Final Lake of the Woods Watershed Restoration and Protection Strategy Report

February 2020

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Key Terms

Assessment Unit Identifier (AUID): The unique water body identifier for each river reach comprised of the USGS eight-digit HUC plus a three-character code unique within each HUC.

Aquatic life impairment: The presence and vitality of aquatic life is indicative of the overall water quality of a stream. A stream is considered impaired for impacts to aquatic life if the fish Index of Biotic Integrity (IBI), macroinvertebrate IBI, dissolved oxygen, turbidity, or certain chemical standards are not met.

Aquatic recreation impairment: Streams are considered impaired for impacts to aquatic recreation if fecal bacteria standards are not met. Lakes are considered impaired for impacts to aquatic recreation if TP and chlorophyll-a or Secchi disc depth standards are not met.

Hydrologic Unit Code (HUC): A HUC is assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the Minnesota River Basin is assigned a HUC-4 of 0702 and the Pomme de Terre River Watershed is assigned a HUC-8 of 07020002.

Impairment: Water bodies are listed as impaired if water quality standards are not met for designated uses including: aquatic life, aquatic recreation, and aquatic consumption.

Index of Biotic integrity (IBI): A method for describing water quality using characteristics of aquatic communities, such as the types of fish and invertebrates found in the waterbody. It is expressed as a numerical value between 0 (lowest quality) to 100 (highest quality).

Protection: This term is used to characterize actions taken in watersheds of waters not known to be impaired to maintain conditions and beneficial uses of the waterbodies.

Restoration: This term is used to characterize actions taken in watersheds of impaired waters to improve conditions, eventually to meet water quality standards and achieve beneficial uses of the waterbodies.

Source (or Pollutant Source): This term is distinguished from ‘stressor’ to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Stressor (or Biological Stressor): This is a broad term that includes both pollutant sources and non-pollutant sources or factors (e.g., altered hydrology, dams preventing fish passage) that adversely impact aquatic life.

Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that may be introduced into a surface water and still ensure that applicable water quality standards for that water are met. A TMDL is the sum of the wasteload allocation for point sources, a load allocation for nonpoint sources and natural background, an allocation for future growth (i.e., reserve capacity), and a margin of safety as defined in the Code of Federal Regulations.

Executive Summary

The Lake of the Woods Watershed (LOWW) falls on the United States and Canadian border. This report will focus on the Minnesota portion of the LOWW (Hydrologic Unit Code [HUC] 09030009) draining approximately 730,000 acres in the northernmost Minnesota counties of Lake of the Woods and Roseau. The LOWW's namesake, the Lake of the Woods, takes up approximately 41% of the total watershed area in Minnesota, with approximately 70% of the total land area in wetlands. Approximately 20% of the remaining land area is used in agriculture, which is found mainly in the southern part of the watershed (MPCA 2016a).

Water quality is generally fair throughout the LOWW. Where sampled, the most common issues are turbidity and poor biological communities. One bacterial impairment exists in the West Branch Warroad River (09030009-503).

The LOWW contains 57 stream reaches that are defined by the state of Minnesota (i.e., have an Assessment Unit ID [AUID]) (MPCA 2016a). In 2012, the Minnesota Pollution Control Agency (MPCA) conducted monitoring on 22 of the 57 stream reaches. The MPCA did not conduct sampling on the remaining stream reaches due to inaccessibility given the remote and wetland nature of the LOWW. The MPCA found that there was insufficient data to conduct assessments on 6 of the 22 stream reaches. Of the remaining 16 assessed stream reaches, the MPCA found that 6 were impaired for aquatic life use (4 fish bioassessments and 5 macroinvertebrate bioassessments) and 1 was impaired for aquatic recreation use. The nature of the impairments found leading to the lack of support for aquatic life and recreation are those commonly occurring in highly-modified landscapes, including an overabundance of sediment, excessive bacteria in the water, low dissolved oxygen (DO) levels, low flow, and reduced biological abundances (MPCA 2016a).

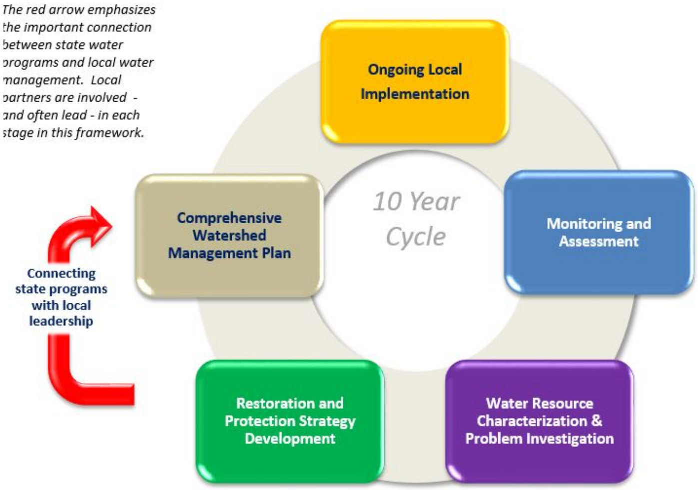
The federal Clean Water Act Section 303(d) list identifies seven LOWW streams as having impaired water quality (i.e., not meeting water quality standards) and requiring a Total Maximum Daily Load (TMDL) study. Overall, three TMDLs were developed to address two aquatic life impairments caused by high total suspended sediment (TSS) and four biological impairments caused by high TSS in the LOWW.

The federal 303(d) list identifies two LOWW lakes as having impaired water quality and requiring a TMDL study. The lakes, Lake of the Woods (main) and Lake of the Woods 4-mile Bay both have impaired aquatic recreation due to nutrient/eutrophication biological indicators. These lake impairments are being addressed in a separate TMDL study and will not be addressed in this report.

The Lake of Woods Watershed Restoration and Protection Strategy (WRAPS) Report used a number of tools to evaluate the LOWW's subwatersheds based on delivery of water quality constituents and identify field-scale opportunities to further target implementation of best management practices (BMP). The report considered the use of filter strips, grass waterways, water and sediment control basins, saturated buffers, bioreactors, perennials, and cover crops when developing the restoration and protection BMP scenarios. The report used a Hydrologic Simulation Program – FORTRAN (HSPF) model of the LOWW to develop three BMP scenarios intended to represent a range of restoration and protection outcomes. The three BMP scenarios are: (1) maximum BMP implementation; (2) top 25% BMP implementation; and (3) top 10% BMP implementation. The maximum BMP scenario represents an upper limit of what could be achieved in load reduction assuming all potential BMPs could be implemented. The 25% BMP scenario represents a targeted implementation approach where BMPs are located only in the catchments that rank in the top 25% for contributing sediment and phosphorus to the Lake of the Woods. The 10% BMP scenario represents an approach targeting the catchments in the top 10% for contributing sediment and phosphorus.

The Lake of the Woods WRAPS process used findings from the Lake of the Woods TMDL Study to guide the development of its implementation strategies for impaired waterbodies. The purpose of the WRAPS process is to support local working groups and jointly develop scientifically-supported restoration and protection strategies that can be used to guide local water planning. These implementation strategies are intended to meet the TMDL goals outlined in this document. Following completion of the WRAPS process, the WRAPS report, as well as numerous other technical reports referenced in this document, will be publicly available on the MPCA's LOWW website located at: https://www.pca.state.mn.us/water/watersheds/lake-woods.

What is the WRAPS Report?


The red arrow emphasizes the important connection between state water programs and local water management. Local partners are involved - and often lead - in each stage in this framework.

Minnesota has adopted a watershed approach to address the state’s 80 major watersheds. The Minnesota watershed approach incorporates **water quality assessment, watershed analysis, public participation, planning, implementation, and measurement of results** into a 10-year cycle that addresses both restoration and protection.

Along with the watershed approach, the MPCA developed a process to identify and address threats to water quality in each of these major watersheds.

This process is called WRAPS development. The WRAPS reports have two parts: impaired waters have strategies for restoration, and waters that are not impaired have strategies for protection.

Waters not meeting state standards are listed as impaired and TMDL studies are developed for them. The TMDLs are incorporated into the WRAPS reports. In addition, the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple water bodies and overall watershed health, including both protection and restoration efforts. A key aspect of this effort is to develop and utilize watershed-scale models and other tools to identify strategies for addressing point and nonpoint source pollution that will cumulatively achieve water quality targets. For nonpoint source pollution, the WRAPS report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. The WRAPS report also serves as the basis for addressing the EPA Nine Minimum Elements of watershed plans, to help qualify applicants for eligibility for Clean Water Act Section 319 implementation funds.

Purpose

- Support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning
- Summarize Watershed Approach work completed to date including the following reports:
  - *Lake of the Woods Watershed Monitoring and Assessment*
  - *Lake of the Woods Watershed Biotic Stressor Identification*
  - *Lake of the Woods Watershed Total Maximum Daily Load Study*

Scope

- Impacts to aquatic life in streams
- Impacts to aquatic recreation in streams

Audience

- Local working groups (local governments, SWCDs, watershed management groups, etc.)
- State agencies (MPCA, DNR, BWSR, etc.)

1. Watershed Background and Description

The Greater LOWW borders the United States and Canada. The Minnesota portion of the LOWW (HUC 09030009) drains approximately 735,000 acres within the counties of Lake of the Woods and Roseau. The LOWW lies entirely in the Northern Minnesota Wetland Ecoregion located within the Rainy River Basin. Land use within the LOWW is predominately wetlands with approximately 41% of the watershed covered by the Lake of the Woods (39000202) (Figure 1). Municipalities within the LOWW include the cities of Roosevelt, Warroad, and Williams and the townships of Cedarbend, Lake, Laona, and Moranville in addition to portions of the Beltrami Island and Lake of the Woods State Forests. Additional background information and description of the LOWW can be found in the resources listed below.

Additional Lake of the Woods Watershed Resources

Lake of the Woods Watershed Conditions Report (HEI 2012):
http://www.lakeofthewoodsswcd.org/projects/mwrpp/CondRpt.pdf

USDA Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the Lake of the Woods Watershed:
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/mn/technical/dma/rwa/?cid=nrcs142p2_023650

Minnesota Department of Natural Resources (DNR) Watershed Assessment Mapbook for the Lake of the Woods Watershed:
http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/wsmb80.pdf

Lake of the Woods Watershed Monitoring and Assessment Report (March 2016):
https://www.pca.state.mn.us/sites/default/files/wq-ws3-09030009.pdf

Lake of the Woods Watershed Stressor Identification Report (June 2016) (add link when available)

The Minnesota Nutrient Reduction Strategy (September 2014):
https://www.pca.state.mn.us/sites/default/files/wq-s1-80.pdf

Minnesota Nutrient Planning Portal: http://mrbdc.mnsu.edu/mnnutrients/

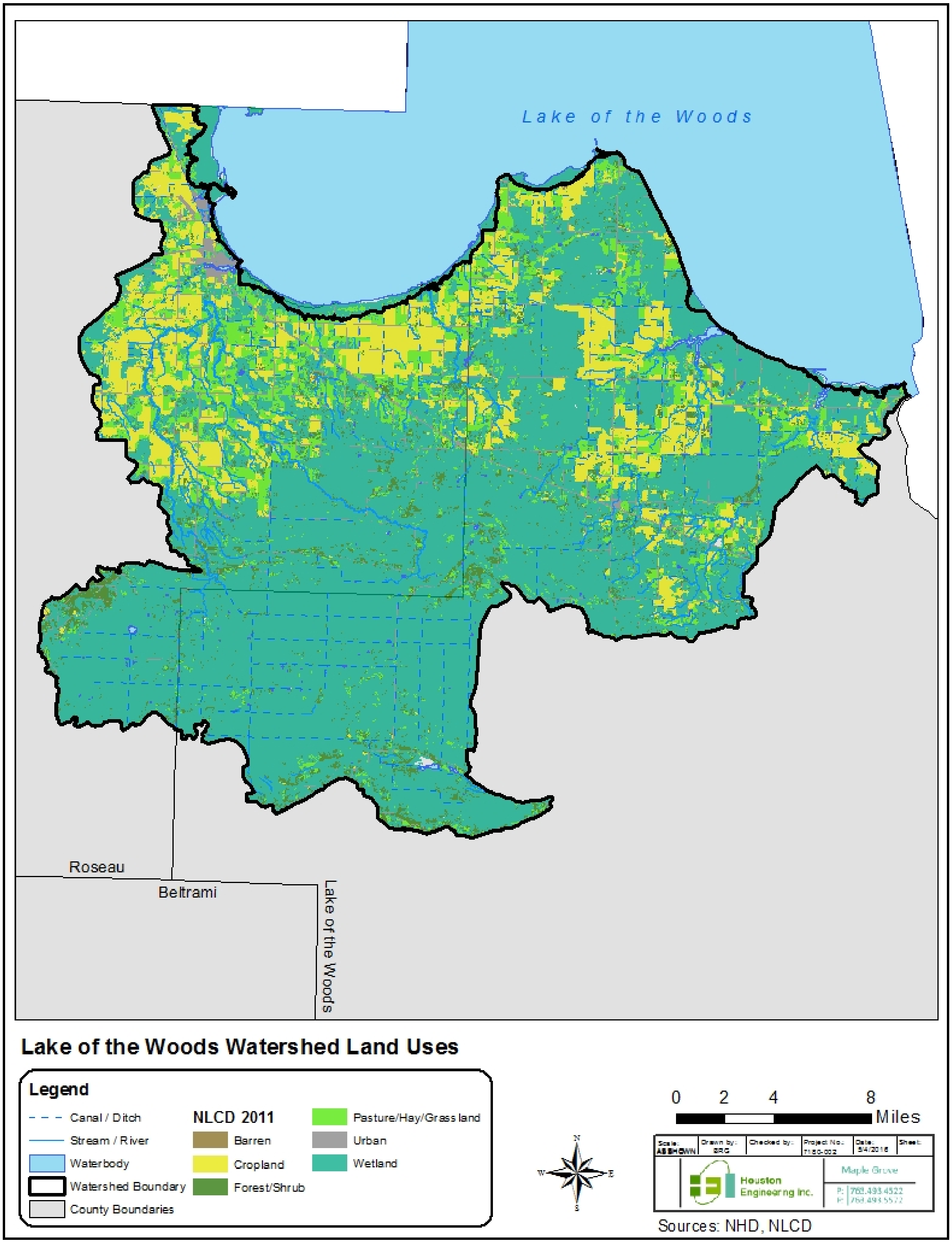


Figure 1: Land use in the LOWW (NLCD 2011)

2. Watershed Conditions

The Lake of the Woods is the prominent surface water feature in the LOWW, encompassing 41% of the total area. There are 540 small ponds and 3 small lakes within the project area in addition to vast areas of wetlands. The LOWW contains 172 miles of intermittent streams, 166 miles of intermittent drainage ditches, 157 miles of perennial drainage ditches, 95 miles of perennial streams, and 64 miles of river. Five main rivers flow from the LOWW into the Lake of the Woods: the Warroad River, Willow Creek, West Branch Zippel Creek, South Branch Zippel Creek, and Bostic Creek (HEI 2012). According to the statewide Altered Water Course project, 60% of the watercourses in the LOWW have been hydrologically altered (i.e., channelized, ditched, or impounded) (MPCA 2016a).

The LOWW contains 57 stream reaches that are defined by the state of Minnesota (i.e., have an AUID) (MPCA 2016a). In 2012, the MPCA conducted monitoring on 22 of the 57 stream reaches. The MPCA did not conduct sampling on the remaining stream reaches due to inaccessibility given the remote and wetland nature of the LOWW. The MPCA found that there was insufficient data to conduct assessments on 6 of the 22 stream reaches. Of the remaining 16 assessed stream reaches, the MPCA found that 6 were impaired for aquatic life use (4 fish bioassessments [F-IBI] and 5 macroinvertebrate bioassessments [M-IBI]) and 1 was impaired for aquatic recreation use. The nature of the impairments found leading to the lack of support for aquatic life and recreation are those commonly occurring in highly-modified landscapes, including an overabundance of sediment, excessive bacteria in the water, low DO levels, low flow, and reduced biological abundances (MPCA 2016a).

Evidence indicates that the nine biological impairments identified within the LOWW are likely a result of low DO levels, high TSS levels, altered hydrology, and/or poor habitat. Altered hydrology and low DO are contributing to the impairments in each of the six biologically-impaired reaches. The natural flow regime of each biologically-impaired reach has been altered by substantial channelization, ditching, and impoundment of watercourses (60%). This altered hydrology results in increased and accelerated peak flows and prolonged periods of low discharge (i.e., “flashy” flow regime). This “flashy” flow regime inhibits biotic diversity. Evidence also supports that these hydrologic alterations are largely responsible for the degradation of physical habitat, high TSS, and low DO conditions that are limiting the fish and macroinvertebrate communities within the LOWW.

There are three National Pollutant Discharge Elimination System/State Disposal System (NPDES/SDS) permitted point sources currently active in the LOWW, all of which are wastewater treatment facilities (WWTF). One WWTF (Williams) discharges to a waterbody impaired by TSS (09030009-501). The remaining two WWTFs are not affected by this WRAPS report or the TMDL study. Additional active permits in the LOWW include 13 construction stormwater permits, 2 industrial stormwater permits (none of which require individual NPDES/SDS permits), and 38 registered feedlots, (HEI 2012).

A more detailed analysis of the quality of the waters within the LOWW can be found in the Watershed Conditions Report (HEI 2012), the Lake of the Woods Monitoring and Assessment Report (MPCA 2016a), and the Lake of the Woods Biotic Stressor Identification (SID) Report (MPCA 2016b). The conditions and associated pollutant sources of these individual streams are summarized in the following sections.

Due to remoteness and dominance of wetlands, the Northwest Angle Inlet Subwatershed (HUC 0903000905) located in the northernmost portion of the LOWW was not assessed and is not discussed in this report (Figure 2).

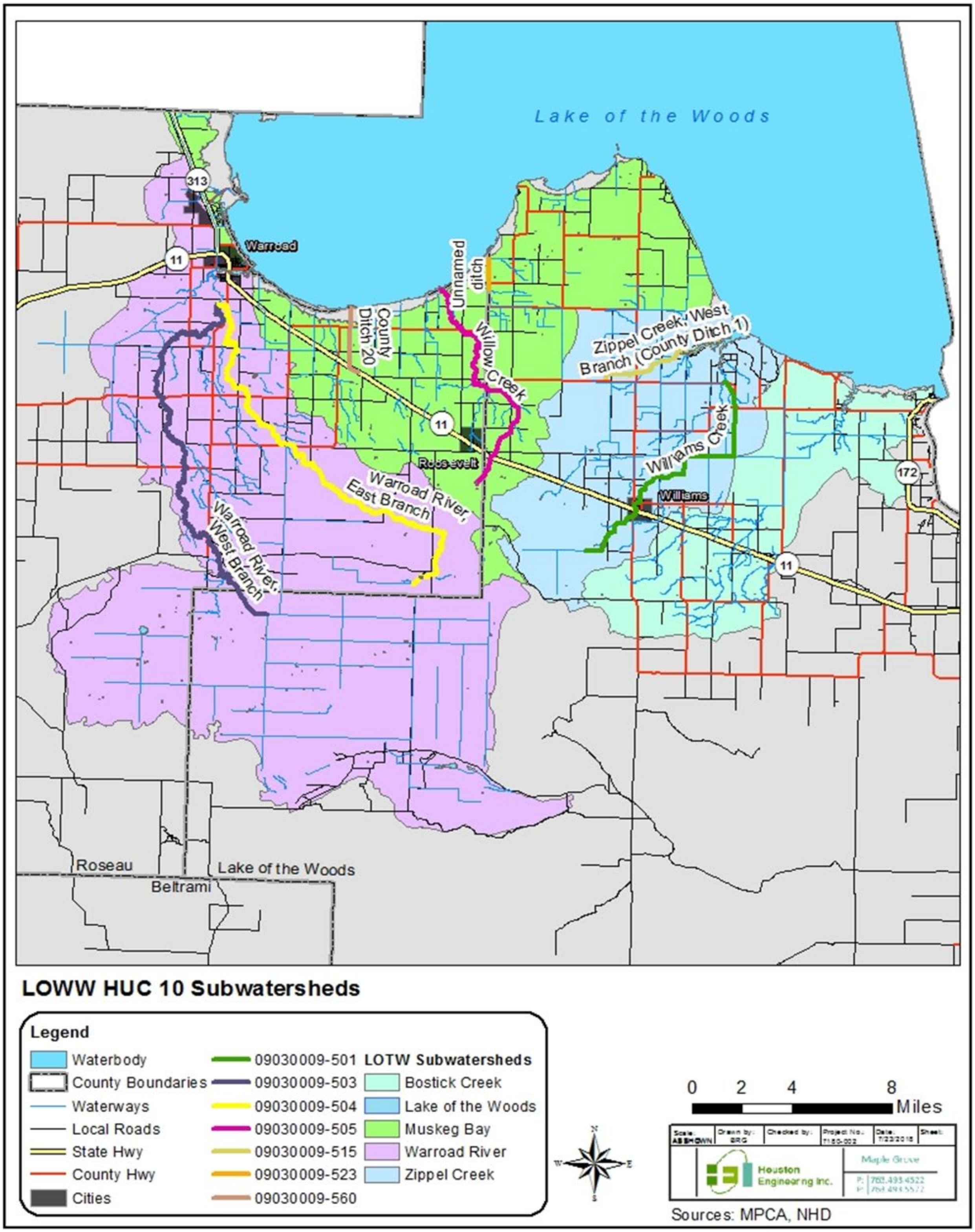


Figure 2: LOWW impaired waters, project boundary, and HUC-10 boundaries.

2.1 Condition Status

This section describes the streams within the LOWW that are impaired or in need of protection. Impaired waters are targets for restoration efforts while waters currently supporting aquatic life and recreation are subject to protection efforts.

Water quality is generally fair throughout the LOWW. Where sampled, the most common issues are sediment level (expressed as TSS) and poor biological communities. Nutrients often meet standards, with few AUIDs experiencing higher than average concentrations. One bacterial impairment exists in the West Branch Warroad River (AUID 09030009-503).

Factors used to determine whether a waterway is capable of harboring and supporting aquatic life (generally fish and aquatic insects) include the fish and macroinvertebrate indices of biological integrity (IBI), the concentration of DO, and the sediment level, expressed as TSS. Factors used to assess the suitability of a water body for aquatic recreation include the amount of bacteria in streams and the levels of nutrients in lakes.

Some of the waterbodies in the LOWW are impaired by mercury; however, this report does not cover toxic pollutants. The state's mercury impairments are addressed in a statewide mercury TMDL. 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.

Streams

A range of parameters were used to assess LOWW streams including fish and macroinvertebrate IBI and concentrations of DO, turbidity/suspended solids and bacteria. Water quality measures were compared to the state standards, as well as the normal range for the ecoregion where the stream is located. The aquatic life standards are based on the IBI scores, DO, turbidity/suspended solids, chloride, pH, and ammonia (NH_3), while the aquatic recreation standard is based on bacteria.

Assessed LOWW stream segments are listed in Table 1, with stream condition summaries provided for each segment. Twenty-two AUIDs were assessed as part of the development of the LOWW Monitoring and Assessment Report (MPCA 2016a) to determine if individual stream reaches met applicable aquatic life and recreation standards for one or more parameters. Two stream reaches were unsupportive of aquatic life due to fish and macroinvertebrate IBI and turbidity impairments (-501 and -515), two for macroinvertebrate IBI (-504, -560), one for fish and macroinvertebrate IBI (-523), and one for fish IBI and DO (-505). One recreational impairment exists due to high levels of *E. coli* found in the West Branch Warroad River (-503). Information used to create this table was summarized using the MPCA Watershed Monitoring and Assessment Report (MPCA 2016a), as well as the MPCA Watershed Biotic SID Report (MPCA 2016b).

Table 1: Status of assessed stream reaches in the Lake of the Woods Watershed, presented numerically by HUC-10 subwatershed and AUID.

HUC-10 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Aquatic Life							Aq. Rec	
				Fish IBI	Macroinvertebrate IBI	Dissolved Oxygen	TSS	Chloride	pH	NH3	Bacteria	Nutrients
Bostic Creek (0903000901)	537	Bostic Creek	Headwaters to Lake of the Woods	SUP	NA	SUP	IMP*	SUP	SUP	SUP	SUP	NA
	539	Unnamed ditch	Unnamed ditch to Bostic Cr	NA	NA	SUP	IF	NA	SUP	NA	NA	NA
	540	Unnamed ditch	Canfield Cr to Unnamed ditch	NA	NA	IF	SUP	NA	SUP	NA	NA	NA
	546	Canfield Creek	Unnamed cr to Unnamed cr	NA	NA	IF	NA	NA	SUP	NA	NA	NA
	553	Unnamed creek	Unnamed cr to Canfield Cr	NA	NA	IF	IF	NA	SUP	NA	NA	NA
Zippel Creek (0903000902)	501	Williams Creek	Headwaters to Zippel Cr	IMP	IMP	IMP	IMP	SUP	SUP	SUP	SUP	NA
	506	Zippel Creek	East Branch, Headwaters to Zippel Bay	NA	NA	IF	IF	NA	SUP	NA	NA	NA
	515	Zippel Creek	West Branch (County Ditch 1), Headwaters to Zippel Bay (Lake of the Woods)	IMP	IMP	IMP	IMP	IF	SUP	NA	NA	NA
	516	Tomato Creek	Headwaters to T161 R34W S3, north line	SUP	SUP	IF	IF	NA	IF	NA	NA	NA
	518	Tomato Creek	T162 R34W S34, south line to Unnamed cr	SUP	SUP	SUP	IF	NA	SUP	NA	NA	NA
	529	County Ditch 1	Unnamed ditch to W Br Zippel Cr	NA	NA	SUP	SUP	NA	SUP	NA	NA	NA
	567	Unnamed creek	Headwaters to 70th Ave NW	NA	NA	IF	NA	NA	SUP	NA	NA	NA
Warroad River (0903000903)	502	Warroad River, W & E Br Warroad R to Lake of the Woods	W & E Br Warroad R to Lake of the Woods	SUP	NA	NA	IF	SUP	SUP	SUP	SUP	NA
	503	Warroad River, West Branch	Headwaters to Warroad R	SUP	SUP	SUP	IF	SUP	SUP	SUP	IMP	NA
	504	Warroad River, East Branch	Headwaters to Warroad R	SUP	IMP	SUP	IF	SUP	SUP	SUP	SUP	NA
	526	Unnamed ditch	Unnamed ditch to E Br Warroad R	SUP	SUP	IF	NA	NA	IF	NA	NA	NA
	533	Clausner Creek	Unnamed cr to Unnamed cr	SUP	NA	IF	IF	NA	IF	NA	NA	NA
	557	Unnamed creek	Headwaters to W Br Warroad R	SUP	SUP	IF	IF	NA	IF	NA	NA	NA
	558	Unnamed ditch (Judicial Ditch 62)	Headwaters to Unnamed ditch	SUP	SUP	IF	IF	NA	IF	NA	NA	NA
Muskeg Bay (0903000904)	505	Willow Creek	Headwaters to Lake of the Woods	IMP	NA	IMP	IF	SUP	SUP	SUP	SUP	NA
	523	Unnamed ditch	Unnamed ditch to Unnamed ditch	IMP	IMP	IF	IF	NA	IF	NA	NA	NA
	560	County Ditch 20	Headwaters to Lake of the Woods	SUP	IMP	IF	IF	NA	IF	NA	NA	NA

Sup = found to meet the water quality standard, **Imp** = does not meet the water quality standard and, therefore, is impaired, **IF** = the data collected was insufficient to make a finding, **NA** = not assessed

*Determined that TSS data was collected during non-representative conditions; therefore, no impairment listing was recommended

Lakes

The Lake of the Woods (Lake ID 39-0002-02) is the prominent water resource in the LOWW. The Lake of the Woods is a prime recreational, fisheries, and economic resource. The Minnesota portion of the Lake of the Woods was listed as impaired in 2008, due to exceedances of eutrophication criteria (high amounts of nutrients and chlorophyll-*a*). The most recent water quality assessments, as part of this watershed study, continue to indicate impairments for recreational use with nutrient and chlorophyll-*a* concentrations that are above the MPCA's criteria. A separate impaired waters study is currently underway to better understand the nature and extent of algae blooms in the Lake of the Woods and develop appropriate restoration strategies. This work is being conducted with cooperation from numerous partner agencies and organizations, including the International Joint Commission's new LOWW Board (MPCA 2016a). This WRAPS report, therefore, does not address the Lake of the Woods, but rather just its contributing watershed within the study boundary (Figure 1).

Table 2: Assessment status of the Lake of the Woods within the Lake of the Woods Watershed.

HUC-10 Subwatershed	Lake ID	Lake	Aquatic Recreation
Lake of the Woods	39-0002-01	Lake of the Woods (Main)	Imp
	39-0002-02	Lake of the Woods (4 Mile Bay)	Imp

2.2 Water Quality Trends

The LOWW is located in north central Minnesota. Within the LOWW, the MPCA conducted intensive watershed monitoring in 2012-2013. In addition, the LOWW has also undergone additional monitoring over the past 10 years. However, there is insufficient long-term water quality monitoring records to evaluate water quality trends over time. Moving forward, as part of the Watershed Approach, water quality monitoring will continue to evaluate trends in water quality within LOWW over time.

2.3 Stressors and Sources

In order to develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or sources impacting or threatening the waterbodies must be identified and evaluated. Biological SID is done for streams with either fish or macroinvertebrate biota impairments, and encompasses both evaluation of pollutants and non-pollutant-related factors as potential stressors (e.g., altered hydrology, fish passage, habitat). Pollutant source assessments and TMDL studies are conducted where a biological SID process identifies a pollutant as a stressor as well as for the typical pollutant impairment listings. Section 3 provides further detail on stressors and pollutant sources.

Stressors of Biologically-impaired Stream Reaches

The magnitude of risk for the primary stressors investigated for the six biologically-impaired stream reaches within LOWW are listed in Table 3. Evidence indicates that low DO levels, high TSS levels, altered hydrology, and/or poor habitat may cause or contribute to the six biological impaired stream reaches identified within the LOWW. The natural flow regime of each biologically impaired reach has been altered by substantial channelization, ditching, and impoundment of watercourses (60%), and agricultural drainage, resulting in increased and accelerated peak flows, and prolonged periods of low discharge (i.e., “flashy” flow regime). This “flashy” flow regime inhibits biotic diversity. Evidence also supports that these hydrologic alterations are largely responsible for the degradation of physical habitat, high-suspended sediment, and low DO conditions that are limiting the fish and macroinvertebrate communities within the LOWW.

Further detailed SID information can be found in the MPCA’s LOWW Biotic SID Report (MPCA 2016b).

Table 3: Primary stressors to aquatic life in biologically impaired reaches in the Lake of the Woods Watershed.

HUC-10 Subwater-shed	AUID (Last 3 digits)	Stream	Reach Description	Biological Impairment	Primary Stressor			
					Dissolved Oxygen	TSS	Altered Hydrology	Habitat
Zippel Creek (0903000902)	501	Williams Creek	Headwaters to Zippel Creek	Fish	○		⭘	
				Macroinvert.	⭘	⭘	⭘	○
	515	Zippel Creek, West Branch (County Ditch 1)	Headwaters to Zippel Bay (Lake of the Woods)	Fish	⭘		○	
				Macroinvert.	●	⭘	⭘	⭘
Warroad River (0903000903)	504	Warroad River, East Branch	Headwaters to Warroad River	Macroinvert.	○	○	○	○
Muskeg Bay (0903000904)	505	Willow Creek	Headwaters to Lake of the Woods	Fish	⭘	⭘	⭘	⭘
	523	Unnamed ditch	to Unnamed ditch	Fish	⭘	○	○	○
				Macroinvert.	⭘	○	⭘	⭘
	560	County Ditch 20	Headwaters to Lake of the Woods	Macroinvert.	⭘	⭘	⭘	⭘

*● = high risk, ⭘ = medium risk, ○ = low risk

Pollutant sources

Point and nonpoint sources of pollutants are identified in Table 4 and Table 5, respectively. Table 4 and Table 5 are summarized from the MPCA’s SID Report (MPCA 2016b) and the LOWW TMDL study (HEI 2016b). It is important to note that the magnitude of sources in Table 5 are inferred from the studies conducted during this investigation, and were not validated by monitoring and/or mass balance investigations. Information regarding the geographic location of nonpoint sources and prioritization for implementation is detailed in Section 3 where various methods of targeting and evaluating geographic areas are described.

Table 4: Point sources in the Lake of the Woods Watershed.

Subwatershed	Point Source			Pollutant reduction needed beyond current permit conditions/limits?	Notes
	Name	Permit #	Type		
Zippel Creek (0903000902)	Williams Wastewater Treatment Facility	MN0021679	Municipal wastewater	No	WLAs based on current permitted TSS limit of 65 mg/L

Table 5: Nonpoint Sources in the Lake of the Woods Watershed. Relative magnitudes of contributing sources are indicated.

HUC-10 Subwatershed	Stream/Reach (AUID)	Pollutant	Pollutant Sources						
			Upland Erosion	Poor Riparian Vegetation Cover	Flow Alteration	Bank Erosion	Wildlife	Livestock	Failing Septic Systems
Bostic Creek	537	TSS	⭘	⭘	⭘	○			
Muskeg Bay	505	TSS	⭘	○	●	⭘			
Warroad River	502	TSS	⭘	⭘	⭘				
	503	*E. coli*					○	●	○
Zippel Creek	501	TSS	⭘	○	●	○			
	515	TSS	○	○	●	○			

*● = high risk, ⭘ = medium risk, ○ = low risk

2.4 TMDL Summary

For purposes of the TMDL study, the LOWW was divided into four 10-digit HUC subwatersheds used to organize TMDL components. These subwatersheds include Bostick Creek (0903000901), Zippel Creek (0903000902), Warroad River (0903000903) and Muskeg Bay (0903000904) HUC-10 Subwatersheds (Figure 2). There are impaired waters located in the Zippel Creek, Warroad River, and Muskeg Bay Subwatersheds. Overall, three TMDLs were developed to address the impairments within the three subwatersheds. There are no impaired waters located in the Bostic Creek Subwatershed; therefore, it was not included in the TMDL study.

Five of the seven impaired stream reaches within the LOWW were identified as being impaired due to a pollutant with a water quality standard. As such, a TMDL study is required to identify allowable loads needed to achieve numeric water quality standards and meet the water quality goals. Of the five stream reaches impaired due to a pollutant with a water quality standard, only three received TMDL studies (TSS), with the remaining two (DO, *E. coli*) being deferred to future TMDL studies. The ones deferred were due to a lack of sufficient data to complete a TMDL at this time. The loading capacities and allocations developed as part of the Lake of the Woods TMDL Study are provided below (HEI 2016b). The nature of the impairments leading to the lack of support for aquatic life and recreation are those commonly occurring in highly modified landscapes, including an overabundance of sediment, low DO, excessive bacteria in the water, and reduced biological abundances. The following tables show the maximum allowable load (loading capacity) and the amount that can come from nonpoint sources (load allocation) and point sources (wasteload allocation). The tables also show the reduction from the existing load needed based on load duration curves. A portion of the allowable load (10%) is placed in the “margin of safety” category reflecting a level of uncertainty in the analysis. The critical duration period for each of the waterbodies is provided elsewhere (HEI 2016b).

Total Suspended Solids

In January of 2015, the EPA issued an approval of the adopted amendments to the State Water Quality Standards, replacing the turbidity standard with TSS standards. Given the change, TSS TMDL studies are being completed to address the impairments. The existing TSS contributions, along with the loading capacity, wasteload allocation, load allocation, and margin of safety (MOS) to meet the standard for the LOWW are summarized by flow condition in Table 6 through Table 8**.** The analysis is based on using the concentrations of TSS using load duration curves. While AUID 09030009-523 was not listed as impaired for TSS, a TMDL study was prepared to partially address the fish and macroinvertebrate biological impairments in that stream reach as high suspended sediment was indicated as a stressor for those impairments.

Table 6: TSS loading capacities and allocations for AUID 09030009-501 (Williams Creek).

Total Suspended Solids		**Flow Condition**				
		High	**Moist Conditions**	**Mid-Range**	**Dry Conditions**	**Low**
		[tons/day]				
Loading Capacity		**3.48**	**1.19**	**0.52**	**0.27**	**0.20**
Wasteload Allocation	**Total WLA**	**0.10**	**0.10**	**0.10**	**0.10**	**0.1**
	Williams WWTF	0.1	0.1	0.1	0.1	0.1
	Construction/Industrial Stormwater	0.0035	0.0012	0.0005	0.0003	0.0001
Load Allocation	**Total LA**	**3.03**	**0.97**	**0.37**	**0.14**	**0.09**
Margin of Safety (MOS)		**0.35**	**0.12**	**0.05**	**0.03**	**0.01**
Existing Load		**8.36**	**1.74**	**0.30**	**0.21**	**0.08**
Unallocated Load		**0.00**	**0.00**	**0.22**	**0.06**	**0.12**
Estimated Load Reduction		**58%**	**32%**	**0%**	**0%**	**0%**

Loading capacity, wasteload allocation, load allocation, and margin of safety are part of the TMDL equation (Section 4) The existing load is based on available water quality data; the unallocated load is the load, if any, that remains if the existing load is below the load capacity minus the margin of safety; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

Table 7: TSS loading capacities and allocations for AUID 09030009-515 (West Branch Zippel Creek).

