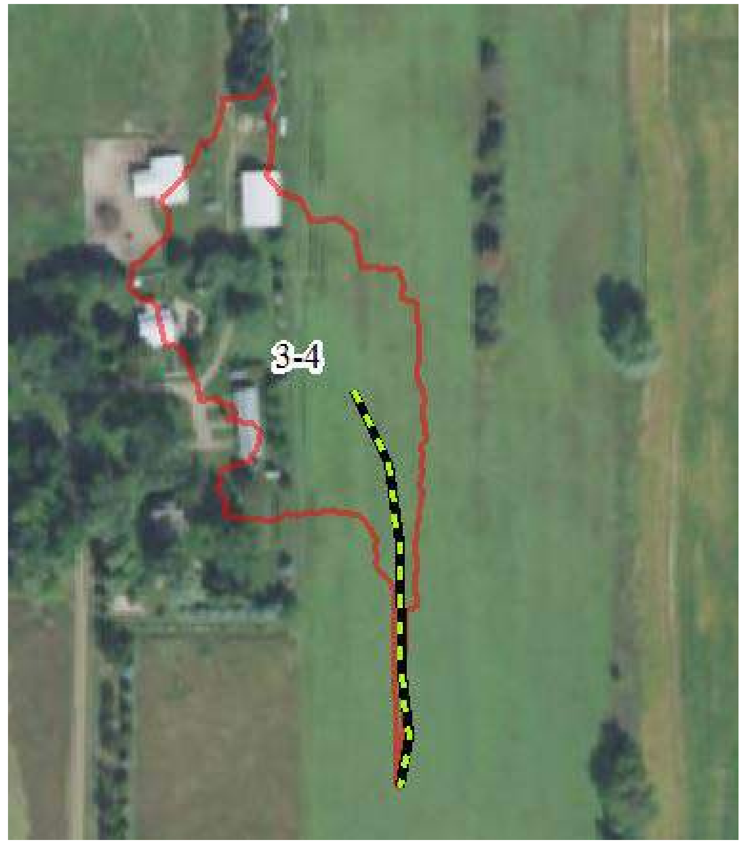
Drainage Area – 2.1 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 60% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located on the east side of the catchment and outlets into adjacent grass field.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$806.48	2.02	$399.25

Current Conditions		Added Practice		Reduction	
Sub-Basin	3	Type	Grassed Waterway	Sediment reduction (t/yr)	2.38
Acres	2.1	Area (acres)		Soil Loss reduction (t/yr)	7.48
Soil	anoka loamy fine sand, 7 to 12 percent slopes	Vol Voided (ft^3)	136	Phosphorus reduction (lb/yr)	2.02
		Length (ft)	136		
Average slope	136	Years	1		
		Distance to SW (ft)	254		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway Subwatershed 3 Catchment 4



Drainage Area – 2.24 acres

Property Ownership – Private

Site Specific Information – The Catchment is estimated 50% agricultural land use and 50% low density residential. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located on the south end of the catchment.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$2,621.06	3.48	$753.18

Current Conditions		Added Practice		Reduction	
Sub-Basin	4	Type	Grassed Waterway	Sediment reduction (t/yr)	4.09
Acres	2.24	Area (acres)		Soil Loss reduction (t/yr)	24.31
Soil	anoka loamy fine sand, 2 to 7 percent slopes	Vol Voided (ft^3)	442	Phosphorus reduction (lb/yr)	3.48
		Length (ft)	442		
Average slope	3.5	Years	1		
		Distance to SW (ft)	5500		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 3
Catchment 5

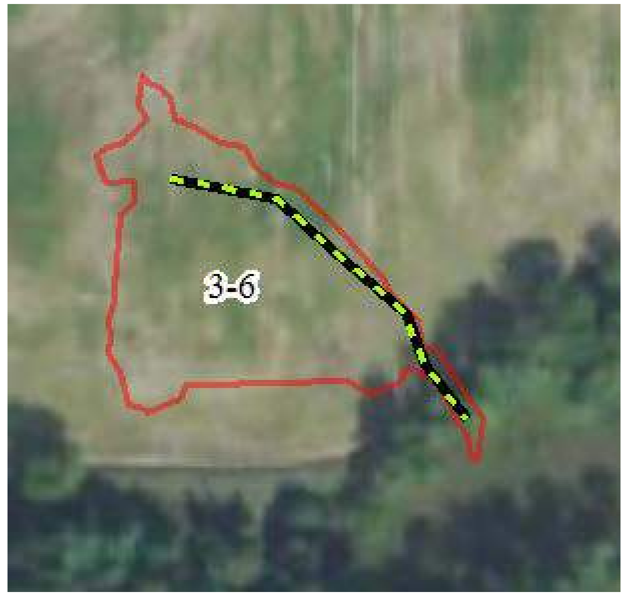
Drainage Area – 3.13 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 80% agricultural land use with a small portion of low density residential and forest. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$670.09	0.95	$705.36

Current Conditions		Added Practice		Reduction	
Sub-Basin	5	Type	Grassed Waterway	Sediment reduction (t/yr)	1.12
Acres	3.13	Area (acres)		Soil Loss reduction (t/yr)	6.22
Soil	anoka loamy fine sand, 2 to 7 percent slopes	Vol Voided (ft^3)	113	Phosphorus reduction (lb/yr)	0.95
		Length (ft)	113		
Average slope	3.8	Years	1		
		Distance to SW (ft)	4000		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 3
Catchment 6



Drainage Area – .62 acres

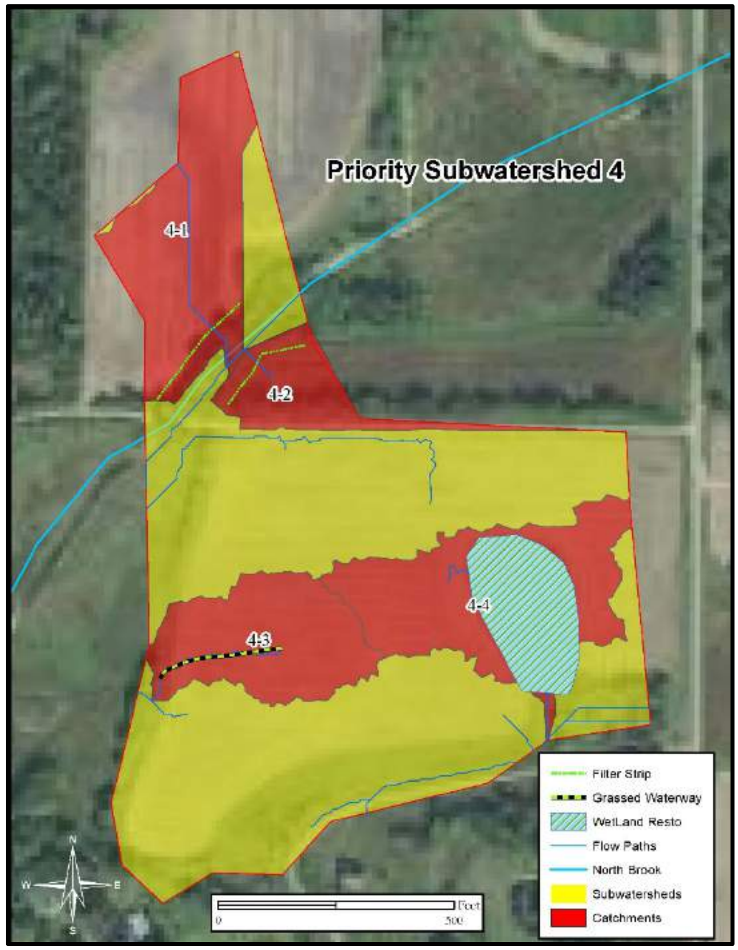
Property Ownership – The Catchment is estimated 99% agricultural land use with a small portion of wetland. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located on northern edge of the catchment and outlets into adjacent wetland.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,387.62	1.97	$704.38

Current Conditions		Added Practice		Reduction	
Sub-Basin	6	Type	Grassed Waterway	Sediment reduction (t/yr)	2.31
Acres	0.62	Area (acres)		Soil Loss reduction (t/yr)	12.87
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	234	Phosphorus reduction (lb/yr)	1.97
		Length (ft)	234		
Average slope	4.8	Years	1		
		Distance to SW (ft)	4000		

Priority Subwatershed 4

Priority subwatershed 4 is 25.31 acres of mainly agricultural land with some forested land use. In addition to the sandy soils, moderate slopes and agricultural land use, the area was prioritized because North Brook runs through the north section of the subwatershed. Four priority catchments were identified during desktop analysis where water quality projects are recommended. One BMP recommendation includes a wetland restoration. Pollution reduction was not calculated for the wetland however based on desktop analysis, a wet land restoration has potential to positively impact the watershed. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to North Brook and Green Lake.



Priority Subwatershed 4 Summary	
Acres addressed	25.31
Dominant Land Cover	Agricultural
Total Catchments	4
Potential BMPs	4
Potential TP reduction (lb/yr)	5.22
Potential TSS reduction (tons/yr)	8.27

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Filter Strip
Subwatershed 4
Catchment 1

Drainage Area – 2.8 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 90% agricultural land use with a portion of forested land. Using aerial photography and GIS tools this area was identified to have a potential for pollution loading directly into the adjacent North Brook. Planting a buffer of permanent vegetation between the surface water and the field will combat soil and nutrient loading. The project is located on southern edge of the catchment on the northern fringe of North Brook.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$224.91	1.99	$113.02

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Filter Strip	Sediment reduction (t/yr)	1.64
Acres	2.8	Area (acres)		Soil Loss reduction (t/yr)	0.03
Soil	Braham loamy fine sand, 2 to 7 percent slopes	Vol Voided (ft^3)	289	Phosphorus reduction (lb/yr)	1.99
		Length (ft)	289		
Average slope	3.2	Years	1		
		Distance to SW (ft)	NA		

Project ID – Filter Strip
Subwatershed 4
Catchment 2

Drainage Area – 3.83 acres

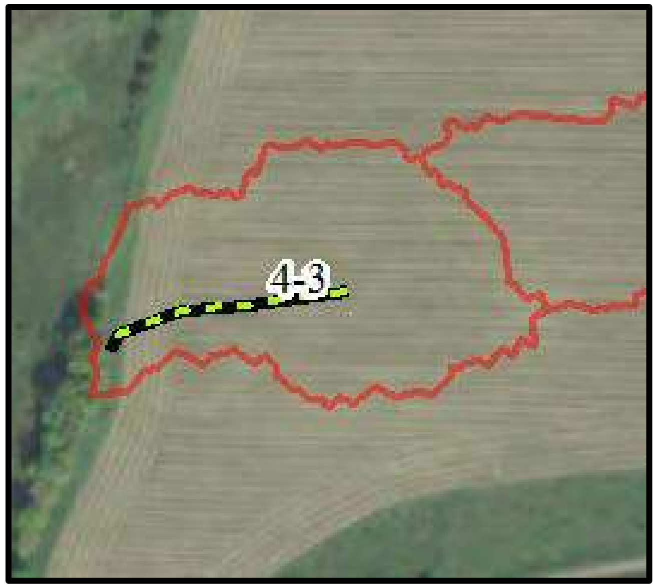
Property Ownership – The small Catchment is estimated 50% agricultural land use with a portion of forested land. Using aerial photography and GIS tools this area was identified to have a potential for pollution loading directly into the adjacent North Brook. Planting a buffer of permanent vegetation between the surface water and the field will combat soil and nutrient loading. The project is located on northern edge of the catchment on the southern fringe of North Brook.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$173.55	2.71	$64.04

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	Filter Strip	Sediment reduction (t/yr)	2.23
Acres	3.83	Area (acres)	0.255968779	Soil Loss reduction (t/yr)	0.02
Soil	Blomford loamy find sand	Vol Voided (ft^3)	0	Phosphorus reduction (lb/yr)	2.71
		Length (ft)			
Average slope	4.4	Years	1		
		Distance to SW (ft)	NA		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 4
Catchment 3



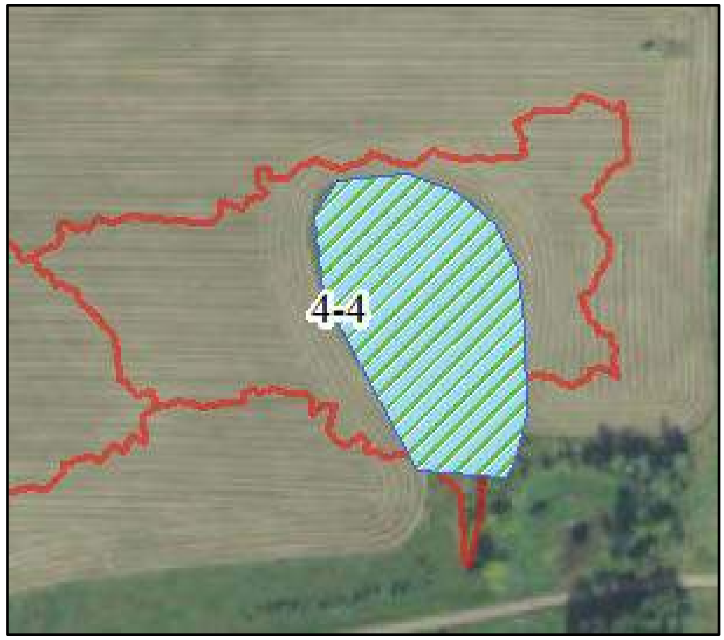
Drainage Area – 2.25 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 98% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located on the west side of the catchment and outlets into adjacent forest wetland area. The wetland area drains directly to North Brook.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,601.10	0.52	$3,079.04

Current Conditions		Added Practice		Reduction	
Sub-Basin	3	Type	Grassed Waterway	Sediment reduction (t/yr)	2.23
Acres	2.25	Area (acres)	0	Soil Loss reduction (t/yr)	14.85
Soil	Bluffton loam and sitly clay loam	Vol Voided (ft^3)	270	Phosphorus reduction (lb/yr)	0.52
		Length (ft)	270		
Average slope	2.25	Years	1		
		Distance to SW (ft)	479		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Wetland Restoration
Subwatershed 4
Catchment 4



Drainage Area – 3.65 acres
Property Ownership – Private
Site Specific Information – Located in the middle of the agricultural field is a low depression in the landscape that has the potential to be restored to wetland. Using historical aerial photos it was determined this location is marginal land, showing hydrologic indicators in the majority of the photos. Wetland Restorations were not modeled during this assessment however the opportunity is there to restore an area to a more diverse environment that would improve water quality and improve wildlife habitat.

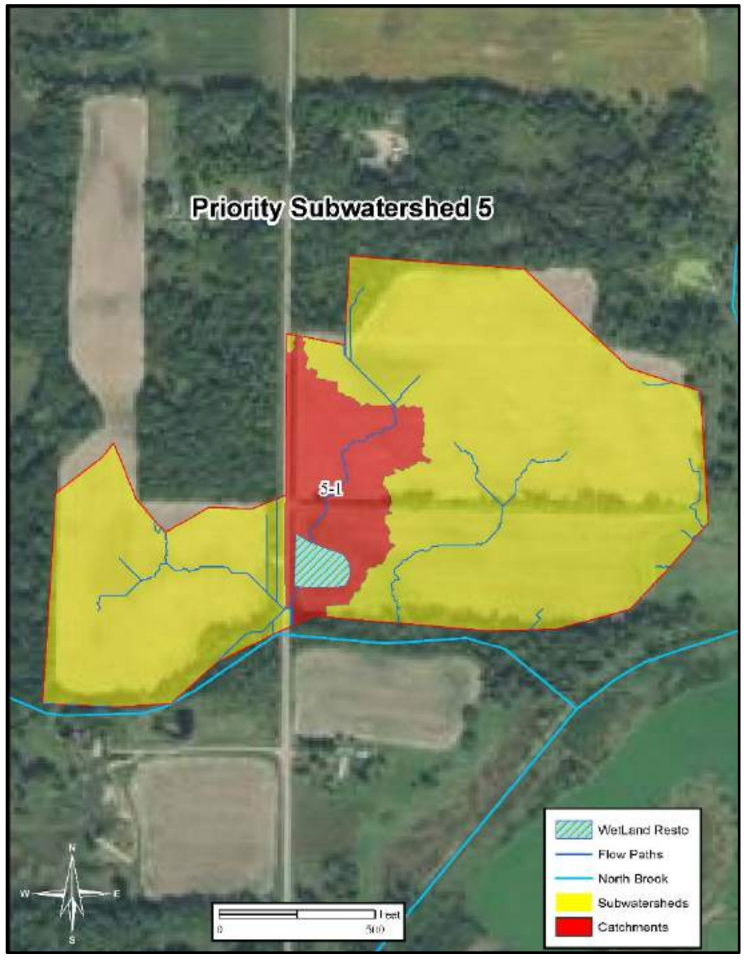
Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
Unknown	Unknown	Unknown

Current Conditions		Added Practice		Reduction	
Sub-Basin	4	Type	Wetland Resto	Sediment reduction (t/yr)	NA
Acres	3.65	Area (acres)	1.34	Soil Loss reduction (t/yr)	NA
Soil	Braham loamy fine sand, 2 to 7 percent slopes	Vol Voided (ft^3)	0	Phosphorus reduction (lb/yr)	NA
		Length (ft)	0		
Average slope	3.6	Years	1		
		Distance to SW (ft)			

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Priority Subwatershed 5

Priority subwatershed 5 is 40 acres of mainly agricultural land with some forested land use. In addition to the sandy soils, moderate slopes and agricultural land use, the area was prioritized because North Brook borders the southern section of the subwatershed. One priority catchment was identified during desktop analysis where a wetland restoration is recommended. Pollution reduction was not calculated; however, based on desktop analysis, a wet land restoration has potential to positively impact the watershed. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to North Brook and Green Lake. Those practices have the potential to be more effective given the location of the subwatershed in relation to North Brook.



Priority Subwatershed 5 Summary	
Acres addressed	40
Dominant Land Cover	Agricultural
Total Catchments	1
Potential BMPs	1
Potential TP reduction (lb/yr)	NA
Potential TSS reduction (tons/yr)	NA

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Wetland Restoration
Subwatershed 5
Catchment 1

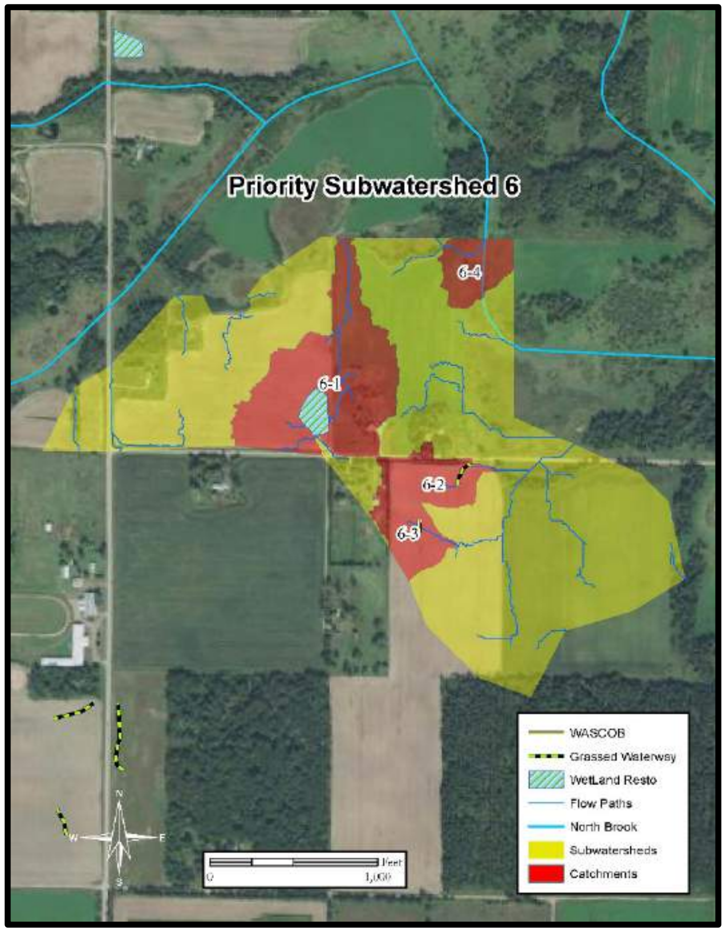
Drainage Area – 5.81 acres
Property Ownership – Private
Site Specific Information – Located on the south side of the agricultural field is a low depression in the landscape that has the potential to be restored to wetland. Using historical aerial photos it was determined this location is marginal land, showing hydrologic indicators in the majority of the photos. Wetland Restorations were not modeled during this assessment however the opportunity is there to restore an area to a more diverse environment that would improve water quality and improve wildlife habitat.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
NA	NA	NA

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	wetland resto	Sediment reduction (t/yr)	TBD
Acres	5.81	Area (acres)	0.51	Soil Loss reduction (t/yr)	TBD
Soil	Isanti mucky loamy fine sand	Vol Voided (ft^3)	0	Phosphorus reduction (lb/yr)	TBD
		Length (ft)	0		
Average slope	2.8	Years	1		
		Distance to SW (ft)			

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Priority Subwatershed 6

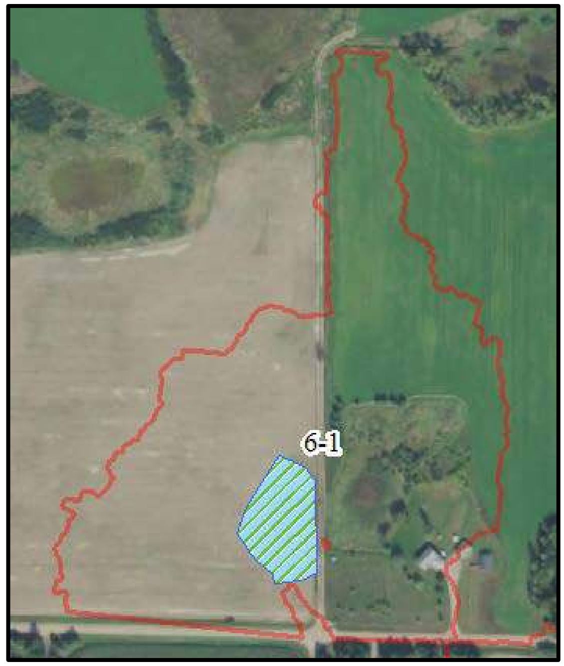


Priority subwatershed 6 is 108 acres of mainly agricultural land with some forested land and several homesteads. In addition to the sandy soils, moderate to severe slopes and agricultural land use, the area was prioritized because North Brook borders the northern section of the subwatershed and overlaps the corner in the northeast. Three priority catchments were identified during desktop analysis where a variety of BMPs are recommended. Pollution reduction was not calculated for the wetland restoration; however, based on desktop analysis, a wetland restoration has the potential to positively impact the watershed. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to North Brook and Green Lake. Those practices have the potential to be more effective given the location of the subwatershed in relation to North Brook.

Priority Subwatershed 6 Summary	
Acres addressed	108
Dominant Land Cover	Agricultural
Total Catchments	1
Potential BMPs	1
Potential TP reduction (lb/yr)	7.37
Potential TSS reduction (tons/yr)	8.67

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Wetland Restoration
Subwatershed 6
Catchment 1



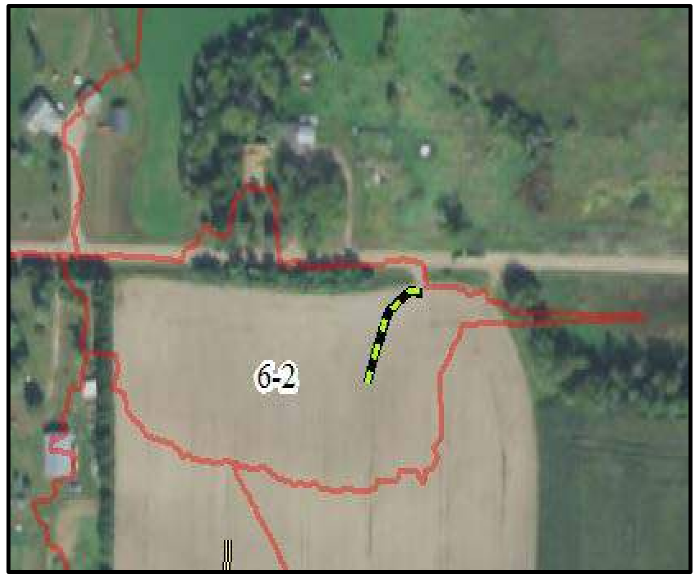
Drainage Area – 2.1 acres
Property Ownership – Private
Site Specific Information – Located in the middle of the agricultural field is a low depression in the landscape that has the potential to be restored to wetland. Using historical aerial photos it was determined this location is marginal land, showing hydrologic indicators in the majority of the photos. Wetland Restorations were not modeled during this assessment however the opportunity is there to restore an area to a more diverse environment that would improve water quality and improve wildlife habitat.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
TBD	TBD	TBD

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Wetland Resto	Sediment reduction (t/yr)	TBD
Acres	2.1	Area (acres)	0.81	Soil Loss reduction (t/yr)	TBD
Soil	Isanti Mucky Loamy Fine Sand	Vol Voided (ft^3)	0	Phosphorus reduction (lb/yr)	TBD
Slope length (ft)		Length (ft)	0		
Average slope	2.1	Years	1		
		Distance to SW (ft)			

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 6
Catchment 2

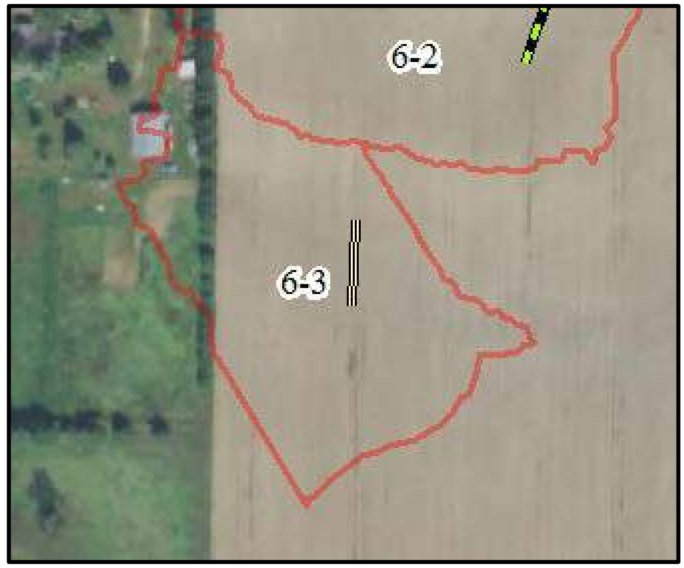


Drainage Area – 3.6 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 90% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located north east side of the catchment and outlets into adjacent roadside ditch.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
895.43	3.51	$255.11

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	Grassed Waterway	Sediment reduction (t/yr)	4.13
Acres	3.6	Area (acres)		Soil Loss reduction (t/yr)	20.74
Soil	zimmerman loamy fine sand and fine sand 7 to 12 percent slopes	Vol Voided (ft^3)	151	Phosphorus reduction (lb/yr)	3.51
Slope length (ft)		Length (ft)	151		
Average slope	8	Years	1		
		Distance to SW (ft)	2451		

Project ID – WASCOB
Subwatershed 6
Catchment 3



Drainage Area – 3.58 acres
Property Ownership – Private
Site Specific Information – Catchment 3 is 95% agricultural land use. Starting in the middle of the catchment running east shows moderate slopes with potential linear depression corresponding with the elevation data. Implementing a WASCOB in this area would greatly reduce overland flow through the concentrated flow path area. Topography also indicates the practice would allow farming alteration to be kept to a minimum.

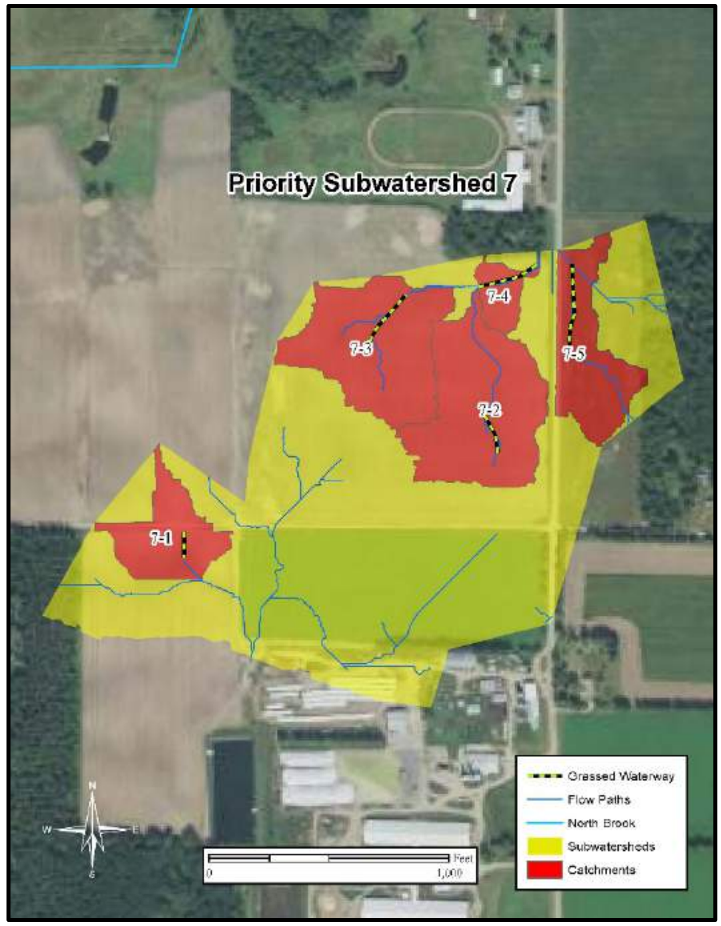
Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$ 35,097	3.86	$9,092.55

Current Conditions		Added Practice		Reduction	
Sub-Basin	3	Type	WASCOB	Sediment reduction (t/yr)	4.54
Acres	3.58	Area (acres)	3.58	Soil Loss reduction (t/yr)	18.87
Soil	lino loamy fine sand	Vol Voided (ft^3)	343	Phosphorus reduction (lb/yr)	3.86
Slope length (ft)		Length (ft)	343		
Average slope	4.88	Years	1		
		Distance to SW (ft)	975		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

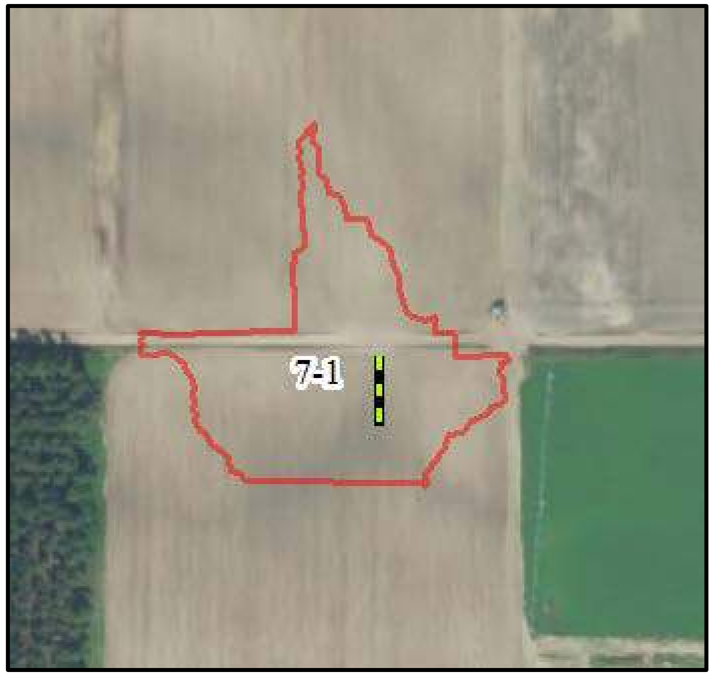
Priority Subwatershed 7

Priority subwatershed 7 is 69 acres of mainly agricultural land with forested land and a small section of a dairy operation. In addition to the sandy soils, moderate to severe slopes and agricultural land use, the area was prioritized because of its close proximity to North Brook. Five priority catchments were identified during desktop analysis where a variety of BMPs are recommended. The concentrated flow paths combined with elevation data suggest these areas could benefit from grass waterways. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to North Brook and Green Lake. Those practices have the potential to be more effective given the location of the subwatershed in relation to North Brook.



Priority Subwatershed 7 Summary	
Acres addressed	69
Dominant Land Cover	Agricultural
Total Catchments	5
Potential BMPs	5
Potential TP reduction (lb/yr)	13.16
Potential TSS reduction (tons/yr)	15.5

Project ID – Grassed Waterway
Subwatershed 7
Catchment 1

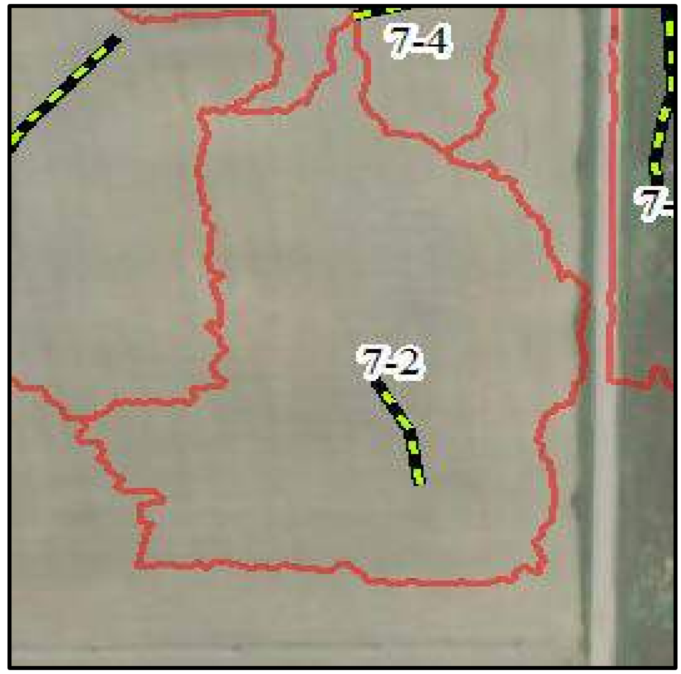


Drainage Area – 3.1 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 99% agricultural land use. Using aerial photography and GIS tools, this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment and outlets into an assumed roadside ditch.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$646.37	1.05	$615.59

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Grassed Waterway	Sediment reduction (t/yr)	1.24
Acres	3.1	Area (acres)	NA	Soil Loss reduction (t/yr)	6
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	109	Phosphorus reduction (lb/yr)	1.05
		Length (ft)	109		
Average slope	3.8	Years	1		
		Distance to SW (ft)	2000		

Project ID – Grassed Waterway
Subwatershed 7
Catchment 2

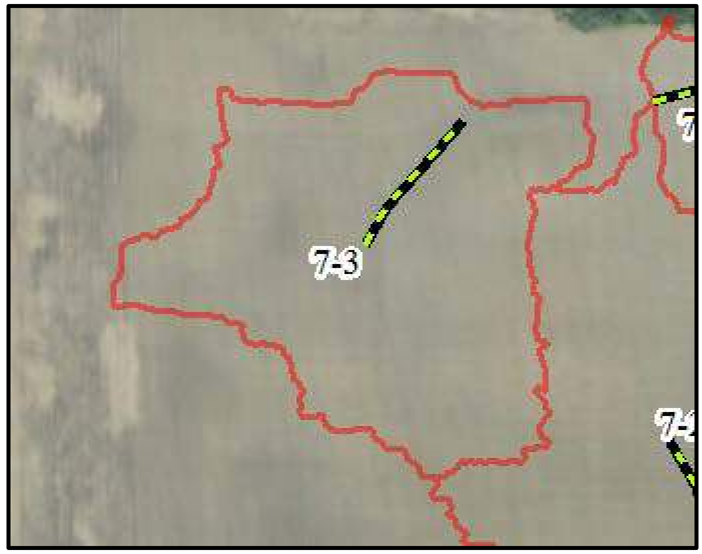


Drainage Area – 7.23 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools, this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$978.45	1.53	$639.51

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	Grassed Waterway	Sediment reduction (t/yr)	1.8
Acres	7.23	Area (acres)	NA	Soil Loss reduction (t/yr)	9.08
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	165	Phosphorus reduction (lb/yr)	1.53
Slope length (ft)		Length (ft)	165		
Average slope	2.3	Years	1		
		Distance to SW (ft)	2500		

Project ID – Grassed Waterway
Subwatershed 7
Catchment 3



Drainage Area – 1.98 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,476.57	3.98	$371.00

Current Conditions		Added Practice		Reduction	
Sub-Basin	3	Type	Grassed Waterway	Sediment reduction (t/yr)	4.69
Acres	1.98	Area (acres)	NA	Soil Loss reduction (t/yr)	12.16
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	249	Phosphorus reduction (lb/yr)	3.98
		Length (ft)	249		
Average slope	3.22	Years	1		
		Distance to SW (ft)	2059		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway Subwatershed 7 Catchment 4

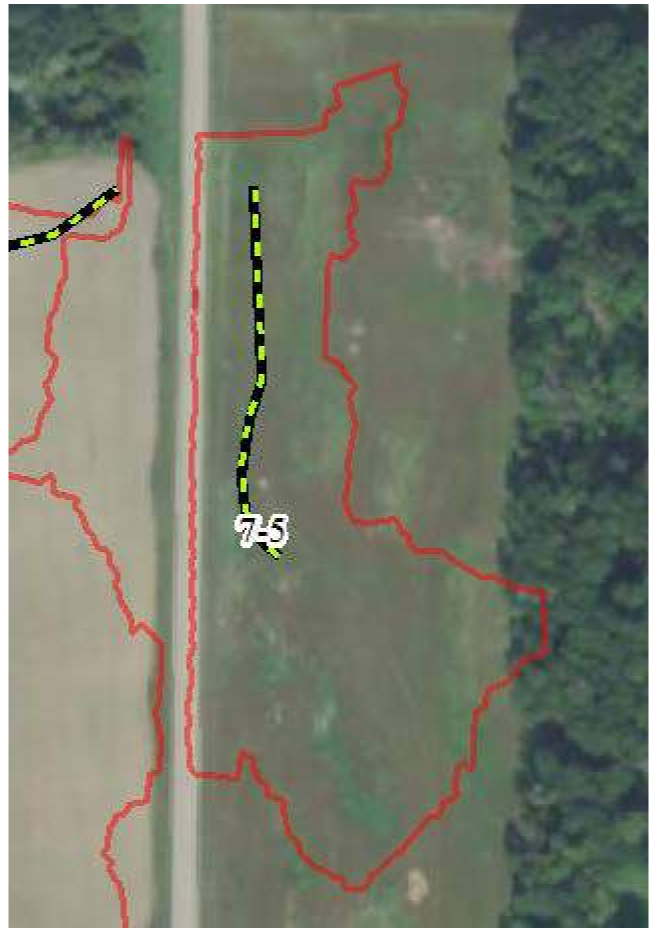
Drainage Area – 1.4 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the north section of the catchment and outlets into an adjacent roadside ditch.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,571.45	2.58	$609.09

Current Conditions		Added Practice		Reduction	
Sub-Basin	4	Type	Grassed Waterway	Sediment reduction (t/yr)	3.04
Acres	1.4	Area (acres)	NA	Soil Loss reduction (t/yr)	14.58
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	265	Phosphorus reduction (lb/yr)	2.58
		Length (ft)	265		
Average slope	3.74	Years	1		
		Distance to SW (ft)	1962		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Filter Strip
Subwatershed 7
Catchment 5



Drainage Area – 2.7 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 99% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the North section of the catchment.