Total Suspended Solids		**Flow Condition**				
		High	**Moist Conditions**	**Mid-Range**	**Dry Conditions**	**Low**
		[tons/day]				
Loading Capacity		**4.31**	**1.50**	**0.64**	**0.32**	**0.10**
Wasteload Allocation	**Total WLA**	**0.0043**	**0.0015**	**0.0006**	**0.0003**	**0.0001**
	Construction/Industrial Stormwater	*0.0043*	*0.0015*	*0.0006*	*0.0003*	*0.0001*
Load Allocation	**Total LA**	**3.87**	**1.35**	**0.58**	**0.28**	**0.09**
Margin of Safety (MOS)		**0.43**	**0.15**	**0.06**	**0.03**	**0.01**
Existing Load		**17.0**	**1.74**	**0.16**	**0.15**	**0.02**
Unallocated Load		**0.0**	**0.0**	**0.49**	**0.17**	**0.08**
Estimated Load Reduction		**75%**	**13%**	**0%**	**0%**	**0%**

Loading capacity, wasteload allocation, load allocation, and margin of safety are part of the TMDL equation (Section 4) The existing load is based on available water quality data; the unallocated load is the load, if any, that remains if the existing load is below the load capacity minus the margin of safety; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

Table 8. TSS loading capacities and allocations for Unnamed ditch, Unnamed ditch to Unnamed ditch (AUID 09030009-523).

Total Suspended Solids		**Flow Condition**				
		High	**Moist Conditions**	**Mid-Range**	**Dry Conditions**	**Low**
		[tons/day]				
Loading Capacity		**1.83**	**0.54**	**0.27**	**0.13**	**0.05**
Wasteload Allocation	**Total WLA**	**0.0018**	**0.0005**	**0.0003**	**0.0001**	**0.00005**
	Construction/Industrial Stormwater	*0.0018*	*0.0005*	*0.0003*	*0.0001*	*0.00005*
Load Allocation	**Total LA**	**1.65**	**0.49**	**0.24**	**0.117**	**0.04**
Margin of Safety (MOS)		**0.18**	**0.05**	**0.03**	**0.013**	**0.005**
Existing Load		**2.7**	**0.40**	**0.02**	**0.01**	**0.002**
Unallocated Load		**0.0**	**0.1**	**0.25**	**0.12**	**0.046**
Estimated Load Reduction		**32%**	**0%**	**0%**	**0%**	**0%**

2.5 Protection Considerations

Designation of streams as candidates for protection or restoration is important for identifying resource management needs and aligning with the Nonpoint Priority Funding Plan for Clean Water Funding Implementation (https://bwsr.state.mn.us/practices/climate_change/Water_Planning.pdf) and Minnesota's Clean Water Roadmap (https://www.pca.state.mn.us/sites/default/files/wq-gov1-07.pdf). Streams in the LOWW are designated as either “protection” or “restoration” based on the available water quality monitoring data. The protection and restoration designations are divided into subcategories to guide management efforts and reflect priorities in the Nonpoint Priority Funding Plan for Clean Water Funding Implementation. The categorization will be used in prioritizing the use of limited time and fiscal resources to stream and lake projects most likely to be successful in protecting and/or restoring water quality.

Streams and rivers currently supporting aquatic life and aquatic recreation in the LOWW are candidates for protection. The purpose of the protection strategy is to reasonably ensure the beneficial uses are maintained into the future. Some of the implementation strategies are focused on protecting these waters. For streams and rivers, the purpose of the protection strategy is to reasonably ensure that the existing loads for the critical duration periods are maintained or reduced.

Stream Protection and Restoration Categories

Stream reaches in the LOWW were prioritized and classified into Protection or Restoration categories based on their existing water quality. Water quality data from 2004 through 2013 were obtained from the MPCA Environmental Quality Information System (EQuIS). Streams assessed as impaired by the MPCA are designated for restoration and those assessed as not impaired are designated for protection. In order to classify stream reaches that have not been assessed by the MPCA, the minimum number of data observations for data analysis was set at five samples for TSS, phosphorus, and nitrate-nitrogen and three samples for *E. coli*. The available data were compared to Class 2A water quality standards for TSS, phosphorus, and *E. coli* and the drinking water standard for nitrate-nitrogen in assigning the reaches to protection or restoration categories. This classification does not replace the formal assessment of streams for impairment following MPCA procedures when adequate data are present. The categories are further divided into subcategories. Streams within the “protection” category are subdivided into three subcategories: Above Average Quality, Potential Impairment Risk, and Heightened Impairment Risk. Streams within the “restoration” category are subdivided into two subcategories: Low Restoration Effort and High Restoration Effort.

Descriptions of the stream protection and restoration categories and water quality attributes for each category is described below, followed by maps of the stream categories by protection and restoration subcategory (Figure 3 for Above Average Quality, Figure 4 for Potential Impairment Risk, Figure 5 for Threatened Impairment Risk, Figure 6 for Low Restoration Effort, and Figure 7 for High Restoration Effort).

Protection Categories

All streams currently supporting aquatic life and aquatic recreation in the LOWW are considered for protection strategies, using a risk-based approach. For purposes of this assessment, LOWW streams within the “protection” category are subdivided into three subcategories: Above Average Quality, Potential Impairment Risk, and Threatened Impairment Risk.

Surface waters exhibiting Above Average Quality for a water quality parameter are defined as those portions of a river or stream (i.e., AUID number) which:

1. have no impairments, and meet the full MPCA assessment methods for determining whether an impairment exists and the 90th percentile (TSS, total phosphorus [TP], NO2+NO3) or the geometric mean (*E. coli*) are less than 75% of the numeric standard; or
2. do not meet the data requirements of MPCA assessment methods (have less than 20 samples, or 5 samples per month for *E. coli*) yet still have a minimum of 5 samples for the AUID number (or 3 samples per month for *E. coli*), if no samples exceed the numeric water quality standard for the AUID number, and the 90th percentile concentration (geometric mean for *E. coli*) of a water quality parameter is less than 75% of the numeric water quality standard.

Potential Impairment Risk for a water quality parameter is defined as the portions of a river or stream with water quality conditions “near” but not exceeding the numeric water quality standard for a given parameter. Surface waters exhibiting Potential Impairment Risk are defined by the following circumstances:

1. When the data requirements of MPCA assessment methods are met (number of samples is greater than 20, or 5 samples per month for *E. coli*), surface waters in the Potential Impairment Risk

subcategory for *E. coli*, inorganic nitrogen, TP, or TSS are defined by the 90th percentile (geometric mean for *E. coli*) concentration exceeding 75%, but less than 90% of the numeric water quality standard.

2. When the data requirements of MPCA assessment methods are not met (number of samples is less than 20, but greater than 5; or less than 5 but at least 3 samples per month for *E. coli*), a Potential Impairment Risk is defined as the 90th percentile (geometric mean for *E. coli*) concentration exceeding 75% of the water quality standard, but not exceeding the water quality standard for a given water quality parameter.

Surface waters exhibiting Threatened Impairment Risk are defined as those portions of a river or stream (i.e., AUID number) with water quality conditions "very near" and which periodically exceed numeric standards, but the number of samples is insufficient to meet the MPCA assessment criteria (the number of samples are greater than 20, or greater than 5 per month for *E. coli*). A Threatened Impairment Risk is categorized as:

1. When the data requirements of MPCA assessment methods are met (number of samples is greater than 20, or 5 samples per month for *E. coli*), the 90th percentile (geometric mean for *E. coli*) concentration exceeding 90%, but less than the numeric water quality standard.
2. The 90th percentile (or geometric mean for *E. coli*) concentration below 110% of the water quality standard when an AUID number has more than 10 samples but less than 20; or
3. When the number of samples is less than 10 but greater than 5, a Threatened Impairment Risk is defined as the 90th percentile (or geometric mean for *E. coli*) concentration less than 120% of the water quality standard. This limits the number of exceedances to one or two observances.

For streams, rivers, and lakes the protection strategy consists of working toward ensuring the existing loads for the critical duration periods are not exceeded. Strategies for addressing protection of these waters are discussed in more detail in Section 3 of this report. Maps of the protection categories by parameter are displayed in Figure 3, Figure 4, and Figure 5.

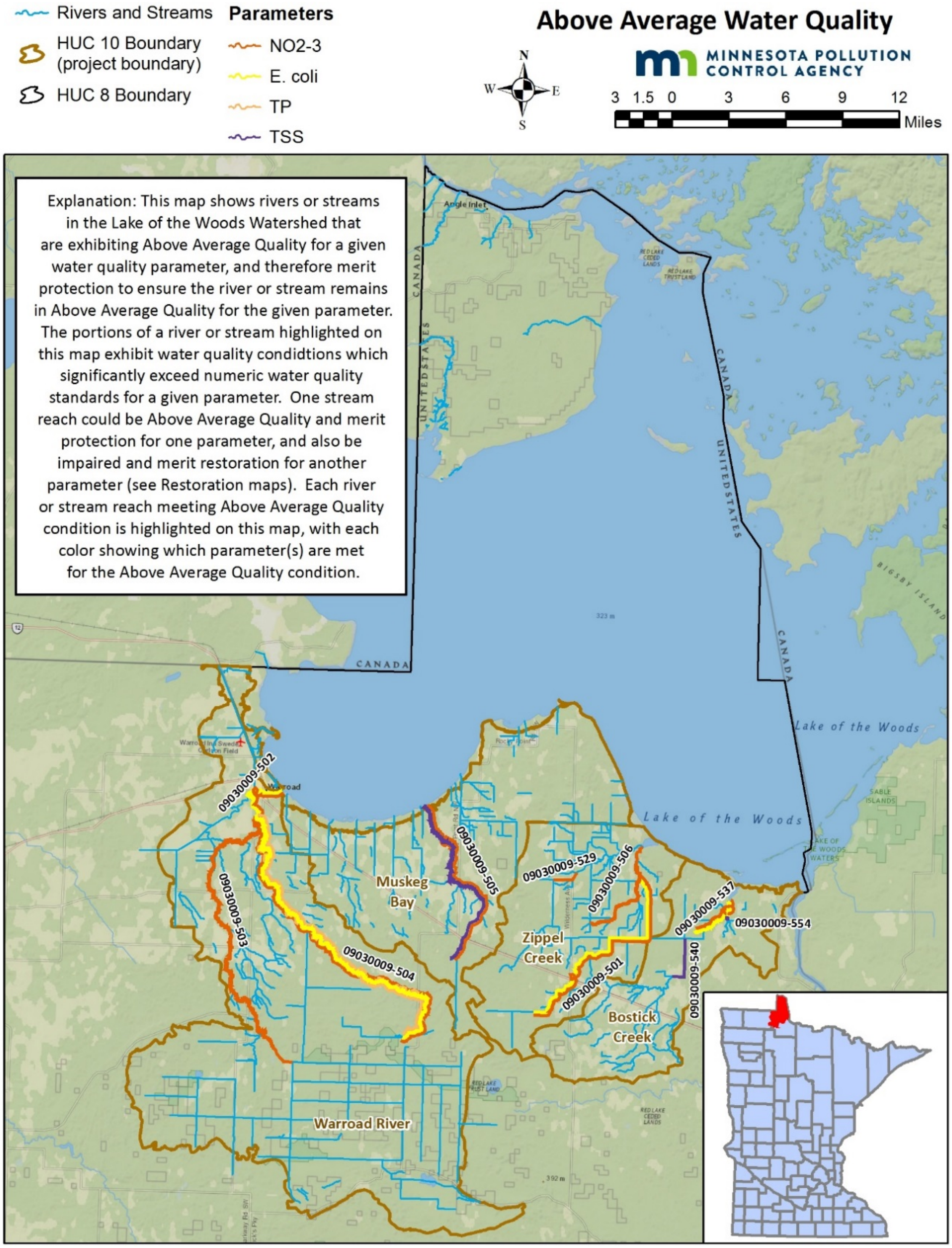
Restoration Categories

LOWW streams in the "restoration" category fail to achieve some minimum threshold condition. Example minimum threshold conditions include failure to achieve a water quality standard or a condition considered degraded or unstable, such as areas of accelerated stream bank erosion. Restoration categories are further divided into two different subcategories: Low Restoration Effort and High Restoration Effort.

Low Restoration Effort is defined as a degraded condition but a condition near the designated minimum threshold. An example is a portion of a river or stream where the numeric standard is exceeded (and therefore is "impaired"), but with restoration has a high probability of attaining the numeric water quality standard. Surface waters are defined as a Low Restoration Effort if more than 5 samples are collected, of which no more than 25% of the samples exceed the water quality standard. Surface waters may also be in the Low Restoration Effort category if the 90th percentile of the samples (5 or more required) is within 125% of the water quality standard.

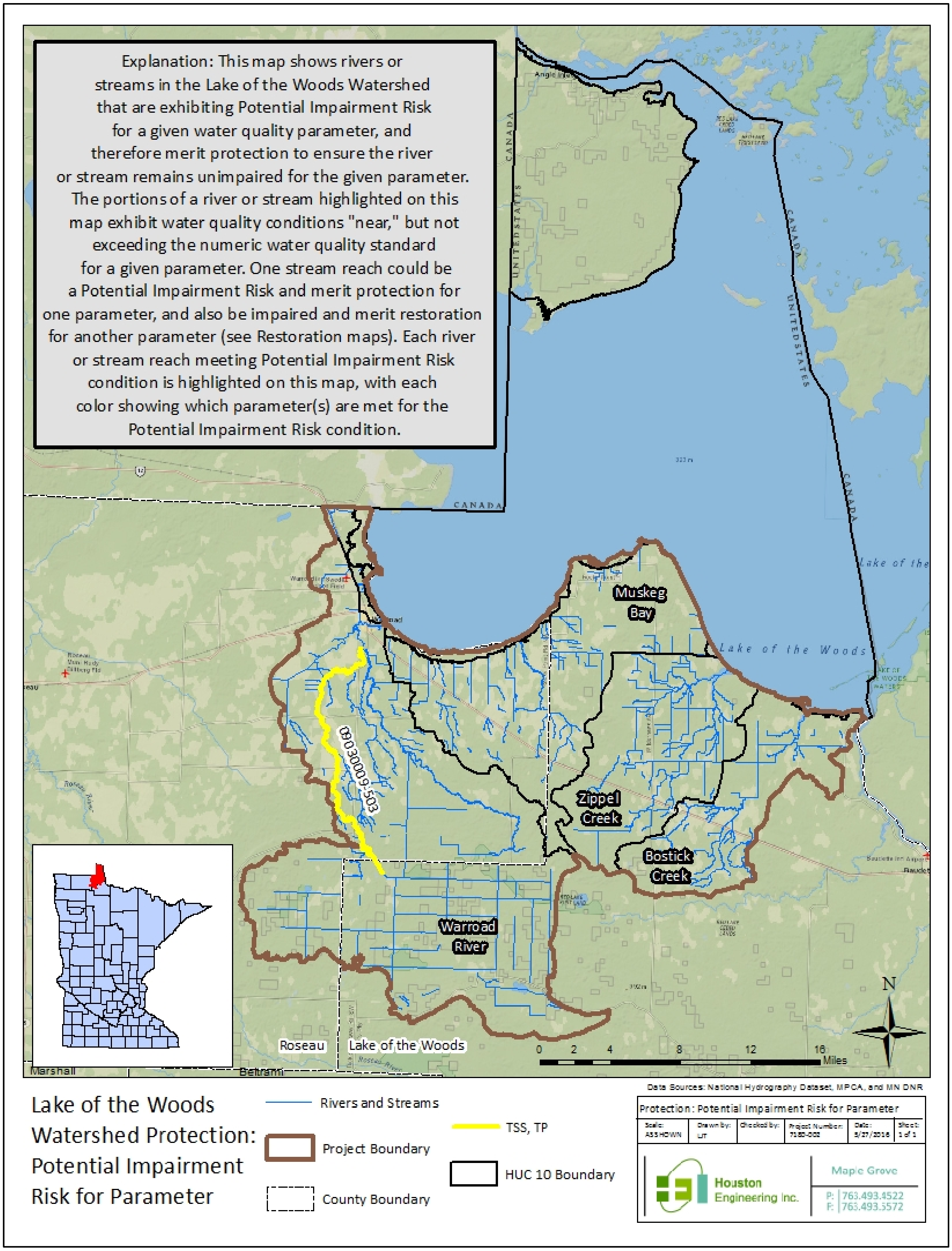
Surface waters in the High Restoration Effort category are degraded, and are no longer near the designated threshold. These surface waters have a lower probability of attaining the numeric water quality standard and may require a large effort to attain water quality compliance. High Restoration Effort surface waters are impaired, with the 90th percentile of at least five samples exceeding 125% of the water quality standard. Impaired waters are also defined in the High Restoration Effort category if more than 25% of samples (five or more required) exceed the water quality standard.

Maps of the restoration categories by parameter are displayed in Figure 6 and Figure 7.



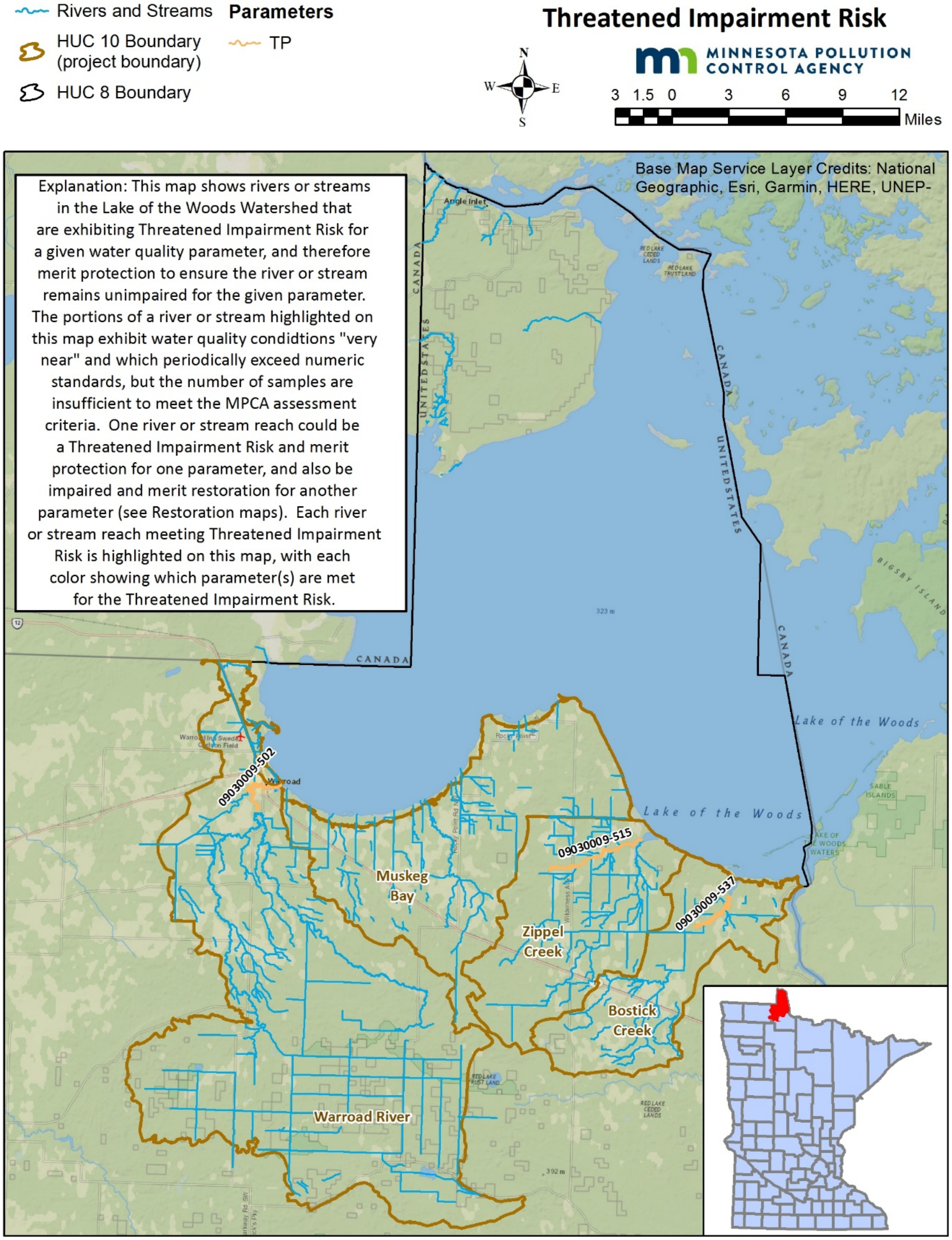
Explanation: This map shows rivers or streams in the Lake of the Woods Watershed that are exhibiting Above Average Quality for a given water quality parameter, and therefore merit protection to ensure the river or stream remains in Above Average Quality for the given parameter. The portions of a river or stream highlighted on this map exhibit water quality condidtions which significantly exceed numeric water quality standards for a given parameter. One stream reach could be Above Average Quality and merit protection for one parameter, and also be impaired and merit restoration for another parameter (see Restoration maps). Each river or stream reach meeting Above Average Quality condition is highlighted on this map, with each color showing which parameter(s) are met for the Above Average Quality condition.

Figure 3: Surface waters exhibiting Above Average Quality for a given water quality parameter, and therefore merit protection



Explanation: This map shows rivers or streams in the Lake of the Woods Watershed that are exhibiting Potential Impairment Risk for a given water quality parameter, and therefore merit protection to ensure the river or stream remains unimpaired for the given parameter. The portions of a river or stream highlighted on this map exhibit water quality conditions "near," but not exceeding the numeric water quality standard for a given parameter. One stream reach could be a Potential Impairment Risk and merit protection for one parameter, and also be impaired and merit restoration for another parameter (see Restoration maps). Each river or stream reach meeting Potential Impairment Risk condition is highlighted on this map, with each color showing which parameter(s) are met for the Potential Impairment Risk condition.

Figure 4: Surface waters exhibiting Potential Impairment Risk for a given water quality parameter, and therefore merit protection.

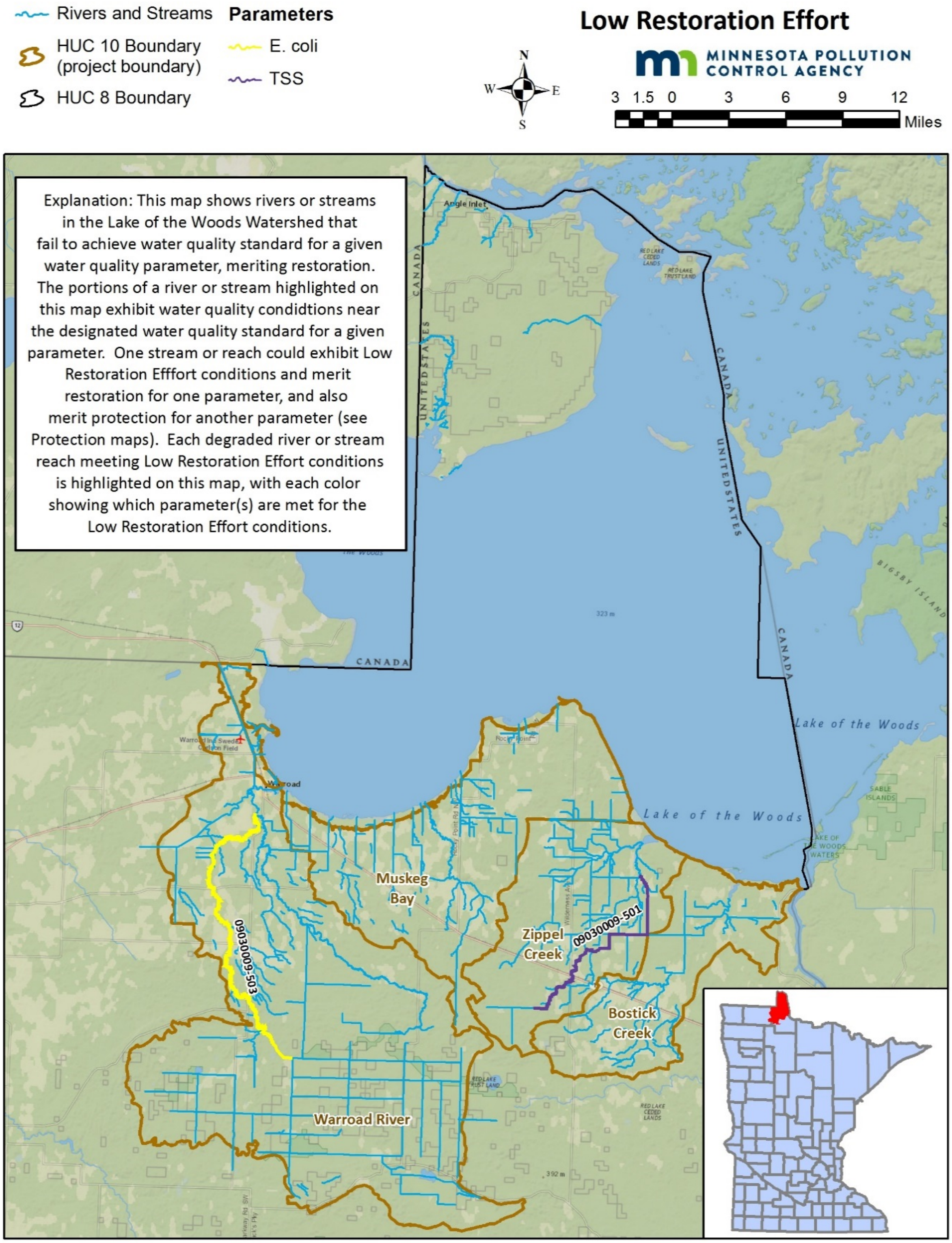


Threatened Impairment Risk

Explanation: This map shows rivers or streams in the Lake of the Woods Watershed that are exhibiting Threatened Impairment Risk for a given water quality parameter, and therefore merit protection to ensure the river or stream remains unimpaired for the given parameter. The portions of a river or stream highlighted on this map exhibit water quality condidtions "very near" and which periodically exceed numeric standards, but the number of samples are insufficient to meet the MPCA assessment criteria. One river or stream reach could be a Threatened Impairment Risk and merit protection for one parameter, and also be impaired and merit restoration for another parameter (see Restoration maps). Each river or stream reach meeting Threatened Impairment Risk is highlighted on this map, with each color showing which parameter(s) are met for the Threatened Impairment Risk.

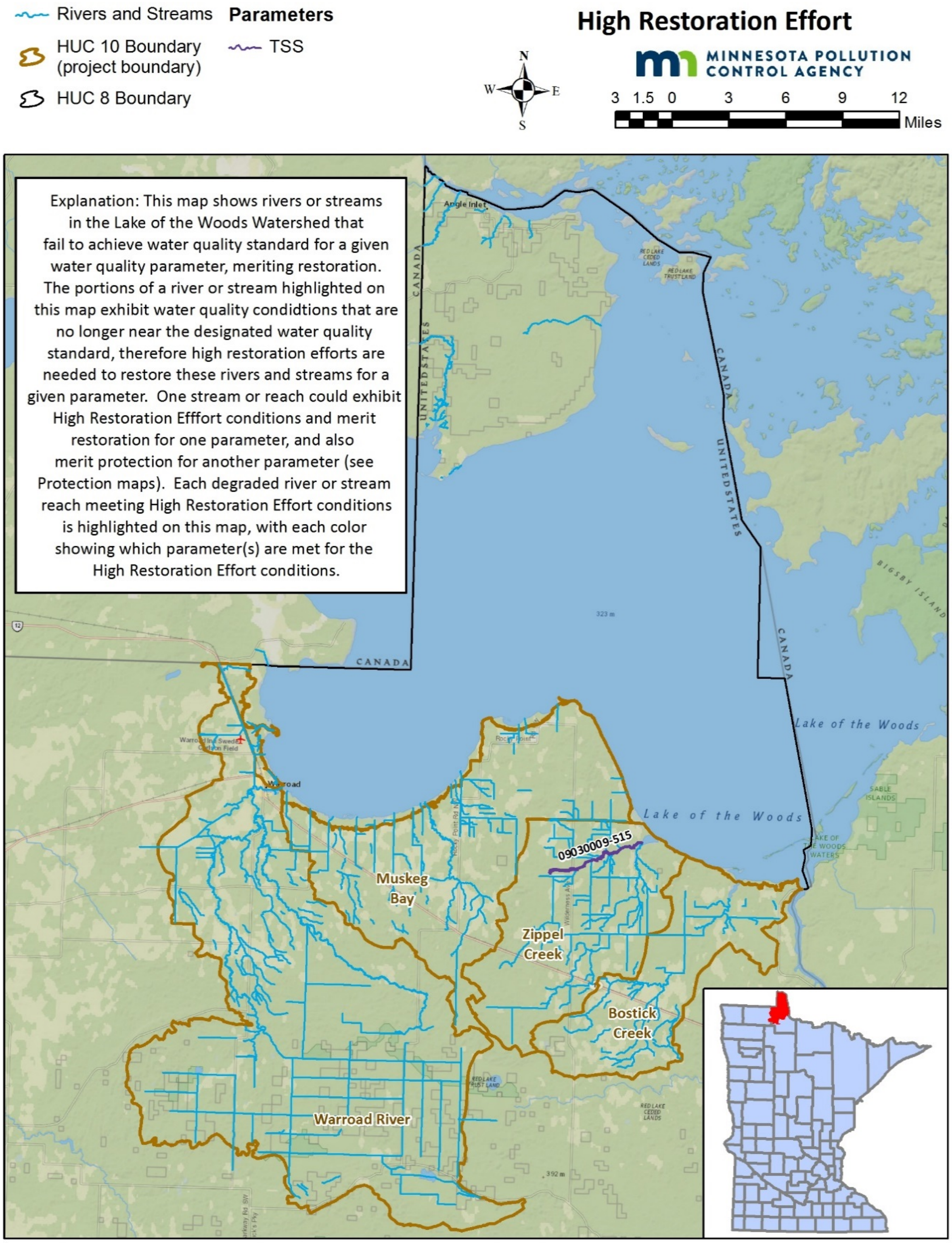
Base Map Service Layer Credits: National Geographic, Esri, Garmin, HERE, UNEP-

Figure 5: Surface waters exhibiting Threatened Impairment Risk for a given water quality parameter, and therefore merit protection.



Explanation: This map shows rivers or streams in the Lake of the Woods Watershed that fail to achieve water quality standard for a given water quality parameter, meriting restoration. The portions of a river or stream highlighted on this map exhibit water quality condidtions near the designated water quality standard for a given parameter. One stream or reach could exhibit Low Restoration Efffort conditions and merit restoration for one parameter, and also merit protection for another parameter (see Protection maps). Each degraded river or stream reach meeting Low Restoration Effort conditions is highlighted on this map, with each color showing which parameter(s) are met for the Low Restoration Effort conditions.

Figure 6: Surface waters categorized as Restoration: Low Restoration Effort by water quality parameter.



Explanation: This map shows rivers or streams in the Lake of the Woods Watershed that fail to achieve water quality standard for a given water quality parameter, meriting restoration. The portions of a river or stream highlighted on this map exhibit water quality condidtions that are no longer near the designated water quality standard, therefore high restoration efforts are needed to restore these rivers and streams for a given parameter. One stream or reach could exhibit High Restoration Efffort conditions and merit restoration for one parameter, and also merit protection for another parameter (see Protection maps). Each degraded river or stream reach meeting High Restoration Effort conditions is highlighted on this map, with each color showing which parameter(s) are met for the High Restoration Effort conditions.

Figure 7: Surface waters categorized as Restoration: High Restoration Effort by water quality parameter.

In addition to mapping stream protection and restoration categories, the loading capacity, existing loads, and remaining loading capacity were calculated for any stream reach with water quality data and which were explicitly represented in the HSPF watershed model, or had observed daily streamflows. Loading capacities and existing loads were calculated for each of the parameters (TSS, TP, NO2+NO3, and *E. coli*) and the Tables can be found in Appendix A**.** A summary of the results are provided as Table 9. Table 9 shows the critical flow regime where the lowest percentage of remaining load occurs based on any existing loads and the calculated load capacities. If the percentage of remaining load is negative, the existing load exceeds the remaining load and the reach is either impaired for the parameter or existing data indicates impairment but does not meet the assessment criteria.

It should be noted that the existing loads shown in Table 9 may be estimated based on one sample, no consideration for the number of water quality samples was given, and official assessment by the MPCA is needed to confirm impairment. For TSS, most stream reaches exceed the TSS load capacity (based on the 15 milligram per liter [mg/L] numeric standard) for at least one flow regime. For TP, all stream reaches with water quality data (where an existing load can be computed) have at least one flow regime exceeding the load capacity (based on the 0.05 mg/L numeric standard). All stream reaches show good water quality relating to inorganic nitrogen (NO2+NO3) and are well below the loading capacity (based on the Class 1 numeric standard of 10 mg/L).

The results shown in Table 9 and the protection/restoration classification maps (Figure 3 through Figure 7) should be used to provide guidance for the prioritizing of protection strategies. A summary of water quality used to develop the maps and Table 9 are provided in Appendix A, as well as the estimated existing load, loading capacity, and protection/restoration classification for each parameter shown. It should be noted that the existing loads and loading capacity in the tables in Appendix A are dependent on availability of flows from the HSPF model. Therefore, the time-period for the existing loads and loading capacity is 2004 through 2013.

Table 9. Critical flow regimes and percentage of remaining load capacity of stream reaches in LOWW.

HUC 10 Subwatershed	AUID (Last 3 digits)	TSS		TP		NO2+NO3		*E. coli*	
		Critical Flow Regime	Remaining Load (%)[1]	Critical Flow Regime	Remaining Load (%)[1]	Critical Flow Regime	Remaining Load (%)[1]	Critical Flow Regime	Remaining Load (%)[1]
Bostic Creek (0903000901)	537	High	0%	Dry Condition	0%	--	--	--	--
	539	--	--	--	--	--	--	--	--
	540	--	--	--	--	--	--	--	--
	546	--	--	--	--	--	--	--	--
	553	--	--	--	--	--	--	--	--
Zippel Creek (0903000902)	501	High	0%	High	0%	Moist Conditions	99%	--	--
	506	Mid-Range	11%	Moist Conditions	0%	High	100%	--	--
	515	High	0%	High	0%	High	98%	--	--
	516	--	--	--	--	--	--	--	--
	518	--	--	--	--	--	--	--	--
	529	--	--	--	--	--	--	--	--
	567	--	--	--	--	--	--	--	--
Warroad River (0903000903)	502	Moist Conditions	0	--	--	--	--	--	--
	503	Mid-Range	39%	Dry Condition	0%	Moist Conditions	99%	Low	30%
	504	Mid-Range	60%	High	0%	Moist Conditions	100%	Moist Conditions	9%
	526	--	--	--	--	--	--	--	--
	533	--	--	--	--	--	--	--	--
	557	--	--	--	--	--	--	--	--
	558	--	--	--	--	--	--	--	--
Muskeg Bay (0903000904)	505	Low	13%	Mid-Range	0%	--	--	Dry Conditions	14%
	523	--	--	--	--	--	--	--	--
	560	--	--	--	--	--	--	--	--

[1] Percentage of remaining load capacity, negative number means existing load exceeds load capacity

--No Available Data

3. Prioritizing and Implementing Restoration and Protection

The Clean Water Legacy Act (CWLA) requires that WRAPS reports summarize priority areas for targeting actions to improve water quality, identify point sources, and identify nonpoint sources of pollution with sufficient specificity to prioritize and geographically locate watershed restoration and protection actions. In addition, the CWLA requires inclusion of strategies that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources.

This section of the report provides the results of such prioritization and strategy development. Because many of the nonpoint source strategies outlined in this section rely on voluntary implementation by landowners, land users, and residents of the LOWW, it is imperative to create social capital (trust, networks, and positive relationships) with those who will be needed to voluntarily implement best management practices (BMPs). Thus, effective ongoing public participation is fully a part of the overall plan for moving forward.

The successful implementation of restoration and protection strategies requires a combined effort from multiple entities within the LOWW, including local and state partners (i.e., soil and water conservation districts [SWCDs] and watershed districts [WDs], MPCA, Minnesota Department of Natural Resources [DNR], and the Board of Water and Soil Resources [BWSR]). By bringing these groups together in the decision making process, it will increase the transparency and eventual success of the implementation. Collaboration and compromise will also ensure that identified priorities and strategies are incorporated into local plans, future budgeting, and grant development.

The implementation strategies, including associated scales of adoption and timelines, provided in this section are the result of watershed modeling efforts and professional judgment based on what is known at this time and, thus, should be considered approximate. Furthermore, many strategies are predicated on securing needed funding. As such, the proposed actions outlined are subject to adaptive management—an iterative approach of implementation, evaluation, and course correction.

The LOWW WRAPS effort has been led by the LOW SWCD. The LOW SWCD has a long history of collaborating with local and state partners to prioritize, implement, and fund restoration and protection activities within its jurisdiction. Future restoration and protection work in the area will benefit from these relationships, building on previous successes.

3.1 Targeting of Geographic Areas

Several watershed tools were used for the purpose of simulating and evaluating hydrology and water quality (sediment, nutrients, and bacteria) within the LOWW. Tools used in this WRAPS effort include:

- HSPF;
- Enhanced Geospatial Water Quality Products (EGWQP);
- BMP Suitability Analysis;
- HSPF BMP load reduction scenarios;

- Lake of the Woods County Local Water Management Plan 2010 through 2020: 2015 Amendment;
- Roseau County Local Water Management Plan 2010 through 2019; and
- Overall Plan of the Warroad River Watershed District (WRWD).

This section gives an overview of the development of these tools, their results, and an outline of how the tools can be used in identifying restoration and protection target areas in the LOWW.

HSPF Model

The HSPF model is a watershed-scale model that simulates hydrology and water quality for both conventional and toxic organic pollutants from pervious and impervious land. The model incorporates watershed-scale and nonpoint source models into a basin-scale analysis framework. It addresses runoff and constituent loading from pervious and impervious land surfaces, and flow of water and transport/ transformation of chemical constituents in stream reaches. The output from the HSPF model is used to identify locations where average yields are greatest at the subwatershed outlet. Figure 8 displays LOWW HSPF Subwatershed priority using total sediment. More information on the LOWW HSPF model's development and calibration can be found in the modeling report (HEI 2015a).

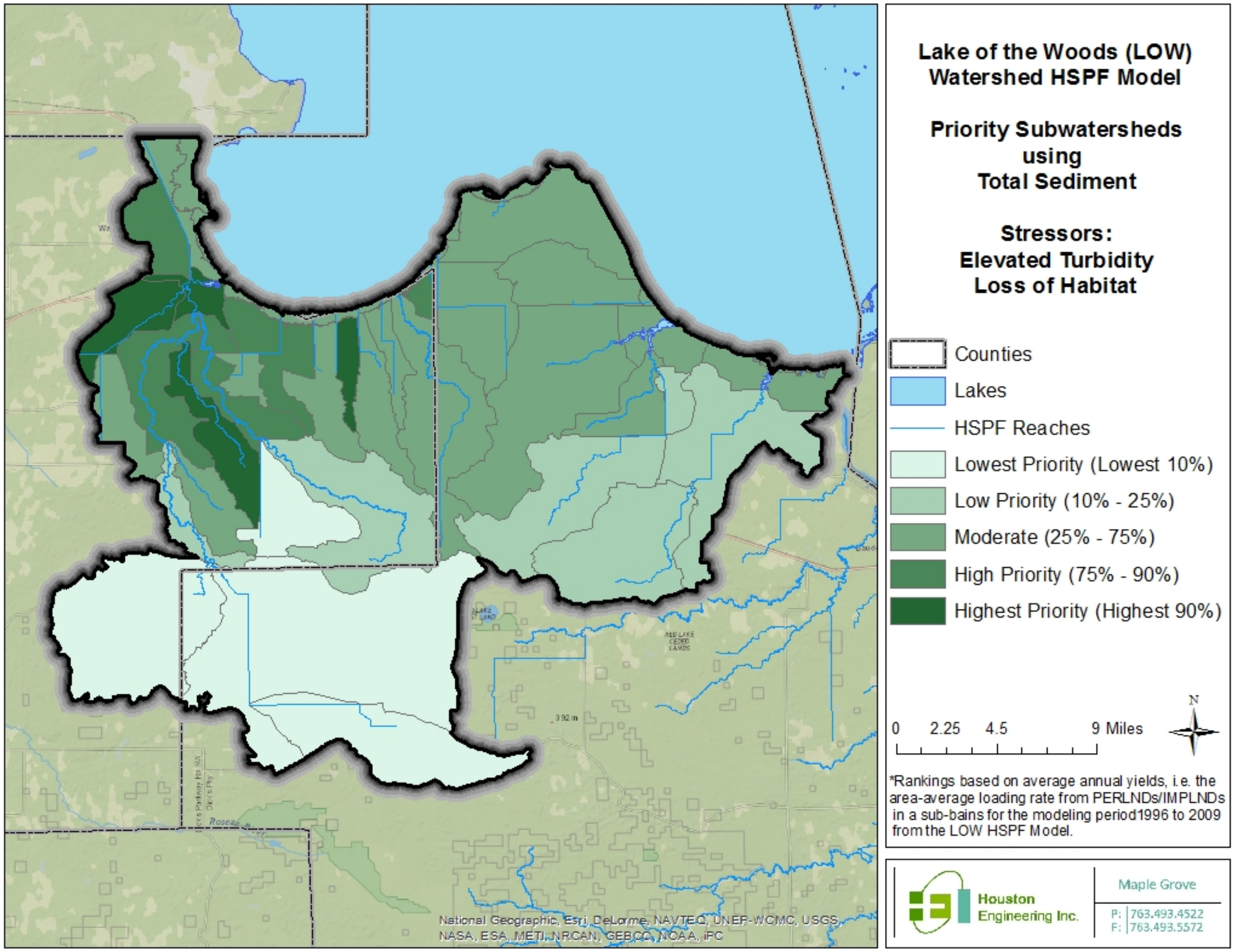


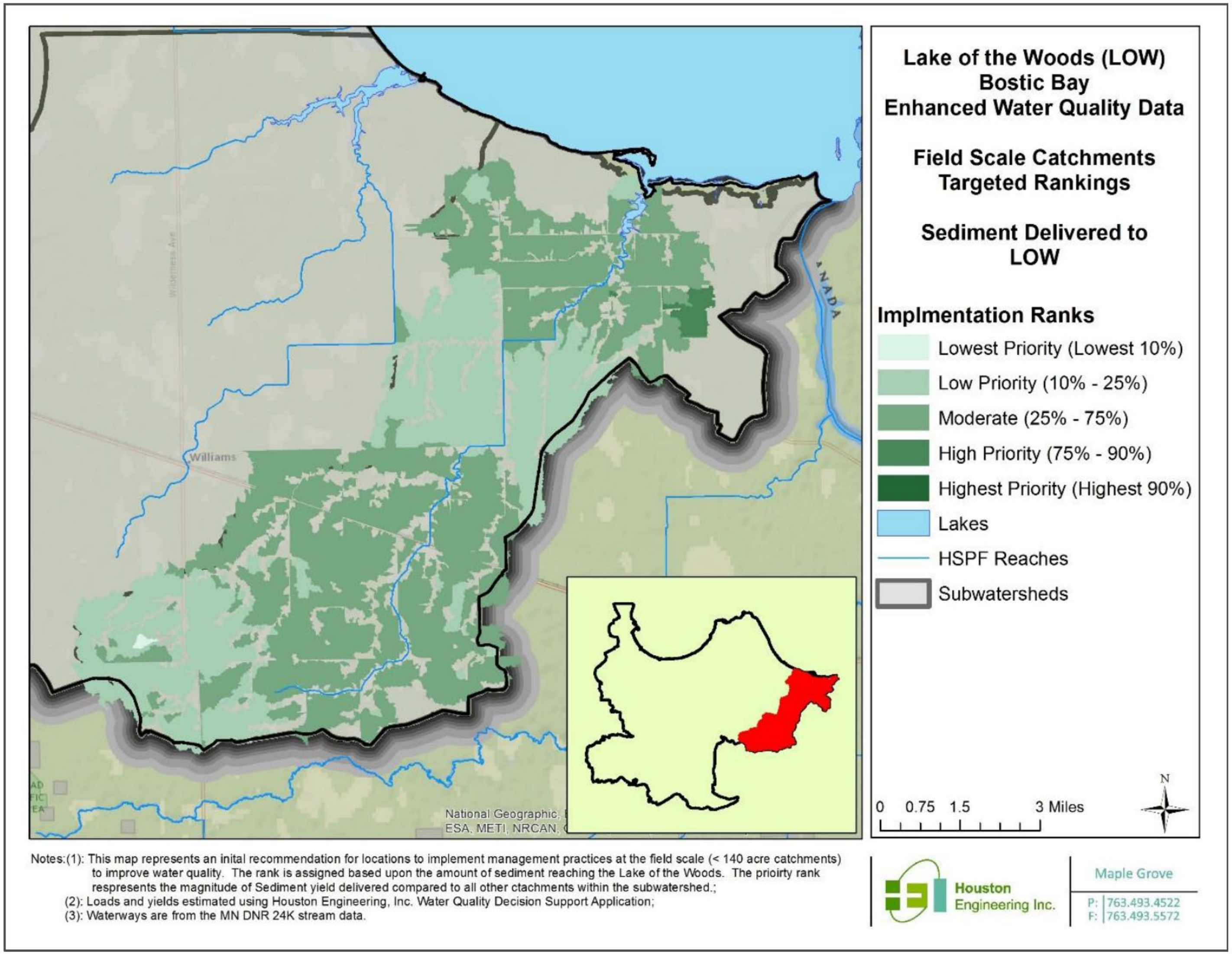
Figure 8: Tributary scale subwatershed priority for implementation for the stressors elevated turbidity and loss of habitat for LOWW using average (1996-2009) annual total sediment yields

Enhanced Geospatial Water Quality Products

Light Detection and Ranging (LiDAR) is a remote sensing technology that uses laser light to detect and measure surface features on the earth. The resulting data can be converted into elevation data and used to create a digital elevation model (DEM) for geographic information system (GIS) analysis. The general mapping and analysis of elevation/terrain has been used for erosion analysis, water storage and flow analysis, siting and design of BMPs, wetland mapping, and flood control mapping.

As part of local planning in the LOWW, EGWQP were developed for targeting fields based on yield (mass/acre/time) of sediment, total nitrogen (TN), and TP and identifying opportunities for BMP and Conservation Practice (CP) implementation.

The EGWQP were developed from GIS that used the hydrologically conditioned 3-meter DEM for LOWW (HEI 2013). Key processing steps involved the development of travel time data, and sediment, TN, and TP yield. Sediment yields leaving a landscape were estimated based on the application of the Revised Universal Soil Loss Equation (RUSLE). The RUSLE accounts for land cover, soil type, topography, precipitation, and management practices to determine an average annual sediment yield estimate. The sediment reaching a channel at the overland catchment outlet was then estimated using a sediment delivery ratio (SDR). Four products are ultimately produced: (1) sediment yield leaving the landscape; (2) sediment yield reaching the overland catchment outlet; (3) sediment yield delivered to a user defined downstream subwatershed outlet; and (4) sediment yield reaching the watershed outlet. An example of a 'Sediment Yield to the Watershed Outlet' layer can be found at Figure 9. Detailed methodology can be found within the associated technical memorandum (HEI 2015b).



Notes:(1): This map represents an inital recommendation for locations to implement management practices at the field scale (< 140 acre catchments) to improve water quality. The rank is assigned based upon the amount of sediment reaching the Lake of the Woods. The prioirty rank respresents the magnitude of Sediment yield delivered compared to all other ctachments within the subwatershed.;
(2): Loads and yields estimated using Houston Engineering, Inc. Water Quality Decision Support Application;
(3): Waterways are from the MN DNR 24K stream data.

Figure 9: Subwatershed prioritization of sediment delivered to Lake of the Woods for Bostic Creek HUC-10 using HSPF outputs.

A bacteria risk assessment was also performed using EGWQP in order to identify areas in the LOWW that pose the greatest risk for contributing bacteria to surface water resources. To identify high-risk areas, sources of bacteria in the LOWW were identified. Malfunctioning Subsurface Sewage Treatment Systems (SSTS) can be an important source of fecal contamination to surface waters, thus, the number of potential Imminent Public Health Threats (IPHT) and potentially failing SSTSs were computed per county and in the LOWW overall. Livestock populations for cattle, chickens, goats, horses, sheep, and turkeys were also estimated for each county.

The risk rankings of potential sources of bacteria in the LOWW by HUC-10 subwatershed are shown in Table 10. By ranking, livestock sources of bacteria consistently posed the greatest risk of contributing disproportionately larger quantities of bacteria to the outlet of the LOWW. Interestingly, the components for the land application of manure and AFO open lots had less impact as compared to livestock grazing for HUC-10 subwatersheds predominantly within Lake of the Woods County (Bostic Creek and Zippel Creek), as compared to subwatersheds predominantly within Roseau County (Warroad River and Muskeg Bay). Bostic Creek and Zippel Creek were also the only subwatersheds to have a risk category of medium or higher for either a human or wildlife related source. This was only found when combining all wildlife sources (geese, ducks, deer, and other wildlife) and is likely due to the smaller amount of livestock-related loading in Lake of the Woods County. Detailed methodology can be found within the associated technical memorandum (HEI 2017).

Table 10: Relative sources of *E. coli* for HUC-10 subwatersheds.

HUC-10	**HUC-10 Name**	**Humans**					**Livestock**				**Wildlife**				
		All	**WWTF Effluent**	**Failing Septic Systems**	**IPHT Septic Systems**	**Domestic Animals**	**All**	**Grazing**	**Manure**	**AFO Open Lots**	**All**	**Deer**	**Ducks**	**Geese**	**Other**
903000901	Bostic Creek	○*	○	○	○	○	●	●	○	○	◉	○	○	○	○
903000902	Zippel Creek	○	○	○	○	○	●	●	○	○	◉	○	○	○	○
903000903	Warroad River	○	○	○	○	○	●	●	●	◉	○	○	○	○	○
903000904	Muskeg Bay	○	○	○	○	○	●	●	●	◉	○	○	○	○	○

*● = high risk, ◉ = medium risk, ○ = low risk

Figure 10 ranks HUC-10 subwatersheds based on the area weighted magnitude of bacterial delivery within LOWW. Higher rates equate to a greater risk of bacterial delivery from the subwatershed to the outlet of the LOWW. Similar to the results shown in Table 10, livestock sources posed the greatest risk of bacterial delivery. The results in Figure 10 are area-weighted, so comparisons can be made between subwatersheds. This information can be used to inform the prioritization of local management efforts aimed at reducing the risk of bacterial delivery to surface waters in the LOWW based on specific bacterial groups (i.e., humans, livestock, wildlife). In addition, Figure 10 can also be used to begin targeting specific subwatersheds for bacterial restoration and protection strategies. It is important to note that the data used to develop Figure 10 is based on county-wide data that was aggregated to subwatersheds within the study area. Therefore, the source magnitudes should not be interpreted to represent the source loading of specific fields within the subwatersheds.

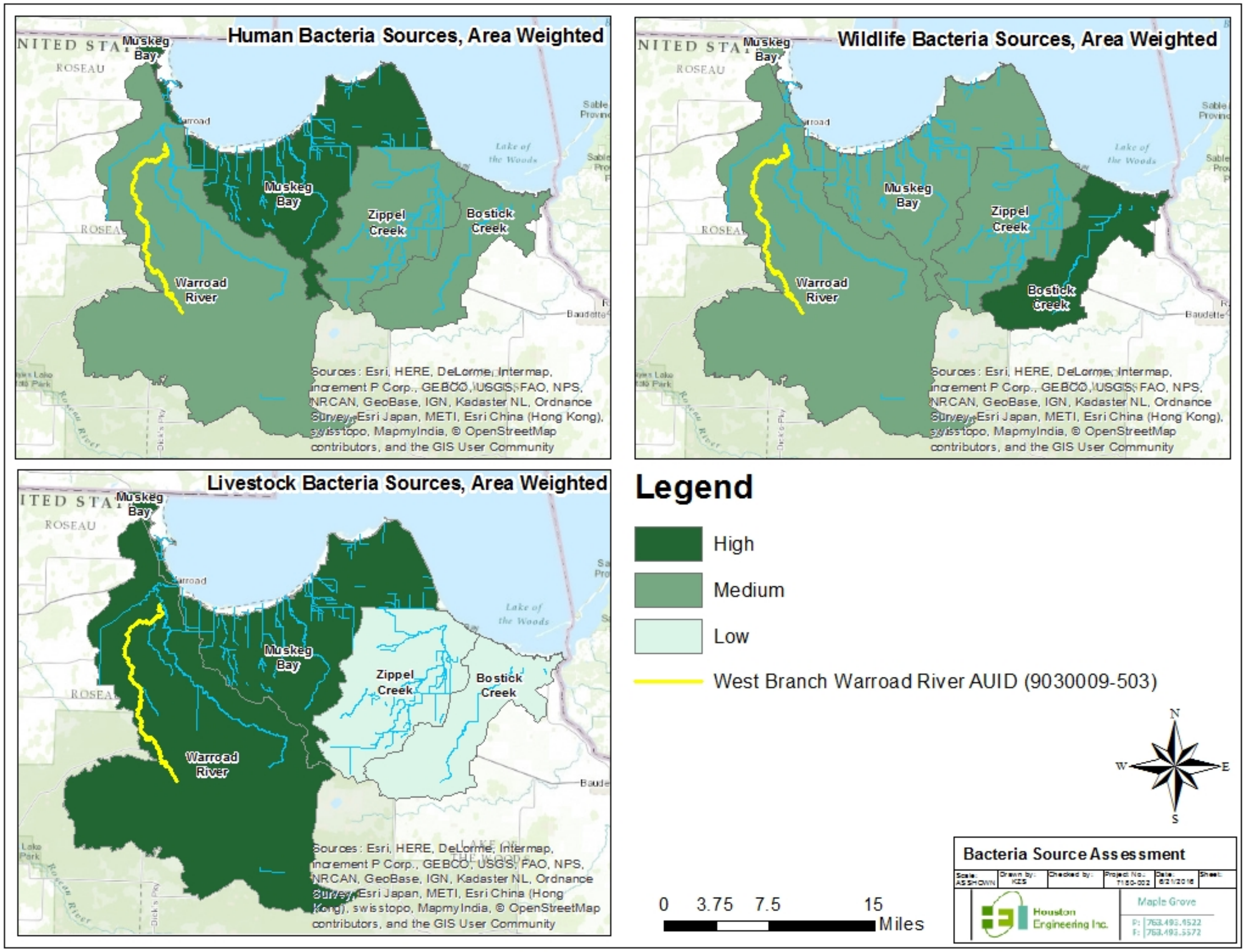
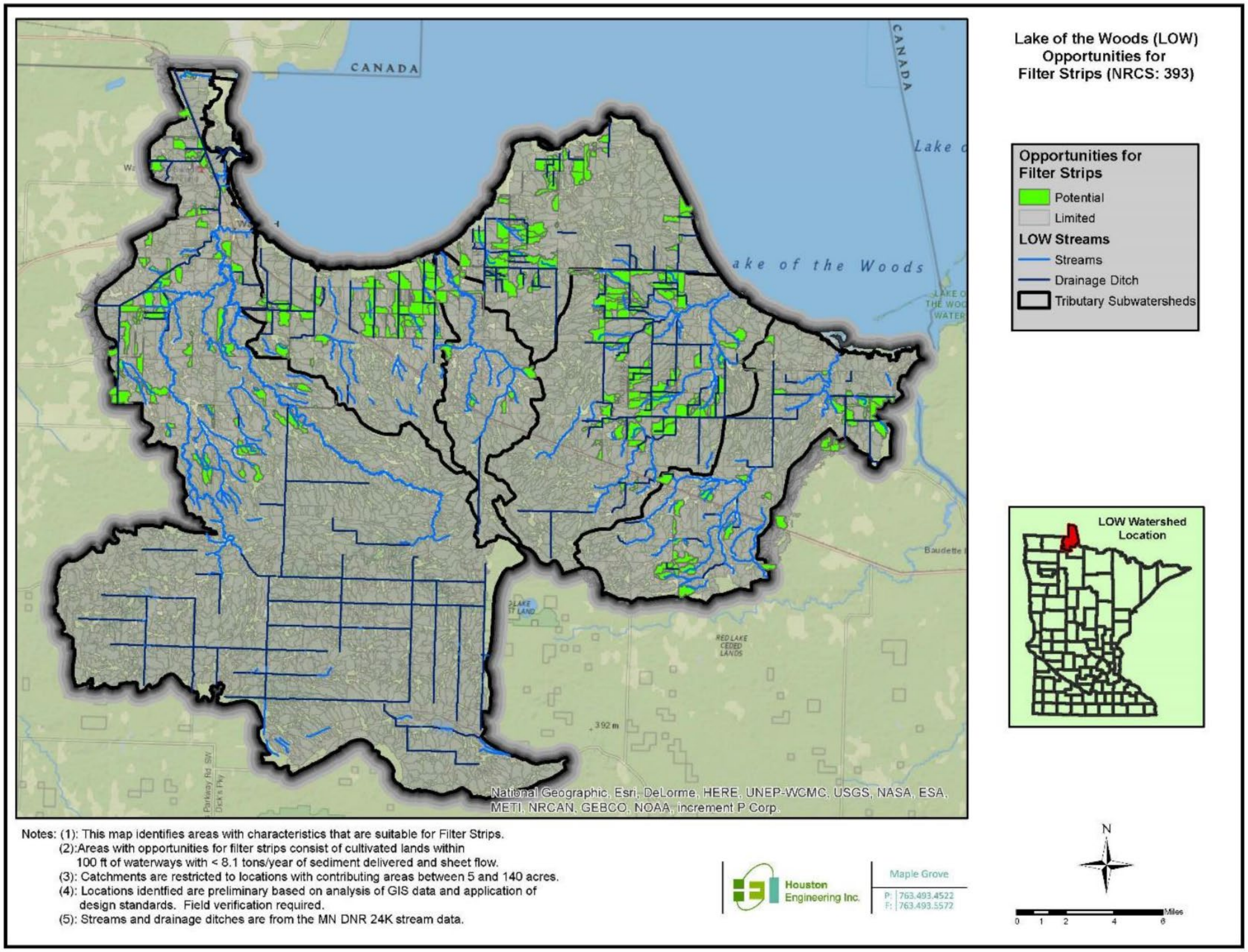


Figure 10: Ranked HUC-10 subwatersheds based upon the percentage of bacterial delivery for the three source groups in the LOWW to the Lake of the Woods. Low ranking is less than 10% of LOWW loading. Medium ranking is 10% – 30% of LOWW loading. High ranking is greater than 30% of LOWW loading. The single AUID with an *E. coil* impairment in the LOWW is highlighted in yellow.

BMP Suitability

In addition to targeting based on the delivery of water quality constituents, fields also can be targeted for opportunities to place BMPs. For instance, a field may produce a moderate to high amount of sediment, but have limited opportunities to implement BMPs to reduce sediment delivery because of the physical setting. As such, field scale opportunities to implement BMPs were targeted across the LOWW. Figure 11 shows an example of field scale catchments that have been targeted for opportunities to place filter strips. This data product can be paired with the catchments that were ranked as high priorities based on their delivery of water quality constituents to identify opportunities to implement BMPs in the locations that are contributing the highest amounts of pollutants to downstream resources. Detailed methodology can be found within the associated technical memorandum (HEI 2015b).



Notes: (1): This map identifies areas with characteristics that are suitable for Filter Strips.
(2):Areas with opportunities for filter strips consist of cultivated lands within 100 ft of waterways with < 8.1 tons/year of sediment delivered and sheet flow.
(3): Catchments are restricted to locations with contributing areas between 5 and 140 acres.
(4): Locations identfied are preliminary based on analysis of GIS data and application of design standards. Field verification required.
(5): Streams and drainage ditches are from the MN DNR 24K stream data.

Figure 11: Field scale catchments with opportunities to place filter strips in the LOWW.

HSPF BMP Load Reduction Scenario

Three HSPF model scenarios representing a range of BMP implementation “aggressiveness” were conceptualized by MPCA, LOW SWCD, and Natural Resources Conservation Service (NRCS) staff. Model inputs were revised to represent the concepts and then run as scenarios in the model. The load reduction benefits of these scenarios were then estimated using the HSPF model. The three scenarios developed and simulated using HSPF represent a range of potential strategies and implementation effort and include: (1) a maximum BMP implementation scenario; (2) a Top 25% BMP implementation scenario, and (3) a Top 10% BMP implementation scenario. The maximum BMP implementation scenario represents an upper limit on what could be achieved in terms of the load reduction by assuming all potential BMPs can be implemented. The Top 25% scenario represents a targeted implementation approach where BMPs are located and constructed only with the catchments that rank in the top 25% with regard to contributing sediment and TP to Lake of the Woods. The Top 10% scenario represents a targeted implementation approach where BMPs are located and constructed only with the catchments that rank in the top 10% with regard to contributing sediment and TP to Lake of the Woods (HEI 2015a).

Table 11 lists the BMPs used to develop the scenarios simulated using the HSPF model. These BMPs include filter strips, grass waterways, water and sediment control basins (WASCOB), saturated buffers, bioreactors, perennials, and cover crops. Additional BMPs were identified in the BMP suitability study (HEI 2015a) but limitations within HSPF restricts the types of BMPs that can be simulated to the ones listed in Table 11**.** Figure 12 shows the extent of the treated drainage area for the maximum BMP implementation scenario.

Federal assistance programs are available to aid landowners with technical and/or financial assistance in implementing BMPs displayed in Table 11. State programs include the Minnesota Agricultural Water Quality Certification Program (MAWQCP) and the AgBMP Loan Program.

The MAWQCP is a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing CPs that protect our water. It is a way for them to have at-risk areas identified and addressed to meet water quality goals. Those who implement and maintain approved farm management practices are certified and in turn obtain regulatory certainty for a period of 10 years. It also provides additional cost-share opportunities. More information can be found at the following: http://www.mda.state.mn.us/awqcp.

The AgBMP Loan Program is a water quality program that provides low interest loans to farmers, rural landowners, and agriculture supply businesses. The purpose is to encourage agricultural BMPs that prevent or reduce runoff from feedlots, farm fields, and other pollution problems identified by the county in local water plans. More information can be found at the following: http://www.mda.state.mn.us/agbmploans.

Table 11: BMP Types Simulation in LOW HSPF Scenarios.

BMP	Type	Treatment	HSPF Notes
Filter Strips	Surface Runoff BMP	Sediment (70%) Nitrogen (30%) Phosphorus (40%) BOD (30%)	Combined with grass waterways, applied to surface water only, priority for surface runoff BMPs.
Grass Waterways	Surface Runoff BMP	Sediment (70%) Nitrogen (30%) Phosphorus (40%) BOD (30%)	Combined with filter strips, applied to surface water only, priority for surface runoff BMPs.
Sediment Control Basins (WASCOBs)	Surface Runoff BMP	Sediment (60%) Phosphorus (30%)	Applied to surface runoff only, secondary to filter strips/grass waterways.
Saturated Buffers	Tile Drainage/Interflow	Nitrogen (60%) Phosphorus (60%) BOD (90%)	Applied to interflow in tiled areas, priority for tile drainage BMPs.
Bioreactors	Tile Drainage/Interflow	Nitrogen (74%) Phosphorus (76.5%)	Applied to interflow in tiled areas, secondary to saturated buffers for tile drainage BMPs.
Perennials	Land Use Change	NA	Land use change – cropland to grassland (PERLNDs), priority for land use change BMPs.
Cover Crop	Land Use Change	NA	Land use change – cropland to grassland (PERLNDs), secondary to perennials for land use change BMPs. Implemented in HSPF through low-till cropland.

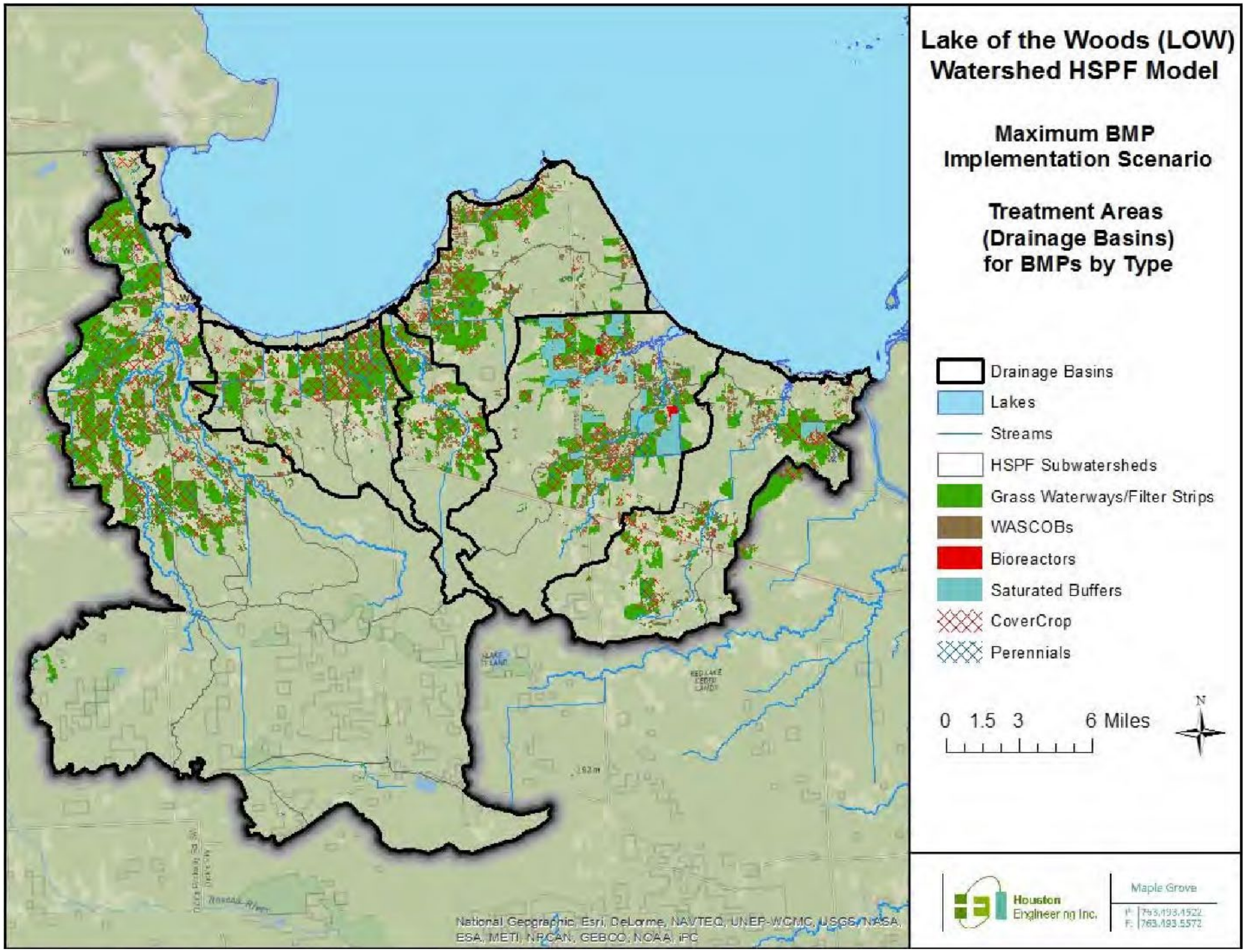


Figure 12: Drainage Areas for Maximum BMP Implementation Scenario by BMP Type.

Watershed Management Plans

Pursuant to Minnesota Statute, Lake of the Woods and Roseau Counties and the WRWD are each required to prepare a Watershed Management Plan (WMP), and to continually update and revise the plan every 10 years. The WMP is an important tool for identifying problems, issues and goals and developing long- and short-term strategies to address these issues and attain the goals. The WMP also inventories resources, assesses resource quality, and establishes regulatory controls, programs, or infrastructure improvements needed to manage the resources within the LOWW. The WMP provides guidance for each of the three districts to manage the water and natural resources within the LOWW boundary.

The Lake of the Woods County Local Water Management Plan was most recently updated in a 2015 amendment (LOW SWCD 2015). The Roseau County Local Water Management Plan was update in 2010 (Roseau SWCD 2010). The overall plan of the WRWD was updated in 2007 (WRWD 2007). In all three of the updated plans, great efforts were made to quantify the goals and suggest implementation strategies for managing water quantity and quality, as well as natural resource enhancement. Results of the WRAPS will be directly incorporated into any future updates of the LOW SWCD, Roseau SWCD and WRWD plans. However, local governments in the LOWW have embarked on a new approach to coordinated local water management moving forward.

In 2017, the LOW and Roseau SWCDs, LOW and Roseau Counties, and the WRWD partnered together to participate in the BWSR One Watershed, One Plan (1W1P) program for the LOWW. The LOW 1W1P aligns local water planning efforts along a uniform watershed boundary, which will result in more efficient water management. The LOW 1W1P was approved and adopted by the local governmental units in 2019.

Additional Tools

A number of additional tools are available for use in restoration and protection of impaired waters in the LOWW. A non-exhaustive list of some of these tools, their description, and how they may be utilized is listed in Table 12.

Table 12: Additional Tools Available for Restoration and Protection of Impaired Waters.

Tool	Description	How can the tool be used?	Notes	Link to Information and data
Ecological Ranking Tool (Environmental Benefit Index - EBI)	This dataset consists of three GIS raster data layers including soil erosion risk, water quality risk, and habitat quality. The 30-meter grid cells in each layer contain scores from 0-100. The sum of all three scores is the EBI score (max of 300). A higher score indicates a higher priority for restoration or protection.	The three layers can be used separately, or the sum of the layers (EBI) can be used to identify priority areas for restoration or protection projects. The layers can be weighted or combined with other layers to better reflect local values.	These data layers are available on the BWSR website. In addition, a GIS data layer that shows the 5% of each 8-digit watershed in Minnesota with the highest EBI scores is available for viewing in the MPCA 'water quality targeting' web map, and download from MPCA.	BWSR Water Planning BWSR Agricultural Landscapes MPCA Web Map MPCA download
Zonation	This tool serves as a framework and software for large-scale spatial conservation prioritization, and a decision support tool for conservation planning. The tool incorporates values-based priorities to help identify areas important for protection and restoration.	Zonation produces a hierarchical prioritization of the landscape based on the occurrence levels of features in sites (grid cells). It iteratively removes the least valuable remaining cell, accounting for connectivity and generalized complementarity in the process. The output of Zonation can be imported into GIS software for further analysis. Zonation can be run on very large data sets (with up to ~50 million grid cells).	The software allows balancing of alternative land uses, landscape condition and retention, and feature-specific connectivity responses. (Paul Radomski, DNR, has expertise with this tool.)	Software Examples

Table 12: Additional Tools Available for Restoration and Protection of Impaired Waters.

Tool	Description	How can the tool be used?	Notes	Link to Information and data
Restorable Wetland Inventory	A GIS data layer that shows potential wetland restoration sites across Minnesota. Created using a compound topographic index (CTI) (10-meter resolution) to identify areas of ponding, and USDA NRCS SSURGO soils with a soil drainage class of poorly drained or very poorly drained.	Identifies potential wetland restoration sites with an emphasis on wildlife habitat, surface and ground water quality, and reducing flood damage risk.	The GIS data layer is available for viewing and download on the Minnesota 'Restorable Wetland Prioritization Tool' web site.	Restorable Wetlands
National Hydrography Dataset (NHD) & Watershed Boundary Dataset (WBD)	The NHD is a vector GIS layer that contains features such as lakes, ponds, streams, rivers, canals, dams, and stream gages, including flow paths. The WBD is a companion vector GIS layer that contains watershed delineations.	General mapping and analysis of surface-water systems. These data have been used for: fisheries management, hydrologic modeling, environmental protection, and resource management. A specific application of the data set is to identify buffers around riparian areas.	The layers are available on the USGS website.	USGS
Light Detection and Ranging (LiDAR)	Elevation data in a digital elevation model (DEM) GIS layer. Created from remote sensing technology that uses laser light to detect and measure surface features on the earth.	General mapping and analysis of elevation/terrain. These data have been used for: erosion analysis, water storage and flow analysis, siting and design of BMPs, wetland mapping, and flood control mapping. A specific application of the data set is to delineate small catchments.	The layers are available on the MN Geospatial Information website for most counties.	MGIO

Table 12: Additional Tools Available for Restoration and Protection of Impaired Waters.

Tool	Description	How can the tool be used?	Notes	Link to Information and data
Hydrological Simulation Program – FORTRAN (HSPF) Model	Simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants from pervious and impervious land. Typically used in large watersheds (greater than 100 square miles).	Incorporates watershed-scale and nonpoint source models into a basin-scale analysis framework. Addresses runoff and constituent loading from pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/ transformation of chemical constituents in stream reaches.	Local or other partners can work with MPCA HSPF modelers to evaluate at the watershed scale: (1) the efficacy of different kinds or adoption rates of BMPs, and (2) effects of proposed or hypothetical land use changes.	USGS

3.2 Civic Engagement

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A key prerequisite for successful strategy development and on-the-ground implementation is meaningful civic engagement. This is distinguished from the broader term 'public participation' in that civic engagement encompasses a higher, more interactive level of involvement. The MPCA has coordinated with the University of Minnesota Extension Service for years on developing and implementing civic engagement approaches and efforts for the watershed approach. Specifically, the University of Minnesota Extension's definition of civic engagement is "Making 'resourceFULL' decisions and taking collective action on public issues through processes that involve public discussion, reflection, and collaboration." Extension defines a resourceFULL decision as one based on diverse sources of information and supported with buy-in, resources (including human), and competence. Further information on civic engagement is available on the University of Minnesota Extension website at: https://extension.umn.edu/community-development/leadership-and-civic-engagement.

A specific goal of the civic engagement process for this WRAPS was to work closely with the residents, cities, counties, businesses, and other stakeholders to ensure that their ideas, concerns, and visions for future conditions were understood and utilized throughout the WRAPS process. The WRAPS process is most likely to be successful when citizens play a greater role in helping to frame the water quality issues in their own community, as well as in the creation of the solutions to those problems. Given this, the civic engagement process included two primary components: technical stakeholder engagement and citizen engagement.