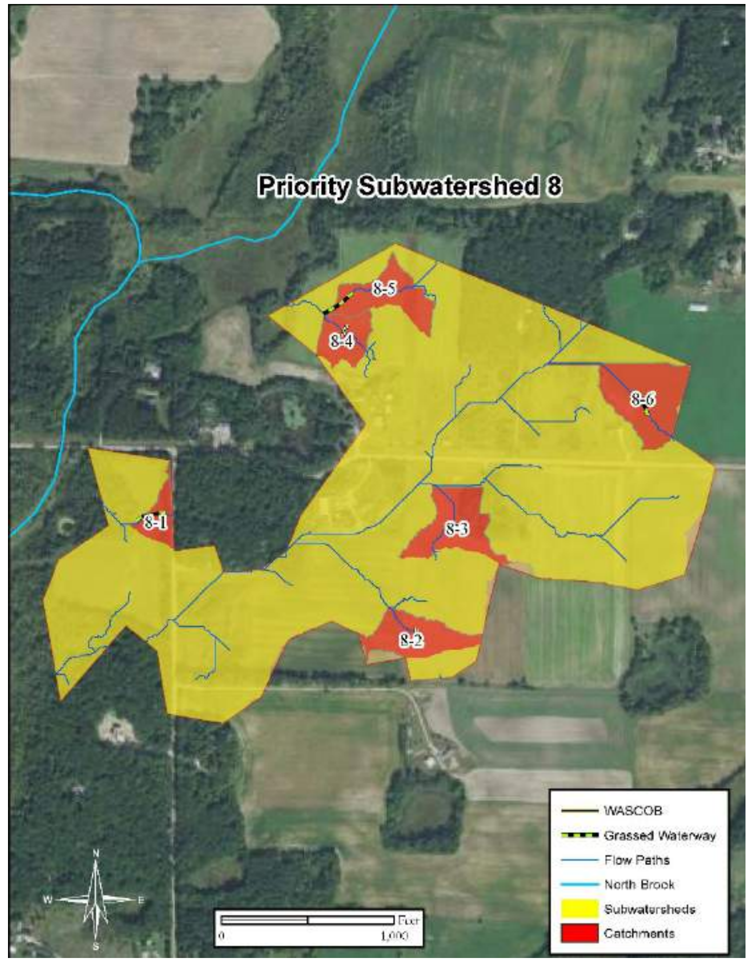
Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$2,496.53	4.02	$621.03

Current Conditions		Added Practice		Reduction	
Sub-Basin	5	Type	Grassed Waterway	Sediment reduction (t/yr)	4.73
Acres	2.7	Area (acres)	NA	Soil Loss reduction (t/yr)	23.16
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	421	Phosphorus reduction (lb/yr)	4.02
		Length (ft)	421		
Average slope	3.18	Years	1		
		Distance to SW (ft)	2167		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Priority Subwatershed 8

Priority subwatershed 8 is 122 acres of mainly agricultural land with small amounts of forest, wetlands and low density residential areas. In addition to the sandy soils, moderate slopes and agricultural land use, the area was prioritized because North Brook runs closely along the west of the subwatershed. Six priority catchments were identified during desktop analysis where water quality projects are recommended. WASCOBs and grassed waterways were the identified as projects for this area because of elevations, soils and concentrated flow paths. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to North Brook and Green Lake



Priority Subwatershed 8 Summary	
Acres addressed	122
Dominant Land Cover	Agricultural
Total Catchments	6
Potential BMPs	6
Potential TP reduction (lb/yr)	29.1
Potential TSS reduction (tons/yr)	34.25

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 8
Catchment 1

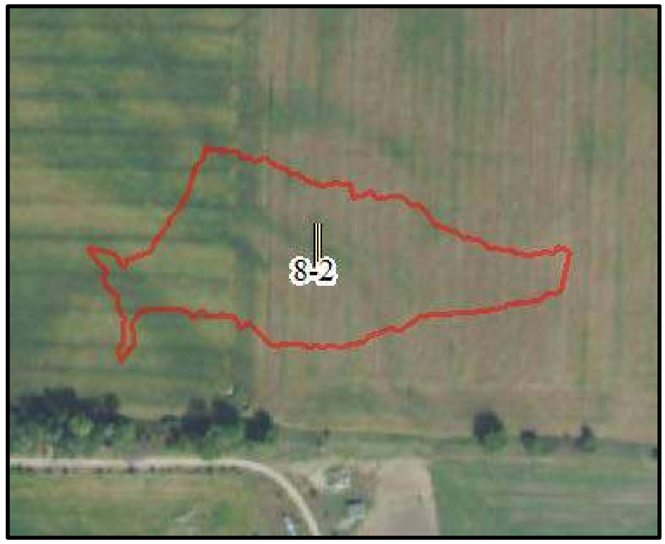
Drainage Area – 4.04 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 50% agricultural land use and 50% forested land. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment and outlets into the adjacent woodland.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$1,043.68	2.23	$468.02

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Grassed Waterway	Sediment reduction (t/yr)	2.62
Acres	4.04	Area (acres)	NA	Soil Loss reduction (t/yr)	9.68
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	176	Phosphorus reduction (lb/yr)	2.23
Slope length (ft)		Length (ft)	176		
Average slope	9.46	Years	1		
		Distance to SW (ft)	553		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – WASCOB
Subwatershed 8
Catchment 2



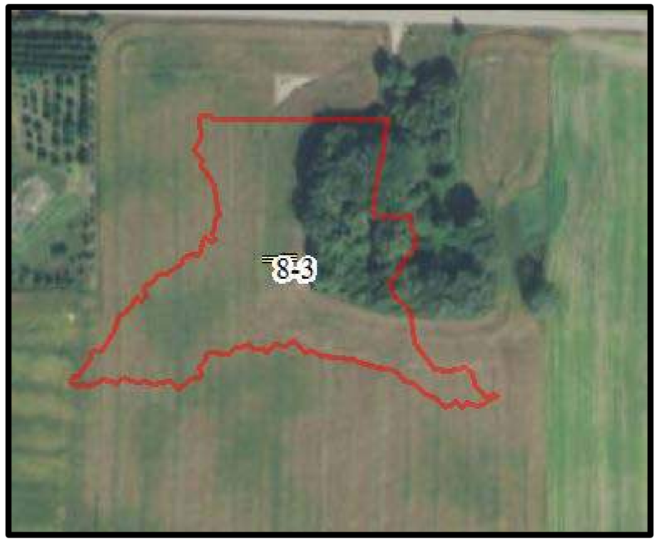
Drainage Area – 2.7 acres
Property Ownership – Private
Site Specific Information –
Catchment 2 is 100% agricultural land use. Starting in the middle of the catchment running east shows moderate slopes with a potential linear depression corresponding with the elevation data. Implementing a WASCOB in this area would reduce overland flow through the concentrated flow path area. Topography also indicates the practice would allow farming alteration to be kept to a minimum.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$26,469.99	9.18	$2,883.44

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	WASCOB	Sediment reduction (t/yr)	10.8
Acres	2.7	Area (acres)	2.7	Soil Loss reduction (t/yr)	53.19
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	967	Phosphorus reduction (lb/yr)	9.18
Slope length (ft)		Length (ft)	967		
Average slope	5.26	Years	1		
		Distance to SW (ft)	2225		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – WASCOB
Subwatershed 8
Catchment 3



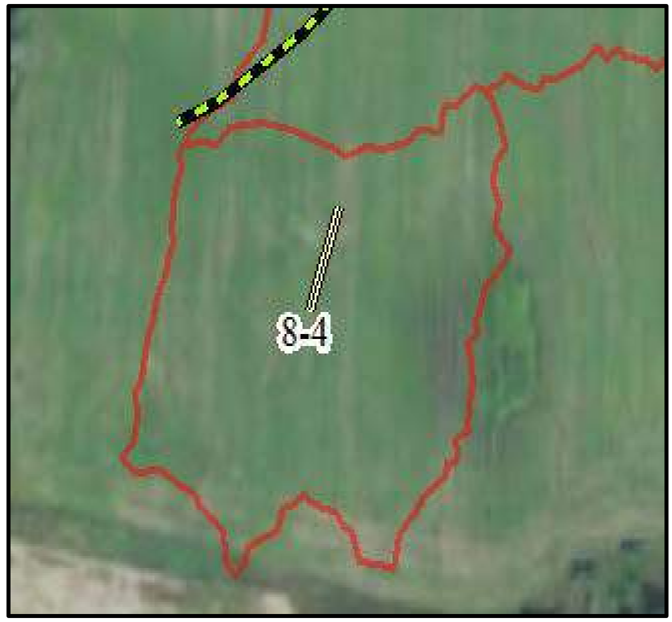
Drainage Area – 3.22 acres
Property Ownership – Private
Site Specific Information –
Catchment 3 is estimated 75% agricultural land use with the remaining 25% forested. Starting in the middle of the catchment running north shows moderate slopes with a potential linear depression corresponding with the elevation data. Implementing a WASCOB in this area would reduce overland flow through the concentrated flow path area.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$31,567.91	6.53	$4,834.29

Current Conditions		Added Practice		Reduction	
Sub-Basin	3	Type	WASCOB	Sediment reduction (t/yr)	7.69
Acres	3.22	Area (acres)	3.22	Soil Loss reduction (t/yr)	38.34
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	697	Phosphorus reduction (lb/yr)	6.53
Slope length (ft)		Length (ft)	697		
Average slope	4.35	Years	1		
		Distance to SW (ft)	2358		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – WASCOB
Subwatershed 8
Catchment 4



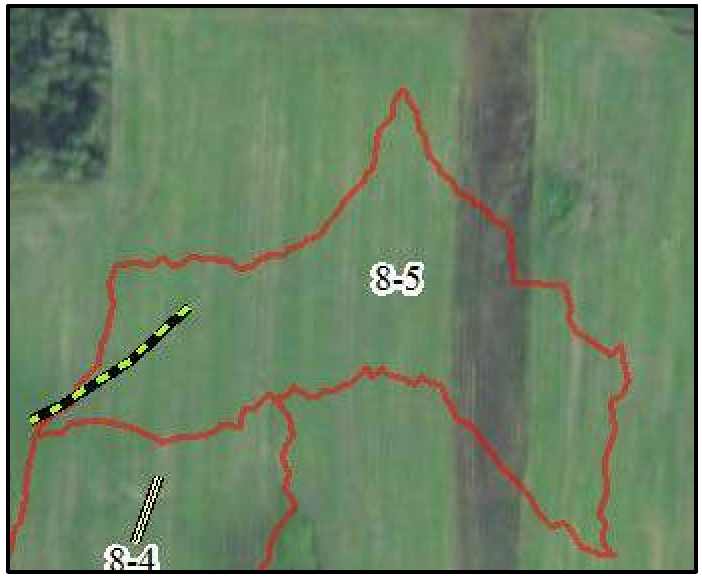
Drainage Area – 1.79 acres
Property Ownership – Private
Site Specific Information –
Catchment 4 is estimated 100% agricultural land use. Starting in the middle of the catchment running South shows moderate to severe slopes with a potential linear depression corresponding with the elevation data. Implementing a WASCOB in this area would reduce overland flow through the concentrated flow path area. There is a depression located on the east side of the catchment that may benefit from a wetland restoration if crop production is marginal each year.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$17,548.62	7.69	$2,282.01

Current Conditions		Added Practice		Reduction	
Sub-Basin	4	Type	WASCOB	Sediment reduction (t/yr)	9.05
Acres	1.79	Area (acres)	1.79	Soil Loss reduction (t/yr)	34.21
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	622	Phosphorus reduction (lb/yr)	7.69
Slope length (ft)		Length (ft)	622		
Average slope	5.08	Years	1		
		Distance to SW (ft)	618		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 8
Catchment 5



Drainage Area – 2.73 acres
Property Ownership – Private
Site Specific Information – The Catchment is 100% agricultural land use. Using aerial photography and GIS tools, this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the west section of the catchment.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$1,191.93	2.51	$474.87

Current Conditions		Added Practice		Reduction	
Sub-Basin	5	Type	Grassed Waterway	Sediment reduction (t/yr)	2.96
Acres	2.73	Area (acres)	0	Soil Loss reduction (t/yr)	11.06
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	102	Phosphorus reduction (lb/yr)	2.51
Slope length (ft)		Length (ft)	102		
Average slope	4.3	Years	1		
		Distance to SW (ft)	2298		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grass Waterway
Subwatershed 8
Catchment 6

Drainage Area – 4.36 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 85% agricultural land use and 25% wetland. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment.

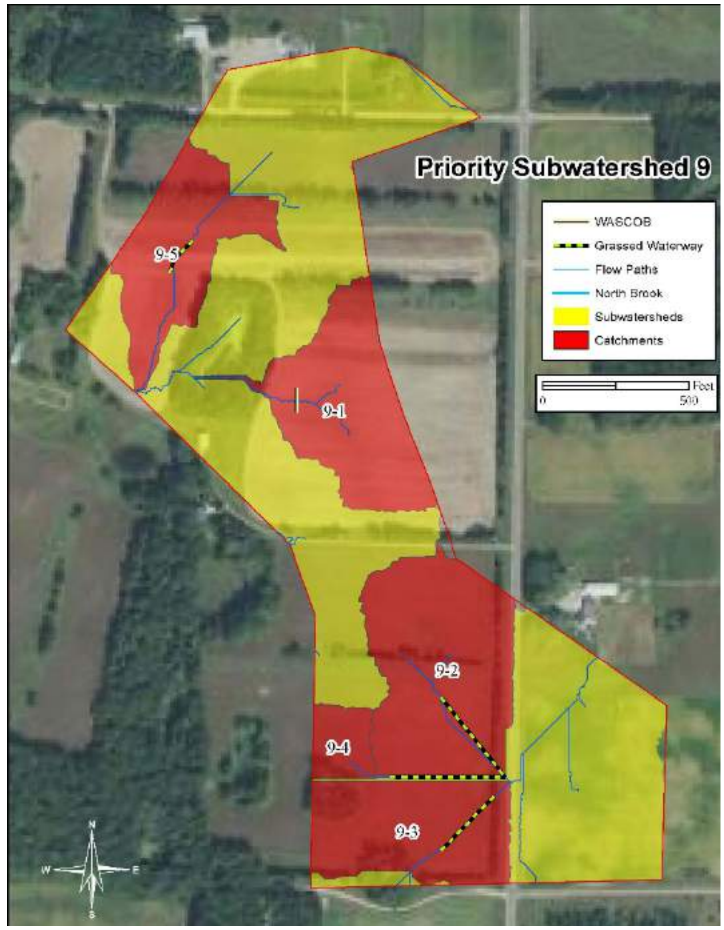
Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$604.86	0.96	$630.06

Current Conditions		Added Practice		Reduction	
Sub-Basin	6	Type	Grassed Waterway	Sediment reduction (t/yr)	1.13
Acres	4.36	Area (acres)	0	Soil Loss reduction (t/yr)	5.61
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	102	Phosphorus reduction (lb/yr)	0.96
Slope length (ft)		Length (ft)	102		
Average slope	6.82	Years	1		
		Distance to SW (ft)	2298		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Priority Subwatershed 9

Priority subwatershed 9 is 58 acres of mainly agricultural land with some forested and low density residential areas. In addition to the sandy soils, moderate to severe slopes and agricultural land use, the area was prioritized because North Brook runs closely along the west side of the subwatershed. Five priority catchments were identified during desktop analysis where water quality projects are recommended. WASCOBs and grassed waterways were the identified projects for this area because of elevations, soils and concentrated flow paths. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to North Brook and Green Lake.



Priority Subwatershed 9 Summary	
Acres addressed	58
Dominant Land Cover	Agricultural
Total Catchments	5
Potential BMPs	5
Potential TP reduction (lb/yr)	15.93
Potential TSS reduction (tons/yr)	18.73

Project ID – WASCOB
Subwatershed 9
Catchment 1

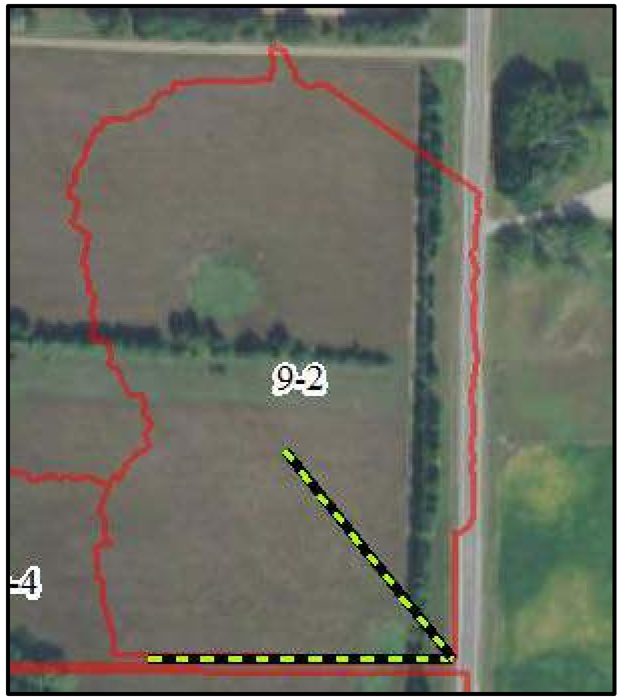
Drainage Area – 2.22 acres
Property Ownership – Private
Site Specific Information – Catchment 1 is estimated 98% agricultural land use. Starting in the middle of the catchment running west shows moderate to severe slopes with a potential linear depression corresponding with the elevation data. Implementing a WASCOB in this area would reduce overland flow through the concentrated flow path area. The outlet of the project would be adjacent to a type 3 wetland with a forested fringe.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$1,043.68	2.23	$468.02

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Grassed Waterway	Sediment reduction (t/yr)	2.62
Acres	2.22	Area (acres)	NA	Soil Loss reduction (t/yr)	9.68
Soil	Zimmerman fine Sand, 1 to 6 % slope	Vol Voided (ft^3)	176	Phosphorus reduction (lb/yr)	2.23
Average slope	4.44	Length (ft)	176		
		Years	1		
		Distance to SW (ft)	553		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 9
Catchment 2



Drainage Area – 3.86 acres
Property Ownership – Private
Site Specific Information- The Catchment is estimated 85% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located on the east side of the catchment and outlets into adjacent roadside ditch.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$2,069.57	3.31	$625.25

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	Grassed Waterway	Sediment reduction (t/yr)	3.9
Acres	3.86	Area (acres)	NA	Soil Loss reduction (t/yr)	19.2
Soil	Zimmerman fine Sand, 1 to 6 % slope	Vol Voided (ft^3)	349	Phosphorus reduction (lb/yr)	3.31
Average slope	6.55	Length (ft)	349		
		Years	1		
		Distance to SW (ft)	2225		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 9
Catchment 3

Drainage Area – 5.71 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 80% agricultural land use and 20% forested. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located on the east side of the catchment and outlets into adjacent roadside ditch.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$1,856.09	2.97	$624.95

Current Conditions		Added Practice		Reduction	
Sub-Basin	3	Type	Grassed Waterway	Sediment reduction (t/yr)	3.49
Acres	5.71	Area (acres)	NA	Soil Loss reduction (t/yr)	17.22
Soil	Zimmerman fine Sand, 1 to 6 % slope	Vol Voided (ft^3)	313	Phosphorus reduction (lb/yr)	2.97
Average slope	6.66	Length (ft)	313		
		Years	1		
		Distance to SW (ft)	2229		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 9
Catchment 4

Drainage Area – 1.51 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 80% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located on the east side of the catchment and outlets into adjacent roadside ditch.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$2,336.42	3.62	$645.42

Current Conditions		Added Practice		Reduction	
Sub-Basin	4	Type	Grassed Waterway	Sediment reduction (t/yr)	4.25
Acres	1.51	Area (acres)	NA	Soil Loss reduction (t/yr)	21.67
Soil	Zimmerman fine Sand, 1 to 6 % slope	Vol Voided (ft^3)	394	Phosphorus reduction (lb/yr)	3.62
Average slope	4.84	Length (ft)	394		
		Years	1		
		Distance to SW (ft)	2613		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

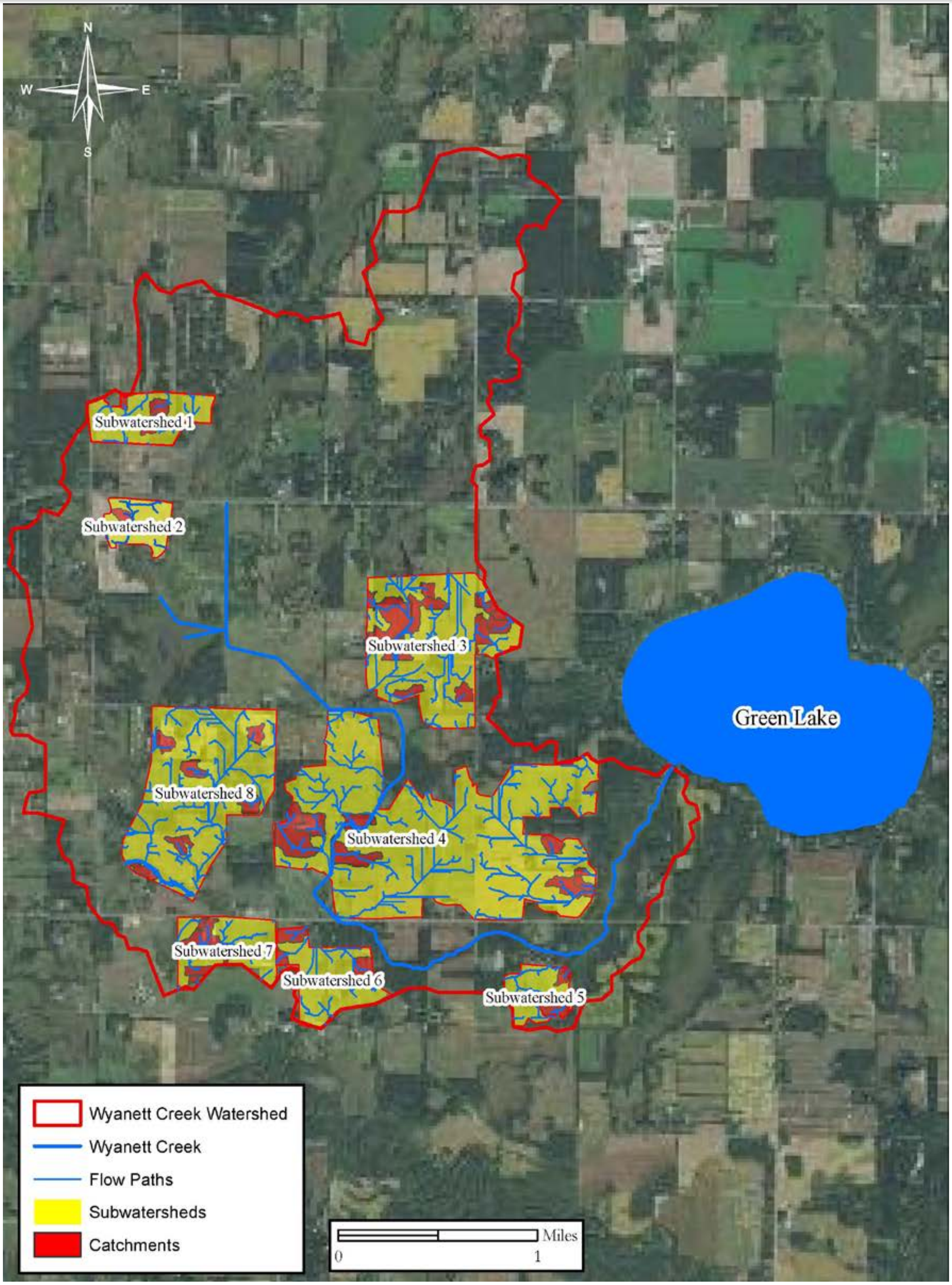
Project ID – Grassed Waterway
Subwatershed 9
Catchment 5

Drainage Area – 5.14 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 90% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$50,391.02	3.8	$13,260.79

Current Conditions		Added Practice		Reduction	
Sub-Basin	5	Type	WASCOB	Sediment reduction (t/yr)	4.47
Acres	5.14	Area (acres)	5.14	Soil Loss reduction (t/yr)	20.02
Soil	Zimmerman fine Sand, 1 to 6 % slope	Vol Voided (ft^3)	364	Phosphorus reduction (lb/yr)	3.8
Average slope	4.84	Length (ft)	364		
		Years	1		
		Distance to SW (ft)	1401		

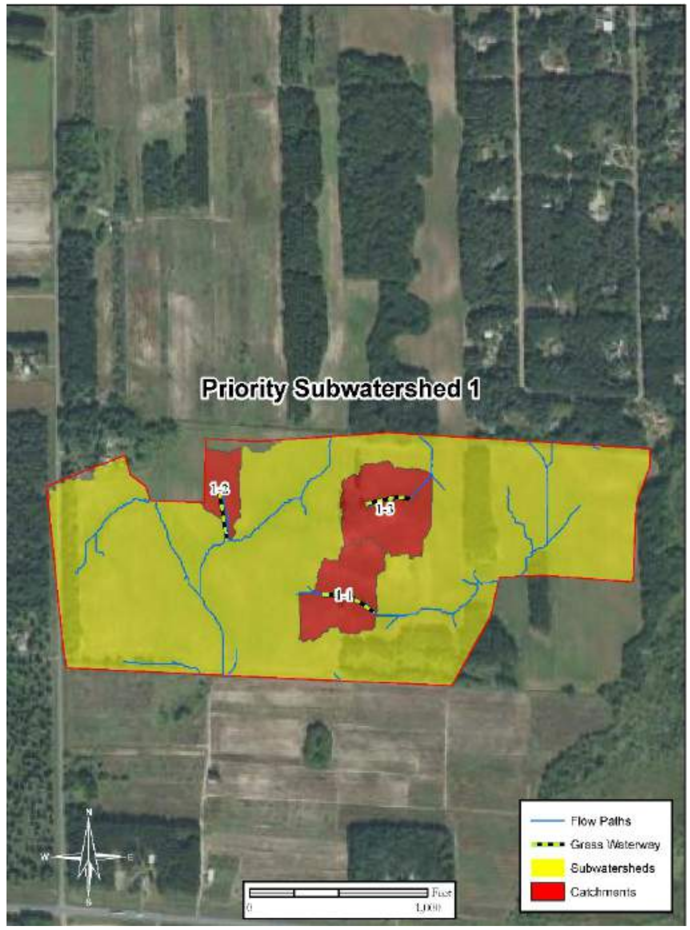
Catchment Profiles – Wyanett Creek Rural Catchments



Wyanett Creek Subwatershed and Catchments

Priority Subwatershed 1

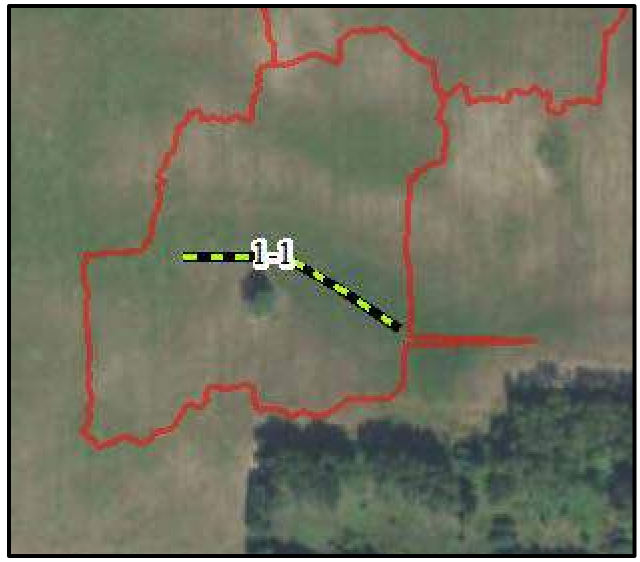
Priority subwatershed 1 is 80 acres of mainly agricultural land with some forested and low density residential areas. In addition to the sandy soils, moderate to severe slopes and agricultural land use, this northern most subwatershed was prioritized because Wyanett Creek runs near the south border of the subwatershed. Three priority catchments were identified during desktop analysis where water quality projects are recommended. Grassed waterways were the identified projects for this area because of the elevations, soils and concentrated flow paths. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to Wyanett Creek and Green Lake.



Priority Subwatershed 1 Summary	
Acres addressed	80
Dominant Land Cover	Agricultural
Total Catchments	3
Potential BMPs	3
Potential TP reduction (lb/yr)	7.94
Potential TSS reduction (tons/yr)	9.34

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 1
Catchment 1



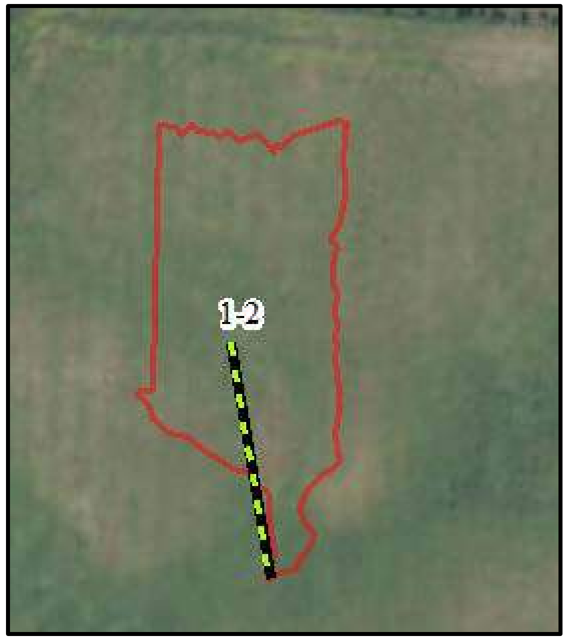
Drainage Area – 4.03 acres.
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,862.02	3.10	$600.65

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Grassed Waterway	Sediment reduction (t/yr)	3.65
Acres	4.03	Area (acres)	NA	Soil Loss reduction (t/yr)	17.27
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	314	Phosphorus reduction (lb/yr)	3.1
		Length (ft)	314		
Average slope	2.27	Years	1		
		Distance to SW (ft)	1841		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 1
Catchment 2



Drainage Area – 1.87 acres

Property Ownership – Private

Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project outlets on the south side of the catchment.

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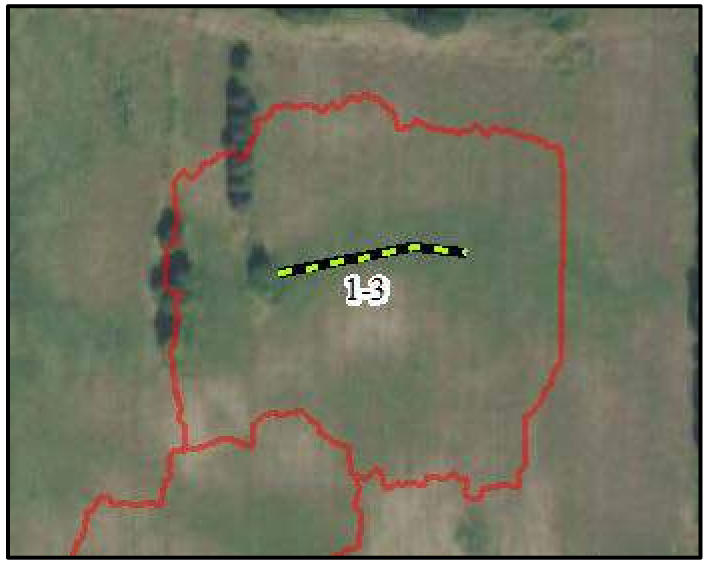
Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,535.87	2.56	$599.95

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	Grassed Waterway	Sediment reduction (t/yr)	3.01
Acres	1.87	Area (acres)	NA	Soil Loss reduction (t/yr)	14.25
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	259	Phosphorus reduction (lb/yr)	2.56
		Length (ft)	259		
Average slope	3.06	Years	1		
		Distance to SW (ft)	1798		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 1
Catchment 3



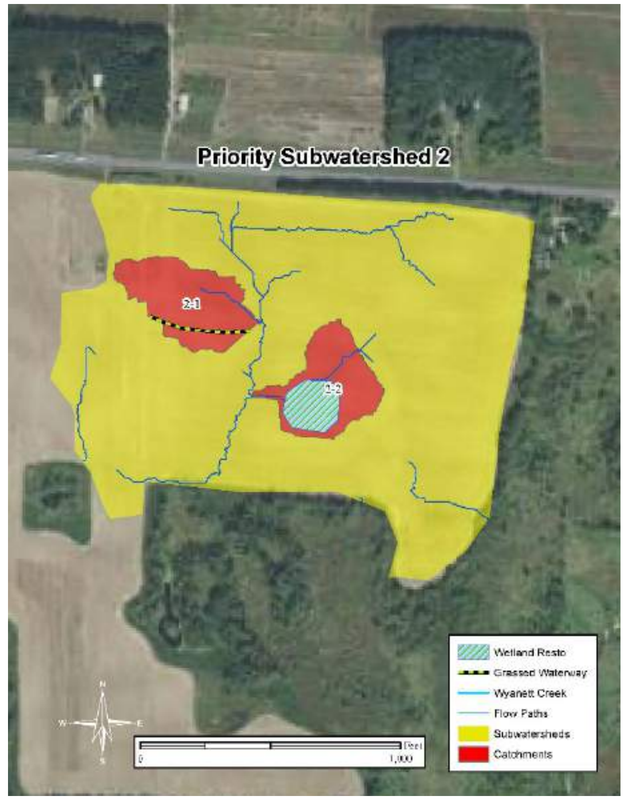
Drainage Area – 4.85 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 99% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,470.64	2.28	$645.02

Current Conditions		Added Practice		Reduction	
Sub-Basin	3	Type	Grassed Waterway	Sediment reduction (t/yr)	2.68
Acres	4.85	Area (acres)	NA	Soil Loss reduction (t/yr)	13.64
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	248	Phosphorus reduction (lb/yr)	2.28
		Length (ft)	248		
Average slope	3.41	Years	1		
		Distance to SW (ft)	2600		

Priority Subwatershed 2

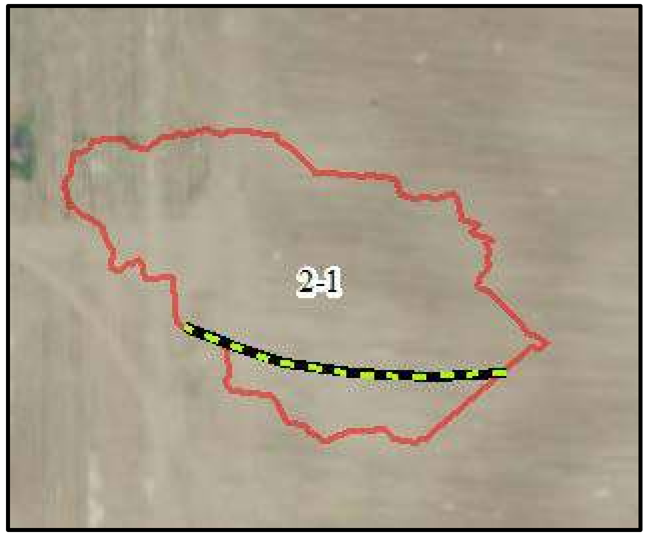
Priority subwatershed 2 is 46 acres of mainly agricultural land surrounded by forests and lowlands. In addition to the sandy soils, moderate to severe slopes and agricultural land use, this subwatershed was prioritized because Wyanett Creek runs .28 miles east of the subwatershed. Two priority catchments were identified during desktop analysis where water quality projects are recommended. A grassed waterway was identified for this area because of the elevation, soils and concentrated flow path data. A small depression was identified in the middle of the field that is assumed marginal cropland. While not modeled during this assessment it is assumed a wetland restoration would be a viable project option for this area. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to Wyanett Creek and Green Lake.