A Technical Stakeholder Group (TSG) was developed to share local knowledge about problems and to guide the development of potential implementation strategies based on technical data. The WRAPS TSG included representatives from the WRWD, the SWCDs, and state agencies. This group was primarily engaged to discuss potential products developed to identify geographic areas for implementing projects.

Accomplishments and Future Plans

The civic engagement efforts related to the LOWW WRAPS have been overseen and carried out by the LOW SWCD. Numerous public meetings and open house events were held at key points in the WRAPS process to update stakeholders on the WRAPS efforts, as well as to receive input and guidance on water quality values and concerns in the area. In addition, the LOW SWCD posted project updates on their website (http://www.lakeofthewoodsswcd.org) and a core team, including LOW SWCD board members and local/state agency partners, was established and kept abreast of technical components of the work.

Since water quality is among the priorities of the LOW SWCD management activities, future civic engagement will continue to be led by the District. The LOW SWCD will update, educate, and engage stakeholders on water quality issues through the normal district communications, including plan update events and on their website.

Expectations are that future implementation will occur through the existing water-related plans, implementation of the 1W1P, and with continued participation in local work groups to address identified erosion and sedimentation issues through priority implementation, targeted information and education, and technical assistance.

Public Notice for Comments

An opportunity for public comment on the draft WRAPS report was provided via a public notice in the State Register from November 12, 2019, to December 12, 2019. The MPCA did not receive any comment letters resulting from the public notice.

3.3 Restoration & Protection Strategies

Water quality restoration and protection strategies within the LOWW were identified through collaboration with local and state partners (i.e., SWCDs, the WRWD, MPCA, DNR, and BWSR). In 2015, Houston Engineering, Incorporated (HEI) used EGWQP and HSPF to complete a Technical Memorandum that identifies areas that are suitable for BMPs, based on sediment, TP, and TN delivery and based on priority ranking of subwatersheds in the LOWW (Appendix B). Bacteria risk areas have also been identified (HEI 2017). Based upon the HEI (2015a) study referenced in Section 3.1, the subwatersheds where BMP projects could be prioritized for implementation are defined in Table 13 and Table 14.

The Minnesota Agricultural BMP Handbook provides information on all BMPs used in Minnesota and provides an additional resource in selection of practices for implementation of a particular restoration or protection strategy.

The Lake of the Woods and Roseau SWCDs and the WRWD have a long history of water quality protection and improvement. All three have been actively seeking grants to improve local water quality since before the passage of the Clean Water, Land, and Legacy Amendment.

Five main priority concerns were identified within the Lake of the Woods County 2010 through 2020 Local Water Management Plan, 2015 amendment, including erosion and sedimentation, land use management, sewage treatment systems and other potential sources of water contamination, water quality, and education. Objectives of these priority concerns, addressed within this report, include river systems, ditch systems, buffers and riparian corridors, surface water, and sewage treatment system, and other pollution risks. Accomplished, ongoing and future actions identified to address these objectives include, but are not limited to, those summarized in Table 13 and Table 14 (LOW SWCD 2015).

Project Examples

Between 2010 and 2016, the LOW SWCD installed half a dozen shoreline stabilization and protection projects, each approximately 100 linear feet, utilizing State Cost Share Program and other funds at approximately $80 per linear foot. In addition, 640 acres of wetland surrounding Graceton Wildlife Management Area were preserved through a wetland banking program. Completion of the Bostic and Zippel Creeks' Watershed Assessment also occurred in 2013. The Low Income Septic Upgrade Grant Program, provided by the LOW SWCD, upgraded over a dozen septic systems over the past five years at a cost of $5,000 to $10,000 per septic system.

Several projects were accomplished by the LOW SWCD between 2010 and 2016 targeted at reducing pollutant loading from ditch systems. These projects include the installation of side water inlets, gully stabilization, and ditch stabilization in areas identified in the Bostic and Zippel Creek Watershed Assessment. In 2009, a Judicial Ditch was reconstructed using a two stage ditch design at a project expense of $150,000. A Clean Water Fund Grant of $61,000 was used to replace 10 side water inlets on Zippel Creek. Lastly, the LOW SWCD partnered with the LOW County Highway Department on the installation of rock chutes concurrent with a county road widening project on County Road 17. Funding was provided utilizing EQIP to accomplish 14 rock chute projects for approximately $4,500 each on Willow Creek and other unnamed ditch sections.

The LOW SWCD has identified several implementation actions planned for river systems between the years of 2016 and 2020. These include the implementation of shoreline stabilization projects and education, a workshop, and cost-share program assistance to landowners. Additionally, inventories and assessments will be used to prioritize and implement the shoreline erosion program to address watershed erosion and sedimentation problems identified in the 2013 Bostic and Zippel Creeks' Watershed Assessment (NRCS 2013). Actions targeted for the years of 2018 to 2020 are to plan restoration projects on Bostic, Zippel, and Warroad Bays, and Pine Creek once upstream erosion has been adequately addressed. Cost and timeline estimates for these restoration projects have not yet been identified. In addition to these future actions, the LOW SWCD will continue to participate in local work groups to address identified erosion and sedimentation issues through priority implementation, targeted education, and technical assistance.

Ongoing LOW SWCD planning efforts to reduce pollutant loading from ditch systems will include: update the 2010 culvert inventory; educate landowners and agriculture producers on the existence and extents of right-of-ways to assist in drainage infrastructure management; and prevent public infrastructure damage by maintaining funding for local beaver control. Actions targeted between the years of 2016 and 2020 include continued partnerships with the Lake of the Woods and Roseau County Highway Departments on road and ditch projects to implement BMPs with private landowners at the same time of construction of public road and ditch infrastructure.

Additional future implementation actions to manage ditch systems will include completion of a Clean Water Plan grant for an additional 10 side water inlet replacements in the Zippel Watershed at a cost of approximately $61,000. Projects with unidentified costs and timelines include updating and implementing a drainage management plan and policy for Lake of the Woods County utilizing the drainage committee and educating and encouraging landowners, county drainage committee, and government officials on BMPs for maintenance of ditches and CPs that can be used along ditches, watercourses, and wetlands. Implementation of the recommendations found in the NRCS' Bostic and Zippel Watershed Assessment Project and the WRAPS report would reduce erosion and sedimentation in the Bostic and Zippel Watersheds, and complete a drainage record digital inventory.

Ongoing LOW SWCD efforts targeted at improving buffers and riparian corridors include: an inventory of areas eligible for filter strips, field borders, or riparian buffers, utilizing GIS and outputs of the WRAPS process to prioritize sites for erosion, water quality, and public value; identification of alternative buffer strip options for landowners, including the development of a local buffer strip cost share program; the application of the state standard and the enforcement of 50-foot buffers along DNR Public Waters; and establishment of riparian corridors and buffers along intermittent or continuous flow rivers and streams. Qualifying landowners will continue to be contacted to encourage the use of buffers, filter strips, and field borders and to inform them of the importance of the BMPs and associated funding opportunities.

Actions targeted by the LOW SWCD for the years of 2016 and 2020 to improve buffers and riparian corridors included: ditch abandonments throughout the watershed to restore hydrologic regimes; ditch reconstruction with implementation of BMPs and/or 2-stage ditch design; wetland restorations; and assisting landowners in establishing buffers on their property for the new state buffer initiative.

The LOW SWCD has ongoing efforts to protect and improve surface water quality. These efforts include: ensuring hazard risk management plans are up to date; adequately addressing transportation of hazardous materials; ensuring companies have adequate procedures, equipment, staff, and trainings for local fire departments to be able to address a spill as safely and quickly as possible; reducing feedlot runoff by implementing the Delegated Feedlot Program; providing feedlot owners technical and financial assistance; and coordinating with Canadian agencies to address binational water quality concerns.

Ongoing efforts identified by the LOW SWCD to manage Sewage Treatment Systems and Other Potential Sources of Water Contamination include: identifying areas of the county potentially in need of community and cluster sewer systems, and holding informational meetings after areas are identified; promoting utilization of community and cluster systems where a surface or ground water pollution potential exists; researching feasibility of performance septic systems; and educating contractors and realtors on ordinance updates and new rules. In addition, the LOW SWCD will complete and maintain an inventory of non-compliant on-site sewage systems, support efforts of the Wheeler's Point Sanitary District for installation and expansion, and work with the county to develop low interest loan programs for septic system upgrades.

Implementation strategies identified within the 2010 through 2019 Roseau County Local Water Plan include, but are not limited to: actions targeted at erosion and sedimentation of surface waters, stormwater runoff, and wetlands; flood control and flood damage reduction; surface water protection and improvement; management of ditch systems; and groundwater protection and quality (Roseau SWCD 2010).

To reduce erosion and sedimentation the Roseau SWCD will enhance and improve the quality of surface waters and wetlands through CPs, BMPs, restoration, and structures including future projects in inventory sites for side-water inlets and provide cost shares to landowners for side-water inlets plus rock weir, rock dams, or rip-rap. Future projects for flood control and damage reduction will include: removal of beavers and beaver dams, raingarden implementation in strategic areas, and the expansion or improvement of gauges in Geenbush, Pelan and SD#72. Cost estimate for the flood control projects is approximately $200,000.

Roseau SWCD has plans for projects that promote and support the restoration of the Warroad River, for proper ditch system care and maintenance, and for the establishment of a cost-share program for septic system protection, quality analysis, and implementation of ordinances.

Table 13 contains a list of the impaired waters in the LOWW, along with goals for restoration, suggested implementation strategies, estimated adoption rates, units/metrics to track progress towards goals, the governmental unit responsible for implementation, and the timeline to achieve those goals. All other waters in the LOWW are assumed to be unimpaired and; therefore, subject to protection strategies. Protection strategies are identified on a watershed-wide basis and generalized for all unimpaired streams.

Interim 10-year milestones are identified in Table 13 for each impaired subwatershed so incremental progress is achieved. On-going water quality monitoring data will be used in future components of the WRAPS process to judge the effectiveness of the proposed strategies and inform adaptive implementation toward meeting the identified long-term goals. The timeline for the identified protection strategies is on-going.

These milestones are intended as general guidelines. Factors that may mean slower progress include: limits in funding or landowner acceptance, challenging fixes, and unfavorable climatic factors. Conversely, there may be faster progress for some impaired waters, especially where high-impact fixes are slated to occur.

Table 13: Strategies and actions proposed for the Lake of the Woods Watershed.

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate				Watershed District	SWCD	MPCA	County	City	MDA	
								Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units							
All	All	All	Parameters cited in permit	-	-	Wastewater facilities -- compliance with NPDES permits								●				-
			Parameters cited in permit	-	-	Construction and Industrial Stormwater permittees -- compliance with general permits								●				-
			Nitrogen (TN) or Nitrate	Varies	45% load reduction per Nutrient Reduction Strategy	**Increase fertilizer and manure efficiency**	Increase row crop acres utilizing U of MN recommendations for the economic optimal nitrogen rate after crediting all legumes and manure, varying with level of adoption of vegetative cover BMP.	100%	100%	100%	% of producers enrolled in Conservation Stewardship Program		●				●	2040 per Nutrient Reduction Strategy
						Store and treat tile drainage waters	Treat tiled cropland using constructed/restored wetlands or other practices	2%	5%	10%	% of agricultural acres	●					●	
							Controlled drainage on tile-drained row cropland	2%	5%	10%	% of row crop acres						●	
						Increase vegetative cover/root duration (to reduce nitrate leaching)	Cover crops on: (a) earlier harvest crops (EHC); and (b) corn and soybean lands (C/S)	<1% EHC <1% C&S	5% of EHC 5% of C/S	10% of EHC 10% of C/S	% of crop land in each category (EHC and C/S)		●				●	
							Convert marginal lands to perennial cover (marginal lands as determined by 61% on Crop Productivity Index)	60%	80%	100%	percent of qualifying acres		●				●	
						Advanced nutrient management practices		16109	20136	30204	acres		●				●	

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone (optional)	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Watershed District	SWCD	MPCA	County	City	MDA	
			TSS, TP	(See watersheds below)		**Improve upland/field surface runoff controls** [to reduce or intercept farm field erosion]	50-ft buffers on all streams and all buffer requirements met	70%	100%	100%	% of streams	•	•					
			TSS, TP, Altered hydrology			**Increase vegetative cover/root duration**	Cover crops on early harvest crops and fallow land	0	5%	15%	% of early harvest and fallow lands with cover		•					
			TP, *E. coli*			**Prevent feedlot runoff**	Fix open lot runoff problems per Minn. R. 7020 and open lot agreement.	80%	90%	100%	% open lots in compliance			•				
						Improve fertilizer and manure application management	Applying P fertilizer only on fields needing P for optimal crop growth	40%	70%	90%	% of agricultural acres		•					
							Fertilizer and manure injected or immediately incorporated	40%	70%	90%	% of agricultural acres		•					
						Improve livestock and manure management	All Minn. R. Ch. 7020 manure spreading setbacks are met	60%	80%	100%	% of agricultural acres			•				
							Winter manure spreading reduced	20%	40%	60%	% of agricultural acres		•					
							Inject or immediately incorporate manure where currently surface applied	20%	40%	60%	% of agricultural acres		•					
Bostic Creek (0903000901)	**Bostic Creek (09030009-537)**	Lake of the Woods	TSS	High = 73.6 mg/L Moist = 4.6 mg/L Ave = .8 mg/L Dry = .4 mg/L Low = .5 mg/L	≤15 mg/L met 90% of time Apr-Sep	**Improve upland/field surface runoff controls**	Increase living cover through cover crops, perennials, and well-managed pastures	70%	75%	80%	% of watershed area		•					2038
							Presentations and engagement at County Board meetings and County Ditch Committee Meetings	4	4	4	Number of public education events per year				•			

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
							Strategy Type	Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction			Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
							Inventory areas eligible for filter strips, field borders, or riparian buffers utilizing GIS and outputs of the WRAPS process to prioritize sites based on erosion, water quality, and public value.	60%	100%	100%	% of watershed		•					
							Install targeted filter strips and grass waterways	2%	2%	2%	% area of watershed		•					
							Field Border, windbreak, and shelterbelt establishment	48,867	61,084	73,300	feet		•					
							Heavy Use Area Protection	0.3	0.4	0.5	acres		•					
							Conservation Crop Rotation and conservation cover	589	737	884	acres		•					
						Protect/stabilize banks/bluffs	Highly-eroding banks identified and stabilized	20%	40%	100%	% of banks identified and stabilized		•					
							50-ft buffers on all streams and all buffer requirements met	75%	100%	100%	% of streams		•	•	•			
							Livestock exclusion on pastures near streams	75%	100%	100%	% of stream miles		•					
							Construct floodwater impoundments	0	100	500	Acre-feet of storage impoundments		•		•	•		
							Accurately size bridges and culverts to improve stream stability	65%	90%	100%	% complete		•		•	•		
							Tree and grass planting for stabilization on streams	0	2	5	stream miles		•					
							Streambank and Shoreline Protection	358	448	537	feet		•					
							Access control	345	431	518	acres		•					
						Stream channel restoration	Re-meander channelized stream reaches	0.5	4	8	stream miles		•		•	•		

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate				Watershed District	SWCD	MPCA	County	City	MDA	
								Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units							
							Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)	0	4	8	stream miles		•		•	•		
							Identify alternative buffer strip options for landowners, including the development of a local buffer strip cost share program, the application of the state standard, and the enforcement of 50-foot buffers along DNR Public Waters.	10%	100%	100%	% of impacted landowners		•		•			
						Habitat Restoration and Management	Tree/Shrub Establishment	324	405	486	acres		•					
							Riparian Forest Buffer	202	253	304	acres		•					
							Forage and Biomass Planting	92	115	138	acres		•					
							Wetland Restoration	22	27	32	acres		•					
							Forest Stand Improvement	16	20	24	acres		•					
							Conifer Crop Tree Release	15	19	23	acres		•					
							Tree/Shrub Site Preparation	13	16	19	acres		•					
							Habitat management practices	2,457	3,071	3,686	acres		•					
						Stabilize ravines	*See all examples for TSS - Improve upland/field surface runoff controls*											
Zippel Creek (0903000902)	**Williams Creek (09030009-501)**	Lake of the Woods	Altered hydrology: insufficient base flow (Fish/Macroinvertebrate IBI)	*Fish IBI = 33 Macro IBI = 42	Fish IBI ≥ 42 Macro IBI ≥ 53	**Increase living cover** (to increase infiltration and evapotranspiration)	Increase living cover in watershed through cover crops, perennials, and well-managed pastures	24%	30%	40%	% of cultivated lands		•					2038

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	580	1,000	2,000	Acres		•					
							Inventory areas eligible for filter strips, field borders, or riparian buffers utilizing GIS and outputs of the WRAPS process to prioritize sites based on erosion, water quality, and public value.	60%	100%	100%	% of suitable areas		•					
							Conifer Crop Tree Release	15	19	23	acres		•					
							Conservation Crop Rotation	28	35	42	acres		•					
						Improve drainage management (to store and control the release of tile drainage water)	Restored / treatment wetlands	60	100	200	acres of wetland				•			
							Controlled drainage on suitable tile-drained row cropland	1%	5%	10%	% of cultivated lands				•			
							Stabilize agricultural drainage outlets that flow into drainage ways.	25%	50%	100%	% of outlets				•			
							Direct landowner contact and a public meeting every other year. Presentations at County Board and Ditch Committee meetings.	4	4	4	Number of public education events per year				•			
							Research options and prioritize areas for redetermination of benefits of public drainage systems.	-	-	-	Complete in the next 10-year cycle				•			
						Reduce flashiness of waterways	Construct floodwater impoundments	3.4	20	50	Acre-feet of storage impoundments		•		•	•		
							Stabilize agricultural drainage outlets that flow into drainage ways.	60%	80%	100%	% of outlets				•			

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	30%	40%	50%	% of agricultural acres		•					
							Inventory areas eligible for filter strips, field borders, or riparian buffers utilizing GIS and outputs of the WRAPS process to prioritize sites based on erosion, water quality, and public value.	100%	100%	100%	% of Watershed		•					
						Improve urban stormwater management (to decrease urban stormwater volume)	Reduce post-construction stormwater volume for redevelopment projects	60%	80%	100%	Percent flow reduction for unpermitted areas		•	•	•	•		
							Promote and educate individuals, developers, commissioners, and general public on properly treated stormwater. Utilize rain gardens and sediment ponds.	1	1	1	Number of public education events per year		•					
							Research and identify issues associated with flowing wells in relation to stormwater and drainage.	-	-	-	Complete in the next 10-year cycle		•					
							Identify options to evaluate county-wide stormwater management, including: costs, management, structure, and needed changes to the current system.						•		•	•		
			Poor Habitat (Macro IBI)	Macro IBI = 42	Macro IBI ≥ 53	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	80%	100%	100%	% of stream miles		•	•	•			2038

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area		•					
							Restore riparian wetlands	20	100	500	acres of wetland		•					
							Accurately size bridges and culverts to improve stream stability	65%	90%	100%	% complete		•					
							Streambank protection / stabilization	10	20	50	miles of shoreline		•					
							Provide education, workshops, and cost-share programs to assist landowners	-	-	-	Ongoing/ Continuous							
							Identify alternative buffer strip options for landowners, including the development of a local buffer strip cost share program, the application of the state standard, and the enforcement of 50-foot buffers along DNR Public Waters.	10%	100%	100%	% of impacted landowners		•					
						Restore/enhance channel	Apply habitat improvement work (per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles)	0	100	500	Feet of stream		•					
							Establish riparian corridors and buffers along intermittent or continuous flow rivers and streams.	20%	30%	50%								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
						Habitat Restoration and Management	Habitat management practices	308	385	462	acres		•					
			Dissolved Oxygen	<5 mg/L during low flow	≥5 mg/L	Reduce phosphorus	*See TP strategies*						•					2028
							Presentations and engagement at County Board meetings and County Ditch Committee Meetings	4	4	4	Number of public education events per year							
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*						•					
						Restore stream channel	Presentations and engagement at County Board meetings and County Ditch Committee Meetings	4	4	4	Number of public education events per year							
			TSS	High = 8.4 mg/L Moist = 1.74 mg/L Ave = 0.30 mg/L Dry = 0.21 mg/L Low = 0.08 mg/L	≤15 mg/L met 90% of time Apr-Sep	Improve upland/field surface runoff controls	Increase living cover through cover crops, perennials and well-managed pastures	24%	30%	40%	% of cultivated lands		•					2038
							Presentations and engagement at County Board meetings and County Ditch Committee Meetings	4	4	4	Number of public education events per year				•			
							Inventory areas eligible for filter strips, field borders, or riparian buffers utilizing GIS and outputs of the WRAPS process to prioritize sites based on erosion, water quality, and public value.	60%	100%	100%	% of watershed		•					
							Install targeted filter strips and grass waterways	3%	3%	3%	% area of watershed		•					
							Field border	472	590	708	acres		•					
						Protect/stabilize banks/bluffs	Highly-eroding banks identified and stabilized	70%	80%	100%	% of banks identified and stabilized		•					

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate				Watershed District	SWCD	MPCA	County	City	MDA	
								Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units							
							50-ft buffers on all streams and all buffer requirements met	%	100%	100%	% of streams		•	•	•			
							Livestock exclusion on pastures near streams	90%	100%	100%	% of stream miles		•					
							Construct floodwater impoundments	10	50	100	Acre-feet of storage impoundments		•		•	•		
							Accurately size bridges and culverts to improve stream stability	65%	90%	100%	% complete		•		•	•		
							Tree and grass planting for stabilization on streams	0	2	5	stream miles		•					
							Establish riparian corridors and buffers along intermittent or continuous flow rivers and streams.	20%	30%	50%	% of streams		•					
							Access control	121	151	182	acres		•					
						Stream channel restoration	Re-meander channelized stream reaches	2	4	15	stream miles		•		•	•		
							Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)	0	1	2	stream miles		•		•	•		

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
							Identify alternative buffer strip options for landowners, including the development of a local buffer strip cost share program, the application of the state standard, and the enforcement of 50-foot buffers along DNR Public Waters.	10%	100%	100%	% of impacted landowners		•		•			
						Stabilize ravines	*See all examples for TSS - Improve upland/field surface runoff controls*											
							Stabilization within ravines--vegetative practices and/or engineered structures	60%	70%	100%	% High-priority ravines addressed		•		•	•		
						Improve urban stormwater management	Feature information in an SWCD newsletter	1	1	1	Number of public education events per year		•	•	•			
	West Branch Zippel Creek (09030009-515)	Lake of the Woods	Altered hydrology: insufficient base flow (Fish/Macroinvertebrate IBI)	**Fish IBI = 45 Macro IBI = 36	Fish IBI ≥ 42 Macro IBI ≥ 51	**Increase living cover** (to increase infiltration and evapotranspiration)	Increase living cover in watershed through cover crops, perennials and well-managed pastures	24%	30%	40%	% of cultivated lands		•					2038
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	5%	10%	15%	% of watershed area		•					
							Inventory areas eligible for filter strips, field borders, or riparian buffers utilizing GIS and outputs of the WRAPS process to prioritize sites based on erosion, water quality, and public value.	60%	100%	100%	% of suitable areas							
						Improve drainage management (to	Restored / treatment wetlands	0	100	200	acres of wetland				•			

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
						store and control the release of tile drainage water)	Controlled drainage on suitable tile-drained row cropland	1%	5%	10%	% of watershed area				•			
							Stabilize agricultural drainage outlets that flow into drainage ways.	10%	50%	100%	% of outlets				•			
							Direct landowner contact and a public meeting every other year. Presentations at County Board and Ditch Committee meetings.	4	4	4	Number of public education events per year				•			
							Research options and prioritize areas for redetermination of benefits of public drainage systems.	-	-	-	Complete in the next 10-year cycle				•			
						Reduce flashiness of waterways	Construct floodwater impoundments	1	15	25	Acre-feet of storage impoundments		•					
							Stabilize agricultural drainage outlets that flow into drainage ways.	60%	80%	100%	% of outlets							
							Grade Stabilization Structure	2	3	4	each		•					
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	40%	80%	100%	% of agricultural acres		•					
							Inventory areas eligible for filter strips, field borders, or riparian buffers utilizing GIS and outputs of the WRAPS process to prioritize sites based on erosion, water quality, and public value.	100%	100%	100%	% of Watershed							
							Residue management, mulch till	104	130	195	acres		•					
			Poor Habitat (Macro IBI)	Macro IBI = 42	Macro IBI ≥ 53	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	35%	100%	100%	% of stream miles		•					2038

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate				Watershed District	SWCD	MPCA	County	City	MDA	
								Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units							
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area		•					
							Restore riparian wetlands	20	100	500	acres of wetland		•					
							Accurately size bridges and culverts to improve stream stability	65%	90%	100%	% complete		•					
							Streambank protection / stabilization	0	5000	10,000	Feet of shoreline		•					
							Implement shoreline stabilization projects	5	20	50	miles of shoreline		•					
							Prioritize shoreline erosion problems through utilizing inventories and assessments.	100%	100%	100%	% of prioritization completed		•					
							Provide education, workshops, and cost-share programs to assist landowners	-	-	-	Ongoing/Continuous		•					
							Identify alternative buffer strip options for landowners, including the development of a local buffer strip cost share program, the application of the state standard, and the enforcement of 50-foot buffers along DNR Public Waters.	10%	100%	100%	% of impacted landowners		•					
						Restore/enhance channel	Apply habitat improvement work (per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles)	0	5,000	10,000	Feet of stream		•					

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate				Watershed District	SWCD	MPCA	County	City	MDA	
								Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units							
							Establish riparian corridors and buffers along intermittent or continuous flow rivers and streams.	20%	30%	50%	% of corridor		•					
							Presentations and engagement at County Board meetings and County Ditch Committee Meetings	4	4	4	Events per year		•					
			Dissolved Oxygen	<5 mg/L during low flow	≥5 mg/L	**Reduce phosphorus**	*See TP strategies*						•					2028
							Presentations and engagement at County Board meetings and County Ditch Committee Meetings	4	4	4	Events per year							
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*						•					
						Restore stream channel	Presentations and engagement at County Board meetings and County Ditch Committee Meetings	4	4	4	Events per year		•					
			TSS	High = 17.0 mg/L Moist = 1.74 mg/L Ave = 0.16 mg/L Dry = 0.15 mg/L Low = 0.02 mg/L	≤15 mg/L met 90% of time Apr-Sep	**Improve upland/field surface runoff controls**	Increase living cover through cover crops, perennials, and well-managed pastures	23%	25%	30%	% of cultivated lands		•					2038
							Presentations and engagement at County Board meetings and County Ditch Committee Meetings	4	4	4	Number of public education events per year				•			

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
							Inventory areas eligible for filter strips, field borders, or riparian buffers utilizing GIS and outputs of the WRAPS process to prioritize sites based on erosion, water quality, and public value.	60%	100%	100%	% of watershed		•					
							Install targeted filter strips and grass waterways	3%	3%	3%	% area of watershed		•					
						Protect/stabilize banks/bluffs	Highly-eroding banks identified and stabilized	20%	40%	100%	% of banks identified and stabilized		•					
							50-ft buffers on all streams and all buffer requirements met	50%	100%	100%	% of streams		•	•	•			
							Livestock exclusion on pastures near streams	95%	100%	100%	% of stream miles		•					
							Construct floodwater impoundments	1	10	50	Acre-feet of storage impoundments		•		•	•		
							Accurately size bridges and culverts to improve stream stability	65%	90%	100%	% complete		•		•	•		
							Tree and grass planting for stabilization on streams	0	2	5	stream miles		•					
							Establish riparian corridors and buffers along intermittent or continuous flow rivers and streams.	20%	30%	50%	% of streams		•					
						Stream channel restoration	Re-meander channelized stream reaches	0	0	10	stream miles		•		•	•		

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate				Watershed District	SWCD	MPCA	County	City	MDA	
								Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units							
							Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)	0	0	5	stream miles		•		•	•		
							Identify alternative buffer strip options for landowners, including the development of a local buffer strip cost-share program, the application of the state standard, and the enforcement of 50-foot buffers along DNR Public Waters.	10%	100%	100%	% of impacted landowners		•		•			
						Stabilize ravines	*See all examples for TSS - Improve upland/field surface runoff controls*											
							Stabilization within ravines--vegetative practices and/or engineered structures	60%	70%	100%	% High-priority ravines addressed		•		•	•		
Warroad River (0903000903)	**Warroad River (09030009-502)**	Roseau	TSS	High = 81.7 mg/L Moist = 31.9 mg/L Ave = 12 mg/L Dry = 8 mg/L Low = 3.5 mg/L	≤15 mg/L met 90% of time Apr-Sep	**Improve upland/field surface runoff controls**	Increase living cover through cover crops, perennials, and well-managed pastures	12%	15%	25%	% of watershed area	•	•					2038
							HEL lands and >3% sloped cropland at ≥30% residue cover or equivalent	80%	90%	100%	% of priority lands with residue protection	•	•					
							Tilled sloping row-cropped lands protected with grassed waterways, contour farming and/or other BMPs	50%	70%	100%	% of applicable lands with listed BMPs	•	•					

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
							Educate and encourage landowners, county drainage committee, and government officials on BMP's for maintenance of ditches and conservation practices that can be used along ditches, watercourses, and wetlands.	4	4	4	Number of public education events per year				•			
							Inventory areas eligible for filter strips, field borders, or riparian buffers utilizing GIS and outputs of the WRAPS process to prioritize sites based on erosion, water quality, and public value.	60%	100%	100%	% of watershed	•	•					
							Install targeted filter strips and grass waterways	2%	2%	2%	% area of watershed	•	•					
							Extend existing filter strips	0.2	0.3	0.4	acres		•					
							Residue and Tillage Management, No-Till	250	313	375	acres		•					
							Conservation Crop Rotation	401	501	602	acres		•					
							Tree/Shrub Establishment	150	187	224	acres		•					
							Tree/Shrub Site Preparation	150	187	224	acres		•					
							Renovation of a windbreak or shelter belt	146	183	219	acres		•					
							Forage and Biomass Planting	135	168	202	acres		•					
							Heavy Use Area Protection	122	153	183	acres		•					
						Protect/stabilize banks/bluffs	Highly-eroding banks identified and stabilized	95%	100%	100%	% of banks identified and stabilized	•	•					
							50-ft buffers on all streams and all buffer requirements met	10%	100%	100%	% of streams	•	•	•	•			

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate				Watershed District	SWCD	MPCA	County	City	MDA	
								Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units							
							Livestock exclusion on pastures near streams	75%	100%	100%	% of stream miles	•	•					
							Construct floodwater impoundments	0	2,002	4,004	Acre-feet of storage impoundments	•	•		•	•		
							Accurately size bridges and culverts to improve stream stability	65%	90%	100%	% complete	•	•		•	•		
							Tree and grass planting for stabilization on streams	0	2	5	stream miles	•	•					
							Establish riparian corridors and buffers along intermittent or continuous flow rivers and streams.	20%	30%	50%	% of streams	•	•					
						Stream channel restoration	Re-meander channelized stream reaches	2	10	30	stream miles	•	•		•	•		
							Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)	0	25	30	stream miles	•	•		•	•		
							Identify alternative buffer strip options for landowners, including the development of a local buffer strip cost share program, the application of the state standard, and the enforcement of 50-foot buffers along DNR Public Waters.	40%	100%	100%	% of impacted landowners	•	•		•			
						Stabilize ravines	*See all examples for TSS - Improve upland/field surface runoff controls*											

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
							Stabilization within ravines--vegetative practices and/or engineered structures	60%	70%	100%	% High-priority ravines addressed	•	•		•	•		
						Habitat Restoration and Management	Habitat management practices	1,659	2,074	2,489	acres		•					
	West Branch Warroad River (09030009-503)	Roseau	TSS	High = 18.69 mg/L Moist = 6.61 mg/L Ave = 3.51 mg/L Dry = 2.09 mg/L Low = 1.30 mg/L	≤15 mg/L met 90% of time Apr-Sep	**Improve upland/field surface runoff controls**	Increase living cover through cover crops, perennials, and well-managed pastures	12%	15%	25%	% of watershed area	•	•					2038
							HEL lands and >3% sloped cropland at ≥30% residue cover or equivalent	80%	90%	100%	% of priority lands with residue protection	•	•					
							Tilled sloping row-cropped lands protected with grassed waterways, contour farming and/or other BMPs	50%	70%	100%	% of applicable lands with listed BMPs	•	•					
							Educate and encourage landowners, county drainage committee, and government officials on BMP's for maintenance of ditches and conservation practices that can be used along ditches, watercourses, and wetlands.	4	4	4	Number of public education events per year				•			
							Inventory areas eligible for filter strips, field borders, or riparian buffers utilizing GIS and outputs of the WRAPS process to prioritize sites based on erosion, water quality, and public value.	60%	100%	100%	% of watershed	•	•					
							Install targeted filter strips and grass waterways	2%	2%	2%	% area of watershed	•	•					

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
							Extend existing filter strips	0.2	0.3	0.4	acres		•					
							Residue and Tillage Management, No-Till	250	313	375	acres		•					
							Conservation Crop Rotation	401	501	602	acres		•					
							Tree/Shrub Establishment	150	187	224	acres		•					
							Tree/Shrub Site Preparation	150	187	224	acres		•					
							Renovation of a windbreak or shelter belt	146	183	219	acres		•					
							Forage and Biomass Planting	135	168	202	acres		•					
							Heavy Use Area Protection	122	153	183	acres		•					
						Protect/stabilize banks/bluffs	Highly-eroding banks identified and stabilized	95%	100%	100%	% of banks identified and stabilized	•	•					
							50-ft buffers on all streams and all buffer requirements met	10%	100%	100%	% of streams	•	•	•	•			
							Livestock exclusion on pastures near streams	75%	100%	100%	% of stream miles	•	•					
							Construct floodwater impoundments	0	2,002	4,004	Acre-feet of storage impoundments	•	•		•	•		
							Accurately size bridges and culverts to improve stream stability	65%	90%	100%	% complete	•	•		•	•		
							Tree and grass planting for stabilization on streams	0	2	5	stream miles	•	•					
							Establish riparian corridors and buffers along intermittent or continuous flow rivers and streams.	20%	30%	50%	% of streams	•	•					
						Stream channel restoration	Re-meander channelized stream reaches	2	10	30	stream miles	•	•		•	•		

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate				Watershed District	SWCD	MPCA	County	City	MDA	
								Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units							
							Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)	0	25	30	stream miles	•	•		•	•		
							Identify alternative buffer strip options for landowners, including the development of a local buffer strip cost share program, the application of the state standard, and the enforcement of 50-foot buffers along DNR Public Waters.	40%	100%	100%	% of impacted landowners	•	•		•			
						Stabilize ravines	*See all examples for TSS - Improve upland/field surface runoff controls*											
							Stabilization within ravines--vegetative practices and/or engineered structures	60%	70%	100%	% High-priority ravines addressed	•	•		•	•		
						Habitat Restoration and Management	Habitat management practices	1,659	2,074	2,489	acres		•					
			E. coli	High = 8.5 org/100mL Moist = 20.5 org/100mL Avg = 83.7 org/100mL Dry = 58.5 org/100mL Low = 88.2 org/100mL	Geometric mean ≤ 126 org/100mL, April - October	**Improve livestock and manure management**	*See strategies to reduce field TSS*											2033
							Livestock exclusion on pastured stream miles	50%	75%	100%	% of priority sites		•				•	
							Animal mortality storage areas consistent with Bd. Animal Health rules and feedlot permits.	0	0	0	# noncompliant mortality storage sites	•	•				•	
							All Minn. R. Ch. 7020 manure spreading setbacks are met	50%	75%	100%	% of priority sites			•			•	

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
							Total containment of manure storage	50%	75%	100%	% of animal units with manure going to storage	•	•				•	
							Inject or immediately incorporate manure where currently surface applied	95%	100%	100%	% of priority sites	•	•				•	
							Educate and encourage landowners, county drainage committee, and government officials on BMP's for maintenance of ditches and conservation practices that can be used along ditches, watercourses, and wetlands.	4	4	4	Number of public education events per year	•					•	
							Rotational and prescribed grazing	1,077	1,346.25	1,616	Acres		•				•	
						Address failing septic systems	Maintain septic (SSTS) systems	6	0	0	% of noncompliant septic systems				•	•	•	
	East Branch Warroad River (09030009-504) 33.47 miles	Roseau	Macro Glide Pool Habitat Threshold; Macro Riffle/Run Habitat Threshold	Glide Pool Macro IBI (yr/score) = 2005 /50; 2012 /50 ; 2014/52; Riffle/Run Macro = 2014/41; 2012/44	Glide Pool Macro IBI ≥ 53; Riffle/Run Macro IBI ≥ 51	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met		100%	100%	% Steam Miles		•		•			2038
							Increase conservation cover: in/near water bodies, to create corridors		12%	15%	% Watershed Area	•	•					
							Restore riparian wetlands		30	165	acres of wetland		•					
							Accurately size bridges and culverts to improve stream stability		90%	100%	% Complete	•			•			

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
							Streambank protection / stabilization		2,500	5,000	Feet of shoreline	•	•					
							Prioritize shoreline erosion problems through utilizing inventories and assessments.		100%	100%	% of prioritizations complete	•	•					
							Provide education, workshops, and cost-share programs to assist landowners	–	–	–	Ongoing/Continuous		•					
							Identify alternative buffer strip options for landowners, including the development of a local buffer strip cost share program, the application of the state standard, and the enforcement of 50-foot buffers along DNR Public Waters.		100%	100%	% of impacted landowners		•		•			
						Restore/enhance channel	Apply habitat improvement work (per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles)		2,500	5,000	Feet of Stream	•						
							Establish riparian corridors and buffers along intermittent or continuous flow rivers and streams.		30%	50%	% of corridor	•	•					
						Pasture Management	Livestock Access Control (472)		2,640	5,280	feet	•	•					

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
						Habitat Restoration and Management	Habitat management practices		1,000	2,000	acres		•					
Muskeg Bay (0903000904)	**Willow Creek (09030009-505)**	Lake of the Woods/Roseau	Altered hydrology: insufficient base flow (Fish IBI)	Fish IBI = 26	Fish IBI ≥ 42	**Increase living cover** (to increase infiltration and evapotranspiration)	Increase living cover in watershed through cover crops, perennials, and well-managed pastures	24%	30%	40%	% of watershed area		•					2038
							Conservation Cover and Conservation Crop Rotation	1,272	1,590	1,908	acres		•					
							Inventory areas eligible for filter strips, field borders, or riparian buffers utilizing GIS and outputs of the WRAPS process to prioritize sites based on erosion, water quality, and public value.	60%	100%	100%	% of suitable areas							
							Forage and Biomass Planting	79	99	119	acres		•					
							Incorporate native grasses and/or legumes into 15% or more of the forage base	65	81	97	acres		•					
							Early Successional Habitat Development/Management	53	67	80	acres		•					
							Tree/Shrub Establishment	22	28	33	acres		•					
							Tree/Shrub Site Preparation	13	16	19	acres		•					
						Improve drainage management (to store and control the release of tile drainage water)	Restored / treatment wetlands	0	100	200	acres of wetland				•			
							Controlled drainage on suitable tile-drained row cropland	1%	5%	10%	% of watershed area				•			

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate				Watershed District	SWCD	MPCA	County	City	MDA	
								Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units							
							Stabilize agricultural drainage outlets that flow into drainage ways.	30%	50%	100%	% of outlets				•			
							Direct landowner contact and a public meeting every other year. Presentations at County Board and Ditch Committee meetings.	4	4	4	Number of public education events per year				•			
							Research options and prioritize areas for redetermination of benefits of public drainage systems.	-	-	-	Complete in the next 10-year cycle				•			
						Reduce flashiness of waterways	Construct floodwater impoundments	5	100	250	Acre-feet of storage impoundments		•					
							Stabilize agricultural drainage outlets that flow into drainage ways.	30%	50%	100%	% of outlets							
							Grade Stabilization Structure	6	8	9	each		•					
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	40%	80%	100%	% of agricultural acres		•					
							Inventory areas eligible for filter strips, field borders, or riparian buffers utilizing GIS and outputs of the WRAPS process to prioritize sites based on erosion, water quality, and public value.	100%	100%	100%	% of Watershed							
							Residue and Tillage Management	1,957			acres		•					
						Improve urban stormwater management (to decrease urban stormwater volume)	Reduce post-construction stormwater volume for redevelopment projects	60%	80%	100%	Percent flow reduction for unpermitted areas			•				
			Dissolved Oxygen		≥5 mg/L		*See TP strategies*						•					2028

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
				<5 mg/L during low flow		**Reduce phosphorus**	Educate and encourage landowners, county drainage committee, and government officials on BMP's for maintenance of ditches and conservation practices that can be used along ditches, watercourses, and wetlands.	4	4	4	Number of public education events per year	•						
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*					•	•					
	Unnamed Ditch to Unnamed Ditch (09030009-523) 1.29 miles	**Lake of the Woods**	**Macro Fish**	Macro IBI (yr/Score) = 2012/37; 2014/44 Fish IBI (yr/score)= 2012/38; 2014/25	Macro IBI ≥ 53 Fish IBI ≥ 42	**Improve riparian vegetation**	50-ft or 16.5-foot buffers on all streams and all buffer requirements met		100%	100%	% Steam Miles	•	•					2038
							Increase conservation cover: in/near water bodies, to create corridors		12%	15%	% of watershed area	•	•					
							Restore riparian wetlands		50	250	acres of wetland		•					

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
							Strategy Type	Estimated Adoption Rate				Watershed District	SWCD	MPCA	County	City	MDA	
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction			Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units							
							Accurately size bridges and culverts to improve stream stability		90%	100%	% complete				•			
							Provide education, workshops, and cost-share programs to assist landowners	–	–	–	Ongoing/Continuous		•					
							Identify alternative buffer strip options for landowners, including the development of a local buffer strip cost share program, the application of the state standards, and the enforcement of 50-foot or 16.5-foot buffers as requireds.		100%	100%	% of impacted landowners		•		•			
						Restore/enhance channel	Presentations and engagement at County Board meetings and County Ditch Committee Meetings		–	–	Ongoing/Continuous	•	•					
						Habitat Restoration and Management	Habitat management practices		782	940	acres		•					

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
	County Ditch 20, Headwaters to Lake of the Woods (09030009-560) 2.69 miles	Lake of the Woods	Macro	Macro IBI = 31	Macro IBI ≥ 37	Improve riparian vegetation	16.5 ft buffer on county ditch systems (CD 20 was removed from the DNR's Buffer Mapping Project)		100%	100%	% of Stream Miles	●	●					2038
							Increase conservation cover: in/near water bodies, to create corridors		12%	15%	% of watershed area	●	●					
							Restore riparian wetlands		34	165	acres of wetland		●					
							Accurately size bridges and culverts to improve stream stability		90%	100%	% complete				●			
							Provide education, workshops, and cost-share programs to assist landowners		–	–	Ongoing/Continuous		●					
							Identify alternative buffer strip options for landowners, including the development of a local buffer strip cost share program, the application of the state standard, and the enforcement of 16.5-foot buffers.		100%	100%	% of impacted landowners		●		●			

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	City	MDA	
						Habitat Restoration and Management	Habitat management practices		516	620	acres		●					
All		**All**	**All**			**Implement volume control / limited-impact development**	Apply to all projects when developing undeveloped land to provide no net increase in volume and pollutants	60%	80%	100%	Percent flow reduction for unpermitted areas			•				
	Note: Many entries from the above restoration rows may be translated for use in protection rows.																	
All		**All**	**All**			**Implement volume control / limited-impact development**	Apply to all projects when developing undeveloped land to provide no net increase in volume and pollutants	60%	80%	100%	Percent flow reduction for unpermitted areas			•				
	Note: Many entries from the above restoration rows may be translated for use in protection rows.																	

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility (optional)						Estimated Year to Achieve Water Quality Target
							Strategy Type	Estimated Adoption Rate				Watershed District	SWCD	MPCA	County	City	MDA	
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction			Current strategy adoption level, if known	Interim 10-year Milestone (optional)	Suggested Goal	Units							
🟥	Restoration																	
🟩	Protection																	
🟦	Strategies to address downstream impairments																	
	Point Sources																	

Table 14: Key for Strategies Column

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	Example BMPs/actions
TSS	<u>Improve upland/field surface runoff controls</u>: Soil and water conservation practices that reduce soil erosion and field runoff, or otherwise minimize sediment from leaving farmland	Cover crops
		Water and sediment basins, terraces
		Rotations including perennials
		Conservation cover easements
		Grassed waterways
		Strategies to reduce flow- some of the flow reduction strategies should be targeted to ravine subwatersheds
		Residue management - conservation tillage
		Forage and biomass planting
		Open tile inlet controls - riser pipes, french drains
		Contour farming
		Field edge buffers, borders, windbreaks, and/or filter strips
		Stripcropping
	<u>Protect/stabilize banks/bluffs</u>: Reduce collapse of bluffs and erosion of streambank by reducing peak river flows and using vegetation to stabilize these areas.	Strategies for altered hydrology (reducing peak flow)
		Streambank stabilization
		Riparian forest buffer
		Livestock exclusion - controlled stream crossings
	<u>Stabilize ravines</u>: Reducing erosion of ravines by dispersing and infiltrating field runoff and increasing vegetative cover near	Field edge buffers, borders, windbreaks, and/or filter strips
		Contour farming and contour buffer strips

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	Example BMPs/actions
	ravines. Also, may include earthwork/regrading and revegetation of ravine.	Diversions
		Water and sediment control basin
		Terrace
		Conservation crop rotation
		Cover crop
		Residue management - conservation tillage
	Stream Channel Restoration	Addressing road crossings (direct erosion) and floodplain cut-offs
		Clear water discharge: urban areas, ag tiling etc. – direct energy dissipation
		Two-stage ditches
		Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)
		Stream channel restoration using vertical energy dissipation: step pool morphology
	Improve forestry management	Proper Water Crossings and road construction
		Forest Roads - Cross-Drainage
		Maintaining and aligning active Forest Roads
		Closure of Inactive Roads & Post-Harvest
		Location & Sizing of Landings
		Riparian Management Zone Widths and/or filter strips
	Improve urban stormwater management (to reduce sediment and flow)	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	Example BMPs/actions
Nitrogen (TN) or Nitrate	Increase fertilizer and manure efficiency: Adding fertilizer and manure additions at rates and ways that maximize crop uptake while minimizing leaching losses to waters	Nitrogen rates at Maximum Return to Nitrogen (U of MN rec's)
		Timing of application closer to crop use (spring or split applications)
		Nitrification inhibitors
		Manure application based on nutrient testing, calibrated equipment, recommended rates, etc.
	Store and treat tile drainage waters: Managing tile drainage waters so that nitrate can be denitrified or so that water volumes and loads from tile drains are reduced	Saturated buffers
		Restored or constructed wetlands
		Controlled drainage
		Woodchip bioreactors
		Two-stage ditch
	Increase vegetative cover/root duration: Planting crops and vegetation that maximize vegetative cover and capturing of soil nitrate by roots during the spring, summer and fall.	Conservation cover (easements/buffers of native grass & trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials
		Crop conversion to low nutrient-demanding crops (e.g., hay).
Phosphorus (TP)	Improve upland/field surface runoff controls: Soil and water conservation practices that reduce soil erosion and field runoff, or otherwise minimize sediment from leaving farmland	Strategies to reduce sediment from fields (see above - upland field surface runoff)
		Constructed wetlands
		Pasture management
	Reduce bank/bluff/ravine erosion	Strategies to reduce TSS from banks/bluffs/ravines (see above for sediment)

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	Example BMPs/actions
	Increase vegetative cover/root duration: Planting crops and vegetation that maximize vegetative cover and minimize erosion and soil losses to waters, especially during the spring and fall.	Conservation cover (easements/buffers of native grass & trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials
	Preventing feedlot runoff: Using manure storage, water diversions, reduced lot sizes and vegetative filter strips to reduce open lot phosphorus losses	Open lot runoff management to meet Minn. R. 7020 rules
		Manure storage in ways that prevent runoff
	Improve fertilizer and manure application management: Applying phosphorus fertilizer and manure onto soils where it is most needed using techniques which limit exposure of phosphorus to rainfall and runoff.	Soil P testing and applying nutrients on fields needing phosphorus
		Incorporating/injecting nutrients below the soil
		Manure application meeting all Minn. R. 7020 rule setback requirements
	Address failing septic systems: Fixing septic systems so that on-site sewage is not released to surface waters. Includes straight pipes.	Sewering around lakes
		Eliminating straight pipes, surface seepages
	Reduce in-water loading: Minimizing the internal release of phosphorus within lakes	Rough fish management
		Curly-leaf pondweed management
		Alum treatment
		Lake drawdown
		Hypolimnetic withdrawal
	Improve forestry management	See forest strategies for sediment control
	Reduce Industrial/Municipal wastewater TP	Municipal and industrial treatment of wastewater P

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	Example BMPs/actions
		Upgrades/expansion. Address inflow/infiltration.
	Treat tile drainage waters: Treating tile drainage waters to reduce phosphorus entering water by running water through a medium which captures phosphorus	Phosphorus-removing treatment systems, including bioreactors
	Improve urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
E. coli	Reducing livestock bacteria in surface runoff: Preventing manure from entering streams by keeping it in storage or below the soil surface and by limiting access of animals to waters.	Strategies to reduce field TSS (applied to manured fields, see above)
		Improved field manure (nutrient) management
		Adhere/increase application setbacks
		Improve feedlot runoff control
		Animal mortality facility
		Manure spreading setbacks and incorporation near wells and sinkholes
		Rotational grazing and livestock exclusion (pasture management)
	Reduce urban bacteria: Limiting exposure of pet or waterfowl waste to rainfall	Pet waste management
		Filter strips and buffers
		See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Address failing septic systems: Fixing septic systems so that on-site sewage is not released to surface waters. Includes straight pipes.	Replace failing septic (SSTS) systems
		Maintain septic (SSTS) systems
	Reduce Industrial/Municipal wastewater bacteria	Reduce straight pipe (untreated) residential discharges
		Reduce WWTP untreated (emergency) releases

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	Example BMPs/actions
Dissolved Oxygen	Reduce phosphorus	See strategies above for reducing phosphorus
	Increase river flow during low flow years	See strategies above for altered hydrology
	In-channel restoration: Actions to address altered portions of streams.	Goal of channel stability: transporting the water and sediment of a watershed without aggrading or degrading.
		Restore riffle substrate
Chloride	Road salt management	(Strategies currently under development within Twin Cities Metro Area Chloride Management Plan)
Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)	Increase living cover: Planting crops and vegetation that maximize vegetative cover and evapotranspiration especially during the high flow spring months.	Grassed waterways
		Cover crops
		Conservation cover (easements & buffers of native grass & trees, pollinator habitat)
		Rotations including perennials
	Improve drainage management: Managing drainage waters to store tile drainage waters in fields or at constructed collection points and releasing stored waters after peak flow periods.	Treatment wetlands
		Restored wetlands
	Reduce rural runoff by increasing infiltration: Decrease surface runoff contributions to peak flow through soil and water conservation practices.	Conservation tillage (no-till or strip till w/ high residue)
		Water and sediment basins, terraces
	Improve urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Improve irrigation water management: Increase groundwater contributions to surface waters by withdrawing less water for irrigation or other purposes.	Groundwater pumping reductions and irrigation management

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	Example BMPs/actions
Poor Habitat (Fish/Macroinvertebrate IBI)	Improve riparian vegetation: Planting and improving perennial vegetation in riparian areas to stabilize soil, filter pollutants, and increase biodiversity	50' vegetated buffer on waterways
		One rod (16.5 feet) ditch buffers
		Lake shoreland buffers
		Increase conservation cover: in/near water bodies, to create corridors
		Improve/increase natural habitat in riparian, control invasive species
		Tree planting to increase shading
		Streambank and shoreline protection/stabilization
		Wetland restoration
		Accurately size bridges and culverts to improve stream stability
	Restore/enhance channel: Various restoration efforts largely aimed at providing substrate and natural stream morphology.	Retrofit dams with multi-level intakes
		Restore riffle substrate
		Two-stage ditch
		Dam operation to mimic natural conditions
		Restore natural meander and complexity
Water Temperature	Urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Improve riparian vegetation: Actions primarily to increase shading, but also some infiltration of surface runoff.	Riparian vegetative buffers
		Tree planting to increase shading
Connectivity (Fish IBI)	Removal fish passage barriers: Identify and address barriers.	Remove impoundments

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	Example BMPs/actions
		Properly size and place culverts for flow and fish passage
		Construct by-pass
All (protection-related)	Implement volume control / limited-impact development: This is aimed at development of undeveloped land to provide no net increase in volume and pollutants	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php

4. Monitoring Plan

The LOW SWCD, with support from the Lake of the Woods County Water Plan Committee, will continue monitoring priority streams in the county as outlined in the Lake of the Woods County Water Quality Monitoring Plan. This plan also supports a River Watch Program for the Rainy River. Data collected are utilized to prioritize projects and priority areas within the county (LOW SWCD 2015). The Roseau SWCD will also continue water quality monitoring efforts for baseline study on the Warroad River and Willow Creek (Roseau SWCD 2015). The WRWD is working to develop a water quality monitoring plan to help identify baseline conditions. As outlined in the Rainy-Lake of the Woods State of the Basin Report (LOWWSF 2014), the Lake of the Woods Water Sustainability Foundation (WSF) will continue coordination with appropriate stakeholders, agencies, and organizations to conduct and expand basin-wide monitoring.

In addition to the stream monitoring sponsored by the Lake of the Woods and Roseau SWCDs, the WRWD, the Lake of the Woods WSF, and the MPCA also have on-going monitoring in the watershed. The major watershed outlet monitoring will continue to provide a long-term record of water quality at the LOWW outlet. The MPCA will return to the LOWW under their Intensive Watershed Monitoring program in 2022-2023. On-going stream flow monitoring has also been undertaken by the U.S. Geological Survey at one site within the LOWW.

5. References and Further Information

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Roseau County Soil and Water Conservation District (Roseau SWCD). 2010. Roseau County Local Water Management Plan 2010-2019.

Warroad River Watershed District (WRWD). 2007. Overall plan of the Warroad Watershed District. January 24, 2007.

Appendix

Appendix A. Existing Water Quality, Existing Loads, and Loading Capacity for Stream Reaches in the LOWW.

Appendix B. BMP Implementation Scenarios using HSPF

Lake of the Woods Watershed Reports

Lake of the Woods Watershed reports referenced in this watershed report are available online at:

Lake of the Woods Watershed webpage: https://www.pca.state.mn.us/water/watersheds/lake-woods

Minnesota Pollution Control Watershed webpage: https://www.pca.state.mn.us/water/watersheds/lake-woods

Appendix A: Existing Water Quality, Existing Loads, and Loading Capacity for Stream Reaches in the LOWW

Table A.1 Existing water quality, existing loads, and loading capacity for stream reaches in the LOWW for Total Suspended Solids.

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	Total Suspended Solids				Existing Conditions (Observed Data) [tons/day]					Loading Capacity (Flow Based) [tons/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	90th Percentile	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
Bostick Creek (0903000901)	537	S005-708	2006-2009, 2011-2013	59	25.2	8.0	--	3.8	1.2	0.7	0.1	4.3	1.7	1.1	0.7	0.5	LRE
	539	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	HRE
	540	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	AAQ
	546	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
	553	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
Zippel Creek (0903000902)	501	S000-795, S000-906, S003-697	2004, 2006, 2009, 2011-2013	93	30.0	22.0	9.2	1.2	1.2	1.2	--	2.5	1.0	0.6	0.4	0.3	LRE
	506	S003-698	2004.00	16	6.0	1.0	0.4	0.2	0.7		--	3.0	1.2	0.8	0.6	0.4	AAQ
	515	S003-699	2004, 2006, 2009, 2011-2013	47	18.8	7.0	4.4	0.4	0.4	0.5	--	3.0	1.2	0.8	0.5	0.4	LRE
	516	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	518	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	AAQ
	529	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	AAQ
	567	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	HRE
Warroad River (0903000903)	502	S006-978	2010-2011	34	30.0	17.0	--	--	--	--	--	29.8	10.6	6.3	3.8	2.4	HRE
	503	S005-679,	2009-2012	11	13.0	1.0	--	--	2.4	--	--	20.9	6.9	4.0	2.4	1.5	PIR

		S004-289															
	504	S005-678, S004-295	2009, 2012	11	5.0	0.0	--	--	0.5	--	--	5.4	2.0	1.2	0.7	0.4	AAQ
	526	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	533	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	557	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	558	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Muskeg Bay (0903000904)	505	S004-293	2012	10	8.1	0.0	--	--	--	--	--	2.1	0.9	0.6	0.4	0.3	AAQ
	523	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	560	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

--No Available Data

Protection/Restoration Classifications: AAQ = Above Average Quality, PIR = Potential Impairment Risk, TIR = Threatened Impairment Risk, LRE = Low Restoration Effort, HRE = High Restoration Effort.

Table A.2 Existing water quality, existing loads, and loading capacity for stream reaches in the LOWW for Total Phosphorus.

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	Total Phosphorus [mg/L]				Existing Conditions (Observed Data) [lbs/day]					Loading Capacity (Flow Based) [lbs/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	90th Percentile	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
Bostick Creek (0903000901)	537	S005-708	2006-2009, 2011-2013	59	0.1	14.0		24.7	9.0	6.0	3.4	28.9	11.5	7.5	4.9	3.3	LRE
	539	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	HRE
	540	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	HRE
	546	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
	553	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
Zippel Creek (0903000902)	501	S000-795, S000-906, S003-697	2004, 2006, 2009, 2011-2013	93	0.1	25.0	41.4	8.6	6.4	5.1	--	16.4	6.6	4.2	2.8	1.9	HRE
	506	S003-698	2004.00	15	0.4	15.0	19.7	8.3	5.6	3.8	2.6	19.7	8.3	5.6	3.8	2.6	HRE
	515	S003-699	2004, 2006, 2009, 2011-2013	48	0.1	13.0	42.1	15.6	9.6	4.6	--	20.1	8.1	5.3	3.5	2.4	HRE
	516	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	518	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	LRE
	529	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	LRE
	567	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	HRE
Warroad River (0903000903)	502	S006-978	2010-2013	64	0.1	13.0	--	--	--	--	--	198.4	70.9	41.8	25.4	16.3	LRE
	503	S004-289, S004-290, S005-679	2003-2012	102	0.0	9.0	102.9	34.0	25.3	22.0	5.2	139.1	46.1	26.4	15.9	10.0	PIR

	504	S004-295, S004-296, S005-678	2003-2012	99	0.0	6.0	259.3	8.2	5.2	3.8	1.9	35.8	13.1	7.7	4.6	2.9	AAQ
	526	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	533	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	557	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	558	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Muskeg Bay (0903000904)	505	S004-293	2003-2012	48	0.2	46.0	52.7	22.3	27.5	11.7	11.8	14.1	5.8	3.9	2.6	1.8	HRE
	523	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	560	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

--No Available Data

Protection/Restoration Classifications: AAQ = Above Average Quality, PIR = Potential Impairment Risk, TIR = Threatened Impairment Risk, LRE = Low Restoration Effort, HRE = High Restoration Effort.

Table A.3 Existing water quality, existing loads, and loading capacity for stream reaches in the LOWW for Inorganic Nitrogen.

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	Inorganic Nitrogen				Existing Conditions (Observed Data) [lbs/day]					Loading Capacity (Flow Based) [lbs/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	90th Percentile	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
Bostick Creek (0903000901)	537	S005-708	2012	10	0.0	0	--	--	--	--	--	4582.9	1798.5	1401.7	927.4	622.1	AAQ
	539	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
	540	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
	546	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
	553	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
Zippel Creek (0903000902)	501	S000-795, S000-906, S003-697	2004, 2009, 2012	71	0.2	0	20.7	10.1	6.4	1.2	--	2607.1	1022.2	795.7	527.8	355.5	AAQ
	506	S003-698	2004	18	0.2	0	384.5	9.7	2.6		--	3160.6	1318.9	1040.1	780.8	539.5	AAQ
	515	S003-699	2004	23	0.2	0	66.7	7.1	2.5	1.5	--	3197.5	1264.8	988.6	658.3	444.8	AAQ
	516	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	518	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	AAQ
	529	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	AAQ
	567	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	AAQ
Warroad River (0903000903)	502	S006-978	2010-2013	41	0.1	0	--	--	--	--	--	28735.5	10070.2	7465.5	4764.1	3213.4	AAQ
	503	S005-679, S004-289	2009, 2012	11	0.1	0	--	39.0	--	--	--	19728.4	6497.9	4746.7	2968.3	2008.8	AAQ
	504	S005-678, S004-295	2009, 2012	11	0.1	0	--	9.2	--	--	--	5211.6	1839.7	1379.9	873.4	575.3	AAQ
	526	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	533	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	557	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

	558	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Muskeg Bay (090300090	505	S004-293	2012	10	0.1	0	--	--	--	--	--	2241.2	925.8	727.9	489.7	334.8	AAQ
	523	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	560	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

--No Available Data

Protection/Restoration Classifications: AAQ = Above Average Quality, PIR = Potential Impairment Risk, TIR = Threatened Impairment Risk, LRE = Low Restoration Effort, HRE = High Restoration Effort.

Table A.4 Existing water quality, existing loads, and loading capacity for stream reaches in the LOWW for *Escherichia coli*.

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	Escherichia coli [org/100mL]				Existing Conditions (Observed Data) [tons/day]					Loading Capacity (Flow Based) [tons/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	Geo.	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
Bostick Creek (0903000901)	537	S005-708	2012-2013	15	38.7	3	--	--	--	--	--	320.3	128.4	85.7	57.0	37.6	AAQ
	539	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
	540	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
	546	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
	553	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Zippel Creek (0903000902)	501	S000-906	2012-2013	15	47.9	1	--	--	--	--	--	181.6	73.0	48.7	32.3	21.4	AAQ
	506	--	--	--	--	--	--	--	--	--	--	217.8	92.4	63.8	43.5	30.0	NA
	515	--	--	--	--	--	--	--	--	--	--	221.8	89.8	60.3	40.6	27.3	NA
	516	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
	518	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
	529	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
	567	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
Warroad River (0903000903)	502	S006-978	2012-2013	15	49.5	1	--	--	--	--	--	2065.7	762.5	477.8	298.7	187.1	AAQ
	503	S004-289, S004-290	2009-2013	53	57.8	15	--	189.0	53.4	144.1	--	1444.3	501.0	301.7	185.5	115.4	TIR
	504	S004-295, S004-296	2009-2013	52	53.0	11	--	16.3	33.8	54.5	--	379.6	139.6	88.1	54.1	33.3	AAQ
	526	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	533	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	557	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

	558	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Muskeg Bay (0903000904)	505	S004-293	2009-2013	30	35.4	3	--	0.5	550.0	57.2	--	156.6	65.0	44.6	30.3	20.7	LRE
	523	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	560	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

--No Available Data

Protection/Restoration Classifications: AAQ = Above Average Quality, PIR = Potential Impairment Risk, TIR = Threatened Impairment Risk, LRE = Low Restoration Effort, HRE = High Restoration Effort.

APPENDIX B

TECHNICAL MEMORANDUM

To: Mike Hirst, Lake of the Woods Soil and Water Conservation District
Cory Hernandez, Minnesota Pollution Control Agency

From: Timothy Erickson, P.E., Houston Engineering, Inc.

Through: Mark Deutschman, Ph.D., P.E., Houston Engineering, Inc.

Subject: Technical Memorandum – BMP Implementation Scenarios using HSPF
Objective 6 Hydrologic Simulation Program – FORTRAN (HSPF) Model Development Assistance and Incorporation.

Date: February 2, 2015

Project: 7180-002

INTRODUCTION

This Technical Memorandum (TM) describes the estimated load reduction benefits for three (3) Best Management Practice (BMP) scenario's for portions of the drainage area along the south shore of Lake of the Woods, USA. The benefits of the scenario's were evaluated using the Lake of the Woods (LOW) Watershed's Hydrologic Simulation Program-FORTRAN (HSPF) model informed by the BMP Suitability Analysis and Catchment Priority Rankings from the Enhanced Geospatial Water Quality Products (EGWQP) (HEI, 2015). The BMP scenarios were developed and the benefits estimated to guide local implementation efforts for use in the Watershed Restoration and Protection Strategy. The intent of preparing this memorandum is to provide 1) greater clarity with regard to the technical feasibility of achieving various nutrient and sediment load reductions and therefore the Lake of the Woods water quality goals (i.e., load allocations); 2) more detailed guidance to those responsible for implementing the TMDL including the numbers and types of BMPs which should be placed on the landscape; and 3) the information expectations memorialized in the Clean Water Accountability Act (https://www.revisor.leg.state.mn.us/statutes/?id=114D&view=chapter).

Through discussion with Minnesota Pollution Control Agency (MPCA), Lake of the Woods Soil and Water Conservation District (SWCD), and Natural Resources Conservation Service (NRCS) staff, three scenario's representing a range of BMP implementation "aggressiveness" were conceptualized. The load reduction benefits of these scenarios were then estimated using the HSPF model. The three scenarios developed and simulated using HSPF are intended to represent a range of potential strategies and include: (1) a maximum BMP implementation scenario; (2) a Top 25% BMP implementation scenario, and (3) a Top 10% BMP implementation scenario. The maximum BMP implementation scenario represents an upper limit on what can be achieved in terms of the load reduction by assuming all potential BMPs (HEI, 2015) can be implemented. The Top 25% scenario represents a targeted implementation approach where BMPs are located and constructed only with the catchments which rank in the top 25% with regard to contributing sediment and total phosphorus to Lake of the Woods (HEI, 2015). The Top 10% scenario represents a targeted implementation approach where BMPs are located and constructed only with the catchments which rank in the top 10% with regard to contributing sediment and total phosphorus to Lake of the Woods (HEI, 2015).

METHODS

BEST MANAGEMENT PRACTICES

Table 1 lists the BMPs used to develop the scenarios and simulated using the HSPF model. These BMPs include filter strips, grass waterways, water and sediment control basins (WASCOBs), saturated buffers, bioreactors, perennials, and cover crops. Additional BMPs were identified in the BMP suitability study (HEI, 2015) but limitations within HSPF restricts the types of BMPs that can be simulated to the ones listed in **Table 1**.

Table 1: BMP Types Simulated in LOW HSPF Scenarios.

BMP	Type	Treatment	HSPF Notes
Filter Strips	Surface Runoff BMP	Sediment (70%), Nitrogen (30%), Phosphorus (40%), BOD (30%)	Combined with grass waterways, applied to surface water only, priority for surface runoff BMPs.
Grass Waterways	Surface Runoff BMP	Sediment (70%), Nitrogen (30%), Phosphorus (40%), BOD (30%)	Combined with grass waterways, applied to surface water only, priority for surface runoff BMPs.
Sediment Control Basins (WASCOBs)	Surface Runoff BMP	Sediment (60%), Phosphorus (30%)	Applied to surface runoff only, secondary to filter strips/grass waterways.
Saturated Buffers	Tile Drainage/Interflow	Nitrogen (60%), Phosphorus (60%), BOD (90%)	Applied to interflow in tiled areas, priority for tile drainage BMPs.
Bioreactors	Tile Drainage/Interflow	Nitrogen (74%), Phosphorus (76.5%)	Applied to interflow in tiled areas, secondary to saturated buffers for tile drainage BMPs.
Perennials	Land Use Change	NA	Land use change-cropland to grassland (PERLNDs), priority for land use change BMPs.

Cover Crop	Land Use Change	NA	Land use change-cropland to grassland (PERLNDs), secondary to perennials for land use change BMPs. Implemented in HSPF through low till cropland.

BMPs where grouped into types based on how they are implemented in and simulated by the HSPF model. The groups include (1) surface BMPs (grass waterways, filter strips, and WASCOBs) that treat surface runoff only; (2) tile drainage/interflow BMPs (saturated buffers and bioreactors) that treat interflow in areas identified as having tile drainage; and (3) land use change BMPs (perennials and cover crops) that change the surface land cover. For simplicity in modeling BMPs in HSPF, it was assumed all BMPs treat runoff from cropland only, except for the cases where a surface BMP or tile BMP treats water from an area of cropland changed to perennials with a land use BMP.

Grass waterways and filter strips were combined into one BMP for simulation in HSPF. These BMPs treat water in the same way, with the only difference being placement (filter strips are located at the edge of the field and grass waterways are located in small ephemeral channels). Since HSPF does not distinguish between overland flow and small ephemeral channels within a subwatershed, these two BMPs were grouped.

For tile drainage BMPs, tiled areas were identified using Geographic Information System (GIS) data provided by the LOW SWCD (Hirst, 2014). These GIS data were in draft form and do not contain all tiled areas in the LOW watershed, but these are the only currently available date about tile locations. These identified areas were assumed to contain tile drainage only when running the BMP scenarios. If/when more information is available, these scenario could be modified to include additional areas. In the LOW HSPF model, tile drainage was not explicitly simulated. This lack of explicit simulation excludes simulation of sediment transport through the tile lines. Therefore, while reduction to nitrogen and phosphorus can be simulated using interflow values within the model sediment reductions could not be simulated without extensive and thereby changing the effectiveness of the water quality calibration.

In addition to limit the amount of modifications needed within the HSPF model required to implement the BMP scenarios, only one BMP per type (surface, tile drainage, and land use) was allowed to treat a given area, eliminating treatment trains where treated water from one BMP is allowed to flow into another BMP for additional treatment. Multiple BMPs from different BMP types were allowed because the BMPs threat different parts of the flow, i.e. surface BMPs treat surface water where tile drainage BMPs treat interflow.

Through discussions with the LOW SWCD, priority was given to the most likely BMP to be implemented in the LOW watershed. For surface BMPs, grass waterways/filter strips were given priority to WASCOBs; for tile drainage BMPs, saturated buffers were given priority over bioreactors; and for land use change, perennials were given priority over cover crops. Perennials were given priority over cover crops because the suitable areas for perennials was much smaller than the areas for cover crops (which is any cropland areas). This may not be realistic because when you change land use from cropland to perennials, you are taking cropland out of production. If cover crops were given priority, no areas would have included perennials as a land use change. The following section describes the estimated load reduction benefits for the three (3) BMP implementation scenarios simulated using the LOW HSPF.

MAXIMUM BMP IMPLEMENTATION SCENARIO

The maximum BMP implementation scenario represents the "maximum" potential treatment through BMP implementation and provides and provides an estimate of the upper limit load reduction, that can be achieved through BMP implementation. It should be noted that treatment trains (i.e. multiple BMPs in series) were not included in any of the BMP implementation scenarios. Treatment trains would require extensive modifications to the LOW HSPF model which is beyond the scope of this objective.

Table 2 shows the treated drainage acreage by BMP for the maximum BMP implementation scenario by major tributary and total watershed. Areas for different BMP types (surface, interflow, and land use change; see **Table 1**) can overlap and cover the same area. **Figure 1** shows the extent of the treated drainage areas for the maximum BMP implementation scenario. The total Lake of the Woods drainage area is 763,643 acres.

Table 2: Treated Areas (acres) of Cropland by BMP for the Maximum BMP Scenario.

Major Tributary	Grass Waterways/ Filter Strips (acres)	WASCOBs (acres)	Saturated Buffers (acres)	Bioreactors (acres)	Cover Crops (acres)	Perennials (acres)
Direct Drainage	10307.6	3666.6	60.8	0.0	10670.2	1054.9
Warroad River	13777.2	2127.8	0.0	0.0	13690.7	2159.2
Willow Creek	826.3	2288.4	0.0	0.0	2692.4	553.5
Zippel Bay	7336.3	3269.2	3737.0	180.5	7673.6	1913.8
Biostic Bay	2851.4	1341.6	288.3	0.0	2980.7	874.4
Total Area	35098.9	12693.5	4086.1	180.5	37707.7	6555.8
Percent of the Watershed	4.6%	1.7%	0.5%	0.0%	4.9%	0.9%

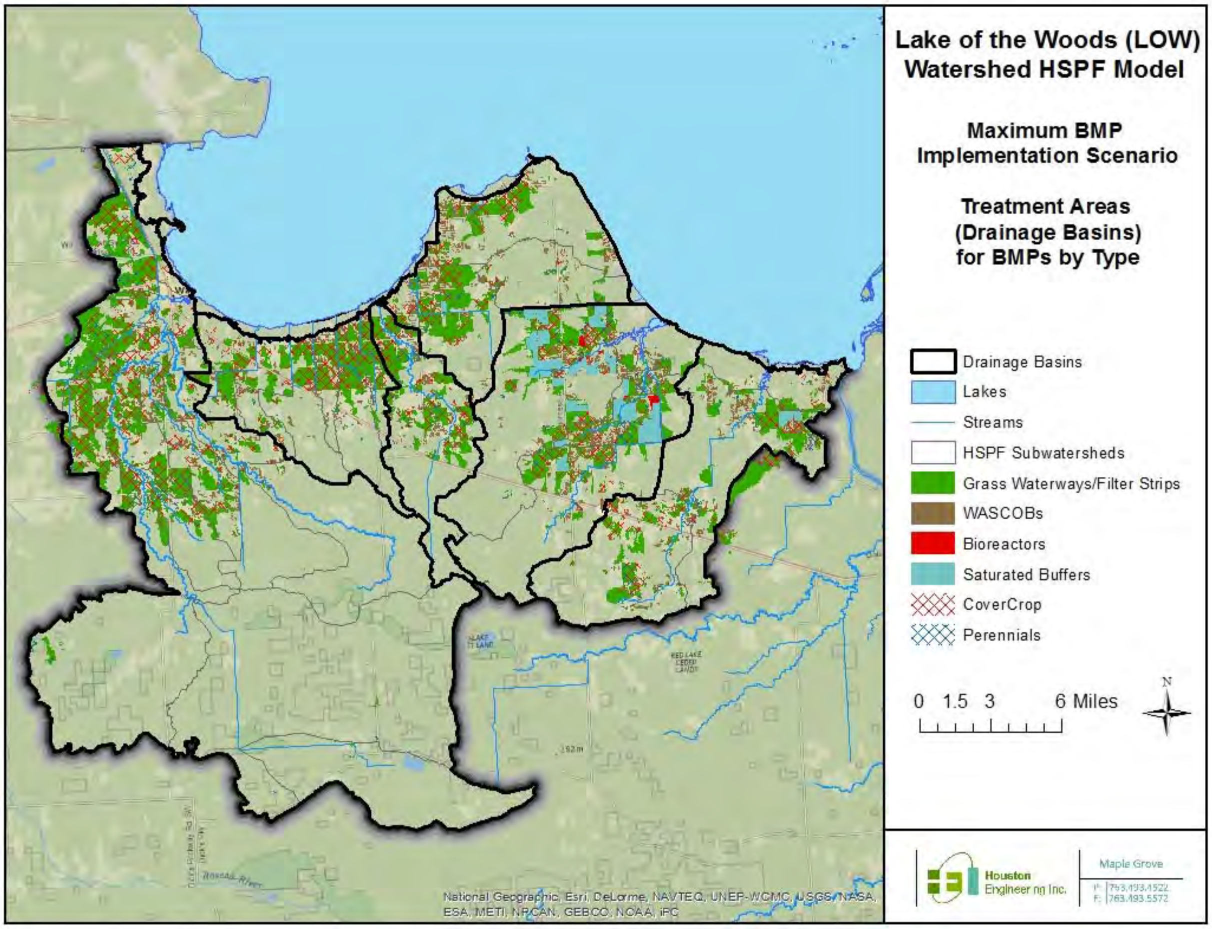


Figure 1: Drainage Areas for Maximum BMP Implementation Scenario by BMP Type.