Priority Subwatershed 2 Summary	
Acres addressed	46
Dominant Land Cover	Agricultural
Total Catchments	2
Potential BMPs	2
Potential TP reduction (lb/yr)	3.66
Potential TSS reduction (tons/yr)	4.30

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 2
Catchment 1



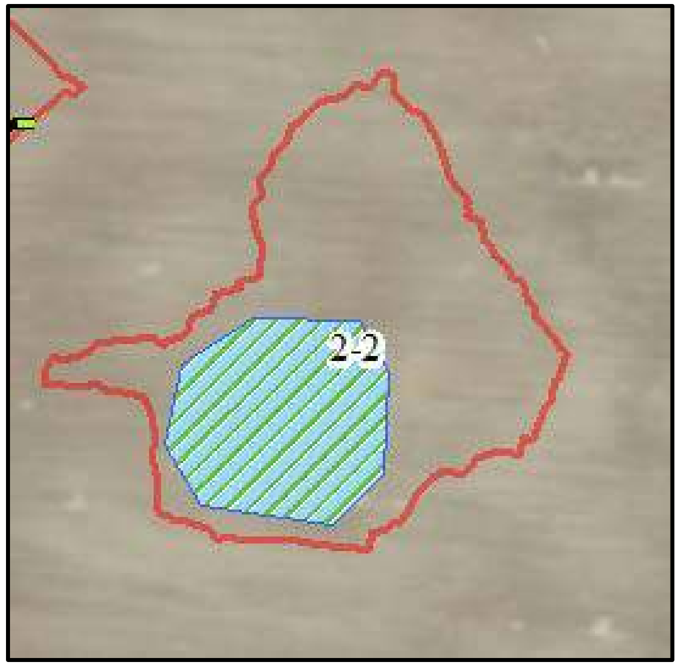
Drainage Area – 4.03 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$2,318.63	3.66	$633.51

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Grassed Waterway	Sediment reduction (t/yr)	4.3
Acres	4.03	Area (acres)	NA	Soil Loss reduction (t/yr)	21.51
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	391	Phosphorus reduction (lb/yr)	3.66
		Length (ft)	391		
Average slope	4.33	Years	1		
		Distance to SW (ft)	2391		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Wetland Restoration
Subwatershed 2
Catchment 2



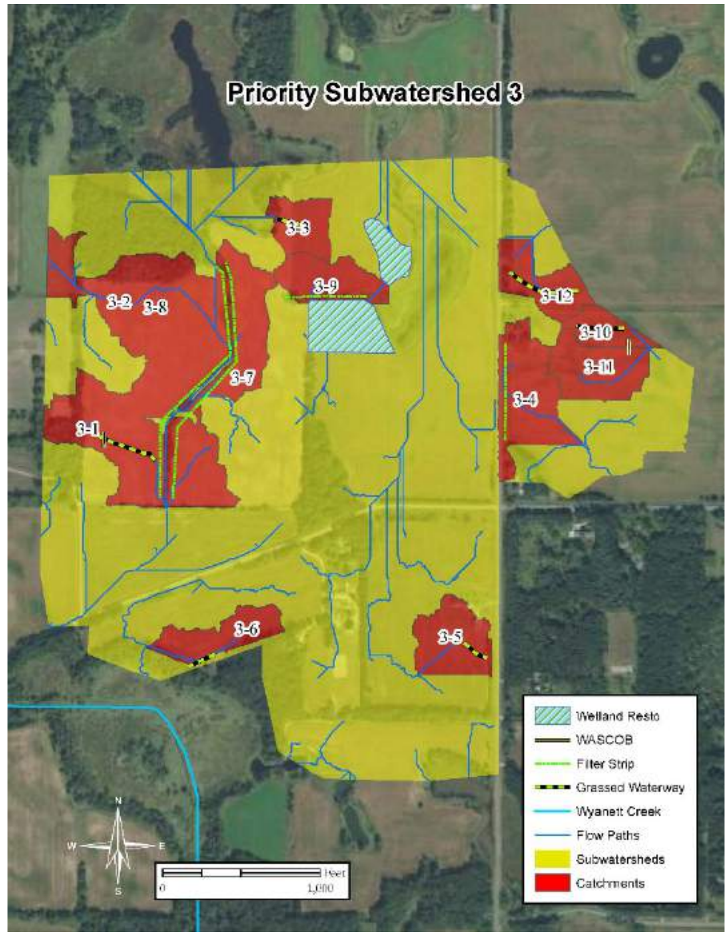
Drainage Area – 2.74 acres
Property Ownership – Private
Site Specific Information – Located in the middle of the agricultural field is a low depression in the landscape that has the potential to be restored to wetland. Using historical aerial photos, it was determined this location is marginal cropland, showing hydrologic indicators in the majority of the photos. Wetland Restorations were not modeled during this assessment however the opportunity is there to restore an area to a more diverse environment that would improve water quality and improve wildlife habitat.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$2,806.65	TBD	TBD

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	Wetland Resto	Sediment reduction (t/yr)	TBD
Acres	2.74	Area (acres)	0.81	Soil Loss reduction (t/yr)	TBD
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	NA	Phosphorus reduction (lb/yr)	TBD
		Length (ft)	NA		
Average slope	5.08	Years	NA		
		Distance to SW (ft)	NA		

Priority Subwatershed 3

Priority subwatershed 3 is 265 acres of mainly agricultural land but also includes areas of low density residential, wetlands and forests. In addition to the sandy soils, moderate to severe slopes and agricultural land use, this subwatershed was prioritized because Creek that runs only 200 feet to the southwest. 12 priority catchments were identified during desktop analysis where water quality projects are recommended. Edge of field filter strips, grass waterways, and WASCOBs were all identified as improvement projects. Areas of small depression were identified in the north end of the subwatershed that are assumed marginal cropland. While not modeled during this assessment it is assumed a wetland restoration would be a viable project option for this area. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to Wyanett Creek and Green Lake.



Priority Subwatershed 3 Summary	
Acres addressed	265
Dominant Land Cover	Agricultural
Total Sub-Basins	12
Potential BMPs	12
Potential TP reduction (lb/yr)	41.30
Potential TSS reduction (tons/yr)	47.06

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – WASCOB
Subwatershed 3
Catchment 1

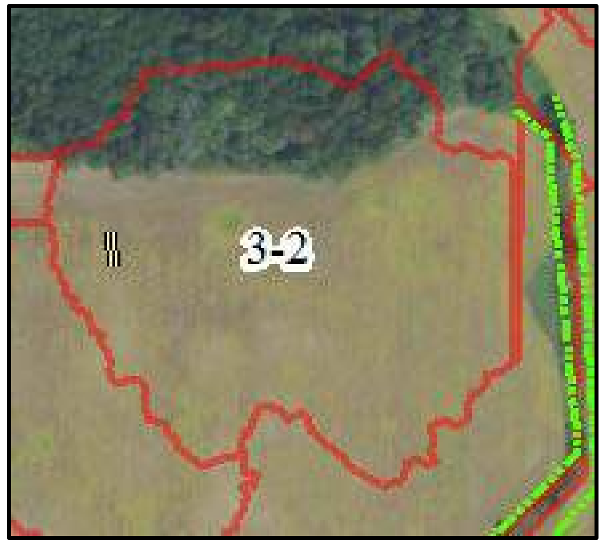
Drainage Area – 8.11 acres
Property Ownership – Private
Site Specific Information –
Catchment 1 is estimated 80% Agricultural land use and 20% forested. Starting in the middle of the catchment running west shows moderate to severe slopes with a potential linear depression corresponding with the elevation data. Implementing a WASCOB in this area would reduce overland flow through the concentrated flow path area. The outlet of the project would be an adjacent field ditch.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$37,254.06	7.93	$4,697.86

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	WASCOB	Sediment reduction (t/yr)	9.33
Acres	8.11	Area (acres)	3.8	Soil Loss reduction (t/yr)	24.09
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	3.8	Phosphorus reduction (lb/yr)	7.93
		Length (ft)	NA		
Average slope	4.01	Years	1		
		Distance to SW (ft)	1296		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – WASCOB
Subwatershed 3
Catchment 2



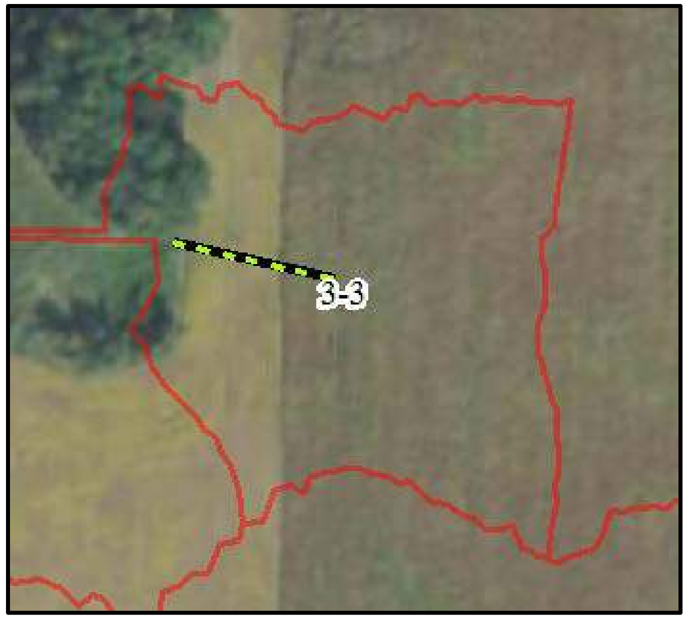
Drainage Area – 9.01 acres
Property Ownership – Private
Site Specific Information –
Catchment 2 is estimated 80% Agricultural landuse and 20% forested. Starting in the middle of the catchment running west shows moderate to severe slopes with a potential linear depression corresponding with the elevation data. Implementing a WASCB in this area would reduce overland flow through the concentrated flow path area. A second project option could be a grassed waterway.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$12,646.77	8.99	$1,406.76

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	WASCOB	Sediment reduction (t/yr)	10.58
Acres	9.01	Area (acres)	1.29	Soil Loss reduction (t/yr)	53.57
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	1.29	Phosphorus reduction (lb/yr)	8.99
		Length (ft)	NA		
Average slope	4.58	Years	1		
		Distance to SW (ft)	2539		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 3
Catchment 3



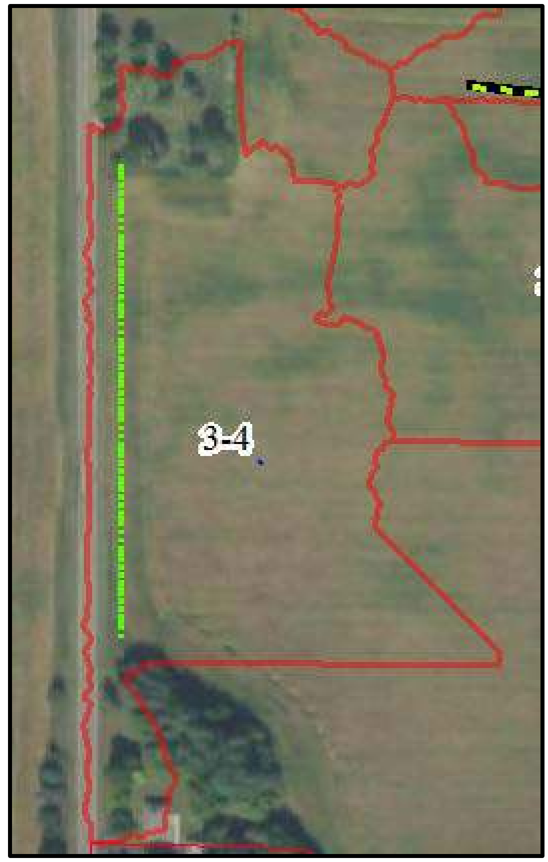
Drainage Area – 3.02 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 95% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located west side of the catchment and outlets into adjacent forested and wetland area.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$889.50	2.23	$398.88

Current Conditions		Added Practice		Reduction	
Sub-Basin	3	Type	Grassed Waterway	Sediment reduction (t/yr)	2.62
Acres	3.02	Area (acres)	NA	Soil Loss reduction (t/yr)	8.25
Soil	Zimmerman fine Sand, 1 to 6 % slope	Vol Voided (ft^3)	150	Phosphorus reduction (lb/yr)	2.23
		Length (ft)	150		
Average slope	3.27	Years	1		
		Distance to SW (ft)	254		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Filter Strip
Subwatershed 3
Catchment 4



Drainage Area – 6.69 acres.
Property Ownership – Private
Site Specific Information – The Catchment is estimated 90% agricultural land use. The proposed project is a perennial vegetative filter strip to be planted along the field's edge creating a buffer between the roadside ditch. The buffer is intended to catch sediment and utilize nutrients prior to entering the surface water ditch. The new projected is located on the west side of the catchment.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$484.06	0.45	$1,075.70

Current Conditions		Added Practice		Reduction	
Sub-Basin	4	Type	Filter Strip	Sediment reduction (t/yr)	0.24
Acres	6.69	Area (acres)	0.71	Soil Loss reduction (t/yr)	0.47
Soil	Zimmerman fine Sand, 1 to 6 % slope	Vol Voided (ft^3)	NA	Phosphorus reduction (lb/yr)	0.45
		Length (ft)	622		
Average slope	3.68	Years	1		
		Distance to SW (ft)	0		

Project ID – Grassed Waterway
Subwatershed 3
Catchment 5

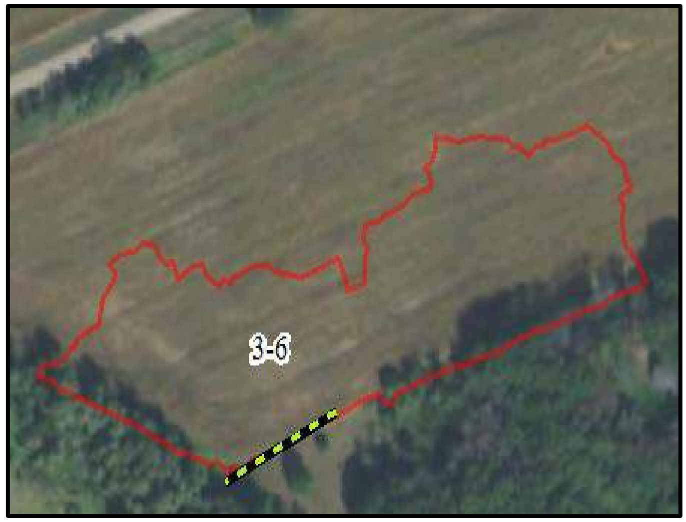
Drainage Area – 4.61 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 85% agricultural land use with small areas of low density residential. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located east side of the catchment and outlets into adjacent forested area.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,014.03	1.76	$576.15

Current Conditions		Added Practice		Reduction	
Sub-Basin	5	Type	Grassed Waterway	Sediment reduction (t/yr)	2.07
Acres	4.61	Area (acres)	NA	Soil Loss reduction (t/yr)	9.41
Soil	Zimmerman fine Sand, 1 to 6 % slope	Vol Voided (ft^3)	171	Phosphorus reduction (lb/yr)	1.76
		Length (ft)	171		
Average slope	4.64	Years	1		
		Distance to SW (ft)	1503		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 3
Catchment 6



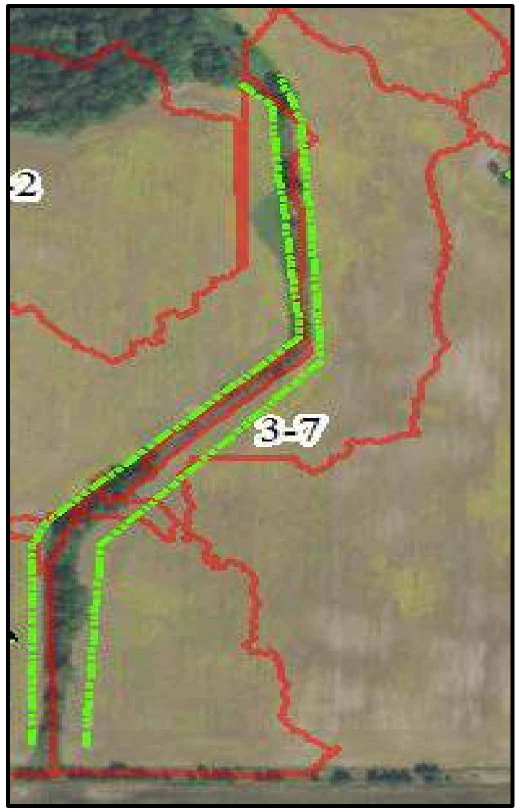
Drainage Area – 3.66 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 98% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located south side of the catchment and outlets into adjacent forested area.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,061.47	2.81	$377.75

Current Conditions		Added Practice		Reduction	
Sub-Basin	6	Type	Grassed Waterway	Sediment reduction (t/yr)	3.31
Acres	3.66	Area (acres)	NA	Soil Loss reduction (t/yr)	9.85
Soil	Zimmerman fine Sand, 1 to 6 % slope	Vol Voided (ft^3)	179	Phosphorus reduction (lb/yr)	2.81
		Length (ft)	179		
Average slope	2.9	Years	1		
		Distance to SW (ft)	195		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Filter Strip
Subwatershed 3
Catchment 7



Drainage Area – 10.13 acres

Property Ownership – Private

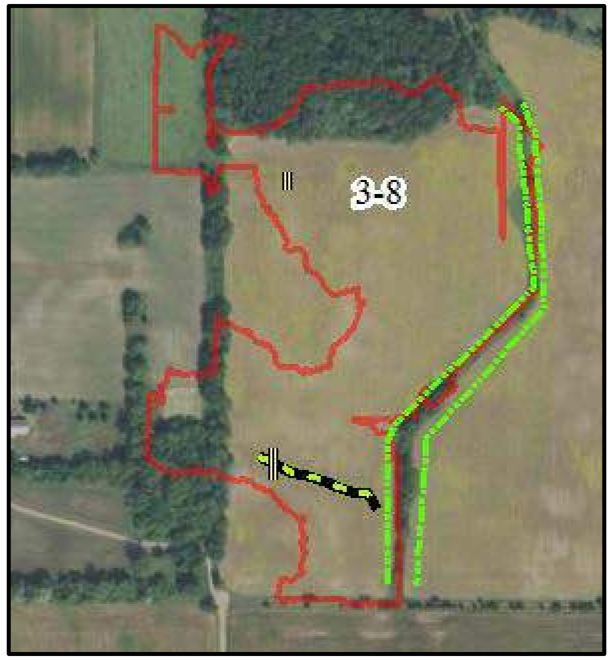
Site Specific Information – The Catchment is estimated 100% agricultural land use. The proposed project is a perennial vegetative filter strip to be planted along the field's edge creating a buffer between the field ditch. The buffer is intended to catch sediment and utilize nutrients from runoff, prior to entering the surface water ditch. The new projected is located on the west side of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$440.70	1	$440.70

Current Conditions		Added Practice		Reduction	
Sub-Basin	7	Type	Filter Strip	Sediment reduction (t/yr)	0.65
Acres	10.13	Area (acres)	1.89	Soil Loss reduction (t/yr)	1.26
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	NA	Phosphorus reduction (lb/yr)	1
		Length (ft)	1644		
Average slope	3.99	Years	1		
		Distance to SW (ft)	0		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Filter Strip
Subwatershed 3
Catchment 8



Drainage Area – 24.45 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 90% agricultural land use and small areas of forested land. The proposed project is a perennial vegetative filter strip to be planted along the field's edge creating a buffer between the field ditch. The buffer is intended to catch sediment and utilize nutrients from runoff, prior to entering the surface water ditch. The new projected is located on the east side of the catchment.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$447.48	1.02	$438.71

Current Conditions		Added Practice		Reduction	
Sub-Basin	8	Type	Filter Strip	Sediment reduction (t/yr)	0.66
Acres	24.45	Area (acres)	1.93	Soil Loss reduction (t/yr)	1.28
Soil	Zimmerman fine Sand, 1 to 6 % slope	Vol Voided (ft^3)	NA	Phosphorus reduction (lb/yr)	1.02
		Length (ft)	1685		
Average slope	5.1	Years	1		
		Distance to SW (ft)	0		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

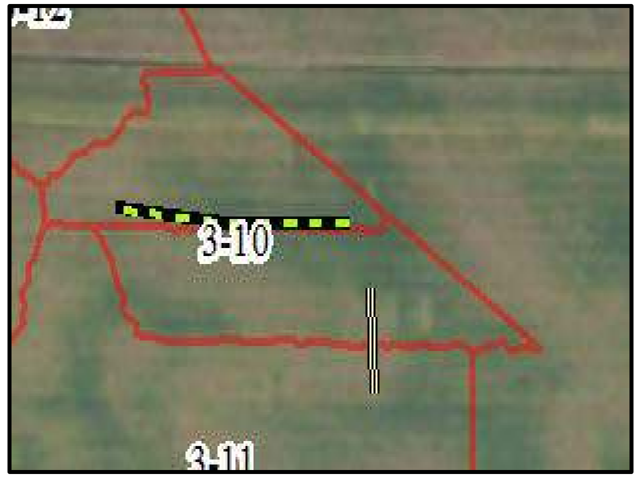
Project ID – Filter Strip
Subwatershed 3
Catchment 9

Drainage Area – 4.08 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 90% agricultural land use. The proposed project is a perennial vegetative filter strip to be planted along the field's edge creating a buffer between the field ditch. The buffer is intended to catch sediment and utilize nutrients from runoff, prior to entering the surface water ditch. The new projected is located on the south side of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$135.60	0.31	$437.42

Current Conditions		Added Practice		Reduction	
Sub-Basin	9	Type	Filter Strip	Sediment reduction (t/yr)	0.2
Acres	4.08	Area (acres)	0.59	Soil Loss reduction (t/yr)	0.39
Soil	Zimmerman fine Sand, 1 to 6 % slope	Vol Voided (ft^3)	NA	Phosphorus reduction (lb/yr)	0.31
		Length (ft)	518		
Average slope	4.06	Years	1		
		Distance to SW (ft)	0		

Project ID – Grassed Waterway
Subwatershed 3
Catchment 10



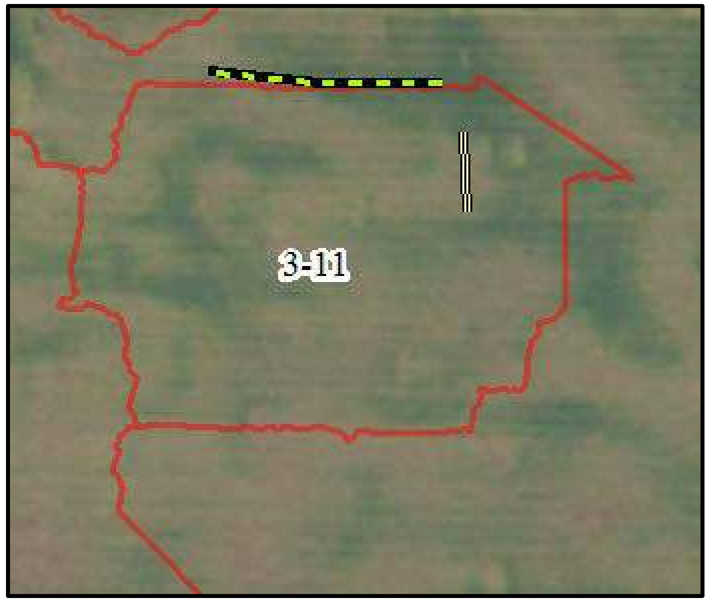
Drainage Area – 2.2 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located south side of the catchment.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$1,802.72	3.48	$518.02

Current Conditions		Added Practice		Reduction	
Sub-Basin	10	Type	Grassed Waterway	Sediment reduction (t/yr)	4.09
Acres	2.2	Area (acres)	NA	Soil Loss reduction (t/yr)	16.72
Soil	Zimmerman fine Sand, 1 to 6 % slope	Vol Voided (ft^3)	304	Phosphorus reduction (lb/yr)	3.48
		Length (ft)	304		
Average slope	3.5	Years	1		
		Distance to SW (ft)	900		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – WASCOB
Subwatershed 3
Catchment 11



Drainage Area – 5.89 acres
Property Ownership – Private
Site Specific Information –
Catchment 11 is estimated 100% Agricultural land use. Located on the east side of the catchment running west shows moderate slopes with a potential linear depression corresponding with the elevation data. Implementing a WASCOB in this area would reduce overland flow on the field. This area could also benefit from a grass waterway project.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$57,743.79	4.75	$12,156.59

Current Conditions		Added Practice		Reduction	
Sub-Basin	11	Type	WASCOB	Sediment reduction (t/yr)	5.58
Acres	5.89	Area (acres)	5.89	Soil Loss reduction (t/yr)	29.7
Soil	Zimmerman fine Sand, 1 to 6 % slope	Vol Voided (ft^3)	540	Phosphorus reduction (lb/yr)	4.75
		Length (ft)	0		
Average slope	2.71	Years	1		
		Distance to SW (ft)	3219		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 3
Catchment 12

Drainage Area – 3.81 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment and outlets into the adjacent forest.

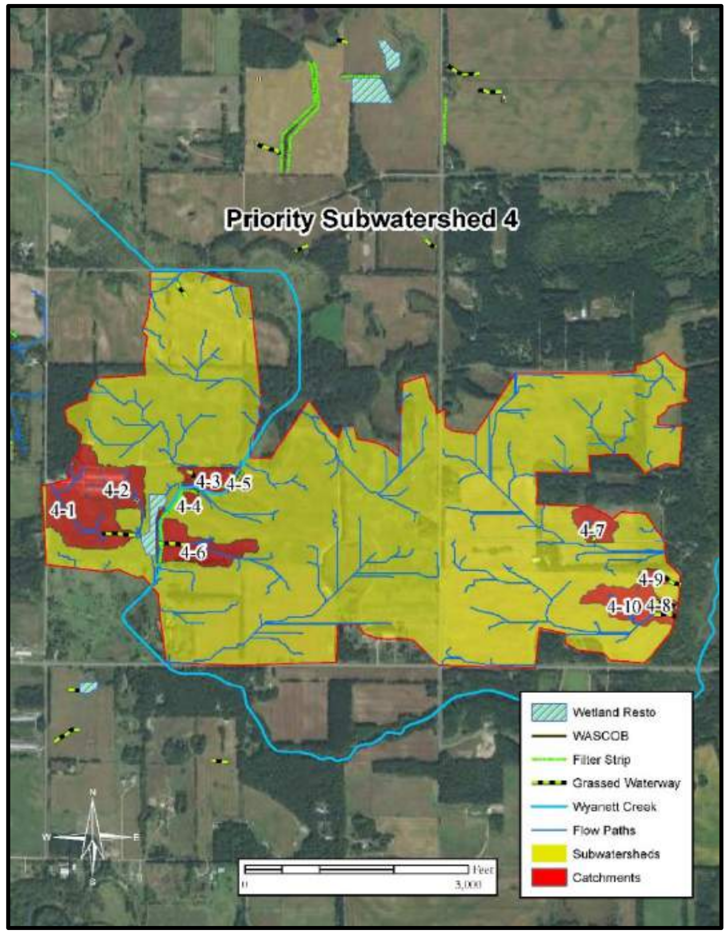
Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$2,793.03	6.57	$425.12

Current Conditions		Added Practice		Reduction	
Sub-Basin	12	Type	Grassed Waterway	Sediment reduction (t/yr)	7.73
Acres	3.81	Area (acres)	NA	Soil Loss reduction (t/yr)	25.91
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	471	Phosphorus reduction (lb/yr)	6.57
		Length (ft)	471		
Average slope	5.07	Years	1		
		Distance to SW (ft)	346		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Priority Subwatershed 4

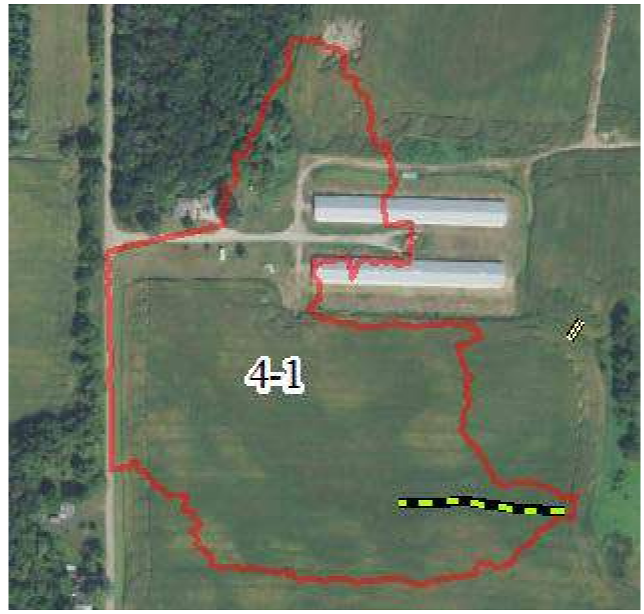
Priority subwatershed 4 is 646 acres and the largest of all priority subwatersheds. The 646 acres is primarily agricultural land but area also includes areas of low density residential, wetlands and forest. In addition to the sandy soils, moderate to severe slopes and agricultural land use, this subwatershed was prioritized because Wyanett Creek meanders through the prioritized zone 10 priority catchments were identified during desktop analysis where water quality projects are recommended. Edge of field filter strips, grass waterways, and WASCOBs were all identified as improvement projects. Areas of small depression were identified in the west end of the subwatershed that are assumed marginal cropland. While not modeled during this assessment it is assumed a wetland restoration would be a viable project option for this area. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to Wyanett Creek and Green Lake.