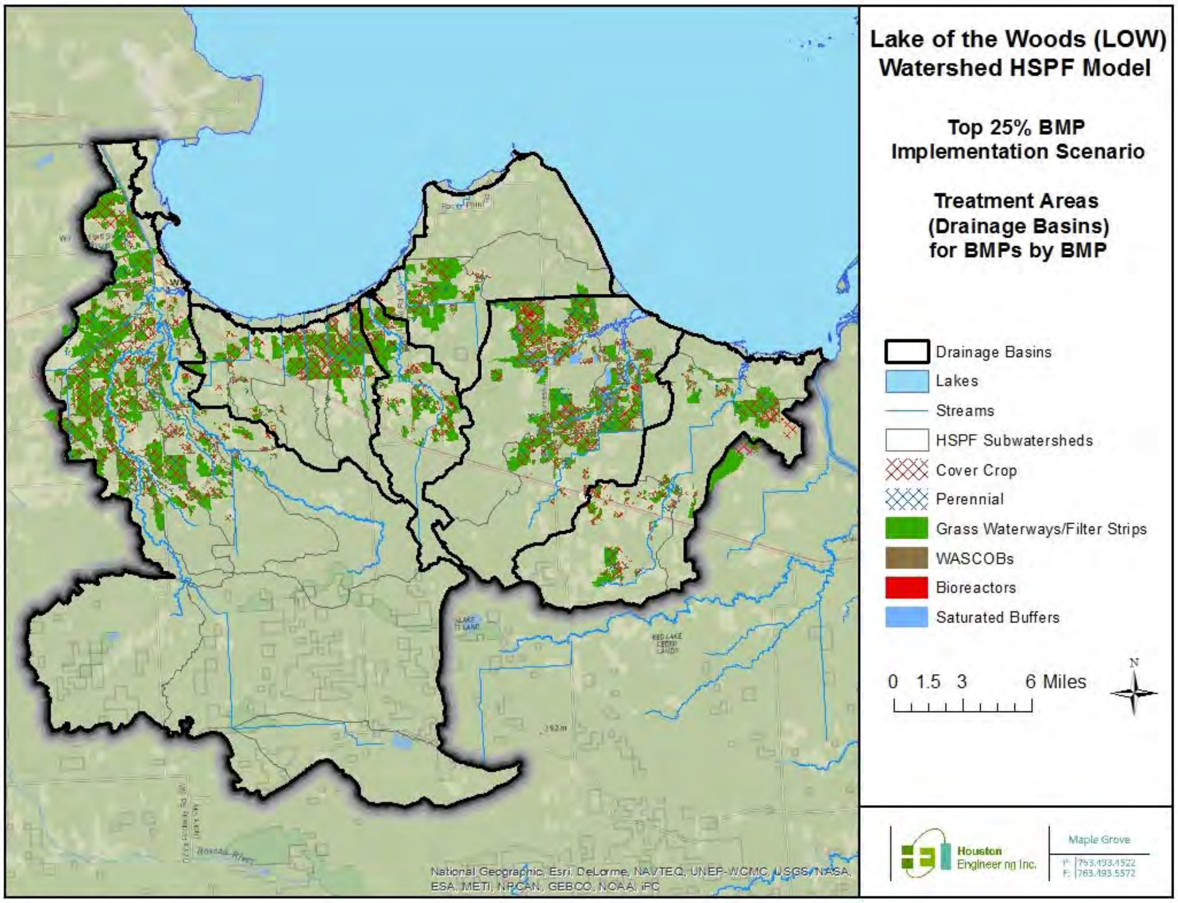
TOP 25% BMP IMPLEMENTATION SCENARIO

The top 25% BMP implementation scenario represents BMP implementation in the highest 25% contributing catchments determined by the BMP Suitability Analysis and Catchment Priority Rankings from EGWQP (HEI, 2015) and represents a broad, targeted approach to bmp implementation.

Table 3 shows the treated drainage acreage by BMP for the Top 25% BMP implementation scenario by major tributary and total watershed. Areas for different BMP types (surface, interflow, and land use change; see **Table 1**) can overlap and cover the same area.   **Figure 2** shows the extent of the treated drainage areas for the maximum BMP implementation scenario.

Table 3: Treated Areas (acres) of Cropland by BMP for the Top 25 BMP Scenario.

Major Tributary	Grass Waterways/ Filter Strips (acres)	WASCOBs (acres)	Saturated Buffers (acres)	Bioreactors (acres)	Cover Crops (acres)	Perennials (acres)
Direct Drainage	7136.8	990.1	60.8	0.0	7546.0	654.8
Warroad River	12679.4	1782.2	0.0	0.0	13355.7	1852.6
Willow Creek	2471.0	462.9	0.0	0.0	2684.4	493.4
Zippel Bay	6829.6	2514.0	2546.2	766.7	7618.7	1830.8
Biostic Bay	2045.7	698.2	279.2	4.4	2834.8	614.8
Total Area	31162.3	6447.4	2886.3	771.2	34039.6	5446.5
Percent of the Watershed	4.1%	0.8%	0.4%	0.1%	4.5%	0.7%



National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC

Figure 2: Drainage Areas for Top 25% BMP Implementation Scenario by BMP Type.

TOP 10% BMP IMPLEMENTATION SCENARIO

The top 10% BMP implementation scenario represents BMP implementation in the highest 10% contributing catchments determined by the BMP Suitability Analysis and Catchment Priority Rankings from EGWQP (HEI, 2015) and represents a targeted approach to bmp implementation.

Table 4 shows the treated drainage acreage by BMP for the Top 10% BMP implementation scenario by major tributary and total watershed. Areas for different BMP types (surface, interflow, and land use change; see **Table 1**) can overlap and cover the same area. **Figure 2** shows the extent of the treated drainage areas for the maximum BMP implementation scenario.

Table 4: Treated Areas (acres) of Cropland by BMP for the Top 10 BMP Scenario.

Major Tributary	Grass Waterways/ Filter Strips (acres)	WASCOBs (acres)	Saturated Buffers (acres)	Bioreactors (acres)	Cover Crops (acres)	Perennials (acres)
Direct Drainage	3326.2	140.6	0.0	0.0	4999.5	180.8
Warroad River	10144.0	1187.2	0.0	0.0	12865.1	1291.4
Willow Creek	2140.5	333.7	0.0	0.0	2556.5	383.2
Zippel Bay	6366.6	1539.6	2446.8	693.1	7350.5	1723.9
Biostic Bay	1480.9	384.5	279.2	4.5	2589.2	430.5
Total Area	23458.2	3585.7	2726.0	697.6	30360.8	4009.8
Percent of Watershed	3.1%	0.5%	0.4%	0.1%	4.0%	0.5%

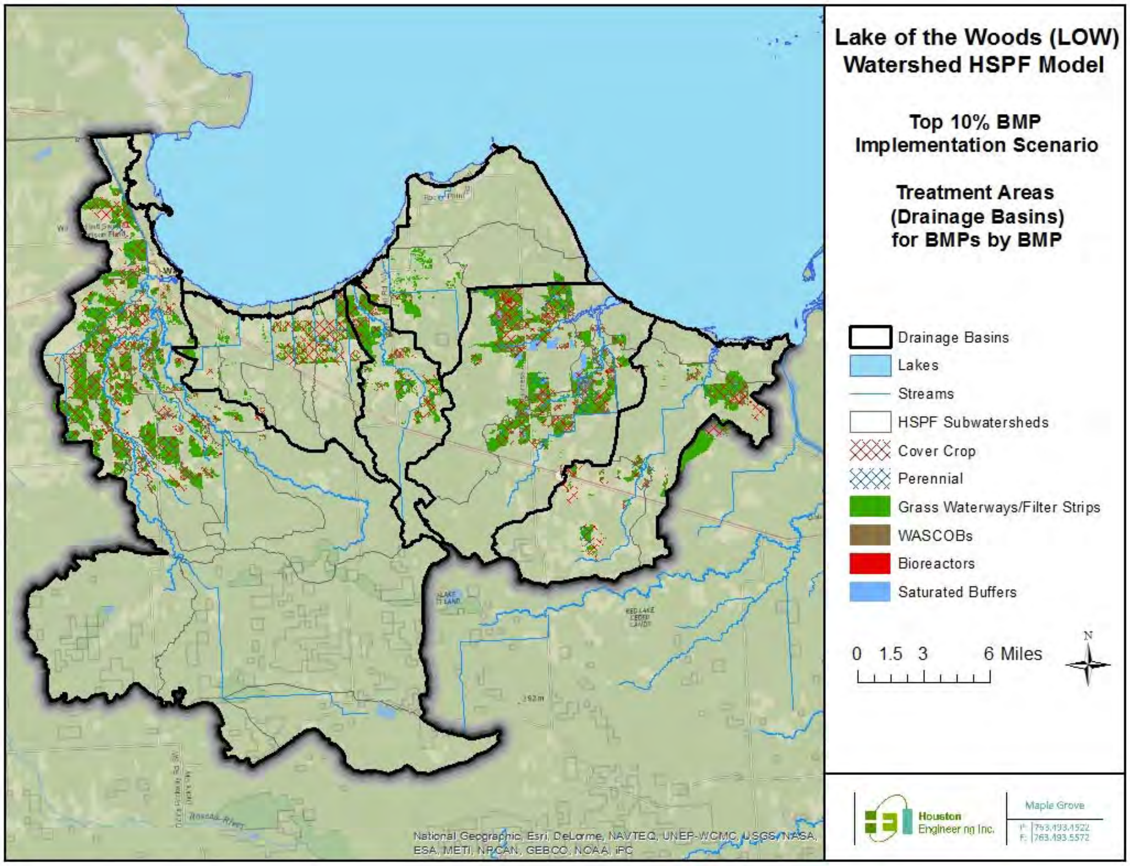


Figure 3: Drainage Areas for Top 10% BMP Implementation Scenario by BMP Type.

RESULTS

Summary results from the LOW HSPF BMP Scenarios are provided in **Table 5** for total nitrogen, **Table 6** for total phosphorus, and **Table 7** for total sediment. For each water quality parameter, the reductions in annual loads delivered to the nearest stream channel (overland loading) and delivered to the outlet of the major tributaries lake loading) are provided for each BMP scenario and the base simulation (without BMPs). **Appendix A** provides maps showing how the loads were reduced by HSPF subwatershed for both delivered to the channel and delivered to the lake loads. These maps provide spatial representation of the simulated load reduction as a percent reduction of the base load.

Table 5: Total Nitrogen Annual (pounds) Load Reductions by Scenario.

Major Tributary	Base Load	Maximum Scenario Load Reduction		Top 25 Scenario Load Reduction		Top 10 Scenario Load Reduction	
	Load (lbs/year)	Load (lbs/year)	Percent (%)	Load (lbs/year)	Percent (%)	Load (lbs/year)	Percent (%)
Delivered to the Stream (overland loading)							
Direct Drainage	149,243	85,259	57.1%	3,243	2.17%	789	0.53%
Warroad River	337,883	95,886	28.4%	7,411	2.19%	5,879	1.74%
Willow Creek	33,678	15,237	45.2%	1,481	4.40%	1,180	3.50%
Zippel Bay	96,714	42,989	44.4%	10,373	10.7%	9,733	10.1%
Biostic Bay	61,957	21,268	34.3%	1,630	2.63%	1,234	1.99%
Total Area	1,187,536	292,933	24.7%	24,483	2.06%	19,109	1.61%
Delivered to Lake of the Woods							
Direct Drainage	145,887	83,061	56.9%	3,245	2.2%	740	0.5%
Warroad River	355,631	102,809	28.9%	7,812	2.2%	6,234	1.8%
Willow Creek	35,786	16,710	46.7%	1,565	4.4%	1,248	3.5%
Zippel Bay	100,383	45,016	44.8%	10,809	10.8%	10,139	10.1%
Biostic Bay	62,524	22,364	35.8%	1,738	2.8%	1,311	2.1%
Total Area	1,141,545	305,895	26.8%	25,566	2.2%	20,019	1.8%

Table 6: Total Phosphorus Annual (pounds) Load Reductions by Scenario.

Major Tributary	Base Load	Maximum Scenario Load Reduction		Top 25 Scenario Load Reduction		Top 10 Scenario Load Reduction	
	Load (lbs/year)	Load (lbs/year)	Percent (%)	Load (lbs/year)	Percent (%)	Load (lbs/year)	Percent (%)
Delivered to the Stream (overland loading)							
Direct Drainage	9,083	6,193	68.2%	544	6.0%	121	1.3%

Warroad River	16,743	6,742	40.3%	1,018	6.1%	769	4.6%
Willow Creek	1,824	1,037	56.9%	176	9.7%	140	7.7%
Zippel Bay	4,995	2,782	55.7%	829	16.6%	741	14.8%
Biostic Bay	3,228	1,384	42.9%	147	4.6%	98	3.0%
Total Area	54,090	20,480	37.9%	2,756	5.1%	1,908	3.5%
Delivered to Lake of the Woods							
Direct Drainage	8,876	6,050	68.2%	542	6.1%	115	1.3%
Warroad River	17,777	7,329	41.2%	1,058	5.9%	804	4.5%
Willow Creek	1,944	1,133	58.3%	183	9.4%	146	7.5%
Zippel Bay	5,269	2,954	56.1%	868	16.5%	778	14.8%
Biostic Bay	3,149	1,470	46.7%	158	5.0%	105	3.3%
Total Area	52,026	21,529	41.4%	2,858	5.5%	1,993	3.8%

Table 7: Total Sediment Annual (tons) Load Reductions by Scenario.

Major Tributary	Base Load	Maximum Scenario Load Reduction		Top 25 Scenario Load Reduction		Top 10 Scenario Load Reduction	
	Load (tons/year)	Load (tons/year)	Percent (%)	Load (tons/year)	Percent (%)	Load (tons/year)	Percent (%)
Delivered to the Stream (overland loading)							
Direct Drainage	2,321	1,615	69.6%	416	17.9%	109	4.7%
Warroad River	3,601	1,651	45.9%	680	18.9%	515	14.3%
Willow Creek	409	245	59.9%	105	25.7%	84	20.6%
Zippel Bay	706	419	59.3%	231	32.8%	183	26.0%
Biostic Bay	532	241	45.3%	53	10.0%	25	4.7%
Total Area	13,470	5,081	37.7%	1,534	11.4%	963	7.1%
Delivered to Lake of the Woods							
Direct Drainage	3,126	2,320	74.2%	698	22.3%	170	5.4%
Warroad River	4,260	2,735	64.2%	1,284	30.1%	971	22.8%
Willow Creek	504	357	70.8%	200	39.6%	161	31.9%
Zippel Bay	1,115	736	66.0%	438	39.2%	347	31.1%
Biostic Bay	638	368	57.7%	102	16.1%	49	7.7%
Total Area	14,643	7,471	51.0%	2,775	19.0%	1,748	11.9%

As would be expected, overall the maximum BMP implementation scenario provide the best reduction in all three water quality parameters, providing a 26.8% reduction in total nitrogen, a 41.4% reduction in total phosphorus, and a 51.0% reduction in total sediment delivered to LOW. The Top 25% and Top 10% BMP implementation scenarios provide much less treatment to water quality. The overall reduction to total nitrogen delivered to LOW was 2.2% for the Top 25% scenario and 1.8% for the Top 10%. Total phosphorus delivered to LOW was reduced by 5.5% and 3.8% for the Top 25% and Top 10% BMP scenarios, respectively.

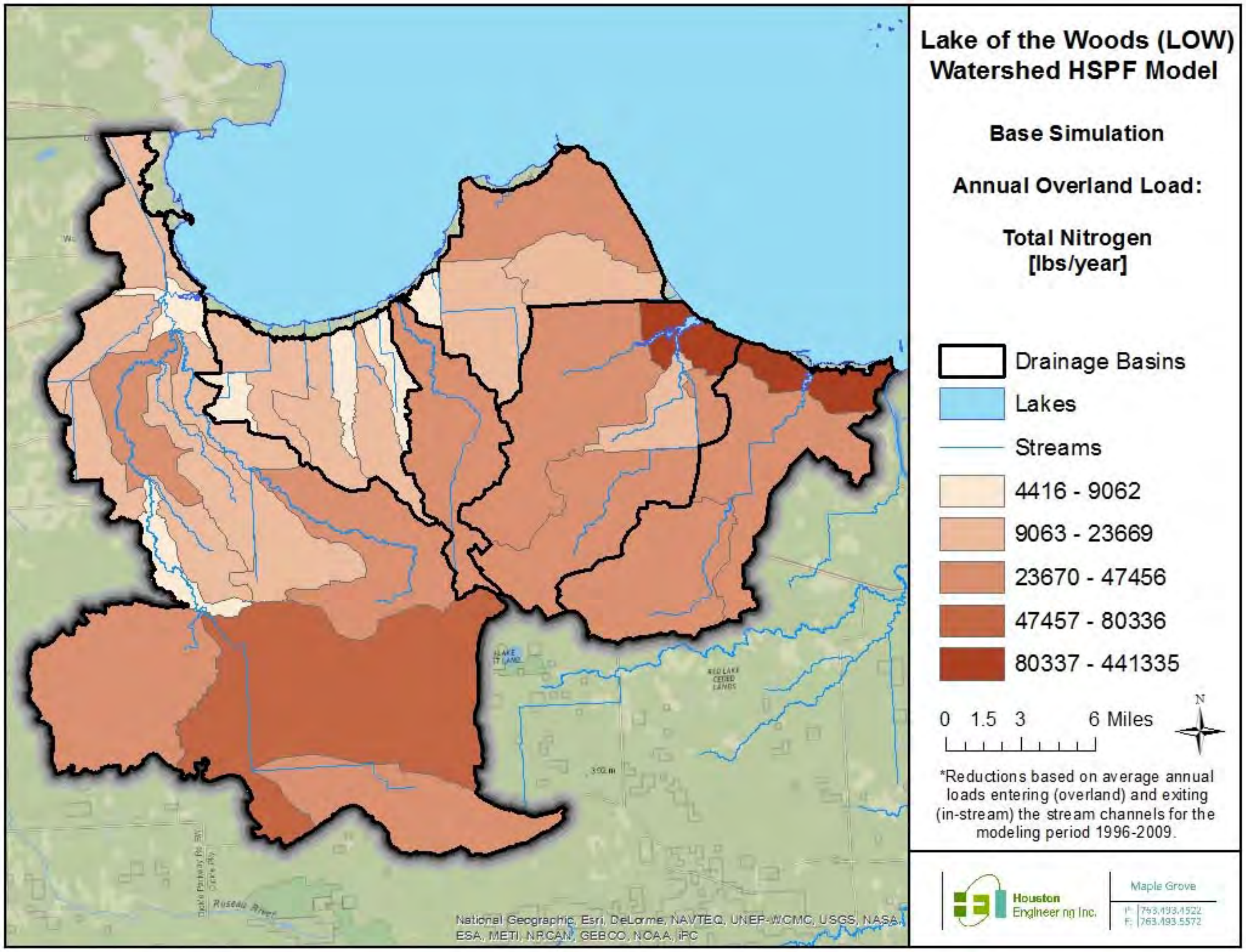
The reductions do not seem to be proportional to the amount of treatment implemented. This can be seen in the differences between the maximum scenario and the Top 25% and Top 10% scenarios. The differences in drainage area treated for surface BMPS between each of the BMP scenarios is approximately 10,000 acres but the treatment achieved with the maximum scenario is an order of magnitude higher when compared to the other two scenarios. This may represent a breaking point in the transport of material in the watershed that may actually exist or may be related to the representation of the transport processes within the HSPF model. Further investigation may be warranted to see if such a breaking point real exists or if it is a shortcoming of HSPF.

REFERENCES

Hirst, Mike. (2014). Personnel Communication. Lake of the Woods SWCD. Email dated March 26, 2014.

Houston Engineering, Inc. (HEI). 2015. Technical Memorandum - PTMA BMPs and Measurement Methods. Technical Memorandum dated January 17, 2015 to Lake of the Woods SWCD and MPCA, 103 pp.

APPENDIX A: LOAD REDUCTION MAPS FOR BMP IMPLEMENTATION SCENARIOS



*Reductions based on average annual loads entering (overland) and exiting (in-stream) the stream channels for the modeling period 1996-2009.

National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC

Figure A.1: Annual average total nitrogen [lbs/yr] delivered to a channel (overland load) from the Base simulation of the LOW HSPF model.

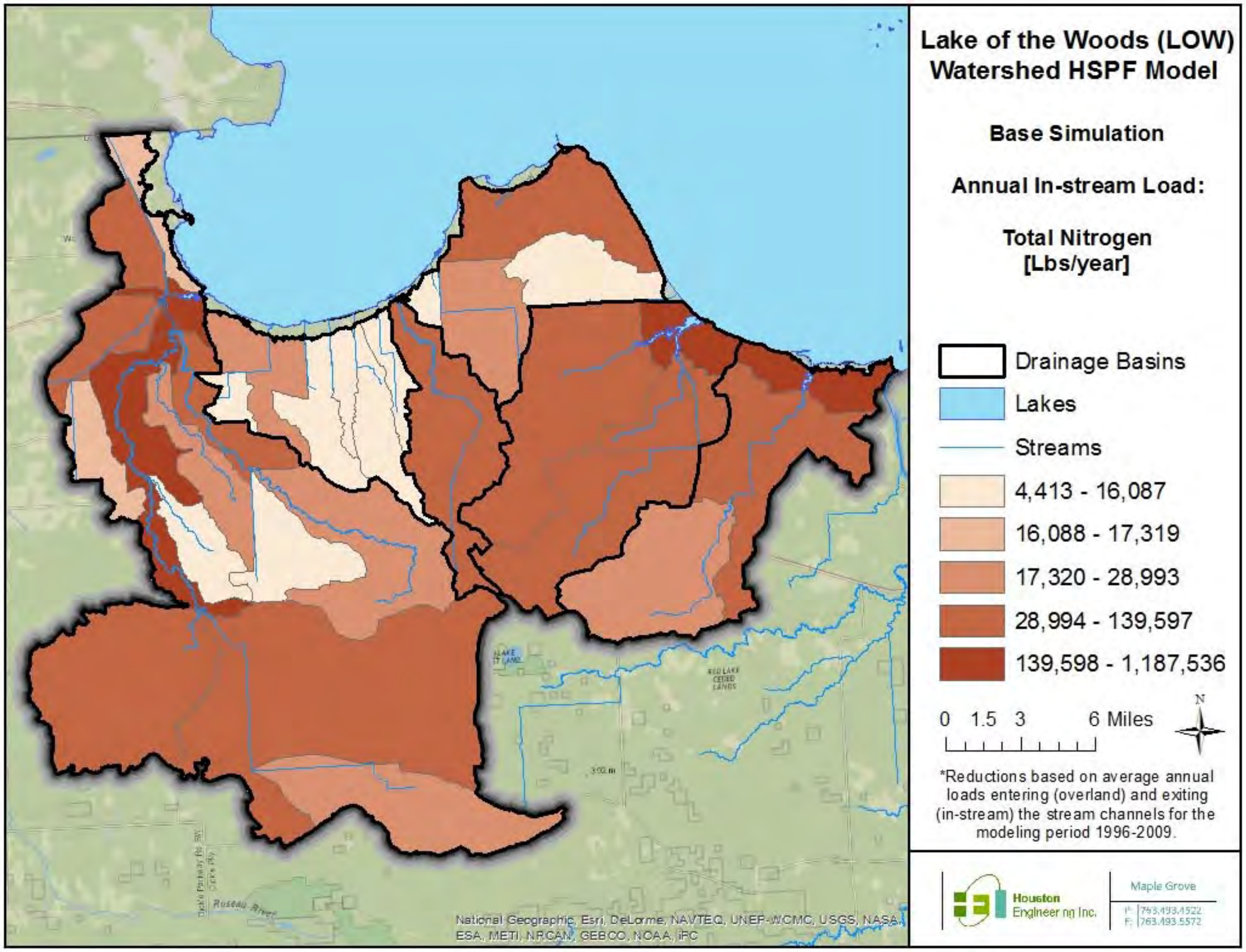
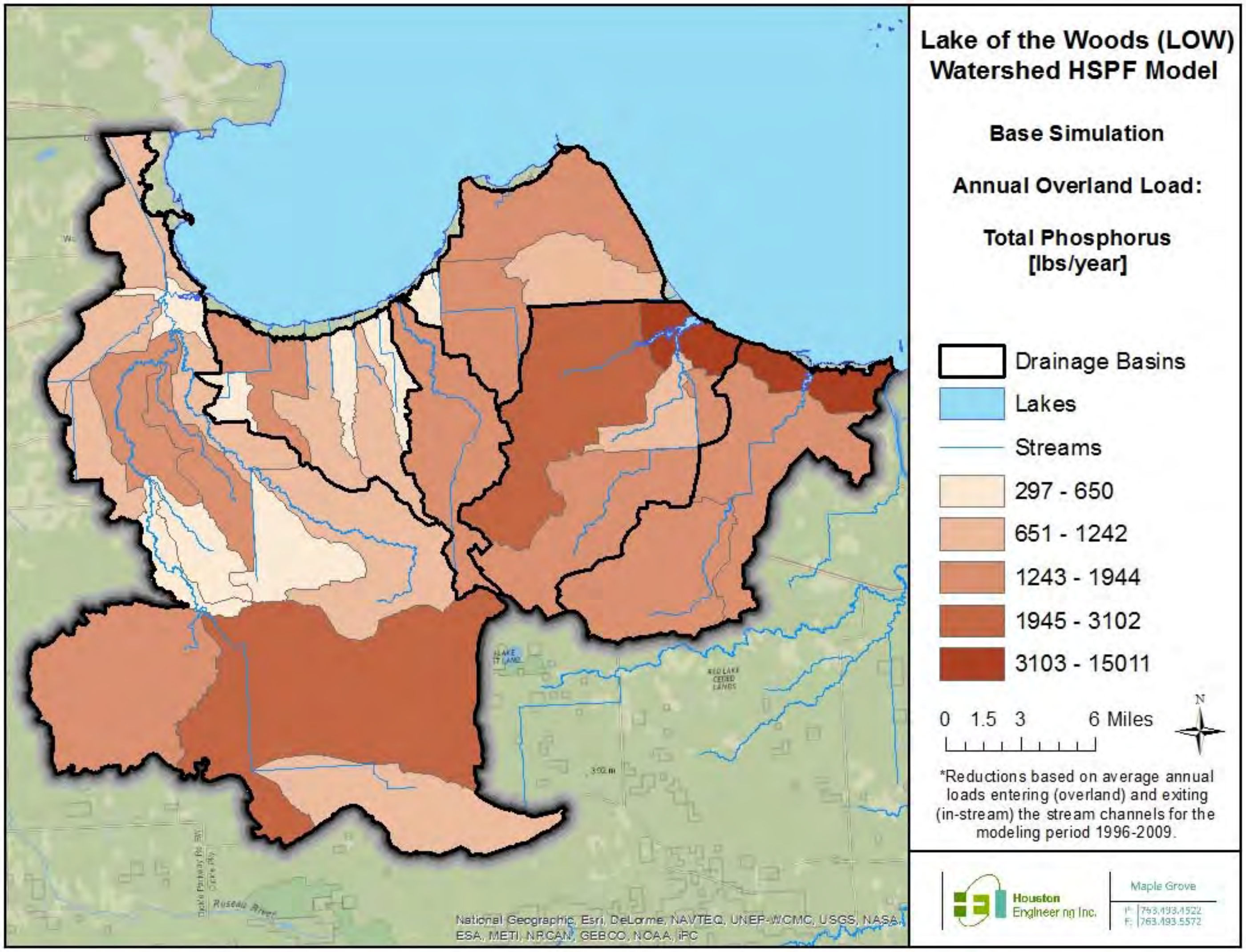


Figure A.2: Annual average total nitrogen [lbs/yr] delivered to outlet of the subwatershed (in-stream load) from the Base simulation of the LOW HSPF model.



*Reductions based on average annual loads entering (overland) and exiting (in-stream) the stream channels for the modeling period 1996-2009.

National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC

Figure A.3: Annual average total phosphorus [lbs/yr] delivered to a channel (overland load) from the Base simulation of the LOW HSPF model.

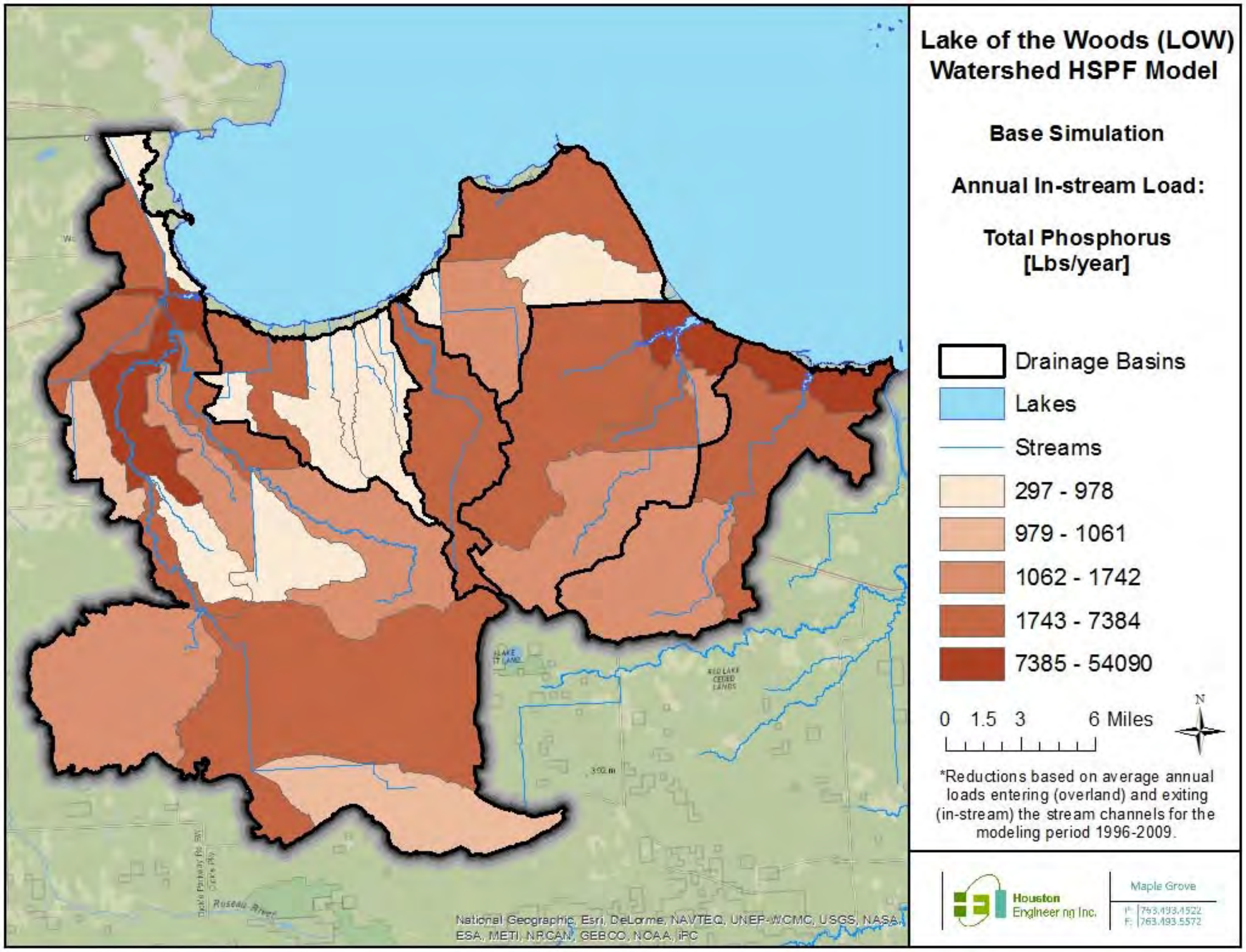


Figure A.4: Annual average total phosphorus [lbs/yr] delivered to subwatershed outlet (in-stream load) from the Base simulation of the LOW HSPF model.

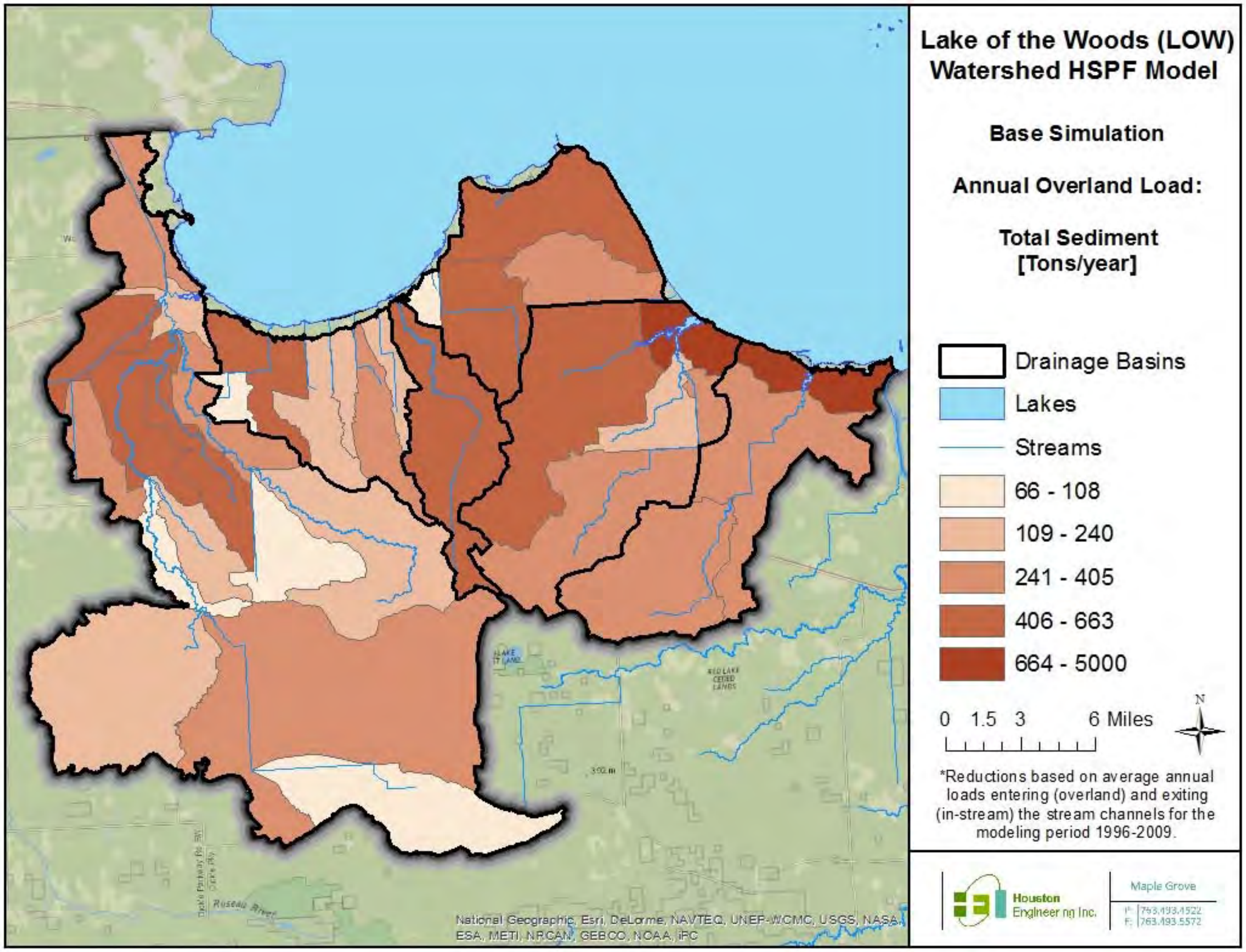
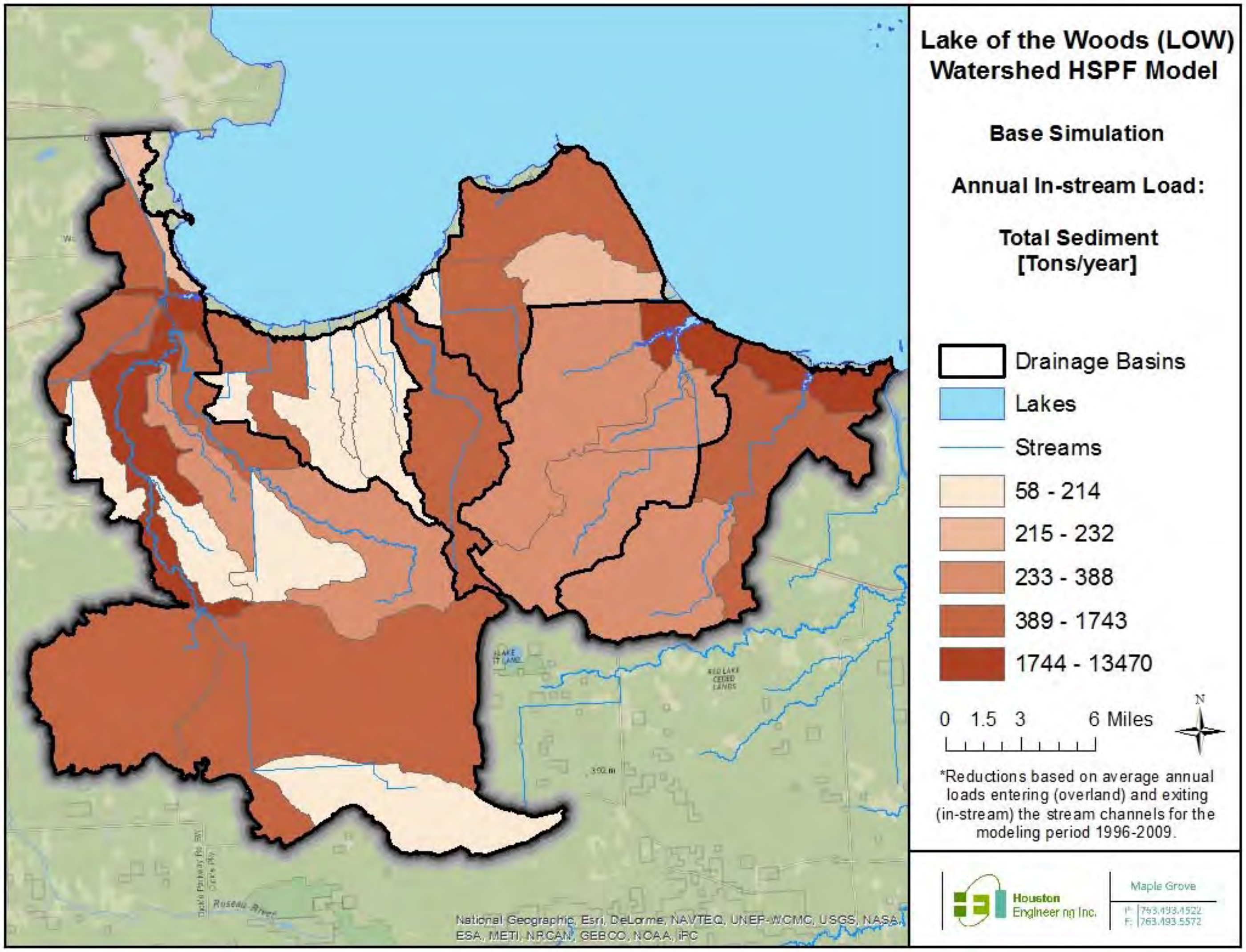


Figure A.5: Annual average total sediment [lbs/yr] delivered to a channel (overland load) from the Base simulation of the LOW HSPF model.


Lake of the Woods (LOW) Watershed HSPF Model

Base Simulation

Annual In-stream Load:

Total Sediment [Tons/year]

*Reductions based on average annual loads entering (overland) and exiting (in-stream) the stream channels for the modeling period 1996-2009.

National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC

Figure A.6: Annual average total sediment [lbs/yr] delivered to subwatershed outlet (in-stream load) from the Base simulation of the LOW HSPF model.

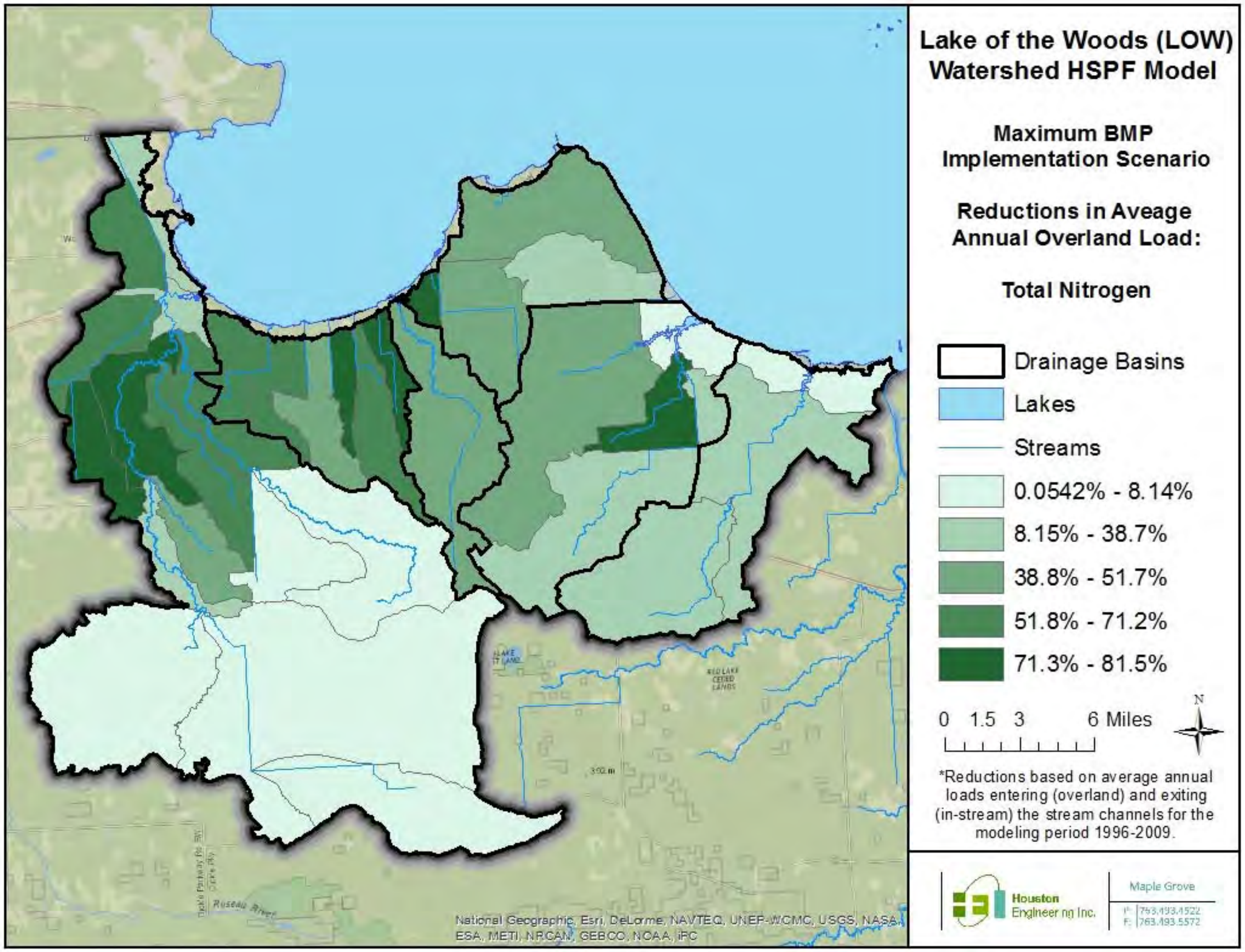


Figure A.7: Reductions in annual average total nitrogen [lbs/yr] delivered to a channel (overland load) from the maximum BMP implantation scenario.

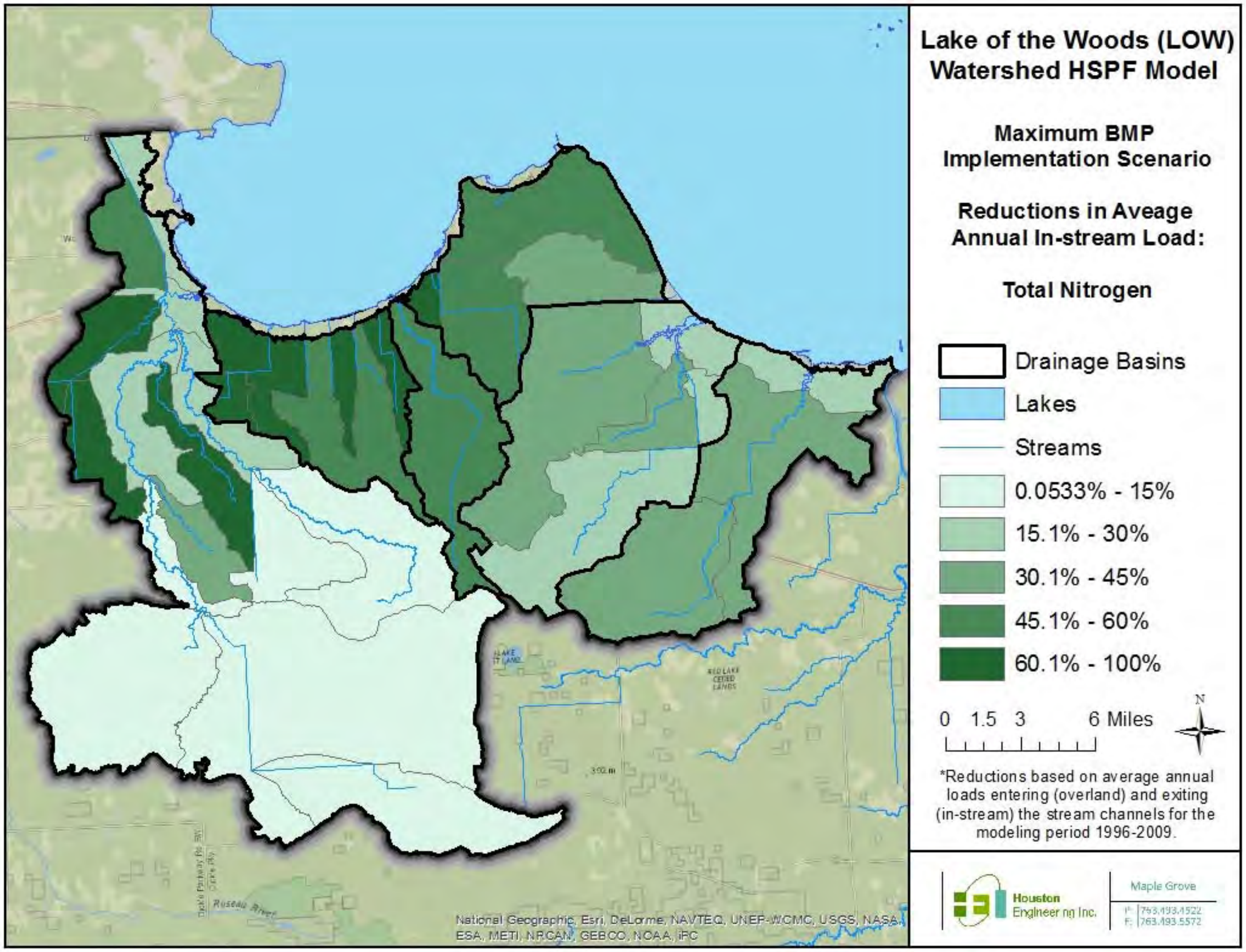


Figure A.8: Reductions in annual average total nitrogen [lbs/yr] delivered to outlet of the subwatershed (in-stream load) from the maximum BMP implantation scenario.

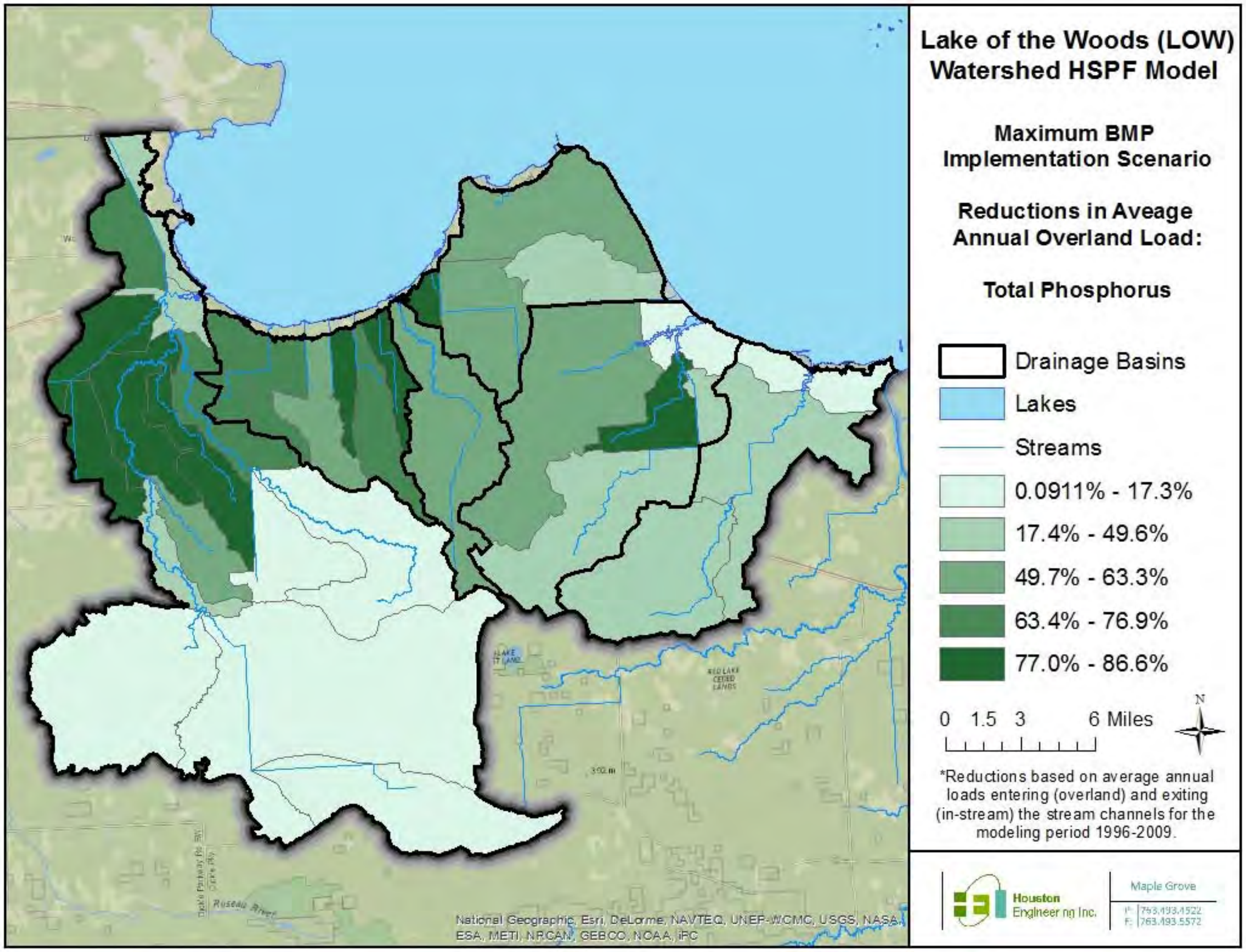


Figure A.9: Reductions in annual average total phosphorus [lbs/yr] delivered to a channel (overland load) from the maximum BMP implantation scenario.

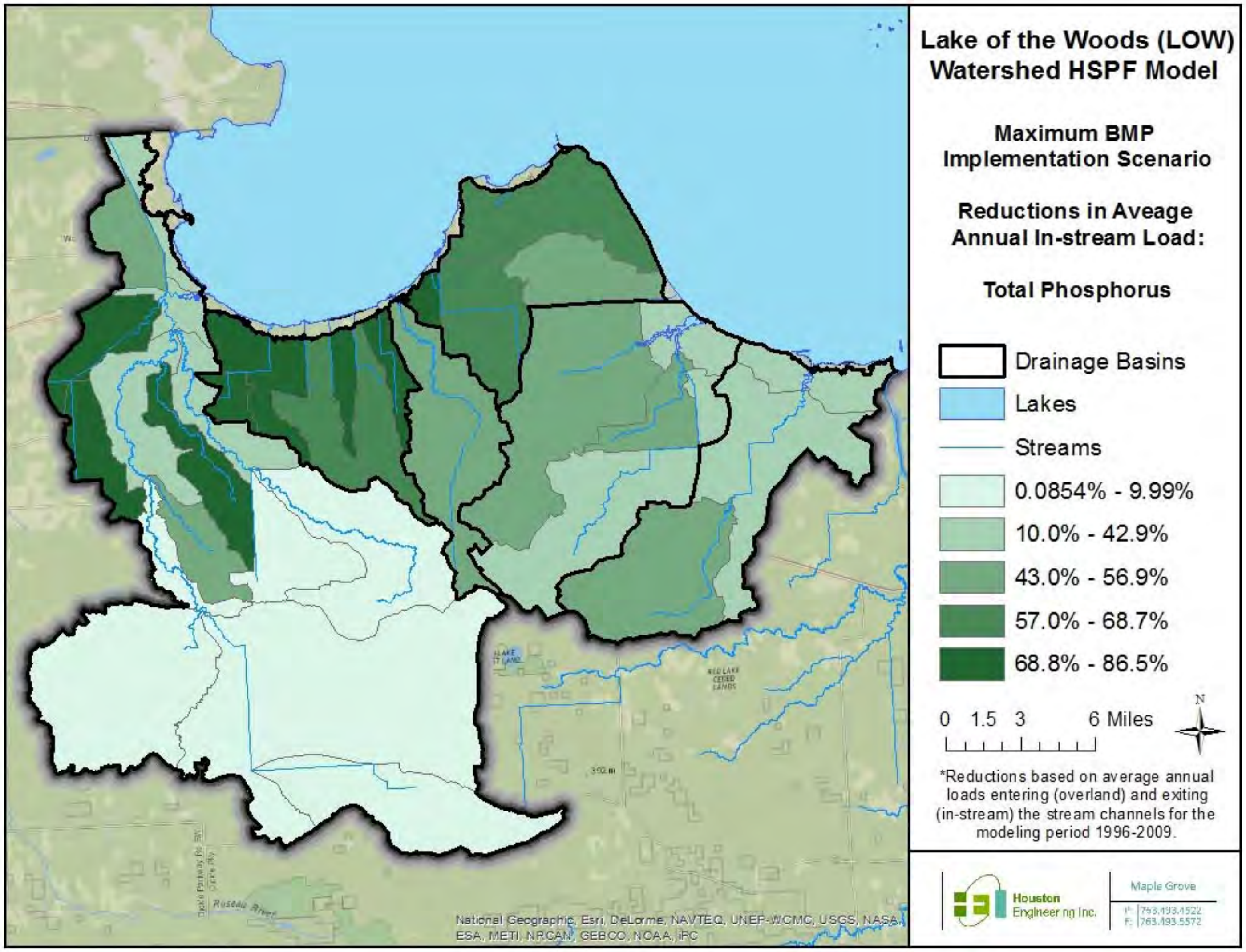
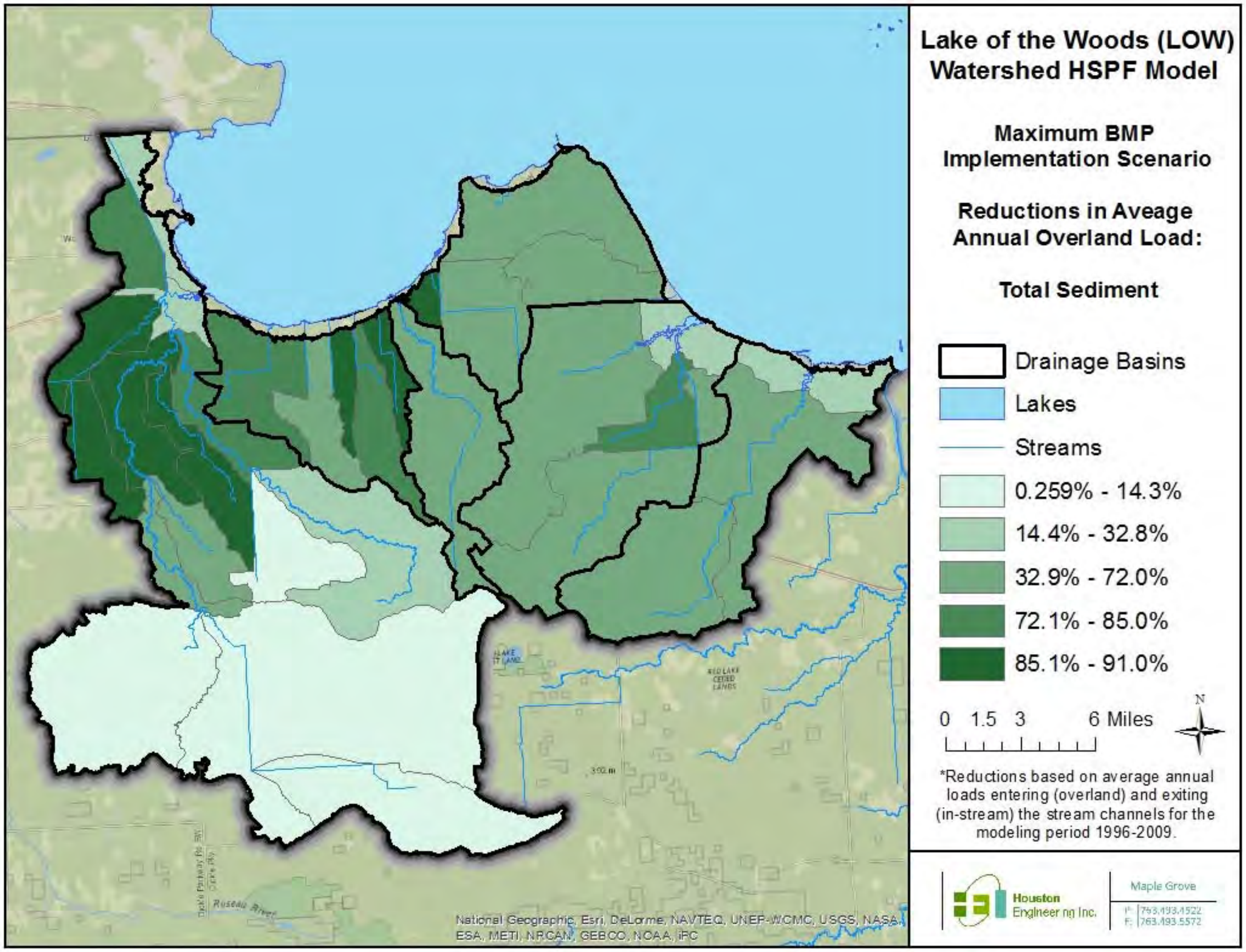


Figure A.10: Reductions in annual average total phosphorus [lbs/yr] delivered to outlet of the subwatershed (in-stream load) from the maximum BMP implantation scenario.



National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC

Figure A.11: Reductions in annual average total sediment [lbs/yr] delivered to a channel (overland load) from the maximum BMP implantation scenario.

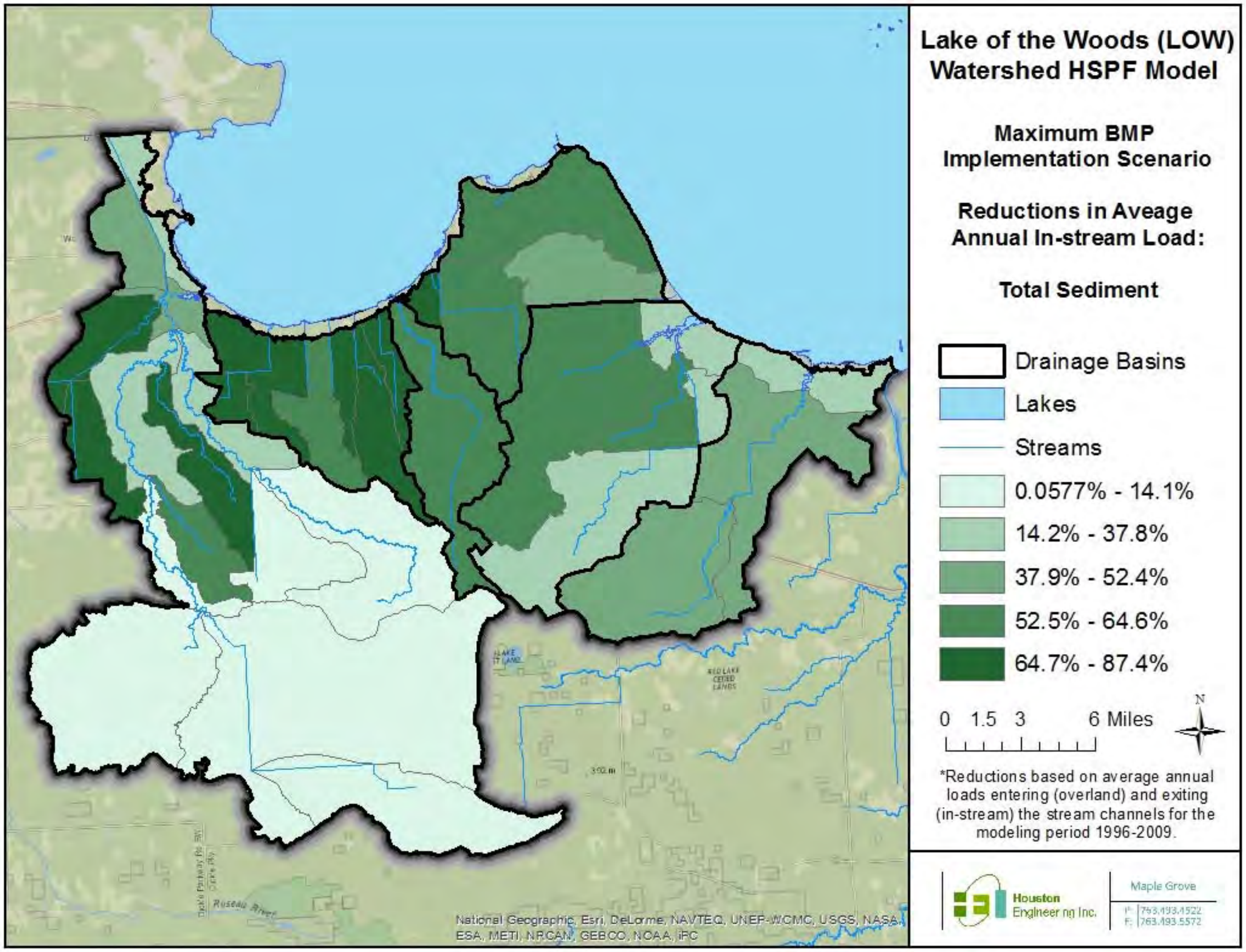
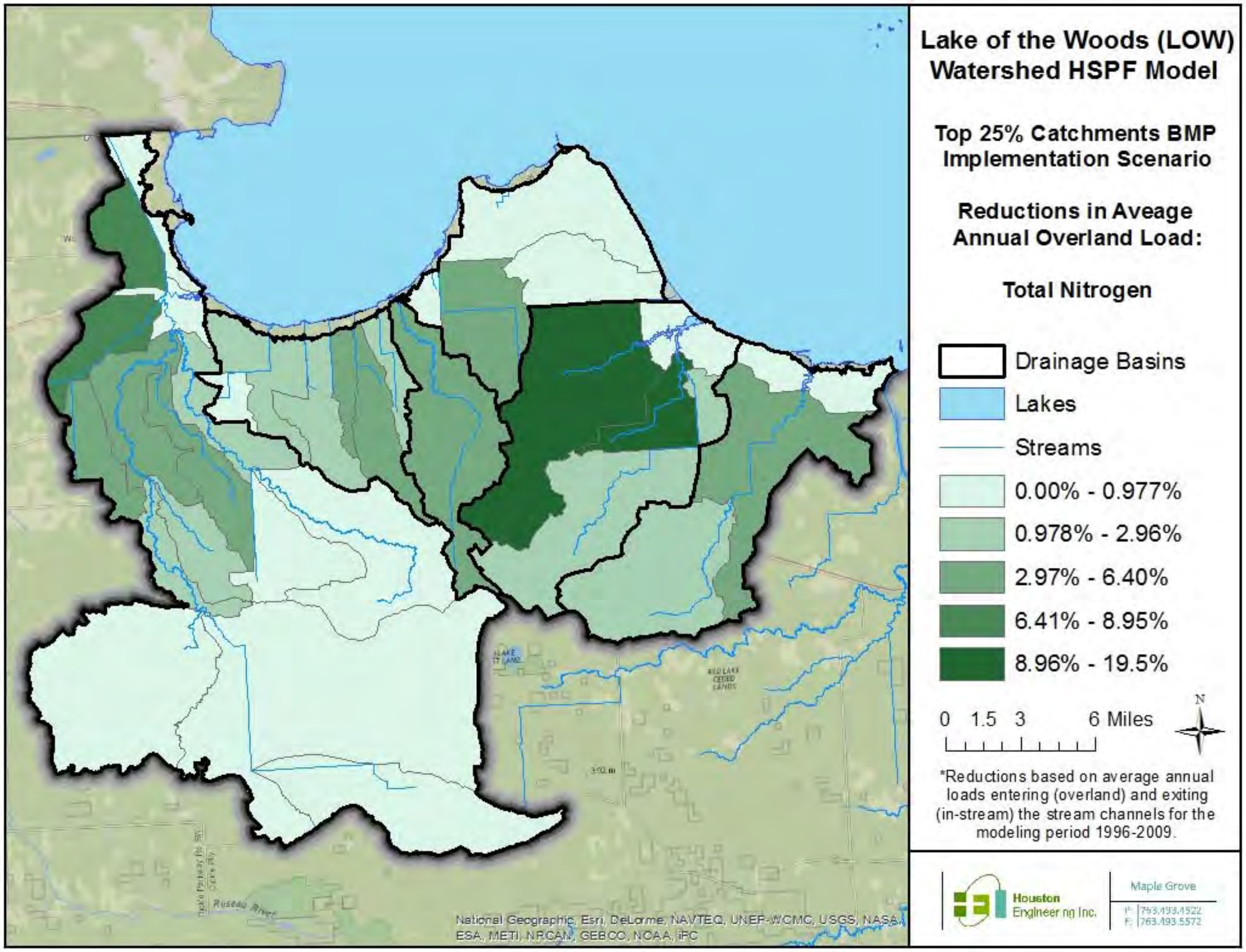


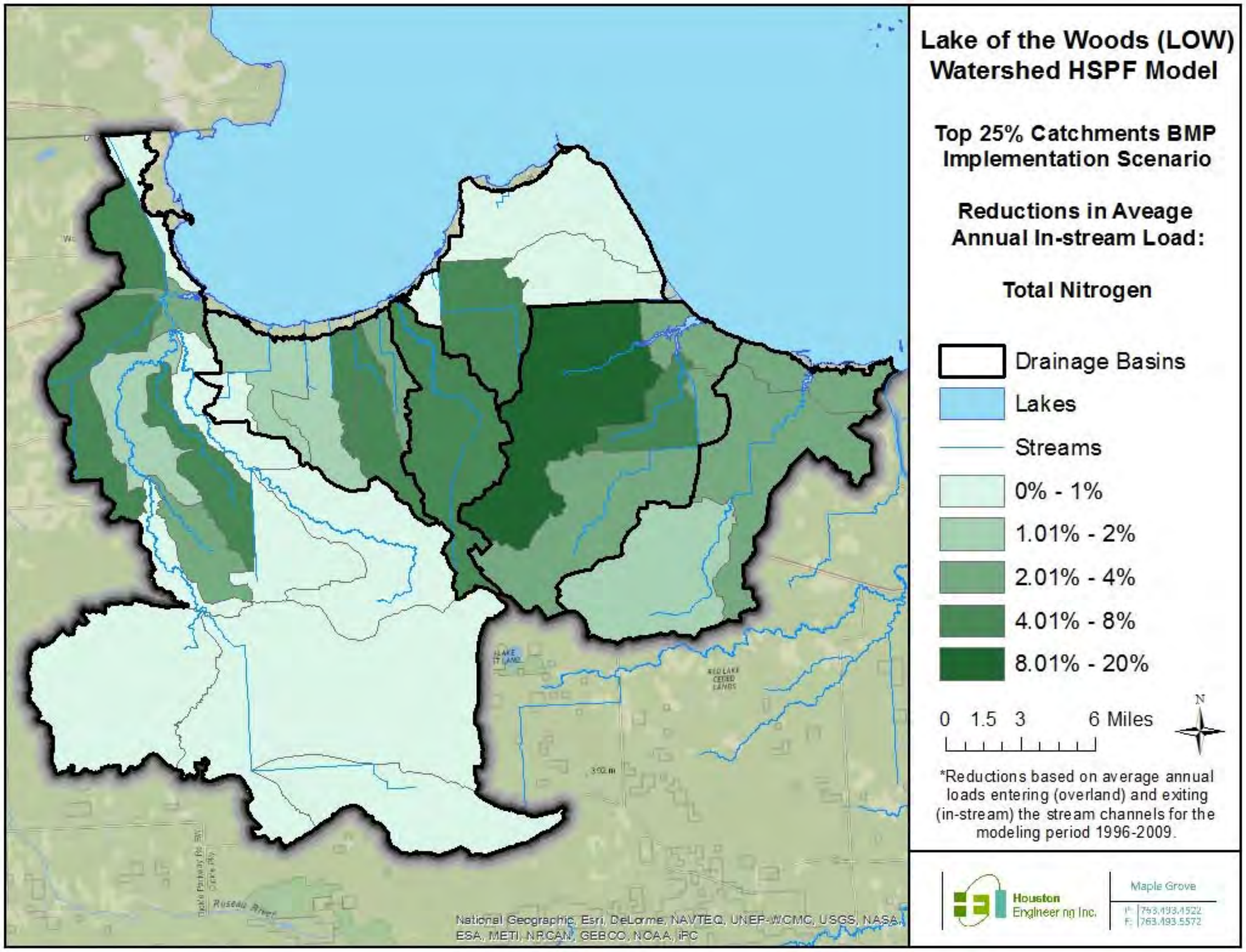
Figure A.12: Reductions in annual average total sediment [lbs/yr] delivered to outlet of the subwatershed (in-stream load) from the maximum BMP implantation scenario.



*Reductions based on average annual loads entering (overland) and exiting (in-stream) the stream channels for the modeling period 1996-2009.

National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC

Figure A.13: Reductions in annual average total nitrogen [lbs/yr] delivered to a channel (overland load) from the Top 25% BMP implantation scenario.



Lake of the Woods (LOW) Watershed HSPF Model

Top 25% Catchments BMP Implementation Scenario

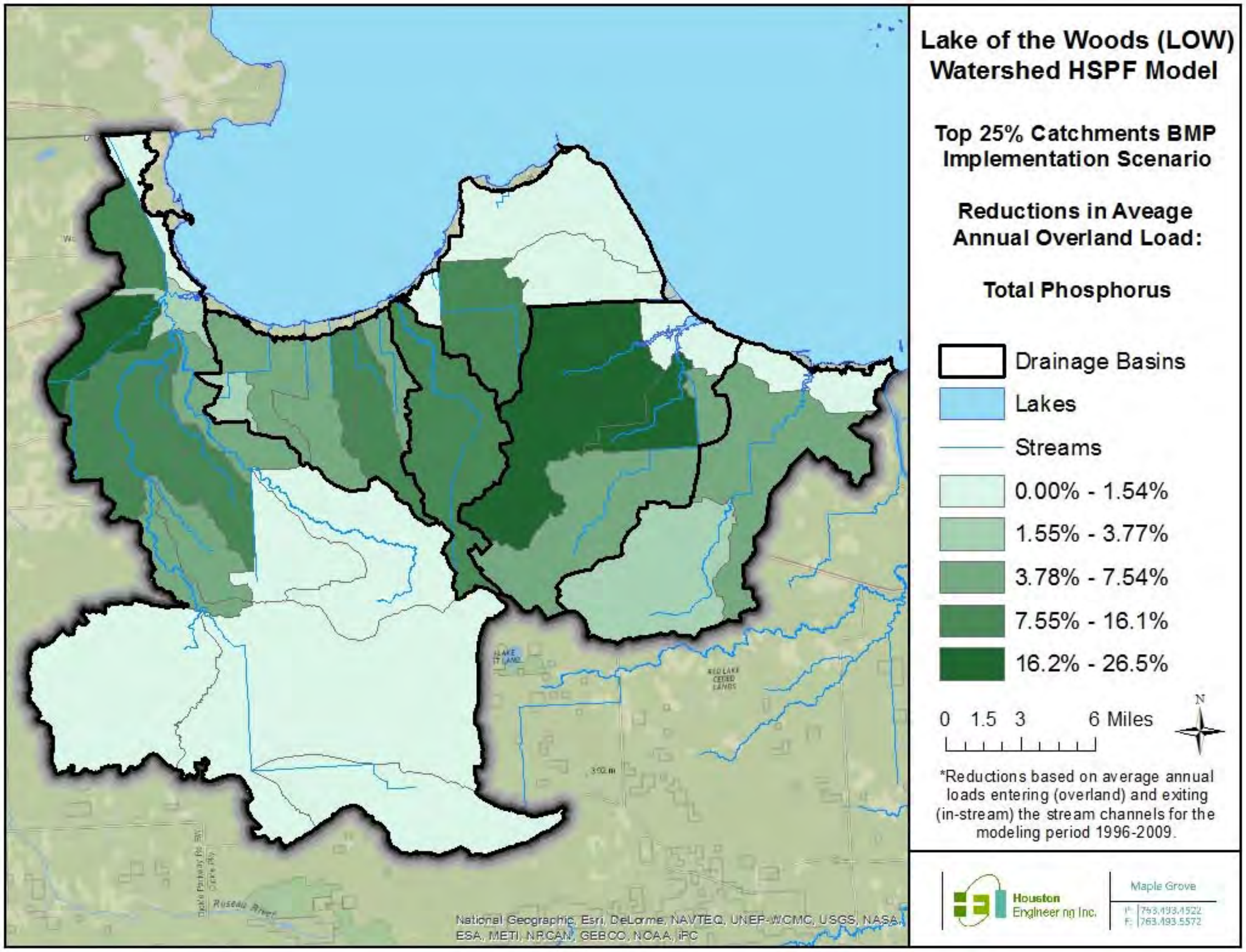
Reductions in Aveage Annual In-stream Load:

Total Nitrogen

*Reductions based on average annual loads entering (overland) and exiting (in-stream) the stream channels for the modeling period 1996-2009.