Priority Subwatershed 3 Summary	
Acres addressed	646
Dominant Land Cover	Agricultural
Total Sub-Basins	10
Potential BMPs	10
Potential TP reduction (lb/yr)	39.33
Potential TSS reduction (tons/yr)	46.03

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 4
Catchment 1

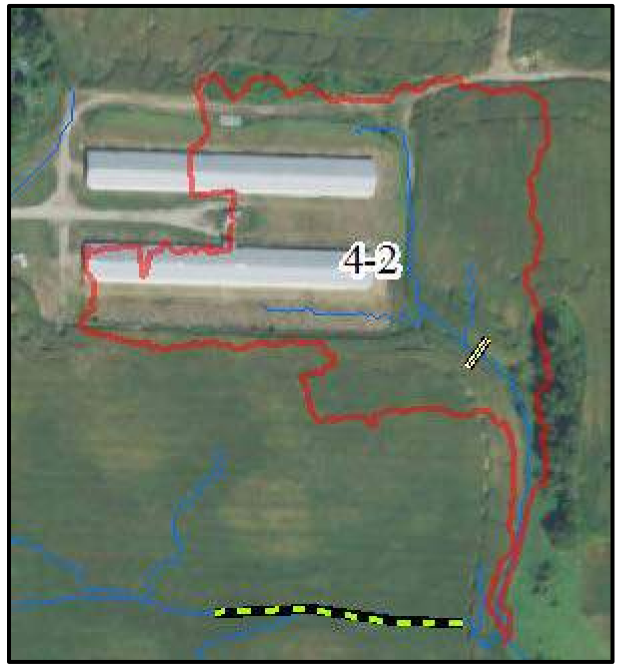


Drainage Area – 20.66 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 75% agricultural land use and 25% low density residential. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located south west side of the catchment and outlets into adjacent wetland.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$2,567.69	5.95	$431.54

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Grassed Waterway	Sediment reduction (t/yr)	7
Acres	20.66	Area (acres)	433	Soil Loss reduction (t/yr)	23.87
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	433	Phosphorus reduction (lb/yr)	5.95
		Length (ft)	NA		
Average slope	4.07	Years	1		
		Distance to SW (ft)	0		

Project ID – WASCOB
Subwatershed 4
Catchment 2

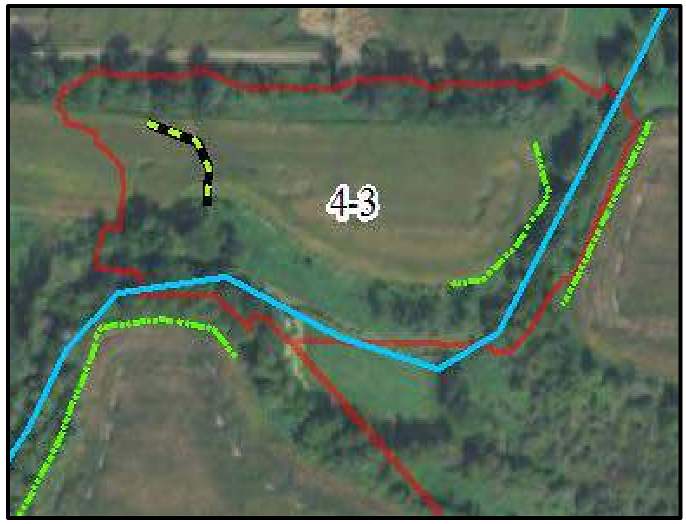


Drainage Area – 7.95 acres
Property Ownership – Private
Site Specific Information –
Catchment 2 is estimated 40% Agricultural land use and 60% low density residential. Starting in the middle of the catchment running west shows moderate to severe slopes with a potential linear depression corresponding with the elevation data. Implementing a WASCOB in this area would reduce overland flow through the concentrated flow path area. The outlet of the project would be an adjacent wetland.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$68,625.90	4.69	$14,632.39

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	WASCOB	Sediment reduction (t/yr)	5.51
Acres	7.95	Area (acres)	7	Soil Loss reduction (t/yr)	14.3
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	764	Phosphorus reduction (lb/yr)	4.69
		Length (ft)	764		
Average slope	3	Years	1		
		Distance to SW (ft)	100		

Project ID – Grassed Waterway
Subwatershed 4
Catchment 3



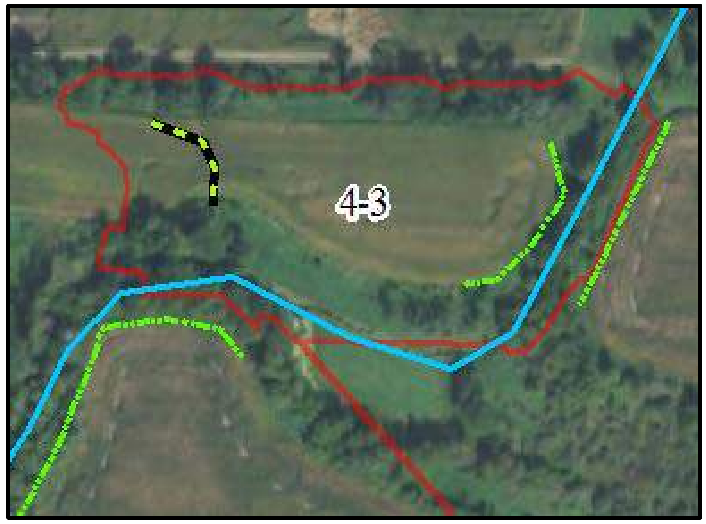
Drainage Area – 5.42 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 80% agricultural land use and small portions of wetland and forest. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located north west side of the catchment and outlets into adjacent forested area.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$990.31	3.16	$313.39

Current Conditions		Added Practice		Reduction	
Sub-Basin	3	Type	Grassed Waterway	Sediment reduction (t/yr)	3.72
Acres	5.42	Area (acres)	NA	Soil Loss reduction (t/yr)	9.19
Soil	Zimmerman loamy fine sand and fine sand, 7 to 12 percent slopes	Vol Voided (ft^3)	167	Phoshorus reduction (lb/yr)	3.16
		Length (ft)	167		
Average slope	7.37	Years	1		
		Distance to SW (ft)	79		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Filter Strip
Subwatershed 4
Catchment 3



Drainage Area – 5.42 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 80% agricultural land use with small areas of wetland and forest. The proposed project is a perennial vegetative filter strip to be planted along the field's edge creating a buffer between Wyanett Creek. The buffer is intended to catch sediment and utilize nutrients from runoff, prior to entering the creek. The new projected is located on the east side of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$207.79	0.16	$1,298.68

Current Conditions		Added Practice		Reduction	
Sub-Basin	3	Type	Filter Strip	Sediment reduction (t/yr)	0.1
Acres	5.42	Area (acres)	0.306473829	Soil Loss reduction (t/yr)	0.2
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	NA	Phosphorus reduction (lb/yr)	0.16
		Length (ft)	267		
Average slope	7.37	Years	1		
		Distance to SW (ft)	NA		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Filter Strip
Subwatershed 4
Catchment 4

Drainage Area – .77 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 95% agricultural land use. The proposed project is a perennial vegetative filter strip to be planted along the field's edge creating a buffer between Wyanett Creek. The buffer is intended to catch sediment and utilize nutrients from runoff, prior to entering surface water. The new projected is located on the west side of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$174.33	0.13	$1,340.96

Current Conditions		Added Practice		Reduction	
Sub-Basin	4	Type	Filter Strip	Sediment reduction (t/yr)	0.09
Acres	0.77	Area (acres)	0.257116621	Soil Loss reduction (t/yr)	0.17
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	NA	Phosphorus reduction (lb/yr)	0.13
		Length (ft)	224		
Average slope	5.19	Years	1		
		Distance to SW (ft)	NA		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Filter Strip
Subwatershed 4
Catchment 5

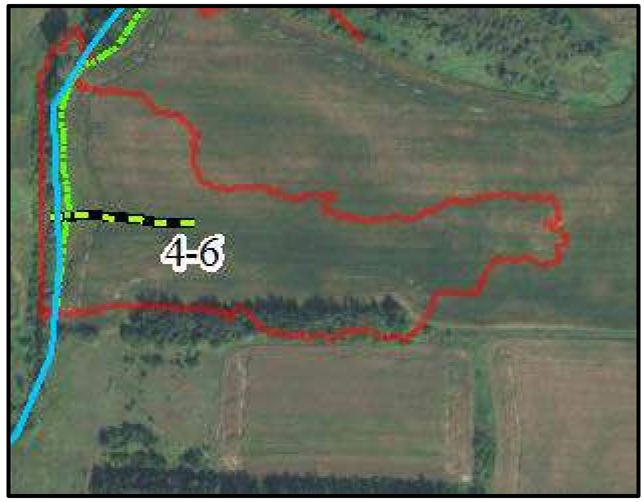
Drainage Area – .45 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. The proposed project is a perennial vegetative filter strip to be planted along the field's edge creating a buffer between Wyanett Creek. The buffer is intended to catch sediment and utilize nutrients from runoff, prior to entering surface water. The new projected is located on the west side of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$211.68	0.16	$1,323.00

Current Conditions		Added Practice		Reduction	
Sub-Basin	5	Type	Filter Strip	Sediment reduction (t/yr)	0.11
Acres	0.45	Area (acres)	0.312213039	Soil Loss reduction (t/yr)	0.21
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	NA	Phosphorus reduction (lb/yr)	0.16
		Length (ft)	272		
Average slope	7.37	Years	1		
		Distance to SW (ft)	NA		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 4
Catchment 6



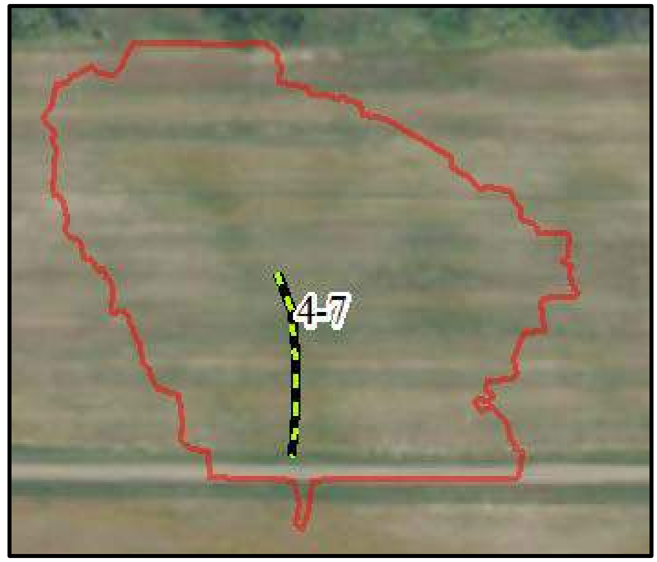
Drainage Area – 11.4 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 98% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located west side of the catchment and outlets into adjacent forested area.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$2,217.82	10.86	$204.22

Current Conditions		Added Practice		Reduction	
Sub-Basin	6	Type	Grassed Waterway	Sediment reduction (t/yr)	12.77
Acres	11.44	Area (acres)	NA	Soil Loss reduction (t/yr)	20.57
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	374	Phosphorus reduction (lb/yr)	10.86
		Length (ft)	374		
Average slope	3.37	Years	1		
		Distance to SW (ft)	10		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 4
Catchment 7



Drainage Area – 4.7 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 98% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located south side of the catchment and outlets into adjacent roadside ditch.

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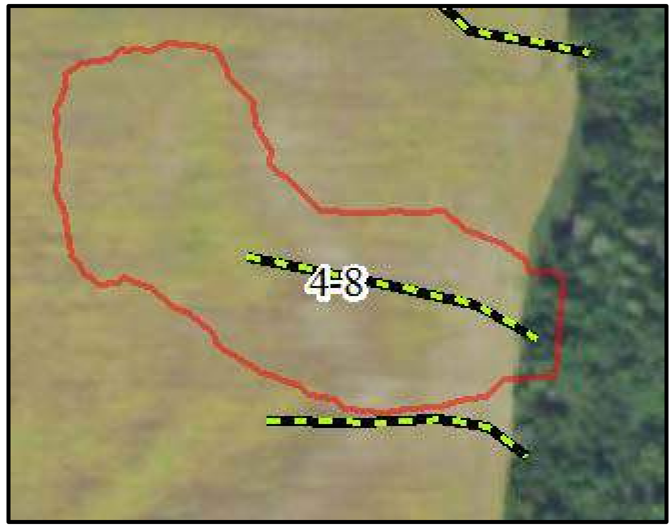
Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,209.72	2	$604.86

Current Conditions		Added Practice		Reduction	
Sub-Basin	7	Type	Grassed Waterway	Sediment reduction (t/yr)	2.35
Acres	4.7	Area (acres)	NA	Soil Loss reduction (t/yr)	11.22
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	204	Phosphorus reduction (lb/yr)	2
		Length (ft)	204		
Average slope	3.49	Years	1		
		Distance to SW (ft)	1646		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 4
Catchment 8



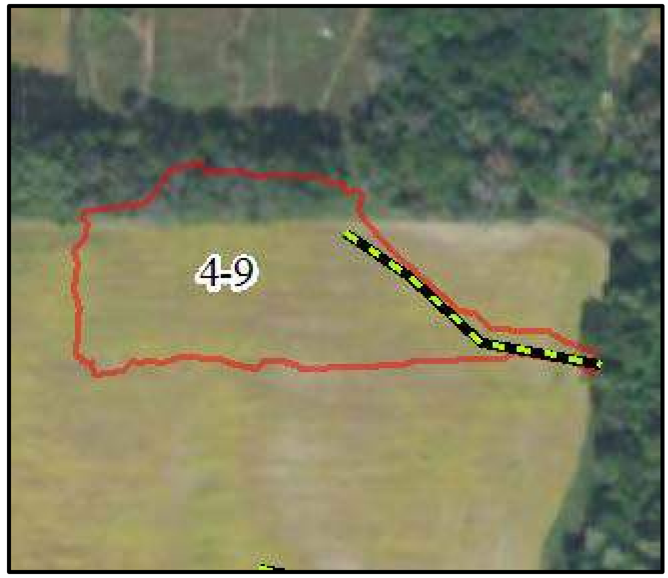
Drainage Area – 2.75 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 99% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located east side of the catchment and outlets into adjacent forested area.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,950.97	4.25	$459.05

Current Conditions		Added Practice		Reduction	
Sub-Basin	8	Type	Grassed Waterway	Sediment reduction (t/yr)	5
Acres	2.75	Area (acres)	10.86	Soil Loss reduction (t/yr)	18.1
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	329	Phosphorus reduction (lb/yr)	4.25
		Length (ft)	329		
Average slope	5.48	Years	1		
		Distance to SW (ft)	468		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 4
Catchment 9

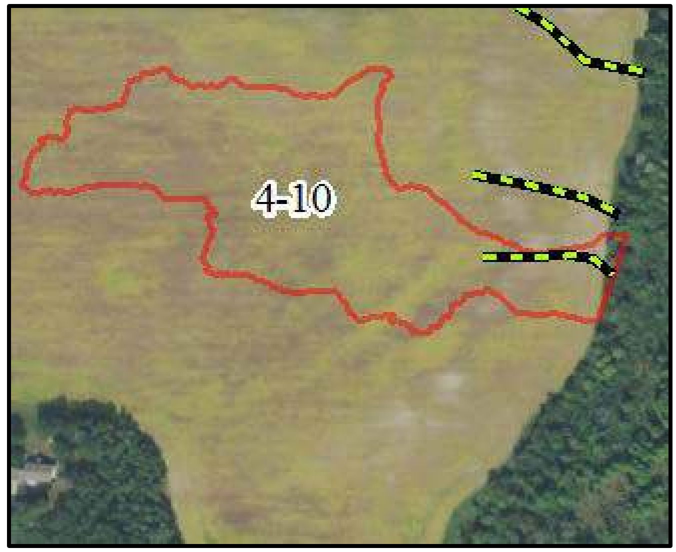


Drainage Area – 1.73 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 90% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located east south side of the catchment and outlets into adjacent forested area.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$1,915.39	4.17	$459.33

Current Conditions		Added Practice		Reduction	
Sub-Basin	9	Type	Grassed Waterway	Sediment reduction (t/yr)	4.91
Acres	1.73	Area (acres)	0	Soil Loss reduction (t/yr)	17.77
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	323	Phosphorus reduction (lb/yr)	4.17
		Length (ft)	323		
Average slope	6.19	Years	1		
		Distance to SW (ft)	517		

Project ID – Grassed Waterway
Subwatershed 4
Catchment 10



Drainage Area – 7.78 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located east side of the catchment and outlets into adjacent forested area.

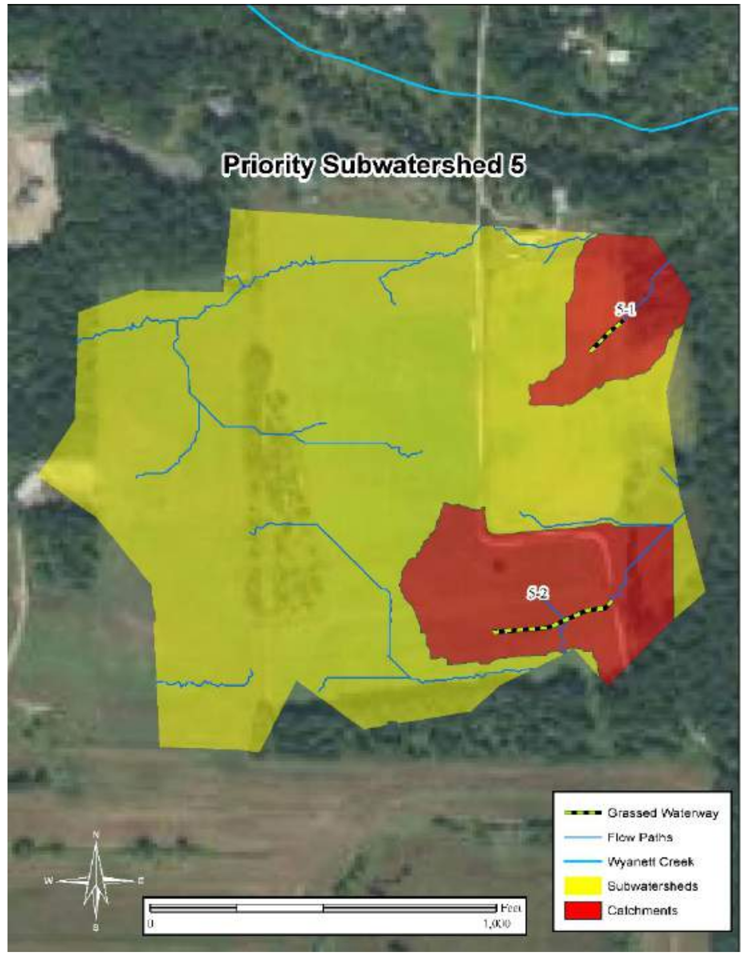
Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,743.42	3.8	$458.79

Current Conditions		Added Practice		Reduction	
Sub-Basin	10	Type	Grassed Waterway	Sediment reduction (t/yr)	4.47
Acres	7.78	Area (acres)	0	Soil Loss reduction (t/yr)	16.17
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	294	Phosphorus reduction (lb/yr)	3.8
		Length (ft)	294		
Average slope	3.17	Years	1		
		Distance to SW (ft)	487		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Priority Subwatershed 5

Priority subwatershed 5 is 51 acres of mainly agricultural land with small areas of low density residential, wetlands and forests. In addition to the sandy soils, moderate to severe slopes and agricultural land use, this subwatershed was prioritized because Wyanett Creek runs only 300 feet to the north. Two priority catchments were identified during desktop analysis where water quality projects are recommended. A grass waterway is recommended for each of the catchments to reduce sediment and nutrient loading. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to Wyanett Creek and Green Lake.



Priority Subwatershed 5 Summary	
Acres addressed	51
Dominant Land Cover	Agricultural
Total Sub-Basins	2
Potential BMPs	2
Potential TP reduction (lb/yr)	10.12
Potential TSS reduction (tons/yr)	11.91

Project ID – Grassed Waterway Subwatershed 5 Catchment 1

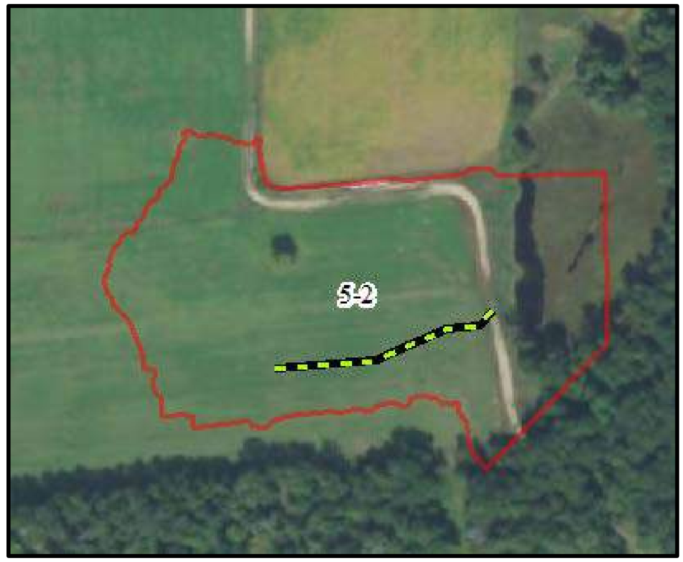
Drainage Area – 3.34 acres.
Property Ownership – Private
Site Specific Information – The Catchment is estimated 80% agricultural land use and 20% forested land. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment and outlets into adjacent forested area.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$776.83	2.03	$382.67

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Grassed Waterway	Sediment reduction (t/yr)	2.39
Acres	3.34	Area (acres)	NA	Soil Loss reduction (t/yr)	7.21
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	131	Phosphorus reduction (lb/yr)	2.03
		Length (ft)	131		
Average slope	8.37	Years	1		
		Distance to SW (ft)	209		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 5
Catchment 2



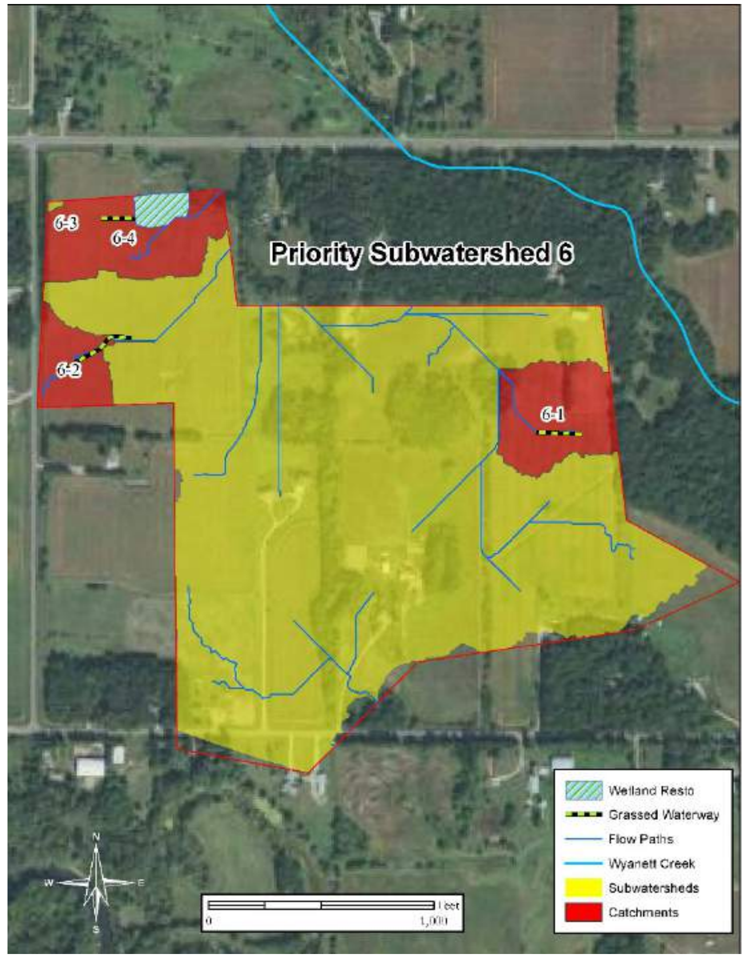
Drainage Area – 7.4 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 85% agricultural land use and a small percentage of wetland. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment and outlets into the wetland on the east.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$2,140.73	8.09	$264.61

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	Grassed Waterway	Sediment reduction (t/yr)	9.52
Acres	7.4	Area (acres)	NA	Soil Loss reduction (t/yr)	23.87
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	361	Phosphorus reduction (lb/yr)	8.09
		Length (ft)	361		
Average slope	5.06	Years	1		
		Distance to SW (ft)	85		

Priority Subwatershed 6

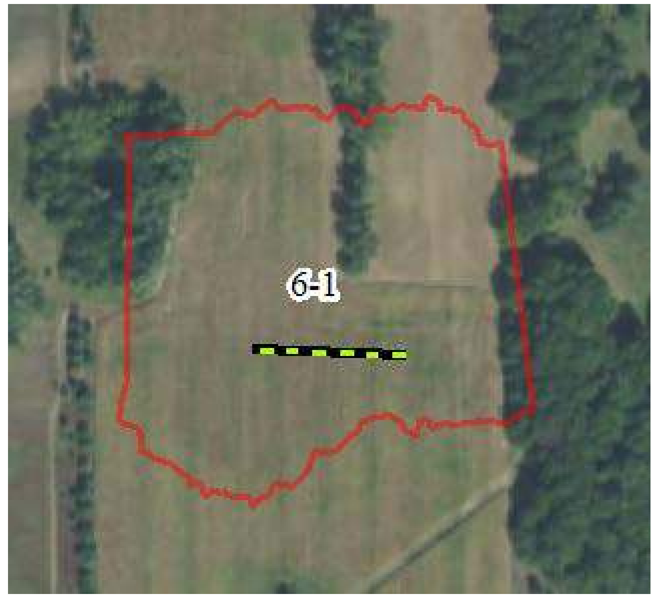
Priority subwatershed 6 is 97 acres of composed mainly of agricultural land with small areas of low density residential, wetlands and forests. In addition to the sandy soils, moderate to severe slopes and agricultural land use, this subwatershed was prioritized because Wyanett Creek runs only 300 feet to the north. Four priority catchments were identified during desktop analysis where water quality projects are recommended. A grass waterway is recommended for three of the four catchments to reduce sediment and nutrient loading. An area of small depression was identified in the north end of the subwatershed that is assumed marginal cropland. While not modeled during this assessment it is assumed a wetland restoration would be a viable project option for this area. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to Wyanett Creek and Green Lake.



Priority Subwatershed 6 Summary	
Acres addressed	97
Dominant Land Cover	Agricultural
Total Sub-Basins	4
Potential BMPs	4
Potential TP reduction (lb/yr)	8.51
Potential TSS reduction (tons/yr)	10.01

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 6
Catchment 1



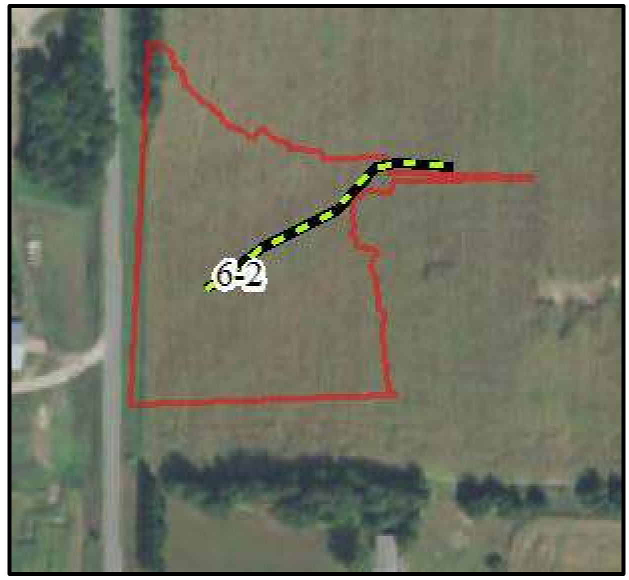
Drainage Area – 5.37 acres.
Property Ownership – Private
Site Specific Information – The Catchment is estimated 90% agricultural land use and a small percentage of forested land. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,197.86	2.51	$477.24

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Grassed Waterway	Sediment reduction (t/yr)	2.95
Acres	5.37	Area (acres)	NA	Soil Loss reduction (t/yr)	11.11
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	202	Phosphorus reduction (lb/yr)	2.51
		Length (ft)	202		
Average slope	4.87	Years	1		
		Distance to SW (ft)	604		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 6
Catchment 2



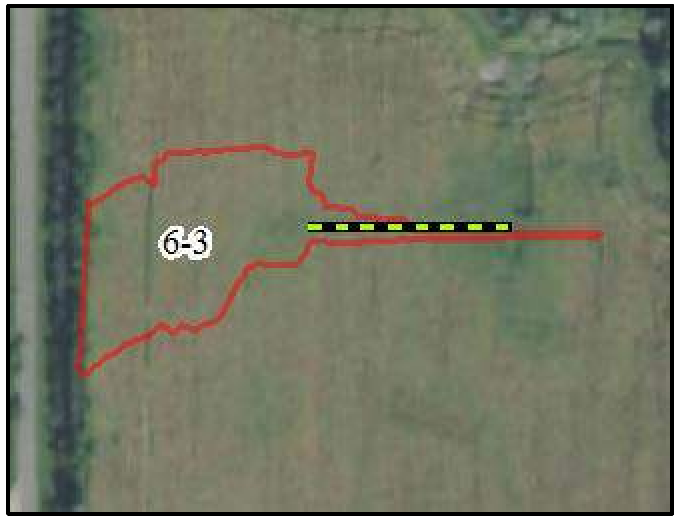
Drainage Area – 4.7 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 99% agricultural land use and a small percentage of forested land. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$2,235.61	3.51	$636.93

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	Grassed Waterway	Sediment reduction (t/yr)	4.13
Acres	4.7	Area (acres)	NA	Soil Loss reduction (t/yr)	20.74
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	377	Phosphorus reduction (lb/yr)	3.51
		Length (ft)	377		
Average slope	5.5	Years	1		
		Distance to SW (ft)	2451		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 6
Catchment 3



Drainage Area – 1.12 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in on the east side of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,310.53	2.49	$526.32

Current Conditions		Added Practice		Reduction	
Sub-Basin	3	Type	Grassed Waterway	Sediment reduction (t/yr)	2.93
Acres	1.12	Area (acres)	NA	Soil Loss reduction (t/yr)	12.16
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	221	Phosphorus reduction (lb/yr)	2.49
		Length (ft)	221		
Average slope	4.22	Years	1		
		Distance to SW (ft)	975		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Wetland Restoration Subwatershed 6 Catchment 4

Drainage Area – 6.17 acres
Property Ownership – Private
Site Specific Information – Located on the north end of the agricultural field is a low depression in the landscape that has the potential to be restored to wetland. Using historical aerial photos, it was determined this location is marginal cropland, showing hydrologic indicators in the majority of the photos. Wetland Restorations were not modeled during this assessment however the opportunity is there to restore an area to a more diverse environment that would improve water quality and wildlife habitat.

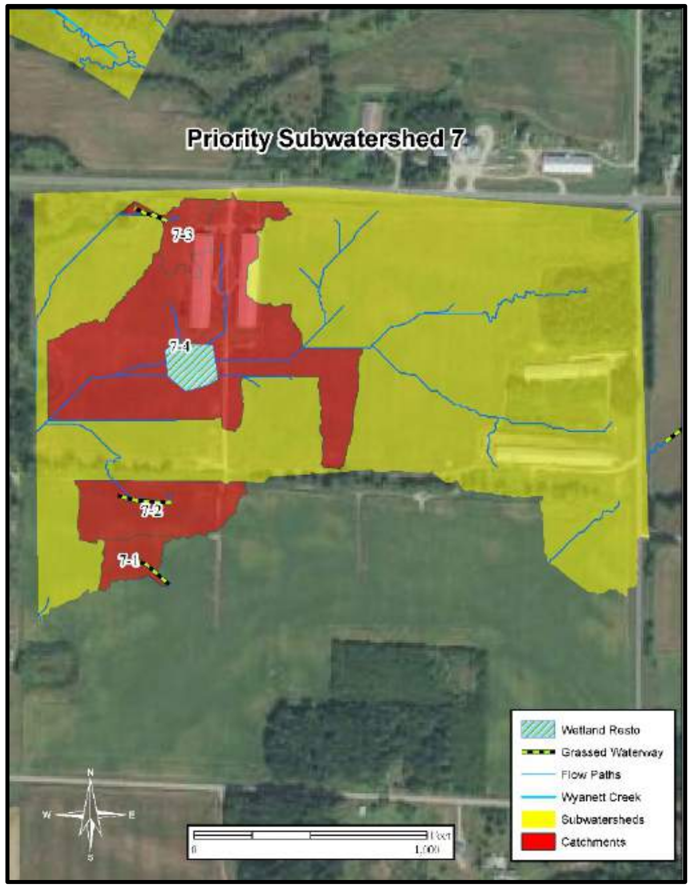
Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$2,425.50	TBD	TBD

Current Conditions		Added Practice		Reduction	
Sub-Basin	4	Type	Wetland Resto	Sediment reduction (t/yr)	TBA
Acres	6.17	Area (acres)	0.7	Soil Loss reduction (t/yr)	TBA
Soil	Isanti Mucky Loamy Fine Sand	Vol Voided (ft^3)	NA	Phosphorus reduction (lb/yr)	TBA
		Length (ft)	NA		
Average slope	3.79	Years	1		
		Distance to SW (ft)	0		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Priority Subwatershed 7

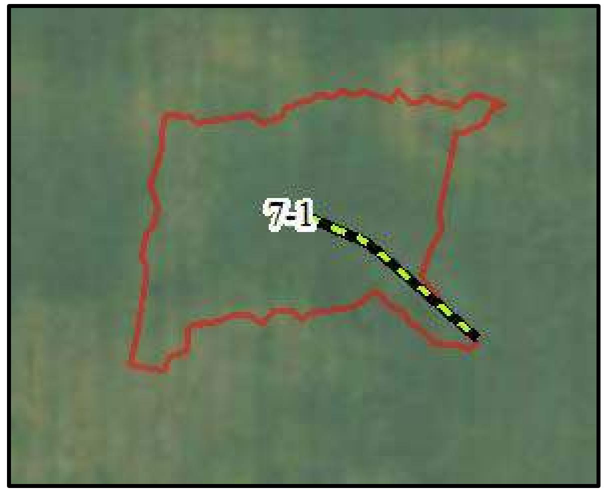
Priority subwatershed 7 is 89 acres of mainly agricultural land with small areas of low density residential and forested land. In addition to the sandy soils, moderate to severe slopes and agricultural land use, this subwatershed was prioritized because Wyanett Creek that runs only 700 feet to the north. Four priority catchments were identified during desktop analysis where water quality projects are recommended. A grass waterway is recommended for three of the four catchments to reduce sediment and nutrient loading. An area of small depression was identified in the middle of the subwatershed that is assumed marginal cropland. While not modeled during this assessment it is assumed a wetland restoration would be a viable project option for this area. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to Wyanett Creek and Green Lake.



Priority Subwatershed 5 Summary	
Acres addressed	89
Dominant Land Cover	Agricultural
Total Sub-Basins	4
Potential BMPs	4
Potential TP reduction (lb/yr)	11.93
Potential TSS reduction (tons/yr)	14.03

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 7
Catchment 1



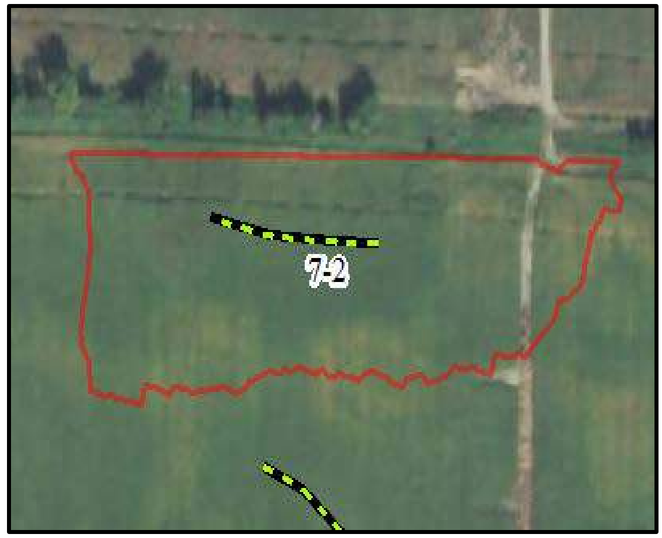
Drainage Area – 1.12 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in on the east side of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
1197.86	2.51	$477.24

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Grassed Waterway	Sediment reduction (t/yr)	2.95
Acres	1.12	Area (acres)	NA	Soil Loss reduction (t/yr)	11.11
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	202	Phosphorus reduction (lb/yr)	2.51
		Length (ft)	202		
Average slope	3.48	Years	1		
		Distance to SW (ft)	608		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 7
Catchment 2



Drainage Area – 7.23 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
2235.61	4.96	$450.73

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	Grassed Waterway	Sediment reduction (t/yr)	5.83
Acres	7.23	Area (acres)	NA	Soil Loss reduction (t/yr)	20.74
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	377	Phosphorus reduction (lb/yr)	4.96
		Length (ft)	377		
Average slope	4.41	Years	1		
		Distance to SW (ft)	460		

Project ID – Grassed Waterway
Subwatershed 7
Catchment 3

Drainage Area – 1.33 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 75% agricultural land use and a small percentage wetland and low density residential. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in on the north west side of the catchment and outlets into the adjacent wetland.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
1310.53	4.46	$293.84

Current Conditions		Added Practice		Reduction	
Sub-Basin	3	**Type**	Grassed Waterway	**Sediment reduction (t/yr)**	5.25
Acres	1.33	**Area (acres)**	NA	**Soil Loss reduction (t/yr)**	12.16
Soil	Zimmerman fine Sand,, 1 to 6 % slope	**Vol Voided (ft^3)**	221	**Phosphorus reduction (lb/yr)**	4.46
		Length (ft)	221		
Average slope	2.36	**Years**	1		
		Distance to SW (ft)	58		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Wetland Restoration
Subwatershed 7
Catchment 4

Drainage Area – 15.95 acres
Property Ownership – Private
Site Specific Information – – Located in the middle of the agricultural field is a low depression in the landscape that has the potential to be restored to wetland. Using historical aerial photos, it was determined this location is marginal cropland, showing hydrologic indicators in the majority of the photos. Wetland Restorations were not modeled during this assessment however the opportunity is there to restore the area to a more diverse environment that would improve water quality and wildlife habitat.