National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC

Figure A.14: Reductions in annual average total nitrogen [lbs/yr] delivered to outlet of the subwatershed (in-stream load) from the Top 25% BMP implantation scenario.



*Reductions based on average annual loads entering (overland) and exiting (in-stream) the stream channels for the modeling period 1996-2009.

National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC

Figure A.15: Reductions in annual average total phosphorus [lbs/yr] delivered to a channel (overland load) from the Top 25% BMP implantation scenario.

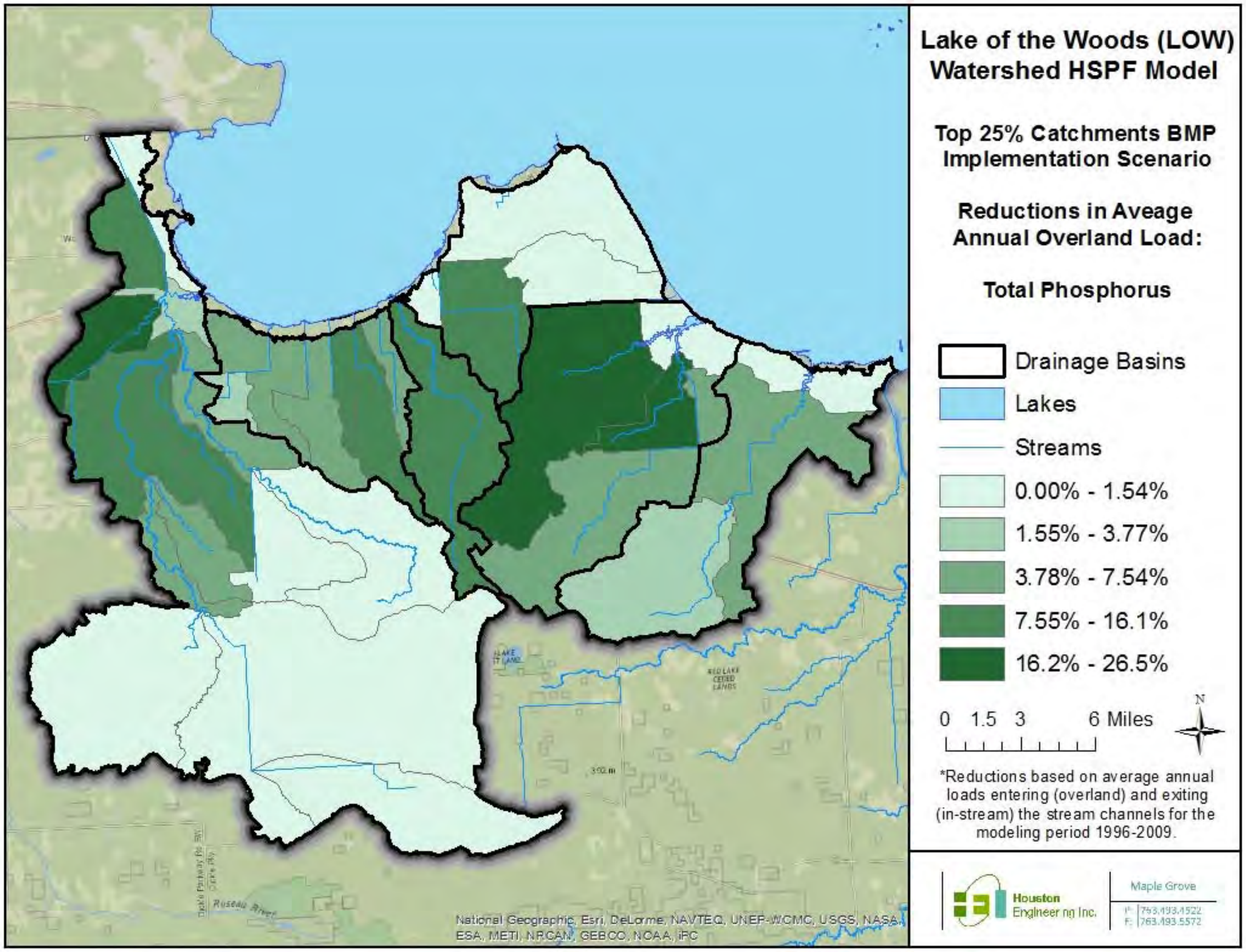
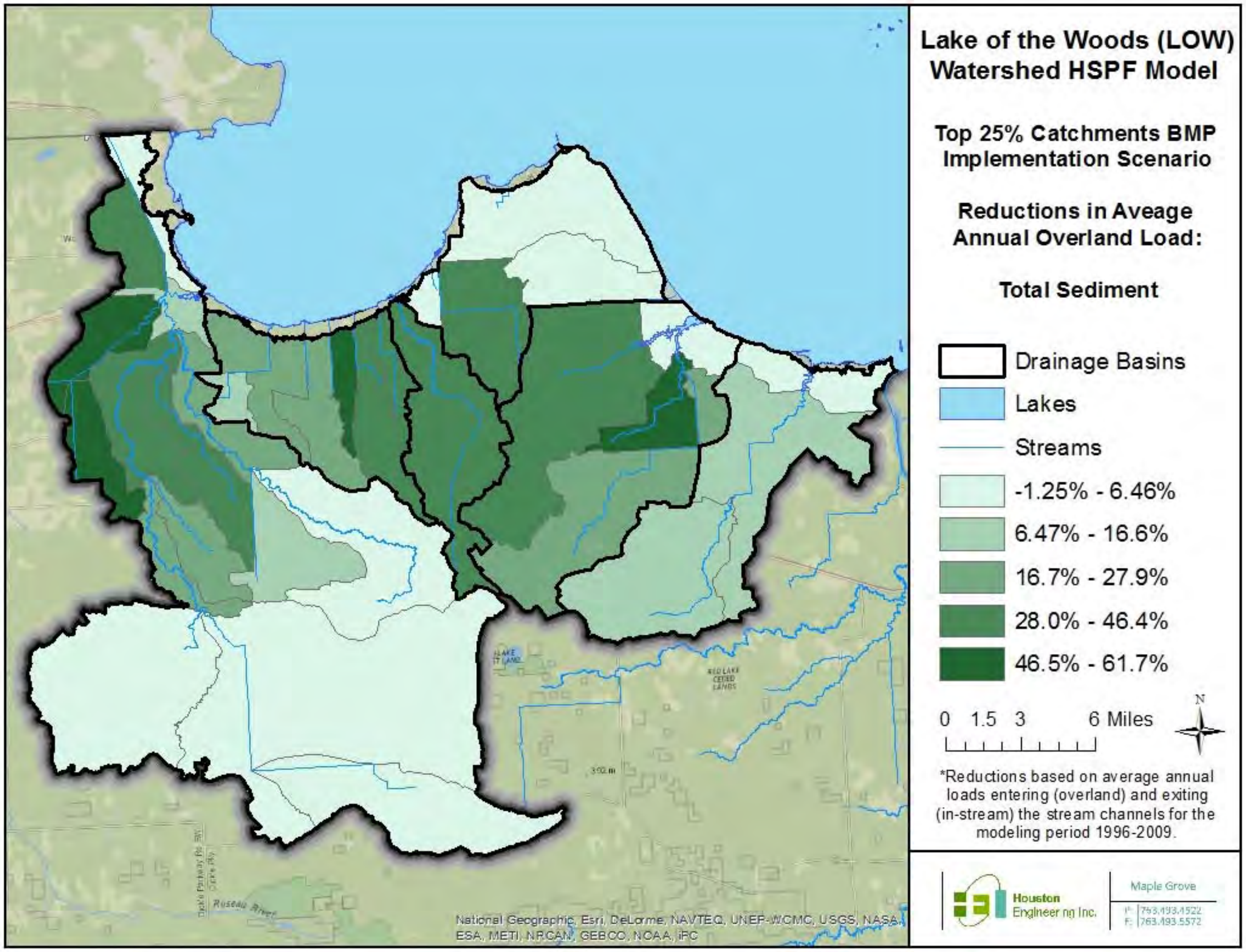


Figure A.16: Reductions in annual average total phosphorus [lbs/yr] delivered to outlet of the subwatershed (in-stream load) from the Top 25% BMP implantation scenario.



*Reductions based on average annual loads entering (overland) and exiting (in-stream) the stream channels for the modeling period 1996-2009.

National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC

Figure A.17: Reductions in annual average total sediment [lbs/yr] delivered to a channel (overland load) from the Top 25% BMP implantation scenario.

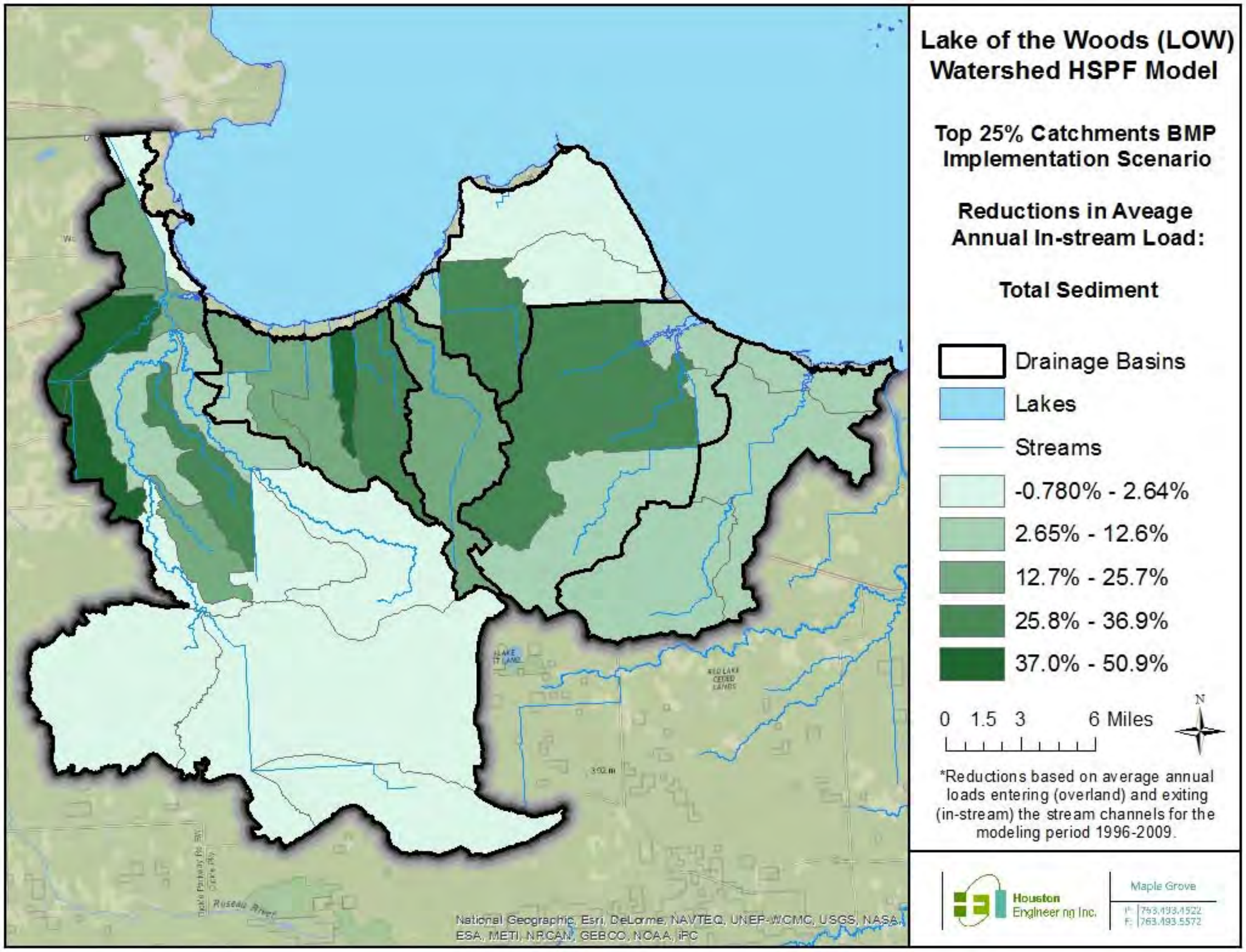


Figure A.18: Reductions in annual average total sediment [lbs/yr] delivered to outlet of the subwatershed (in-stream load) from the Top 25% BMP implantation scenario.

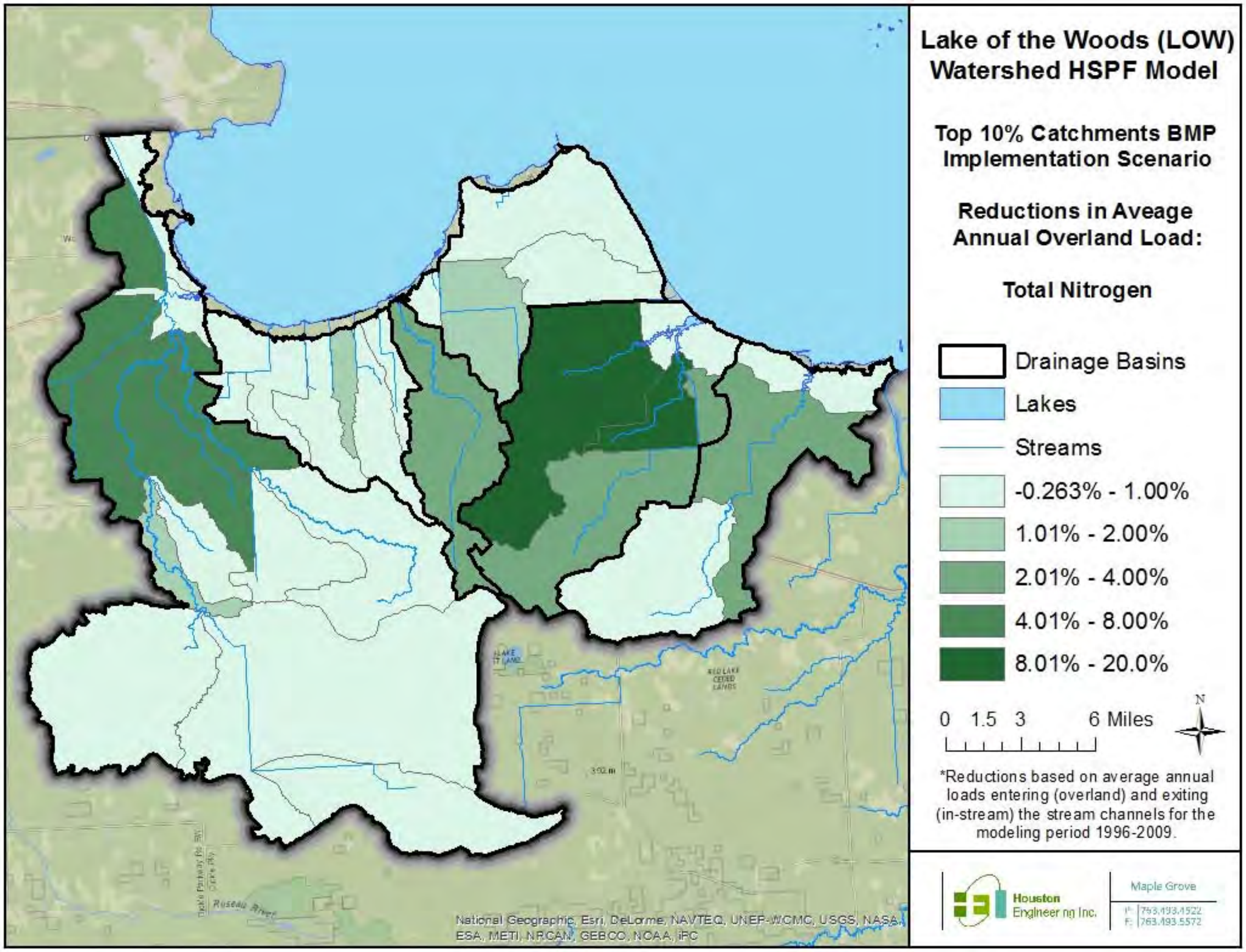


Figure A.19: Reductions in annual average total nitrogen [lbs/yr] delivered to a channel (overland load) from the Top 10% BMP implantation scenario.

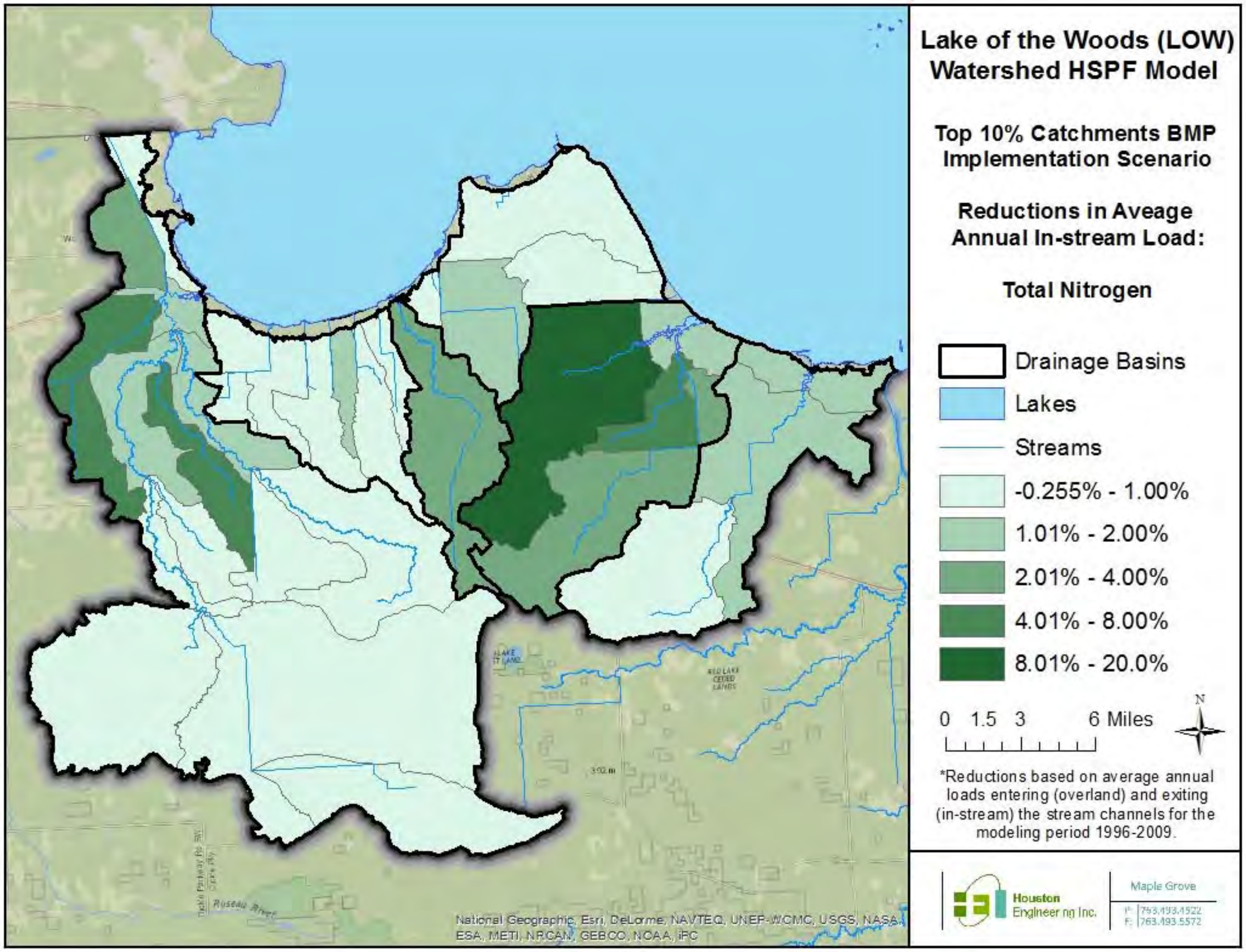


Figure A.20: Reductions in annual average total nitrogen [lbs/yr] delivered to outlet of the subwatershed (in-stream load) from the Top 10% BMP implantation scenario.

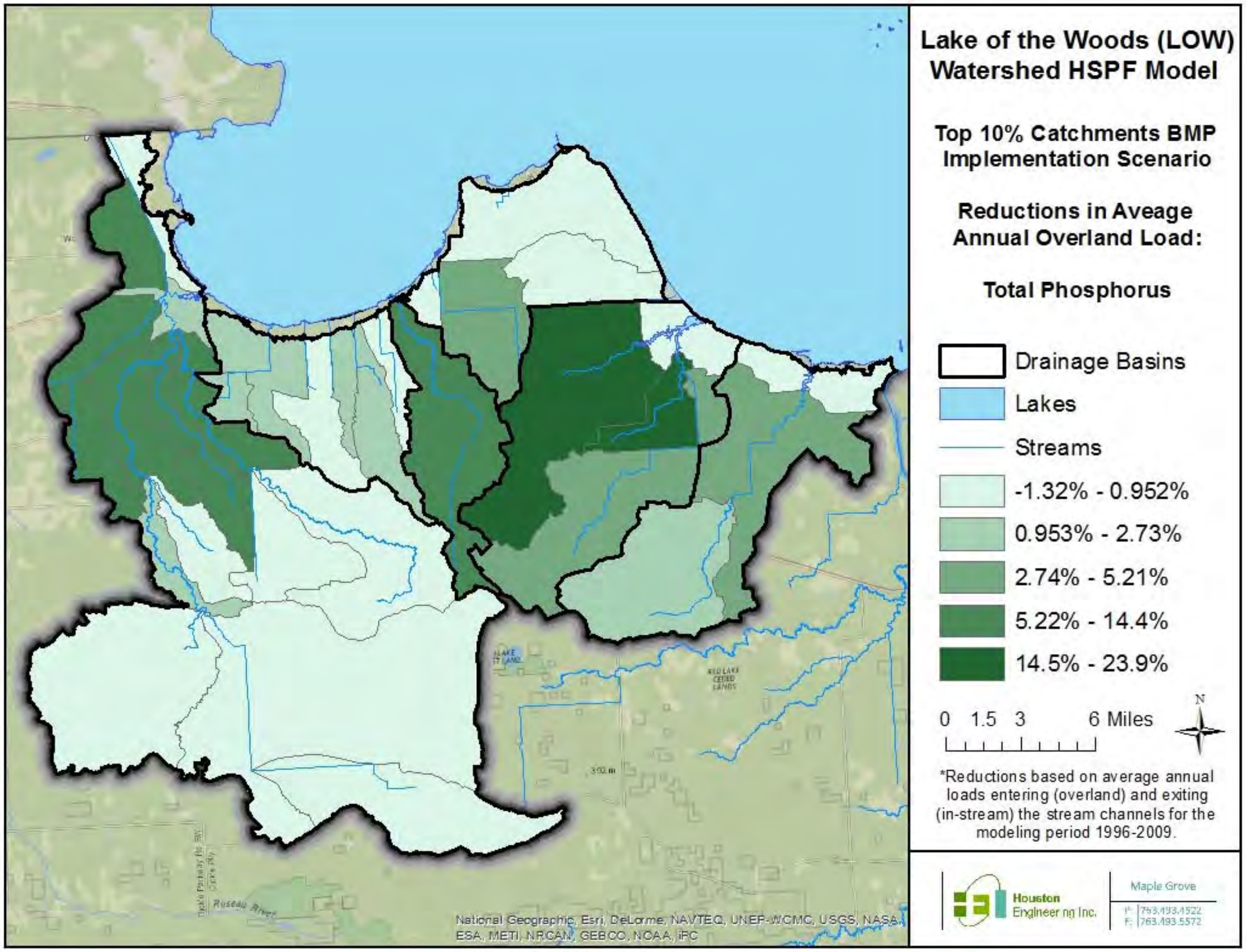


Figure A.21: Reductions in annual average total phosphorus [lbs/yr] delivered to a channel (overland load) from the Top 10% BMP implantation scenario.

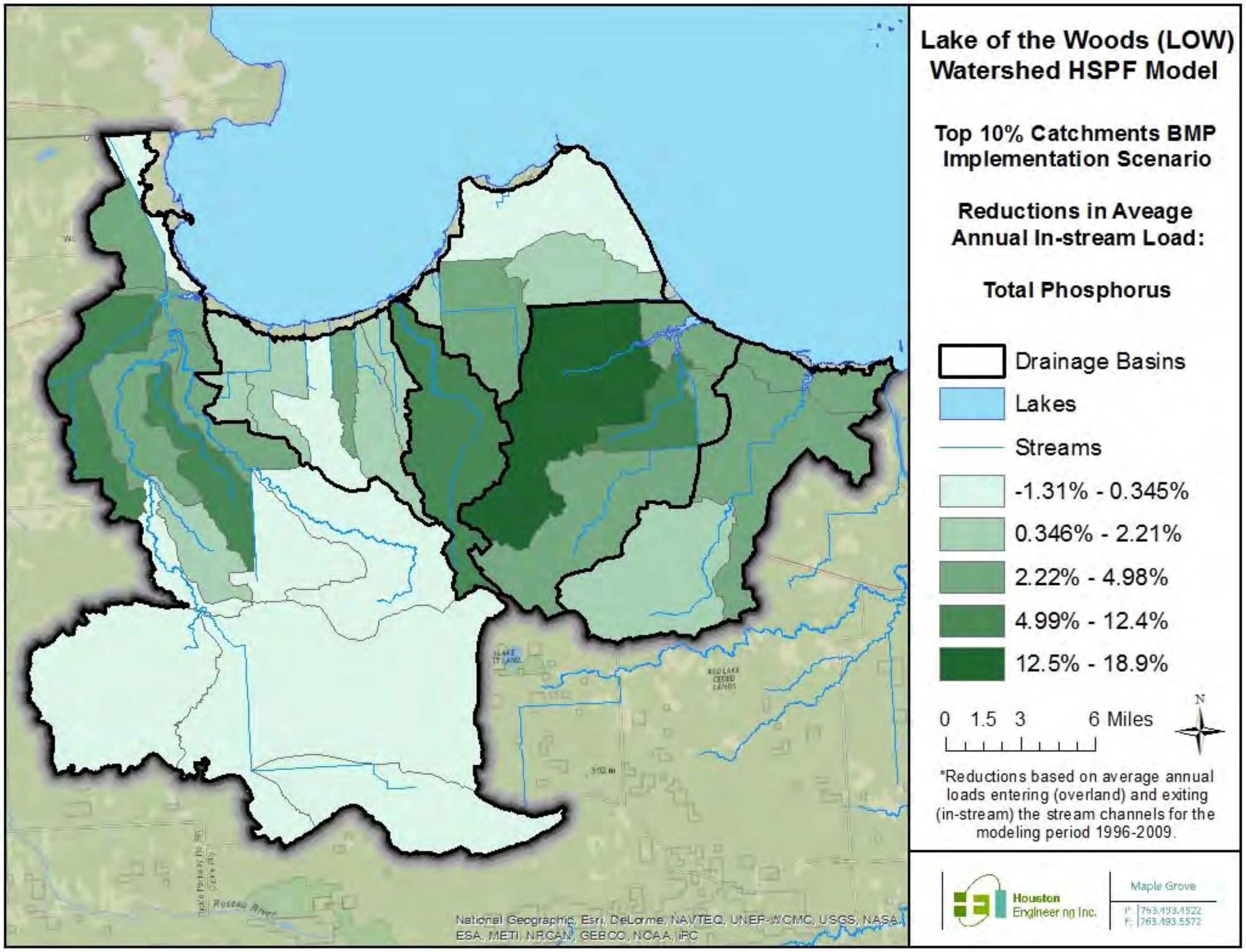


Figure A.22: Reductions in annual average total phosphorus [lbs/yr] delivered to outlet of the subwatershed (in-stream load) from the Top 10% BMP implantation scenario.

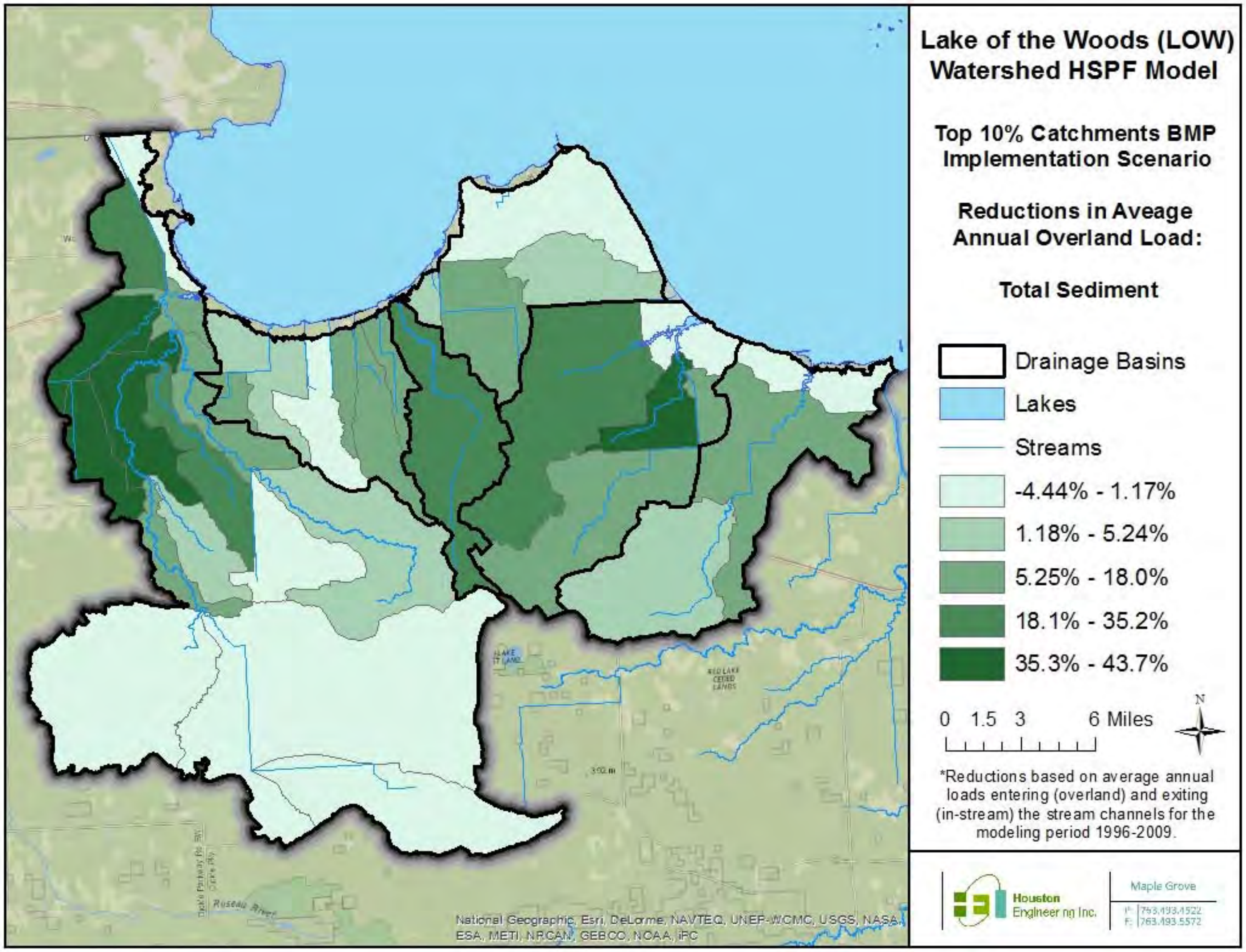


Figure A.23: Reductions in annual average total sediment [lbs/yr] delivered to a channel (overland load) from the Top 10% BMP implantation scenario.

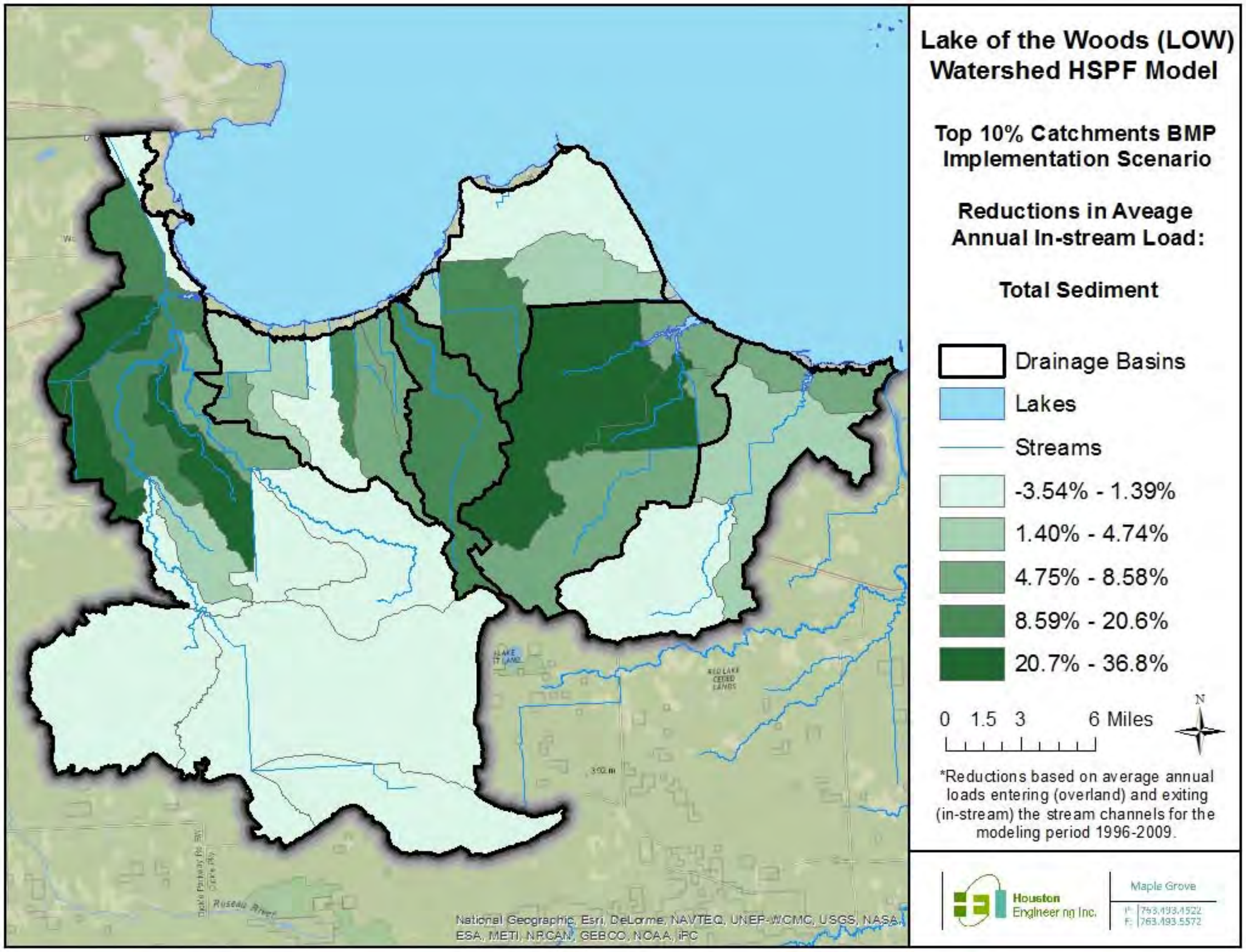


Figure A.24: Reductions in annual average total sediment [lbs/yr] delivered to outlet of the subwatershed (in-stream load) from the Top 10% BMP implantation scenario.