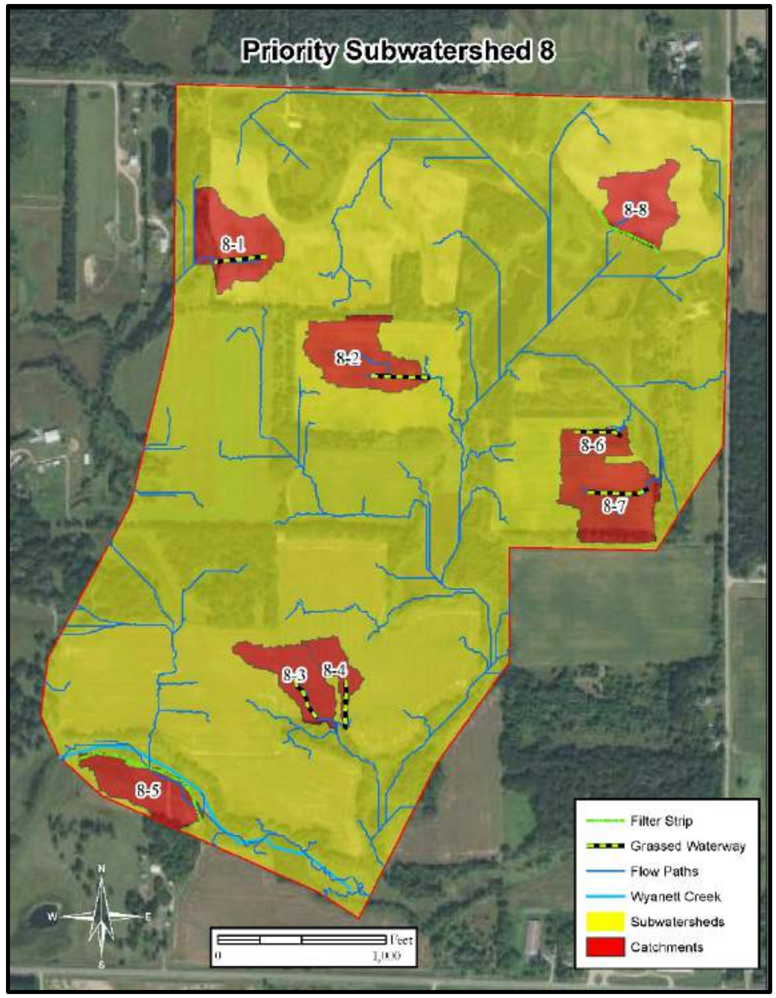
Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
2979.9	TBD	TBD

Current Conditions		Added Practice		Reduction	
Sub-Basin	4	Type	Wetland Resto	Sediment reduction (t/yr)	TBD
Acres	15.95	Area (acres)	0.86	Soil Loss reduction (t/yr)	TBD
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	NA	Phosphorus reduction (lb/yr)	TBD
		Length (ft)	NA		
Average slope	3.67	Years	1		
		Distance to SW (ft)	NA		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Priority Subwatershed 8

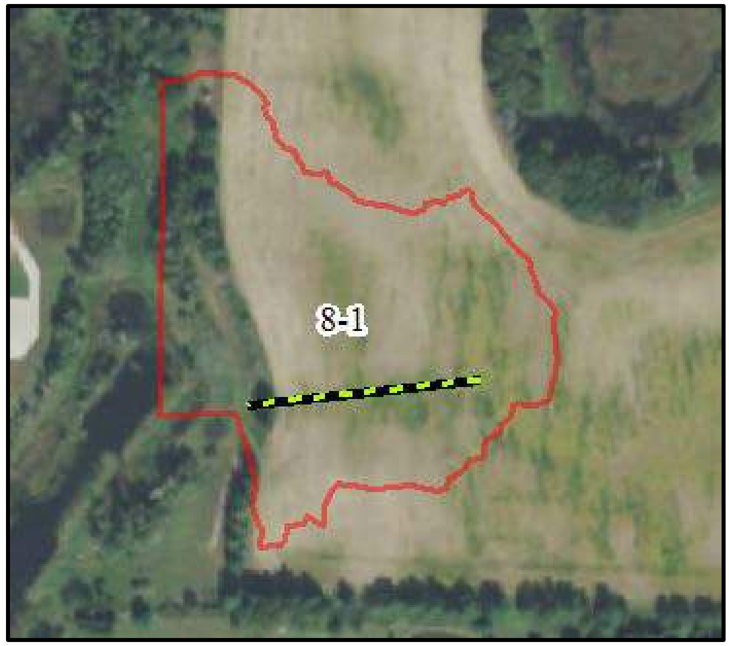
Priority subwatershed 8 is 306 acres of mainly agricultural land but also includes areas of forest and large wetlands. In addition to the sandy soils, moderate to severe slopes and agricultural land use, this subwatershed was prioritized because Wyanett Creek runs through the south section of the subwatershed. Eight priority catchments were identified during desktop analysis where water quality projects are recommended. Grass waterways and filter strips were the two projects chosen to combat sediment and nutrient loading. Like every subwatershed identified in this assessment, the area could benefit from cover crops, conservation tillage or permanent vegetation establishments to improve soil health, increase biodiversity and reduce nutrient loading to Wyanett Creek and Green Lake.



Priority Subwatershed 8 Summary	
Acres addressed	89
Dominant Land Cover	Agricultural
Total Sub-Basins	8
Potential BMPs	8
Potential TP reduction (lb/yr)	34.45
Potential TSS reduction (tons/yr)	40.00

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 8
Catchment 1

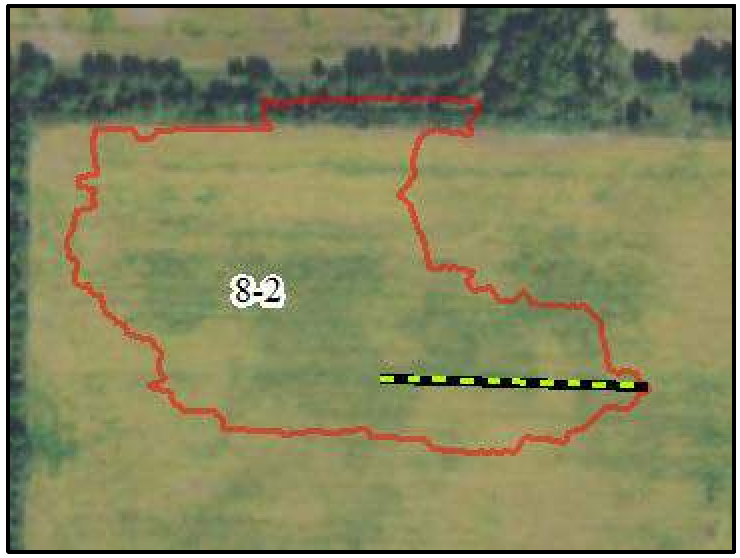


Drainage Area – 4.73 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 80% agricultural land use and a small percentage of forested land and wetland. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in on the south side of the catchment and outlets into the adjacent wetland to the west.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,856.09	5.39	$344.36

Current Conditions		Added Practice		Reduction	
Sub-Basin	1	Type	Grassed Waterway	Sediment reduction (t/yr)	6.34
Acres	4.73	Area (acres)	NA	Soil Loss reduction (t/yr)	17.22
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	313	Phosphorus reduction (lb/yr)	5.39
		Length (ft)	313		
Average slope	5.58	Years	1		
		Distance to SW (ft)	125		

Project ID – Grassed Waterway
Subwatershed 8
Catchment 2

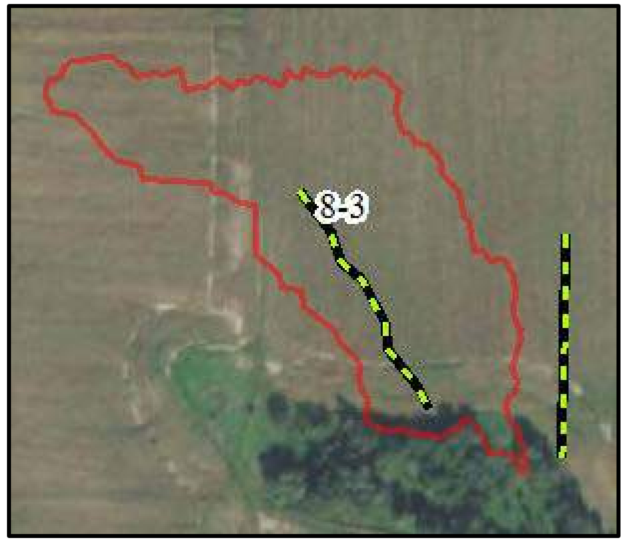


Drainage Area – 4.92 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 99% agricultural land use and a small percentage of forested land. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in on the east side of the catchment.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$2,235.61	5.45	$410.20

Current Conditions		Added Practice		Reduction	
Sub-Basin	2	Type	Grassed Waterway	Sediment reduction (t/yr)	6.41
Acres	4.92	Area (acres)	NA	Soil Loss reduction (t/yr)	20.74
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	377	Phosphorus reduction (lb/yr)	5.45
		Length (ft)	347		
Average slope	2.38	Years	1		
		Distance to SW (ft)	291		

Project ID – Grassed Waterway
Subwatershed
Catchment



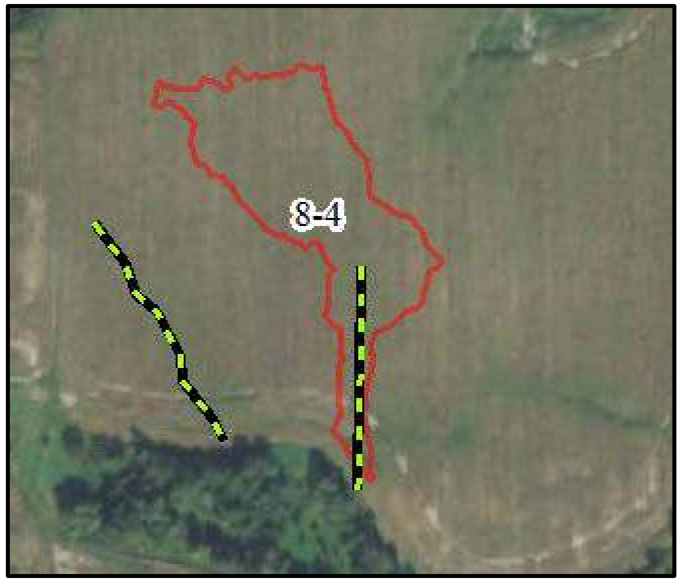
Drainage Area – 3.28 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 99% agricultural land use and a small percentage of forested land. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project in the middle of the catchment and outlets into the forest bordering a wetland.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$2,057.71	6.08	$338.44

Current Conditions		Added Practice		Reduction	
Sub-Basin	3	Type	Grassed Waterway	Sediment reduction (t/yr)	7.31
Acres	3.28	Area (acres)	NA	Soil Loss reduction (t/yr)	19.09
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	347	Phosphorus reduction (lb/yr)	6.08
		Length (ft)	347		
Average slope	3.32	Years	1		
		Distance to SW (ft)	347		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 8
Catchment 4

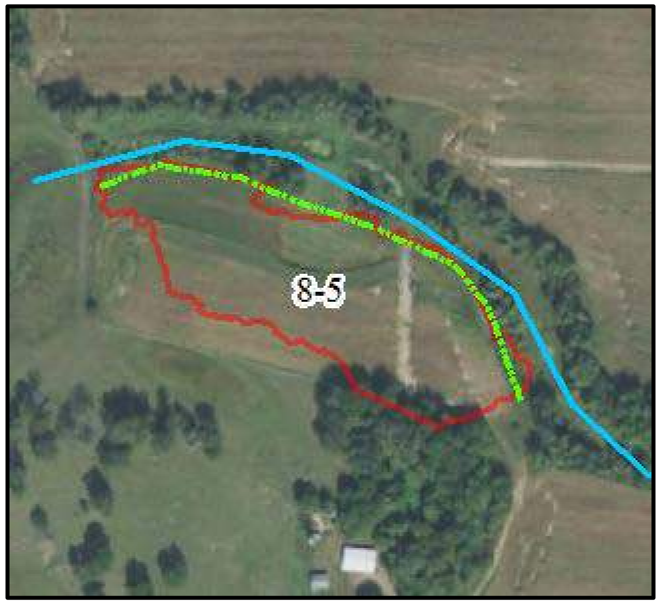


Drainage Area – 1.4 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in on the south side of the catchment and outlets into a forested area bordering a wetland.

Cost-Benefit		
Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
$1,719.70	5.81	$295.99

Current Conditions		Added Practice		Reduction	
Sub-Basin	4	Type	Grassed Waterway	Sediment reduction (t/yr)	6.84
Acres	1.14	Area (acres)	0	Soil Loss reduction (t/yr)	15.95
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	290	Phosphorus reduction (lb/yr)	5.81
		Length (ft)	290		
Average slope	2.88	Years	1		
		Distance to SW (ft)	60		

Project ID – Filter Strip
Subwatershed 8
Catchment 5



Drainage Area – 3.66 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 98% agricultural land use. The proposed project is a perennial vegetative filter strip to be planted along the field's edge creating a buffer between Wyanett Creek. The buffer is intended to catch sediment and utilize nutrients from runoff, prior to entering surface water. The new projected is located on the north side of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$716.76	0.67	$1,069.79

Current Conditions		Added Practice		Reduction	
Sub-Basin	5	Type	Filter Strip	Sediment reduction (t/yr)	0.36
Acres	3.66	Area (acres)	1.057162534	Soil Loss reduction (t/yr)	0.7
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	NA	Phosphorus reduction (lb/yr)	0.67
		Length (ft)	921		
Average slope	3.58	Years	1		
		Distance to SW (ft)	0		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Grassed Waterway
Subwatershed 8
Catchment 6

Drainage Area – 1.48 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in on the north side of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$1,701.91	5.32	$319.91

Current Conditions		Added Practice		Reduction	
Sub-Basin	6	Type	Grassed Waterway	Sediment reduction (t/yr)	6.15
Acres	1.48	Area (acres)	0	Soil Loss reduction (t/yr)	15.79
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	287	Phosphorus reduction (lb/yr)	5.32
		Length (ft)	287		
Average slope	3.25	Years	1		
		Distance to SW (ft)	95		

Project ID – Grassed Waterway
Subwatershed 8
Catchment 7

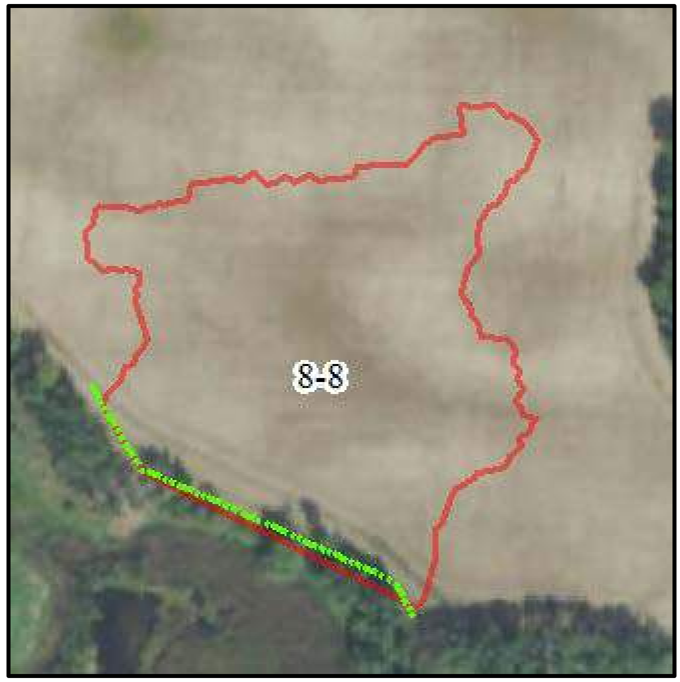
Drainage Area – 5.82 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 90% agricultural land use and a small percentage of forested land. Using aerial photography and GIS tools this area was identified to have a potential for forming a gully. Planting a strip of permanent vegetation in the concentrated flow path would reduce soil loss and prevent nutrient loading. The project is located in the middle of the catchment and outlets in a forested area to the east.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$2,158.52	5.45	$396.06

Current Conditions		Added Practice		Reduction	
Sub-Basin	7	Type	Grassed Waterway	Sediment reduction (t/yr)	6.41
Acres	5.82	Area (acres)	0	Soil Loss reduction (t/yr)	20.02
Soil	Lino Loamy Fine Sand	Vol Voided (ft^3)	364	Phosphorus reduction (lb/yr)	5.45
		Length (ft)	364		
Average slope	2.82	Years	1		
		Distance to SW (ft)	245		

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Project ID – Filter Strip
Subwatershed - 8
Catchment - 8



Drainage Area – 3.71 acres
Property Ownership – Private
Site Specific Information – The Catchment is estimated 100% agricultural land use. The proposed project is a perennial vegetative filter strip to be planted along the field's edge creating a buffer between the open water wetland. The buffer is intended to catch sediment and utilize nutrients from runoff, prior to entering surface water. The new projected is located on the south west side of the catchment.

Cost-Benefit		
Practice Cost	**P reduction (lb/yr)**	**$ per lb TP Removed**
$350.98	0.28	$1,253.52

Current Conditions		Added Practice		Reduction	
Sub-Basin	8	Type	Filter Strip	Sediment reduction (t/yr)	0.18
Acres	3.71	Area (acres)	0.517676768	Soil Loss reduction (t/yr)	0.35
Soil	Zimmerman fine Sand,, 1 to 6 % slope	Vol Voided (ft^3)	0	Phosphorus reduction (lb/yr)	0.28
		Length (ft)	451		
Average slope	2.81	Years	1		
		Distance to SW (ft)	0		

Appendices:

References:

Isanti SWCD in partnership with the Metro CD, Green Lake Subwatershed Retrofit Analysis; For Areas Draining Directly to the Lake.

The Natural Resource Conservation Service (NRCS) Engineering Tool

Chisago SWCD, 2015. Rural Subwatershed Analysis Protocol, Part 1 – Targeting. Version 1.0. http://chisagoswcd.org/

Chisago SWCD, 2015. Rural Subwatershed Analysis Protocol, Part 2 – Prioritizing. Version 1.0. http://chisagoswcd.org/

Chisago SWCD, 2014. Chisago Lakes Chain of Lakes Watershed Rural Subwatershed Analysis. http://chisagoswcd.org/

BWSR Water Erosion Pollution Reduction Estimator. Available for download at http://www.bwsr.state.mn.us/outreach/eLINK/index.html

Revised Universal Soil Loss Equation 2 (RUSLE2). United States Department of Agriculture Natural Resource Conservation Service.

Definitions:

Water and sediment control basins: An earthen embankment that traps water and sediment running off cropland upslope from the structure, and reduces gully erosion by controlling flow within the drainage area.

Grassed waterways: Are broad, shallow channels designed to move surface water across farmland without causing soil erosion. The vegetative cover in the waterway slows the water flow and protects the channel surface from rill and gully erosion. (NRCS)

Permanent vegetation: An area permanently vegetated with a variety of grasses in order to stabilize the soil, filter runoff, utilize nutrients and increase the biodiversity.

Wetland restoration: Improving or creating an area of land with the characteristics of a wetland; hydrology, vegetation and soils.

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

Appendix D
Green Lake Diagnostic Study October 2019

Technical Memo

WENCK

Responsive partner.
Exceptional outcomes.

To: Tiffany Determan, Isanti Soil and Water Conservation District

From: Jeff Strom, Wenck Associates, Inc.
Aaron Claus, Wenck Associates, Inc.

Date: October 3, 2019

Subject: Green Lake Phosphorus Diagnostic Study

Green Lake is a deep lake located in Isanti County. Historic water quality monitoring efforts for Green Lake (Attachment A) suggest the lake does not meet state water quality standards. Green Lake was placed on the State of Minnesota's 303(d) list of impaired waters in 2015 and a Total Maximum Daily Load (TMDL) study for the lake was completed in 2017. Since the completion of the TMDL study, the Isanti Soil and Water Conservation District (SWCD) and the Green Lake Improvement District (LID) have collected additional flow and water quality measurements from various ditches and streams that discharge to the lake.

The SWCD contracted with Wenck Associates, Inc. (Wenck) to review the newly collected data, compare these data to the original TMDL study, and provide further recommendations to reduce phosphorus loading to the lake. This technical memorandum presents the results of this work which includes the following components:

- Review historic and recently collected data
- Update lake phosphorus budget and model using new data
- Establish phosphorus goals and reductions based on new data
- Recommended strategies

Existing Data Review

Table 1 summarizes the data, studies and models that were compiled and reviewed for this study. All information in Table 1 was supplied by the SWCD staff or was available online.

Table 1. Data, studies and models reviewed for this study

Data/Study	Description	Source
Green Lake water quality data (2016-2018)	Includes temperature/DO profiles and surface TP, Chl-a, TSS and Secchi measurements for Green Lake	Isanti SWCD
Green Lake water quality data (pre-2016)	Includes various surface parameters (1973-2015) as well as hypolimnion TP concentrations (1988-1989, 1991, 1993, 1998)	EDA (link)
Green Lake tributary monitoring data	Includes TP, TSS, Secchi tube, DO, gauged flow and water level measurements for four tributary stations (Figure 1)	Isanti SWCD
DNR Fisheries Surveys for Green Lake	Historic DNR fisheries survey results for the following years: 2016, 2012, 2007, 2002, 1997, 1992, 1987, 1982, and 1979	MnDNR (link)
Green Lake Aquatic Plant Survey Report	Early spring (May 7-14, 2018) aquatic vegetation survey of Green Lake with focus on curly-leaf pondweed	LIMNOPRO
Green Lake Status Report (2018)	Review of historic data and recommendations for future studies and management for water quality and nuisance vegetation	LIMNOPRO

Data/Study	Description	Source
Rum River TMDL and WRAPS Reports (2017)	TMDL report includes TMDL allocations and reductions for Green Lake. WRAPS report outlines restoration strategies based on available data and TMDL results.	MPCA (link)
Rum River HSPF-SAM Model	HSPF Simulation Application Manager (SAM) tool developed by the MPCA and used in the Rum River TMDL and WRAPS	MPCA (link)
Green Lake Rural Stormwater Retrofit Analysis of North Brook	Reports providing recommendations for treatment of stormwater from tributaries and direct watershed draining to Green Lake	Isanti SWCD
Green Lake Subwatershed Retrofit Analysis		

In-Lake Water Quality

In order for Green Lake to be considered an impaired waterbody, the 10-year average growing season total phosphorus (TP) concentration and at least one “response variable” (chlorophyll-a or Secchi depth) must exceed State water quality standards. Growing season TP concentrations for Green Lake have averaged 61 µg/L over the most recent 10-year period, which is above the 40 µg/L standard for deep lakes in the North Central Hardwood Forest (NCHF) Ecoregion. Planktonic algae, which is measured by chlorophyll-a (chl-a), has averaged 25 µg/L which is above the 14 µg/L standard for deep lakes. Secchi depth, a measure of water clarity, is relatively good in Green Lake and has met the 1.4-meter Secchi depth standard in five of the seven years measured since 2009. Although Secchi depth has generally met State water quality standards over the past 10 years, Green Lake is still considered impaired since TP and chl-a do not currently meet State standards.

Tributary Flow and Water Quality

SWCD staff monitored flow and water quality throughout the watershed draining to Green Lake (Figure 1) from 2016-2018. Continuous water levels (transducers) and gauged flow were recorded and measured at two of the four stations (North Brook and Wyanett Creek). Based on review of these data, both monitoring stations demonstrated reasonably reliable stage-discharge relationships that could be used to convert the continuous water level readings to continuous flow (Attachment B).

Water quality monitoring results for the four tributaries are summarized in Attachment B. Monitoring parameters included TP, total suspended solids (TSS), Secchi tube, temperature and dissolved oxygen (DO). In general, TSS concentrations in all four tributaries are typically below the 30 mg/L State standard for streams in the Central River Nutrient Region. Old Judge’s Creek (18%), North Brook (9%), and Wyanette Creek (9%) exhibited some individual exceedances of the 30 mg/L standard. Median TSS concentrations were highest in Old Judge’s Ditch (24 mg/L) followed by North Brook (11 mg/L), Wyanett Creek (9 mg/L), and Bratline Creek (<2 mg/L). Elevated TSS measurements in Old Judge’s Ditch, North Brook, and Wyanett Creek coincided with storm events and higher flow conditions suggesting sediment loading from upland sources and/or in-channel sources.

Median TP concentrations were highest in North Brook (170 µg/L) followed by Wyanett Creek (155 µg/L), Old Judge’s Ditch (111 µg/L), and Bratline Creek (66 µg/L). In general, elevated TP concentrations for the four tributaries coincide with high TSS levels and therefore particulate phosphorus sources (i.e. phosphorus attached to sediment) are likely a major source to Green Lake. That said, there are several instances in which TSS levels were low (<10 mg/L) and TP measurements were relatively high (>150 ug/L) in North Brook and Wyanett Creek. Thus, it is recommended that ortho-phosphorus samples be collected at each tributary monitoring station to determine the presence of dissolved/soluble phosphorus during different times of year and flow conditions.

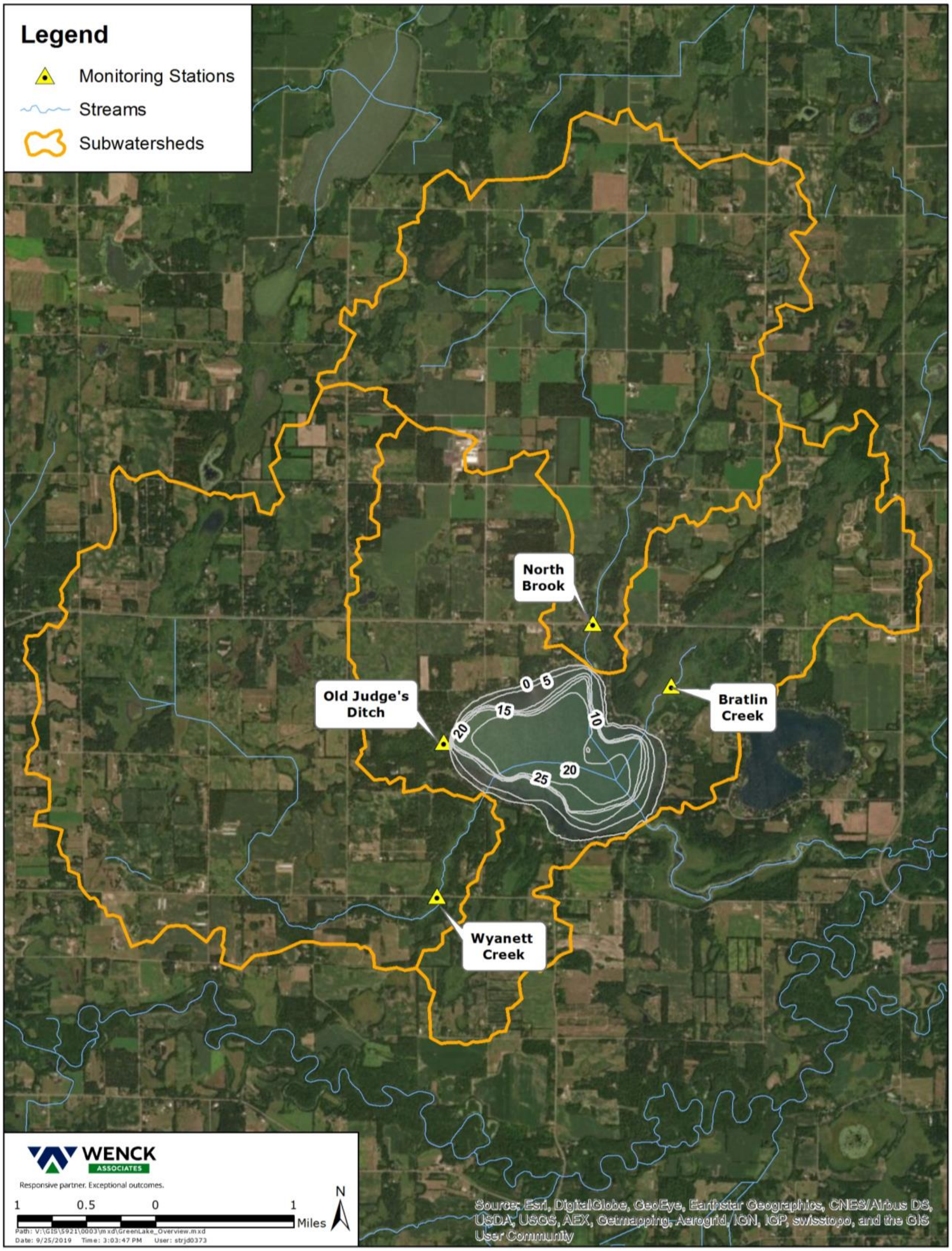


Figure 1. Green Lake subwatersheds and tributary monitoring stations.

DNR Fisheries Surveys

Abundance of fish can sometimes have strong effects on water quality through ecological interactions between fishes and the other components of the lake's food web (Noonan et al. 1994). While bottom up ecological effects (lake productivity and abiotic factors) related to nutrient loadings are usually the driving force behind a lake's stable state (algal or macrophyte dominated; Scheffer et al. 1993), other types of ecological interactions can emerge when fish abundances are relatively high (Carpenter and Kitchell 1996). The species of fish represented within the overall abundance is an important factor in attributing ecological effects as they each have different effects based on their ecological niche.

A simplified way to divide the species into functional groups is by categorizing them according to general trophic guild (a group that shares similar feeding habits). Three primary trophic guilds exist in local lakes, planktivores (includes all larval/juvenile life stages of fishes, small bodied "forage" species such as minnows and shiners, and some large-bodied specialist species: data is always lacking for this guild), piscivores (fish predators such as native game fish species: surveyed by MN DNR lake survey methods), and benthivores (specialists at feeding on/within substrates: partially/weakly surveyed by MNDNR lake survey methods). In general, each of these guilds has a different type of effect on the lake ecosystem.

Planktivorous species exert top-down effects on the ecosystem through predation on herbivorous zooplankton which are the main consumers of phytoplankton (algae). A trophic cascade is a top down effect that is manifested when higher trophic levels exert a predatory force onto successive lower trophic levels. In this way high abundance of planktivorous fish can create a trophic cascade and increase relative phytoplankton abundance (reduced water clarity).

In similar fashion piscivorous fishes can exert cascading trophic effects on the food web by predating upon and reducing the abundance of planktivorous fishes (increased water clarity). Lastly, benthivorous fishes exert very different effects on the lake ecosystem. Coined "middle-out" effects, benthivores contribute to bioturbation of sediments and uprooting of macrophytes through their feeding activities (Kaemink et al 2016). These effects are attributed to increased internal nutrient loadings in lakes with dense populations of benthivorous fishes (Bajer and Sorensen 2015; Huser et al. 2016). Often growing too large for piscivores to consume (White Sucker and Common Carp) or possessing defensive adaptations that limit predation (Black Bullhead and Common Carp); benthivorous fish populations act to sequester a large proportion of biological energy available to other organisms, held in the form of fish biomass and nutrients cycled by said biomass. This indirectly acts to reduce the available energy and "population space" for piscivorous species, reducing their relative abundance and thus the relative power of their cascading effects related to predation upon piscivorous species/life stages.

The Minnesota Department of Natural Resources has conducted surveys of fish relative abundance with standardized methods on a 5-year cycle in Green lake since 1979. These survey methods allow inference of relative abundance by comparing catch rates over time and to normal ranges for lakes with similar characteristics (lake eco-class; Schupp 1992). Figure 2 plots the trends over time for all fish species and Figure 3 plots the same trends for benthivorous species (Black Bullhead, White Sucker, and Common Carp) compared to respective normal ranges for MN lakes in class 27.

Lake survey catch per unit effort data from Green Lake suggest that overall fish abundance has varied significantly over time, has stayed mostly within normal ranges for similar lakes, and based on most recent survey in 2016 abundance is currently reaching the upper normal range in abundance. Benthivore (substrate feeding) fish populations exhibit similar trends over time in Green Lake, but account for small proportion of overall catch per unit effort (sampling bias may account for these differences).

An important note to consider with these data that standard lake survey methods (trap-nets and gill-nets) are known to ineffectively sample some species such as Common Carp and Largemouth Bass, in which case targeted sampling methods (electrofishing, capture-mark-recapture) are performed when deemed necessary. Special electrofishing surveys were performed on Green Lake for Largemouth Bass but are excluded from this analysis because normal range data is not available.

Inference about the effects of fish abundance on water quality in Green lake is limited by the lack of data on planktivorous fish abundance and Common Carp biomass density. Available data suggests that currently the state of its piscivorous game fishery is favorable for high water clarity and a macrophyte dominated stable state. The predictable occurrence of Common Carp in DNR catch data over time is indicative of a reproducing population existing within the lake and/or subwatershed, warranting specific sampling to quantify biomass density of this benthivorous species. If Common Carp biomass density is higher than 100 kg/ha (Bajer et al 2009), suppressive management of this invasive/nuisance species would be a method to increase water quality in Green Lake that is commonly employed by water managers in the region.

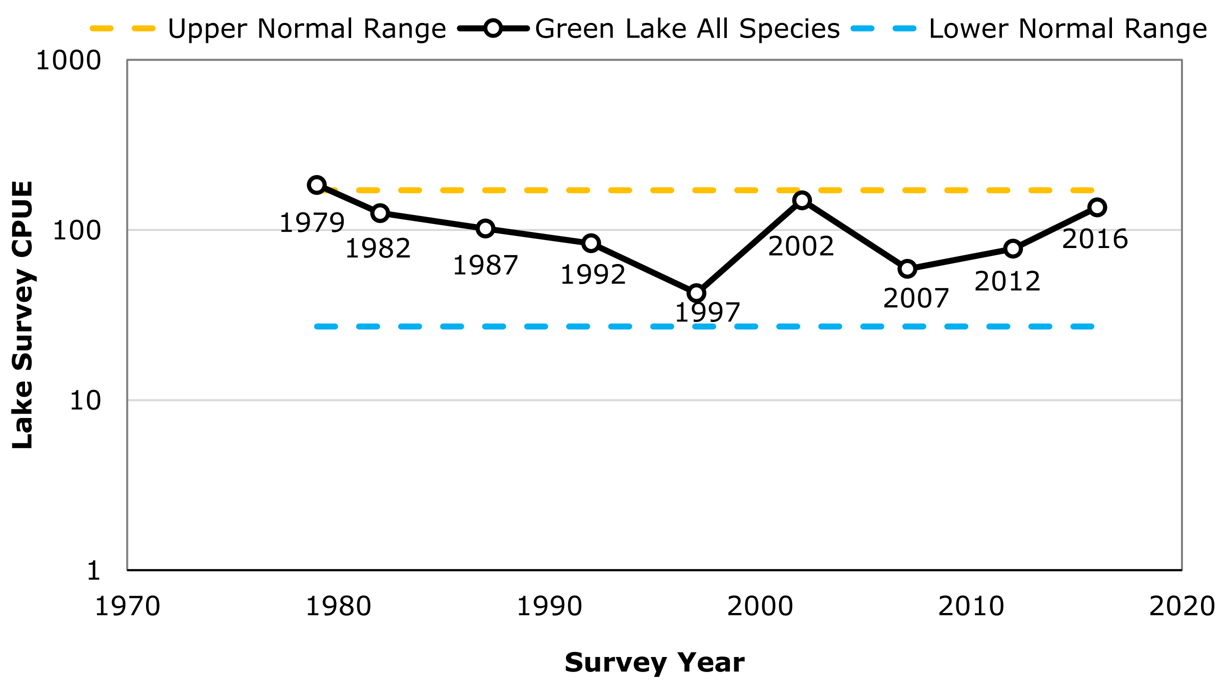


Figure 2. Trends in MNDNR lake survey catch per unit effort over time (all species).

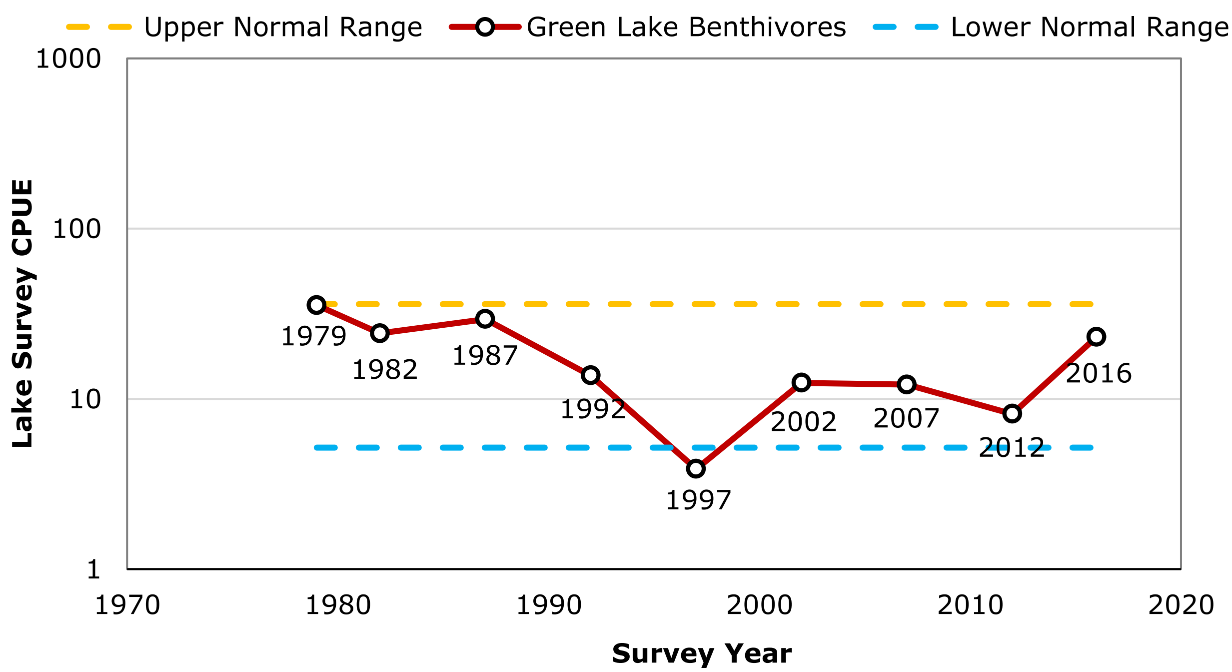


Figure 3. Trends in MNDNR lake survey catch per unit effort over time (benthivorous = substrate feeding species).

Updated Green Lake Phosphorus Budget and Model

Original TMDL Model

The Green Lake TMDL study used the Rum River Watershed HSPF model to estimate watershed flows and phosphorus loads to the lake, and a model residual approach (if necessary) to estimate internal load. The model baseline years for development of the TMDL allocations were 2006 through 2015. The original TMDL model called for watershed, subsurface sewage treatment system (SSTS), and internal TP load reduction goals of approximately 1,729 lbs/year, 110 lbs/year, and 0 lbs/year, respectively (Table 2).

Table 2. Summary of TP load reductions by source presented in the Green Lake TMDL

Source Load	Existing TP Load [lbs/yr]	Allowable TP Load [lbs/yr]	Estimated Load Reduction [lbs/yr]	Estimated Load Reduction [Percent]
C & I Stormwater	6	6	0	0%
Wyanett Creek	1,821	1,086	735	40%
North Brook	1,290	810	480	37%
Local Watershed	1,286	772	514	40%
SSTS	110	0	110	100%
Internal Load	0	0	0	0%
Atmosphere	199	199	0	0%
TOTAL LOAD	4,712	2,873	1,839	39%

As discussed previously, a significant amount of data has been collected for Green Lake since the TMDL model baseline years and the completion of the TMDL study. These data include: in-lake water quality monitoring, temperature and dissolved oxygen profiles, vegetation surveys, and tributary flow and water quality. Wenck has reviewed these data and developed an updated lake response model for Green Lake (baseline years 2016, 2017, and 2018) that reflects the newly collected data. The updated lake response model, existing TP budget, and allowable TP targets for Green Lake are presented below.

Updated Lake Response Model

To develop the updated lake response model for Green Lake, Wenck used methods similar to the lake TMDLs in the Rum River Watershed TMDL Study (MPCA, 2017) and other TMDL studies throughout the State. The four major phosphorus sources defined in the model were watershed load, internal load from lake sediments, loading from curly-leaf pondweed (CLP) senescence, loading from SSTSs near the lake, and atmospheric load.

Watershed TP loading was estimated using the tributary monitoring data described in the previous section that was collected by SWCD staff from 2016-2018. Since North Brook and Wyanett Creek were the only tributary station in which continuous flow was monitored, monitored runoff depths from these tributaries were applied to the other tributary subwatersheds (i.e. Bratlin Creek and Old Judge's Ditch) and areas immediately surrounding the lake. Results of this analysis indicate average (2016-2018) runoff depth for the entire Green Lake watershed is ~2.9 inches per year. This runoff rate is low and significantly less than the ~7.3 inches per year predicted by the Rum River HSPF model (average for model years 1997-2015). The monitored data suggests a significant portion of rainfall across the Green Lake watershed is being lost to evapotranspiration and/or deep/shallow groundwater that is not returned to the tributaries as baseflow. The average monitored TP concentration (~161 µg/L) for the entire Green Lake watershed was similar to the HSPF predicted TP concentration (~175 µg/L). Once the annual flow volumes for each tributary were calculated they were multiplied by the average monitored TP concentrations to estimate annual TP loads for each tributary.

Phosphorus loading from CLP senescence was estimated using CLP phosphorus content and areal density relationships developed by Three Rivers Park District (MPCA, 2015) for other Minnesota lakes. These relationships were combined with the percent occurrence and relative density ratings from a recent point intercept vegetation survey performed by LIMNOPRO in 2018. A CLP phosphorus content to internal load ratio of 1:½ (James et. al, 2002) was used in the Green Lake response model since not all of the phosphorus in the decaying plant matter is believed to be released to the water column.

Phosphorus loading to Green Lake from SSTSs located near the lake were estimated using methods similar to the Lower Minnesota River Watershed TMDL (MPCA, 2018). An estimate of the total number of SSTSs immediately surrounding the lake (~175 systems) was provided by Isanti County staff and assumptions were made regarding number of people per household (~2.8 people) and the number of days per year each household is occupied (~245 days/yr). It was also assumed that SSTSs that are imminent public health threats (IPHTs) or are failing to protect groundwater (FTPGW) contribute more phosphorus than SSTSs that comply with State design/performance standards. At this time, we do not know the number SSTSs immediately surrounding Green Lake that are IPHTs or FTPGW. Therefore, Wenck used the most recent county-wide SSTS failure rates for Isanti County that are reported annually to the MPCA. The county-wide estimates assume that approximately 6% of the SSTSs in Isanti County FTPGW and 0% are IPHTs.

Atmospheric phosphorus loading to Green Lake were estimated using literature rates for dry (<25 inches of rainfall), average (25-38 inches), and wet (>38 inches) precipitation years (Barr Engineering, 2004). Atmospheric loading to lakes is typically small compared to other sources and is very difficult, if not impossible, to manage.

Internal phosphorus loading for Green Lake was estimated using a model residual approach whereby the other four sources (watershed, CLP, SSTS, and atmosphere) were added to the models first, and then if necessary, additional load was added to calibrate the model. This approach assumes that the additional loads are likely attributed to internal phosphorus loading from rough fish (i.e. Common Carp) and/or lake sediments. It is also possible that a portion of the additional load needed to calibrate the model are the result of one (or more) of the other four sources being under-represented, or one or more loading source(s) that is not currently accounted for in the TP source assessment.

Internal phosphorus loading from substrate-feeding fish is extremely difficult, if not impossible to directly quantify *in-situ*. That said, Common Carp are known to uproot vegetation and re-suspend sediment through their feeding habits which, when there are high densities of carp in a lake, can lead to increase water turbidity, reduced vegetation coverage and lower waterfowl populations. Recent research suggests that these impacts begin to occur at Common Carp densities of ~100 kg of carp biomass/hectare (89 lbs/acre) (Bajer et al. 2009). As discussed above, Green lake is inhabited by a population of Common Carp but biomass density has not been quantified.

Internal phosphorus loading from lake sediments often occurs when anoxic conditions are present, meaning that the water in and above the sediment is devoid of oxygen. One way to estimate phosphorus release from the sediment is by collecting sediment cores and incubating them in the lab under anoxic conditions to measure phosphorus release over time. At this time sediment cores have not been collected or analyzed for Green Lake. Release rates can also be estimated by calculating the observed rate of change in hypolimnetic TP concentrations during the summer growing season. Based on review of available data for Green Lake in the State's EDA database, hypolimnetic TP measurements were collected in three different years (1991, 1993, and 1998; Attachment A). Analysis of these data suggest an average sediment phosphorus release rate of 10.4 $mg/m^2/day$. This rate is significantly higher than the release rate estimated using the model residual approach (6.0 $mg/m^2/day$). For the purposes of this study, the model residual rate was selected over the hypolimnetic TP release rate since neither sediment cores nor Common Carp biomass have been assessed. It is recommended that both sediment and Common Carp be evaluated to help refine the internal loading component of the updated lake response model and better inform management strategies moving forward.

Updated Modeling Results

With the watershed, CLP, SSTS and atmospheric phosphorus loads defined, the model predicted average annual TP concentrations from 2016 through 2018 were compared to available monitored in-lake TP concentrations during the same period. The model predicted TP concentration was significantly lower than monitored value, and therefore adjustments were made by increasing phosphorus loading to represent internal load (model residual approach).

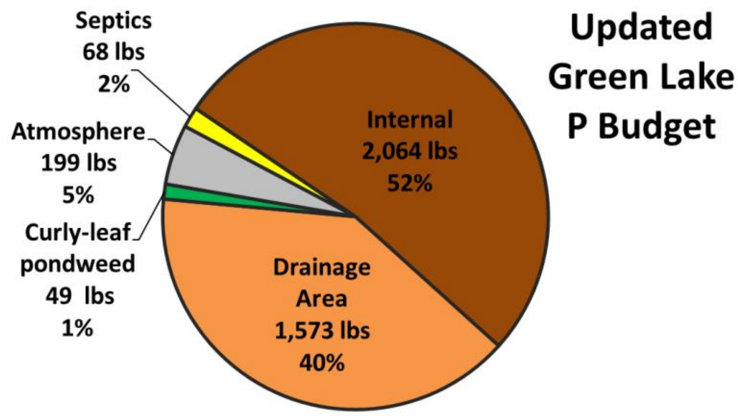


Figure 4. Green Lake Updated Phosphorus Budget (2016-2018)

The updated lake response model results suggest internal loading is likely the largest source (52%) of TP loading to the lake (Figure 4). This is a significant difference from the TMDL model which assumed minimal contributions from internal load. Watershed loading is the second largest contributor and accounts for approximately 40% of the lake's annual TP budget. Atmospheric loading (5%), septic system inputs (2%), and CLP senescence (1%) account for relatively small portions of the overall budget. Attachment C contains detailed information of the lake response model inputs and results.

Green Lake Phosphorus Goals and Source Reductions

Wenck used the updated lake response model to estimate TP load reductions (all sources) needed to meet Green Lake's 40 µg/L water quality goal. The updated model suggests TP loading to Green Lake will need to be reduced by approximately 2,142 pounds/year (54%) in order to meet this goal. Wenck reviewed each phosphorus loading source to Green Lake and performed a series of load reduction scenarios to determine which source(s) could be reduced to achieve the TP load reduction target/goal. Below is a discussion of these scenarios.

SSTS Reduction Scenario

The first scenario reviewed by Wenck was to evaluate the benefits of upgrading all "failing" (i.e. failing to protect groundwater) SSTSs immediately surrounding the lake. This scenario resulted in a TP load reduction of approximately 4 pounds/year (<1% of target/goal).

Watershed Reduction Scenario

For this scenario, TP loads from each tributary were reduced to meet the 100 µg/L standard for rivers/streams in the Central River Nutrient Region. Average monitored TP concentrations for Bratlin Creek (~87 µg/L) currently meet the Central River Nutrient Region standard, while TP concentrations for Wyanett Creek (~194 µg/L), North Brook (~171 µg/L), and Old Judge's Ditch (~193 µg/L) do not meet the standard. This scenario resulted in a TP load reduction of approximately 613 pounds/year (20% of target/goal; Table 3).

Sediment Load Reduction Scenario

The final scenario evaluated by Wenck was phosphorus load reductions benefits of internal load management via sediment inactivation and/or rough fish management. The updated lake response model suggests internal loading in Green Lake would need to be reduced by approximately 74% (1,525 pounds/year) to meet State water quality standards if the 613 pounds/year watershed load reduction scenario is achieved (Table 3). Based on our experience, chemical treatments, such as aluminum sulfate (alum), can reduce phosphorus release from lake sediments by approximately 90% (or greater) if designed and dosed correctly.

Table 3. Load reductions by source for Green Lake using updated lake response model (2016-2018)

	Existing TP Load	Allowable TP Load	Estimated Load Reduction	
Source Load	[lbs/yr]	[lbs/yr]	[lbs/yr]	[Percent]
Wyanett Creek	753	388	365	49%
North Brook	438	256	182	42%
Bratlin Creek	120	120	0	0%
Old Judge's Ditch	193	136	57	29%
Remaining Local Watershed	70	61	9	12%
SSTS	68	64	4	6%
Internal Load	2,064	539	1,525	74%
Curly-leaf pondweed	49	49	0	0%
Atmosphere	199	199	0	0%
TOTAL LOAD	3,954	1,812	2,142	54%

Recommendations

Based on our review of available information/data for Green Lake and the updated modeling analysis presented above, we recommend the following next steps: 1) conduct review of available SSTS information 2) implement best management practices (BMPs) throughout the watershed; 3) conduct sediment internal load feasibility study; 4) conduct Common Carp population assessment; and 5) minor adjustments to current monitoring program. Each of these recommendations is described below in more detail.

Recommendation: Conduct Review of Available SSTS Information

This study uses recently reported county-wide SSTS failure rates to estimate phosphorus contributions from septic systems immediately surrounding Green Lake. The county-wide failure rates are low (0% ITPHS and 6% FTPGW) and therefore our modeling suggest SSTSs are not a significant source of loading to the lake. In order to determine if the county-wide failure rates are applicable to Green Lake, it is recommended that a review of available information be conducted for the homes/cabins/parcels immediately surrounding the lake. This could be accomplished by compiling a database with the following information for each cabin/home/parcel:

- Year home built
- Lot size
- Most recent point of sale (if applicable)
- Age of SSTS (if information available)

- SSTS inspection records (if applicable)
- Review of pump maintenance records (if available)

Recommendation: Implement Watershed BMPs

Two recent subwatershed assessment (SWA) studies were completed for Green Lake: The Green Lake Rural Stormwater Retrofit Analysis which covered North Brook and Wyanett Creek; and The Green Lake Subwatershed Retrofit Analysis which covered areas draining directly to the lake. These studies identified over 100 BMPs throughout the Green Lake watershed. Various types of BMPs were sited in these assessments, including: rain gardens, grassed swales, lakeshore restorations, permeable asphalt, hydrodynamic separators, settling ponds, land protection, grassed waterways, water and sediment control basins, filter strips, and wetland restorations. These studies estimate that if all of the sited BMPs were implemented, phosphorus loading to Green Lake would be reduced by approximately 334 pounds per year. This reduction is approximately 54% of the "updated" watershed load reduction goal (613 pound per year) for Green Lake based on the model scenarios discussed above. It is highly recommended that the SWCD and other partners continue to work with landowners throughout the watershed to implement the BMPs identified in these assessments as well as other opportunities as they are identified.

It is also recommended that the County assess areas within the stream/ditch corridor for potential projects that may have multiple benefits, including water quality improvement. For example, desktop review along the major tributaries to the lake, North Brook and Wyanett Creek, indicate there are several in-line ditched wetlands throughout the main channel network (Figure 4). These features can, over time, become overloaded and degraded which can lead to increased sedimentation, hydrology impacts, low dissolved oxygen, phosphorus release from the sediment, and degraded habitat. Thus, it is recommended that the SWCD establish a process to evaluate these sites and identify potential improvements where necessary. The evaluation process could include, but is not limited to, the following items:

Figure 4. Example in-line wetland feature along Wyanett Creek

- Upstream/downstream paired water quality monitoring
- Walking survey of channel to assess sedimentation, channel conditions, hydrology, etc.
- Wetland vegetation assessment such as the rapid floristic quality assessment (RFQA) (link)

Results of these evaluations can then be used to identify and prioritize projects such as:

- In-line or off-line settling ponds, basins, and/or filters
- Alterations to improve or restore hydrology
- Alterations to increase storage (if possible)
- Alterations to improve habitat and other wetland functions
- Stream/ditch channel restoration and/or maintenance

Recommendation: Conduct Sediment Internal Load Feasibility Study

The internal load rate used in the updated Green Lake model (6.0 $mg/m^2/day$) is high compared to other lakes in Minnesota where we've directly measured internal load from lake sediments. While this rate was not directly measured in the lab, it was estimated using a mode residual approach and is further supported by the large spikes in surface water TP concentrations that commonly occur in the late summer and fall when stratification weakens (Appendix A). As discussed above, phosphorus release from the sediment represents the largest source (~52%) of TP loading to Green lake and will likely need to be addressed at some point for the lake to consistently meet state water quality standards.

Based on our experience, an alum treatment to manage internal loading in Green Lake would likely cost between $0.75M-$2.00M depending on the size of the treatment area and the amount of alum needed. In order to refine these cost estimates, we recommend that an internal load feasibility study be conducted for Green Lake in which sediment cores are collected at a minimum of five sites and analyzed in the laboratory. Lab analysis of the cores should include the following parameters: sediment phosphorus release rate, moisture content-bulk density, loss-on-ignition, total iron, total aluminum, biologically-labile phosphorus and maximum allowable alum dosage. Results of these analyses will allow Wenck staff to validate and compare the internal loading rate used in the Green Lake model and develop a treatment plan to meet internal load reduction goals. The estimated cost of an internal load feasibility study for Green Lake is ~$17K and includes sediment core collection (5 sites), laboratory analysis and a final memo detailing recommended alum dosing rates, dosing schedule, treatment area and estimated treatment costs.

Recommendation: Conduct Common Carp Abundance and Density Assessment

In order to determine the likelihood that benthivorous fish abundance is contributing to internal nutrient loading, Common Carp abundance and biomass density surveys are recommended as per methods of Bajer et al. 2012. These surveys would produce baseline absolute abundance estimates that would add clarity to the source of internal nutrient loadings and add information to future Common Carp capture trends in MNDNR lake surveys. It is recommended that three individual Common Carp abundance and biomass density survey events (different days) be conducted each consisting of multiple (three or more) 20-minute electrofishing transects. Each survey event will require a MnDNR permit and follow-up modeling and data analysis of the survey results. A general cost estimate for these surveys is $5K per survey, or $15K total for three surveys.

Monitoring Recommendations

Wenck recommends the following monitoring activities to complement current lake and tributary monitoring efforts for Green Lake:

- Add ortho-phosphorus and dissolved phosphorus to the list of monitoring parameters for North Brook, Wyanett Creek, Bratlin Creek, and Old Judge's Ditch
- Conduct longitudinal surveys (4-5 events) along North Brook and Wyanett Creek to evaluate changes in water quality from upstream to downstream and pinpoint potential problem areas. Surveys should target different times of year and flow conditions and include the following parameters: TSS, TP, ortho-P, DO, temperature, pH, and flow.

- Collect hypolimnion (i.e. approx. 1 meter from bottom) TP and ortho-phosphorus samples during each surface sampling event for Green Lake
- Continue water quality sampling for Green Lake through the end of September and, if necessary, into October until the water column is completed mixed
- Perform early season (i.e. June) and late season (i.e. August) point-intercept submerged aquatic vegetation (SAV) surveys for Green Lake to track effectiveness of CLP treatments and evaluate/track health of SAV community as BMPs are implemented

References

Bajer, P. G., & Sorensen, P. W. (2012). Using boat electrofishing to estimate the abundance of invasive Common Carp in small Midwestern lakes. *North American Journal of Fisheries Management*, *32*(5), 817-822.

Bajer, P. G., & Sorensen, P. W. (2015). Effects of Common Carp on phosphorus concentrations, water clarity, and vegetation density: a whole system experiment in a thermally stratified lake. *Hydrobiologia*, *746*(1), 303-311.

Barr Engineering. 2004. (Updated 2007.) Detailed Assessment of Phosphorus Sources to Minnesota Watersheds. Prepared for the Minnesota Pollution Control Agency, St. Paul, MN

Carpenter, S. R., & Kitchell, J. F. (Eds.). (1996). *The trophic cascade in lakes*. Cambridge University Press.

Huser, B. J., Bajer, P. G., Chizinski, C. J., & Sorensen, P. W. (2016). Effects of Common Carp (Cyprinus carpio) on sediment mixing depth and mobile phosphorus mass in the active sediment layer of a shallow lake. *Hydrobiologia*, *763*(1), 23-33.

James WF, Barko JW, Eakin HL, Sorge PW. 2002. Phosphorus Budget and Management Strategies for an Urban Wisconsin Lake. Lake and Reservoir Management 18(2): 149-163

Kaemingk Mark A., Jolley Jeffrey C., Paukert Craig P., Willis David W., Henderson Kjetil, Holland Richard S., Wanner Greg A., Lindvall Mark L. (2016) Common Carp disrupt ecosystem structure and function through middle-out effects. *Marine and Freshwater Research* 68, 718-731.

Minnesota Pollution Control Agency. 2015. Elm Creek Watershed Management Commission Watershed Total Maximum Daily Load. https://www.pca.state.mn.us/sites/default/files/wq-iw11-04e.pdf

Minnesota Pollution Control Agency. 2017. Rum River Watershed Total Maximum Daily Load. https://www.pca.state.mn.us/sites/default/files/wq-iw8-56e.pdf

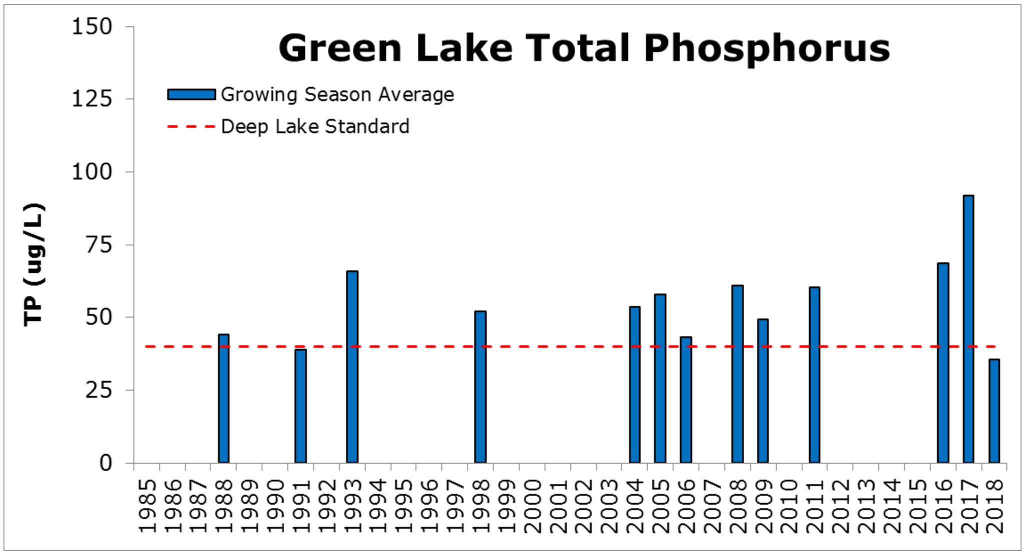
Minnesota Pollution Control Agency. 2017. Rum River Watershed Restoration and Protection Strategy Report. https://www.pca.state.mn.us/sites/default/files/wq-ws4-34a.pdf

Nürnberg GK. 2004. Quantified Hypoxia and Anoxia in Lakes and Reservoirs. The Scientific World Journal 4: 42-54.

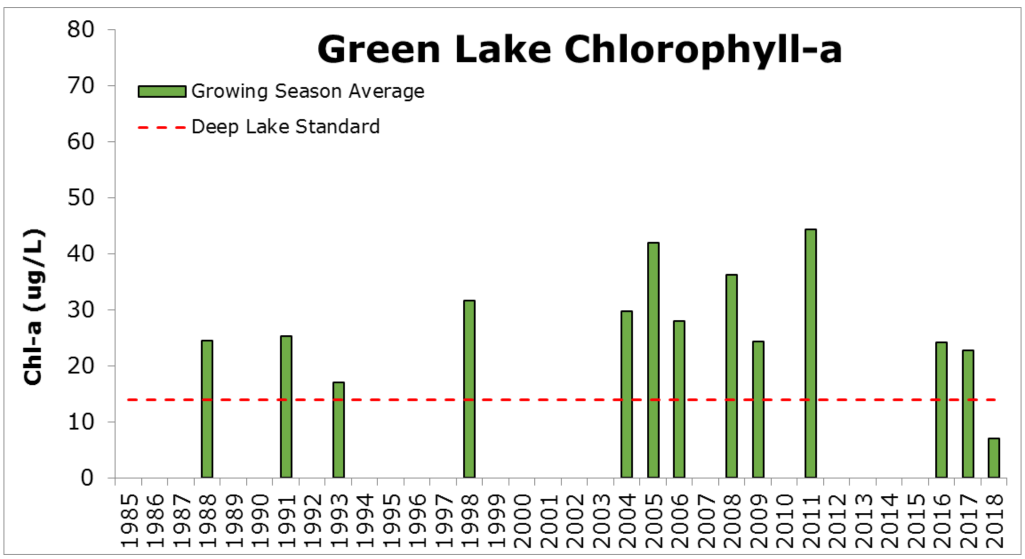
Scheffer, M., Hosper, S. H., Meijer, M. L., Moss, B., & Jeppesen, E. (1993). Alternative equilibria in shallow lakes. *Trends in ecology & evolution*, *8*(8), 275-279.

Attachment A

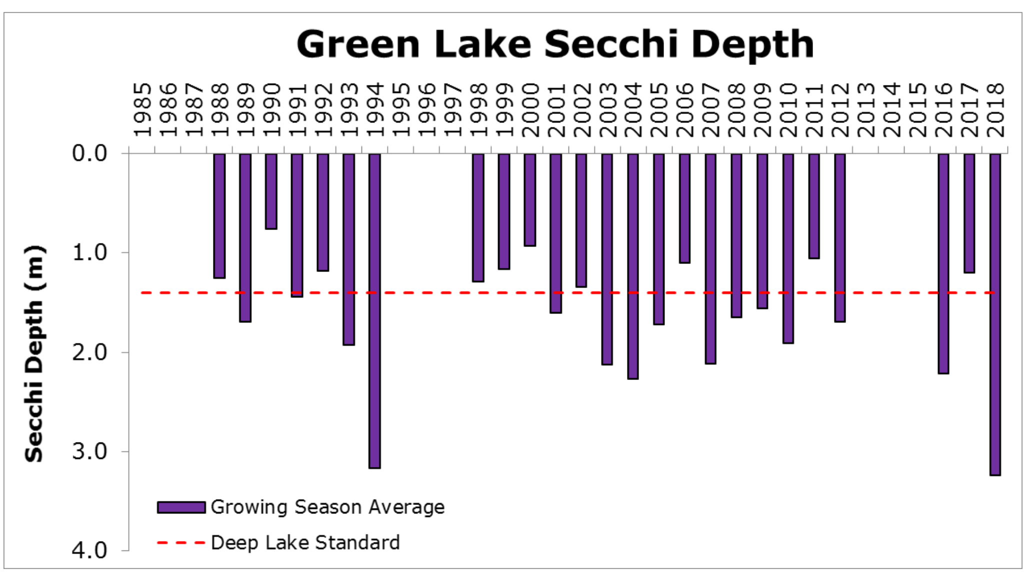
Green Lake Historic Water Quality



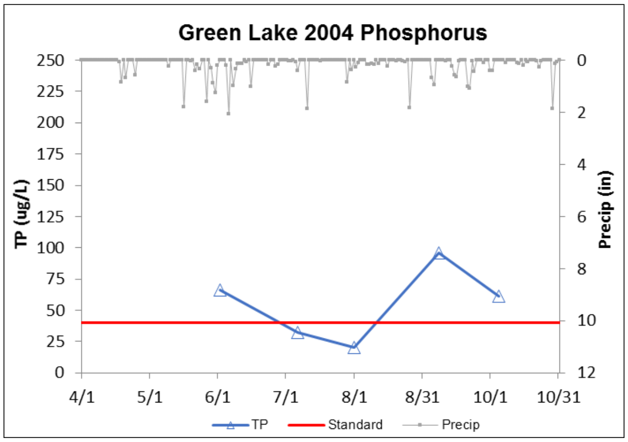
Green Lake Total Phosphorus
Growing Season Average
Deep Lake Standard
TP (ug/L)
150
125
100
75
50
25
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

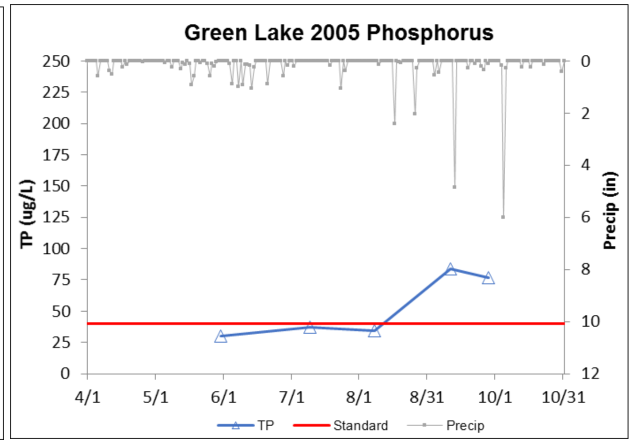


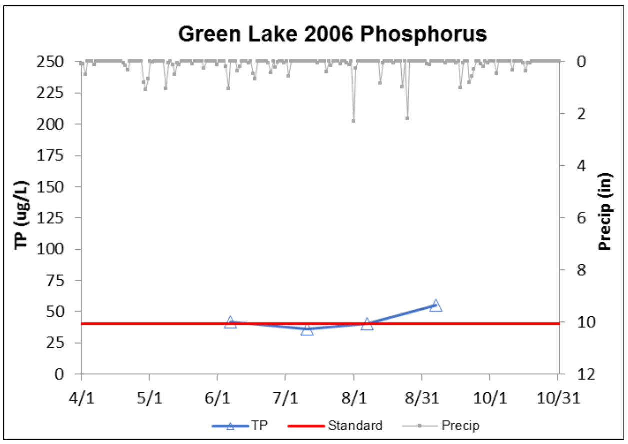
Green Lake Chlorophyll-a
Growing Season Average
Deep Lake Standard
Chl-a (ug/L)
80
70
60
50
40
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

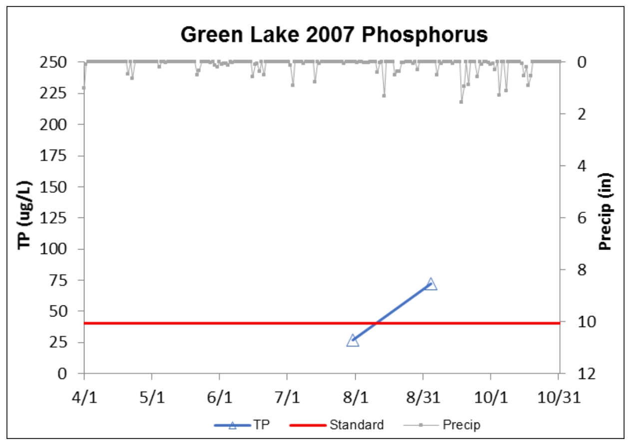


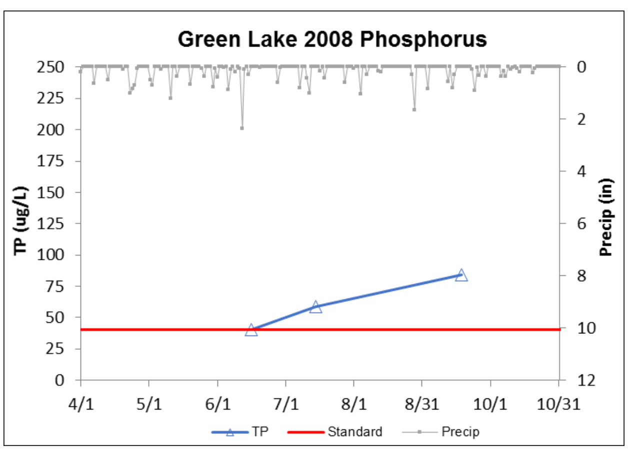
Green Lake Secchi Depth
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Secchi Depth (m)
0.0
1.0
2.0
3.0
4.0
Growing Season Average
Deep Lake Standard

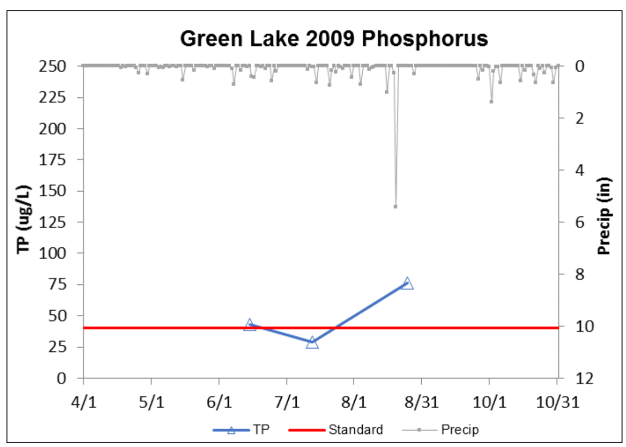

Green Lake 2004 Phosphorus
TP (ug/L)
Precip (in)
4/1 5/1 6/1 7/1 8/1 8/31 10/1 10/31
TP Standard Precip

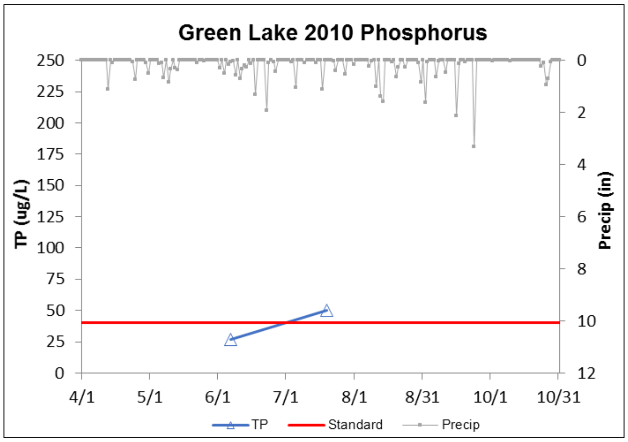

Green Lake 2005 Phosphorus
TP (ug/L)
Precip (in)
4/1 5/1 6/1 7/1 8/1 8/31 10/1 10/31
TP Standard Precip

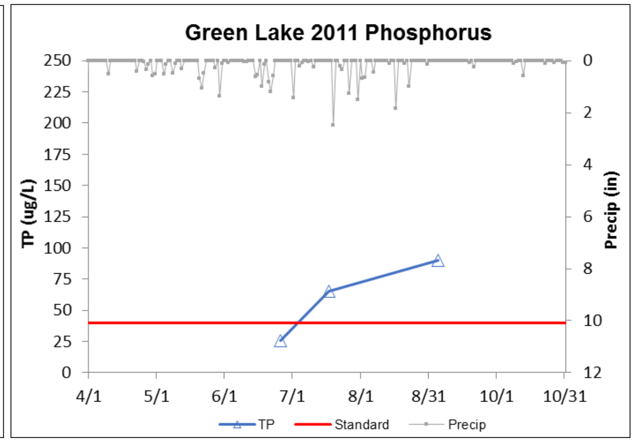

Green Lake 2006 Phosphorus
TP (ug/L)
Precip (in)
4/1 5/1 6/1 7/1 8/1 8/31 10/1 10/31
TP Standard Precip

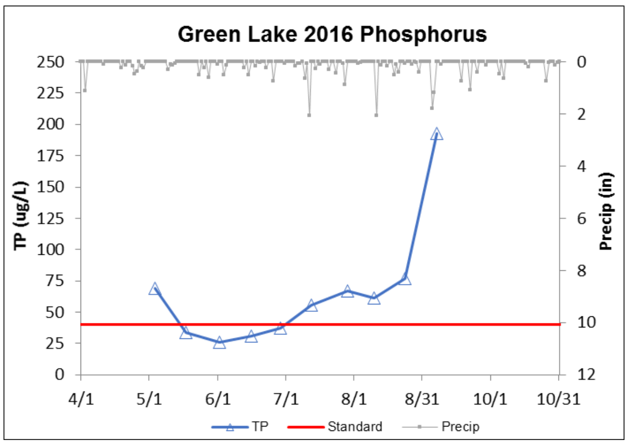

Green Lake 2007 Phosphorus
TP (ug/L)
Precip (in)
4/1 5/1 6/1 7/1 8/1 8/31 10/1 10/31
TP Standard Precip

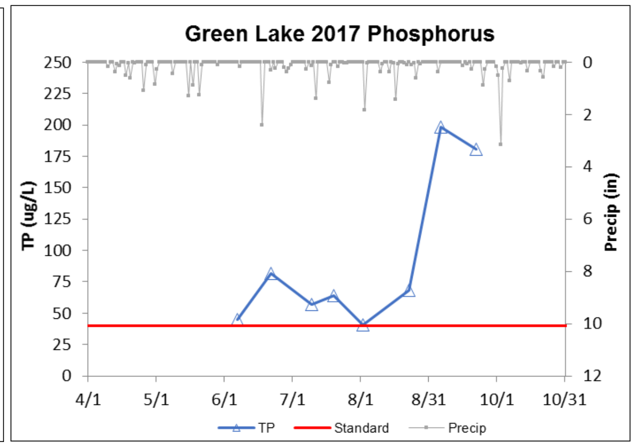

Green Lake 2008 Phosphorus
TP (ug/L)
Precip (in)
4/1 5/1 6/1 7/1 8/1 8/31 10/1 10/31
TP Standard Precip

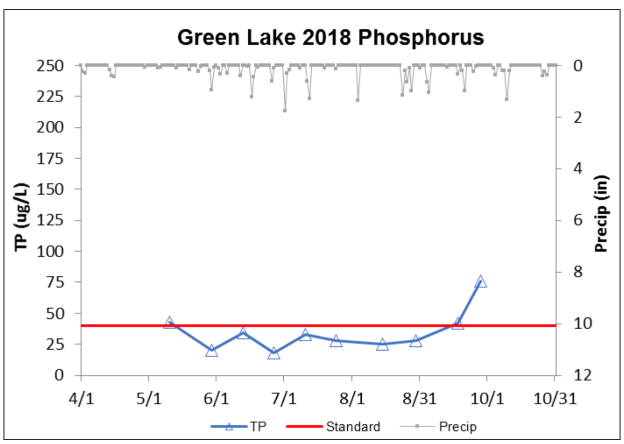

Green Lake 2009 Phosphorus
TP (ug/L)
Precip (in)
4/1 5/1 6/1 7/1 8/1 8/31 10/1 10/31
TP Standard Precip

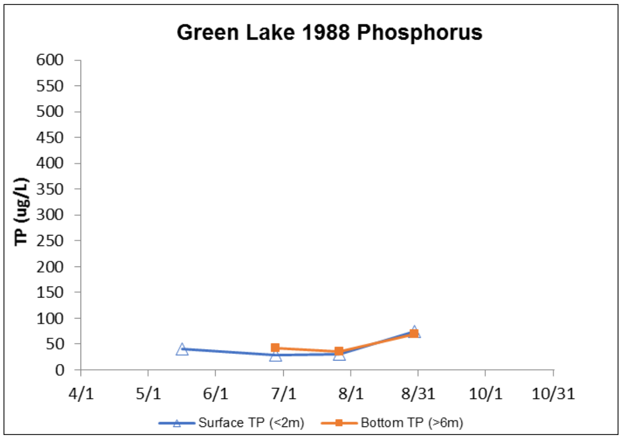

Green Lake 2010 Phosphorus
TP (ug/L)
Precip (in)
TP
Standard
Precip

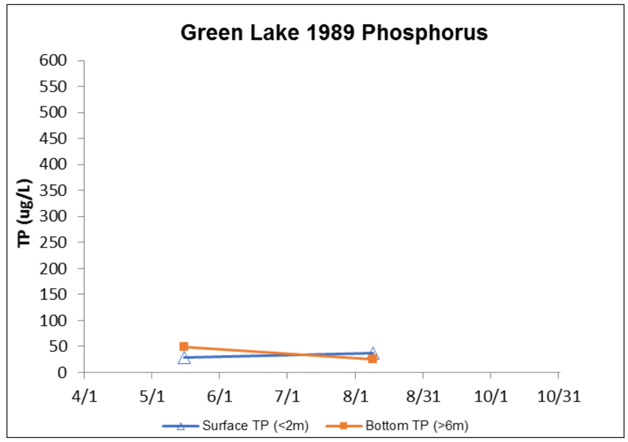

Green Lake 2011 Phosphorus
TP (ug/L)
Precip (in)
TP
Standard
Precip

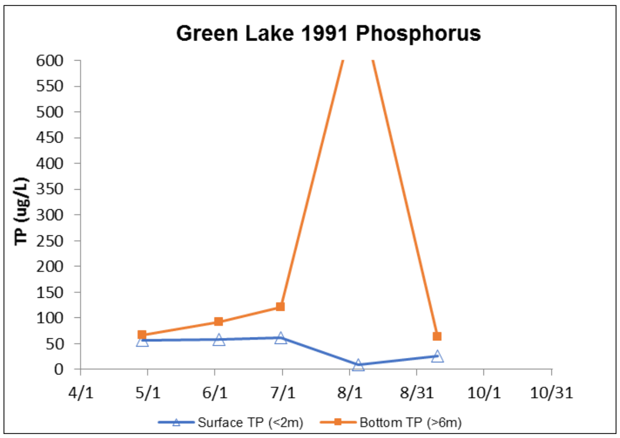

Green Lake 2016 Phosphorus
TP (ug/L)
Precip (in)
TP
Standard
Precip

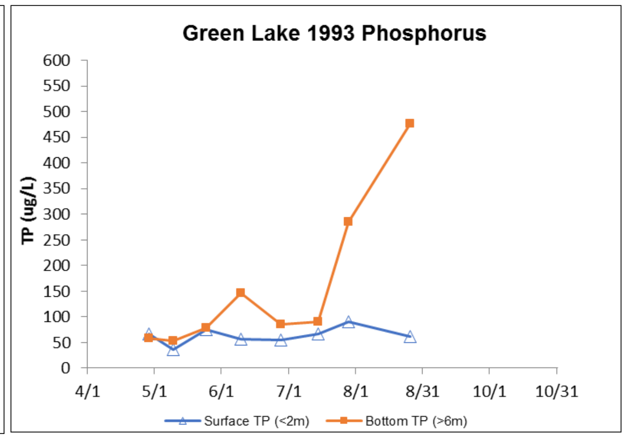

Green Lake 2017 Phosphorus
TP (ug/L)
Precip (in)
TP
Standard
Precip

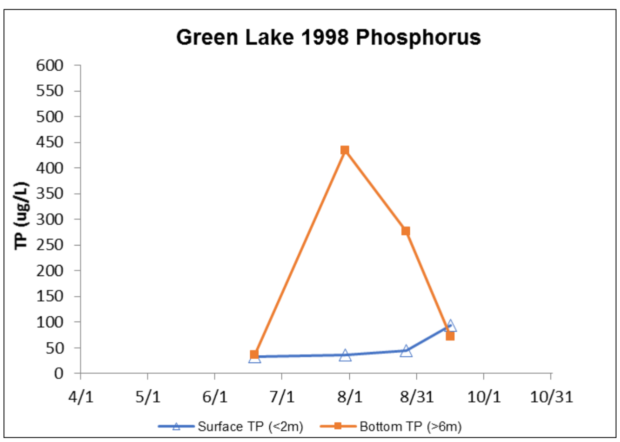

Green Lake 2018 Phosphorus
TP (ug/L)
Precip (in)
TP
Standard
Precip


Green Lake 1988 Phosphorus
TP (ug/L)
600
550
500
450
400
350
300
250
200
150
100
50
0
4/1
5/1
6/1
7/1
8/1
8/31
10/1
10/31
Surface TP (<2m)
Bottom TP (>6m)


Green Lake 1989 Phosphorus
TP (ug/L)
600
550
500
450
400
350
300
250
200
150
100
50
0
4/1
5/1
6/1
7/1
8/1
8/31
10/1
10/31
Surface TP (<2m)
Bottom TP (>6m)

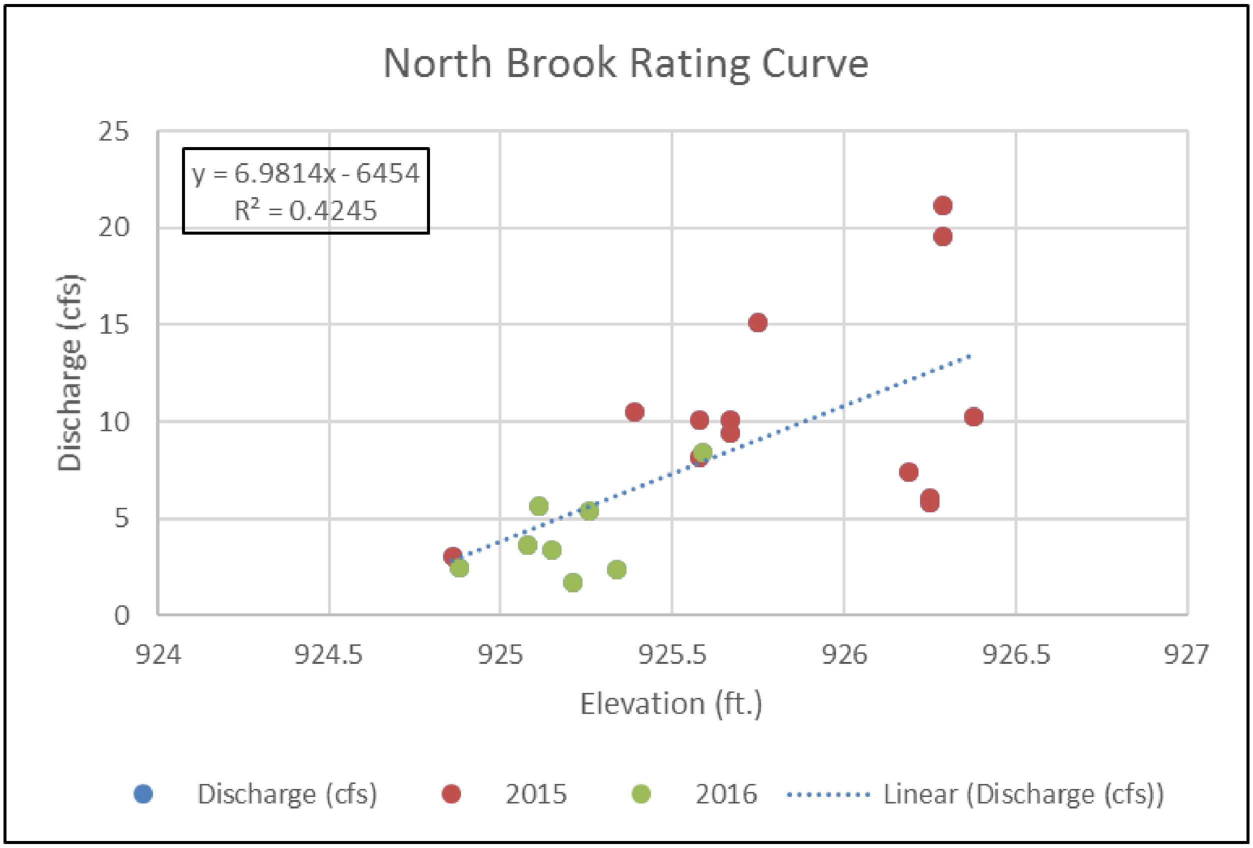

Green Lake 1991 Phosphorus
TP (ug/L)
600
550
500
450
400
350
300
250
200
150
100
50
0
4/1
5/1
6/1
7/1
8/1
8/31
10/1
10/31
Surface TP (<2m)
Bottom TP (>6m)

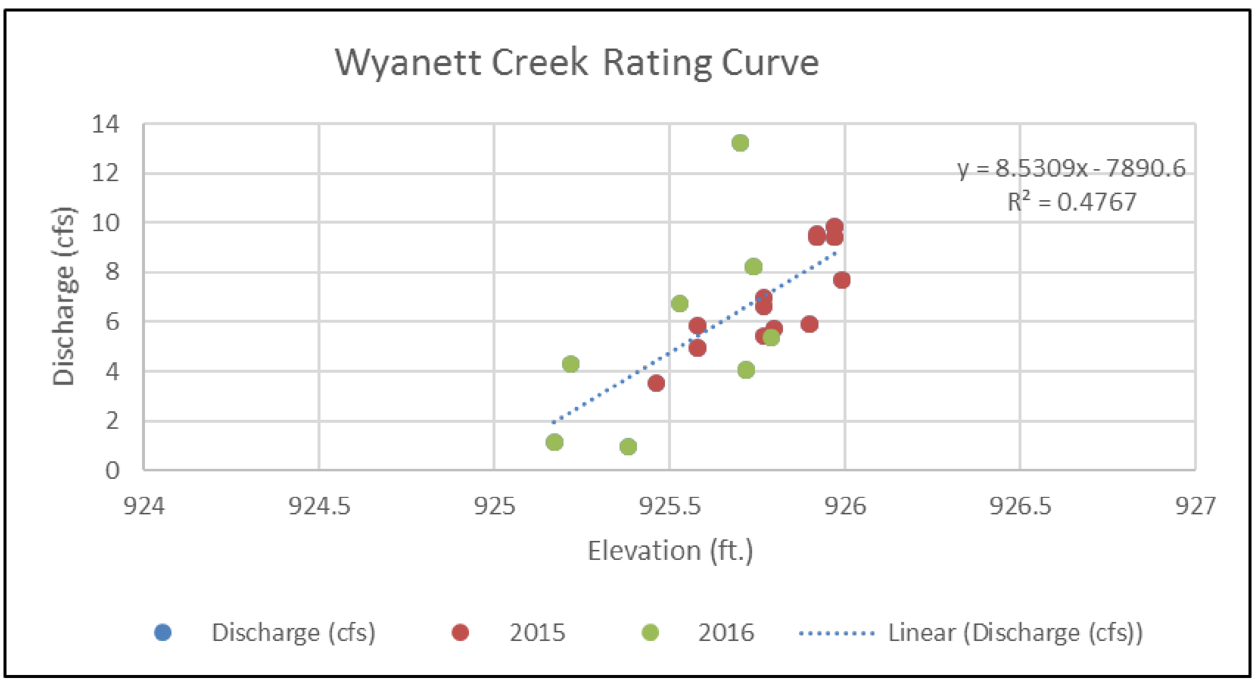

Green Lake 1993 Phosphorus
TP (ug/L)
600
550
500
450
400
350
300
250
200
150
100
50
0
4/1
5/1
6/1
7/1
8/1
8/31
10/1
10/31
Surface TP (<2m)
Bottom TP (>6m)

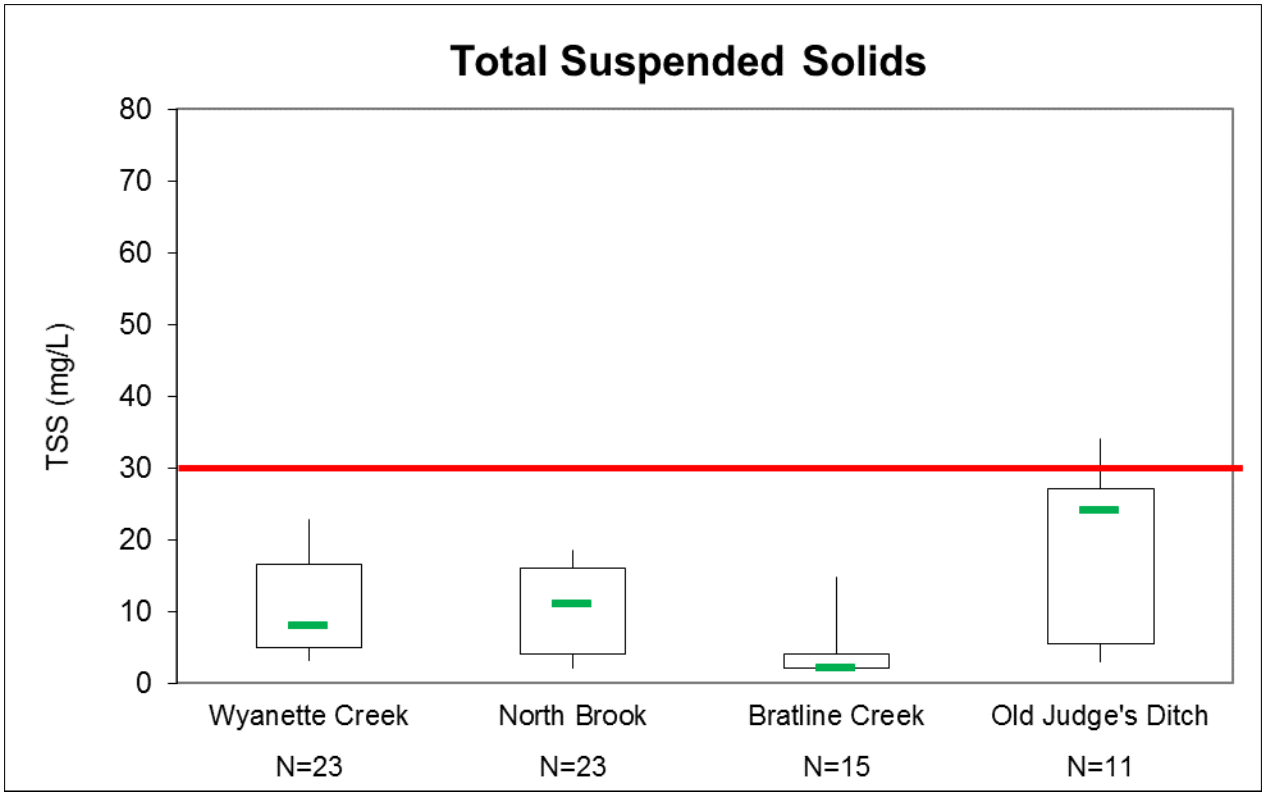

Green Lake 1998 Phosphorus
TP (ug/L)
600
550
500
450
400
350
300
250
200
150
100
50
0
4/1
5/1
6/1
7/1
8/1
8/31
10/1
10/31
Surface TP (<2m)
Bottom TP (>6m)

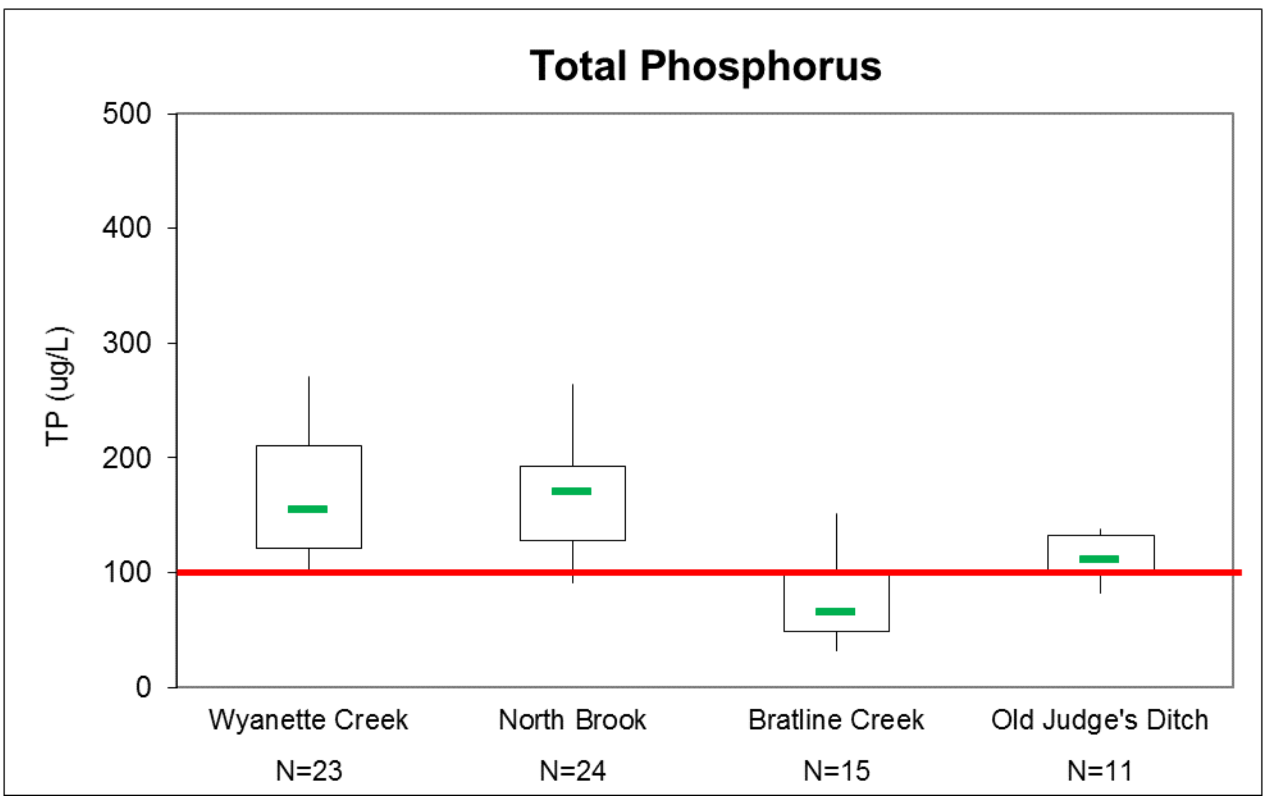
Attachment B

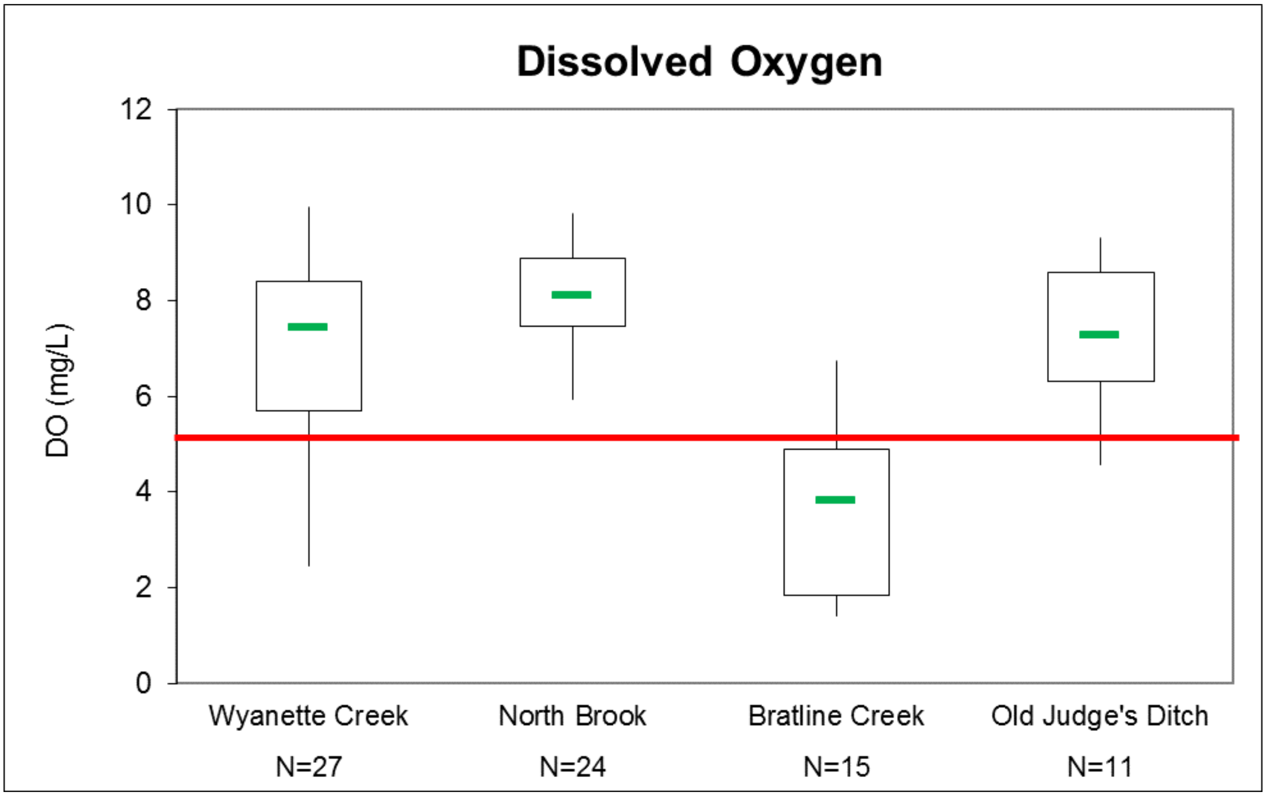
Green Lake Tributary Stage-Discharge Relationships and Water Quality Monitoring Summary


North Brook Rating Curve
y = 6.9814x - 6454
R² = 0.4245
Discharge (cfs)
0
5
10
15
20
25
924
924.5
925
925.5
926
926.5
927
Elevation (ft.)
Discharge (cfs)
2015
2016
Linear (Discharge (cfs))


Wyanett Creek Rating Curve
y = 8.5309x - 7890.6
R² = 0.4767
Discharge (cfs)
0
2
4
6
8
10
12
14
924
924.5
925
925.5
926
926.5
927
Elevation (ft.)
Discharge (cfs)
2015
2016
Linear (Discharge (cfs))


Total Suspended Solids
TSS (mg/L)
80
70
60
50
40
30
20
10
0
Wyanette Creek
N=23
North Brook
N=23
Bratline Creek
N=15
Old Judge's Ditch
N=11


Total Phosphorus
TP (ug/L)
500
400
300
200
100
0
Wyanette Creek
N=23
North Brook
N=24
Bratline Creek
N=15
Old Judge's Ditch
N=11


Dissolved Oxygen
DO (mg/L)
12
10
8
6
4
2
0
Wyanette Creek
N=27
North Brook
N=24
Bratline Creek
N=15
Old Judge's Ditch
N=11

Attachment C

Updated Lake Response Model Documentation

Input Parameters			
Lake Name:	Green Lake		
Model Year:	Average	[2016, 2017, 2018]	

Average Loading Summary for Green Lake

	Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas							
		Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF)[1]	Load
	Name	[acre]	[in/yr]	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1	Wyanett Creek	5,506	3.1	1,425	194	1.0	753
2	North Brook	4,779	2.4	939	171	1.0	438
3	Bratlin Creek	1,959	3.1	507	87	1.0	120
4	Old Judge's Creek	1,936	3.1	501	141	1.0	193
5	Direct (Remainder)	869	3.1	225	114	1.0	70
6							
	Summation	*15,049*	2.9	*3,598.02*			*1,572.9*

Curly-leaf Pondweed							
						Loading Calibration Factor (CF)[1]	Load
	Name					[--]	[lb/yr]
1	Curly-leaf Pondweed Load					1.0	49
	Summation						*49.4*

Failing Septic Systems							
	Name	Total Systems	Failing Systems	Discharge [ac-ft/yr]	Failure [%]		Load [lb/yr]
1	Surrounding Lake	175	10.5	0	6%		68
2							
3							
4							
5							
	Summation	*175*	*11*	*0.0*	6%		*68.1*

Atmosphere							
	Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
	[acre]	[in/yr]	[in/yr]	[ac-ft/yr]	[lb/ac-yr]	[--]	[lb/yr]
	833	32.0	32.0	0.00	0.24	1.0	199.2
		Dry-year total P deposition =			0.222		
		Average-year total P deposition =			0.239		
		Wet-year total P deposition =			0.259		
		(Barr Engineering 2004)					

Internal (Model Residual)							
	Lake Area	Anoxic Factor			Release Rate	Calibration Factor	Load
	[km^2]	[days]			[mg/m^2-day]	[--]	[lb/yr]
	3.37	0		Oxic		1.0	0
	3.37	46.0		Anoxic	6.0	1.0	2,064
	Summation						*2,063.7*
		Net Discharge [ac-ft/yr] =		**3,598**	**Net Load [lb/yr] =**		**3,953**

Average Lake Response Modeling for Green Lake

Modeled Parameter	**Equation**	**Parameters**	**Value**	**[Units]**
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	as f(W,Q,V) from Canfield & Bachmann (1981)			
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	1,793	[kg/yr]
		Q (lake outflow) =	4.4	[10^6 m^3/yr]
		V (modeled lake volume) =	16.7	[10^6 m^3]
		T = V/Q =	3.76	[yr]
		P_i = W/Q =	404	[µg/l]
Model Predicted In-Lake [TP]			**65.3**	**[ug/l]**
Observed In-Lake [TP]			**65.3**	**[ug/l]**

Input Parameters

Lake Name:	Green Lake	
Model Year:	Updated TMDL Reductions	

Average Loading Summary for Green Lake

	Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas							
		Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF)[1]	Load
	Name	[acre]	[in/yr]	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1	Wyanett Creek	5,506	3.1	1,425	100	0.5	388
2	North Brook	4,779	2.4	939	100	0.6	256
3	Bratlin Creek	1,959	3.1	507	87	1.0	120
4	Old Judge's Creek	1,936	3.1	501	100	0.7	136
5	Direct (Remainder)	869	3.1	225	100	0.9	61
6				0	0		0
	Summation	*15,049*	*15*	*3,598.02*			*960.4*

Curly-leaf Pondweed

	Name					Loading Calibration Factor (CF)[1]	Load
						[--]	[lb/yr]
1	Curly-leaf Pondweed Load					1.0	49
	Summation						*49.4*

Failing Septic Systems

	Name	Total Systems	Failing Systems	Discharge [ac-ft/yr]	Failure [%]		Load [lb/yr]
1	Surrounding Lake	175	0	0	0%		64
2							
3							
4							
5							
	Summation	*175*	*0*	*0.0*	0%		*63.7*

Atmosphere

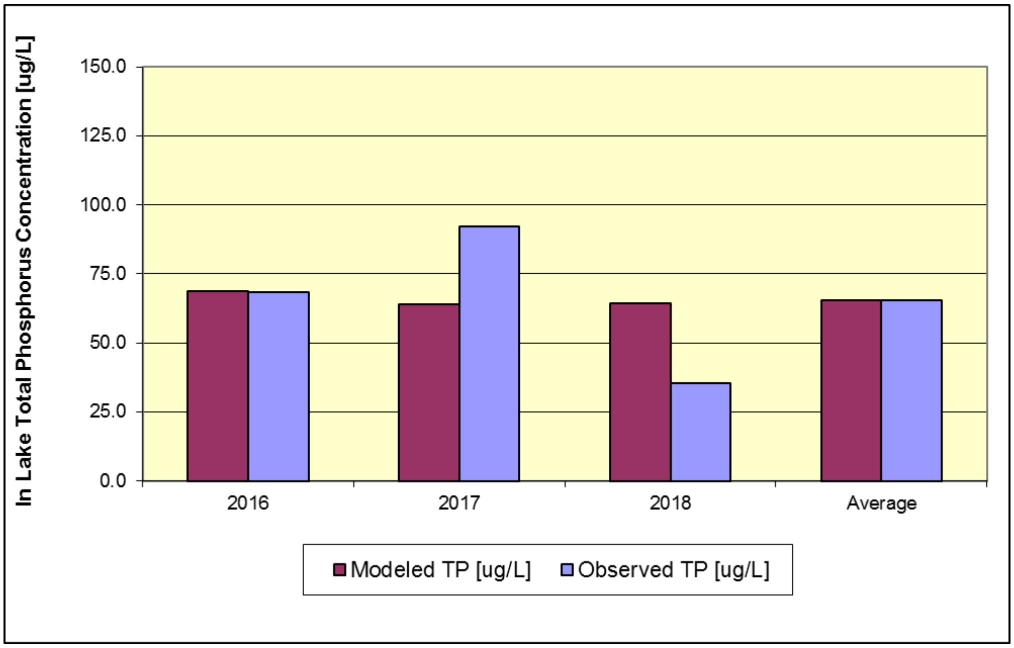
	Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
	[acre]	[in/yr]	[in/yr]	[ac-ft/yr]	[lb/ac-yr]	[--]	[lb/yr]
	833	32.0	32.0	0.00	0.24	1.0	199.2
		Dry-year total P deposition =			0.222		
		Average-year total P deposition =			0.239		
		Wet-year total P deposition =			0.259		
		(Barr Engineering 2004)					

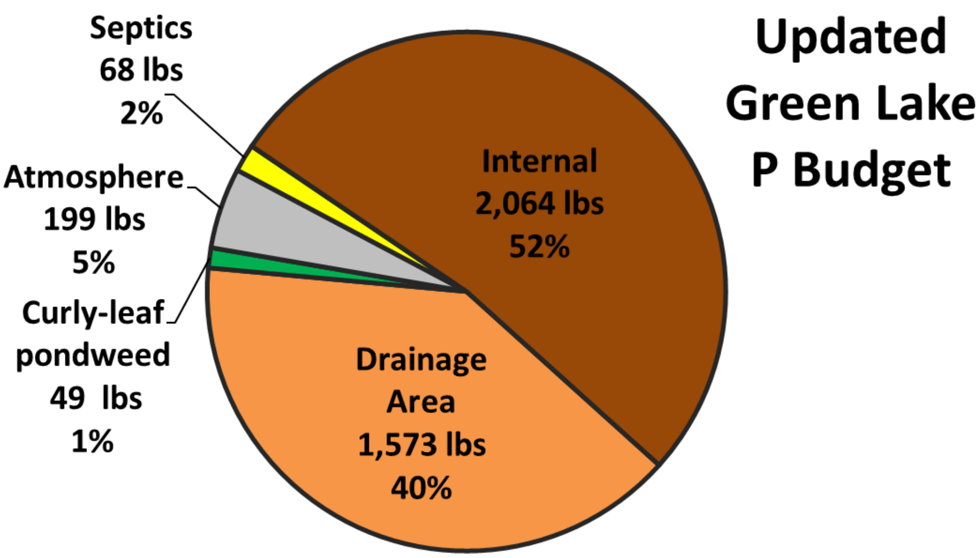
Internal (Model Residual)

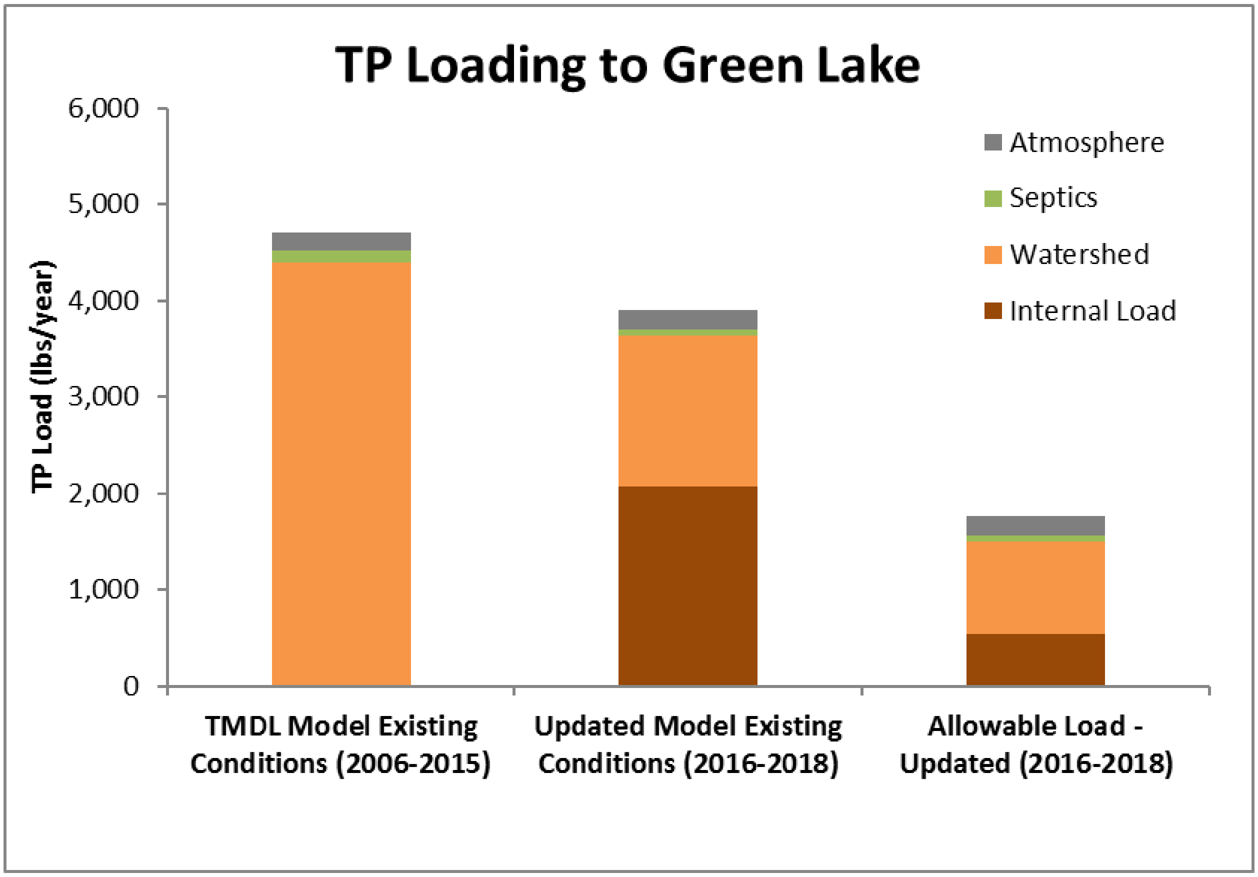
	Lake Area	Anoxic Factor			Release Rate	Calibration Factor	Load
	[km^2]	[days]			[mg/m^2-day]	[--]	[lb/yr]
	3.37	0		Oxic		1.0	0
	3.37	46.0		Anoxic	1.6	1.0	539
	Summation						*538.9*
		Net Discharge [ac-ft/yr] =		**3,598**	**Net Load [lb/yr] =**		**1,812**

Average Lake Response Modeling for Green Lake

Modeled Parameter	Equation	Parameters	Value	[Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION				
	$$P = \frac{P_i}{1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T}$$	as f(W,Q,V) from Canfield & Bachmann (1981)		
		C_P =	1.00	[--]
		C_{CB} =	0.162	[--]
		b =	0.458	[--]
		W (total P load = inflow + atm.) =	822	[kg/yr]
		Q (lake outflow) =	4.4	[10^6 m^3/yr]
		V (modeled lake volume) =	16.7	[10^6 m^3]
		T = V/Q =	3.76	[yr]
		P_i = W/Q =	185	[µg/l]
Model Predicted In-Lake [TP]			**40.0**	**[ug/l]**
Observed In-Lake [TP]			**65.3**	**[ug/l]**


In Lake Total Phosphorus Concentration [ug/L]
150.0
125.0
100.0
75.0
50.0
25.0
0.0
2016
2017
2018
Average
Modeled TP [ug/L]
Observed TP [ug/L]


Updated Green Lake P Budget
Septics 68 lbs 2%
Atmosphere 199 lbs 5%
Curly-leaf pondweed 49 lbs 1%
Internal 2,064 lbs 52%
Drainage Area 1,573 lbs 40%

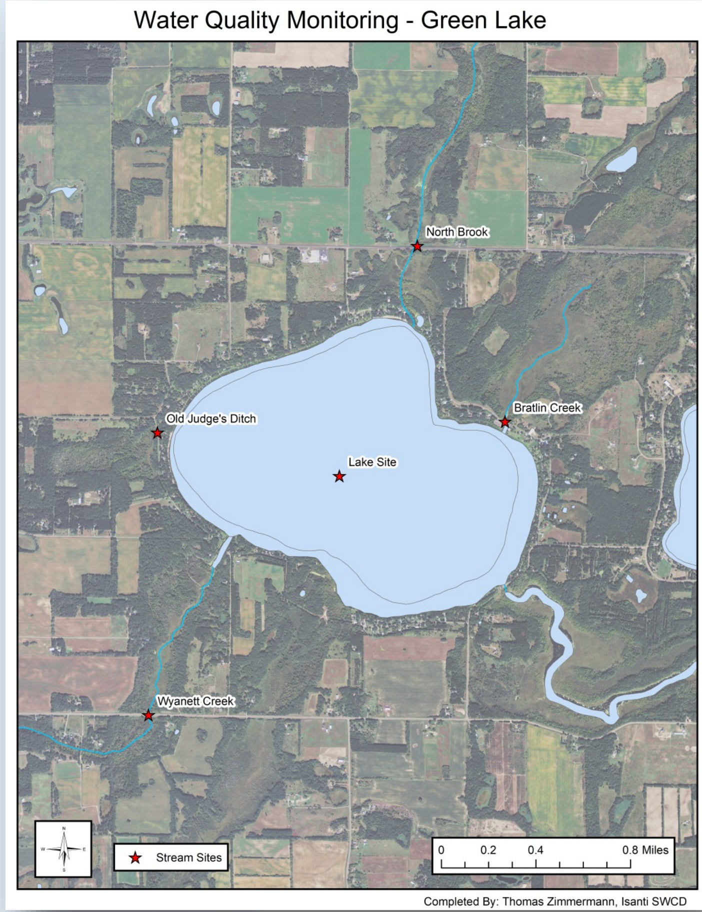

TP Loading to Green Lake
TP Load (lbs/year)
6,000
5,000
4,000
3,000
2,000
1,000
0
Atmosphere
Septics
Watershed
Internal Load
TMDL Model Existing Conditions (2006-2015)
Updated Model Existing Conditions (2016-2018)
Allowable Load - Updated (2016-2018)

Appendix E
Green Lake: Lake Status Report, Isanti County 2018

Green Lake Tributary Monitoring 2018

North Brook

Wyanett Creek



2018 was the third year the Green Lake Improvement District (GLID) partnered with the Isanti Soil and Water Conservation District (SWCD) to monitor the health of inlets that empty into Green Lake:

- North Brook at highway 95
- Wyanett Creek at 325th Ave.
- Bratlin Creek
- Old Judge's Creek

This report describes the results of monitoring that occurred in 2018 as well as comparisons to previous years.

General Definitions:

Total Phosphorus: An essential plant nutrient in which an excess can cause severe algal blooms.

Orthophosphate: The amount of phosphorus that is immediately available for algae and plant growth.

Total Suspended Solids: Tiny particles of soil and other matter that remain suspended in water making it cloudy. Particles include sediment and organic matter.

Transparency: An indirect measure of suspended and dissolved materials (soil particles and tea color caused by organic materials) in the water.

2018 Area Conditions

2018 Rainfall Summary

The area was largely missed by heavy rains throughout the year. The majority of rain events occurred during the growing season (vegetation was growing and available to take up water) and nearly all events were under two inches. As a result, less sediment and phosphorus made its way into surface waters and water levels and flow were lower than usual across the county. Consistent (though still small) rain events and cooler than average temperatures in the fall led to a sight rebound in stream levels late in the season.

Water Health Comparisons:

- TP measurements for this ecoregion typically range between 60 and 150 µg/L.
- TSS measurements for this area typically range between 4.8 and 16 mg/L.
- The State goal or standard for TP in streams is 100 µg/L (i.e. we would like to see TP stay below this number).

Tributary Monitoring

What: In 2018 eight sampling events were targeted at four inlets. We targeted four samples during rain events and four during base flow. The samples were tested for total phosphorus (TP), total suspended solids (TSS) and transparency. Dissolved oxygen, temperature, conductivity, pH and water flow were also measured in the field.

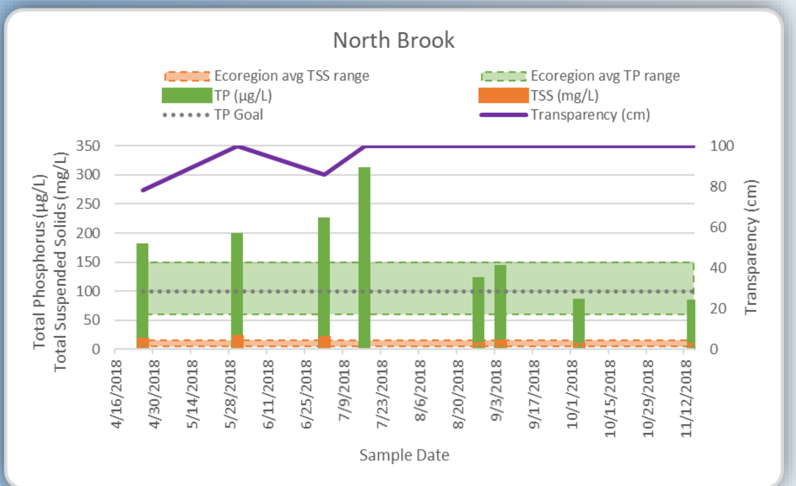
In addition to water quality, water levels were continually tracked using in-stream data loggers at North Brook and Wyanett Creek. The water levels were recorded every four hours from early May through early November.

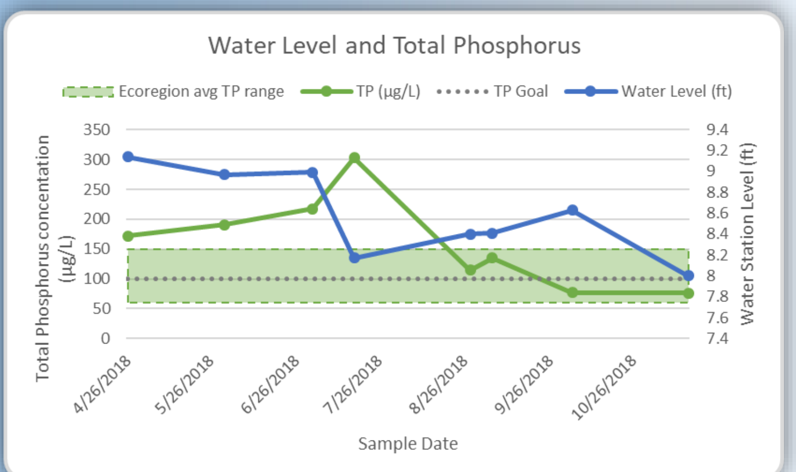
Why: The information collected is used in conjunction with the Subwatershed Assessment for North Brook and Wyanett Creek completed in 2017. The data helps us determine which tributary should be a higher priority for water quality projects. In theory, the stream that delivers the most nutrients to the lake would be the highest priority. Additionally, the information collected can be used to track trends and to determine how well water quality improvement projects are working.

2018 Tributary Monitoring Results

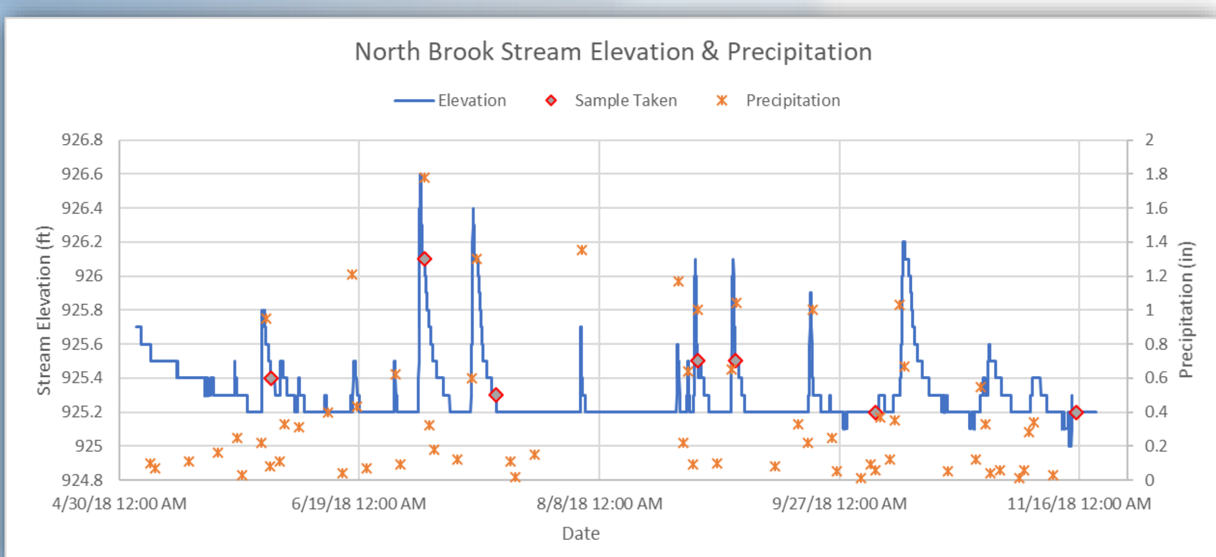
Total Suspended Solids (TSS), Total Phosphorus (TP) and Transparency Tube

Site: North Brook





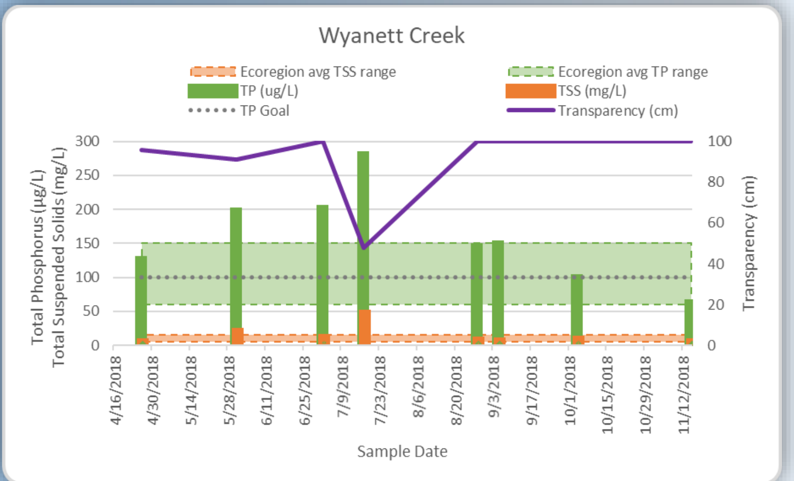
- 2018 average TP was 173 µg/L. The average TP range from 2016-2017 was 169-181µg/L.
- This tributary had the highest TP of all four tributaries monitored in 2018. Elevated TP in July corresponds with rain events.
- TP concentrations were relatively lower than previous years. The timing of rainfall as described at the beginning of the report likely has something to do with this (less nutrients being flushed from the land in 2018).
- 2018 average TSS was 9 mg/L. The average TSS range from 2016-2017 was 10-21 mg/L.
- 2018 average transparency was 96 cm. The average transparency range from 2016-2017 was 86-93 cm.
- TP levels appear to have an inverse relationship with water level.
- In 2018, based on paired flow and sample information, North Brook contributed more nutrients to the lake than Wyanett Creek. The reverse was true in 2016 and 2017.

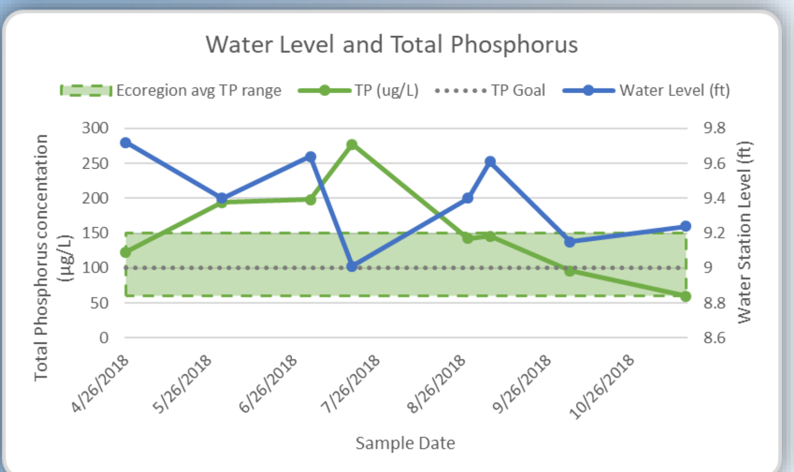


2018 Tributary Monitoring Results

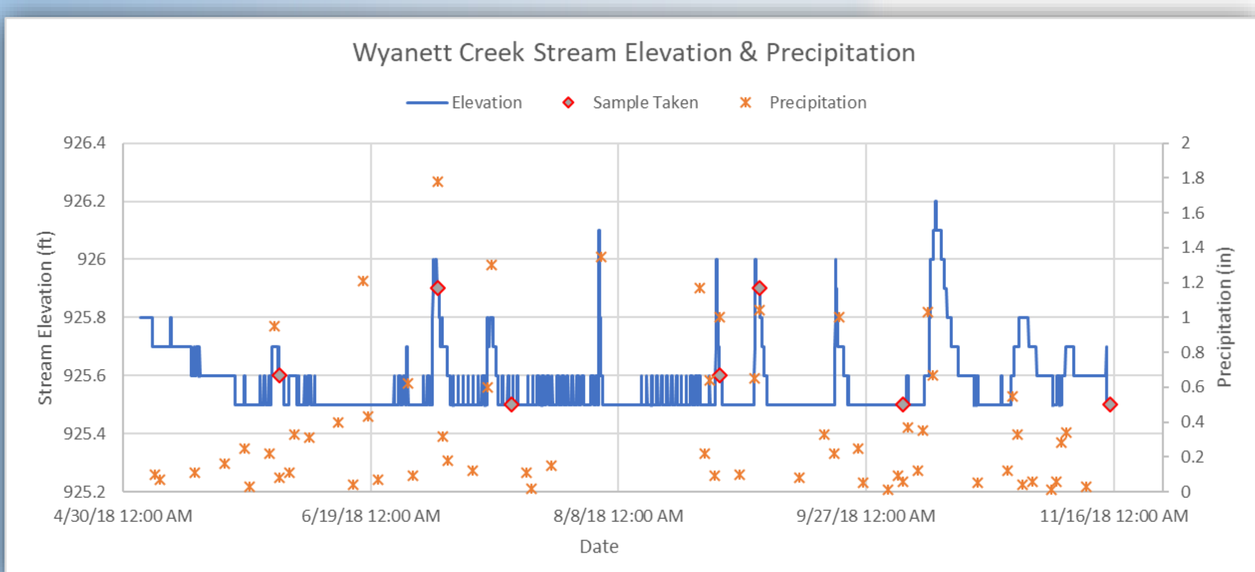
Total Suspended Solids (TSS), Total Phosphorus (TP) and Transparency Tube

Site: Wyanett Creek





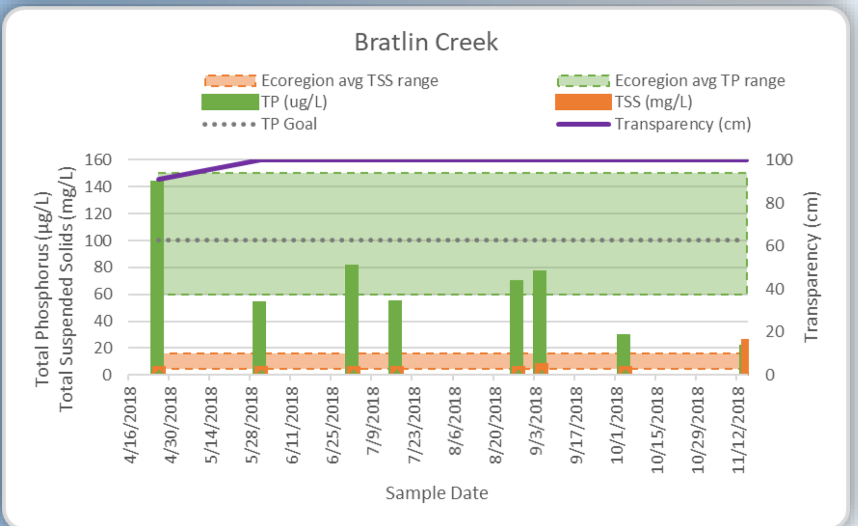
- 2018 average TP was 154 µg/L. The average TP range from 2016-2017 was 220-247 µg/L.
- This site had the second highest TP of the four sites monitored.
- TP concentrations were relatively lower than previous years. The timing of rainfall as described at the beginning of the report likely has something to do with this (less nutrients being flushed from the land in 2018).
- 2018 average TSS was 11 mg/L. The average TSS range from 2016-2017 was 18-24 mg/L.
- 2018 average transparency was 92 cm. The average transparency range from 2016-2017 was 79-84 cm.
- TP levels appear to have an inverse relationship with water level.
- In 2018, based on paired flow and sample information, North Brook contributed more nutrients to the lake than Wyanett Creek. The reverse was true in 2016 and 2017.

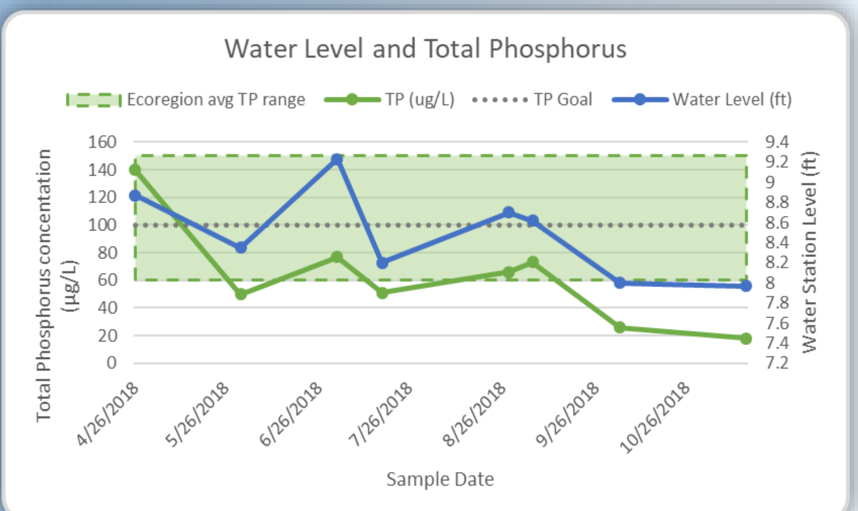


2018 Tributary Monitoring Results

Total Suspended Solids (TSS), Total Phosphorus (TP) and Transparency Tube

Site: Bratlin Creek

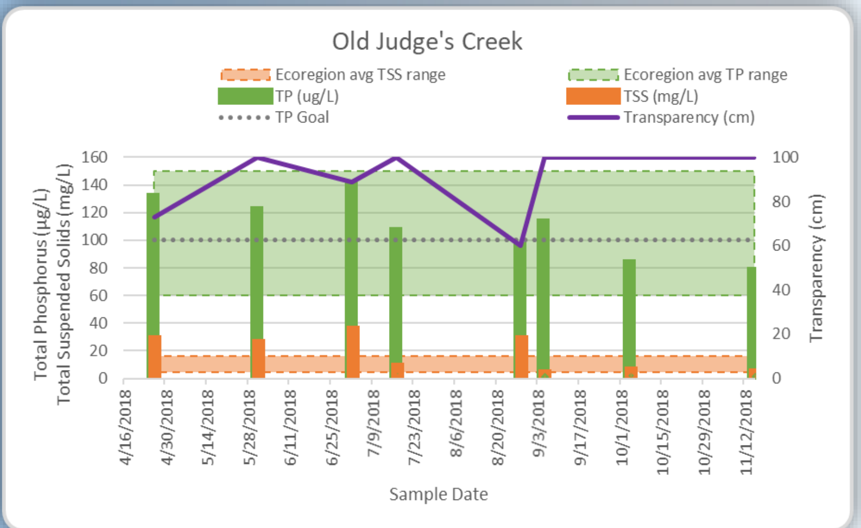


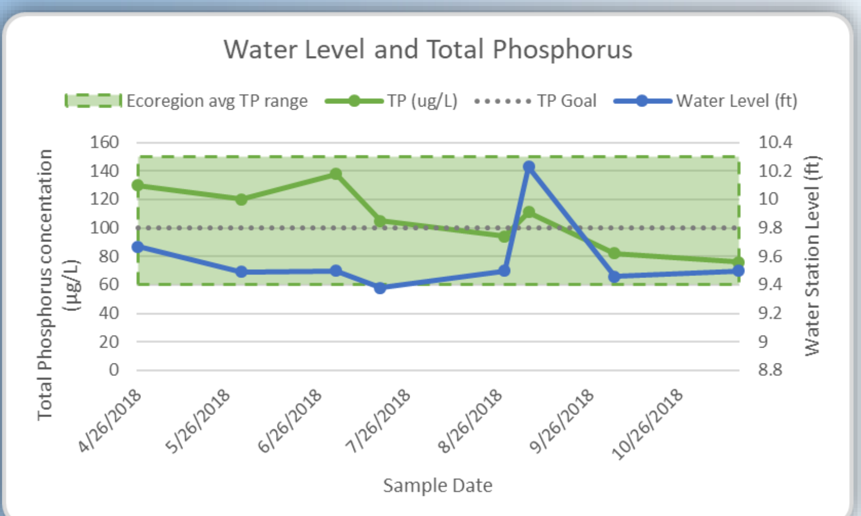


- 2018 average TP was 63 µg/L. The average TP in 2017 was 102µg/L.
- This site had the lowest TP of all four tributaries monitored.
- This site has relatively low TP throughout the season; however, early season high TP occurred in both 2017 and 2018.
- TP concentrations were relatively lower than previous years. The timing of rainfall as described at the beginning of the report likely has something to do with this (less nutrients being flushed from the land in 2018).
- 2018 average TSS was 2 mg/L. The average TSS in 2017 was 6 mg/L.
- 2018 average transparency was 99 cm. The average transparency in 2017 was 100 cm.
- TP levels correspond with water level fluctuations.
- Based on paired flow and TP measurements, Bratlin Creek contributed the second lowest amount of TP to the lake in 2018.

2018 Tributary Monitoring Results

Total Suspended Solids (TSS), Total Phosphorus (TP) and Transparency Tube





Site: Old Judge's Creek

- 2018 average TP was 107 µg/L. The average TP in 2017 was 102µg/L.
- TP concentrations were relatively lower than previous years. The timing of rainfall as described at the beginning of the report likely has something to do with this (less nutrients being flushed from the land in 2018).
- 2018 average TSS was 16 mg/L. The average TSS in 2017 was 6 mg/L.
- 2018 average transparency was 90cm. The average transparency in 2017 was 100cm.
- Stream flow is typically blocked by a man-made dam (log) in the culvert.
- TP levels correspond with water level fluctuations.
- Based on paired flow and TP measurements, Old Judge's Creek contributed the lowest amount of TP to the lake in 2018.

2018 Results and Recommendations

2018 summary:

North Brook: While TP levels were lower than previous years, there is plenty of opportunity for improvement. This watershed should be a priority location for restoration projects such as cover crops, filter strips, buffers, and/or a wetland restoration. More investigation would be necessary before moving forward with a wetland restoration. Isanti County is currently in the process of initiating a county ditch maintenance program– North Brook is planned to be the first ditch to go though the process. The County will work closely with the SWCD to identify restoration opportunities during the process.

Wyanett Creek: While TP levels were lower than previous years, there is plenty of opportunity for improvement. This watershed should be a priority location for restoration projects such as cover crops, filter strips, buffers, and/or a wetland restoration. More investigation would be necessary before moving forward with a wetland restoration.

Bratlin Creek: This location typically has good water health (with the exception of the early season). While there may be restoration opportunities here– time and effort may be best focused at North Brook and Wyanett Creek to start. However, if the opportunity arises, the protection of existing natural areas (wetland, forest, grassland) in this watershed would be beneficial (i.e. land easements or purchases and/or increased building set-backs from the creek and wetland boundaries).

Old Judge's Creek: Water flow at this location is the lowest of all sites; thus, this site contributes the least TP to the lake. Nonetheless, if opportunities for restoration projects arise in this watershed they should be investigated– time and effort may be best focused at North Brook and Wyanett Creek to start.

Future Monitoring

- No monitoring is scheduled for 2019. The SWCD recommends sampling every other year OR three years on and three years off. Cost estimates will be provided to the LID for both scenarios prior to the July Annual meeting.

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Tiffany Determan, District Mgr, TDeterman@isantiswcd.org

Thanks to the GLID members who have assisted with lake and stream monitoring, notably Ken and Barb Murray.

Appendix F
Projects planned by subwatershed

The watershed partners have developed two subwatershed analysis that are attached in Appendices B and C. These projects are included in the implementation plan in Section 7; however, the following tables describe more precise targeting for the projects.

Table 24 describes the projects planned in the *Green Lake Subwatershed Retrofit Analysis for Areas Draining Directly to the Lake* report that can be referenced in its entirety in Appendix B.

Table 1. Summary of preferred stormwater opportunities, ranked by cost-effectiveness (*Green Lake Subwatershed Retrofit Analysis for Areas Draining Directly to the Lake*)

Retrofit Type (refer to catchment profile pages for additional detail)	Projects Identified	TP Reduction (lb/yr)	Total Project Cost	Estimated cost/ lb-TP (30-year)	Notes/Description
Rain gardens - Feldspar St	2	0.7	$29,550	$2,050	Pave gravel road that washes out into the lake, install 2 rain gardens.
Swale - public boat parking	1	0.3	$15,541	$2,060	Redirect boat landing runoff into the lakeshore swale.
Grass swale at bottom of Feldspar St (road not paved)	1	0.6	$22,472	$2,648	A grass swale at the water's edge of Feldspar St, which currently runs into the lake.
Land protection - 62 acres	1	8.9	$611,910	$2,966	Purchase fee title or an easement for property on SW side of the lake, currently for sale.
Lakeshore restoration - All 95 Candidate Sites	95	10.7	$437,770	$3,352	Restore all candidate lakeshore restoration sites, or some lesser amount. Offers habitat benefits in addition to water quality.
Lakeshore restoration - 15 High Priority Sites	15	1.6	$70,129	$3,505	Restore the 15 candidate lakeshores where active erosion and concentrated flow occur.
Permeable asphalt - 20% of Fedlspar St	1	0.7	$59,334	$4,254	Pave gravel road that washes out into the lake, including 20% permeable pavement.
Diversion to swale - Rhinestone St	1	0.1	$11,509	$4,836	Divert street runoff to roadside swale. Some diversion already occurs due to road crowning.
Permeable asphalt - 20% public boat parking	1	0.6	$61,884	$5,438	Install permeable asphalt on 20% of public boat landing parking.

Retrofit Type (refer to catchment profile pages for additional detail)	Projects Identified	TP Reduction (lb/yr)	Total Project Cost	Estimated cost/ lb-TP (30-year)	Notes/Description
Trench grate sediment traps - Feldspar St	1	0.4	$35,415	$5,535	Pave gravel road that washes out into the lake, including trench grate sediment traps.
Hydrodynamic device - Feldspar St	1	0.4	$41,014	$7,168	Pave gravel road that washes out into the lake, including commercial hydrodynamic separator.

Table 25 and **Table 26** describes the projects planned in the *Green Lake Rural Stormwater Retrofit Analysis of North Brook and Wyanett Creek* report that can be referenced in its entirety in Appendix C. These projects are ranked by the cost per pound of TP removal. The projects and maps can be

Table 2. North Brook Watershed BMP ranking based on dollars per pound of TP removed

BMP characteristics				Cost-benefit		
Project Ranking	**Priority Zone**	**Sub-Basin**	**Applicable Practice**	**Practice Cost**	**P reduction (lb/yr)**	**$/lb TP**
1	4	2	Filter Strip	$ 173.55	$ 2.71	$ 64.04
2	4	1	Filter Strip	$ 224.91	$ 1.99	$ 113.02
3	1	2	Grassed Waterway	$ 3,148.83	$ 24.84	$ 126.76
4	1	1	Grassed Waterway	$ 1,666.33	$ 13.14	$ 126.81
5	6	2	Grassed Waterway	$ 895.43	$ 3.51	$ 255.11
6	1	14	Grassed Waterway	$ 539.63	$ 1.54	$ 350.41
7	3	2	Grassed Waterway	$ 978.45	$ 2.74	$ 357.10
8	7	3	Grassed Waterway	$ 1,476.57	$ 3.98	$ 371.00
9	3	3	Grassed Waterway	$ 806.48	$ 2.02	$ 399.25
10	1	5	Grassed Waterway	$ 824.27	$ 1.86	$ 443.16
11	1	4	Grassed Waterway	$ 1,197.86	$ 2.69	$ 445.30
12	1	8	Grassed Waterway	$ 1,891.67	$ 4.12	$ 459.14

BMP characteristics				Cost-benefit		
Project Ranking	**Priority Zone**	**Sub-Basin**	**Applicable Practice**	**Practice Cost**	**P reduction (lb/yr)**	**$/lb TP**
13	2	2	Grassed Waterway	$ 2,223.75	$ 4.79	$ 464.25
14	8	1	Grassed Waterway	$ 1,043.68	$ 2.23	$ 468.02
15	9	1	Grassed Waterway	$ 1,043.68	$ 2.23	$ 468.02
16	8	5	Grassed Waterway	$ 1,191.93	$ 2.51	$ 474.87
17	1	9	Grassed Waterway	$ 1,553.66	$ 3.19	$ 487.04
18	7	4	Grassed Waterway	$ 1,571.45	$ 2.58	$ 609.09
19	1	12	Grassed Waterway	$ 1,476.57	$ 2.42	$ 610.15
20	7	1	Grassed Waterway	$ 646.37	$ 1.05	$ 615.59
21	7	5	Grassed Waterway	$ 2,496.53	$ 4.02	$ 621.03
22	9	3	Grassed Waterway	$ 1,856.09	$ 2.97	$ 624.95
23	9	2	Grassed Waterway	$ 2,069.57	$ 3.31	$ 625.25
24	8	6	Grassed Waterway	$ 604.86	$ 0.96	$ 630.06
25	7	2	Grassed Waterway	$ 978.45	$ 1.53	$ 639.51
26	9	4	Grassed Waterway	$ 2,336.42	$ 3.62	$ 645.42
27	3	1	Grassed Waterway	$ 907.29	$ 1.29	$ 703.33
28	3	6	Grassed Waterway	$ 1,387.62	$ 1.97	$ 704.38
29	3	5	Grassed Waterway	$ 670.09	$ 0.95	$ 705.36
30	3	4	Grassed Waterway	$ 2,621.06	$ 3.48	$ 753.18
31	8	4	WASCOB	$ 17,548.62	$ 7.69	$ 2,282.01
32	8	2	WASCOB	$ 26,469.99	$ 9.18	$ 2,883.44
33	4	3	Grassed Waterway	$ 1,601.10	$ 0.52	$ 3,079.04

BMP characteristics				Cost-benefit		
Project Ranking	Priority Zone	Sub-Basin	Applicable Practice	Practice Cost	P reduction (lb/yr)	$/lb TP
34	1	13	WASCOB	$ 17,058.44	$ 4.92	$ 3,467.16
35	8	3	WASCOB	$ 31,567.91	$ 6.53	$ 4,834.29
36	6	3	WASCOB	$ 35,097.25	$ 3.86	$ 9,092.55
37	1	3	WASCOB	$ 46,763.65	$ 5.00	$ 9,352.73
38	9	5	WASCOB	$ 50,391.02	$ 3.80	$ 13,260.79

Table 3. Wyanett Creek Watershed BMP ranking based on dollars per pound of TP removed

Project Ranking	Priority Zone	Sub-Basin	Applicable Practice	Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
24	4	6	Grassed Waterway	$ 2,217.82	$ 10.86	$ 204.22
30	5	2	Grassed Waterway	$ 2,140.73	$ 8.09	$ 264.61
37	7	3	Grassed Waterway	$ 1,310.53	$ 4.46	$ 293.84
42	8	4	Grassed Waterway	$ 1,719.70	$ 5.81	$ 295.99
20	4	3	Grassed Waterway	$ 990.31	$ 3.16	$ 313.39
44	8	6	Grassed Waterway	$ 1,701.91	$ 5.32	$ 319.91
41	8	3	Grassed Waterway	$ 2,057.71	$ 6.08	$ 338.44
39	8	1	Grassed Waterway	$ 1,856.09	$ 5.39	$ 344.36
11	3	6	Grassed Waterway	$ 1,061.47	$ 2.81	$ 377.75
29	5	1	Grassed Waterway	$ 776.83	$ 2.03	$ 382.67
45	8	7	Grassed Waterway	$ 2,158.52	$ 5.45	$ 396.06
8	3	3	Grassed Waterway	$ 889.50	$ 2.23	$ 398.88
40	8	2	Grassed Waterway	$ 2,235.61	$ 5.45	$ 410.20

Project Ranking	Priority Zone	Sub-Basin	Applicable Practice	Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
17	3	12	Grassed Waterway	$ 2,793.03	$ 6.57	$ 425.12
18	4	1	Grassed Waterway	$ 2,567.69	$ 5.95	$ 431.54
14	3	9	Filter Strip	$ 135.60	$ 0.31	$ 437.42
13	3	8	Filter Strip	$ 447.48	$ 1.02	$ 438.71
12	3	7	Filter Strip	$ 440.70	$ 1.00	$ 440.70
36	7	2	Grassed Waterway	$ 2,235.61	$ 4.96	$ 450.73
28	4	10	Grassed Waterway	$ 1,743.42	$ 3.80	$ 458.79
26	4	8	Grassed Waterway	$ 1,950.97	$ 4.25	$ 459.05
27	4	9	Grassed Waterway	$ 1,915.39	$ 4.17	$ 459.33
31	6	1	Grassed Waterway	$ 1,197.86	$ 2.51	$ 477.24
35	7	1	Grassed Waterway	$ 1,197.86	$ 2.51	$ 477.24
15	3	10	Grassed Waterway	$ 1,802.72	$ 3.48	$ 518.02
33	6	3	Grassed Waterway	$ 1,310.53	$ 2.49	$ 526.32
10	3	5	Grassed Waterway	$ 1,014.03	$ 1.76	$ 576.15
2	1	2	Grassed Waterway	$ 1,535.87	$ 2.56	$ 599.95
1	1	1	Grassed Waterway	$ 1,862.02	$ 3.10	$ 600.65
25	4	7	Grassed Waterway	$ 1,209.72	$ 2.00	$ 604.86
4	2	1	Grassed Waterway	$ 2,318.63	$ 3.66	$ 633.51
32	6	2	Grassed Waterway	$ 2,235.61	$ 3.51	$ 636.93
3	1	3	Grassed Waterway	$ 1,470.64	$ 2.28	$ 645.02
43	8	5	Filter Strip	$ 716.76	$ 0.67	$ 1,069.79

Project Ranking	Priority Zone	Sub-Basin	Applicable Practice	Practice Cost	P reduction (lb/yr)	$ per lb TP Removed
9	3	4	Filter Strip	$ 484.06	$ 0.45	$ 1,075.70
46	8	8	Filter Strip	$ 350.98	$ 0.28	$ 1,253.52
21	4	3	Filter Strip	$ 207.79	$ 0.16	$ 1,298.68
23	4	5	Filter Strip	$ 211.68	$ 0.16	$ 1,323.00
22	4	4	Filter Strip	$ 174.33	$ 0.13	$ 1,340.96
7	3	2	WASCOB	$ 12,646.77	$ 8.99	$ 1,406.76
6	3	1	WASCOB	$ 37,254.06	$ 7.93	$ 4,697.86
16	3	11	WASCOB	$ 57,743.79	$ 4.75	$ 12,156.59
19	4	2	WASCOB	$ 68,625.90	$ 4.69	$ 14,632.39